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Synergistic Effects of Kojic Acid and Calcium Lactate on the Fruit Quality of Banana (*Musa* spp.) cv. Poovan (AAB)

Sandeep Saran V.[1], B. Gopu[1*], A. Akino[1] and R. Nagajothi[2]
[1]Department of Fruit Science, SRM College of Agricultural Sciences,
SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu (Tamil Nadu), India.
[2]Section of Biochemistry and Physiology, SRM College of Agricultural Sciences,
SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu (Tamil Nadu), India.

(Corresponding author: B. Gopu)*
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ABSTRACT: The present study was conducted to evaluate the Synergistic effects of kojic acid and calcium lactate on the fruit quality of banana (*Musa* spp.) cv. Poovan (AAB) during the year 2023–24. The experiment was laid out in an RBD with nine treatments replicated thrice. The treatments are T_1: Control, T_2: Calcium lactate – 1 %, T_3: Calcium lactate – 2%, T_4: Kojic acid – 0.5%, T_5: Kojic acid – 1%, T_6: Calcium lactate – 1% + Kojic acid – 0.5%, T_7: Calcium lactate – 1% + Kojic acid – 1%, T_8: Calcium lactate – 2% + Kojic acid – 0.5% and T_9: Calcium lactate – 2% + Kojic acid – 1%. Among the various pre-harvest treatments, the combination of 1% calcium lactate and 1% kojic acid significantly enhanced the fruit quality and shelf life of banana fruits.

Keywords: Kojic acid, calcium lactate, pre-harvest spray, banana.

INTRODUCTION

Banana (*Musa* spp.) is one of the most widely consumed fruits globally, valued for its rich nutritional profile, ease of availability, and economic significance in tropical and subtropical regions of the world (Gol *et al.*, 2011; Divya *et al.*, 2023; Nischitha *et al.*, 2023). The plant is called Kalpataru (Plant of all virtues) owing to versatile use of all parts (Kiranmayi *et al.*, 2022). Being a climacteric fruit, post-harvest loss in banana is huge, about 21.67 per cent (Saha and Zude-Sasse 2021). Among the various cultivars, 'Poovan' (AAB) is significant due to its unique flavour, texture, and high consumer preference. However, bananas are highly perishable, with a limited shelf life due to rapid ripening, softening and susceptibility to post-harvest diseases, leading to substantial storage losses. Post-harvest banana fruit ripens quickly within a few days at ambient temperature conditions, and its quality degrades significantly afterward. Therefore, extending its stability during storage and distribution is necessary to enhance its economic value (Minh, 2021). Hence, pre-harvest treatments play a vital role in extending shelf life and reducing post-harvest losses in bananas.

To address these challenges, various chemical treatments have been explored to enhance the post-harvest quality and extend the shelf life of bananas. Calcium lactate and kojic acid are two promising compounds that have shown the potential to improve fruit quality and shelf life. Calcium is a vital macronutrient that plays a crucial role in maintaining cell wall structure and integrity, thereby reducing fruit softening and spoilage, and it is essential for fruit quality (Khedr, 2022). Using calcium sources as pre-harvest treatments has a significant effect on retaining quality (Naser *et al.*, 2018), maintaining firmness (Wang and Long 2015), reducing browning (Koutinas *et al.*, 2010), and decreasing deterioration (Sugar and Basile 2011). Calcium lactate is a potential alternative to calcium chloride for shelf-life extension (Guzman and Barret 2000).

Pre-harvest application of 2 per cent calcium lactate and post-harvest spray of 0.3 per cent kojic acid significantly enhanced the total phenols, ascorbic acid, TSS/acid ratio, overall appearance, colour purity, browning incidence and decay percentage of mango cv. Keitt (Khedr, 2022). According to Elmer *et al.* (2007), calcium treatments can enhance firmness, reduce ethylene production, and delay the ripening process in bananas. Similarly, kojic acid, a natural compound derived from fungal species, has gained attention for its antioxidant and antimicrobial properties. Shah *et al.* (2017) demonstrated that kojic acid can inhibit enzymatic browning and microbial growth, thereby contributing to the preservation of fruit quality.

Combining calcium and kojic acid treatments on fruits can significantly improve their quality and extend shelf life by simultaneously inhibiting browning reactions due to kojic acid (Khedr, 2022) and strengthening cell walls due to calcium (Karemera *et al.*, 2014), resulting in better texture, appearance, and reduced decay, particularly in fruits prone to browning and softening during storage; this effect has been observed across various fruit crops like apples, pears, berries and mangoes, with research showing that the combined treatment can be more effective than either treatment alone. The synergistic effects of calcium lactate and kojic acid on the post-harvest quality of banana remain underexplored. However, limited information is available regarding the effects of kojic acid and calcium lactate on bananas. In this context, the main goal of this study was to investigate the pre-harvest foliar application of kojic acid and calcium lactate on the quality attributes and storage life of banana cv. Poovan (AAB). By evaluating the efficacy of these compounds, we aim to develop a novel post-harvest treatment strategy that can extend the shelf life of banana.

MATERIALS AND METHODS

The experiment titled "Synergistic effects of kojic acid and calcium lactate on the fruit quality of banana (*Musa* spp.) cv. Poovan (AAB)" was conducted at the College Orchard, Department of Fruit Science, SRM College of Agricultural Sciences, Baburyanpettai, Chengalpattu. The research was carried out from 2023-2024. The adopted spacing was 2 × 2 meters, with bananas grown in clay soil using a drip irrigation system. The experimental design was a Randomized Block Design (RBD) with nine treatments and three replications. The plants were maintained under uniform cultural practices throughout the investigation period. The treatments are T_1: Control, T_2: Calcium lactate – 1 %, T_3: Calcium lactate – 2%, T_4: Kojic acid – 0.5%, T_5: Kojic acid – 1%, T_6: Calcium lactate – 1% + Kojic acid – 0.5%, T_7: Calcium lactate – 1% + Kojic acid – 1%, T_8: Calcium lactate – 2% + Kojic acid – 0.5% and T_9: Calcium lactate – 2% + Kojic acid – 1%. For each treatment, the required concentrations of kojic acid and calcium lactate were prepared according to standard protocols. Bunch sprays were applied twice: first at the male bud removal stage and again 30 days after the first spray. The sprays were applied using a hand-operated pressure sprayer, incorporating a wetting agent. The entire bunches of five plants per treatment were sprayed.

Quality and Biochemical Parameters. The TSS was recorded directly using a digital refractometer (range 0-32° Brix) and expressed in degrees Brix (°Brix). Acidity was measured by extracting the pulp from the fruits. Ten grams of finely chopped fruit pulp were ground in a mortar, transferred to a beaker, and mixed with 50 ml of distilled water. The mixture was filtered and the filtrate was transferred to a 100 ml volumetric flask, with the volume adjusted to the mark. A 10 ml aliquot was taken for titration against 0.1 N NaOH using phenolphthalein as an indicator. The acidity was calculated as a percentage of citric acid, following the method described by Ranganna (2000).

To estimate total sugars a 50 ml portion of the clarified solution (filtrate of reducing sugars) was gently boiled with the addition of citric acid and water. It was then neutralized using NaOH and the volume was adjusted to 250 ml. This solution was titrated against a mixture of Fehling's solution A and B, and the total sugars were expressed as a percentage (A.O.A.C., 2012).

For reducing sugars the method outlined by Lane and Eynon (Ranganna, 2000) was followed. The fruit sample was ground and filtered through Whatman No. 4 paper. A 25 ml aliquot of the filtered juice was transferred to a 250 ml volumetric flask, diluted with distilled water, and neutralized with NaOH. The solution was clarified using neutral lead acetate. Excess lead acetate was removed by adding potassium oxalate, and the volume was adjusted to 250 ml. After filtration, an aliquot of the filtrate was titrated against a mixture of Fehling's solution A and B using methylene blue as an indicator. The reducing sugar content was expressed as a percentage.

Shelf Life (Days). The harvested banana fruits were visually monitored until they reached the consumption stage. Shelf life was determined by calculating the average storage duration of each replication, after which the fruits lost their consumer appeal and marketability. The shelf life was expressed in days.

Statistical Analysis. The results from the experiment were statistically analyzed using the General R-Based Analysis Platform Empowered by Statistics (GRAPES), developed by the Department of Agricultural Statistics, Kerala Agricultural University, Kerala (www.kaugrapes.com). Analysis of Variance (ANOVA) was performed to compare the means, using a significance level of $P \leq 0.05$.

RESULTS AND DISCUSSION

Effect of pre-harvest spray of chemicals on TSS (°Brix) in banana cv. Poovan (AAB). The combined application of calcium lactate and kojic acid significantly influenced the TSS at different storage periods (Table 1). The treatment T_7 (Calcium lactate 1per cent + kojic acid 1per cent) recorded the highest TSS followed by Kojic acid alone (T_5), while the control treatment recorded the lowest TSS indicating a synergistic effect in enhancing sugar accumulation. However, continued ripening during storage was undoubtedly responsible for the increasing TSS. It could be that kojic acids improve the antioxidative properties of banana, whereas calcium treatment enhances post-harvest sugar retention. The increase in TSS aligns with improved metabolic activities during ripening. Kojic acid at 1per cent alone also enhanced TSS substantially. The treatments with kojic acid alone or in combination with calcium lactate consistently showed higher TSS values, while calcium lactate alone (1 per cent and 2 per cent) had minimal effect. The enhancement in TSS with the application of kojic acid, particularly at 1per cent concentration indicates the role of kojic acid in enhancing fruit sweetness and overall quality by modulating enzymatic activities involved in sugar metabolism (Khedr *et al.,* 2022). An increase in TSS due to treatment was also reported by Vanoli *et al*. (1995); Bakshi and Masoodi (2009) Reduced respiration during peach fruit storage may result in less use of the sugar metabolic pathway, which could in calcium application increasing TSS (Gupta *et al.,* 1980).

Effect of pre-harvest spray of chemicals on titrable acidity (%) in banana cv. Poovan (AAB). The titrable acidity significantly decreased in treatments involving kojic acid (1 per cent) in the treatments T_5 and T_7 showing the lowest acidity during both the stages *i.e.*, initial stage and firm-ripe stage. The treatment control (T_1) recorded the highest titrable acidity during both stages (Table 2). This suggests that kojic acid may accelerate organic acid metabolism. The results corroborate studies by Khedr *et al.* (2022), who observed similar trends in acid reduction with calcium lactate and kojic acid applications.

Effect of pre-harvest spray of chemicals on total sugar (%) and reducing sugars (%) in banana cv. Poovan (AAB). In the present study, during the storage period, the total sugar and reducing sugars were highest recorded by calcium lactate – 1 per cent + kojic acid – 1 per cent (T_7) followed by kojic acid - 1 per cent (T_6). However, the treatment control (T_{11}) recorded the lowest total sugar (per cent) and reducing sugars (per cent) at both stages (Table 2). Kojic acid's role in enhancing sugar is associated with starch hydrolysis during ripening. The increase in sugar content may be the enhanced conversion of starch to sugars resulting from calcium's activation of hydrolytic enzymes. The results of the current investigation are in accordance with the findings of Kuchi and Kabir (2017) for calcium in banana. The increasing endogenous level of calcium and kojic acid after external application may have positively impacted metabolic processes. With a strong source-sink relationship, they might have improved the synthesis, translocation, and accumulation of quality compounds like total sugars and reducing sugars (Vani *et al.*, 2020; Khedr, 2022).

Effect of pre-harvest spray of chemicals on shelf life (days) in banana cv. Poovan (AAB). Shelf life was notably extended in treatments involving the combination of kojic acid and calcium lactate, with T_7 showing the longest duration and the control treatment T_1 recorded the lowest shelf life (Table 2). This result highlights the combined treatment's ability to retard senescence and maintain fruit quality longer. It might be because kojic acid and calcium lactate were assumed to strengthen the cellular tissue and increase the shelf life of the banana. Similar results were also obtained by (Khedr, 2022). Moreover, the synergistic effect of calcium and antioxidants in reducing oxidative stress and prolonging shelf life. Shah *et al.* (2017) found that applying kojic acid to litchi fruit before storage can delay the browning of the pericarp. Kojic acid is an anti-browning agent, that inhibits polyphenol oxidase and other oxidant activity by reducing pH and binding the copper ions at the active site of this enzyme to form an inactivated complex (Liu *et al.*, 2020; Siddiq *et al.*, 2013), which reduces its deterioration and make them less susceptible to pathogens.

Table 1: Effect of pre-harvest spray of chemicals on TSS (°Brix) and titrable acidity (%) in banana cv. Poovan (AAB).

Treatments	TSS (°Brix)		Titrable acidity (%)	
	Initial stage	Firm ripe stage	Initial Stage	Firm ripe stage
T_1 : Control	16.35	21.34	0.89	0.65
T_2 : Calcium Lactate - 1%	16.66	21.36	0.85	0.59
T_3 : Calcium Lactate - 2%	16.23	21.42	0.87	0.61
T_4 : Kojic Acid - 0.5%	17.11	21.98	0.76	0.51
T_5 : Kojic Acid - 1%	17.21	23.05	0.66	0.39
T_6 : Calcium Lactate - 1% + Kojic Acid - 0.5%	17.05	22.88	0.78	0.45
T_7 : Calcium Lactate - 1% + Kojic Acid - 1%	17.08	24.19	0.66	0.39
T_8 : Calcium Lactate - 2% + Kojic Acid - 0.5%	16.85	22.28	0.83	0.57
T_9 : Calcium Lactate - 2% + Kojic Acid - 1%	16.87	22.23	0.81	0.50
SE (d)	**0.44**	**0.43**	**0.018**	**0.009**
CD (0.05)	**NS**	**0.91**	**0.038**	**0.018**

Table 2: Effect of pre-harvest spray of chemicals on total sugar (%) and reducing sugars (%) in banana cv. Poovan (AAB).

Treatments	Total sugar (%)		Reducing sugar (%)	
	Initial stage	Firm ripe stage	Initial Stage	Firm ripe stage
T_1 : Control	7.20	15.11	5.32	12.81
T_2 : Calcium Lactate - 1%	7.20	15.13	5.27	12.53
T_3 : Calcium Lactate - 2%	7.23	15.11	5.26	12.41
T_4 : Kojic Acid - 0.5%	7.88	15.87	5.41	13.86
T_5 : Kojic Acid - 1%	8.22	16.05	6.11	14.07
T_6 : Calcium Lactate - 1% + Kojic Acid - 0.5%	7.98	15.96	5.53	13.99
T_7 : Calcium Lactate - 1% + Kojic Acid - 1%	8.26	16.05	6.13	14.07
T_8 : Calcium Lactate - 2% + Kojic Acid - 0.5%	7.31	15.30	5.46	13.21
T_9 : Calcium Lactate - 2% + Kojic Acid - 1%	7.53	15.21	5.58	13.20
SE (d)	**0.21**	**0.30**	**0.08**	**0.23**
CD (0.05)	**0.45**	**0.64**	**0.17**	**0.49**

Table 3: Effect of pre-harvest spray of chemicals on shelf life (days) in banana cv. Poovan (AAB).

Treatments	Shelf life (days)
T_1 : Control	8.60
T_2 : Calcium Lactate - 1%	10.00
T_3 : Calcium Lactate - 2%	10.33
T_4 : Kojic Acid - 0.5%	12.60
T_5 : Kojic Acid - 1%	12.66
T_6 : Calcium Lactate - 1% + Kojic Acid - 0.5%	13.01
T_7 : Calcium Lactate - 1% + Kojic Acid - 1%	13.66
T_8 : Calcium Lactate - 2% + Kojic Acid - 0.5%	11.66
T_9 : Calcium Lactate - 2% + Kojic Acid - 1%	12.33
SE (d)	**0.17**
CD (0.05)	**0.36**

CONCLUSIONS

In the present study of various pre-harvest chemicals, the application of calcium lactate 1 per cent + kojic acid 1 per cent (T_7) enhances the quality and shelf life of banana fruits and provides a sustainable solution for post-harvest management of banana cv. Poovan (AAB).

FUTURE SCOPE

This study opens up several avenues for future research, including optimizing calcium lactate and kojic acid concentrations and application stages for various banana cultivars under different agro-climatic conditions. Exploring the physiological mechanisms behind their synergistic effects and extending this approach to other perishable fruits can enhance their applicability. Furthermore, evaluating their compatibility with advanced storage techniques could improve post-harvest management. Additionally, developing cost-effective commercial formulations, assessing their impact on nutritional and sensory qualities and studying their role in post-harvest disease resistance can help establish this as a viable solution for reducing post-harvest losses and improving fruit quality.

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