Engineering Perspectives in Filtration and Separation, Vol. 3, No. 1, 2025
ISSN:3107-5290

Improving the Storage Duration and Improving the Characteristics of Tender Coconut Water using Non-thermal Two-phase Microfiltration

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Abstract--- Coconut (Cocos nucifera L.) is a significant crop in tropical climates. Tender coconut water (TCW) is ingested as a revitalizing beverage due to its nutritive and medicinal attributes. The combination of electrolytes and minerals renders TCW appropriate as a sports beverage. Nonetheless, it is very susceptible to degradation, rendering the TCW unfit for consumption after about one day owing to contamination from outside by bacteria and oxidization, which results in the loss of almost all of its taste and nutrients. A non-thermal two-phase microfiltration (NTM) method for sterile circumstances has been employed in this work to protect TCW. The levels of acidic substances like citric acid (CA), the antioxidant ascorbic acid (AA), and L-cysteine (LC) were calibrated based on flavor and included in TCW as organic additions. After purging the head with nitrogen, TCW was contained in the plastic and glass jars and kept in the refrigerator.

The NTM-TCW had been examined for microbiological, taste, and physiological qualities for 45 days. The purity of TCW contained in glass jars was superior in every aspect. The impact of refrigerated storage has been investigated. During storage, the total acidity level went up. TCW stored in plastic had the highest amounts, followed by TCW stored in glass, and finally, TCW was stored in its original state. The sugar content showed a different trend. The original sample kept the highest amounts of sugar after storage, while the values slowly dropped in glass and plastic storage, with plastic showing the most significant drop. The amount of amino acids was reduced in all of the settings. The original specimen was better preserved than those in glass and plastic, while TCW dropped in plastic broke down the fastest. As time went on, the original state constantly did a better job than glass and plastic at keeping the quality and nutritional content of TCW, with plastic being the least effective. Microfiltering (MF) and the incorporation of compounds have been determined to enhance the storage duration of TCW.

Keywords--- Tender coconut water, Non-thermal, Microfiltration, Refrigeration, Taste, Purging.

Received: 15 - 10 - 2024; Revised: 21 - 11 - 2024; Accepted: 17 - 12 - 2024; Published: 30 - 01 - 2025

I. Introduction to TCW Properties, Processing, and Storage

Coconut (Cocos nucifera L) is a fibrous crop rich in various nutrients, electrolytes, and carbohydrates. It has appealing flavors and little caloric content. Customers' interest in pure TCW is increasing because of its nutritional benefits and heightened knowledge about caffeinated and artificial drinks. It is a nutritious sports beverage with significant hydrating capabilities. TCW has significant medicinal properties and may be utilized in alleviating many disorders (Ekpenyong & Okafor, 2018). It may alleviate urinary tract infections and abdominal discomfort, avoid heat rashes, and assist in maintaining the body's pH balance. TCW has features comparable to human plasma, promoting its utilization as a replacement (Rajashri et al., 2022).

Furthermore, TCW use protects the heart from coronary artery disease and minimizes high blood pressure. The TCW efficiently mitigates severe conditions like sickle cell syndrome (Ekpenyong & Okafor, 2018). Nonetheless, excessive intake of TCW may elevate levels of potassium in the bloodstream, potentially resulting in renal complications. Notwithstanding its advantageous attributes, the product's restricted lifespan hinders its widespread use.

The activity of dietary enzymes, including polyphenol oxidases (PPO) and peroxidases (POD), significantly reduces the shelf life and commercial viability of TCW. The catalytic activity of these enzymes produces several undesirable consequences in TCW, even under refrigeration. Likewise, the production of pink coloration, browning, unpleasant tastes, and smells are undesirable results of catalytic processes and bacterial activity (Rajashri et al., 2022). Moreover, the newly produced TCW is particularly vulnerable to microbial invasion by botulism-causing bacteria (Raghubeer et al., 2020).

TCW is very susceptible to microbial contamination within hours after it is removed from the nut, reducing nutritious components and decreasing lifespan (Mahnot et al., 2019). Reportedly, certain intrinsic constituents of TCW, such as antibiotic peptides and amino acids, limit the development of pathogenic strains (Raghubeer et al., 2020). Therefore, it is essential to maintain a high-quality beverage of nutritional and sensory significance. Heat treatment procedures are the predominant preservation strategies used for TCW. Nonetheless, these therapies impair the product's general acceptability while diminishing its beneficial properties.

Heat treatment techniques, including evaporation, pasteurization, and sanitation, are the most energy-intensive technologies in the food sector (Picart-Palmad et al., 2019). Furthermore, heat treatments adversely affect color, clarity, and sensory attributes. Conventional heat processing techniques sometimes modify the organic features by degrading sensitive components, changing the product's inherent characteristics. Therefore, it is essential to investigate non-thermal approaches for the retention and increasing the storage life of TCW.

II. Related Works

Filtration by membrane is an innovative method in the dietary processing industry. Nonetheless, published research about TCW treatment using various microfiltration methodologies is relatively sparse. The fundamental concept of microfiltration (MF) is the dimensions disparity or sieving activity produced by the filtration medium. In MF, it is essential to choose an appropriate pore dimension for the screening element to ensure the retention of the enzyme while permitting the passage of every other element (Mahnot et al., 2019). This approach is a cold disinfection procedure sometimes used with other heating and NT processing techniques to get optimal results.

Ultra filtering (UF) with a particle size of 0.001 to 0.05 µm effectively retains enzymes on the film's supply face, substantially reducing their ability to function (Lamdande et al., 2020). MF TCW, supplemented with the antioxidant L-ascorbic acid, has shown superiority over heating techniques. The quantity of PPO and POD enzymes decreases with a rising level of ascorbic acid. The inhibition of enzyme function may be ascribed to air absorption and obstructing the chemical catalyst's active location. Nevertheless, an elevated ingredient concentration results in a heightened acidic taste in TCW, diminishing the good's overall appeal. Additionally, similar outcomes were achieved by (Mahnot et al., 2019), whereby additions including AA, CA, and LC inhibited the decomposition of MF TCW. Furthermore, regarding packing, TCW in glass jars exhibited higher quality in all respects than plastic jars.

Moreover, NTM using reduced ash filter media and a 0.1 µm nitrate-cellulose membrane effectively confirmed the efficiency of MF in maintaining TCW quality (Prithviraj et al., 2022). Nonetheless, nutritional deficiencies were noted throughout the trial, leading to decreased product acceptance. Similar results were seen when TCW was treated with specific compounds in conjunction with MF, extending the shelf life to 85 days without adverse consequences. Kinetic research by (Prithviraj et al., 2021) revealed that acidity adjustment, soluble lipids, and decreased sugar had zero-order kinetics, while all soluble solids, AA content, and antioxidant functions adhered to first-order kinetics.

Nonetheless, additional frameworks, such as Weibull, biphasic, log-linear, and numerical representations of curve fitting variables, need examination due to their efficacy in diverse non-thermal methods exhibiting identical deactivation processes. MF decreased amino acids, lowering carbohydrates and overall basic sugars without impacting total quality from a sensory perspective (Rethinam & Krishnakumar, 2022). Likewise, membrane approaches need more investigation to ascertain their viability in TCW synthesis. When appropriately planned and optimized, membrane methods are more feasible than other methods with significant energy consumption.

III. Materials and Methods

Sterilization of TCW

The entire treatment space was meticulously cleansed and disinfected with methanol and potassium chloride a day before treatment. On the filtering day, the TCW was rinsed with normal water to eliminate exterior dirt and immersed in a 350 mg/L sodium hypochlorite mixture for sanitization. All equipment for processing had been cleaned in a sterilizing chamber at 104.13 KPa for 20 minutes.

Incorporation of AA, CA, and LC

Various amounts of CA, from 0.006 to 0.01 g/120 mL, and AA, from 0.02 to 0.25 g/120 mL, were incorporated into TCW and assessed on a 9-point Hedonistic score by a team of 10 trained evaluators. The judges favored the 0.01 g/120 mL CA mixture and 0.02 g/120 mL AA incorporated into TCW. This specific mixture of CA and AA included four distinct amounts of LC. Ten trained reviewers assessed the specimens' sensory qualities, including taste, fragrance, texture, and general efficacy.

The Process of TCW

The TC was opened with a sterilized blade of stainless steel, and the water was filtered into a glass vessel within an annular air circulation. The MF procedure was conducted under a turbulent flow environment. The gathered TCW was initially filtered using a strainer and secure connection with the Whatman No. 4 filtering paper. The purified TCW was conveyed via a Teflon pipe to a microbiological filtering unit with a 0.75 mm MF connected to a vacuum compressor. The MF was gathered, and the procedure was executed again using a second filtering device equipped with a 0.5 mm filter.

Any leakage of TCW within the annular circulation was removed using cotton swabs saturated with alcohol. The resulting filtered TCW was gradually loaded into a robust vacuum container. After the precise measurement and calculation of CA, AA, and LC, these substances were introduced into the robust vacuum chamber and combined gradually. The treated TCW was then packaged into disinfected plastic and glass jars containing 45 mL. The headspace was purged with nitrogen-containing gases under a laminar flow chamber. The containers were securely fastened, and the specimens were maintained under refrigeration at 4°C.

Storage Analysis

The TCW in plastic and glass jars was evaluated at 7, 21, and 45 days. The specimens were first assessed for the level of bacteria and then subjected to sensory assessment by trained experts. Each specimen was evaluated for multiple variables: pH, total acidity, carbohydrates, amino acids, and free lipids. Raw TCW (distinctive) was kept in a glass container and evaluated on the 0th and 45th days. The evaluation of packaged TCW was predicated on its taste characteristics. The study concluded on the 45th day due to the loss of flavor and unique taste in packaged TCW, apart from the microbiological burden.

The pH remained relatively stable in all samples throughout storage, but a declining trend was seen. The statistical evaluation revealed a significant variation in pH across the NTM specimens, but the comparable MF specimens had no impact. A little rise was seen in MF materials on day 45 of the study. Consequently, the MF technology facilitated the maintenance of steady pH levels throughout storage. NTM specimens on day 45 exhibited increased pH, attributable to enhanced protein degradation.

IV. Results

The contamination level of unfiltered, additive-free fresh TCW was 138 cfu/mL. Microfiltered TCW contained in glass jars exhibited no microbial development during its preservation duration, demonstrating its efficacy in eliminating germs. Nonetheless, microfiltered TCW packaged in plastic jars, which remained sterile for a week, exhibited microbial development on the 21st and 45th days of the trial. The proliferation of microbes in plastic jars may result from specific faults and contamination inside the containers.

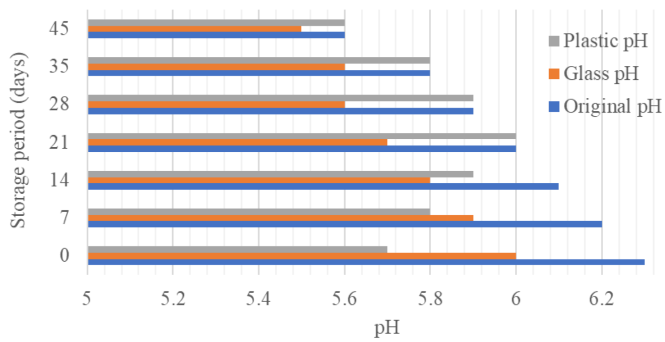

Figure 1: Comparative Variation in pH During Storage of TCW Using NTM

Figure 1 depicts the variations in pH of TCW using NTM held in various packing materials (original, glass, and plastic) throughout a 45-day storage period. The initial pH of TCW in its native state (6.3) exceeded that held in glass (6.0) and plastic (5.7). Over time, the pH of TCW under all storage settings progressively decreased, indicating heightened acidity. Significant variations in the rate of pH drop were noted depending on the storage medium. On day 45, the pH values for the original, glass, and plastic samples were 5.6, 5.5, and 5.6, respectively, with glass exhibiting the most pronounced decline. This indicates that storage in glass may expedite pH decline relative to plastic and the initial condition, likely attributable to variations in material interaction and gas permeability, such as CO_2.

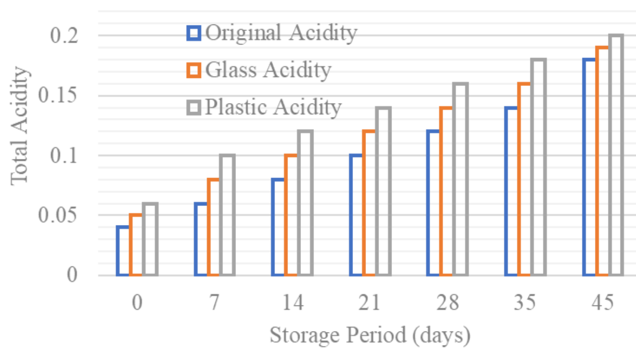

Figure 2: Comparative Variation in Total Acidity During Storage of TCW Using NTM

Figure 2 shows the comparative variation in total acidity during storage of TCW using NTM. Figure 2 illustrates the rise in total acidity of TCW held in various packing materials (original, glass, and plastic) during 45 days. The original sample exhibited the lowest acidity at 0.04%, followed by glass at 0.05% and plastic at 0.06%. Over time, overall acidity escalated under all storage settings, with the plastic-stored TCW exhibiting the most significant rate of rise. On day 45, the acidity levels were recorded at 0.18%, 0.19%, and 0.20% for the original, glass, and plastic specimens. The data indicate that storage in plastic hastens acidification relative to glass and the initial condition, possibly owing to interactions between the packaging material and the TCW, which may affect microbial activity and chemical reactions.

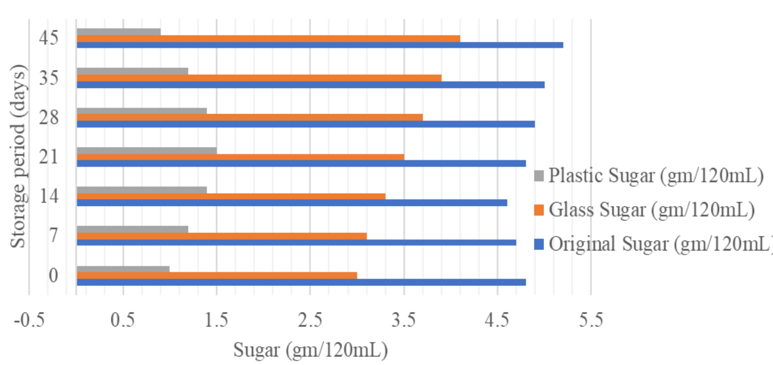

Figure 3: Comparative Variation in Total Sugar (gm/120mL) During Storage of TCW Using NTM

Figure 3 depicts the comparative variation in total sugar (gm/120mL) during storage of TCW using NTM. The original sample had the greatest sugar content (4.8 g/120mL), followed by glass (3 g/120mL) and plastic (1 g/120mL). The sugar level in the original and glass-stored samples consistently rose with time, reaching maxima of 5.2 g/120mL and 4.1 g/120mL, respectively. Still, the plastic-stored TCW exhibited a decrease in sugar content after day 21, falling to 0.9 g/120mL by day 45. This pattern indicates that sugar deterioration is more significant in plastic-stored TCW, possibly attributable to microbial activity or interactions with the plastic, while glass storage and the original state more effectively retain or marginally boost sugar levels throughout storage.

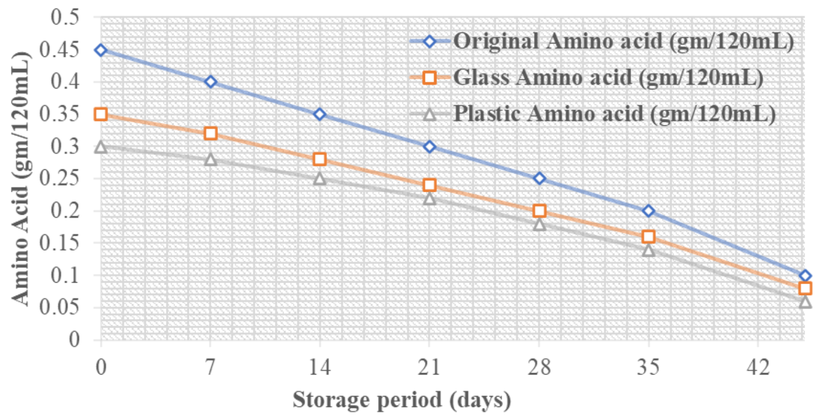

Figure 4: Comparative Variation in Amino Acid (gm/120mL) During Storage of TCW Using NTM

Figure 4, entitled "Comparative Variation in Amino Acid (gm/120mL) During Storage of TCW Using Non-Thermal Two-Phase Microfiltration (NTM)," illustrates a progressive reduction in amino acid concentration under all storage settings during a 45-day duration. The original sample exhibited the greatest amino acid concentration (0.45 g/120 mL), followed by glass (0.35 g/120 mL) and plastic (0.3 g/120 mL). During the storage duration, the amino acid concentrations progressively decreased, with the initial sample maintaining superior levels (0.1 g/120mL at day 45) relative to glass (0.08 g/120mL) and plastic (0.06 g/120mL). This tendency suggests that the original TCW state maintains amino acid content more effectively. However, storage under glass and plastic hasten its destruction, maybe owing to environmental interactions or oxidative mechanisms. Plastic-stored TCW had the fastest deterioration, indicating its inferior efficacy in preserving amino acid stability.

V. Discussion

The results reveal substantial discrepancies in pH, total acidity, sugar, and amino acid levels in TCW while storage under various circumstances (original, glass, and plastic). The pH consistently decreased in each specimen, with the initial condition demonstrating the greatest stability, but plastic-stored TCW had the lowest pH values, indicating heightened acidity. Total acidity rose throughout storage time, with plastic-stored TCW exhibiting the highest levels, followed by glass and the original state. The sugar content revealed a divergent pattern, with the original sample maintaining the greatest levels after storage, while glass and plastic storage showed gradually decreasing values, with plastic exhibiting the most significant reduction. Amino acid concentration decreased under all environments, with the original specimen exhibiting superior preservation relative to glass and plastic, whilst TCW placed in plastic saw the most rapid deterioration. The original state consistently surpassed glass and plastic in preserving the quality and nutritional content of TCW throughout the storage duration, with plastic demonstrating the lowest efficiency.

VI. Conclusion

This study used a non-thermal two-phase microfiltration (NTM) technique under sterile conditions to safeguard TCW. The concentrations of acidic compounds such as CA, AA, and LC were standardized according to taste and included in TCW as organic additives. Following the nitrogen purging of the head, TCW was stored in plastic and glass jars and then refrigerated. The NTM-TCW underwent evaluation for microbiological, sensory, and physiological attributes over 45 days. The purity of TCW stored in glass jars was exceptional in all respects. The effects of cold storage have been examined. Throughout storage, the overall acidity level increased. TCW kept in plastic had the greatest concentrations, followed by TCW stored in glass and TCW in its original condition. The sugar content exhibited a divergent trend. The original sample retained the maximum sugar content post-storage, but the levels gradually decreased in glass and plastic containers, with plastic exhibiting the most significant reduction. The quantity of amino acids decreased in all situations. The original specimen exhibited superior preservation compared to those encased in glass and plastic, but TCW encased in plastic deteriorated most rapidly. Over time, the original condition consistently outperformed glass and plastic in preserving the quality and nutritional content of TCW, with plastic proving to be the least effective. Micro Filtering (MF) and the integration of compounds have been shown to prolong the storage period of TCW.

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