Adv. Hort. Sci., 2025 39(2): 93-100

DOI: 10.36253/ahsc-16106
https://oaj.fupress.net/index.php/ahs

AHS
Advances in Horticultural Science

# Lettuce postharvest quality: Affordable packaging and storage durations

**S.M. Shamsi, D. El Pebrian (*), S. Mustaffha, H. Sulaiman, M.K. Zahari, N.A.A. Ghazali**
*Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA, Melaka Branch, Jasin Campus, 77300 Merlimau, Melaka, Malaysia.*

OPEN ACCESS

*Key words*: Lettuce, packaging, postharvest, shelf life.

(*) **Corresponding author:**
darius@uitm.edu.my

**Citation:**
SHAMSI S.M., EL PEBRIAN D., MUSTAFFHA S., SULAIMAN H., ZAHARI M.K., GHAZALI N.A.A., 2025 - *Lettuce postharvest quality: Affordable packing and storage durations.* - Adv. Hort. Sci., 39(2): 93-100.

**ORCID**:
SSM: 0000-0002-4820-1931
EPD: 0000-0001-9139-9755
MS: 0000-0002-5373-8573
SH: 0000-0003-3329-3383
ZMK: 0000-0001-5687-2519



**Data Availability Statement:**
All relevant data are within the paper and its Supporting Information files.

**Competing Interests:**
The authors declare no conflict of interests.

Received for publication 1 May 2024
Accepted for publication 27 May 2025

**Abstract: The affordability of packaging materials and proper storage facilities to preserve the quality of lettuce (*Lactuca sativa* L.) has become a problematic issue for small-scale farmers in Malaysia, who have limited resources and rely on their crops for income. This study compares the post-harvest quality preservation of lettuce using plastic bags and newspapers as cost-effective packaging materials under storage durations of 0, 3, 6, 12, and 15 days. The lettuce quality parameters measured were chlorophyll, sucrose, weight loss, and overall visual quality (OVQ). The results showed newspapers had the highest mean weight loss (7.91 g), while plastic had the lowest one (5.81 g). However, chlorophyll content did not significantly differ between the two packaging types. Lettuce packaged in plastic bags had a significantly lower total soluble solids (TSS) content mean value (2.89%) compared to newspaper (3.89%). In addition, the plastic bag materials gave a better OVQ than that of the newspaper. Generally, the use of plastic bags as a packaging option for small-scale lettuce farmers in Malaysia is affordable and readily available.**

## 1. Introduction

Lettuce (*Lactuca sativa* L.) is a widely consumed vegetable known for its high nutritional value, low calorie content, and potential health benefits. It is a valuable source of vitamins, minerals, and dietary fiber, which are essential for maintaining good health and preventing chronic diseases (Shatilov *et al*., 2019). The increasing demand for organic lettuce in Malaysia has led to more farmers adopting organic farming practices. This crop, along with tomatoes, brassicas, cabbage, and cucumbers, ranked in the top 5 among vegetables with the highest production in the country. FAOSTAT (2025) reported that lettuce production from Malaysian farmers was recorded at 101,680.39 metric tons in 2023. Such production gave a share of 8.99% of the total 1,130,287.58 metric tons' production of all 30 types of cash crops and vegetables in the country.

Being a perishable crop, lettuce requires proper post-harvest handling and storage conditions, such as optimal temperature and humidity levels,

AHS - Firenze University Press
ISSN 1592-1573 (on line) - 0394-6169 (print)

are critical to ensure the quality and freshness of lettuce. The optimal storage temperature ranges of 0ºC to 5°C is crucial to maintain the quality and freshness of lettuce (Gross *et al*., 2016). Farmers need to get the vegetables to the market or supplier as quickly as possible to maintain their freshness and quality. Once lettuce has lost its freshness, it cannot be sold, leading to further losses and waste (Ravula *et al*., 2020).

Unfortunately, many small-scale farmers in Malaysia still lack access to adequate storage facilities, and they often lack the equipment and know-how necessary to preserve their harvests, which can lead to large losses. When lettuce is stored improperly, it might wilt, become brown, and show indications of decomposition, which will make it unsellable. Inadequate storage practices can cause farmers to lose 20-50% of their harvest, resulting in waste and financial losses (Nkolisa *et al.*, 2018). Due to their limited resources and reliance on their crops for revenue, small-scale farmers are most affected by this issue.

Previous studies reported that polymeric films were commonly used as packaging materials for lettuce preservation. According to Lee and Chandra (2018), packaging films have shown beneficial effects in maintaining sensory, nutritional, and microbial qualities in many fresh or fresh-cut products. However, to the best of our knowledge, little is known about the benefits of plastic bags and newspapers, which have been identified as the most used packaging materials for preserving post-harvest vegetables among small-scale lettuce farmers in Malaysia. These materials were affordable and accessible for packaging options for preserving post-harvest vegetables among farmers. Therefore, this study compared newspaper and plastic bags as economical packaging materials for preserving the post-harvest quality of lettuce under varied storage durations. By systematically comparing these factors, this study offers novel insights into how different packaging materials influence key postharvest qualities such as weight loss, chlorophyll content, and total soluble solids (TSS), which sheds new light on their impact on the nutritional value and visual appeal of lettuce. Building on these findings, this study addresses a critical gap in understanding the role of effective and affordable packaging materials in maintaining lettuce quality during storage, with practical implications for small-scale lettuce farmers.

## 2. Materials and Methods

The lettuce was grown in a greenhouse at the Universiti Teknologi MARA (UiTM) farm, Jasin campus, Melaka, Malaysia, was harvested and transported to the postharvest laboratory within one h. Leaves that were overly mature, uneven, or abnormal, as well as those that were damaged or physically injured, were removed from the samples and discarded. The lettuce was chosen based on size, color, and absence of defects.

The plastic bag used in the experiment was made of low-density polyethylene (LDPE), measuring 15 cm (W) × 30 cm (L) + 4 cm (gusset). This type of plastic is specifically designed for packaging vegetables and fruits, and it is commonly used by the farmers for lettuce packaging. The plastic film has a thickness of 0.05 mm, with an oxygen transmission rate (OTR) of approximately 40,000 mL $m^{-2}$ $day^{-1}$ and a water vapor transmission rate (WVTR) of around 9 g $m^{-2}$ $day^{-1}$ under standard conditions.

The samples were then stored in a 5°C cooling room until the end of their shelf life. This temperature was selected as the optimal lettuce storage temperature range. This is in line with the FDA (2010), which advised that cut-leafy greens must be maintained at temperatures of 5°C or less during cold storage and display. In this study, the growth parameters of chlorophyll, sucrose, weight loss, and visual quality (OVQ) were measured.

*Weight loss evaluation*

The lettuce was weighed after being stored. Using an analytical balance (ELT602, Sartorius, Gottingen, Germany), the weight loss percentage was computed by subtracting the current sample weight from the initial sample weight (Waghmare and Annapure, 2015). The percentage of weight loss was computed using the formula in Equation (1):

$$\text{Weight loss (\%)} = (Wi - Wt)/Wi \times 100 \quad (1)$$

where *Wi* represents the initial sample weight (g) at day 0 and *Wt* represents the most recent sample weight (g) at day *t*.

*Chlorophyll evaluation*

The chlorophyll content of the lettuce leaves was measured using a SPAD 502 Plus Chlorophyll Meter (Minolta Camera Co., Osaka, Japan). The chlorophyll

content was measured by placing the meter's measuring head on the adaxial side of five randomly selected leaves from each treatment. The SPAD values were recorded, and the mean value for each treatment was calculated. The chlorophyll concentration was expressed in terms of SPAD units (SU).

*Total soluble solids analysis*

The total soluble solids (TSS) of the lettuce samples were determined using a Brix meter (Brand HUILEY, Model HT113ATC) in accordance with the instructions provided by the manufacturer. The sampled lettuces awas washed, cut into small pieces, and homogenized briefly. Before each measurement, the Brix meter was calibrated with distilled water. The measurement range of the Brix meter was 0-32%, and each sample was replicated three times. The measurements were conducted on days 0, 3, 6, 12, and 15 of storage.

*Overall visual quality (OVQ)*

The OVQ rating is a measure of the lettuce's condition during storage. It considers factors such as appearance, texture, and color to determine the overall quality of the lettuce. These variables can be affected by a variety of factors, such as lettuce storage duration, storage temperature, and the storage method employed. A panel comprised of three individuals from the university's farm was chosen to evaluate the OVQ rating. One man and two women, ages 20 to 23, were selected as the panelists.

Before the test, the panelists were trained to recognize and evaluate the lettuce's OVQ. This training is vital because it ensures that panel members can evaluate samples of lettuce consistently and accurately. The OVQ score considers the appearance of lettuce, including its color, texture, and overall freshness. OVQ was evaluated using a 9-point scale adapted from Wheeler *et al*. (2015): 9= excellent, 7= good, 5= acceptable, 3= poor, and 1= unusable. The overall visual quality was evaluated on the day of processing and every three days until the end of the shelf life during 5°C storage.

Factorial experiment in the IBM SPSS software was used to statistically analyze the effects of different packing materials and storage durations on mean weight loss, chlorophyll, and TSS content. The interaction between packaging materials and storage duration as factors towards the respective mean weight loss, chlorophyll, and TSS were evaluated.

An analysis of variance (ANOVA) was applied to test the mean significance between the storage duration and the quality of lettuce stored under the respective plastic and newspaper packaging. Tukey's range test was used to compare the differences between treatments.

## 3. Results and Discussion

*Weight loss*

As shown in Table 1, both packaging type and storage duration had a significant effect on weight loss. The packaging type showed a statistically significant difference with a p-value of 0.021, indicating that the choice of packaging material influenced the extent of weight loss. This is further supported by the data in Table 2, where lettuce stored in newspaper packaging experienced a higher mean weight loss (7.91 g) compared to plastic packaging (5.81 g), suggesting that newspaper is less effective in preserving the product and minimizing weight loss.

The p-value of less than 0.001 for the duration of

Table 1 - Analysis of variance of weight loss

| Source of Variation | Degree of freedom | Sum of squares | Mean square | F value | Significant |
|---|---|---|---|---|---|
| Packaging | 1 | 39.543 | 39.543 | 261.927 * | .021 |
| Duration | 5 | 398.222 | 79.644 | 6.107 ** | <.001 |
| Packaging x Duration | 5 | 38.158 | 7.632 | 12.301 | .349 |
| Error | 24 | 155.396 | 6.475 | | |
| Total | 36 | 2327.250 | | | |

* significant at the 0.05 probability level.
** significant at the 0.01 probability level.

Table 2 - Mean comparisons of the quality of lettuce with different packaging materials

| Packaging material | Quality of lettuce | | |
|---|---|---|---|
| | Weight loss (g) | Chlorophyll content (SU) | TSS content (%) |
| Control | 3.15 c | 13.23 a | 4.72 a |
| Newspaper | 7.91 a | 12.80 a | 3.89 b |
| Plastic | 5.81 b | 13.39 a | 2.89 c |

Means in the same column followed by the same letters are not significantly different at the 0.05 probability level.

storage indicated that the storage duration of lettuce had a significant effect on weight loss. This suggests that the longer the product was stored, the higher the weight loss would be. However, the p-value of 0.349 for the interaction between packaging type and storage duration suggested that there was no significant difference in the effect of storage duration on weight loss between plastic and newspaper packaging. This implies that both types of packaging were equally affected by storage duration; therefore, storage duration is an important factor to consider for both types of packaging.

Lettuce undergoes weight reduction during storage mostly because of transpiration and respiration. Respiration is the mechanism by which lettuce utilizes oxygen and emits carbon dioxide to produce energy, resulting in the decomposition of carbohydrates and the release of water. Furthermore, enzyme activity, subject to the influence of storage conditions, plays a role in these physiological alterations (Escalona *et al*., 2006; Yang *et al*., 2024; Nitu et *al*., 2025).

Overall, the study findings suggested that plastic packaging was more effective in preventing weight loss in lettuce compared to newspaper packaging. The lower weight loss in plastic packaging may be attributed to its better barrier properties, which can limit the exchange of gases, such as oxygen and carbon dioxide, between the product and its environment. These gases can promote respiration and accelerate the metabolic processes in lettuce, leading to weight loss (Semco, 2014). Moreover, plastic packaging can prevent moisture loss and maintain high humidity around the product, which can help reduce water loss and keep the product fresh for a longer period.

*Chlorophyll content*

The results in Table 3 show that the type of packaging material used had a significant effect on the SPAD value for chlorophyll, with a p-value of 0.021. This effect is further illustrated in Table 2, where the mean SPAD value for lettuce packaged in plastic (13.39 SU) was higher than that for lettuce packaged in newspaper (12.81 SU), indicating a higher concentration of chlorophyll in plastic-packaged lettuce. The duration of storage had a significant effect on the SPAD value for chlorophyll, with longer storage durations leading to lower chlorophyll content.

The findings of this study are consistent with previous research on the degradation of chlorophyll during storage. The interaction between packaging type and storage duration was not significant, suggesting that regardless of the type of packaging material used, the degradation of chlorophyll will

Table 3 - Analysis of variance of chlorophyll content

| Source of variation | Degree of freedom | Sum of squares | Mean square | F value | Significant |
|---|---|---|---|---|---|
| Packaging | 1 | 39.543 | 3.121 | 5.054 * | .021 |
| Duration | 5 | 398.222 | 30.139 | 48.807 ** | <.001 |
| Packaging x duration | 5 | 38.158 | 1.591 | 2.577 | .349 |
| Error | 24 | 155.396 | 0.618 | | |
| Total | 36 | 2327.250 | | | |

* significant at the 0.05 probability level.
** significant at the 0.01 probability level.

occur over time, resulting in a decrease in the SPAD value for chlorophyll in lettuce as stated by Mattos *et al*. (2013). While, in addition, Ferrante and Maggiore (2007) stated that as lettuce is a non-durable vegetable, the degradation of leaf pigments such as chlorophylls and carotenoids occurs during storage, leading to tissue browning. Degl'Innocenti et *al.* (2005) and Ferrante and Maggiore (2007) added that a common indicator of these processes is browning and discoloration resulting from damage to the leaf surface. The loss of color occurs due to the degradation of chlorophylls because of vegetable aging during storage.

In response to the above findings, the appropriate selection of packaging materials is crucial to maintaining the quality and freshness of lettuce during storage and transportation. The use of plastic packaging can result in higher SPAD values for chlorophyll in lettuce compared to newspaper packaging, but this effect may be limited over time due to the natural degradation of chlorophyll. Therefore, it is important to balance the need for optimal packaging materials with the limitations of prolonged storage durations.

*Total soluble solids content*

As shown in Table 4, both the type of packaging and the duration of storage had a statistically significant effect on the total soluble solids (TSS) content of lettuce ($p<0.001$). Table 2 further illustrates this effect, with lettuce stored in newspaper packaging exhibiting higher TSS levels (3.89%) than those stored in plastic packaging (2.89%). In addition, TSS levels increased progressively with longer storage durations, suggesting that extended storage promotes sucrose accumulation. The significant interaction between packaging type and storage duration indicates that the influence of storage time on TSS content differs depending on the packaging material used. Overall, these findings emphasize the importance of both packaging type and storage duration in determining the TSS content of lettuce

Packaging materials play a crucial role in maintaining the freshness and quality of lettuce by providing a barrier against moisture loss and physical damage during storage and transportation. The use of newspaper packaging may lead to higher sucrose levels in lettuce due to its absorbent nature, which can draw moisture from the vegetables. TSS content is a key component of the flavor and texture of fruits and vegetables, and excess moisture can lead to an increase in TSS production in lettuce. However, the absorbent nature of newspaper packaging can also increase the risk of moisture loss and spoilage in lettuce.

In contrast, plastic packaging can provide a more effective barrier against moisture loss and protect the lettuce from external factors that may affect its quality. This can lead to a lower concentration of sugars in the lettuce compared to newspaper packaging. It is important to use appropriate packaging materials that balance the need for moisture retention with the need for protection and safety. The findings of this study suggest that different packaging materials may have different effects on the TSS content levels of lettuce, and that storage duration is an important factor to consider when selecting the appropriate packaging.

Based on the comparison of mean quality values for lettuce packed with different materials (Table 5), it appears that the newspaper had the highest mean value (7.91 g) while the plastic had a lower mean value (5.81 g) for weight loss. Although there

Table 4 - Analysis of variance of TSS content

| Source of variation | Degree of freedom | Sum of squares | Mean square | F value | Significant |
|---|---|---|---|---|---|
| Packaging | 1 | 9.000 | 9.000 | 32.400** | <.001 |
| Duration | 5 | 21.222 | 4.244 | 15.280** | <.001 |
| Packaging x duration | 5 | 11.667 | 2.333 | 8.400** | <.001 |
| Error | 24 | 6.667 | .278 | | |
| Total | 36 | 462.000 | | | |

** significant at the 0.01 probability level.

is no specific research on the effect of packaging materials between paper and plastic on the quality and shelf life of lettuce, some studies have investigated the effect of packaging on the shelf life of other fruits and vegetables. A study on tomato storage conditions and packaging materials found that HDPE packaging material resulted in the least weight loss when stored in a refrigerator (Sualeh *et al*., 2016).

For the chlorophyll content, the mean value for the lettuce stored in plastic packaging is 13.39 SU, and for the lettuce stored in newspaper packaging, the mean value is 12.80 SU (Table 2), whereas there is no significant difference between these two packaging due to their falling into the same grouping. The chlorophyll content was not significantly different between the two types of packaging. This could be because chlorophyll is relatively stable and is not affected by moisture or air. However, it is important to note that the chlorophyll content can be affected by other factors, such as light exposure and temperature.

While for TSS content, the mean value for the lettuce packed with plastic has the lowest value, which is 2.89%, compared with the newspaper, whose mean value is 3.89% (Table 2). TSS corresponding to sucrose, which is a disaccharide composed of glucose and fructose and is commonly known as table sugar. The query suggests that the lower sucrose content in plastic packaging could be due to its hygroscopic nature, which leads to the absorption of moisture. Water vapor permeation through the package material occurs in three steps: water vapor adsorption, diffusion, and desorption from the package. This process is driven by transferring from high to low water activity or relative humidity (RH) (Sand, 2021). However, plastic packaging has lower moisture permeability, which could prevent the loss of moisture and the absorption of sucrose, resulting in lower levels of sucrose in plastic-packaged products.

Table 5 shows the weight loss and chlorophyll content of lettuce stored for 0 days in plastic and newspaper packaging are significant with the storage duration of 3, 6, 9, 12, and 15 days. This occurs due to the shock of the environment from a normal temperature to a cold temperature. However, there is no significant difference in TSS content between the storage durations of lettuce under plastic packaging. When the lettuce was stored under newspaper packaging, it was found that there were significant differences between the storage durations of 0, 3, 6, 9, 12, and 15 days.

*Overall visual quality*

The findings of this study, as presented in figure 1, indicate that the overall visual quality (OVQ) of lettuce stored at 5°C can be effectively maintained for up to 12 days with the use of plastic bags. This is evidenced by the consistency of OVQ scores of 7 or

Table 5 - Mean comparisons of the quality of lettuce with different storage durations under both packaging materials

| Packaging | Quality of lettuce | | |
|---|---|---|---|
| | Weight loss (g) | Chlorophyll content (SU) | TSS content (%) |
| *Plastic* | | | |
| Day 0 | 0.00 b | 16.23 a | 3.00 a |
| 3 | 8.95 a | 13.97 b | 2.67 a |
| 6 | 6.54 ab | 13.77 b | 2.67 a |
| 9 | 5.93 ab | 13.00 bc | 2.67 a |
| 12 | 5.04 ab | 12.30 bc | 3.00 a |
| 15 | 8.44 ab | 11.10 c | 3.33 a |
| *Newspaper* | | | |
| Day 0 | 0.00 c | 17.47 a | 2.67 b |
| 3 | 8.59 ab | 13.77 b | 3.33 b |
| 6 | 7.78 b | 13.10 bc | 3.00 b |
| 9 | 8.10 b | 11.80 bc | 3.00 b |
| 12 | 9.93 ab | 11.33 cd | 5.00 a |
| 15 | 13.07 a | 9.37 d | 6.33 a |

Means in the same column followed by the same letters are not significantly different at the 0.05 probability level.

higher, which exceed the marketability cut-off score of 6. However, when stored in newspaper packing, the OVQ scores of lettuce samples deteriorated rapidly, falling below the marketability cut-off score after just 6 days.

The results suggest that the choice of packaging material is a critical factor in maintaining the quality

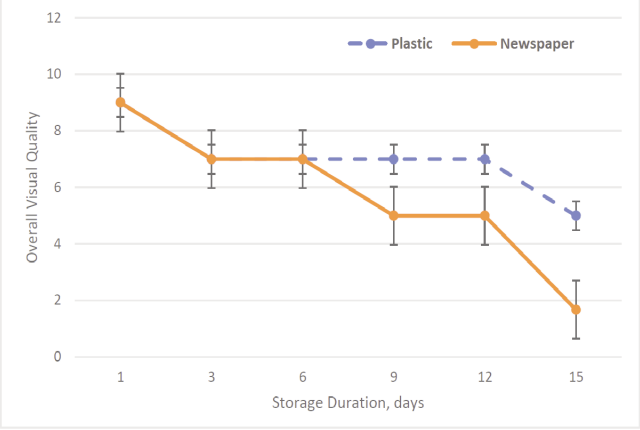


Fig. 1 - Overall visual quality of leaf lettuce packaged with plastic bags and newspapers during storage at 5°C for up to 15 days.

of lettuce during storage, with plastic bags proving more effective than newspaper in this regard. This may be attributed to plastic bags' superior ability to prevent moisture loss and inhibit microbial growth, which can contribute to the deterioration of lettuce quality and appearance. Additionally, the findings indicate that storage temperature plays a crucial role in preserving lettuce quality, with lower temperatures being more effective in achieving this objective.

The significant effect of storage duration on weight loss highlights the importance of proper storage conditions in preserving the quality and shelf-life of lettuce. Low temperatures, high humidity, and adequate ventilation are some of the essential storage conditions that can help slow down the metabolic processes and reduce weight loss in lettuce. The lack of significant interaction between packaging type and storage duration suggests that both types of packaging can benefit from proper storage conditions to minimize weight loss. Figure 2 shows the physical appearance of lettuce in 15 days using plastic in 5°C.

Overall, the study suggests that small-scale lettuce farmers in Malaysia may benefit from using plastic packaging to preserve the quality and freshness of their produce. However, the choice of packaging material should also consider factors such as cost and accessibility to ensure it is both effective and practical for small-scale operations. Additionally, to align with sustainable development goals, the environmental impact of using recycled materials such as newspapers should be an important consideration when selecting packaging options. It has been proven that newspaper as packaging material aligns with environmental sustainability goals due to its biodegradable nature and origin from renewable resources. Newspapers are also easily recycled or used for renewable energy, which helps reduce reliance on fossil resources.

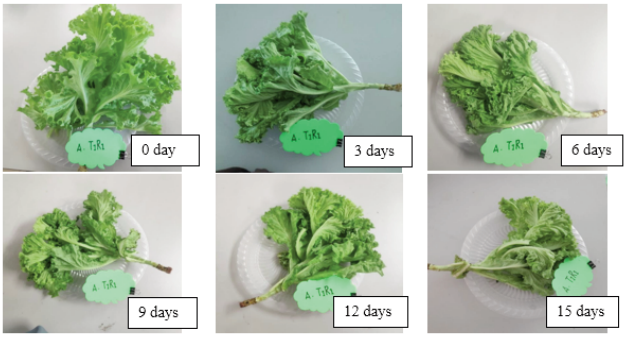


Fig. 2 - The physical appearance of lettuce in 15 days using plastic in 5°C.

## 4. Conclusions

The selection of appropriate packaging materials is crucial to maintaining the quality and freshness of lettuce during storage and transportation. The study found that plastic packaging was more effective in preventing weight loss and maintaining higher concentrations of chlorophyll in lettuce than newspaper packaging. However, newspaper packaging resulted in higher TSS levels compared to plastic packaging. The length of time the product was stored also had a significant effect on weight loss, chlorophyll degradation, and TSS levels. The study highlights the importance of balancing the need for optimal packaging materials with the limitations of prolonged storage durations.

Further studies are recommended to explore the use of alternative recycled packaging materials that are not only effective and environmentally friendly

but also affordable for small-scale farmers. This research could focus on identifying cost-effective and locally available options, such as biodegradable or compostable materials. Additionally, investigating the feasibility of a shared packaging system among small-scale farmers may offer a practical solution to reduce costs and enhance access to sustainable packaging options.

**Acknowledgements**

The authors are very grateful to the Universiti Teknologi MARA (UiTM) for funding this research under the UiTM Grant MyRA Science Technology No. 600-RMC/GPM ST 5/3 (039/2021).

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