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ENHANCING THE SHELF LIFE AND QUALITY OF MEXICAN LIME THROUGH γ-AMINOBUTYRIC ACID TREATMENT

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Abstract: The key factors limiting the postharvest shelf life of limes are weight loss, rapid peel discoloration, and the degradation of their green color, which significantly reduces their market value. The Mexican lime, a citrus fruit of considerable economic and nutritional importance, was evaluated for the effects of γ-aminobutyric acid (GABA) immersion on postharvest quality and storage life. Fruits were treated with GABA solutions (0, 4, 8, or 12 mM) and stored at 7°C with 80 ± 5% relative humidity for 30 days. Measurements of fruit weight loss, total soluble solids (TSS), titratable acidity (TA), taste index (TSS/TA ratio), ascorbic acid content in juice, and rind pigments (chlorophyll *a*, chlorophyll *b*, total chlorophyll, and carotenoids) were conducted every 10 days. GABA treatment, particularly at higher concentrations, significantly reduced weight loss and slowed TSS increases while enhancing TA and ascorbic acid levels. By the end of storage, the treated fruits exhibited higher organic acid levels and a more desirable taste index, as indicated by a reduced TSS/TA ratio. Additionally, GABA treatments preserved higher chlorophyll levels for up to 20 days and delayed carotenoid accumulation, effectively slowing peel yellowing. The 8 mM concentration was the most effective in maintaining postharvest quality. These findings demonstrate that GABA can enhance the storage life and quality of Mexican lime, providing a promising strategy to minimize postharvest losses and boost economic value.

Key words: *Citrus aurantifolia*, γ-aminobutyric acid, peel discoloration, taste index, weight loss.

Introduction

The global lemon and lime market, which accounts for a substantial share of global citrus production, yielded 21.53 million tons from 1.33 million hectares (FAO, 2022c). A diverse range of producers and exporters supports this market. The top ten producers—India, Mexico, China, Argentina, Brazil, Spain, the United

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States, Turkey, Italy, and Iran—highlight the global significance of these citrus fruits (FAO, 2022c).

Spain leads the world in lemon and lime exports, contributing approximately 60% of its production to the global market (FAO, 2022a). Mexico, the second-largest exporter, allocates 23% of its production to exports, while Turkey, ranked eighth in production, stands third in exports, exporting nearly half of its harvest (FAO, 2022a; 2022c). Argentina, ranked fourth in both production and exports, significantly contributes to the global market by exporting 18% of its production (FAO, 2022a; 2022c). Interestingly, despite not being among the top ten producers, South Africa ranks fifth in global exports, underscoring its strong international market presence (FAO, 2022a; 2022c). Iran, while ranking tenth in production, has relatively low export volumes, highlighting a production-export disparity (FAO, 2022a; 2022c).

The United States, despite ranking seventh in production, imports as much as 50% of its production, making it the world's largest importer of lemons and limes (FAO, 2022b). Other leading importers are Russia, the Netherlands, Germany, and France (FAO, 2022b).

This diverse landscape illustrates the critical role of various countries in shaping the global lemon and lime market, where distinct production and export strategies influence the global supply chain.

The Mexican lime (*Citrus aurantifolia* Swingle cv.), an acidic citrus fruit, is extensively cultivated in tropical and subtropical regions worldwide because of its economic importance. It is the third most widely grown citrus fruit, and it is valued for its delightful taste and the presence of beneficial natural compounds (Singh et al., 2021). This fruit contains abundant phytochemicals, including phenols, flavonoids, steroids, terpenoids, and alkaloids, which contribute to its antioxidant and anti-inflammatory properties (Chriscensia et al., 2020; Izah et al., 2024). Additionally, its essential oils demonstrate antimicrobial activity, suggesting their potential as natural food preservatives (Izah et al., 2024). The health benefits of Mexican lime extend to its antidiabetic effects, making it a valuable dietary addition (Izah et al., 2024). Furthermore, combining Mexican lime extracts with compounds such as doxorubicin (a chemotherapy medication used to treat cancer) has shown promise in enhancing therapeutic effects, such as inducing apoptosis in cancer cells (Adina et al., 2014).

Although the Mexican lime is a non-climacteric fruit with a low respiration rate, it still undergoes some softening and compositional changes after harvest, leading to a short postharvest shelf life and a loss of approximately 18–25% (CABI, 2022; Lerslerwong et al., 2023; Mohammadi et al., 2024a). The primary obstacles limiting the postharvest longevity of limes are weight loss and rapid peel discoloration and degradation of the green color, reducing their market value (Mohammadi et al., 2024a; 2024b).

γ-aminobutyric acid (GABA) is a non-protein amino acid that plays a significant role in plant physiology, including stress response, growth, and development. It is mainly metabolized via a short pathway called the GABA shunt, which bypasses two steps of the TCA cycle (Sheng et al., 2017). Exogenous pre- or postharvest application of GABA enhances citrus fruit quality by modulating biochemical pathways, including the elevation of phytohormone levels critical for development and ripening (Badiche-El Hilali et al., 2023) and the improvement of citrate and amino acid accumulation, contributing to better quality and storage performance (Sheng et al., 2017). Additionally, GABA boosts the antioxidant system in fruits, maintaining quality during storage by reducing oxidative stress and prolonging shelf life, as shown in studies on mangoes (Rastegar et al., 2020). Research by Nehela and Killiny (2023) sheds light on the crucial role of GABA accumulation in the response of *Citrus sinensis* to huanglongbing (HLB), a devastating bacterial disease lacking a sustainable cure. Their findings demonstrate that GABA significantly influences the metabolic and defence mechanisms of plants, boosting the biosynthesis of essential compounds such as amino acids, organic acids, fatty acids, and phytohormones. This, in turn, activates antioxidant defences, reducing oxidative stress and bolstering plant resilience against HLB. The implications of the study extend beyond HLB, suggesting that GABA may play a critical role in mitigating the effects of various biotic stresses.

Building on this understanding and addressing the existing knowledge gap regarding the effects of GABA on the postharvest quality of Mexican lime, this study aimed to evaluate the influence of this generally recognized as safe (GRAS) compound (Sheng et al., 2017) on key quality parameters during 30 days of storage. Specifically, it investigated the effects of GABA on fruit weight loss, total soluble solids (TSS), titratable acidity (TA), taste index (TSS/TA ratio), ascorbic acid content in fruit juice, and rind pigments, including chlorophyll *a*, chlorophyll *b*, total chlorophyll, and carotenoids.

Material and Methods

Plant material, experimental design, and treatments

Mexican lime fruits at the mature green stage were harvested from a commercial orchard located in Maniyan, a village in the Jolgah Rural District, Central District of Jahrom County, Fars Province, Iran, with geographic coordinates of 53°12′57″E and 28°34′38″N. The fruits were immediately transferred to the laboratory, where they were selected and sorted based on uniformity in color, shape, and size, as well as freedom from physical damage, pests, and diseases. Before applying the treatments, the fruits were disinfected with a 2% sodium hypochlorite solution for 2 minutes, followed by rinsing with distilled water and drying at room temperature.

The experimental design was factorial within a completely randomized design framework, including two experimental factors: GABA immersion (four levels: 0, 4, 8, and 12 mM) and sampling time (three levels: days 10, 20, and 30 of the storage period). Each treatment was replicated four times, with 15 fruits per replicate. Fruits were immersed in GABA (Sigma-Aldrich, St. Louis, MO, USA) solutions for 5 minutes, with distilled water serving as a control, and then dried at room temperature for one hour. They were then placed in perforated zip-top plastic bags with a 3%-hole ratio and stored at 7°C and 80 ± 5% relative humidity for one month. Additionally, for informational purposes and not for statistical comparison, the parameters were assessed on the initial day of the experiment, before the start of the storage period.

Fruit weight loss

The mass variation method was used (Taghipour and Assar, 2021). The weight of the fruits was measured at different time points during storage using a digital scale with an accuracy of 0.1 g. The weight loss was calculated as the difference between the initial mass and the mass at each time point, expressed as a percentage of the initial mass using Equation (1):

$$\textit{Weight loss}\ (\%) = \frac{W_0 - W_1}{W_0} \times 100 \qquad [1]$$

where W_0 represents the initial mass and W_1 represents the final mass.

Juice total soluble solids (TSS)

The TSS of the fruit juice was measured using a digital refractometer (Milwaukee MA871, Hungary) at room temperature and expressed as a percentage (%) (Taghipour and Assar, 2021).

Juice titratable acidity (TA)

The TA of the fruit juice was determined by titration with a 0.1 N NaOH solution (Taghipour and Assar, 2021). The endpoint of the titration was reached when the pH of the solution reached 8.2. The results were subsequently expressed as a percentage of citric acid.

Juice taste index

The taste index was calculated by dividing the TSS value by the TA value (Taghipour and Assar, 2021).

Juice ascorbic acid content

The ascorbic acid content of the fruit juice was measured using a titration method with a 2,6-dichlorophenolindophenol (DCPIP) solution (Taghipour and Assar, 2021). The results were expressed as milligrams per 100 grams (mg 100 g^{-1}) of the fruit juice.

Chlorophyll *a*, chlorophyll *b*, total chlorophyll, and carotenoid content of peels

The chlorophyll *a*, chlorophyll *b*, total chlorophyll, and carotenoid contents in the citrus fruit peel were measured using the method described by Wellburn (1994). Fresh citrus fruit peel was thoroughly cleaned and cut into small pieces (about 1–2 cm^2). Approximately 0.5 g of the peel was weighed and ground into a fine paste using a mortar and pestle with a small amount of 80% acetone (v/v). The homogenized paste was transferred to a centrifuge tube, and mixed with 10 mL of 80% acetone. The mixture was allowed to stand for 10 minutes in the dark to prevent pigment degradation. The sample was then centrifuged at 4000 rpm for 10 minutes, and the supernatant was carefully decanted into a clean tube, avoiding any pellet at the bottom. The supernatant was filtered through a filter paper to remove any remaining particles. The absorbance of the filtrate was measured at 663, 645, and 470 nm using a spectrophotometer. The chlorophyll *a*, chlorophyll *b*, total chlorophyll, and carotenoid contents were calculated using Equations (2), (3), (4), and (5), respectively.

$$\text{Chlorophyll } a \text{ (mg g}^{-1}\text{ FW)} = 12.25 \times A_{663} - 2.79 \times A_{645} \quad [2]$$
$$\text{Chlorophyll } b \text{ (mg g}^{-1}\text{ FW)} = 21.50 \times A_{645} - 5.10 \times A_{663} \quad [3]$$
$$\text{Total chlorophyll (mg g}^{-1}\text{ FW)} = \text{Chlorophyll } a + \text{Chlorophyll } b \quad [4]$$
$$\text{Carotenoid (mg g}^{-1}\text{ FW)} = (1000 \times A_{470} - 1.82 \times \text{Chlorophyll } a - 85.02 \times \text{Chlorophyll } b)/198 \quad [5]$$

Statistical analysis

Data were analyzed using analysis of variance (ANOVA) at a significance level of $P < 0.05$, and mean comparisons were performed using the least significant difference (LSD) test. All statistical analyses were performed using SAS software version 9.4.

Results and Discussion

The Mexican lime (*Citrus aurantifolia* Swingle cv.) is an economically important acidic citrus fruit, that is widely cultivated in tropical and subtropical regions worldwide. Renowned for its significant health benefits, it is characterized by a short postharvest life and high global postharvest losses (CABI, 2022; Lerslerwong et al., 2023; Mohammadi et al., 2024a; Singh et al., 2021). Key indicators such as fruit weight loss, juice attributes including total soluble solids (TSS), titratable acidity (TA), taste index (TSS/TA ratio), and ascorbic acid content, as well as peel color, are critical for assessing citrus fruit quality and consumer acceptance (Sheng et al., 2017). In this context, the authors investigated the effect of exogenous GABA (a GRAS compound) applied via the dip method on these parameters during a one-month storage period.

The analysis of variance (Table 1) revealed a significant effect of all experimental factors and their interactions on the evaluated traits, except for the lack of interaction effects on juice TSS and peel carotenoid content.

Weight loss in the control group increased steadily throughout the storage period and was significantly higher than that in the treated fruits. In the treated fruits, weight loss rose significantly until day 20, after which no further increase was observed. Additionally, no differences in weight loss were detected among fruits treated with different GABA concentrations on day 20. By the end of the storage period, the fruits treated with 12 mM GABA exhibited the lowest weight loss among all treated groups (Figure 1).

GABA immersion was associated with a reduction in juice total soluble solids (TSS), although no significant differences were observed among the different GABA concentrations (Figure 2a). The juice TSS increased significantly during storage up to 20 days, with no significant changes detected between the final two sampling times (Figure 2b).

The juice titratable acidity (TA) of the control fruits increased with storage time, showing a statistically significant rise up to day 20. Beyond this point, the increase in TA was no longer significant. On day 10, the fruits treated with 8 and 12 mM GABA exhibited a significantly higher TA compared to the control fruits. On day 20, no differences were observed between the treated and control fruits. However, by the final sampling time, TA peaked in the treated fruits. Although no significant differences were found among the different GABA concentrations, the TA in the treated fruits remained significantly higher than in the control fruits. Notably, in the control fruits, TA increased significantly between days 10 and 20, while in the treated fruits, the significant increase occurred during the final 10 days of storage (Figure 3).

The juice taste index (TSS/TA ratio) of the control fruits decreased over the storage period, with a significant reduction observed up to day 20. Beyond this point, the decrease in the ratio was no longer significant. On day 10, the fruits treated with all GABA concentrations exhibited significantly lower TSS/TA ratios compared to the control fruits. On day 20, no differences were observed between the treated and control fruits. However, at the final sampling, the TSS/TA ratio of the treated fruits reached its lowest value. Although no significant differences were found among the various GABA concentrations, the TSS/TA ratio was significantly lower in the treated fruits than in the control. Notably, the control fruits showed a significant decrease in the TSS/TA ratio between days 10 and 20, whereas the treated fruits experienced this significant decrease during the final 10 days of storage (Figure 4).

In the control fruits, the ascorbic acid content decreased by approximately 17.48% after 10 days of storage, followed by a slight and gradual increase until the end of the storage period. Despite this increase, the final ascorbic acid content in the control fruits remained 11.14% lower than at the start of the experiment. In contrast, the fruits treated with GABA, especially at 8 mM, consistently exhibited the highest ascorbic acid levels. After 10 days, these fruits had a significantly higher ascorbic acid content compared to the control fruits and those treated with 4 mM GABA. On day 20, the 8 mM GABA-treated fruits maintained a significantly higher ascorbic acid content than the control group and the other GABA-treated groups. By the end of the 30-day storage period, fruits treated with 4, 8, or 12 mM GABA had 0.43%, 4.95%, and 2.32% more ascorbic acid, respectively, compared to the beginning of the experiment. Throughout the storage period, the 8 mM GABA-treated fruits consistently had the highest ascorbic acid content, surpassing the initial levels and showing the most significant difference compared to the control fruits (Figure 5).

The chlorophyll *a* content in the peels of both the control and the treated fruits decreased significantly over time. Up to day 20 of storage, the fruits treated with higher concentrations of GABA had a significantly higher chlorophyll *a* content compared to the control fruits and those treated with the lowest GABA concentration. However, by the end of the 30-day storage period, no significant difference was observed in chlorophyll *a* content between the treated and control fruits (Figure 6a).

As storage progressed, the chlorophyll *b* content in the peels of both the control and the treated fruits decreased significantly. After 10 days, the fruits treated with higher GABA concentrations exhibited higher chlorophyll *b* content compared to the control group and those treated with the lowest GABA concentration, with no significant difference between the control group and the group with the lowest GABA concentration. On day 20, the chlorophyll *b* content was similar across the treated fruits and significantly higher than in the control fruits. By the end of the storage period, only the fruits treated with 8 mM GABA exhibited a significantly higher chlorophyll *b* content compared to the control group, with no significant differences observed among the treated groups. Furthermore, the chlorophyll *b* content in the peels of the fruits treated with the lowest and highest GABA concentrations was similar to that of the control fruits (Figure 6b).

The changes in total chlorophyll content followed a pattern similar to that of the chlorophyll *a* content (Figure 6c).

GABA treatment at higher concentrations was associated with a significantly lower carotenoid content in the peel compared to the control (Figure 6d). Nevertheless, carotenoid levels increased significantly in the fruit peel over the storage period (Figure 6e).

Table 1. Analysis of variance for the effect of γ-aminobutyric acid (GABA) treatment on the evaluated characteristics of Mexican lime fruit during storage.

		Mean square									
Source of variation	Degrees of freedom	Weight loss	Juice total soluble solids (TSS)	Juice titratable acidity (TA)	Juice taste index	Juice ascorbic acid	Peel chlorophyll *a*	Peel chlorophyll *b*	Peel total chlorophyll	Peel carotenoid
Dip in GABA	3	23.05**	0.244**	0.946**	0.034**	1062.6**	0.069**	0.0006**	0.083**	0.042**
Storage time (day)	2	62.48**	0.479**	9.51**	0.096**	63.63*	1.44**	0.0049**	1.609**	0.231**
Dip in GABA × Storage time (day)	6	3.74**	0.040ns	0.476**	0.0093**	50.74*	0.013**	0.0002**	0.0142**	0.002ns
Error	36	0.116	0.042	0.086	0.0024	16.07	0.003	0.00002	0.0028	0.0049
Coefficient variation (%)		4.2	2.3	3.6	4.5	3.8	10.6	13.2	9.9	10.9

**, *, and ns denote significant differences at P ≤ 0.01, P ≤ 0.05, and no significant difference, respectively, as determined by the LSD test.

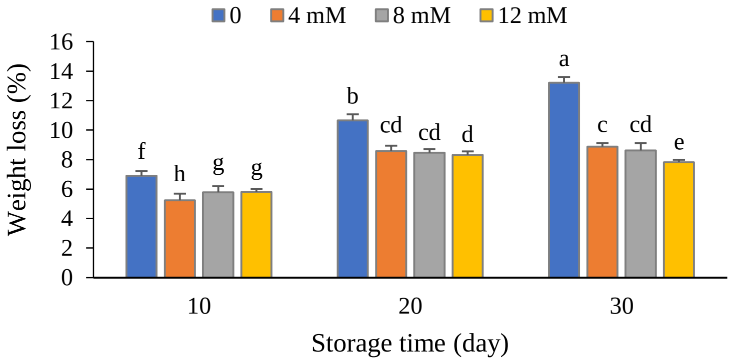

Figure 1. Changes in the weight loss of Mexican lime fruits during 30 days of storage at 7°C and 80 ± 5% RH. Fruits were dipped in γ-aminobutyric acid (GABA) solutions at 0, 4, 8, or 12 mM for 5 minutes prior to storage. Measurements were taken on days 10, 20, and 30. Data are presented as means of 4 replicates ± SD. Different letters indicate significant differences according to the LSD test (P ≤ 0.05).

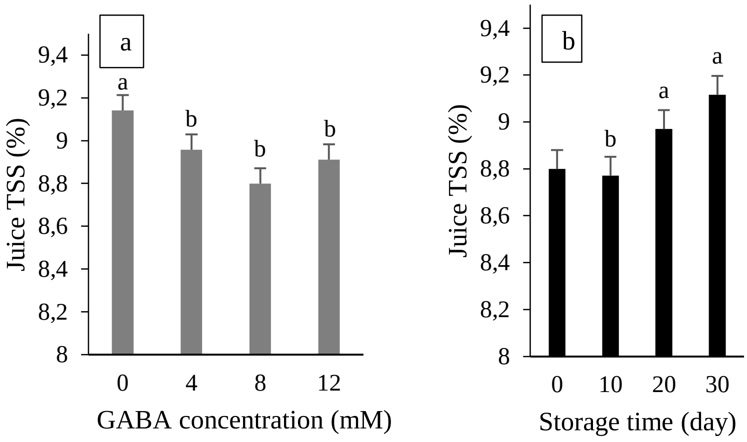

Figure 2. Changes in the juice total soluble solids (TSS) of Mexican lime fruits under the main effects of γ-aminobutyric acid (GABA) treatment (a) and storage time (b) during 30 days of storage at 7°C and 80 ± 5% RH. Fruits were dipped in GABA solutions at 0, 4, 8, or 12 mM for 5 minutes prior to storage. Measurements were taken on days 10, 20, and 30. Data are presented as means of 12 replicates for (a) and 16 replicates for (b) ± SD. Different letters indicate significant differences according to the LSD test ($P \leq 0.05$).

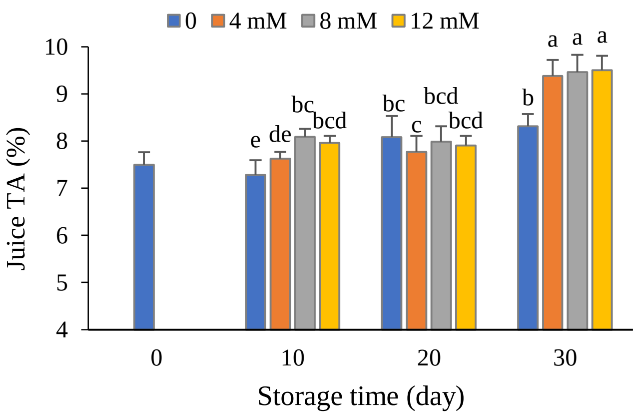

Figure 3. Changes in the juice titratable acidity (TA) of Mexican lime fruits during 30 days of storage at 7 °C and 80 ± 5% RH. Fruits were dipped in γ-aminobutyric acid (GABA) solutions at 0, 4, 8, or 12 mM for 5 minutes prior to storage. Measurements were taken on days 10, 20, and 30. Data are presented as means of 4 replicates ± SD. Different letters indicate significant differences according to the LSD test ($P \leq 0.05$).

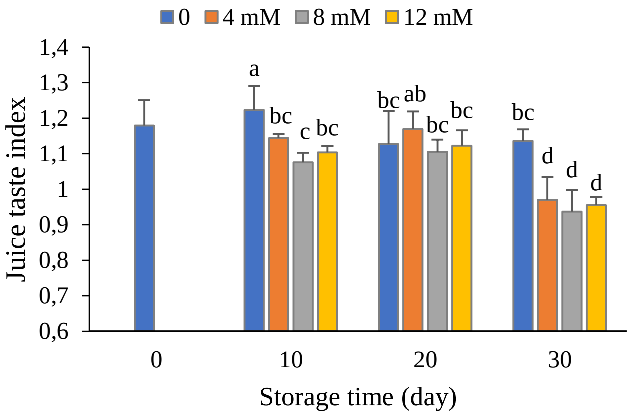

Figure 4. Changes in the juice taste index (TSS/TA ratio) of Mexican lime fruits during 30 days of storage at 7°C and 80 ± 5% RH. Fruits were dipped in γ-aminobutyric acid (GABA) solutions at 0, 4, 8, or 12 mM for 5 minutes prior to storage. Measurements were taken on days 10, 20, and 30. Data are presented as means of 4 replicates ± SD. Different letters indicate significant differences according to the LSD test ($P \leq 0.05$).

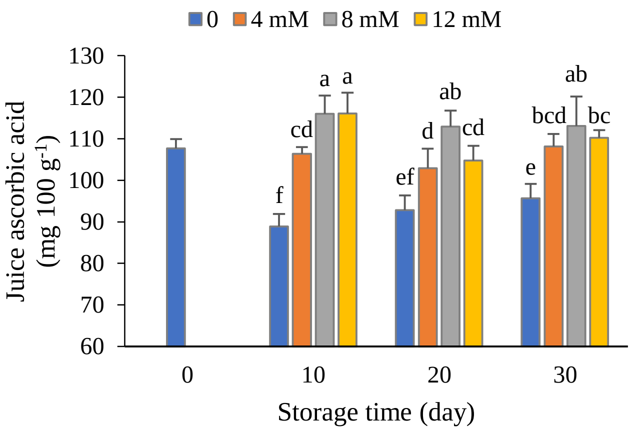

Figure 5. Changes in the juice ascorbic acid content of Mexican lime fruits during 30 days of storage at 7°C and 80 ± 5% RH. Fruits were dipped in γ-aminobutyric acid (GABA) solutions at 0, 4, 8, or 12 mM for 5 minutes prior to storage. Measurements were taken on days 10, 20, and 30. Data are presented as means of 4 replicates ± SD. Different letters indicate significant differences according to the LSD test ($P \leq 0.05$).

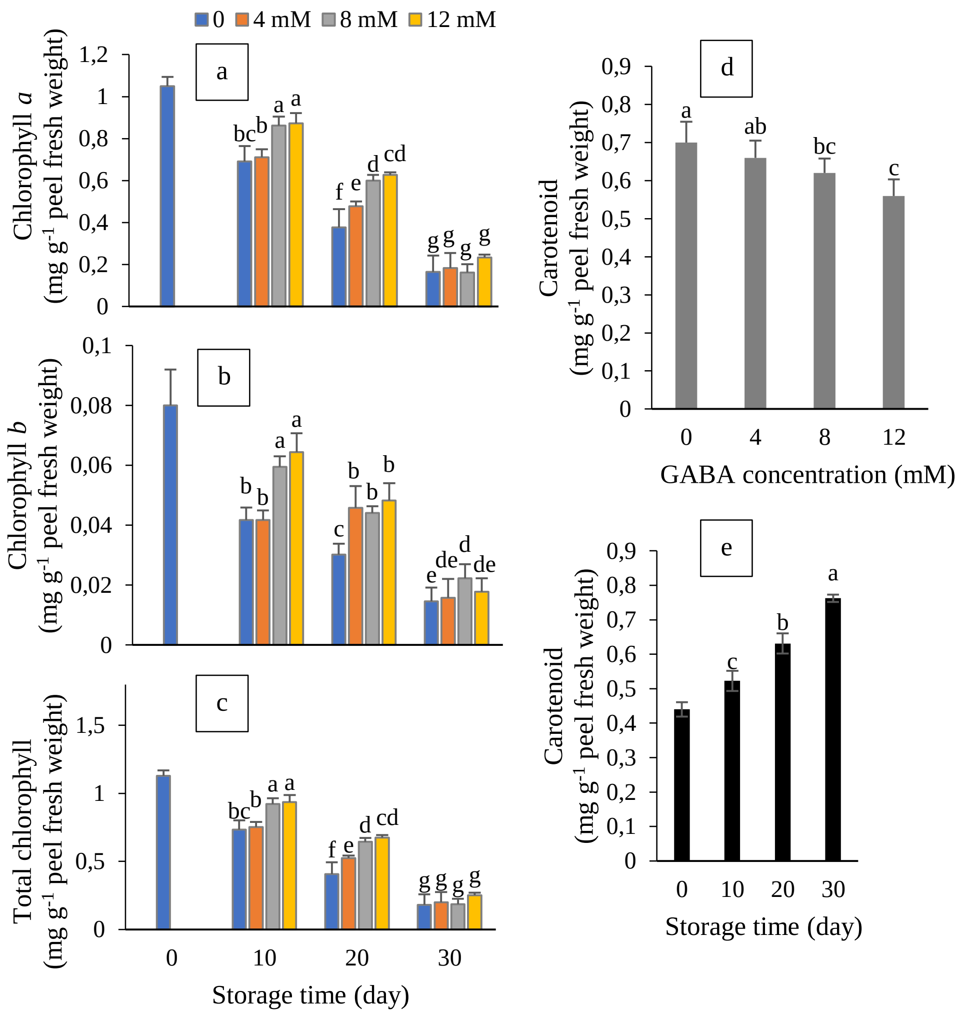

Figure 6. Changes in peel chlorophyll *a* (a), chlorophyll *b* (b), and total chlorophyll (c) of Mexican lime fruits during 30 days of storage. Changes in peel carotenoid content under the main effects of γ-aminobutyric acid (GABA) treatment (d) and storage time (e). Fruits were dipped in GABA solutions at 0, 4, 8, or 12 mM for 5 minutes prior to storage at 7°C and 80 ± 5% RH. Measurements were taken on days 10, 20, and 30. Data are presented as means of 4 replicates for (a), (b), and (c); 12 replicates for (d); and 16 replicates for (e) ± SD. Different letters indicate significant differences according to the LSD test ($P \leq 0.05$).

The substantial water loss in postharvest limes due to transpiration and respiration, particularly in hot and humid climates, limits their storage life to 6–9 days (Mohammadi et al., 2024a; 2024b). The reduced internal water content leads to increased juice TSS levels, whereas cell wall-degrading enzymes further elevate TSS levels (Zhang et al., 2024). For the Mexican lime, which is valued for its sour taste, an increase in TSS is undesirable. According to previous studies, GABA treatment enhances the postharvest quality of various horticultural crops by influencing physiological mechanisms. GABA application upregulates antioxidant enzymes, including superoxide dismutase (SOD), peroxidase (POD), and catalase (CAT), which play a key role in scavenging reactive oxygen species (ROS) and alleviating postharvest oxidative stress. Consequently, by stabilizing cell membranes, GABA reduces electrolyte leakage and prevents cell wall degradation (Badiche-El Hilali et al., 2023; Ge et al., 2018; Sheng et al., 2017). Additionally, GABA affects crop preservation by decreasing ethylene biosynthesis, thereby reducing respiration rates and delaying senescence (Han et al., 2018; Li et al., 2021). Collectively, these effects can lead to improved water retention in fruit tissues, reducing dehydration and limiting subsequent increases in juice TSS (Badiche-El Hilali et al., 2023; Rastegar et al., 2020).

Organic acids and amino acids are crucial for citrus fruit quality, with organic acids being particularly significant (Sheng et al., 2017). Citric acid is the main organic acid in juice, whereas ascorbic acid is present in very low amounts (Sheng et al., 2017). Our results revealed an accelerated increase in titratable acidity (TA) and a higher ascorbic acid content in GABA-treated fruits compared with the control fruits during the storage period. Sheng et al. (2017) reported that exogenous GABA improves the postharvest quality and storage performance of citrus fruits by increasing citrate content through inhibiting glutamate decarboxylase and enhancing amino acid accumulation. They also found that higher antioxidant enzyme activities and ATP content in GABA-treated fruits reduced organic acid consumption during storage.

Our results indicated that the titratable acidity (TA) in the juice increased during storage, with the treated fruits exhibiting a more pronounced increase than the controls. Therefore, the increase in the TSS of the juice is likely due to weight loss rather than to the conversion of organic acids into sugars (Mohammadi et al., 2024a; 2024b).

The TSS/TA ratio reflects the changes in the juice TSS and TA. After one month of storage, fruits treated with various GABA concentrations showed a significantly lower TSS/TA ratio than controls, indicating superior quality and a better taste index.

Postharvest peel discoloration results from chlorophyll degradation and carotenoid accumulation related to fruit senescence (Mohammadi et al., 2024b). Harvest maturity affects storage life and quality, with climate influencing preharvest rind color. Warm temperatures hinder chlorophyll loss and carotenoid accumulation, while cool temperatures enhance fruit color development. Therefore, lime fruits in tropical regions remain greener compared to those in subtropical regions. Extended storage in subtropical regions generally leads to peel yellowing, reducing postharvest shelf life (CABI, 2022). Market preferences also impact peel color acceptability, namely, dark green or transitioning green is preferred for exports, while light-yellow is suitable for domestic markets. Managing fruits picked at the mature green stage is crucial for maintaining their green color, as storage conditions and treatments influence peel color. Treatments that alleviate postharvest stress and delay senescence can help preserve the green color of the peel.

Statistical results showed that GABA treatment, especially at higher concentrations, effectively preserved chlorophyll *a*, chlorophyll *b*, and total chlorophyll up to the 20th day. After one month, there was no significant difference between the treated fruits and the control fruits, except for chlorophyll *b*, where the fruits treated with 8 mM GABA had higher levels. Although carotenoid content increased over time, treatment with higher concentrations of GABA attenuated this increase. These effects may be attributed to the modulation of oxidative stress and delayed senescence by GABA (Badiche-El Hilali et al., 2023; Ge et al., 2018; Sheng et al., 2017).

A study by Sun et al. (2013) demonstrated that organic acids in citrus fruits activate the antioxidant enzymatic system under storage stress. Therefore, the positive effects of GABA on increasing TA and ascorbic acid content could enhance antioxidant activity and maintain peel color and health better in treated fruits than in controls.

Although the Mexican lime is a non-climacteric fruit, its internal ethylene concentration is related to peel color, as ethylene promotes chlorophyll degradation and color change (CABI, 2022). Thus, the ability of GABA to inhibit ethylene biosynthesis could positively influence the postharvest quality and lifespan of Mexican lime (Han et al., 2018; Li et al., 2021).

Conclusion

This study has demonstrated that GABA treatment significantly enhanced the postharvest quality of Mexican lime by reducing weight loss, improving juice quality, and delaying peel discoloration. Among the tested concentrations, 8 mM GABA was the most effective in preserving and improving postharvest quality. GABA treatment effectively minimized fruit weight loss and mitigated the increase in juice TSS, while enhancing TA and ascorbic acid content in the juice. These changes contributed to a more desirable taste index, as indicated by a lower TSS/TA ratio. Furthermore, GABA treatment delayed the degradation of chlorophyll pigments and the accumulation of carotenoids in the peel, slowing the transition to a yellow color. These findings underscore the potential of GABA as a safe treatment for extending shelf life and enhancing the quality of citrus fruits during postharvest storage. Future studies are recommended to investigate the molecular mechanisms underlying the effects of GABA, assess its efficacy in other citrus and horticultural fruits, and optimize application methods to maximize its benefits.

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POBOLJŠANJE VEKA SKLADIŠTENJA I KVALITETA MEKSIČKIH LIMETA TRETMANOM γ –AMINOBUTERNOM KISELINOM

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R e z i m e

Ključni faktori koji ograničavaju postharvest rok trajanja limete su gubitak težine, brzo žutenje kore i degradacija njene zelene boje, što značajno smanjuje tržišnu vrednost. Meksička limeta, citrusno voće od značajnog ekonomskog i nutritivnog potencijala, ocenjivana je efektima potapanja u γ-aminobuternu kiselinu (GABA) na postharvest kvalitet i vek skladištenja. Plodovi su tretirani GABA rastvorima (0, 4, 8 ili 12 mM) i čuvani na 7°C sa relativnom vlažnošću od 80 ± 5% tokom 30 dana. Merenja gubitka mase plodova, rastvorne suve materije (TSS), titracione kiselosti (TA), indeksa ukusa (TSS/TA odnos), sadržaja askorbinske kiseline u soku i pigmenata kore (hlorofil a, hlorofil b, ukupni hlorofil i karotenoidi) vršena su svakih 10 dana. GABA tretman, posebno na višim koncentracijama, značajno je smanjio gubitak mase i usporio porast TSS, dok je poboljšao nivo TA i askorbinske kiseline. Na kraju skladištenja, tretirani plodovi su pokazali viši nivo organskih kiselina i poželjniiji indeks ukusa, što je naznačeno smanjenjem TSS/TA odnosa. Pored toga, GABA tretmani su očuvali viši nivo hlorofila do 20 dana i odložili akumulaciju karotenoida, efektivno usporavajući žutenje kore. Koncentracija od 8 mM bila je najučinkovitija u očuvanju postharvest kvaliteta. Ovi rezultati ukazuju da GABA može poboljšati vek skladištenja i kvalitet meksičke limete, pružajući obećavajuću strategiju za smanjenje postharvest gubitaka i povećanje ekonomske vrednosti.

Ključne reči: *Citrus aurantifolia*, požutelost kore, indeks ukusa, vitamin C, gubitak težine.

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