

Original Research Article

Evaluation of Postharvest Quality of Fresh Kesum Leaves (*Persicaria minor*) During Storage in Different Temperatures and Packaging

ABSTRACT

Persicaria minor, locally known as kesum, is an herb synonym in Southeast Asia as a food flavor enhancer and seasoning for Eastern delicacies. Kesum leaves are quickly wilted, shrink, and lose moisture once harvested. This study aimed to determine optimum parameters: storage temperature and suitable packaging to maintain the freshness and quality of kesum and prolong the storage life. This study consisted of two activities: determining the best storage temperature and determining suitable packaging. For the first activity, kesum leaves were harvested manually from matured plants, transported to a packinghouse, sorted, cleaned, packed, and sealed in polyethylene (PE) 0.04mm before being stored at different temperatures, which were 5°C, 8°C, 10°C and 13°C, while for the second activity, kesum leaves were packed and sealed in different packaging: polyethylene (PE) 0.04mm and polypropylene (PP) 0.04mm and stored at 5°C. The postharvest quality of all samples and treatments (weight, moisture content, pH, total titratable acidity, total soluble solids, respiration rate of the leaves, total phenolic content, and leaf color values) was measured and recorded weekly throughout the storage period. The study's results found that storing fresh kesum leaves at 5°C temperature and in PE 0.04mm packaging can delay the senescence and maintain the quality and postharvest attributes for up to 35 days, as shown in lower respiration rate, maintain the pH, total titratable acidity, total soluble solids and color of the leaves, and show higher total phenolic content for up to 35 days of storage compared to storing in temperature of 8°C, 10°C, and 13°C and PP 0.04mm packaging.

Keywords: Herb, postharvest, storage, temperature, packaging

1. INTRODUCTION

Kesum, or scientifically named *Persicaria minor* (Huds.) Opiz is an herb belonging to the family Polygonaceae that is synonymous with Malay and Asian dishes such as *asam pedas* (spicy tamarind curry), *laksa* (spicy noodle dish), *nasi kerabu* (fried herbal rice), *nasi ulam* (herbal rice), *tom yam* (spice tangy soup) and salad because of its property in enhancing flavor and aroma. In traditional medicine, kesum was used to treat dandruff, indigestion, ulcers, and fungal infections on the skin [1–2]. Kesum leaf contains various phenolic compounds that contribute to the antiulcer, antioxidant, antimicrobial, anti-inflammatory, anti-leishmanial, anti-cytotoxicity, and anti-genotoxicity [3–5]. Previous research showed that the kesum leaf is high in natural antioxidants that can combat oxidative damage by free radicals [6–7] and natural antimicrobials that can

inhibit various pathogenic microbes [2,8,9]. The tangy, lemony flavor in kesum leaves was contributed by oxalic acid, a reducing agent contained in kesum leaves [10]. After harvest, kesum leaves were subjected to moisture loss, shrinking, curling leaves, and leaf discoloration at ambient (25 – 27 °C) conditions. Quality preservation through postharvest practices, especially during storage and retailing, is essential so kesum leaves can be marketed and reach its users in maintained quality and freshness. This study determined optimal storage temperature and suitable packaging to preserve the quality and freshness of kesum leaves after harvest.

Information on postharvest handling techniques of leafy herbs is still lacking. Handling leafy vegetables and herbs, especially for distribution and processing, requires proper postharvest handling to reduce postharvest losses [11]. Temperature and packaging techniques play a role in postharvest handling to ensure that quality and freshness are maintained and that produce can be stored longer to be marketed more widely. Temperature and packaging also influence quality during handling, distribution, and processing. The type of packaging material chosen will affect the shelf life of fresh produce during storage [22]. The packaging commonly used in the market for packaging fresh vegetables are polyethylene (PE) and polypropylene plastic bags (PP) [23]. These two packaging materials were chosen because they have been proven to be effective in extending the shelf life where PE can extend the shelf life of chili, pitahaya, grey oyster mushroom, split gill mushroom, and tamarind (*Garcinia atroviridis*) based on previous studies [24, 25, 26, 11]. At the same time, PP plastic effectively extends the shelf life of chilies, yams, and Terengganu cherries [27, 28, 29, 30, 31, 32]. Each harvest has its optimum temperature for storage. The optimal storage temperature will ensure that the rate of respiration and the production of ethylene gas is at a low and controlled level to ensure that fresh produce is slow to senescence and thus extend the storage life [33]. The study on postharvest handling of kesum leaves is still limited, especially regarding their optimum storage temperature and suitable packaging. Thus, this study aimed to determine the effect of temperature and type of packaging on the quality of kesum leaves to prolong the storage life.

2. material and methods

2.1 Samples preparation

Kesum (*Persicaria minor* (Huds.) Opiz) leaves were harvested from matured plants (16 weeks after planting) from a research plot in the Industrial Crop Research Centre, MARDI Headquarters, Serdang, and transported to a packing house for sorting, washing, drip drying, and packaging. This study determined the optimum storage temperature (activity 1) and suitable packaging (activity 2). In this study, the kesum leaves planted were from the selected elite accession MKSM004, screened and selected in previous research.

2.1.1 Storage temperature and packaging

In the determination of storage temperature, an amount of 50±2g of kesum leaves was packed and sealed in polyethylene (PE) 0.04mm before being stored at different storage temperatures (5°C, 8°C, 10°C and 13°C). These temperature parameters were selected based on previous studies on several types of leafy and rhizome vegetables with different optimum temperatures. Meanwhile, for determination of packaging, 50±2g of kesum leaves were packed and sealed in low-density polyethylene (LDPE) 0.04mm and low-density polypropylene (PP) 0.04mm, then stored at optimum temperature, which was determined from activity 1. All samples were evaluated for postharvest quality weekly throughout the storage period on changes of physiology (appearance,

fresh weight, moisture content, color, and respiration rate) and chemical [pH, total soluble solids content (TSS), total titratable acidity (TTA) and total phenolic content (TPC)]. All samples were prepared in triplicate for all treatments.

2.2 Quality measurement

2.2.1 Physical and physiology analysis (fresh weight, moisture content, color values, respiration rate)

Fresh weights of the samples were measured using a 2-decimal balance (AND, Japan), if any. Moisture content in leaves was measured using a moisture analyzer (AND, Japan) by placing 1 g of fresh leaf on a stainless-steel tray in a moisture analyzer, and the temperature was set to 105°C. The leaf's color values (a^* -greenness, Hue and Chroma - color intensity) were measured using Chromameter CR-300 (Minolta, Japan). For measurement of leaf respiration rate, CO₂ gas in the package was taken using a 10mL syringe before being injected into the gas chromatography-mass spectrometry (GCMS) Clarus 680 (Perkin Elmer, USA) for enumeration of CO₂ percentage.

2.2.2 Chemical analysis (pH, total titratable acidity, total soluble solids content)

For the enumeration of pH and total titratable acidity (TTA), which were referred to as the AOAC method [34], a 5g ground sample was mixed into 20 mL of distilled water, and the pH reading of the solution was recorded using a pH meter (Hanna Instruments, USA). The solution was then titrated with 0.1 mol l⁻¹ NaOH to an end point of pH 8.1. The volume of NaOH titrated was recorded as total titratable acidity. A 5g ground sample was squeezed in cotton cloth to get its juice before the total soluble solids (TSS) content was read using a digital refractometer (Atago, CO., LTD, Japan).

2.2.3 Total phenolic content

The total phenolic content in leaf samples was estimated according to the Folin–Ciocalteu colorimetric method described by Mirfat *et al.* (2020)[12]. Before analysis, samples were extracted using a 70% methanol solvent (5g ground sample in 50 mL solvent; 1:10 w:v). The mixture was shaken on an orbital shaker at 200 rpm for 48 hours before being filtered using Whatmann filter paper No. 4. The extracts were then dried at 60°C using a rotary evaporator. The dried extracts were weighed and diluted with 70% methanol, and the mixtures were mixed using a sonicator (JAC ultrasonic, 1505) to achieve a final concentration of 100 mg/mL. 50 µL extract was mixed with 100 µL Folin Ciocalteu's phenol reagent. After 3 min, 100 µL 10% sodium carbonate (Na₂CO₃) was added to the reaction mixture and allowed to stand in the dark for 60 min. The analysis was carried out in triplicates with a minimum exposure of light. The resulting blue-colored complex was measured at 725 nm absorbance against a blank using a spectrophotometer. Using the calibration curve, the gallic acid was used as a reference standard, and the total phenol content was expressed in gallic acid equivalents (GAE) in milligram per g samples.

2.3 Statistical analysis

~~Data from three replicates of each treatment were used for statistical analysis.~~
The data analysis was done using Analysis of Variance (ANOVA) IBM SPSS software version 26. A mean comparison between samples and treatments was obtained using Duncan's multiple range test at p = 0.05.

3. results and discussion

Tables 1 and 2, respectively, show the physicochemical measurements of kesum leaves during the storage period at different storage temperatures (5°C, 8°C, 10°C, and 13°C) and types of packaging (low-density polyethylene (PE) 0.04mm and low-density polypropylene (PP) 0.04mm).

Table 1. Effect of temperature on physicochemical values of kesum leaves during storage

Day	Temp	Fresh weight (g)	Moisture content (%)	pH	Total titratable acidity (mg/g)	Total soluble solids (°Brix)
0		50.86bc	82.03a	5.32l	2.93ab	3.43fg
7	5°C	53.04a	75.70cde	6.03j	2.63c	3.90ef
	8°C	50.99bc	76.56bcde	6.01j	2.53cd	3.73efg
	10°C	51.97ab	72.90e	5.78k	2.73bc	3.63efg
	13°C	52.50ab	66.04f	5.81k	3.00a	3.93ef
14	5°C	51.89ab	81.99a	6.39gh	2.07efg	3.63efg
	8°C	51.55ab	81.70ab	6.21i	2.33de	3.97de
	10°C	52.93ab	77.80abcde	6.35h	2.33de	3.93ef
	13°C	51.89ab	78.79abcd	6.58def	2.20ef	4.13cde
21	5°C	52.09ab	76.84abcde	6.53efg	2.07efg	3.40g
	8°C	51.47ab	80.03a	6.67cde	1.90gh	4.60bc
	10°C	51.34ab	78.29abcd	6.69cd	2.07efg	5.30a
	13°C	50.82bc	79.66abcd	7.08b	1.40i	5.60a
28	5°C	51.48ab	77.67abcde	6.77c	1.90gh	3.90ef
	8°C	49.73c	82.11a	6.49fg	1.73h	4.07de
	10°C	51.73ab	80.50abc	6.95b	1.73h	4.43bcd
	13°C	51.81ab	78.25abcd	7.41a	1.30i	4.80b
35	5°C	51.89ab	74.87de	6.59def	2.00fgh	4.70b
42	5°C	52.31ab	79.27abcd	7.01b	2.05efg	4.60bc

Different letters between treatments indicate significant differences at $P=0.05$ according to Duncan's Multiple Range Test

Except for 5°C temperature, data measurements for temperatures 8°C, 10°C, and 13°C were taken until 28 days of storage due to the samples' senescence.

Table 2. Effect of packaging on physicochemical values of kesum leaves during storage

Day	Packaging	Fresh weight (g)	Moisture content (%)	pH	Total titratable acidity (mg/g)	Total soluble solids (°Brix)
0		50.86bc	80.64ab	5.32i	2.93a	3.43c
7	PP 0.04	50.68bc	73.74bc	6.13gh	2.73ab	3.47c

	PE 0.04	53.04a	75.69abc	6.03h	2.63b	3.90bc
14	PP 0.04	50.40bc	76.71abc	6.29fg	2.07c	3.73bc
	PE 0.04	51.89ab	81.99a	6.39ef	2.07c	3.63bc
21	PP 0.04	51.36ab	77.02abc	6.47de	2.03c	4.07b
	PE 0.04	52.09ab	76.84abc	6.53de	2.07c	3.40c
28	PP 0.04	50.36bc	78.98abc	6.55de	2.05c	3.67bc
	PE 0.04	51.48ab	77.67abc	6.77c	2.05c	3.90bc
35	PP 0.04	50.51bc	77.21abc	6.90bc	1.90d	3.73bc
	PE 0.04	51.89ab	74.86bc	6.59d	2.00c	4.70a
42	PP 0.04	49.25c	73.58c	7.24a	1.40e	4.85a
	PE 0.04	52.31ab	79.27abc	7.01b	1.70d	4.60a

Different letters between treatments indicate significant differences at $P=0.05$ according to Duncan's Multiple Range Test

The results show that storage temperatures did not affect the fresh weight of the samples, as there was no significant difference ($P>0.05$) between treatments, except on days 7 and 28 when samples stored at 8°C were subjected to significant weight decrease ($P<0.05$). Meanwhile, the packaging type influences the leaves' fresh weight during storage. Samples in PE plastic were measured to have higher weight than PP plastic. This is related to the results of the water content analysis, where the water content of kesum leaves in PE plastic is higher than in PP plastic.

Moisture or water content is related to the fresh weight of the sample. It was found that there was no significant difference in the moisture content in the kesum leaves between the storage temperatures for most of the storage days. However, on day 7, it was found that the moisture content was significantly lower ($P<0.05$) compared to the other days of storage, where samples from 10°C and 13°C recorded the lowest values. The moisture content maintained around $80\pm 2\%$ throughout the storage period in all treatments. On day-7 storage, moisture content was significantly reduced in all storage temperatures. However, the leaves regained their moisture content on day 14 and were maintained until the last day of storage. This may be due to leaves having undergone rapid moisture loss during harvesting and processing before packaging and storage. Moisture content or water loss is often related to a reduction in the fresh weight of the produce [13]. Moisture content is also associated with fresh appearance, and loss of moisture content can relate to stress that reduces postharvest quality [14]. Meanwhile, the moisture content of samples in PE plastic was significantly higher ($P<0.05$) than in PP plastic on days 14 and 42 but not significant on other days. Moisture content in both packagings was observed to drop at the end of the storage period. On day 42, the moisture content of leaves in PP plastic dropped to a lower value than in PE plastic.

The pH value of kesum leaves increased significantly throughout the 42-day storage period in all temperatures and packaging treatments. The pH value of the leaves was found to increase from 5.32 on day 0 to 7.01 on day 42. There was a significant difference ($P<0.05$) in pH values between storage temperatures, where the trend showed an increase in pH value as the storage temperature increased. However, there was no significant difference in pH between packaging PP and PE up to 21 days of storage. However, after 28 days, there was a significant difference ($P<0.05$) where leaves in PP packaging showed higher pH than PE. This indicates that lower temperatures and PE plastic could maintain the quality (pH) of kesum leaves. pH

changes result from physiological and cell activity due to conditions such as increased temperature, storage time, and packaging, which change complex sugars to acidic or alkaline compounds. The trend of increasing pH values during storage was also seen in the *asam gelugur* (*Garcinia atroviridis*) [11] and green citrus [15] stored in different packaging. A study from [31] showed Terengganu cherry (*Lepisanthes fruticosa*) maintained its pH in PE plastic compared to PP plastic.

In contrast to pH, the TTA of kesum leaves in different storage temperatures and packaging showed a decreasing trend up to 42 days of storage (2.93 on day 0 to 1.70 on day 42). There was no significant difference between storage temperatures of 5°C, 8°C and 10°C throughout the storage period, but at 13°C temperature, the TTA of kesum leaves decreased significantly on days 21 and 28. There was also no significant difference between packaging PP and PE until day 28, but on days 35 and 42, TTA in PP was significantly lower than in PE. This indicates that lower temperatures and PE plastic can maintain the quality (TTA) of kesum leaves. The decrease in TTA is also reported in chili during storage in different packaging. Chili in plastic PE has a more stable TTA value than PP plastic, as reported in [35]. TTA value is a quantitative measure of the organic acid, which decreases with the senescence process [16].

As storage time increased, the total soluble solids (TSS) of kesum leaves increased. Storage temperature affected TSS in kesum leaves, whereas TSS of kesum leaves stored at 8°C, 10°C, and 13°C increased significantly after 21 days of storage (4.60, 5.30, and 5.60, respectively). However, TSS at 5°C remained lower until 28 days (3.40, 3.80) before increasing to 4.70 and 4.60 for the rest of the storage time. The packaging type did not affect the TSS value of kesum leaves during storage. There was no significant difference between TSS in packaging PP and PE throughout the storage period, except on day 21, where TSS was slightly higher in plastic PP than PE. The increment of TSS may be because of the degradation of complex components of carbohydrates and organic acids converted to reducing sugar when fruit prolongs the storage life [17]. Cells and tissues carry out these biological processes to carry on respiration and other metabolic functions [18]. A lower TSS value indicated delayed quality changes.

Figures 1 and 2 show the respiration rate of kesum leaves in storage at different temperatures and in different packaging throughout the 42 days of storage. There was no significant difference in the respiration rate of kesum leaves in all storage temperatures up to 14 days of storage. At this period, the respiration rate in all storage temperatures is around 0.48 - 0.99%. After 22 days, it was found that the leaf respiration rate in the 13°C temperature had increased significantly (1.2%), but there was no significant difference in the respiration rate in the 5°C (0.43%), 8°C (0.86%) and 10°C (0.94%) temperatures. However, after 28 days, there was a significant increase in leaf respiration rate in temperatures of 8°C (0.74%), 10°C (1.07%), and 13°C (1.72%). The respiration rate of kesum leaves at a storage temperature of 5°C remained low throughout the 42 days of storage (0.81 - 0.53%). Meanwhile, kesum leaves in polyethylene (PE) plastic exhibited significantly lower respiration rates than in polypropylene (PP) plastic throughout the storage period at 5°C. This may be due to the different plastic materials used in PE and PP. Respiration rate is correlated with the senescence of plant tissue and can be used as an indicator for the rate of metabolism and perishability of plant tissue [19]. The respiration rate rises as the tissue undergoes senescence and deteriorates [20]. Temperature is an important factor affecting the quality of harvested herbs. All metabolism activities in plant tissues increased as the

temperature increased, thus accelerating the senescence process.

Figure 1. Respiration rate of kesum leaves in different storage temperatures throughout the storage period

Different letters between treatments indicate significant differences at $p=0.05$ according to Duncan's Multiple Range Test

Figure 2. Respiration rate of kesum leaves in different packaging (PP 0.04mm, PE 0.04mm) throughout the storage period

Different letters between treatments indicate significant differences at $p=0.05$ according to Duncan's Multiple Range Test

Storage temperature and type of packaging were also found to affect the total phenolic content (TPC) in kesum leaves during the storage period, as shown in Figures 3 and 4. There was an increase in TPC after 7 and 14 days of storage in all four storage temperatures. On day 14, there was no significant difference in TPC in temperatures of 5°C, 8°C and 10°C (148.58, 148.11, and 135.73 mg GAE/g), compared to temperatures of 13°C which showed a significant decrease in TPC (71.98 mg GAE/g). However, after 28 days, the TFC of kesum leaves was found to show significant differences between storage temperatures. An increase in storage temperature causes a decrease in TPC. Storage at 5°C maintained the highest TPC (137.33 mg GAE/g) and decreased in temperature of 8°C (119.73 mg GAE/g), 10°C (76.27 mg GAE/g) and lowest at 13°C (47.27 mg GAE/g). Storage in different packaging at 5°C showed that the TPC of kesum leaves increased from day 0 until day 14. There was no significant difference in TPC between kesum leaves in PE and PP plastic until day 14 of storage. However, on days 28 and 35, the TPC of kesum leaves in PE plastic was significantly higher (137.77 and 90.46 mg GAE/g, respectively) compared to PP plastic, where it decreased significantly at day 28 and 35 (101.05 and 60.04 mg GAE/g). Kesum leaves are rich in various phenolic compounds. Vimala et al. [1] found 2800.6 mg/100g GAE of total phenolic content in kesum leaf aqueous extract, while Nor Syamimi et al. [7] reported 645.6 mg/100g GAE in methanol extract. Sasongko et al. [21] found 28 volatile compounds in extracts of fresh and dried kesum, where the significant compounds were eupatoriocromene, dodecanal, alpha-caryophyllene, beta-caryophyllene, and decanal.

Figure 3. Total phenolic content of kesum leaves at different storage temperatures throughout the storage period

Different letters between treatments indicate significant differences at $p=0.05$ according to Duncan's Multiple Range Test

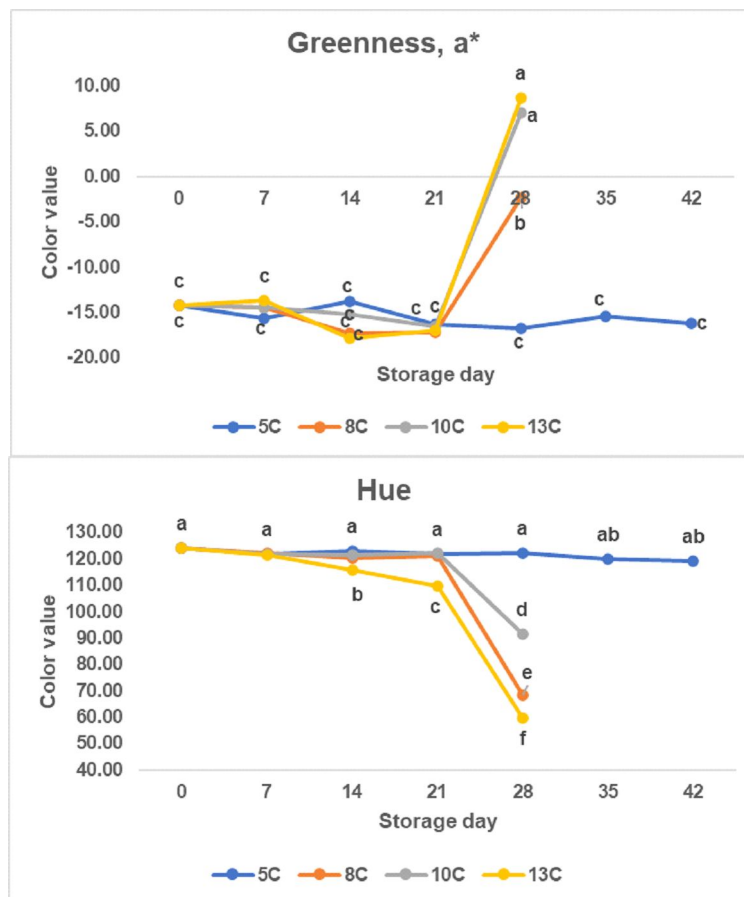
Except for 5°C temperature, data measurements for temperatures 8°C, 10°C, and 13°C were taken until 28 days of storage due to the samples' senescence.

Figure 4. Total phenolic content of kesum leaves in different packaging (PE 0.04mm, PP 0.04mm) throughout the storage period

Different letters between treatments indicate significant differences at $p=0.05$ according to Duncan's Multiple Range Test

The leaf's color of kesum during storage in different storage temperatures and

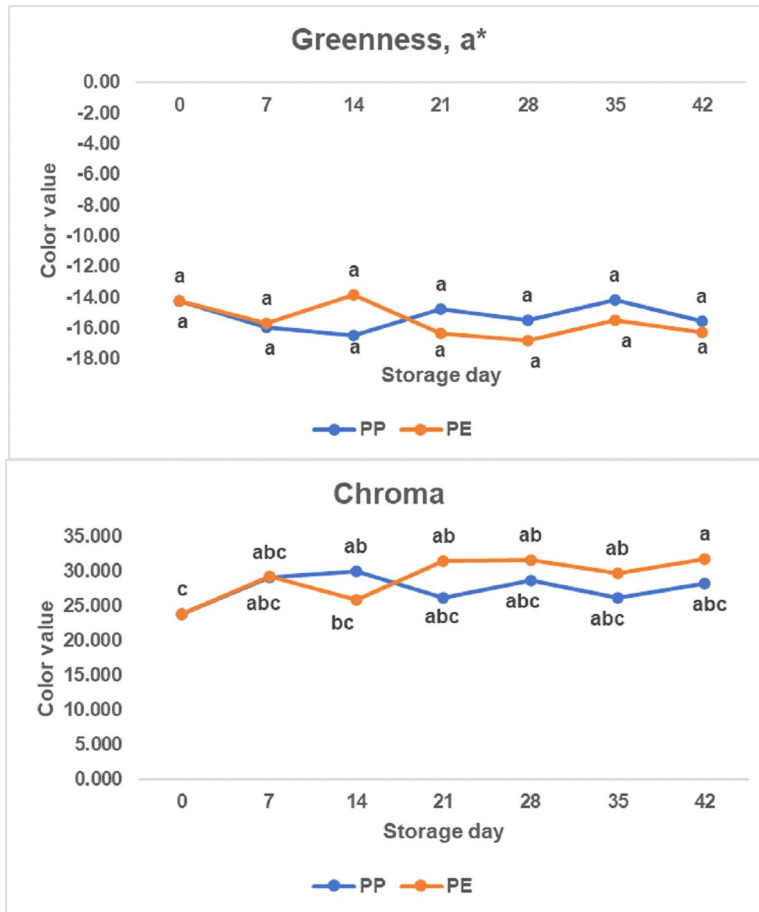
packaging are shown in Figures 5 and 6. The a^* value measures the green color, while the hue and chroma value indicates color intensity. The color value a^* and hue at 5°C temperature remained stable throughout the storage period, indicating the green leaves color was retained, compared to higher temperatures where the color intensity dropped after 21 days of storage. However, at temperatures of 8°C, 10°C, and 13°C, it was observed that the color of the leaf changed from green to brown after 21 days of storage, which showed an increase and decrease in a^* and hue values, respectively. The packaging does not significantly affect the leaf's color value as there was no significant difference in a^* and chroma color value between PE and PP throughout the storage period. The decreased chroma and hue value during storage indicated the discoloration from green to yellow or browning [11].



Figures 5a and 5b. Color value (a^* and hue) of kesum leaves in different storage temperatures throughout the storage period

Different letters between treatments indicate significant differences at $p=0.05$ according to Duncan's Multiple Range Test

Except for 5°C temperature, data measurements for temperatures 8°C, 10°C, and 13°C were taken until 28 days of storage due to the samples' senescence



Figures 6a and 6b. Color value (a* and chroma) of kesum leaves in different packaging (PP 0.04mm, PE 0.04mm) throughout the storage period

Different letters between treatments indicate significant differences at $p=0.05$ according to Duncan's Multiple Range Test

4. Conclusion

Temperature affected some postharvest attributes during storage, especially moisture content, total soluble solids (TSS) content, pH, total titratable acidity (TTA), rate of respiration, total phenolic content (TPC), and color of kesum leaves during storage. Fresh kesum leaves stored at 5°C can maintain sample weight, moisture content, pH, TTA, lower TSS content and respiration rate, higher total phenolic content, and color up to 35 days of the storage period, compared to temperatures 8°C, 10°C and 13°C where the quality declined earlier after 21 - 28 days of storage. Meanwhile, the type of packaging affected the weight, moisture content, pH, and TTA of kesum leaves. However, the packaging did not significantly affect the color or TSS. PE 0.04mm plastic was more suitable for packaging kesum because it kept the respiration rate lower and had higher moisture and total phenolic content than PP 0.04mm plastic. The findings of this study can be used as a guide for good postharvest practice for the postharvest handling of leafy herbs, especially kesum.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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