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Effect of Evaporative Cooling on Colour and Quality Changes During Ripening of Grand Naine Banana

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ABSTRACT

The Grand Naine banana comes under *Musa acuminata* (AA) is one of the most commonly cultivated bananas where color development is an important feature during ripening which is used to determine the quality of fruit for marketing. As calcium carbide and direct contact of fruits with ripening agents was banned due to its hazardous health effects by FSSAI, a further method for utilizing ethylene gas to commence ripening is used. Temperature and exposure time of ethrel is essential for the quality and longevity in storage of the fruits. The postharvest study was laid out in a completely randomized design consisting of three treatments *viz.,* T1 – air tight chamber; T2 – zero energy cool chamber; T3 - cold chamber with seven replications. The fruits were exposed to ethrel treatment in three distinct temperature-controlled chambers over 24 hours after which the fruits were stored at the ambient condition to study the ripening behaviour. The various observations on shelf-life parameters and biochemical attributes were taken on alternate days from the 2^{nd} day after treatment to the 8^{th} day of storage. The sensory assessment was conducted on the exact day of complete maturation of fruits. Based on the summary findings of the research, we found that the physiological and shelf-life parameters of fruits placed in zero energy cool chamber were found to be on par with that have been processed in cold chamber on the time of full maturity whereas the quality parameters were found to be preferable in fruits that have been handled in a zero-energy cool chamber in contrast to cold chamber. During banana harvest, zero energy cool chamber might be utilized as an alternative to a cold chamber for ripening operations in addition to the regular use of prolonging the durability of fruits and vegetables.

Keywords: Banana, Colour development,Fruit quality. Ripening, Zero energy cool chamber.

INTRODUCTION

Grand Naine bananas, also known as Cavendish bananas, play a pivotal role in India's banana production. India produces more bananas annually than any other country in the world exceeding 30 million MT cultivated across approximately 800,000 ha (Rajamanickam, 2021; Kumar *et al,* 2024). Among the various banana varieties grown in the country, Grand Naine is increasingly prominent due to its high yield and suitability for commercial markets (Jayavalli, 2024). This cultivar's popularity is attributed to its consistent quality and export potential, which align with the growing demand for Cavendish bananas globally (Alagukannan *et al,* 2015; Patel *et al,* 2024). Among the various banana cultivating states, Tamil Nadu leads due to the significant contribution of Grand Naine bananas to the local banana industry (Badgujar, 2016). The economic impact of Grand Naine bananas in Tamil Nadu extends beyond local markets to international exports such as the Middle East, Europe, and North America.

The temperature has a significant impact on the quality and shelf life of fruits (Othman *et al,* 2021). When fruits are ripened at ambient temperature, they exhibit a sharp rise in respiration rate and ethylene production after 3-4d of harvesting, thereby limiting its popularity among customers and after harvest period (Narayana *et al,* 2005). For the Cavendish group, including Grand Naine, ripening is typically controlled through the application of ethylene, which accelerates these changes by promoting the production of enzymes like amylase and polygalacturonase (Gonge *et al,* 2013).Various ripening chambers have been used to control the ripening environment of banana. Innovations such as zero energy cool chambers and evaporative cooling systems offer more sustainable alternatives by reducing energy consumption while maintaining favorable ripening conditions (Ravikumar *et al,* 2018).

Studies have shown that different ripening conditions can significantly impact the quality attributes of Grand Naine bananas. For instance, higher temperatures and optimal ethylene levels can enhance

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sweetness and flavor but may also increase physiological loss in weight (PLW) and reduce longevity (Chiwate *et al,* 2023). Conversely, cooler ripening conditions can help preserve ascorbic acid levels and extend shelf life but may result in slower ripening and delayed color development (Kulkarni *et al,* 2011). Hence, the present study was conducted with the objective to evaluate the effect of ethrel-induced ripening at different temperature-controlled storage conditions on the shelf-life, quality, and sensory attributes of Grand Naine banana, and to assess the potential of a zero-energy cool chamber as an alternative to cold chambers for ripening operations.

MATERIALS AND METHODS

The current study was conducted at Horticultural College and Research Institute (HC&RI), Tamil Nadu Agricultural University, Coimbatore, during the year 2024. This study was carried out to find the best ripening chamber for Grand Naine fruits that results in high quality and shelf life. Three types of chambers having three different temperatures were used for ethrel treatment of banana fruits. The air tight chamber (33 ±1°C, 85 % RH) and cold chamber (22 ±1°C, 94 % RH) located in the Analytical lab and the zero-energy cool chamber (26 ±1°C, 90 % RH) located in the College orchard used for the study (Table 1). The Fruits were harvested from college orchard, washed with clean water and then subjected to 0.1% Bavistin treatment for 10 minutes to decrease the prevalence of postharvest maladies such as anthracnose and stem end rot (Waskar and Gaikwad, 2005). The banana fruits had been exposed to ethylene at 100 ppm for 24 hours in three various storage conditions. Twenty-four hours later, the fruits had been subjected to ambient conditions for studying the maturity behaviour and shelf life.

The number of days taken by fruits to attain ripened stage suitable for consuming in more than 90 % of the fruit in a treatment is considered as days taken for ripening. That's additionally referred to as pre-climacteric life or green life (Peacock, 1972). The fruits were observed for ripening daily in all treatments. The post-harvest life of the fruits was calculated on the harvest time until the fruits remained in a good edible state without any spoilage under ambient storage conditions inferred through visual appearance and expressed in days. The yellow life of the fruits was calculated from the day of ripening until the end of edible life of the fruits (Dadzie and Orchard, 1997). The fruit colour was estimated using the book Horticultural Colour Chart by Royal Horticulture Society. The total soluble solids (T.S.S.) of the banana pulp was estimated by using a hand refractometer (ERMA®) between the scale of 0-32 and values were expressed in ˚Brix. The amount of Vitamin C is expressed as mg /100g pulp and Titratable acidity was determined (Ranganna, 1986).

A digital pH scale was used to measure the pulp's pH. Sensory evaluations of the fruits ripened in different chambers having different temperatures were evaluated for sensory assessment such as appearance, chroma, flavour, taste and wider preference to identify the best treatment using a 9-point hedonic scale (9 and 1 points indicating extreme like and dislike) (Maduwanthi and Marapana, 2019). The marketability of fruits was calculated on the day of full maturity of fruits and 2nd day after complete ripening and expressed in terms of percentage. A one-way analysis of variance (ANOVA) was used to compare the means by least significant difference (LSD) analysis in the experiment, which was set up using a completely randomized design using R 0.05 software. Data significance was established at $p < 0.05$.

RESULTS AND DISCUSSION

Shelf life parameters

The air tight chamber had the highest mean temperature (33±1°C), while the cold chamber maintained the lowest (22±1°C), contributing to slower ripening (Table 2). Bananas ripened faster in the cold chamber (4 d) compared to the zero energy cool chamber (6d), likely due to lower temperatures and higher humidity in the latter. The yellow life was shortest in the air tight chamber (2 d) and similar in the other two chambers (3d). Physiological loss in weight elevated starting on the day of treatment till the ripening of fruits regardless of the chambers used. The highest physiological loss in weight was reported in fruits processed in cold chamber (T3) (9.88%) subsequently by fruits placed in air tight chamber(T2) (9.09%) and the lowest PLW were recorded in fruits handled in zero energy cool chamber (T1) (8.06%). This could indicate higher moisture loss in the cold chamber due to its chilling conditions, which might affect fruit texture and weight retention. In terms of moisture content, the air tight chamber recorded the highest (77.85%), suggesting better moisture retention but also potentially indicating less effective ethylene diffusion.

Biochemical attributes and quality assessment

The total soluble solids (T.S.S.) content,

Table 1: The amount of water (ml), ethrel (ml), and NaOH (g) necessary to discharge 100 ppm of ethylene.

Sr. No.	Chamber	Ethrel (ml)	Water (ml)	NaOH (g)
1.	Zero Energy Cool Chamber	0.9	450	0.18
2.	Air Tight Chamber	0.86	0.43	0.173
3.	Cold Chamber	31.6	15800	6.3

Table 2: Impact of temperature on physiological and shelf-life indicators during ethrel treatment in various chambers.

Treatment	Green Life (Days)	Yellow Life (Days)	Shelf Life (Days)	Physiological Loss in Weight (%)	Fruit Marketability (%)	Moisture content
T1-Zero energy chamber	6	3	10	10.48	89	80.91
T2-Air Tight Chamber	4	3	7	11.39	71.43	86.93
T3-Cold Chamber	4	2	8	11.17	62.14	85.93
SE(d)	0.25	0.154	0.37	3.0312	9.033	0.3108
CD 5%	0.72	0.32	0.77	9.65	18.977	0.6529

Table 3: The temperature's effect upon ethrel treatment in various chambers on biochemical parameters.

Treatment	T.S.S. (%)	Titratable acidity (%)	Ascorbic acid (mg/100g)	pH	Colour values
T1	23	0.26	18	4.6	Sulphur yellow 1/3
T2	23	0.8	16.49	4.85	Chartreuse green 663/2
T3	22.57	0.75	20.75	4.57	Empire yellow 603/2
SE(d)	0.4666	0.0543	1.5880	0.059	-
CD 5%	0.9802	0.1329	5.0537	0.125	-

Table 4: The impact of temperature on ethrel exposure in multiple chambers on quality assessment.

Treatment	Colour and appearance (peel)	Colour and appearance (pulp)	Texture	Taste	Flavour	Overall acceptability
T1	8.6	8.1	8.3	8.3	8.6	8.3
T2	7.0	8.4	7.0	8.6	7.6	7.3
T3	9.0	7.4	8.9	7.6	8.4	8.1
SE(d)	0.24	0.32	0.36	0.33	0.29	0.39
CD 5%	0.51	0.66	0.76	0.69	0.60	0.82

indicative of fruit sweetness was highest in the air tight chamber, likely due to higher temperatures accelerating sugar development. Conversely, the cold chamber showed a delayed increase in T.S.S., suggesting slower ripening. The highest titratable acidity was found in the cold chamber, reflecting a more acidic profile, which might be a result of slower fruit ripening. Ascorbic acid content decreased across all treatments, with the cold chamber maintaining the highest levels (37.44 mg/100g) and the zero-energy cool chamber following (29.86 mg/100g). The cold chamber's ability to delay the decline in ascorbic acid could be due to its lower temperature, which might slow down the oxidation processes. The pH levels were highest in the air tight chamber, suggesting more acidic conditions compared to other chambers (Table 3). Sensory evaluations indicated that the cold chamber had the highest scores for peel colour and appearance, while the air tight chamber excelled in pulp color and taste. The zero-energy cool chamber achieved high scores in flavor and overall acceptability, which might reflect a balance between quality and sustainability. The air tight chamber, despite its superior taste and pulp appearance, showed lower overall acceptability, possibly due to its impact on shelf life and ripening uniformity (Table 4).

The results underscored the impact of the maturation conditions on Grand Naine bananas. While the cold chamber offers superior control over temperature and may enhance certain quality aspects like acidity and shelf life, the zero energy cool chamber provides a viable, cost-effective alternative with commendable ripening outcomes and overall acceptability. The air tight chamber, although beneficial for certain quality traits, exhibited limitations in shelf life and overall acceptability. These findings highlight the importance of choosing appropriate ripening conditions to optimize banana quality and align with sustainability goals.

CONCLUSION

This study evaluated the effects of different ethylene treatment environments on the ripening of Grand Naine bananas, focusing on temperature, relative humidity, and fruit quality. Three chambers were compared: a cold chamber, a zero energy cool chamber, and an air tight chamber. The cold chamber maintained the lowest temperature (22±1°C) and the highest relative humidity (94%), leading to the highest physiological loss in weight (9.88%) and delayed increases in total soluble solids (T.S.S.). The zero energy cool chamber, with a moderate temperature (26±1°C) and relative humidity (90%), extended the ripening period (6 d) and shelf life (8 d), offering a balance between quality and sustainability. The air tight chamber, which had the highest temperature (33±1°C) and lower relative humidity (85%), resulted in the shortest ripening time (4 d) and lower shelf life (2 d), but excelled in taste and pulp appearance. Quality assessments revealed that bananas from the cold chamber had the highest acidic profile and Vitamin C content, indicating slower ripening and better retention of certain nutrients. In contrast, the zero energy cool chamber provided high overall acceptability and flavor, while the air tight chamber, despite its advantages in taste and pulp color, showed lower marketability and shelf life. Overall, the study highlights the trade-offs between ripening speed, fruit quality, and sustainability, emphasizing the zero energy cool chamber as a viable, eco-friendly alternative that balances ripening efficiency with fruit quality.

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