Postharvest biology of fresh *Moringa oleifera* leaves

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Abstract

Moringa (*Moringa oleifera)* leaves are a highly nutritious but perishable vegetable. Postharvest respiration rates of the leafy stems are high, with average rates over 6 d of 16, 55 and 210 µL CO_2 g^{-1} h^{-1} at 0, 10 and 20°C, respectively. These rates are comparable to those of asparagus stems. Ethylene production is very high for a leafy vegetable, with average rates over 6 d of 0.25, 1.9 and 3.8 nL g^{-1} h^{-1} at 0, 10 and 20°C, respectively. The major causes of postharvest deterioration are yellowing, leaf drop or abscission, dehydration and decay. Lowering the storage temperature from 20 to 5°C helped maintain green leaf color, and reduced leaf drop and dehydration. Shelf-life was 2-3 d at 20°C, 5-8 d at 10°C and 10-14 d at 5°C. Moringa leaves are extremely sensitive to exogenous ethylene, and a 500 ppb 1-MCP treatment for 4 h effectively controlled leaf drop both in the air-stored and ethylene-exposed moringa stored at 10°C. These data can support improved postharvest management along the value chain for fresh moringa leaves.

Keywords: ethylene production, leaf abscission, 1-MCP, respiration, storage temperature

INTRODUCTION

Moringa (*Moringa oleifera*) is a pantropic tree of broad adaptability and multiple uses that produces nutritious and edible leaves, flowers, and pods (Ebert and Palada, 2017). Leaves (rachises with paired pinnules) of moringa, a botanical relative of cruciferous vegetables, contain glucosinolates and isothiocyanates which contribute to one aspect of their reported medicinal value (Waterman et al., 2014; Gopalakrishnan et al., 2016; Fahey, 2017). The leaves contain higher amounts of protein, vitamins, and carotenoids compared to other leafy greens (Ebert and Palada, 2017). The fresh leaves are usually marketed quickly under ambient conditions, or because of their perishability, marketed as a dried leaf powder (Bridgemohan et al., 2020). The marketability and nutritional quality of minimally processed moringa leaves has been studied at 5°C and ambient temperature, using different packaging materials (Kumar et al., 2013; Ambrose et al., 2017; Suganthi et al., 2019).

In general, leafy vegetables are characterized as being very perishable, with high rates of respiration and water loss. Temperature is the most important factor for maintaining postharvest quality of leafy vegetables (Cantwell, 2021). While all plant tissues produce some ethylene as part of their normal metabolism, leafy vegetables are generally very sensitive to exogenous ethylene. Symptoms of ethylene exposure include increased yellowing and leaf drop or abscission (Brecht, 2019). The compound 1-methylcyclopropene (1-MCP) physiologically prevents ethylene action by competitively binding to ethylene receptors (Watkins, 2016). The main commercial use of 1-MCP is to extend the storage life and crispiness of fruits such as apples. Although 1-MCP is effective to reduce ethylene effects on vegetables, logistics and costs have limited its commercial use for leafy vegetables.

The objective of this study was to develop postharvest information that could extend shelf-life and maintain quality of fresh moringa leaves.

MATERIALS AND METHODS

Moringa leaves ('Manila', 'PKM1' and unknown cultivars) were harvested before 8 am in May and June of 2016 and 2017 from commercial plantings in the Fresno, CA area. Mature

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leaves (rachises with paired pinnules, commonly known as stems and leaflets) at typical commercial stage (Figure 1) were snap harvested, loosely bunched in groups of 13 leaves, with 5 bunches placed in large unsealed plastic bag, with 2 bags per cooler which were separated by cardboard layers from gel ice packs and ice to maintain cool and fresh conditions. After transport to the lab in Davis, CA the arrival temperatures were 7-15°C and leaf bunches in the unsealed bags were placed at 10°C overnight. Dry weight was determined on leafy stems by drying in a forced air oven at 70°C until constant weight. Weight loss was determined on some leafy stems at 20°C with 70% RH and little air movement.

Figure 1. Moringa (cultivar unknown) leaves (stems and leaflets are botanically called rachis and paired pinnules) harvested immature (left), mature (middle) and overmature (right).

For storage tests at 5, 10, 15 and 20°C, leaves (stems and leaflets) were placed on trays covered with an unsealed polyethylene bag, with 6-10 leaves per replication per evaluation. For the 500 ppb 1-MCP treatment, 50 leaves were placed upright in each of 4 water-tight Rubbermaid containers at 10°C for 4 h. The 1-MCP gas was generated from tablets with buffer obtained from Agrofresh Solutions, Inc. Leaves were evaluated periodically for various quality aspects. Shatter or leaflet drop was measured by weighing the leaves abscised and calculating the weight percentage. Yellowing was evaluated on a scale of 1 to 5, where 1 = dark green and 5 = yellow, and this scale was referenced to objective color values measured with a Minolta color meter. Yellowed leaflets sometimes were calculated as a weight percentage. Decay was evaluated on a scale of 1 to 5, where 1 = none, and 5 = severe. Overall visual quality was rated on a scale of 9 to 1, where 9 = excellent and 1 = unusable, with 6 indicating the limit of marketability. Shelf-life was based on the number of days to reach a score of 6.

Respiration rate and ethylene production rates were measured on 100 g of leaves (stems and leaflets) in containers at 0, 10 and 20°C connected to a flow of humidified air to allow accumulation of CO_2 to 0.5%. The inlet and exit CO_2 and ethylene concentrations were measured by taking 1 mL gas samples and injecting into an infrared CO_2 analyzer and a gas chromatograph equipped with a modified alumina F1 column and a flame ionization detector, respectively. Standards of 0.5% CO_2 and 1.1 ppm ethylene were used for calibration. Respiration rates and ethylene production rates were calculated as $\mu L\ CO_2\ g^{-1}\ h^{-1}$ and $nL\ g^{-1}\ h^{-1}$, respectively.

Experiments were repeated at least once, with a minimum of 3 replicates per treatment. Data were analyzed by ANOVA with mean separation by LSD.05.

RESULTS AND DISCUSSION

In the initial testing, we did not protect the leaves sufficiently from dehydration after harvest or we packed the stems too tightly and heat of respiration quickly reduced quality. Those difficulties served to illustrate the very perishable nature of the moringa leaves. In later tests, we placed a few stems in unsealed polyethylene bags inside coolers and separated from gel ice packs and ice so they were transported under humid and fresh conditions. The moringa leaves alone have a high average dry weight of 22.6% (the percentage dry weight of the rachis with pinnules was 21.7%). The leaves are very susceptible to water loss (Figure 2), losing about 11% when held in a dry vase at 20°C for 6 h. Symptoms of water loss are observed with 4-5% weight loss. Over a 24-h period at 20°C, the leaves completely dried and this is why the leaves are often sold as a dried product.

Figure 2. Appearance of moringa leaves (stems and leaflets) after 6 h at 20°C and 70% RH. Leaves were held in a vase with water (left) and in a dry vase (right). The leafy stems lost 0.6 and 11% weight, respectively, over the 6 h.

Moringa leaves (stems and leaflets) have very high respiration rates compared to other green vegetables, which are most similar to the respiration rates of asparagus stems (Asparagus produce facts; http://postharvest.ucdavis.edu). The respiration rates of untreated and 1-MCP treated leaves were similar (Figure 3), but the ethylene production rates of the 1-MCP treated leaves were notably higher than the untreated leaves. The ethylene production rates increased with time and were very high compared to other leafy vegetables which have rates from 0.1 to 1.00 nL g^{-1} h^{-1} at 20°C (Cantwell, 2021). Moringa leaves stored at 0 and 10°C were transferred to 20°C after 6 d (Figure 4) and a typical burst of respiration and ethylene production was observed. However, both rates fell to near normal levels at 20°C indicating that the product, at least for 6 d, may not have suffered chilling injury.

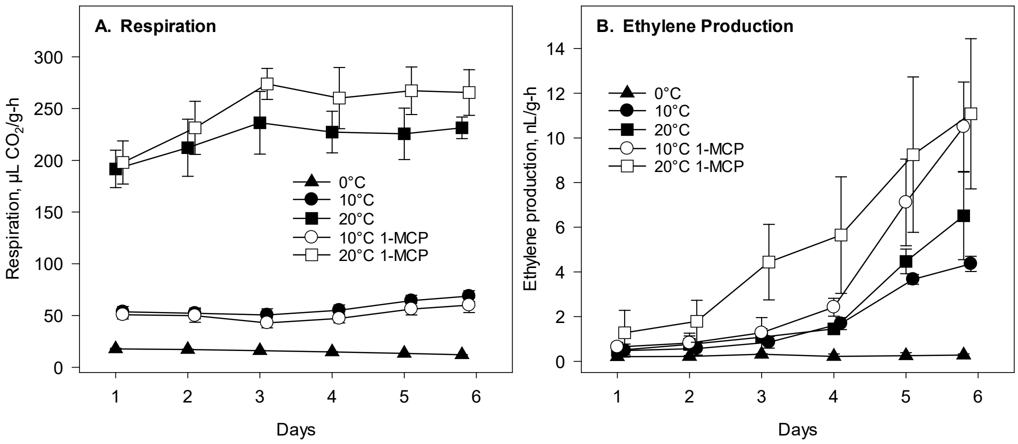

Figure 3. Respiration rates and ethylene production rates of mature moringa ('Manila') leaves (stems and leaflets) at 0, 10 and 20°C. Some leaves were pre-treated with 500 ppb 1-MCP for 4 h at 10 or 20°C. Data are the averages of 3 replicates ± standard deviation.

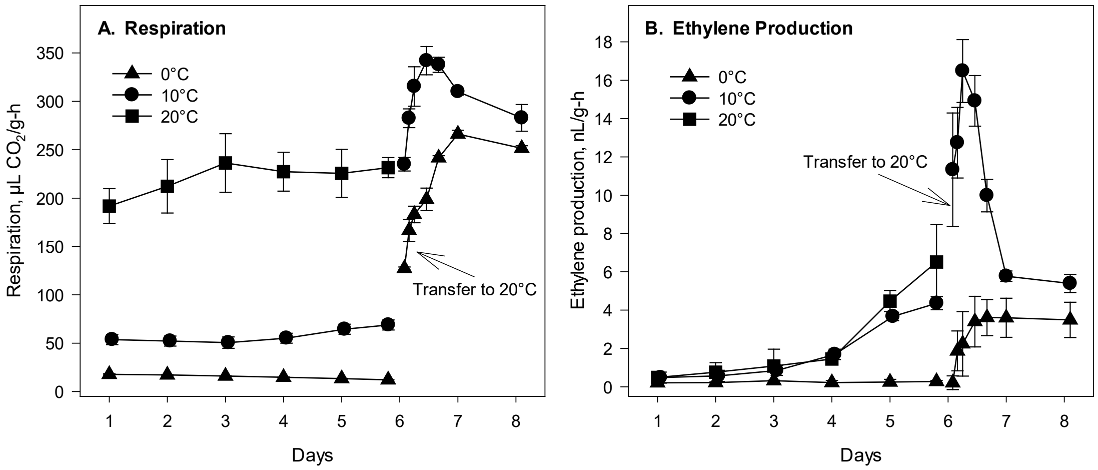

Figure 4. Respiration rates and ethylene production rates of mature moringa ('Manila') leaves (stems and leaflets) at 0, 10 and 20°C. After 6 days, leaves at 0 and 10°C were transferred to 20°C for 2 days. Data are the averages of 3 replicates ± standard deviation.

Leaf yellowing is a common postharvest defect (Table 1). Yellowing, leaf abscission and dehydration were all reduced by storing the moringa below 20°C (Figure 5). For product stored at 15°C or lower for 6 d, leaf abscission and dehydration were more important defects than yellowing. Several storage tests were conducted. In some cases, there was considerable superficial mold growth. To avoid that problem, some weight loss needs to be tolerated. In tests without mold growth, we estimated shelf-life to be 10-14 d at 5°C. These results are comparable to other postharvest studies on moringa leaves (Kumar et al., 2013; Ambrose et al., 2017; Suganthi et al., 2019).

Table 1. Visual appearance and corresponding color values for the 5-point yellowing scale of moringa leaflets ('Manila').

Color value	1	2	3	4	5
L*	45.1	45.8	55.1	65.3	70.9
a*	-10.9	-16.3	-17.5	-17.4	-8.6
b*	10.8	20.7	27.1	31.5	33.8
Chroma	15.4	26.3	32.2	35.8	35.4
Hue	135.2	128.7	123.3	119.2	104.2

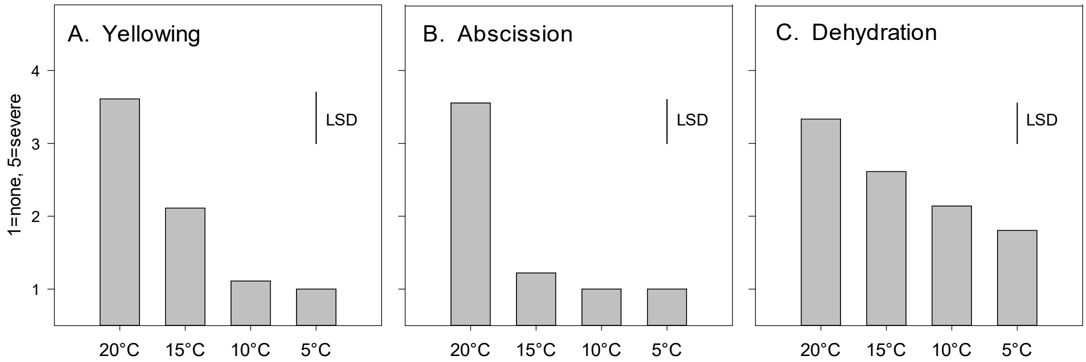

Figure 5. Yellowing, leaflet abscission and dehydration scores for moringa leaves ('Manila') stored at 5, 10, 15 and 20°C for 6 days. Data are averages of 3 replications of 6 leafy stems.

Moringa leaves not only produce high amounts of ethylene leading to significant leaflet abscission after storage, but they are very sensitive to exogenous ethylene. Moringa was treated with 7 ppm ethylene for 4 h at 10°C (high dose for a short period) and that was sufficient to cause almost complete leaf abscission (Figure 6), although the moringa not exposed to ethylene also had very high leaf drop. The 1-MCP treatment reduced abscission in both the air-stored and the ethylene exposed moringa leaves. Recently it was shown that a combination of 1-MCP and ethylene absorbent sachets greatly reduced abscission of leaflets of irradiated moringa in simulated air shipments (2 d at 7°C followed by 4 d at 12°C) (Paull and Uruu, 2021).

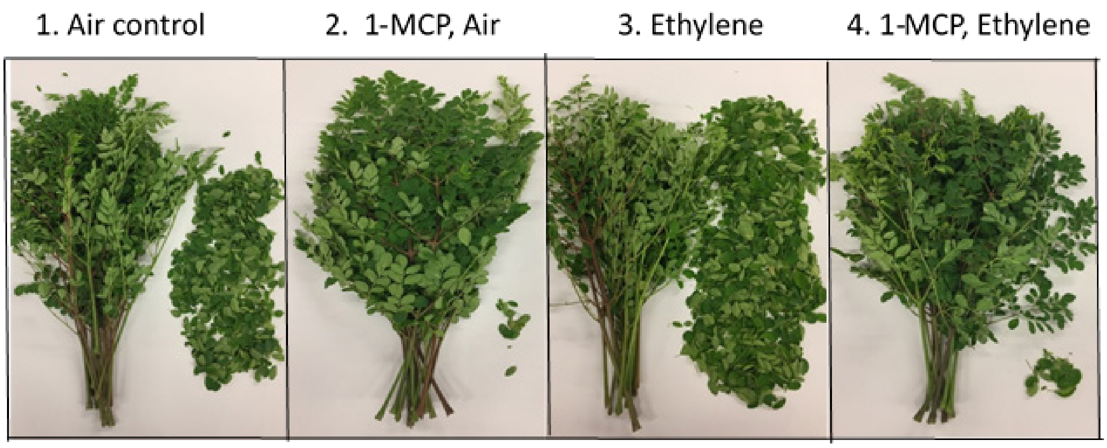

Figure 6. Postharvest conditions affect leaflet abscission in moringa ('Manila'). Treatment with 500 ppb 1-MCP prevented leaf drop in moringa stored in air (1 vs. 2). An ethylene treatment (7 ppm for 4 h before storage) increased leaf drop (3), but the 1-MCP treatment prevented abscission (4). The photos were taken after 5 days at 10°C. The percentage by weight of abscised leaflets was 64, 2, 93, and 4% for treatments 1, 2, 3 and 4, respectively.

CONCLUSIONS

Nutritious and tender moringa leaves have very high respiration and ethylene production rates and are very perishable. Yellowing, dehydration, leaf abscission and decay are the major postharvest defects. Storing the moringa leaves at 10 and 5°C resulted in a shelf-life of 6-8 days and 10-14 days, respectively. Moringa leaves abscise from the stems and this is accelerated with exposure to ethylene. A 1-MCP treatment greatly reduced leaf drop in control and ethylene-exposed moringa leaves.

Literature cited

Ambrose, D.C.P., Naik, R., and Duanty, A.L. (2017). Studies on fresh processing of *Moringa oleifera* leaves. Intl. J. Food Ferment. Technol. *7* (*2*), 306–309 https://doi.org/10.5958/2321-5771.2017.00042.4.

Brecht, J.K. (2019). Ethylene technology. In Postharvest Technology of Perishable Horticultural Commodities, Chapter 14, E.M. Yahia, ed. (Cambridge, UK: Woodhead Pub.), p.481–497 https://doi.org/10.1016/B978-0-12-813276-0.00014-6.

Bridgemohan, P., Goordeen, A., Mohammed, M., and Bridgemohan, R.S.H. (2020). Review of the agro-ecology, phytochemistry, postharvest technology and utilization of moringa (*Moringa oleifera* Lam.). J. Hortic. Postharvest Res. *3* (*2*), 311–322 https://doi.org/10.22077/JHPR.2020.3037.1116.

Cantwell, M. (2021). Postharvest handling systems: flower, leafy, and stem vegetables. In Postharvest Technology of Horticultural Crops, J.F. Thompson, ed. (Oakland: UC ANR Communications Services) (in press).

Ebert, A.W., and Palada, M.C. (2017). Moringa – a vegetable tree for improved nutrition, health and income of smallholder farmers. Acta Hortic. *1158*, 309–316 https://doi.org/10.17660/ActaHortic.2017.1158.35.

Fahey, J.W. (2017). *Moringa oleifera*: a review of the medicinal potential. Acta Hortic. *1158*, 209–224 https://doi.org/10.17660/ActaHortic.2017.1158.25.

Gopalakrishnan, L., Doriya, K., and Kumar, D.S. (2016). *Moringa oleifera*: a review on nutritive importance and its medicinal application. Food Sci. Hum. Wellness *5* (*2*), 49–56 https://doi.org/10.1016/j.fshw.2016.04.001.

Kumar, P.A., Nirmala, R., and Bhavya, E.P. (2013). Effect of different packaging and storage conditions on shelf-life of processed drumstick leaves. Int. J. Agric. Eng. *6* (*11*), 28–31.

Paull, R.E., and Uruu, G. (2021). Reducing moringa leaflet abscission during irradiation and during shipping. Horttechnology *31* (*1*), 74–76 https://doi.org/10.21273/HORTTECH04738-20.

Suganthi, M., Balamohan, T.N., Beaulah, A., and Vellaikumar, S. (2019). Extending the shelf life of moringa leaves through packaging and cold storage. Intl. J. Chem. Studies *7* (*3*), 483–486.

Waterman, C., Cheng, D.M., Rojas-Silva, P., Poulev, A., Dreifus, J., Lila, M.A., and Raskin, I. (2014). Stable, water extractable isothiocyanates from *Moringa oleifera* leaves attenuate inflammation in vitro. Phytochemistry *103*, 114–122 https://doi.org/10.1016/j.phytochem.2014.03.028. PubMed

Watkins, C.B. (2016). Pre- and postharvest inhibition of ethylene production and action by 1-MCP and the quality of apples and other horticultural products. Acta Hortic. *1120*, 1–10 https://doi.org/10.17660/ActaHortic.2016.1120.1.