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Original Research Article

Evaluationof Plastic Packaging Types and Storage Temperature on the Shelf-Life and Quality of Cili Padi (*Capsicum Frutescens* L.)

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Abstract: *Capsicum frutescens* L., commonly known as Cili Padi, is a highly perishable, seasonal vegetable prone to damage, with a shelf life of only two to three days under room temperature conditions. For Cili Padi to have a longer shelf life and preserving its quality post-harvesting, proper packaging and storage temperatures are essential. The purpose of this study is to assess how various plastic packaging options affect the physicochemical quality of *Capsicum frutescens* L. during 14 days period while stored in varying temperatures (5°C and 28°C). Furthermore, the plastic packaging material's anti-fogging qualities were also evaluated. The packaging material tested includes low-density polypropylene (LDPE), polyethylene (PE), polypropylene (PP), perforated polypropylene (P-PP), micro-perforated polypropylene (M-PP), Nylon (vacuum packaging), and uncovered plastic container as the control. The results revealed that micro-perforated polypropylene (M-PP) and perforated polypropylene (P-PP) exhibited superior anti-fogging properties and higher firmness, while other packaging materials showed limited anti-fogging performance. Low temperature (5°C) storage of Cili Padi better preserved its physicochemical properties, compared to the room temperature (28°C), over 14 days across all packaging types. Cili Padi packed in Nylon was the most successful in reducing weight loss ($4.18 \pm 0.08\%$) and colour changes ($\Delta E = 19.4 \pm 1.96$), retaining moisture content ($80.04 \pm 3.23\%$) as well as preserving the ascorbic acid content (278 ± 14.5 mg/100 g). However, from the study, the antioxidant qualities of Cili Padi were not significantly impacted by the various packaging materials. In conclusion, the best material for prolonging the shelf life of Cili Padi was Nylon by outperforming other conventional plastic packaging materials.

Keywords: *Capsicum frutescens L.*; plastic packaging materials; storage temperature; physicochemical properties; anti-fogging

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1. Introduction

Food packaging has maintained its role in preserving the freshness and qualities of perishable agricultural fresh produce, including Cili Padi. *Capsicum frutescens* L., also referred to as Cili Padi, is an important ingredient in various culinary traditions, holding both commercial and cultural values, especially in Malaysia. Cili Padi and those in the Capsicum genus not only provide pungency and flavors, but they also provide nutritional values such as antioxidants and anti-obesity (Azlan *et al.*, 2022). However, Cili Padi has a highly perishable nature, which becomes a challenge in the preservation of its quality post-harvesting. Adewoyin *et al.* (2017) and Ziv *et al.* (2022) explained that pepper loses its quality as the metabolic changes, dehydration, microbial degradation and storage conditions happen more often, particularly in tropical climates due to the fluctuation of temperature and humidity. Therefore, chillies need to be stored in a controlled environment as explained by Muthmainnah *et al.* (2019), that chillies can prolong their shelf life by 10 to 20 days if they are kept in a room with a temperature of 5 to 7°C and humidity levels of 90 to 95%. As the demand for fresh Cili Padi keeps on growing across global markets, it is crucial to identify the best method to extend the shelf-life without compromising its physicochemical properties.

Post-harvest deterioration of green chillies predominantly results from several factors, including water loss, respiration, microbial contamination, and environmental conditions (Chitravathi *et al.*, 2015). The deterioration and degradation of fresh produce's colour, texture and flavour have negatively impacted the consumer's appeal and marketability, thus posing a huge challenge that needs to be addressed. Packaging systems and temperature control have been emerging as a viable solution (Koibur & Bintoro, 2021; Muthmainnah *et al.*, 2019). In the food sector, plastic food packaging plays a vital role in protecting fresh produce and extending its shelf life. There are a huge number of different plastic packaging materials that are conventionally used in the industry, including low-density polyethylene (LDPE), polyethylene (PE), polypropylene (PP), perforated polypropylene (P-PP), micro-perforated polypropylene (M-PP), and Nylon. However, these conventional packaging materials also have limitations that might lead to the degradation of fresh produce. This study assesses and contrasts how well various plastic packaging materials affect the physicochemical characteristics and 14-days shelf life of Cili Padi. The physicochemical qualities of the Cili Padi were assessed by observing various parameters, which is weight loss, moisture content, colour changes, firmness, ascorbic acid (vitamin C)

contents and antioxidant properties after storage at different temperatures using different plastic packaging materials.

The study will evaluate the anti-fogging properties of different plastic packaging materials. This phenomenon is especially noticeable when moisture from the food product comes into contact with cooler surfaces within the packaging, forming droplets on the film's interior surface (Durán & Laroche, 2019). As Li *et al.* (2020) point out, fogging not only diminishes the visual appeal and transparency of the packaging, thus affecting the consumer's ability to assess the quality of the product, but it also contributes to an environment conducive to the growth of microorganisms that can accelerate spoilage and shorten the shelf-life.

2. Materials and Methods

2.1 Preparation of Cili Padi Samples for Physicochemical Analysis

The conventional plastic packaging samples were sourced online and categorized by material type. Cili Padi samples were purchased directly from a farmer’s plantation in Semenyih, Selangor and underwent a meticulous sorting process. Each Cili Padi samples were carefully selected based on its maturity stage for commercial and its uniform size ranging from 6–9 mm diameter, with the sorting performed manually to prevent contamination and ensure only defect-free samples were chosen. Before packing, the Cili Padi were thoroughly cleaned and gently patted dry to remove any external contaminants.

2.2 Packaging and Storage

Each packaging consists of 15 g of Cili Padi to imitate the package that are available in the market. The Cili Padi samples were stored in different storage conditions. The details of the two storage conditions are as follows:

(i) Room temperature (28°C)

(ii) Low temperature (5°C)

In this method, the Cili Padi (15 g) were packed and sealed in seven different types of conventional films consisting of:

(i) Low Density Polyethylene (LDPE) (12.7 cm x 20.32 cm) (BB Packaging, Malaysia),

(ii) Polyethylene (PE) (12.7 cm x 17.78 cm) (Maju Jaya Packaging Sdn. Bhd., Malaysia),

(iii) Polypropylene (PP) (12.7 cm x 20.32 cm) (Maju Jaya Packaging Sdn. Bhd., Malaysia),

(iv) Perforated Polypropylene (P-PP) (12.7 cm x 20.32 cm) (LTL Venture, Malaysia),

(v) Micro-perforated Polypropylene (M-PP) (11.5 cm x 19.0 cm) (K&H Sdn. Bhd., Malaysia),

(vi) Nylon (13.0 cm x 20.0 cm) (KS Packaging & Solutions, Malaysia), and

(vii) Unpacked (Control group).

The combination of pre-packaging and storage temperature are presented as:

T_{P1} Control group (Unpacked) + room temperature (28°C)

T_{P2} Low Density Polyethylene (LDPE) + room temperature (28°C)

T_{P3} Polyethylene (PE) + room temperature (28°C)

T_{P4} Polypropylene (PP) + room temperature (28°C)

T_{P5} Perforated polypropylene (P-PP) + room temperature (28°C)

T_{P6} Micro-perforated polypropylene (M-PP) + room temperature (28°C)

T_{P7} Nylon (N) + room temperature (28°C)

T_{P8} Control group (Unpacked) + low temperature (5°C)

T_{P9} Low Density Polyethylene (LDPE) + low temperature (5°C)

T_{P10} Polyethylene (PE) + low temperature (5°C)

T_{P11} Polypropylene (PP) + low temperature (5°C)

T_{P12} Perforated polypropylene (P-PP) + low temperature (5°C)

T_{P13} Micro-perforated polypropylene (M-PP) + low temperature (5°C)

T_{P14} Nylon (N) + low temperature (5°C)

Then, the samples were stored in the refrigerator (5°C) and at ambient temperatures (28°C) for 14 days with three replications. Figure 1 illustrates how Cili Padi were packaged using different types of conventional plastic packaging and analyzed on day-7 (D7) and day-14 (D14).



Figure 1. Cili Padi samples packed in various conventional packaging materials

2.3 Physicochemical Properties of Cili Padi Samples

2.3.1 Weight loss

One Cili Padi sample from each package was weighed using a digital scale (Mettler-Toledo, Malaysia), with an accuracy of 0.01 g to determine the initial weight (W_1) and final weight after storage (W_2) to calculate the weight loss of Cili Padi. Equation 1 is used to calculate the weight loss, which is referred to (Purbasari & Sari, 2022).

$$Weight\ loss\ (WL) = \frac{(W_1 - W_2)}{W_1} \times 100\% \quad (1)$$

Where, W1 is the initial weight of the sample (g) and W2 is the weight of the sample of the nth day (g).

2.3.2 Moisture content

The Cili Padi samples' moisture content was determined using the method described by Rossa *et al.* (2015), which employed a 400 W halogen lamp to effectively dry the samples and an ML-50 moisture analyzer (A&D Company Limited, Japan) with an accuracy of 0.005 g. After being weighed to 3 g, the Cili Padi samples were put on the moisture analyzer plate. The drying temperature was then adjusted to 105°C. Three replications were used to collect the experimental data.

2.3.3 Colour changes

The colour of the Cili Padi samples was assessed using a colourimeter, Colour Analyser (VTSYIQI, France), calibrated with standard white and black tiles, according to the method from Guiné & Barroca, (2012). The measurements were made by targeting the one Cili Padisample in each packaging and the obtained values of ΔL*, Δa*, and Δb* were calculated. All measurements were done in duplicate. The value of a* refers to the colour axis ranging from green (-a*) to redness (+a*), b* explains the colour axis ranging from blue (-b*) to yellowness, meanwhile, L* describes the lightness of a sample. The overall degree of colour change (ΔE) was calculated by Equation 2, which was obtained from (Manninen *et al.*, 2015). The colour was measured on day 7 and day 14 of the storage.

$$\Delta \mathbf{E} = \sqrt{(\boldsymbol{L_{n^*}} - \boldsymbol{L_{0^*}})^2 + (\boldsymbol{a_{n^*}} - \boldsymbol{a_{0^*}})^2} + (\boldsymbol{b_{n^*}} - \boldsymbol{b_{0^*}})^2 \quad (2)$$

Where, L_{0*} , a_{0*}, b_{0*} represents the colour parameters on day-0 while, L_{n*}, a_{n*}, b_{n*}, referred as the colour parameters at a specific time (day-7 and day-14), respectively.

2.3.4 Firmness

The firmness of chili pepper was tested by using a texture analyser (Ta xt2, Stable MicroSystems, UK) and a metal probe of 10 mm in diameter. The penetration depth was 15 mm. The firmness measurements were carried out on using three replications for each sample. The readings of the firmness (N) were obtained and recorded from the Texture software, which was connected to the equipment.

2.3.5 Ascorbic acid content

The method by Chitravathi *et al.* (2015b) was used to measure the ascorbic acid content. A final volume of 100 milliliters was obtained by dissolving 10 grams of materials in 3% meta-phosphoric acid. After that, a 10 ml aliquot of this extract was titrated with the standard 2,6-dichloro-phenol indophenol (DCPIP) solution until a light pink hue that lasted for 15 to 20 seconds was seen. The value of the ascorbic acid content during storage was determined using the following Equation 3.

$$\text{Ascorbic acid content } \left(\frac{\text{mg}}{100\text{ g}}\right) = \frac{\text{Volume of titrant used} \times \text{Concentration of DCPIP} \times \text{Equivalent weight of ascorbic acid}}{\text{Weight of sample (g)}} \quad (3)$$

2.3.6 Antioxidant properties

Antioxidant properties were measured by following the method outlined by Maryam *et al.* (2023) with a slight modification. 50 mg of mashed samples were added with 25 mL of

methanol to make a 0.25% (w/v) extract. 0.2 mL of the extract was pipette using a micropipette and added into 3.8 mL of 50 µM of 2,2-diphenyl-1-picrylhydrazyl (DPPH) solution. The mixture of extract and solution was mixed well and left in a dark place for 30 minutes. The absorbance of samples was measured using UV-Vis spectrophotometry (Genesys 180, China) at the wavelength range of 490-530 nm, and the absorbance at the maximum DPPH wavelength (517 nm) was observed. The percentage of inhibition or free radical binding was calculated using Equation 4.

$$\frac{\text{abs standard} - \text{abs sample}}{\text{abs standard}} \, x \, 100\% \tag{4}$$

2.3.7 Anti-fogging properties of different types of films

Anti-fogging properties of different plastic packaging were observed by placing the Cili Padi in containers with different plastic packaging materials. The package samples were refrigerated for 24 hours. Then, the containers were transferred to the room temperature of 28°C with relative humidity (RH) of 55%. The anti-fogging behaviour of the plastic films were recorded by using a mobile phone camera.

3. Results and Discussions

3.1 Weight loss

Weight loss (WL) of Cili Padi samples in different storage conditions and plastic packaging material provide the insight into its effectiveness in preserving the quality of Cili Padi. According to Mahajan *et al.* (2016), weight loss is one of the key indications for determining the quality of fruits and vegetables since it shows the water loss from the samples, which greatly accelerates the degradation and reduces the shelf life of green chillies. Data collected over 14 days reveals the same trend in weight loss in different plastic packaging for both at room temperature (28℃) and low temperature (5℃), with low temperature exhibiting a lower value of weight loss for each sample. Figure 3 shows the variations in weight loss of Cili Padi at 28℃. Nylon exhibits the lowest weight loss with 27.24 ± 0.16%. The weight loss of Cili Padi in LDPE was 29.64 ± 0.1%, followed by PE (31.63 ± 0.2%) and PP (32.91 ± 0.03%). Perforated and Microperforated PP exhibit higher weight loss at 41.84 ± 0.3% and 42.98 ± 0.6%, respectively, while the control exhibits the highest weight loss at 43.62 ± 0.12%.

Figure 4 shows the weight loss of Cili Padi samples in various plastic packaging at 5℃. Similar to at room temperature, the weight loss was lowest when packed in Nylon (4.18 ± 0.08%), with LDPE having the second lowest (4.23 ± 0.1%). PE followed closely with 4.58 ± 0.3% and PP exhibits slightly higher than PE with 5.43 ± 0.2%. The P-PP and M-PP exhibit higher weight loss compared to others, with 22.78 ± 0.5% and 22.98 ±0.39%, respectively. The highest was exhibited by the control samples with 26.56 ± 0.2% weight loss in the Cili Padi samples.

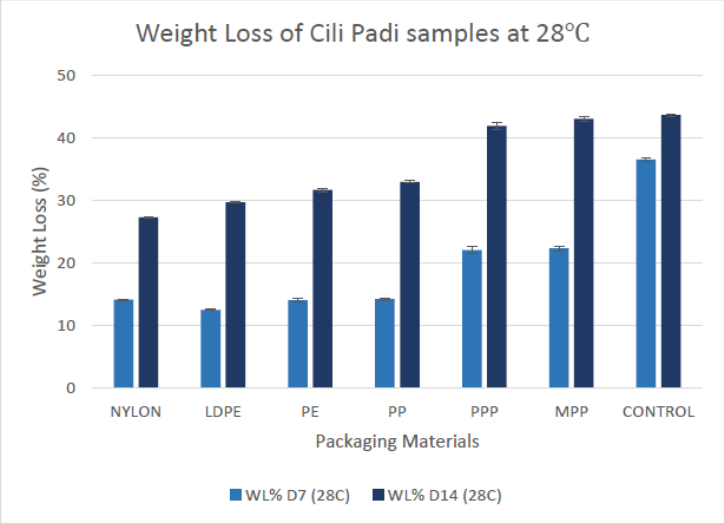


Figure 2. Weight loss in Cili Padi at 28 °C after 7 and 14 days

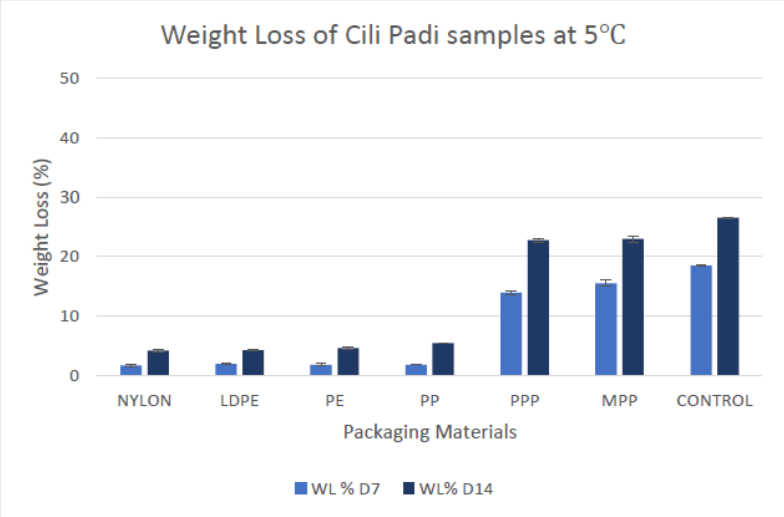


Figure 3. Weight loss in Cili Padi at 5 °C after 7 and 14 days

The results highlight the effectiveness of plastic packaging materials in minimizing weight loss at lower temperatures, likely due to reduced moisture loss in cooler conditions. The results show that samples that were kept at room temperature suffered higher weight loss as compared to samples that were kept at lower temperatures, which is directly due to a higher rate of transpiration and respiration. The weight loss happened due to the exchange of moisture from the process of respiration and transpiration as mentioned by Chitravathi *et al.* (2015) explained that the reduction of weight loss in lower temperatures is related to these processes as the rate of the processes is reduced. Li *et al.* (2022) explained that cooling techniques are able to reduce the weight loss by reducing the field heat that leads to the acceleration of metabolic processes and promotes microbial growth, thus preserving the freshness and qualities of the fruit and vegetables. This also aligns with a study by Javanmardi

and Kubota (2006) which explains that vegetables such as tomato that are kept at room temperature have higher biochemical reactions of compounds such as lycopene, which contributes to weight loss. Nylon demonstrated most significant moisture retention, resulting in the lowest weight loss at both temperatures compared to other materials. These findings are consistent with the work of Simões *et al.* (2019), which also identified Nylon as one of the most effective materials for minimizing weight loss in processed yams. In contrast, higher weight loss was observed in perforated packaging and control samples. The results align with a study by Haile and Safawo (2018) which shows that perforated packaging has higher weight loss compared to non-perforated packaging. The weight loss in P-PP and M-PP can be attributed to their increased permeability, leading to reduced moisture retention and consequently higher weight loss.

3.2 Moisture Content

Moisture content (MC) of Cili Padi was assessed under different storage conditions and plastic packaging materials to evaluate their effectiveness in preserving moisture. The results demonstrate that plastic packaging materials influence moisture retention at both 28°C and 5°C, with significant variations in moisture content across different packaging types. Figures 5 and 6 illustrate different patterns of moisture content retention, however, Nylon consistently shows the highest moisture retention. In Figure 5, Nylon exhibited the highest moisture content at 73.45 ± 1.8%. PP recorded to have the second highest moisture content (63.91 ± 3.98%) followed by LDPE (63.09 ± 4.5%) and PE (62.28 ± 4.3%). Perforated packaging showed to have lower moisture retention with P-PP (39.8 ± 1.84%) and M-PP (38.56 ± 5.52%), reflecting greater moisture loss due to the higher permeability of these films. The control group has the lowest moisture content of 31.8 ± 8.11%, demonstrating the least effectiveness in moisture retention.

Figure 6 presents moisture content data for Cili Padi samples stored at 5°C, where all plastic packaging materials showed higher moisture retention compared to storage at 28°C, confirming that lower temperature storage improves moisture retention of Cili Padi. Nylon demonstrated the highest moisture content at 80.04 ±3 .23%, followed by PE at 79.63 ± 4.59%. LDPE has slightly lower moisture content, with 78.58 ± 0.36% and PP at 76.86 ± 3.79%. Both P-PP (65.62 ± 0.69%) and M-PP (62.44 ± 1.57%) showed to have the lowest moisture content compared to other packaging materials. The control group showed the lowest moisture retention at 43.76 ± 0.16%, further highlighting its ineffectiveness.

Similar to weight loss, results showed that the moisture content of Cili Padi that were kept at room temperature is lower compared to Cili Padi that were kept at a lower temperature proving that Cili Padi is suitable to be kept at a lower temperature to reduce the deterioration rate post-harvesting. Dupont (2009) stated that up to 23% of perishable foods in developing countries were spoiled due to the lack of cool storage. This cool storage can lower the transpiration and respiration rate, thus reducing the moisture loss to the surroundings. Overall, the data indicate that storage at lower temperatures results in superior moisture

retention across all plastic packaging materials, with Nylon proving to be the most effective in preserving moisture content. These findings align with the work of Shakerardekani and Karim (2013), who demonstrated that Nylon is highly effective in preserving pistachio nut quality by delaying moisture absorption. A study on green leafy vegetables by Pavani and Aduri (2018) also proved that LDPE has higher moisture content compared to PP. Additionally, the higher moisture loss observed in perforated films, such as P-PP and M-PP, is consistent with the results of Ngcobo *et al.* (2012), who found that grapes packed in perforated packaging have significantly higher moisture loss than in those packed with non-perforated films. This may be due to the increased transpiration rate in perforated packaging, which accelerates moisture loss to the surrounding environment.

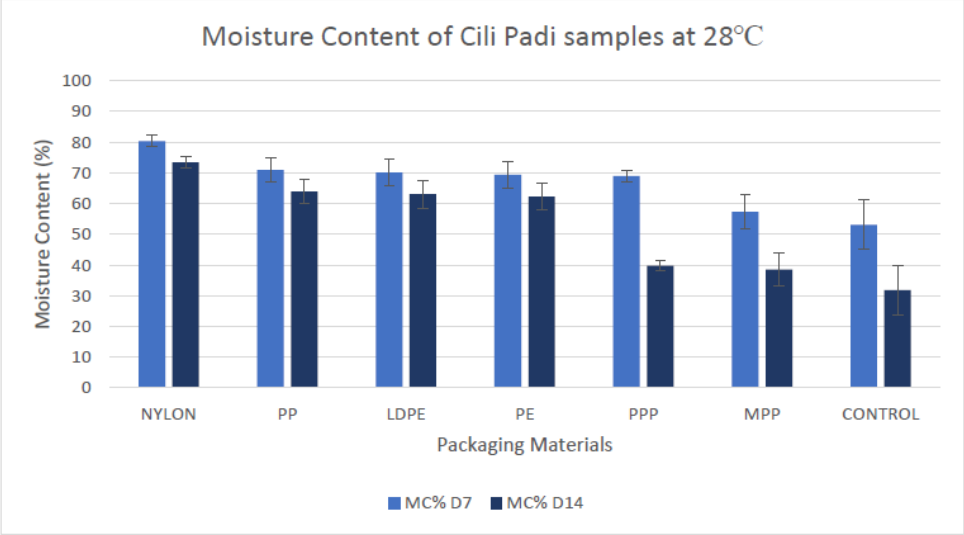


Figure 4. Moisture content of Cili Padi 28 °C after 7 and 14 days

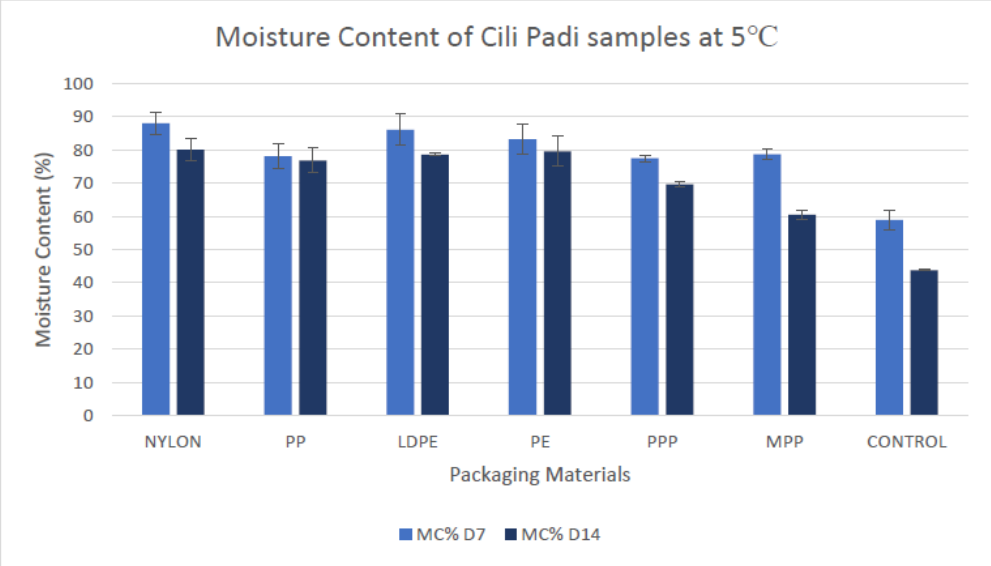


Figure 5. Moisture content of Cili Padi at 5 °C after 7 and 14 days

3.3 Colour Changes

As Cili Padi ripens, it undergoes a colour transformation from green to orange or red due to enzymatic reactions, oxidative processes and physical deterioration. By monitoring this colour change, the ripening process can be controlled, helping to preserve the Cili Padi 's fresh appearance, texture, and flavour for an extended period, while also maintaining its visual appeal and customer acceptance. The colour changes of Cili Padi were observed over 14 days. Tables 1 and 2 show the colour of Cili Padi samples that were kept at 28°C and 5°C, respectively. From optical observation, the colour of Cili Padi samples that were kept at 28°C changes rapidly and is visible as early as day 7. The colour changes significantly in samples that were kept at room temperature, as higher temperatures accelerate the degradation of Cili Padi qualities. The result aligns with a study by Waskale and Bong (2017) which explains that the redness of fruit and vegetables increases directly with the temperature.

Table 1 shows the colour of Cili Padi samples that were kept at room temperature. Over 14 days, almost all of the Cili Padi samples change their colour in different packaging materials. Samples that were kept as controls and in perforated packaging showed significant colour changes as the samples turn red. Meanwhile, samples in other packaging materials, such as Nylon, PE, LDPE and PP showed have slightly turned brown. Oshima *et al.* (2021) suggest that drying processes cause the browning of fruits by the Maillard reaction.

Table 1. Colour of Cili Padi samples after storage at 28°C for 7 and 14 days

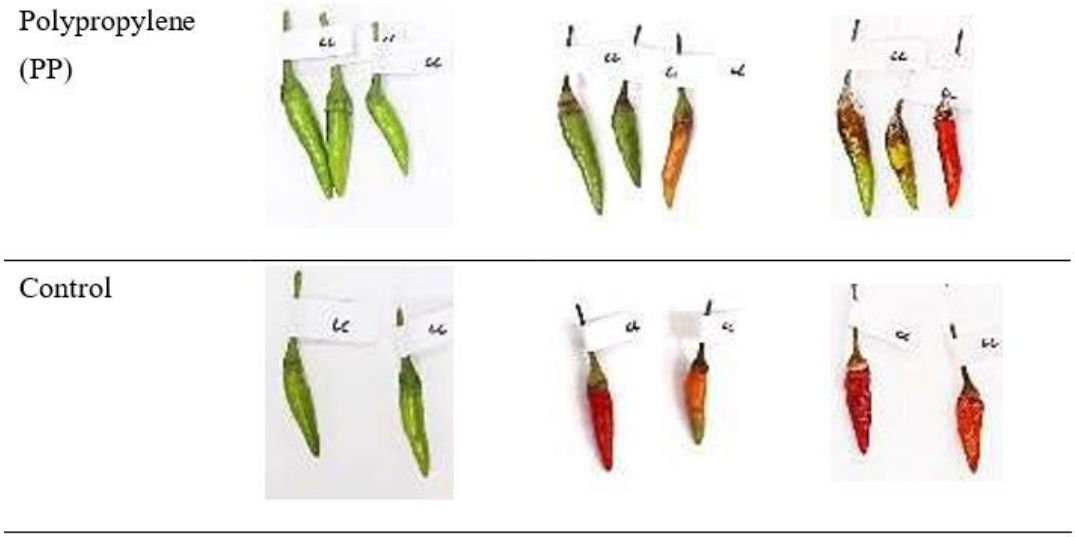
Type of film	Day 0	Day 7	Day 14
Micro-perforated polypropylene (M-PP)			
Perforated polypropylene (P-PP)			
Nylon			

Low-Density Polyethylene (LDPE)			
Polyethylene (PE)			
Polypropylene (PP)			
Control			

Table 2 shows the colour of Cili Padi samples that were stored at 5°C for 14 days have similar trend to samples kept at room temperature. However, these Cili Padi samples showed to have retained their green colour longer with no visible colour changes at Day 7. Samples that were packed in Nylon, LDPE, PE and PP showed have slight change in colour by day 14 by slightly turns orange. Meanwhile, samples that were kept as controls and in perforated packaging have more visible colour changes as they almost turn completely red. Cili Padi samples stored in Nylon exhibited the highest negative a value (-35.64), indicating that the samples retained a green hue, though they appeared slightly darker. The next lowest negative a values were observed in PP (-33.27), LDPE (-28.48), and PE (-24.6), indicating that these samples also maintained a green hue after 14 days. In contrast, samples in P-PP and M-PP exhibited a slight colour shift toward orange, with a value of 9.84 and 15.34, respectively. Control samples showed the most significant colour change, turning almost entirely red, with a value of 36.84.

Table 2. Colour of Cili Padi samples after storage at 5 ℃ for 7 and 14 days

Type of film	Day 0	Day 7	Day 14
Micro-perforated polypropylene (M-PP)			
Perforated polypropylene (P-PP)			
Nylon			
Low-Density Polyethylene (LDPE)			
Polyethylene (PE)			



The colour changes, measured using the delta E value scale as defined by Schuessler (2020), are commonly used in commercial applications. According to this scale, a delta E value less than 1 is imperceptible to the human eye, while values between 1–2 are only noticeable with close inspection. Values between 2–10 are visible at a glance, and changes in the range of 11–49 are noticeable but still similar in appearance. If the delta E value exceeds 49, the colour shift is considered drastic and opposite in hue. Figures 7 and 8 illustrate the colour change (ΔE) values of Cili Padi stored at 28°C and 5°C for 14 days, respectively. In both temperatures, the value of ΔE is higher for P-PP, M-PP and control samples. At low temperature, ΔE values recorded for these samples are more than 49 with P-PP (52.25 ± 1.79), M-PP (56.54 ± 2.96) and control (59.66 ± 3.47) while Cili Padi packed in other packaging materials have smaller values of ΔE, ranging from 19.4 to 26.69. Meanwhile, at room temperature, all samples recorded high values of ΔE with a dramatic shift from green to red, indicating their ineffectiveness in preserving colour. The ΔE values range from 58.92 ± 1.44 to 70.94 ± 1.01, with Nylon having the lowest value and control having the highest value.

These findings are consistent with previous studies by Purbasari and Sari (2022), which suggested that materials with minimal colour change are more effective in preserving visual quality. The darkening of colour in Nylon could be attributed to fruit ageing during storage, as noted by Lufu *et al.* (2021). The result showed that perforated packaging was found to be less effective in maintaining colour integrity as they have the highest colour changes (ΔE) value compared to other conventional plastic packaging. This aligned with findings by Lufu *et al*. (2021), who attributed the greater colour fading to excessive moisture loss in perforated films compared to non-perforated packaging. Lee and Chandra (2018) explained that these perforated packaging increases water vapour transmission that dehydrates the cell, which concentrates the pigments and enzymes in the samples, thus accelerating the oxidation process that changes its colour.

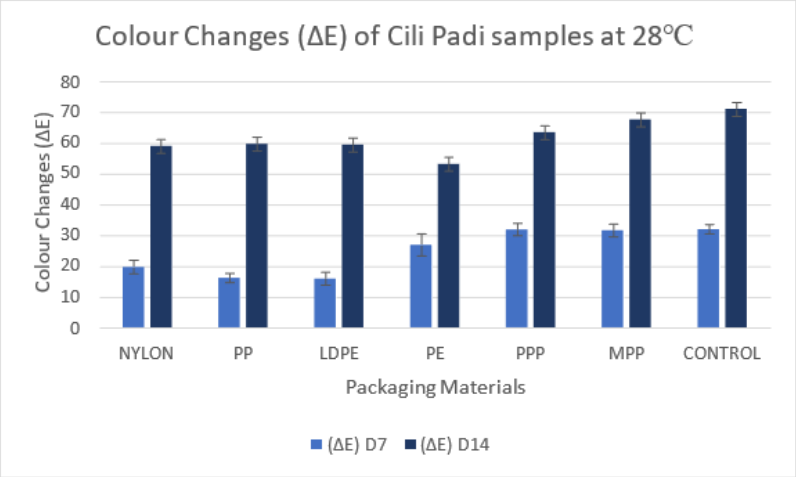


Figure 6. Colour change of Cili Padi at 28°C after 7 and 14 days

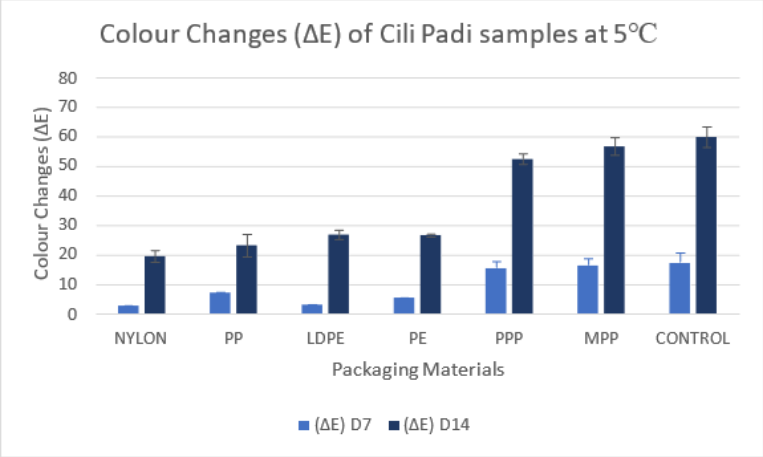


Figure 7. Colour change of Cili Padi at 5°C after 7 and 14 days

3.4 Firmness

Fruit and vegetable texture including firmness and crispness is one of the crucial attributes that are evaluated by the consumer as they relate the physical and visual appearance of the produce to their quality and shelf-life. Firmness of Cili Padi samples reflects how well different materials preserve Cili Padi's textural quality. Figures 8 and 9 illustrate the variation in firmness values across different packaging types at 28°C and 5°C, respectively. The firmness of Cili Padi samples is higher at 5°C, proving that lower temperature can retain the texture of Cili Padi and maintain its structural integrity compared to higher temperatures. Figure 9 shows that control (480.11 ± 17.56 g/mm²), P-PP (438.46 ± 18.31 g/mm²) and M-PP (430.58 ± 26.8 g/mm²) have higher firmness compared to other packaging materials. LDPE has a slightly lower value with 425.96 ± 32.7 g/mm², followed by PP (385.74 ± 58.36 g/mm²) and PE (374.32 ± 29.14 g/mm²). Nylon recorded the lowest firmness with 341.53 ±

78.45 g/mm², potentially due to higher moisture retention on the inner surface of the packaging, which causes the Cili Padi samples to be mushy.

Figure 10 has a similar trend with control samples having the highest firmness value of 686.51 ± 3.96 g/mm². M-PP (690.67 ±2 1.79 g/mm²) and P-PP (686.91 ± 20.46 g/mm²) demonstrated higher firmness compared to other samples, likely due to reduced water condensation inside the packaging. In contrast, LDPE (469.96 ± 12.27 g/mm²), PP (467.36 ± 26.2 g/mm²), and PE (459.70 ± 40.18 g/mm²) exhibited lower firmness values, possibly due to the effects of condensed water inside the packaging. Similarly, Nylon recorded the lowest firmness value of 432.15 ± 89.18 g/mm².

The results indicate a reduction in firmness by day 14 in both storage temperature conditions, likely due to moisture loss and transpiration. This is consistent with findings by Al-Dairi *et al.* (2021), who reported that the firmness of tomatoes is influenced by cell wall degradation caused by transpiration and enzymatic changes. Over 14 days, Cili Padi in most non-perforated packaging showed have mushy texture compared to Cili Padi kept in perforated packaging. Sañudo-Barajas *et al.* (2019) explained further in their books that the ripening event in fleshy fruit causes drastic changes towards the parenchyma cells and the softening process is driven by the hormonal processes. Conventional plastic packaging, with varying moisture permeability. This increases water condensation on the inner surface of the film, leading to change of humidity inside the packaging thus affecting the texture of the samples. Linke and Geyer (2013) noted that condensed water in postharvest storage contributes to defects in the external appearance of fruits and vegetables. Farcuh and McPherson (2022) also supported the claim by explaining that the ideal storage humidity ranges from 85% to 95% as excess humidity potentially causes fruits and vegetables to absorb water from the atmosphere which increases the internal pressure towards their cell wall, resulting in a soft or mushy texture.

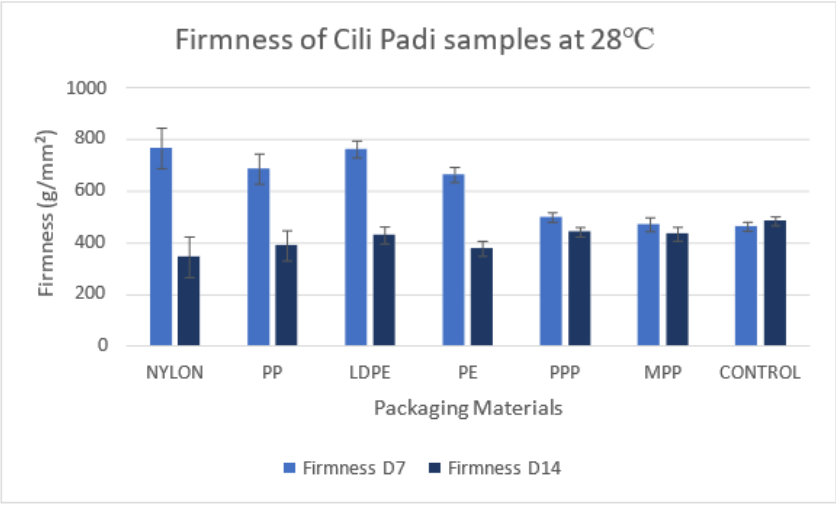


Figure 8. Firmness of Cili Padi samples at 28 °C after 7 and 14 days

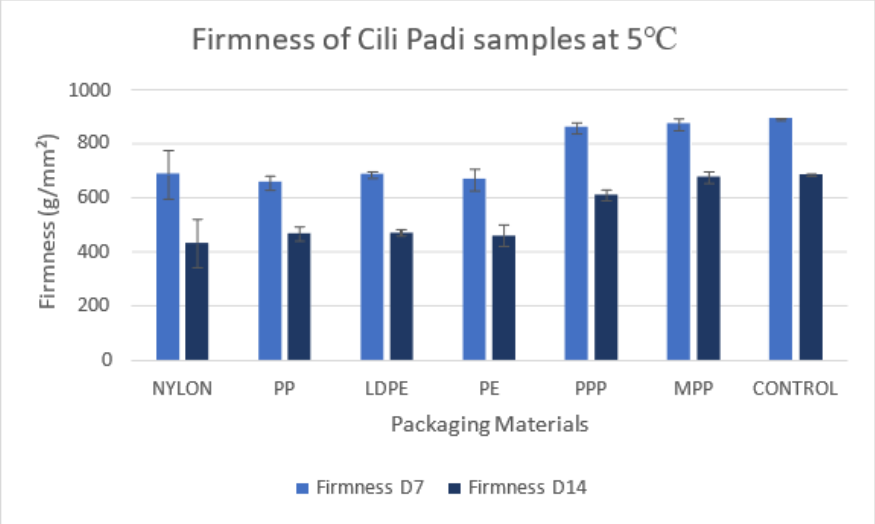


Figure 9. Firmness of Cili Padi samples at 5 °C after 7 and 14 days

3.5 Ascorbic Acid Content

The ascorbic acid (AA) content of Cili Padi was compared after storage in different packaging types at 28 °C and 5 °C with the concentration of extract at 10% (w/v). Figure 10 illustrates that the preservation of ascorbic acid is higher at a lower temperature compared to at room temperature. A study by Dioha *et al.* (2011) showed that ascorbic acid decreases as temperature increases due to the increase in oxidation of ascorbic acid from redox reactions. The ascorbic acid content of samples at 28 °C ranges from the lowest in control samples with 101.86 ± 12.4 mg/100 mg to the highest in Nylon with 266.88 ± 22.24 mg/100 mg. The ascorbic acid content of LDPE is 222.39 ± 26.69 mg/100 mg followed by PE (166.79 ± 16.2 mg/100 mg) and PP (161.74 ± 6.68 mg/100 mg). Perforated packaging has lower ascorbic acid content with P-PP (127.08 ± 11.12 mg/100 mg) and M-PP (111.19 ± 12.71 mg/100 mg).

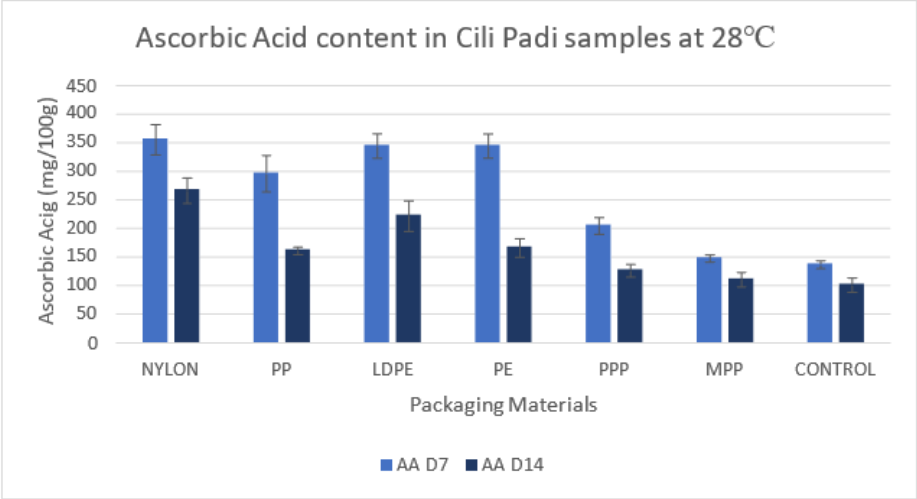


Figure 10. Ascorbic acid content of Cili Padi at 28°C after 7 and 14 days

Meanwhile, Figure 11 proved to have higher preservation of ascorbic acid at lower temperatures compared to room temperature for all packaging materials. Nylon is proven to be most effective by maintaining a substantial amount of ascorbic acid at 277.99 ± 14.5 mg/100 g. This is closely followed by LDPE with 220.56 ± 18.5 mg/100 g, showing the ability of this material to preserve the ascorbic acid content. PE (216.97 ± 21.7 mg/100 g) and PP (184.69 ± 27.8 mg/100 g) have very close values of ascorbic acid content preservation, showing that both packaging materials have the same ability in terms of preserving the ascorbic acid content of Cili Padi. M-PP (145.04 ± 15.61 mg/100 g) and P-PP (156.07±22.06 mg/100g) have a lower value of ascorbic acid content showing that it is less effective in preserving ascorbic acid compared to other plastic packaging materials, meanwhile Cili Padi that is unpacked shown to have the lowest value of ascorbic acid of 124.13±13.8 mg/100g.

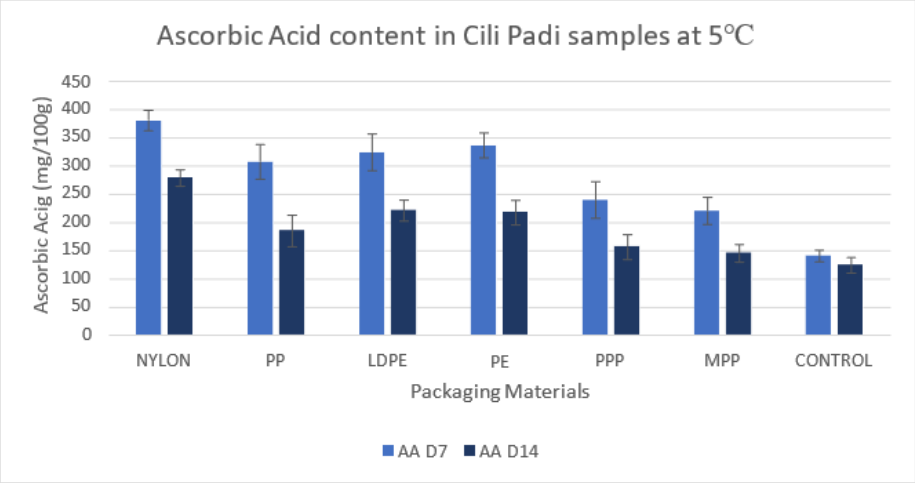


Figure 11. Ascorbic acid content of Cili Padi at 5°C after 7 and 14 days

Generally, the content of ascorbic acid in fruits and vegetables declines over time after harvesting and storage, even at low temperatures as the fruits and vegetables undergo oxidation processes. Several studies by Külen *et al.* (2013) and Cho *et al.* (2013) obtain similar results with the decline of ascorbic acid in fruits and vegetables after storage. Uddin *et al.* (2002) summarize that ascorbic acid degradation is influenced by temperature and water activity, and was observed to be a good indicator of the index of nutrient quality, proving that the preservation of ascorbic acid is crucial in maintaining the quality of Cili Padi. Results showed that the preservation of ascorbic acid at low temperatures exceeds that at room temperature. Align with the study by Yin *et al.* (2022) explained that ascorbic acid degradation significantly reduces at low temperatures (4 to 10 °C). Nylon has been shown to be superior for preserving the ascorbic acid content of Cili Padi in both temperatures, as Nylon has a good oxygen barrier property. Zhang *et al.* (2019) explained that the oxygen barrier of packaging material affects vitamin C degradation, as more vitamin C content were retained in materials with a low oxygen transmission rate (OTR).

On the other hand, control samples and perforated packaging showed to have the lowest ascorbic acid content in both temperatures, potentially due to the impact of the gas exchange and respiration process as it increases the rate of respiration by allowing more gas exchange and accelerate the oxidation of the ascorbic acid content as explained by Talukder *et al.* (2015). Aside from that, higher moisture loss in perforated packaging could potentially cause leaching of ascorbic acid content, align with a study made by Singh and Singh (2015) on cabbage and tomatoes which found that vegetables kept in non-perforated polythene bag in in refrigerator and dark area can retain more vitamin C compared to perforated packaging.

3.6 Antioxidant properties

Cili Padi are known for their antioxidant properties, attributed to their phytochemical compounds. Azlan *et al.* (2022) explained that phenolics, flavonoids, and capsaicin compounds in Cili Pepper provide significant antioxidant benefits by exhibiting anti-inflammatory, anti-allergy, and antioxidative properties. The antioxidant (AO) activity of Cili Padi was evaluated after storage in different packaging types at 28 °C and 5 °C on day 7 and day 14 using the DPPH assay. Figure 12 illustrates the percentage of inhibition in Cili Padi samples after storage. The results show samples that were kept at room temperature have a significantly lower percentage of inhibition compared to Cili Padi kept at a lower temperature across all packaging types, potentially due to the decline of antioxidant properties due to thermal degradation. Figure 12 shows that at 28°C, Nylon was found to have the highest inhibition percentage of 37.24 ± 0.31% followed by LDPE with 35.71 ± 1.19%. P-PP and M-PP have inhibition percentages of 31.86 ± 2.04% and 30.40 ± 1.35%, respectively, with PE (29.37 ± 1.12%) and PP (28.96 ± 0.17%) having slightly lower percentages of inhibition. Meanwhile, control samples have the lowest inhibition percentage with only 22.40 ± 2.49%.

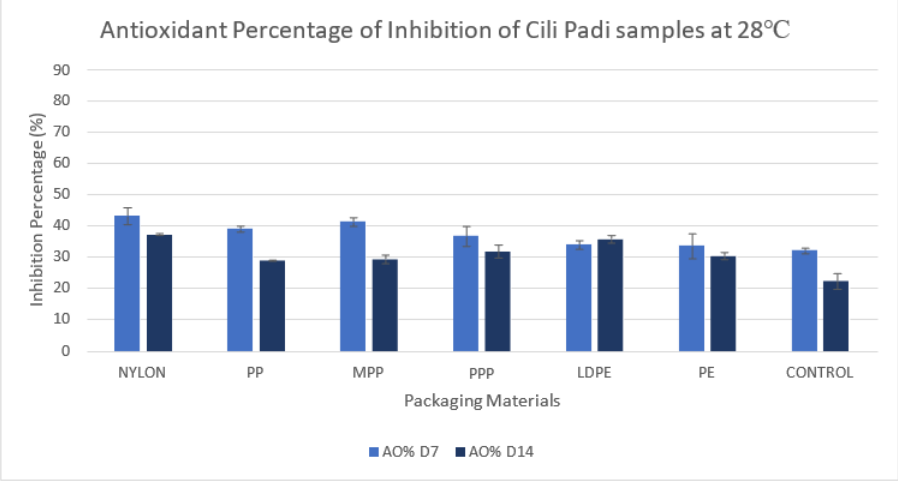


Figure 12. Antioxidant properties of Cili Padi at 28°C after 7 and 14 days

On day 14, Figure 13 shows that PE exhibited the highest percentage of inhibition at 71.24 ± 0.15%, followed by LDPE at 70.80 ± 0.07% while Nylon had inhibition percentage of 70.39 ± 1.83%. Both M-PP and P-PP showed identical inhibition percentages of 69.29 ±

0.14% and 69.29 ± 0.24% respectively, while PP displayed lower antioxidant inhibition with 66.94 ± 0.25%. The control sample had the lowest at 59.50 ± 0.3%. Result showed that difference in plastic packaging type did not affect the antioxidant properties, as all of the plastic packaging shows the same trend with decline of inhibition percentage at day 14. The differences between the plastic packaging materials did not directly affect antioxidant activity, with only minor variations in inhibition percentages across the different packaging types. This suggests that, in this storage period, temperature and the stability of antioxidants in Cili Padi samples might play a bigger role than moderate differences in the barrier properties among different packaging materials. This result was also in line with reports that, in peppers, the impact of packaging material on the retention of antioxidants is realized only at relatively longer storage. Study by Fikiru *et al.* (2024) that were conducted in long period of 10 months showed that total phenolic content (TPC) that contributed to antioxidant of red pepper experienced higher loss in packaging with lower hermetic property, proving that packaging materials did affect the antioxidant activity of capsicum group.

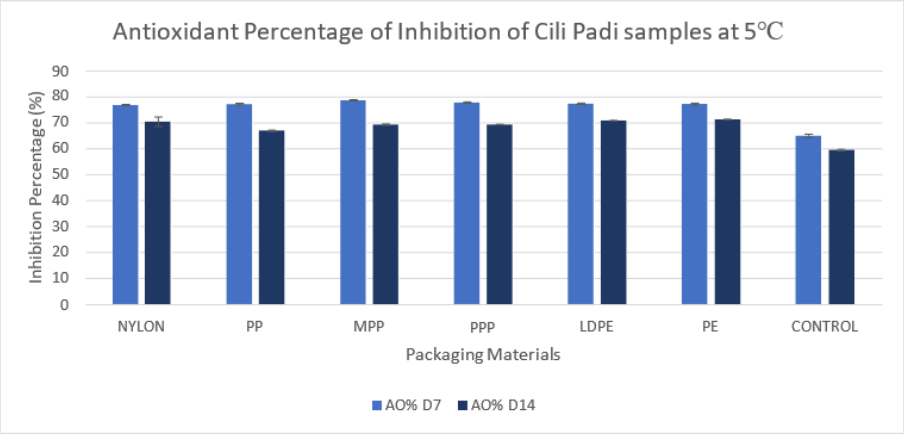


Figure 13. Antioxidant properties of Cili Padi at 5°C after 7 and 14 days

From the results, Cili Padi that were kept at room temperature have lower inhibition percentage, potentially from the degradation of phenolic compound in Cili Padi samples. A study by Galani *et al.* (2017no) explains that total phenolic content (TPC) in potato samples initially increases but is later found to decrease for most of the potato samples at room temperature. Meanwhile, another study by Moldovan, Popa and David (2016) proved that thermal degradation occurs in the phenolic compounds of Cornelian cherries extract that leads to the reduction of antioxidant activities. The results showed that only small differences were found between the plastic packaging materials, with only minor variations in inhibition percentages across the different packaging types. However, samples that were kept without packaging (control) have been found to have lower antioxidant properties at both temperatures. The results align with results by Azali *et al.* (2022) who reported that packaged tomatoes have higher values of lycopene content compared to unpacked tomatoes. Aside from that, results showed that the antioxidant properties decline over time, consistent with findings from Mditshwa *et al.* (2017), who showed a reduction in the antioxidant compound

(vitamin C) in citrus fruits with extended storage. The results also supported by Skrovankova *et al.* (2015), who observed a similar decline in phenolic content during the fruit development stages of strawberries.

3.7 Anti-Fogging Properties

Fogging is a common issue in plastic food packaging, resulting from the condensation of water vapour on the surface of the packaging film. This occurs due to the respiration and transpiration of fresh produce, causing a blurry appearance on the packaging. The results showed that, after 24 hours, only M-PP and P-PP exhibited no fog formation on the surface, in contrast to the other packaging materials. This was attributed to the ability of these films to facilitate adequate gas exchange through micro-holes, preventing condensation. In contrast, conventional packaging materials exhibited fogging due to their inability to absorb water and their hydrophobic characteristics (Pehlivan *et al.*, 2003). This ineffective anti-fogging behaviour could potentially compromise the quality of Cili Padi.

Table 3. Anti-fogging properties of plastic packaging materials

Type of film	Sample	Description
Micro-perforated polypropylene (M-PP)		Clear
Perforated polypropylene (P-PP)		A bit clear (minimal fogging)
Nylon		Not clear (fogging)

Low-Density Polyethylene (LDPE)		Not clear (fogging)
Polyethylene (PE)		Not clear (fogging)
Polypropylene (PP)		Not clear (fogging)

The results showed that perforated plastic packaging exhibits the best anti-fogging properties by minimizing the condensation as it allows excess moisture from the respiration process to escape rather than accumulate inside the packaging. Hameed *et al.* (2013) explained that fresh green chillies continuously lose water from respiration after harvest, consuming oxygen and releasing carbon dioxide and water vapour. The accumulated water vapour inside the packaging materials condensed on the film surface, resulting in fogging. Meanwhile, other conventional plastic packaging exhibits less anti-fogging properties due to low permeability. Linke and Geyer (2013) noted that poor gas permeability can trap excess moisture, leading to fogging and accelerating spoilage, further highlighting the need for packaging materials that allow for balanced gas exchange.

4. Conclusions

The study showed that packaging type and storage temperature significantly affect the physicochemical qualities and shelf-life of Cili Padi. Storage at 5°C consistently reduced qualitative losses compared with room temperature, underscoring the importance of cold storage for maintaining product quality. Among the tested packaging materials, Nylon

provided the most effective overall preservation, while micro-perforated polypropylene (MPP) offered added benefits for firmness retention and anti-fogging performance.

These results indicate the possibility of improving the postharvest quality of Cili Padi and other perishable fruits and vegetables through appropriate packaging selection. In industry practice, Nylon or MPP coupled with low temperature storage may be viable options to extend marketable shelf-life. Further effort should be made towards determining the economic viability of these materials as well as testing their performance under commercial supply-chain conditions and developing sustainable alternatives that assure similar preservation outcomes.

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