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EFFECTS OF POLYPROPYLENE AND POLYETHYLENE TEREPHTHALATE BOTTLE PACKAGING AND STORAGE TEMPERATURES ON THE QUALITY AND STABILITY OF ROSELLE DRINKS

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Abstract: The short shelf life of Roselle drinks presents a major challenge for commercialization and consumer satisfaction. Packaging material and storage conditions significantly influence the quality and stability of these beverages. This study aimed to evaluate the effects of different types of plastic bottle packaging (Polypropylene and Polyethylene Terephthalate) and storage temperatures (ambient 25°C and refrigerated 4°C) on the physicochemical and microbiological properties of Roselle drinks. It was hypothesized that PP bottles combined with refrigeration at 4°C would outperform PET bottles and ambient storage in preserving the drink's quality. The research involved systematic evaluation of physicochemical parameters, such as color (L*, a*, b*), pH, titratable acidity, and vitamin C content, as well as microbial load over a seven-day storage period. Statistical analysis was conducted using two-way ANOVA. The results indicated that PP bottles combined with refrigeration at 4°C demonstrated superior performance in maintaining physicochemical stability and reducing microbial growth. In contrast, PET bottles, particularly at 25°C, showed significant degradation of quality attributes due to higher oxygen permeability and exposure to external factors. The findings highlighted the role of oxygen permeability and temperature sensitivity in quality preservation. PP bottles and refrigerated storage conditions were found to be optimal for extending the shelf life and maintaining the quality of Roselle drinks. It is recommended that the food and beverage industry adopt PP bottles and consistent cold storage practices for commercial-scale production.
Keywords: Roselle drink, storage study, polypropylene, polyethylene terephthalate, packaging, stability

1. Introduction

Roselle (*Hibiscus sabdariffa L.*) is a popular tropical plant cultivated widely for its calyces, which are commonly used to produce various beverages, jams, and sauces (Cisse, 2010). Roselle drinks are well-regarded for their vibrant red color, unique tart flavor, and potential health benefits, including antioxidant and anti-inflammatory properties (Da-Costa-Rocha et al., 2014). The increasing consumer demand for Roselle drinks necessitates effective packaging solutions to preserve their quality and shelf life.

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Packaging is crucial for maintaining the quality and freshness of food and beverage products (Nur Farah Hani et al., 2022). Various types of plastic bottles, such as PET, PP, and Polyvinyl Chloride (PVC) are commonly used. Each plastic type possesses unique properties, including permeability, mechanical strength, and chemical resistance, which can impact the shelf life and overall quality of Roselle drinks (Siracusa, 2012).

Roselle has a notably short shelf life, which poses a significant challenge for its commercialization. A strategy to extend this shelf life involves producing Roselle drinks using suitable packaging materials combined with appropriate storage temperatures. The type of plastic bottle packaging can profoundly influence the shelf life across different storage temperatures. Therefore, measuring and analyzing key indicator parameters, such as color, pH level, titratable acidity (TTA), vitamin C content, and microbial load, is essential to accurately determine the shelf life.

This research aims to fill existing knowledge gaps regarding the optimal type of plastic bottle packaging for maximizing the shelf life of Roselle drinks. The findings of this study are expected to provide practical implications for the food and beverage industry. The comprehensive analysis of parameters like color, pH levels, titratable acidity, vitamin C content, and microbial load will provide a robust framework for future studies on shelf life extension and quality preservation.

2. Objectives

1. To evaluate the impact of different types of plastic bottle packaging on the quality of Roselle drinks by analyzing changes in color parameters, pH levels, titratable acidity, vitamin C content, and microbial load over time.
2. To evaluate the effects of different storage temperatures on the quality and stability of Roselle drinks by measuring variations in color parameters, pH levels, titratable acidity, vitamin C content, and microbial load during storage.

3. Material and Methods

Material and equipment

Roselle (*Hibiscus sabdariffa L.*) utilized in this study was harvested from the farm of Lembah Bidong, Setiu, Terengganu. All chemicals and equipment of analytical grade were sourced from the analytical laboratory, Universiti Sultan Zainal Abidin (UniSZA), Kampus Besut, Terengganu. The 250 mL PP and PET bottles were procured from MyBotol HQ in Klang, Selangor.

Roselle Extraction

The fully harvested Roselle calyces were thoroughly washed and subsequently added to boiling water for 30 minutes to facilitate juice extraction and the destruction of heat-sensitive microorganisms. The resulting juice was filtered using a muslin cloth, and this procedure was repeated twice to ensure full extraction. Granulated sugar was added to sweeten the clear juice (Abiose & Adeniran, 2010). The formulation utilized 60.6% Roselle extract, 26.9% water, and 12.5% granulated sugar (Table 3.1).

Table 3.1: Formulation of Roselle drink with some modifications

Ingredients	Total Volume (%)
Roselle extract	60.6
Water	26.9
Granulated Sugar	12.5

The mixture was then pasteurized. PET bottles were sterilized at 55°C for 30 minutes, while PP bottles were sterilized at 72°C for 10 minutes in a water bath. The extract was filled into the bottles while still hot and packaged at 45°C to minimize microbial growth and avoid the collapsing of the packaging bottles. The packaged Roselle drink samples were divided into equal portions and stored under two conditions: ambient temperature (25°C) and refrigerated temperature (4°C).

Color Analysis

Color measurement was performed at one-day intervals over a one-week storage period using a chromameter calibrated with a standard white tile. The color parameters recorded were L* (lightness), a* (greenness to redness), and b* (blueness to yellowness) values, according to the Commission Internationale d'Eclairage (CIE) L*a*b* color space standard (León et al., 2006). The L* value indicates lightness, the a* value represents greenness to redness, and the b* value measures blueness to yellowness.

pH Analysis

pH value determination was obtained at one-day intervals for one week using a calibrated pH meter at 25°C. The pH meter was standardized using buffer solutions of 4.01, 7.00, and 10.01 at 25°C. Samples were stirred to ensure homogenization before measurement, and readings were taken when the electrode displayed stability.

Titratable Acidity (TTA)

TTA was measured daily for one week using the titration method. A 20 mL sample was titrated with 0.1N Sodium Hydroxide (NaOH) until the endpoint of pH 8.2±0.2 was reached, as measured by a pH meter. The TTA results were calculated using the titre volume and expressed as a percentage (%) of Malic acid:

$$\%\, Malic\ acid = A \cdot 0.009 \cdot \frac{100}{V}$$

where A is the volume of 0.1 NaOH required for the titration in ml and V is the sample volume taken for the test in ml.

Vitamin C Analysis

Vitamin C levels were measured at one-day intervals over a one-week storage period using the Association of Official Analytical Chemists (AOAC) method. A 10-gram sample was diluted, filtered, and a 25 mL filtrate was titrated rapidly with 0.01 N standard iodine solution until a blue color formed (Yurliasni et al., 2023). Vitamin C is calculated as follows:

$$Vitamin\ C\ levels\ (\frac{mg}{100g}) = \left(\frac{0.88\ \times vol.iodine\ \times DF}{material\ weight\ \times 100}\right) \times 100$$

where DF is diluent factor and vol. iodine is the sample titration volume.

Microbiological Analysis

Microbial media (Nutrient Agar [NA] and Potato Dextrose Agar [PDA]) were prepared and autoclaved at 121°C for 15 minutes. Samples were withdrawn aseptically and serially diluted to 10^{-5}. Aliquots (100 µL) were spread-plated on NA for Total Bacteria enumeration (incubated at 37°C for 24 h) and on PDA for Yeast enumeration (incubated at 25°C for 48 h). Colony counts were calculated in colony forming units per mL (CFU/mL) and converted to Log^{10} CFU/ml (Obinna-Echem & Cookey, 2022).

Statistical Analysis

Data were statistically analyzed using Minitab (Release 18.1) Statistical Software. Statistical differences were evaluated using two-way analysis of variance (ANOVA) and Pairwise Comparison.

4. Results and Discussion

Color Analysis

Color parameters (L*, a*, and b*) are crucial sensory attributes and quality indicators for beverages. They are primarily affected by the degradation of anthocyanins, which are highly sensitive to external factors like temperature, light exposure, and oxygen permeability.

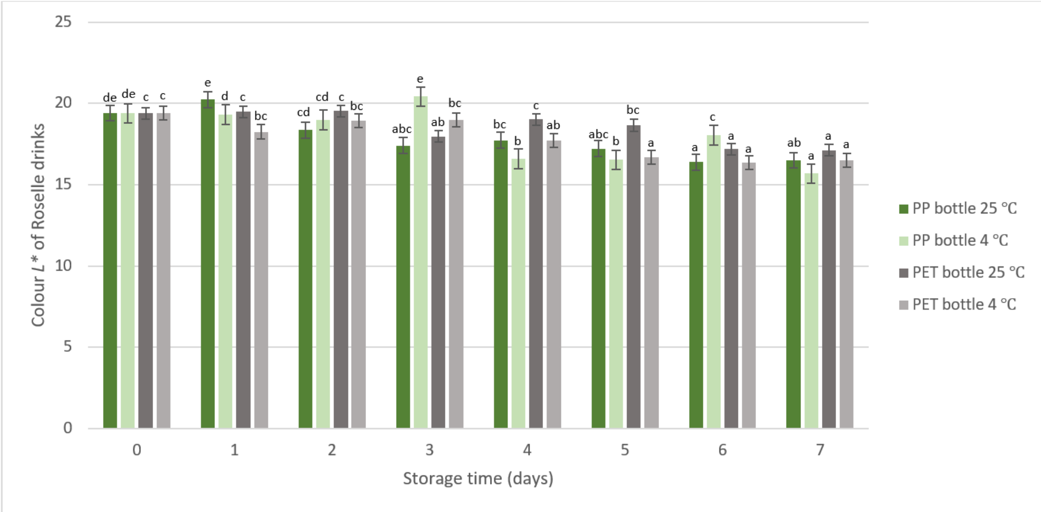

Figure 4.1: Changes in colour *L of Roselle drinks in the PP and PET bottles for different temperatures (25 and 4 °C) during storage time**

The L* value (lightness) decreased in all samples over time as shown in Figure 4.1. This decrease is associated with anthocyanin degradation, leading to a duller color. Elevated storage temperatures (25°C) accelerated L* reduction compared to 4°C. PET bottles, being more transparent, potentially allowed greater light penetration, which accelerates anthocyanin degradation. At 25°C, PP bottles declined from 19.39 (Day 0) to 16.50 (Day 7), while PET bottles dropped from 19.39 to 17.11. In Figure 4.2, the a* value (redness) fluctuated, decreasing more rapidly at 25°C than at 4°C, indicating faster anthocyanin degradation at the higher temperature (Pacheco-Palencia, Duncan, & Talcott, 2009). High temperatures accelerate oxidative degradation. PET bottles stored at 25°C showed the steepest decline in a* values (from 7.10 on Day 0 to 5.37 on Day 7). Storage at 4°C resulted in better retention of redness for both PET and PP bottles, as drinks stored at lower temperatures showed minimal losses in anthocyanins. Anthocyanin instability is exacerbated by heat, high pH, light exposure, dissolved oxygen, and interaction with ascorbic acid degradation products (Fennema & Tannenbaum, 1996).

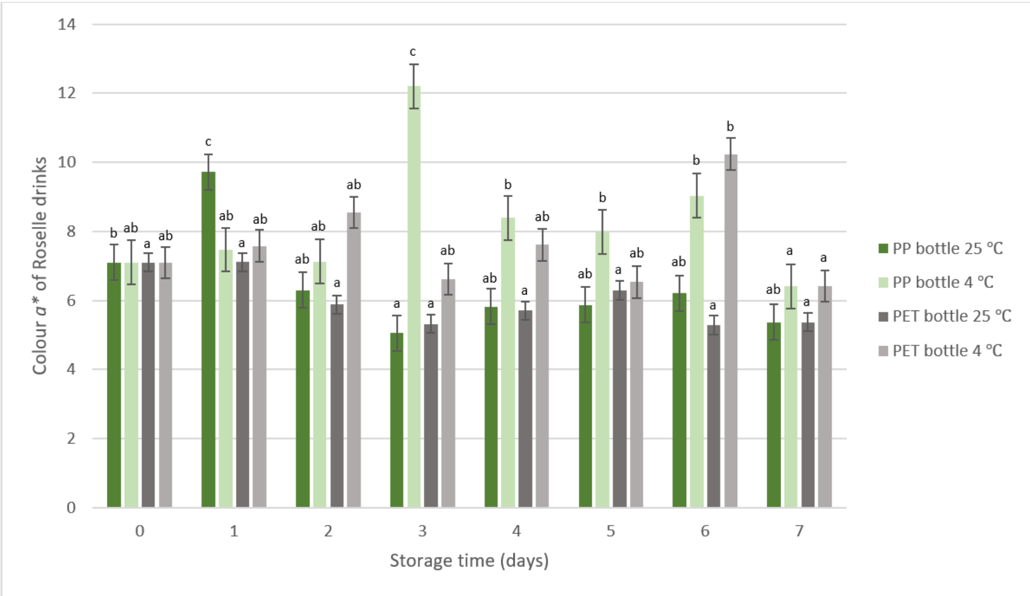

Figure 4.2: Changes in colour *a of Roselle drinks in the PP and PET bottles for different temperatures (25 and 4 °C) during storage time**

The b* value (yellowness) indicated that PP bottles generally demonstrated slightly better stability compared to PET bottles at both storage temperatures (see Figure 4.3). Changes in b* reflect oxidative processes and shifts in pigment composition. At 4°C, the b* values in both bottle types exhibited minimal changes.

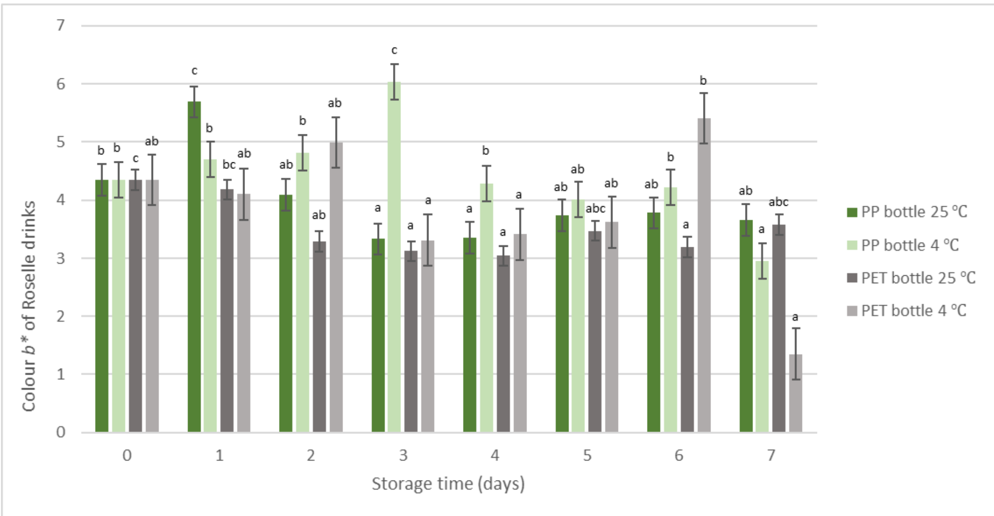

Figure Error! No text of specified style in document.**.1 Changes in colour *b** of Roselle drinks in the PP and PET bottles for different temperatures (25 and 4 °C) during storage time**

pH Analysis

The pH of Roselle drinks increased significantly during storage, particularly at 25°C (refer Figure 4.4). The pH increase (reduction in acidity) is contrary to expectations for beverages without preservatives. This increase is attributed to microbial metabolism of organic acids and accelerated chemical breakdown. Chemical breakdown of organic acids is accelerated by exposure to air, light, and oxygen, especially at higher temperatures. At 25°C, PP bottles showed a steeper increase in pH (e.g., Day 0: 2.73 to Day 7: 2.98) compared to PET bottles. Roselle's natural acidity comes from organic acids, such as oxalic, tartaric, malic, and succinic acids (Abdulmumini, 2018).

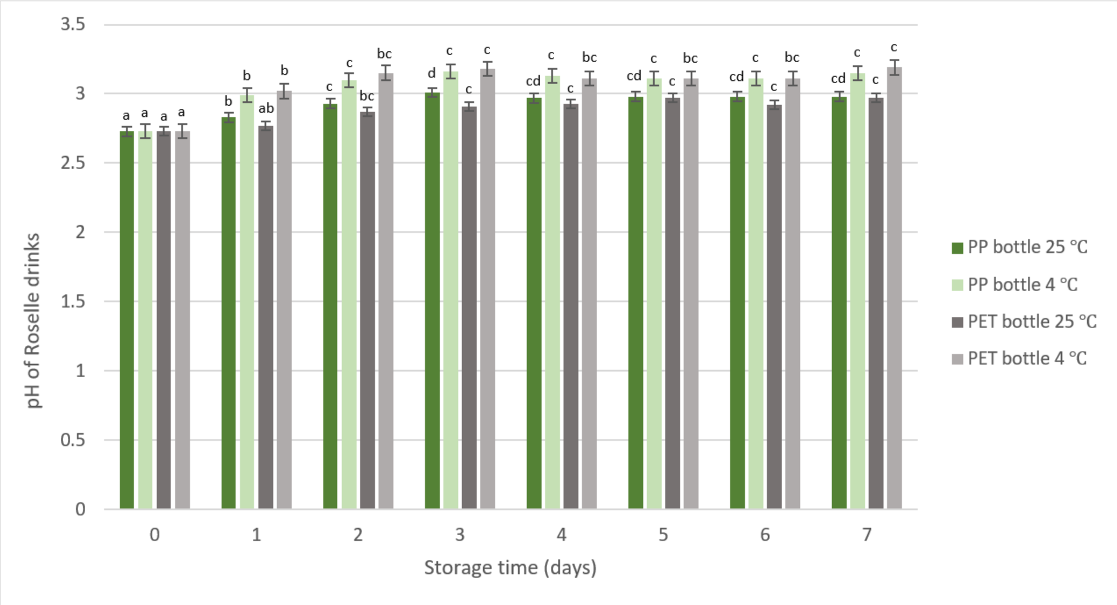

Figure Error! No text of specified style in document.**.2 Changes in pH of Roselle drinks in the PP and PET bottles for different temperatures (25 and 4 °C) during storage time**

TTA Analysis

TTA measures the concentration of dissociable acids. Refrigeration at 4°C provided stability, with TTA remaining relatively stable in both bottle types. At 25°C, PP bottles showed increased TTA peaking around Day 5. For PET bottles at 25°C, TTA increased steadily, potentially facilitated by slight oxygen ingress promoting aerobic microbial activity (Shah et al., 2016). At 4°C, neither bottle type showed significant differences in TTA.

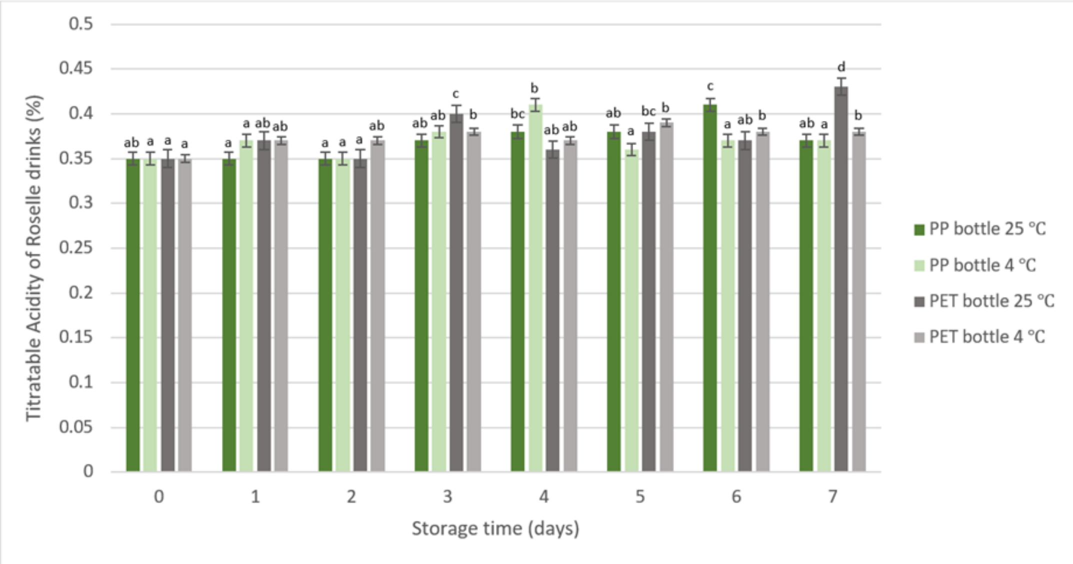

Figure 4.5: Changes in titratable acidity of Roselle drinks in the PP and PET bottles for different temperatures (25 and 4 °C) during storage time

Vitamin C Analysis

Vitamin C is a key quality index due to its role as an antioxidant and its sensitivity to oxygen and temperature. Vitamin C degradation is accelerated by temperature and oxygen exposure (Giannakourou & Taoukis, 2021). PP bottles, particularly at 4°C, showed better retention of Vitamin C compared to PET bottles. The higher oxygen permeability of PET exacerbates oxidative degradation at higher temperatures. The study noted an unexpected *increase* in Vitamin C levels during storage, which may suggest experimental errors such as over-titration. Transparent PET bottles exposed to high light intensities showed accelerated degradation of vitamins.

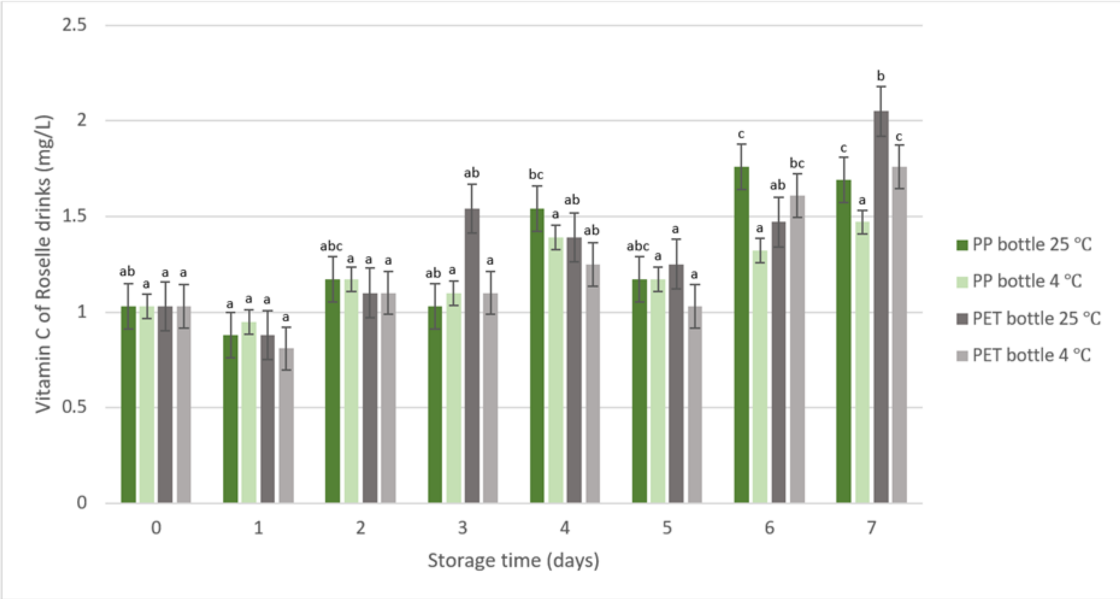

Figure 4.6: Changes in vitamin C of Roselle drinks in the PP and PET bottles for different temperatures (25 and 4 °C) during storage time

Nutrient Agar (Total Bacteria)

Microbial analysis on Nutrient Agar (NA) showed that bacterial load increased over time in all samples. At 25°C, PET bottles exhibited more rapid microbial growth (5.96 log CFU/mL by Day 7) compared to PP bottles. Unexpectedly, microbial counts were sometimes higher at 4°C than at 25°C, attributed to the growth of psychrotrophic bacteria. PP bottles likely showed better microbial inhibition due to lower oxygen permeability.

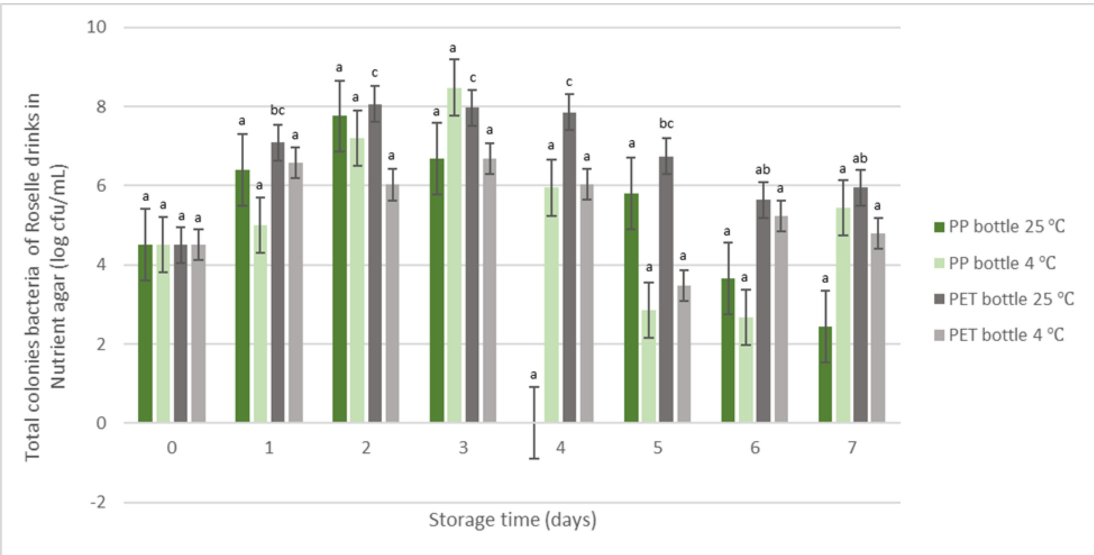

Figure 4.7 Changes in total colonies bacteria of Roselle drinks in Nutrient agar in the PP and PET bottles for different temperatures (25 and 4 °C) during storage time.

Potato Dextrose Agar (Yeast/Mold)

Potato Dextrose Agar (PDA) is used for quantifying yeasts and molds, which commonly spoil acidic beverages like Roselle drinks. Yeasts flourish in acidic, nutrient-rich environments. Microbial load on PDA generally increased from Day 0 to Day 4 before declining (death phase). Higher microbial counts were sometimes observed at 4°C, potentially indicating the presence of psychrotrophic spoilage microorganisms. At 25°C, PET bottles showed consistently higher colony-forming units (CFUs) compared to PP bottles, likely due to PET's higher oxygen permeability supporting aerobic microbial proliferation.

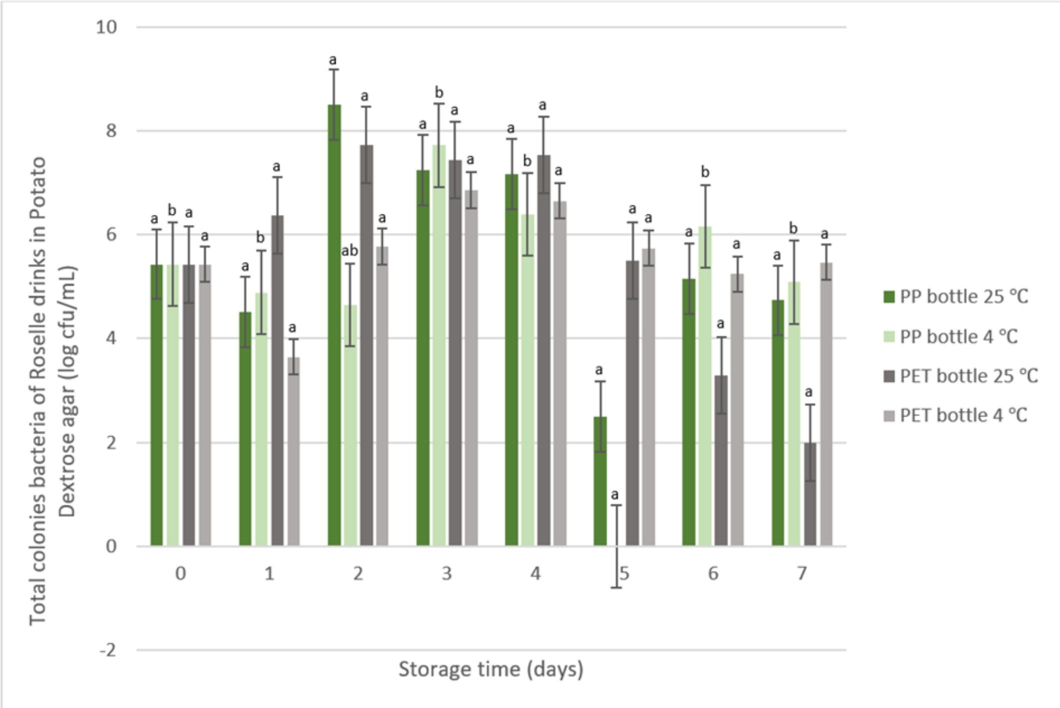

Figure 4.8: Changes in total colonies bacteria of Roselle drinks in Potato Dextrose agar in the PP and PET bottles for different temperatures (25 and 4 °C) during storage time

5. Conclusion

This study successfully investigated the impact of PP and PET plastic bottle packaging combined with two storage temperatures (25°C and 4°C) on the quality and stability of Roselle drinks. The findings confirm that PP bottles were superior to PET bottles in preserving the physicochemical properties. PP bottles demonstrated superior retention of color parameters (L*, a*, b*), pH stability, titratable acidity, and vitamin C content. This superior performance is largely attributed to the PP bottles' lower oxygen permeability, which effectively minimized microbial growth and enhanced overall product stability. Furthermore, refrigerated storage at 4°C significantly reduced physicochemical degradation and microbial growth rates compared to ambient storage conditions (25°C). PET bottles stored at 25°C showed the fastest quality degradation. The optimal strategy for extending the shelf life and maintaining the quality of Roselle drinks involves utilizing PP bottles in combination with consistent cold storage practices.

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