Changes in physicochemical properties of pasteurized coconut (*Cocos nucifera*) milk during storage at refrigeration condition

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ABSTRACT

The objective of this study is to evaluate the changes in physicochemical properties of pasteurized coconut milk at refrigeration condition. Four groups of samples, viz. sample–1: coconut milk from endosperm without testa, sample–2: coconut milk from endosperm with testa, sample–3: pasteurized coconut milk from endosperm without testa and sample–4: pasteurized coconut milk from endosperm with testa, were prepared for this study. Pasteurization was done by heating at a temperature of 72 ± 1°C for 15 minutes. The coconut milk samples were stored for 3 weeks in refrigeration condition (4°C). The biochemical analysis of coconut milk samples in terms of proximate composition, total solids, acidity and pH were determined and the total viable count method was applied for the evaluation of microbiological quality. The acceptability of coconut milk samples was assessed by visual observation and sensory evaluation. Results indicated that significant retention in nutrient content was observed in all samples during storage. Statistical analysis of sensory parameters (viz. color, flavor and taste) indicated an acceptable quality of coconut milk samples during storage. The total viable count of coconut milk samples was in an acceptable range of up to 3 weeks but fungal growth occurred after 2 weeks. Conclusively, coconut milk samples can be stored up to 2 weeks without affecting its overall acceptability.

Keywords: Coconut milk, pasteurization, physiochemical, storage, refrigeration, testa

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INTRODUCTION

Milk is a highly nutritious and multipurpose food consumed by almost everyone in various forms but mainly by children and provides the primary source of nutrition for newborns. About 36% of the population in rural areas live below the poverty line who are suffering from malnutrition, night blindness, anemia and various kinds of other diseases due to the shortage of milk and other energy and protein–rich food. The scarcity of fresh milk supply in developing countries perhaps leads to the development of alternative milk from various sources (Adesola *et al*., 2013).

A wide variety of milk–like products can be obtained from oilseeds including groundnut, coconut, soybean and chestnuts. The growing awareness of the nutritional benefits of plant-based foods by health-conscious consumers has renewed interest in the development of vegetable milk and vegetable milk products (Diarra *et al*., 2005; Onweluzo and Owo, 2005). In this case, coconut milk can play a vital role in balancing nutritional deficiency of our diet. Coconut (*Cocos nucifera* L.) is the most extensively grown and used nut in the world, which belongs to the palm family (*Arecaceae*). Besides, it is an important commercial crop in many tropical countries, contributing significantly to their economies (Sani *et al*., 2014). On many islands, coconut is a staple ingredient in the diet. Nearly one–third of the world's population depends on coconut to some degree for their food and their economy (Ramaswamy, 2014). Coconut is the most important versatile crop, which provides all required amenities for human life which help to regulate blood sugar, protect against diabetes, prevent heart disease and cancer, aid in digestion and weight loss (Mensink *et al*., 2003; Saleem-ur-Rehman *et al*., 2004; Amarasiri and Dissanayake, 2006; Balogun *et al*., 2016). It is a major and essential ingredient in the preparation of a wide variety of food products (Gwee, 1988; Gonzalez, 1990; Ekanayaka *et al*., 2013).

Coconut milk is a milky fluid obtained by the manual or mechanical extraction of fresh coconut endosperm with or without addition of water. It is also the natural oil–in–water emulsion extracted from the endosperm of mature coconut (Seow and Gwee, 1997), which is valued mainly for its characteristic nutty flavour and its nutritional content (Seow and Gwee, 1997; Simuang *et al*., 2004; Tansakul and Chaisawang, 2006). The importance of coconut milk is increasing as a raw material in home cooking as well as in the food processing industries (Muda, 2002; Alyaqoubi *et al*., 2015). Recovery of coconut oil remains the major concern in the coconut industry which appears to be an increasing demand for coconut milk products. It is estimated that 25% of the world's coconut output is consumed as coconut milk (Gwee, 1988). Moreover, the commercial production of coconut milk can help to reduce the wastage of nuts, hence effective utilization of by-products. It can also be used as a substitute for milk in some desserts e.g. chocolate and other confectioneries which are exotically flavoured with coconut milk (Magda, 1992; Muda, 2002).

Pasteurization is a mild heat treatment process to inactivate or kill pathogenic microorganisms present in the milk sample at the temperature of 63°C or 72°C for 30 and 15–20 minutes (Narataruksa *et al*., 2010) and reduce the numbers of pathogenic microorganisms to increase the shelf life of milk products (Obinna-Echem *et al*., 2019). Also, pasteurization influence many important parameters like protein, which become denatured during heat treatment (Konkamdee and Saikhwan, 2015) and organoleptic quality (Obinna–Echem *et al*., 2019). However, the literature on biochemical properties and shelf life of coconut milk is comparatively sparse and widely scattered. Therefore, the present study has been planned to extract milk from the coconut and to observe the changes in the physicochemical properties of coconut milk during storage at refrigeration condition.

MATERIALS AND METHODS

Collections of Raw Materials

The mature coconuts were collected from local markets of Dinajpur, Bangladesh. All chemicals used were of analytical grade and were purchased from Sigma Aldrich Chemical Co. (St. Louis, MO, USA).

Extraction of Coconut Milk and Preparation of Samples

Collected coconuts were washed by running potable water and broken into two halves. Coconut scraper (ODIRIS Grater–B5, Odiris Engineering Co. Ltd, Colombo, Sri Lanka) was used to collect grated coconut. Coconut milk was extracted with and without testa. The grated coconut was steam blanched for 10 minutes and milk was extracted using hydraulic press (SKY004, Sakaya Automate Co. Ltd, Bangkok, Thailand) without adding water. Calculated amounts (coconut milk to water was 2 : 1 w/w) of warm distilled water was added to the extracted coconut milk. The mixture was screened through a clean wire mesh sieve (150SIW.300, Endecotts Ltd, London, UK). The extracted coconut milk was separated into four samples, viz. sample–1: coconut milk from endosperm without testa, sample–2:

coconut milk from endosperm with testa, sample–3: pasteurized coconut milk from endosperm without testa and sample–4: pasteurized coconut milk from endosperm with testa. Pasteurization of coconut milk was done in a thermostatic water bath (VS–310SWR, Vision Scientific Co. Ltd., Daejeon, Korea) at about 72 ± 1°C for 15 minutes. After that, we poured the coconut milk into low–density polyethylene (LDPE) of 28 μm thickness (Moyls *et al*.,1992) and sealed by a hand sealing machine (PFS–200, Yongkang Golden Sky Imp.& Exp. Co., Ltd., Zhejiang, China). It was then stored at refrigeration temperature (4°C) and the analyses mentioned afterwards were carried out on 0, 7, 14 and 21 days.

Proximate Analysis

Proximate composition serves as an important base to study the nutritive quality of coconut endosperm and milk. Samples were analyzed for proximate composition using standard methods of analyses of AOAC (2005). The moisture content of the samples was determined by oven (VS–4150ND, Vision Scientific Co. Ltd., Daejeon, Korea) drying method (at 105°C for 6 hours), whereas, the total ash content was determined using the muffle furnace (5300A30/F6010–TS, Thomas Scientific, Swedesboro, USA) at 550°C. Meanwhile, the solvent extraction method was used to determine the fat content by the soxhlet apparatus (GI–1706–A, Garg Process Glass India Private Ltd., Mumbai, India). The protein (N × 6.25) content of the samples was determined by the Kjeldahl (KjelMaster K–375, BUCHI, Flawil, Switzerland) method and carbohydrate was calculated by the difference method (Amon *et al*., 2014). The total energy value of coconut milk samples was determined as follows:

$$\text{Energy (Kcal/100g)} = [(9 \times \%\text{Fat}) + (4 \times \%\text{Protein}) + (4 \times \%\text{Carbohydrate})]$$

Determination of Total Solids

The %Total solids content was calculated by using the data obtained during moisture estimation using the following formula:

$$\%\text{Total solids} = 100 - \%\text{Moisture content}$$

Determination Titratable of Acidity

Titratable acidity (TA) was determined by titration of a known quantity of sample (10 mL) against 0.1 N sodium hydroxide using 1% phenolphthalein solution as an indicator. The endpoint was denoted by the appearance of pink colour. The titration was repeated thrice and the average value was recorded (Srivastava and Sanjeev, 1994). The results were expressed as a percentage using the following equation:

$$\%\text{Acidity} = \frac{\text{Titre} \times 0.1 \times 0.064 \times 100}{\text{Weight or volume of sample}}$$

Determination of pH

Ten grams of each replicate were homogenized with 100 mL deionized water in a 250–mL beaker by using a homogenizer (Ultra–Turrax T25, IKA, Germany). The pH of the homogenized solution was measured with a potentiometer (Micron pH 2001, Crison Instruments, S.A., Barcelona, Spain). The pH electrode was previously calibrated by using standard solutions of pH 4.0 and 7.0.

Determination of Total Viable Microorganism

The standard plate count method was followed for total viable count of microorganisms during storage of coconut milk samples. For this, one milliliter of the coconut milk sample was aseptically measured into a sterilized McCartney bottle and 9 mL of sterile distilled water was added and shaken vigorously on a vortex mixer (XH–D, Pioway Medical Lab Equipment Co. Ltd., Jiangsu, China) which gave a homogenous suspension to be serially diluted. From homogenous suspension, 1 mL of 10^{-1} to 10^{-6} dilution was placed on a plate containing PCA agar and incubated for 24 h at 37°C. Petri dishes overloaded with bacterial colonies were avoided and colonies on each plate (having 30–300 colonies) were counted using a colony counter (Majk–Cc–30A, Guangzhou Maya Medical Equipment Co. Ltd., Guangdong, China). Finally, the total number of bacteria per gram of sample was calculated by the following equation:

Observation of the Sample during Storage

The coconut samples were periodically (at 7 day's interval from processing day up to the 21st days) observed during storage for colour, fungal growth and overall status.

Sensory Evaluation

Sensory evaluation of coconut milk was performed through a testing panel consisting of 15 members using 9 points hedonic scale. The panelists were selected from the students and employees of the Department of Food Processing and Preservation, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur–5200, Bangladesh, who frequently take part in such evaluation. The panelists were asked to assign the appropriate numerical score to each product for characteristics colour, flavour, taste and overall acceptability of coconut milk. The hedonic scale arranged was such that: 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like or dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much and 1 = dislike extremely.

Statistical Analysis

Each experiment was repeated in triplicate. The obtained data were analyzed by SPSS (version 20.0). The results were expressed as mean ± standard error mean (SEM). Significant differences between the groups were assessed by one-way analysis of variance (ANOVA) test and means were separated by Duncan's Multiple Range Test (DMRT) at the 95% confidence level.

RESULTS AND DISCUSSION

Proximate Composition of Fresh Coconut Endosperm

The fresh coconut endosperm was analyzed for proximate composition such as moisture, ash, fat, protein and carbohydrate. The results are summarized in Table 1. The results revealed that the moisture content of fresh coconut endosperm without testa was 68.62% while the moisture content of fresh coconut endosperm with testa was 45.26%. The ash content of fresh coconut endosperm without testa (0.75%) is lower than that of coconut with testa (2.76%). The fat content of fresh coconut endosperm without testa was 22.82% and fresh coconut endosperm with testa was 30.84%, while higher protein content was observed in fresh coconut endosperm with testa (4.89%) than coconut without testa (2.39%). The carbohydrate content of coconut without testa was 5.42% and 16.45% for coconut with testa. The findings of this research work for proximate composition of fresh coconut endosperm are approximately equal to Laureles *et al*. (2000). Moreover, the energy value of coconut endosperm without and with testa was found as 236.62 Kcal/100g and 360.92 Kcal/100g, respectively. The composition of coconut milk varies according to variety, age, growing environment of the coconut, cultural practices, method of preparation and the process conditions used in extraction, for example, the amount of added water and the temperature used for extraction (Cancel, 1979; Gonzalez, 1990).

Table 1 Proximate composition of fresh coconut endosperm

Parameters	Composition of fresh coconut endosperm	
	Without testa	With testa
Moisture (%)	68.62 ± 0.161	45.26 ± 0.155
Ash (%)	0.75 ± 0.015	2.76 ± 0.021
Protein (%)	2.39 ± 0.006	4.89 ± 0.003
Fat (%)	22.82 ± 0.212	30.84 ± 0.236
Carbohydrate (%)	5.42 ± 0.083	15.95 ± 0.066
Energy (Kcal/100g)	236.62 ± 0.522	360.92 ± 0.312

Note: All values are mean ± SEM of three replicates

Changes in Proximate Composition of Coconut Milk

Changes in proximate composition of coconut milk samples during storage are presented in Figure 1. Moisture is an important property of food that determines the nutritional and microbiological quality of foods during storage. A significant difference ($P < 0.05$) in the moisture content of coconut milk samples was observed from processing day to 21st days of storage (Figure 1A) and ranged from 82.36 to 88.41% (sample–1), 84.74 to 90.08% (sample–2), 82.37 to 89.17% (sample–3) and 80.66 to 86.75% (sample–4). It is clear from Figure 1A that there is an increasing trend of moisture content of coconut milk samples during storage.

Because, most of the carbohydrates in coconut milk are sugars (sucrose) and starch (Seow and Gwee, 1997). The oxygen (O_2) transmission rate (OTR) of the packaging material (LDPE) at 0 and 10°C are 1,679 and 2,448 mL m^{-2} d^{-1} (Moyls *et al.*,1992). The manual handling and packaging method could not stop the air entrapment fully in sealed packages. Therefore, the aerobic microorganisms present in coconut milk can disintegrate these carbohydrates into carbon dioxide, water and energy may be the reason for a reduction in carbohydrate content and responsible for the addition of moisture internally into the coconut milk (Tetra Pak, 2016). All sample treatments reported by Ukwuru and Ogbodo (2011) had high moisture contents between 77.0 and 80.7%, which is comparable to the moisture content of coconut milk (80.66–84.74% to 86.75–90.08%, from processing day and after 21st days of storage, respectively) obtained in this study.

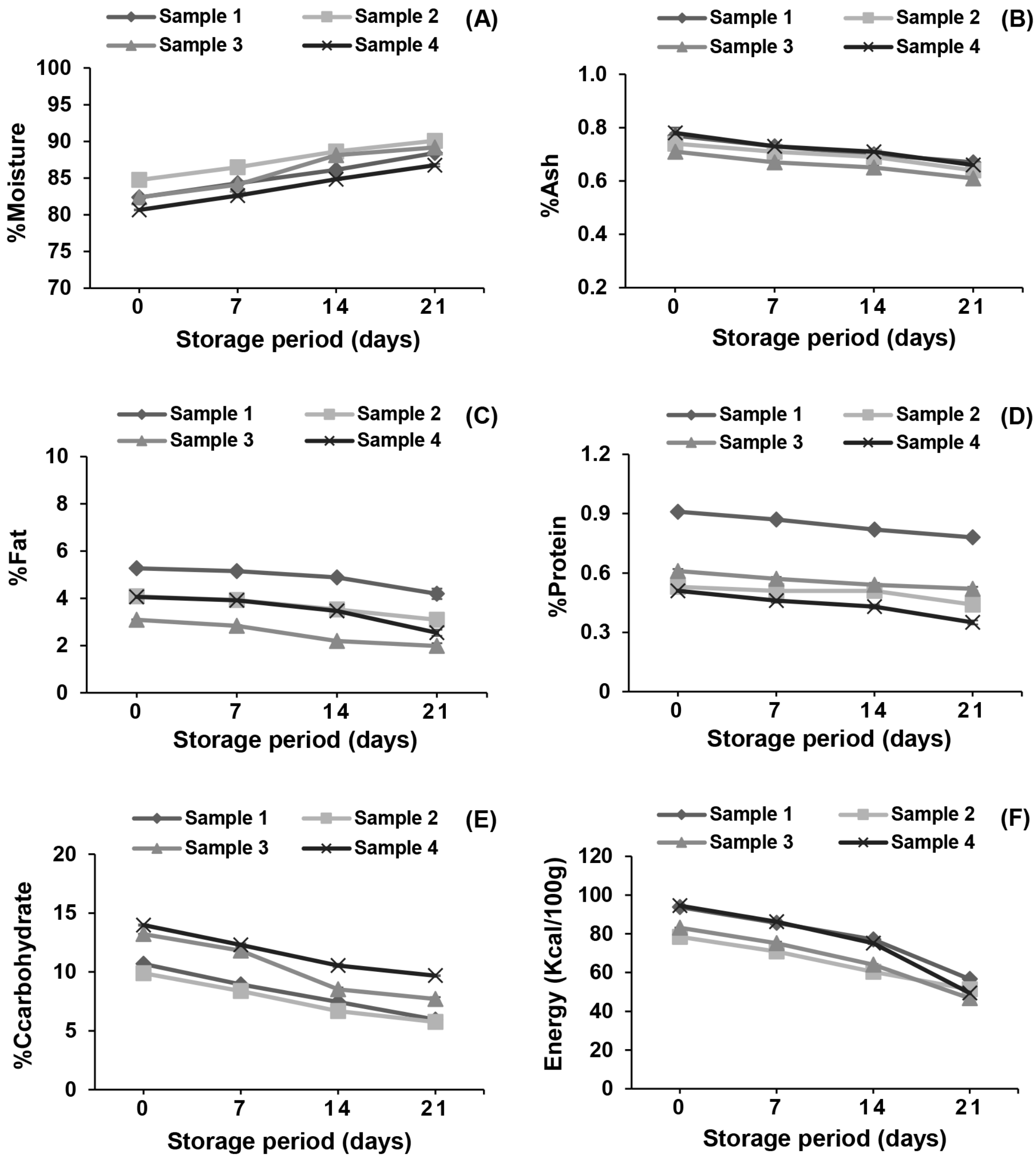

Figure 1 Changes in proximate composition of coconut milk samples during storage, %Moisture (A), %Ash (B), %Fat (C), %Protein (D), %Carbohydrate (E), Energy (F), sample–1 = coconut milk from endosperm without testa, sample–2 = coconut milk from endosperm with testa, sample–3 = pasteurized coconut milk from endosperm without testa, sample–4 = pasteurized coconut milk from endosperm with testa

The ash content, which represents the mineral contents in the coconut milk samples, showed a significant ($P < 0.05$) difference in most of the samples on the processing day up to 21st days of storage in refrigeration condition (Figure 1B). All samples contained a good amount of ash. Initially, the ash content ranged between 0.71 and 0.78% being highest in sample–4 and lowest in sample–3. The ash content was found to decrease in the subsequent storage period (Figure 1B). After 21st days of storage, the ash content ranged from 0.61 to 0.67% with significantly ($P < 0.05$) highest ash content was found in sample–1 and lowest in sample–3. The variation in ash content during storage may be due to the compositional difference in the samples during storage at the refrigerated condition.

On the processing day, the fat content of extracted coconut milk ranged from 3.09 to 5.27% and was found very low compared to fresh coconut (22.82 to 30.84%). Figure 1C shows the changes in the fat content of coconut milk samples during storage at refrigeration temperature (4°C). The results revealed that there was a significant difference ($P < 0.05$) in the fat content of coconut milk samples on the processing day up to the 21st days of storage. The fat content in all samples was found to decrease during the storage period. After 21st days of storage, the fat content ranged from 1.98 to 4.19%. The significantly ($P < 0.05$) highest fat content was recorded in sample–1 and lowest in sample–3. The results of this study are in agreement with the findings of Seow and Gwee (1997).

The microbial activity may decrease the fat percentage of coconut milk. Therefore, it is essential to lessen microbial degradation of oil caused by lipolysis and cannot break pure oil but able to breakdown oil–in–water emulsions or in contact with water, whereas microbial enzymatic split requires water (Tetra Pak, 2016). A slight volume of oxygen can lead to a self–speed up oxidation chain reaction (Schaich, 2005). During the storage period, we opened the refrigerator hood several times for our research purpose. Therefore, some O_2 exchange may happen from the refrigerator environment to the inside of the package and the coconut milk may be susceptible to various biochemical reactions and microbial activity (Staffolo *et al*., 2004; Tseng and Zhao, 2013). As a result, during the storage period, the short and medium–chain fatty acids and aldehydes of thermally treated coconut milk increased for lipid oxidation. The increase of storage period can cut down the nutritive significance of coconut milk (Tinchan *et al.*, 2014).

The protein content of extracted coconut milk (0.51 to 0.91%, on the processing day) was found very low compared to fresh coconut (2.39 to 4.89%). The results revealed that there was a significant difference ($P < 0.05$) in protein content of coconut milk samples on the processing day up to the 21st days of storage (Figure 1D). Protein contents in the coconut milk ranged from 0.35 to 0.78% after 21st days of storage with sample–1 having significantly highest ($P < 0.05$) protein content compared to other samples. The decreasing trend of protein during storage may be due to the microbial breakdown of protein in the samples. Proteins and their constituent amino acids have a wide range of chemical elements. They comprise carbon, hydrogen, oxygen, sulphur, nitrogen and phosphorus. As an outcome, there is a frequent wider range of acids, alcohols, gases (hydrogen, carbon dioxide, hydrogen sulphide and ammonia) and diverse compounds. Therefore, protein disintegration, as proteolysis in coconut milk, can farther be catalyzed by proteases generated by microorganisms (Tetra Pak, 2016).

The changes in carbohydrate content of coconut milk samples during storage are presented in Figure 1E. On the processing day, the carbohydrate content was significantly highest ($P < 0.05$) in sample–4 (13.98%), while sample–2 (9.89%) had the lowest carbohydrate content. The carbohydrate content of all coconut milk samples was gradually decreased up to the 21st days of storage at the refrigerated condition. After 21st days of storage, the carbohydrate content of coconut milk sample ranged from 5.42 to 9.68%, being highest in sample–4 and lowest in sample–2. This change in carbohydrate content of coconut milk samples may be due to the compositional difference of the samples during storage at the refrigerated condition.

Figure 1F illustrates that there is a significant difference (P < 0.05) in the energy content of coconut milk samples on the processing day up to the 21st days of storage. The energy values of the coconut milk samples ranged from 78.44 to 94.51 Kcal/100g on the processing day while this content varied between 46.68 and 56.59 Kcal/100g after 21st days of storage. Fat is the major nutrient in coconut that serves as the main source of energy (Gunathllake and Bandara, 2005). The variation in energy value might be due to the compositional difference between the samples.

Changes in Total Solids

Total solids show the level of macro and micronutrients in the food differed from one production site to another. The total solids present in Figure 2 for all samples initially showed a slight difference (ranging from 15.25 to 19.33%) and found decreased during 21st days of storage (ranging from 9.91 to 13.24%). It is possible that the total solids present the dry matter content of the samples (Belewu *et al.*, 2010; Khalifa *et al*., 2011) and considered as substrates for many biochemical reactions, even microorganisms use the total solids for metabolic activity (Staffolo *et al*., 2004; Tseng and Zhao, 2013). That is why the solid content decreased with time in storage.

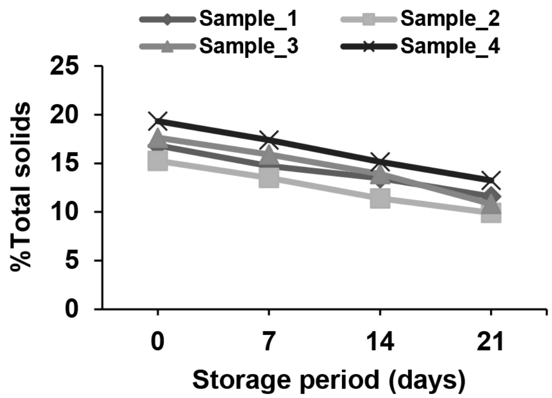

Figure 2 Changes in %Total solids of coconut milk samples during storage, sample–1 = coconut milk from endosperm without testa, sample–2 = coconut milk from endosperm with testa, sample–3 = pasteurized coconut milk from endosperm without testa, sample–4 = pasteurized coconut milk from endosperm with testa

Changes in Titratable Acidity and pH

Generally, titratable acidity and pH are used primarily to estimate consumption quality. They could be considered as indicators of maturity or ripeness. Titratable acidity is directly proportional and is a measure of the shelf life of a product and guard against the attack of microorganisms. It also helps to ensure some chemical changes during preparation and storage. The titratable acidity (Figure 3A) of all coconut milk samples were found to be increased in each observation during storage from processing day (0.12 to 0.32%) up to the 21st day (0.32 to 0.44%) with statistically significant (P < 0.05). On the other hand, pH (Figure 3B) of all samples decreased with increasing storage period (from initial 6.42–6.45 to final 5.78–5.93). Pasteurized samples showed a lower rate of acid production.

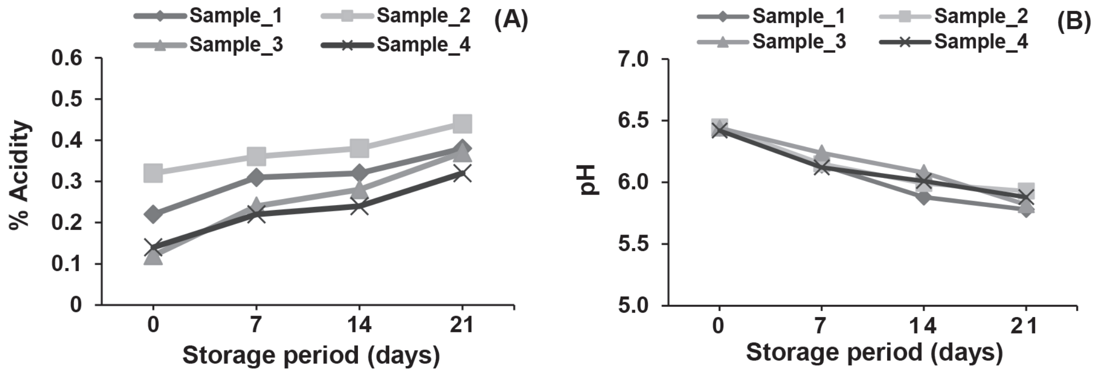

Figure 3 Changes in %Acidity (A) and pH (B) of coconut milk samples during storage, sample–1 = coconut milk from endosperm without testa, sample–2 = coconut milk from endosperm with testa, sample–3 = pasteurized coconut milk from endosperm without testa, sample–4 = pasteurized coconut milk from endosperm with testa

The increase in acidity and decrease in pH may be due to the production of acetic acid and lactic acid. Researchers could not understand the development of acetic acid in coconut milk during storage but originated through microbial activity and thermal deterioration of hexose sugar. There are a few investigations that have suggested the production pathway of acetic acid by heat treatment (Tinchan *et al.*, 2014). Huang *et al.* (2011) mentioned that acetic acid was a minor product of carbohydrate degradation. The heat treatment can form the significant transitional compounds in coconut milk and reduced into acetic acid during storage (Blank *et al*., 2003; Davidek *et al*., 2006; Tinchan *et al.*, 2014). A previous study reported that anaerobic microbial disintegration of carbohydrates in coconut milk into lactic and acetic acids showing an increase in acidity and reduction in the pH value (Tetra Pak, 2016). In addition, fat and protein breakdown were more pronounced in the raw samples resulting in the release of free fatty acids (Tinchan *et al*., 2014) and amino acids (Tetra Pak, 2016) respectively.

Changes in Total Viable Count

A change in the total viable count of coconut milk samples during storage is shown in Table 2. An increasing trend of microbial growth in all samples was observed from the processing day up to the 21st day of storage and was found to be significantly different ($P < 0.05$) among the samples. On the processing day, the total microbial count ranged from 3.45×10^5 CFU/mL to 6.72×10^5 CFU/mL The highest microbial count was found in sample–2 and the lowest was found in sample–4. After 21 days of storage, the highest microbial load was 8.93×10^5 CFU/mL in sample–2 and the lowest was 4.32×10^5 CFU/mL in sample–4. The previous study of APCC (1994) stated that the viable plate count shall not exceed 5×10^4 microorganisms per mL and shall not over 1×10^5 per mL. However, the present study reported much higher values for total viable count. Another study reported that the total aerobic plate count of coconut milk was 2.9×10^8 (Kajs *et al*., 1976). The changes in microbial load during storage may be due to various reasons such as the change in the coconut milk composition and manufacturing process especially if fermentation takes place (Mabbit, 1981).

The spoilage of fresh coconut milk might be supported by the fast chilling condition in the refrigerator (Fernandez *et al*., 1970). Typical spoilage microbes can grow in coconut milk because the milk is a nutritive medium, brought in via contaminated shells, equipment, preparing machinery, operators, etc. The common microbes detected comprise *Bacillus*, *Achromobacter*, *Microbacterium*, *Micrococcus*, and *Brevibacterium* and some coliform bacteria, while *Penicillium*, *Geotricum*, *Mucor*, *Fusarium* and *Saccharomyces* species emerge to be the dominant fungi screened from coconut milk (Mabesa and del Rosario, 1979). Most natural ecosystems show pH values between 5 and 9, and it helps the common microbes to grow in this range. Maximum moulds and yeasts develop best in a somewhat acidic medium, while optimum conditions for bacteria are neutral or lightly alkaline medium (Tetra Pak, 2016). So, moulds may be responsible for the quality deterioration of coconut milk at low pH during storage.

Table 2 Changes in total viable count of coconut milk samples during storage at refrigerated condition

Samples	**Total viable count (CFU/mL)**			
	Storage period (days)			
	0	**7**	**14**	**21**
Sample–1	6.52×10^{5a}	6.63×10^{5a}	6.76×10^{5b}	6.93×10^{5b}
Sample–2	6.72×10^{5a}	6.89×10^{5a}	7.63×10^{5a}	8.93×10^{5a}
Sample–3	3.51×10^{5b}	3.74×10^{5b}	3.98×10^{5c}	4.58×10^{5c}
Sample–4	3.45×10^{5b}	3.66×10^{5b}	3.89×10^{5c}	4.32×10^{5c}

Note: All values are means of three replicates, [a–c] means followed by different letters indicates significant difference at $P < 0.05$, sample–1 = coconut milk from endosperm without testa, sample–2 = coconut milk from endosperm with testa, sample–3 = pasteurized coconut milk from endosperm without testa, sample–4 = pasteurized coconut milk from endosperm with testa

Observation of the Sample during Storage

The observation of coconut milk samples for fungal growth, colour and overall status is presented in Table 3. There was no change in colour and no fungal growth occurred up to 2 weeks (14 days) of storage and all coconut milk samples were within the acceptable quality. After 2 weeks of storage, colour was changed slightly and fungal growth has occurred. Sample–1 and sample–2 become completely spoiled after 21st days of storage while other coconut milk samples were slightly spoiled.

Table 3 Observation of coconut milk samples during storage at refrigerated condition

Storage period (days)	Samples	Colour	Visual fungal growth	Status of sample
0	Sample–1	Creamy white	No growth	Good
	Sample–2	Creamy white	No growth	Good
	Sample–3	Creamy white	No growth	Good
	Sample–4	Creamy white	No growth	Good
7	Sample–1	No change	No growth	Good
	Sample–2	No change	No growth	Good
	Sample–3	No change	No growth	Good
	Sample–4	No change	No growth	Good
14	Sample–1	No change	No growth	Good
	Sample–2	Slightly change	No growth	Good
	Sample–3	No change	No growth	Good
	Sample–4	No change	No growth	Good
21	Sample–1	Change slightly	Growth slightly	Spoiled
	Sample–2	Change slightly	Growth slightly	Spoiled
	Sample–3	Change slightly	Growth slightly	Slightly spoiled
	Sample–4	Change slightly	Growth slightly	Slightly spoiled

Note: Sample–1 = coconut milk from endosperm without testa, sample–2 = coconut milk from endosperm with testa, sample–3 = pasteurized coconut milk from endosperm without testa, sample–4 = pasteurized coconut milk from endosperm with testa

Changes in Sensory Attributes

The scores given by the panelists to coconut milk samples for colour, flavour, taste and overall acceptability and results of analysis of variance ($P < 0.05$) are given in Table 4. The sensory scores for colour, flavour, taste and overall acceptability decreased with the increase in storage period.

Table 4 Changes in sensory attributes of coconut milk samples during storage at refrigerated condition

Samples	Sensory attributes	Storage period (days)			
		0	7	14	21
Sample–1	Color	7.70 ± 0.213[a]	7.60 ± 0.163[a]	7.30 ± 0.152[a]	7.20 ± 0.133[a]
	Taste	7.80 ± 0.133[ab]	7.80 ± 0.133[a]	7.50 ± 0.166[a]	7.30 ± 0.152[a]
	Flavor	8.10 ± 0.001[a]	7.80 ± 0.133[a]	7.20 ± 0.133[a]	7.20 ± 0.133[a]
	Overall acceptability	7.83 ± 0.055[a]	7.73 ± 0.066[a]	7.33 ± 0.070[a]	7.23 ± 0.050[a]
Sample–2	Color	7.50 ± 0.166[a]	7.50 ± 0.223[a]	7.20 ± 0.200[ab]	7.00 ± 0.210[ab]
	Taste	7.60 ± 0.163[b]	7.50 ± 0.166[a]	6.80 ± 0.200[b]	6.70 ± 0.213[b]
	Flavor	7.50 ± 0.166[bc]	6.50 ± 0.166[c]	6.70 ± 0.152[a]	6.70 ± 0.152[b]
	Overall Acceptability	7.53 ± 0.088[b]	7.16 ± 0.102[b]	6.90 ± 0.131[b]	6.80 ± 0.133[b]
Sample–3	Color	7.50 ± 0.166[a]	7.40 ± 0.163[a]	7.40 ± 0.221[a]	7.20 ± 0.133[a]
	Taste	8.20 ± 0.133[a]	7.70 ± 0.152[a]	7.40 ± 0.163[a]	7.30 ± 0.152[a]
	Flavor	7.90 ± 0.100[ab]	7.80 ± 0.133[a]	6.70 ± 0.213[a]	7.10 ± 0.179[ab]
	Overall Acceptability	7.86 ± 0.073[a]	7.63 ± 0.059[a]	7.17 ± 0.151[ab]	7.20 ± 0.113[a]
Sample–4	Color	7.20 ± 0.200[a]	6.60 ± 0.266[b]	6.60 ± 0.266[b]	6.50 ± 0.223[b]
	Taste	7.90 ± 0.179[ab]	7.00 ± 0.001[b]	7.00 ± 0.210[ab]	6.80 ± 0.200[ab]
	Flavor	7.30 ± 0.260[c]	7.00 ± 0.149[b]	6.80 ± 0.133[a]	6.70 ± 0.152[b]
	Overall Acceptability	7.46 ± 0.150[b]	6.86 ± 0.101[c]	6.80 ± 0.113[c]	6.67 ± 0.086[b]

Note: Sample–1 = coconut milk from endosperm without testa, sample–2 = coconut milk from endosperm with testa, sample–3 = pasteurized coconut milk from endosperm without testa, sample–4 = pasteurized coconut milk from endosperm with testa

The results revealed that up to 14[th] days of storage, there was no significant difference in the opinion of panelists to colour acceptability among the coconut milk samples at $P < 0.05$ while a significant difference was observed after 21[st] days of storage. The results show that there was a significant ($P < 0.05$) difference in flavour acceptability among the coconut milk samples during each observation period up to 21[st] days of storage. However, the panelists have considered the flavour of coconut milk better and gave good scores. This might be due to the preference of coconut flavour which was felt pleasant and attractive to the panelists. The scores given by the panelists to coconut milk for taste revealed that there was a significant ($P < 0.05$) difference in taste acceptability among the coconut milk samples during each observation period up to the 21[st] days of storage. The scores given by the panelists to the coconut milk indicated that the taste of coconut milk was good. This is natural since the judges are accustomed to the taste of coconut milk. The results of scores awarded and analysis of variance ($P < 0.05$) showed that all the panelists had an almost same opinion about overall acceptability for coconut milk of sample–1 and sample–3 during each observation period up to the 21st days of storage. However, panelists had differed in their opinion for coconut milk of sample–2 and sample–4. They ranked the coconut milk of sample–1 and sample–3 better having mean scores of 7.23 and 7.20, respectively after 21st days of storage.

CONCLUSIONS

The present study was conducted to evaluate the physicochemical properties of pasteurized coconut milk storage at refrigeration condition for 3 weeks. The findings of the present study indicated that all the coconut milk samples contained a significant quantity of nutrients like protein, ash and carbohydrate. Pasteurization significantly reduced loads of viable microorganisms and their limit laid at an acceptable range up to 3 weeks, however, fungal growth occurred after 2 weeks of storage while colour and flavour were changed slightly. The sensory evaluation indicated that scores for colour, flavour, taste and overall acceptability decreased with increases in storage period. Conclusively, coconut milk samples can be stored up to 2 weeks without affecting its overall acceptability using the pasteurization process. Coconut milk could be considered as a promising food component that could be used in many foods in adjunct with fresh coconut. This study has paved the way for further study to standardize the efficient and sustainable technique for processing and preserving coconut milk with improved technology as well as chemical pretreatment methods both in domestic and industrial scales.

REFERENCES

Adesola, A.O., G.S. Olasunkanmi and T. Adekunbi. 2013. Effects of some processing factors on the characteristics of stored groundnut milk extract. Afr. J. Food Sci. 7(6): 134–142.

Alyaqoubi, S., A. Abdullah, M. Samudi, N. Abdullah, Z.R. Addai and K.H. Musa. 2015. Study of antioxidant activity and physicochemical properties of coconut milk (Pati santan) in Malaysia. J. Chem. Pharm. Res. 7(4): 967–973.

Amarasiri, W.A. and A.S. Dissanayake. 2006. Coconut fats. Ceylon Med. J. 51(2): 47–51.

Amon, A.S., R.Y. Soro, E.F. Assemand, E.A. Dué and L.P. Kouamé. 2014. Effect of boiling time on chemical composition and physico–functional properties of flours from taro (*Colocasia esculenta* cv fouê) corm grown in Côte d'Ivoire. J. Food Sci. Technol. 51(5): 855–864.

AOAC (Association of Official Analytical Chemists). 2005. Official Method of Analysis. 12th Edition. Washington, D.C., USA.

APCC (Asian and Pacific Coconut Community). 1994. International Codes and Standard for Aqueous Coconut Products. 2nd Draft. Standards Task Force, Asian and Pacific Coconut Community, Jakarta, Indonesia

Balogun, M.A., F.L. Kolawole, J.K. Joseph, T.T. Adebisi and O.T. Ogunleye. 2016. Effect of fortification of fresh cow milk with coconut milk on the proximate composition and yield of warankashi, a traditional cheese. Croat. J. Food Sci. Technol. 8(1): 10–14.

Belewu, M.A., K.Y. Belewu and R.A. Bamidele. 2010. Cyper–coconut yoghurt: preparation, compositional and organoleptic qualities. Afr. J. Food Sci. Technol. 1(1): 010–012.

Blank, I., S. Devaud, W. Matthey–Doret and F. Robert. 2003. Formation of odorants in Maillard system based on L–proline as affected by pH. J. Agric. Food. Chem. 51: 3643–3650.

Cancel, L.E. 1979. Coconut food products and bases, pp. 162–187. *In*: J.G. Woodroof, (Ed.), Coconuts: Production, Processing, Products. AVI Publishing Co., Westport, Conn., USA.

Davidek, T., D. Stephanie, R. Fabien and I. Blank. 2006. Sugar fragmentation in the Maillard reaction cascade: Isotope labeling studies on the formation of acetic acid by a hydrolytic beta–dicarbonyl cleavage mechanism. J. Agric. Food Chem. 54(18): 6667–6676.

Diarra, K., Z.G. Nong and C. Jie. 2005. Peanut milk and peanut milk based products production: a review. CRC Crit. Rev. Food Sci. Nutr. 45: 405–423.

Ekanayaka, R.A.I., N.K. Ekanayaka, B. Perera and P.G.S.M. De Silva. 2013. Impact of a traditional dietary supplement with coconut milk and soya milk on the lipid profile in normal free living subjects. J. Nutr. Metab. 2013: 481068.

Fernandez, W.L., E.V. Ignacio, C.K. Linga and A.H. Malapitan. 1970. Bihourly bacterial plate count of gata (coconut milk) stored for 24 h at 30°C, 20°C and 10°C. Philippine Agriculturist 54: 202–209.

Gonzalez, O.N. 1990. Coconut milk, pp. 13–48. *In*: J.A. Banzon, O.N. Gonzalez, S.Y. de Leon and P.C. Sanchez, (Eds.), Coconut as Food. Philippine Coconut Research and Development Foundation, Quezon City, The Philippines.

Gunathllake, K.D.P.P. and A.G.A. Bandara. 2005. Preparation of a ready–to–use coconut cum spices paste for chicken curry and evaluation of its physicochemical and storage properties. Cocos 17: 21–29.

Gwee, C.N. 1988. New technologies open the passage into new usage of coconut milk products, pp. 157–162. *In*: S. Maneepun, P. Varangoon and B. Phithakpol, (Eds.), Food Science and Technology in Industrial Development. Institute of Food Research and Product Development, Kasetstart University, Bangkok, Thailand.

Huang, X., H. Duan and S.A. Barringer. 2011. Effects of buffer and temperature on formation of furan, acetic acid and formic acid from carbohydrate model systems. Food Sci. Technol. 44: 1761–1765.

Kajs, T.M., R. Hagenmaier, C. Vanderzant and K.F. Mattil. 1976. Microbiological evaluation of coconut and coconut products. J. Food Sci. 41: 352–356.

Khalifa, M., A. Elgasim, A. Zaghloul and M. Maufouz. 2011. Application of inulin and mucilage as stabilizers in yoghurt production. Am. J. Food Technol. 1: 10–17.

Konkamdee, W. and P. Saikhwan. 2015. Effect of pasteurization on protein and fat contents remaining in coconut milk. Journal of Food Science and Agricultural Technology 1(1): 182–187.

Laureles, L.R., F.M. Rodriguez, M.A.A. Caraos, C.E. Reaño, G.A. Santos, A.C. Laurena and E.M.T. Mendoza. 2000. Storage lipid variability in promising coconut cultivars and hybrids: fatty acids and triacylglycerol composition. Philippine Journal of Coconut Studies 25(1–2): 42–54.

Mabbit, L.A. 1981. Metabolic activity of bacteria in raw milk. *In*: Proceedings of the IDF Symposium on On Bacteriological Quality of Raw Milk. Kieler Milchwirtschaft, Forschungsber.

Mabesa, R.C. and R.R. del Rosario. 1979. Quality control in coconut milk processing II. Microbial Contaminants. Philippine Agriculturist 63: 167–175.

Magda, R.R. 1992. Coco–soft drink: health beverage from coconut water. Food Mark. Technol. 6: 22–23.

Mensink, R.P., P.L. Zock, A.D. Kester and M.B. Katan. 2003. Effects of dietary fatty acids and carbohydrates on the ratio of serum total to HDL cholesterol and on serum lipids and apolipoproteins: a meta–analysis of 60 controlled trials. Am. J. Clin. Nutr. 77(5): 1146–1155.

Moyls, A.L., R. Hocking, T. Beveridge and G. Timbers. 1992. Exponential decay method for determining gas transmission rate of films. Trans ASAE 35(4): 1259–1265 .

Muda, N. 2002. Rheological Behaviour of Coconut Milk: Effects of Concentration and Temperature. MS Thesis, University Putra Malaysia, Malaysia.

Narataruksa, P., W. Pichitvittayakarn, P.J. Heggs and S. Tia. 2010. Fouling behavior of coconut milk at pasteurization temperatures. Appl. Therm. Eng. 30: 1387–1395.

Obinna–Echem, P.C., N.J.T Emelike and J.M. Udoso. 2019. Effect of pasteurization on the proximate composition, mineral and sensory properties of fresh and dry tiger nuts, and their milk extracts. Int. J. Food Nutr. Res. 2(18): 1–13.

Onweluzo, J.C. and O.S. Owo. 2005. Stabilization potential of water soluble polysaccharide from two legumes (*Deterrummisso carpum* and *Mukurafla gellipes*) in vegetable milk: effects on selected quality characteristics. J. Home Econ. Res. 6: 39–44.

Ramaswamy, L. 2014. Coconut flour– a low carbohydrate, gluten free flour. Int. J. Ayurvedic Herb. Med. 4(1): 1426–1436.

Saleem–ur–Rehman, M.M. Ahmad, A. Yameen, K. Almas and Sidra–til–Muntaha. 2004. Sensory and nutritional evaluation of coconut–natural milk blend. Pak. J. Life Soc. Sci. 2(2): 104–108.

Sani, I., C. Owoade, A. Abdulhamid, M.F. Isah and F. Bello. 2014. Evaluation of physicochemical properties, phytochemicals and mineral composition of *Cocos nucifera* (coconut) kernel oil. Int. J. Adv. Res. Chem. Sci. 1(8): 22–30.

Schaich, K.M. 2005. Lipid oxidation: theoretical aspects, pp. 269–355. *In*: F. Shahidi, (Ed.), Bailey's Industrial Oil and Fat Products, Volume 1: Edible Oil and Fat Products: Chemistry, Properties, and Health Effects. 6th Edition. John Wiley & Sons, Inc., New Jersey, USA.

Seow, C.C. and C.N. Gwee. 1997. Coconut milk: chemistry and technology. Int. J. Food Sci. Technol. 32(1): 189–201.

Simuang, J., N. Chiewchan and A. Tansakul. 2004. Effect of fat content and temperature on the apparent viscosity of coconut milk. J. Food Eng. 64: 193–197.

Srivastava, R.P. and K. Sanjeev. 1994. Fruits and Vegetable Preservation: Principle and Practices. International Book Distributing Company, Charbagh, Lucknow.

Staffolo, M.D., N. Bertola, M. Martino and Y.A. Bevilacqua. 2004. Influence of dietary fiber addition on sensory and rheological properties of yogurt. Int. Dairy J. 14: 263–268.

Tansakul, A. and P. Chaisawang. 2006. Thermo physical properties of coconut milk. J. Food Eng. 73: 276–280.

Tetra Pak. 2016. The chemistry of coconut milk and cream. *In*: Coconut Handbook. Available Source: https://coconuthandbook.tetrapak.com/chapter/chemistry-coconut-milk-and-cream. July 10, 2020.

Tinchan, P., Y. Lorjaroenphon, K.R. Cadwallader and S. Chaiseri. 2014. Changes in the profile of volatiles of canned coconut milk during storage. J. Food Sci. 80(1): C49–C54.

Tseng, A. and Y. Zhao. 2013. Wine grape pomace as antioxidant dietary fibre for enhancing nutritional value and improving storability of yogurt and salad dressing. Food Chem. 138: 356–365.

Ukwuru, M.U. and A.C. Ogbodo. 2011. Effect of processing treatment on the quality of tiger nut milk. Pak. J. Nutr. 10(1): 95–100.