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EFFECT OF POST HARVEST CHEMICALS ON SHELF LIFE AND PHYSIOLOGICAL CHANGES OF BANANA (*Musa paradisiaca* L.) CV. GRAND NAINE UNDER AMBIENT AND REFRIGERATED STORAGE CONDITION

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ABSTRACT

The present investigation was carried out during 2023 at Dept. of Horticulture, VNMKV, Parbhani to envisage the effect of different post harvest chemicals on shelf life and physiological changes of banana cv. Grand Naine under ambient and refrigerated storage condition. The experiment was laid out in Factorial Completely Randomized Design (FCRD) with two factor i.e., storage condition with two levels viz., ambient storage (S_1), refrigerated storage (S_2 : 13C ± 1 temp. and 85% RH) and chemical treatment with five levels viz., C_1: GA_3 @ 150 ppm, C_2: benzyl adenine @ 50 ppm, C_3: salicylic acid @ 2 mM, C_4: hexanal @ 1% and C_5: KMS @ 1% with ten treatment combinations which were replicated three times. Interaction effect of storage condition and chemical treatment on physical properties of fruit was found significant. Highest shelf life (33.89 days) was recorded in fruits stored in treatment combination S_2C_1 (Refrigerated Storage + GA_3 @ 150 ppm). Among the treatments, post harvest dipping of fruits in GA_3 @ 150 ppm and stored in refrigerated condition (S_2C_1) significantly recorded minimum PLW, higher fruit firmness and peel thickness, minimum pulp to peel ratio and respiration rate, higher organoleptic score along with progressing of storage period at every 4 days interval.

Introduction

One of the most significant common fruits enjoyed by man in daily life is the banana (*Musa paradisiaca* L.) which belongs to the Musaceae family. The edible banana is a native of tropical Asia's warm, wet regions, including India, Burma and Thailand. It ranks as the fourth-most significant food item in terms of gross value after paddy, wheat and maize products in India. Banana is the cheapest, plentiful and most nourishing of all fruits. Tropical and subtropical regions all around the country are used to grow bananas. Even though bananas favour tropical climates, they thrive also in humid tropics, humid subtropics and semi-arid subtropics. 33.4% of the overall fruit crop production is contributed by banana. With an annual production of 31.5 million tonnes from an area of 8.4 lakh hectares, India is the largest producer of banana in the world. The top producer of banana in India is Andhra Pradesh which produces 5838.88 thousand tonnes followed by Maharashtra which produces 4628.04 thousand tonnes (NHB, 2021-22). It is abundantly accessible all year round and is not seasonal like many other fruit crops. However, because of its perishability and lack of technology to extend shelf life, the export potential is extremely limited.

A climacteric fruit like the banana ripens quickly by an autocatalytic climacteric burst of the gaseous hormone ethylene, which in turn regulates several ripening-related biochemical changes and sensory characteristics. Being a highly perishable fruit, it is vulnerable to significant post-harvest losses due to poor handling and unsuitable storage practises; as a result, even though India is a major producer, export commerce cannot be exploited. Due to their high perishability, they have significant post-harvest losses that range from 30 to 40%. Following harvest, all beneficial qualities including freshness, taste and texture will gradually deteriorate.

The main obstacles to post-harvest handling of bananas are their accelerated ripening and short shelf life in tropical climates. In developing nations, it is crucial to conduct research on effective ways to extend banana shelf life in order to preserve fruit quality for long distances to domestic and export markets. Alternative, less sophisticated technologies for shelf-life extension at ambient temperature are required so that subsistence farmers can transport green banana to long distances without refrigeration (Huang *et al*., 2013). Due to frequent exposure to spoiling brought on by bruising, ageing and microbiological decay in market channels, post-harvest losses in bananas are caused by inappropriate handling, transport, storage and marketing. Delaying ripening and senescence till they are ready to be consumed is extremely desired (Ramana *et al*., 1989).

By using a variety of techniques including cold storage, the application of growth regulators and chemical treatments, conventional traders can readily reduce post-harvest losses and extend the storage life of their products. Grand Naine bananas, a very perishable tropical fruit crop, can have their ripening process delayed through post-harvest care and extending their shelf life. With this background, the present investigation was carried out with an objective to study the effect of post-harvest application of chemicals on shelf life and physiological changes of banana under ambient and refrigerated conditions.

Material and Methods

Experimental Site

The experiment was conducted at Dept. of Horticulture, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during the year 2023.

Collection of Banana fruits

Collection of banana fruits At. Post. Lohgaon Tq., Dist. Parbhani. During harvesting, the bunches were removed from the plants. After that bunches were separated into hands. The hands were sorted for freedom from visual defects, uniformity of weight and shape.

Stage of Harvest

Banana fruits cv. Grand Naine was harvested at 80-85% maturity stage. Bunches of uniform size having cylindrical or nearly cylindrical shape were selected. The bunches with green, unripe, whole and clean fruits free from scratches, brushes, sun burns and fungal/insect attack were selected and brought to the laboratory. The fruits were cleaned with tap water and then allowed to dry in shade prior to imposition of the treatments.

Preparation of Chemical Solution

Gibberellic Acid (GA_3)

150 mg of GA_3 was weighed and dissolved in small amount of ethanol at slight warm state and made up to one litre with distilled water to get 150 ppm solution.

Benzyl Adenine (BA)

50 mg of BA was weighed and added to 1lt. of distilled water along with 0.1% Tween 80 as a wetting agent to prepare solution of benzyl adenine 50 ppm.

Salicylic Acid (SA)

The 2 mM salicylic acid solution was prepared by using distilled water and 0.1% Tween 80 as a wetting agent.

Hexanal

Hexanal solution of 1% was made by adding 1 ml hexanal to 100 ml of 10% ethanol along with 0.1% Tween 80 as a wetting agent.

Potassium Metabisulphite (KMS)

1g. of KMS was weighed and added to 100 ml of distilled water to prepare a solution of KMS 1%.

Design of Experiment

The experiment was conducted with factorial completely randomized design (FCRD) by keeping storage condition (S_1 : Ambient Storage and S_2 : Refrigerated Storage @ 13°C ± 1 and 85 % RH) and chemicals (C_1 : GA_3 150 ppm, C_2 : BA 50 ppm, C_3 : SA 2 m M, C_4 : Hexanal 1% and C_5 : KMS 1%) as two factors.

Table 1: Treatment and its details

Treatment	Treatment Details
T_1	S_1C_1 (Ambient Storage + GA_3 @ 150 ppm)
T_2	S_1C_2 (Ambient Storage + BA @ 50 ppm)
T_3	S_1C_3 (Ambient Storage + SA @ 2 mM)
T_4	S_1C_4 (Ambient Storage + Hexanal @ 1%)
T_5	S_1C_5 (Ambient Storage + KMS @ 1%)
T_6	S_2C_1 (Refrigerated Storage + GA_3 @ 150 ppm)
T_7	S_2C_2 (Refrigerated Storage + BA @ 50 ppm)
T_8	S_2C_3 (Refrigerated Storage + SA @ 2 mM)
T_9	S_2C_4 (Refrigerated Storage + Hexanal @ 1%)
T_{10}	S_2C_5 (Refrigerated Storage + KMS @ 1%)

Collectively, ten treatments were laid out in FCRD with 3 replications. 24 fingers were selected for each treatment. Thus, there were 240 bananas for single replication.

Establishment of Experiment

The selected fruits were divided in lots and kept ready for post-harvest treatments with chemical and storage. The chemical solution of GA_3 150 ppm, BA 50 ppm, SA 2 mM, Hexanal 1% and KMS 1% were prepared, the required amount of chemicals as per treatments fruits were dipped in solution for 5-10 minutes. After 36 these treatments fruits are allow to dry and finally these fruits were kept as per treatments in ambient condition and cold storage maintaining the 13°C ± 1 temp. and 85 % RH. Storage temperature and relative humidity were recorded daily.

Parameters to be taken for observation

Following properties of banana fruits were studied during the course of present investigation at 4 days interval up to 20th day.

Physiological Loss in Weight (PLW %)

Physiological weight loss of stored fruits was calculated by subtracting final weight from the initial weight of the fruits and expressed in percentage. Physiological weight loss (%) of fruits was calculated as per the formula given below.

$$\text{PLW}(\%) = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \times 100$$

Fruit Firmness (kg/cm^2)

Penetrometer was used to record the unconfined strength and direct readings were obtained in terms of kg/cm^2. The sample fruits were subjected to penetrometer by pressing the centre of the fruit and direct reading on the scale was recorded on specified intervals.

Peel Thickness (mm)

Thickness of the peel of individual fruit was measured with vernier callipers after separating the peel from the pulp by cutting transversely at midpoint of fruit and expressed in mm.

Pulp to Peel Ratio

The ratio between pulp to peel weight was determined to assess the maturity of the fruit and ripening of banana. The pulp and peel were separated by means of stainless-steel knife and weighed separately and ratio between fresh weights of pulp was calculated.

$$\text{Pulp to Peel Ratio} = \frac{\text{Pulp Weight (g)}}{\text{Peel Weight (g)}}$$

Shelf Life (Days)

The shelf life of fruits was recorded based on the development of discolouration i.e., blackened skin, off flavour, fungal attack, skin shrivelling and softness. The stage at which more than 50% of the stored fruits become unsuitable for consumption, that stage of fruit was considered as the end of shelf life.

Organoleptic Evaluation

Sensory evaluation of the fruits obtained from different treatment plots was taken up with a panel of five judges containing different people and they were asked to give the score (1-4) on characteristics like appearance, colour, flavour, taste and overall acceptability of the fruit (Peryam and Pilgrim, 1957). Organoleptic evaluation was done at eating ripe stage.

Respiration Rate (ml CO_2 kg^{-1} h^{-1})

Respiration rate of banana fruits was measured in terms of CO_2 concentration (Kader and Saltveit, 2003). For the measurement, each fruit per treatment was weighed and placed in a plastic container sealed with a lid. After one hour, gas samples were drawn from the container through silicon rubber septum using needle and CO_2 concentration was measured out using Checkpoint portable gas analyzer. Respiration rate was expressed in ml CO_2 kg^{-1}h^{-1}.

Statistical Analysis

The data collected on various observations during the course of investigation were statistically analyzed by Factorial Completely Randomized Design as suggested by Panse and Sukhatme (1987). The treatment means were compared by means of critical differences at 5% level of probability.

Results and Discussion

The results were assessed and discussed with supporting evidence from previous works.

Physiological Loss in Weight (PLW%)

The data presented in table 2 revealed that the effect of interaction between storage condition and chemical treatment was found to be nonsignificant regarding PLW on 4th day. Physiological loss in weight from 8th day to 20th day was found minimum in treatment combination (S_2C_1: Refrigerated Storage + GA_3 @ 150 ppm) showed (3.94%, 4.73%, 6.79% and 8.25% respectively) followed by treatment combination (S_2C_2: Refrigerated Storage + BA @ 50 ppm i.e., 4.11%, 6.87%, 8.59% and 10.48% respectively), while maximum physiological weight loss recorded in treatment combination (S_1C_4: Ambient Storage + Hexanal @ 1% i.e., 10.18%, 14.20%, 20.33% and 25.80% respectively). However, it is supported by Rao and Chundawat (1984) and Patil and Hulamani (1998) in banana.

Table 2 : Effect of different storage condition and chemical treatments on PLW of banana

Treatments	Storage Period (No. of Days)				
	4th Day	8th Day	12th Day	16th Day	20th Day
S_1C_1	2.38	4.66	7.43	11.84	14.68
S_1C_2	2.68	4.96	7.89	12.93	15.70
S_1C_3	3.02	5.16	9.94	14.04	17.87
S_1C_4	5.25	10.18	14.20	20.33	25.80
S_1C_5	4.57	9.21	13.59	20.18	25.12
S_2C_1	2.25	3.94	4.73	6.79	8.25
S_2C_2	2.85	4.11	6.87	8.59	10.48
S_2C_3	3.00	5.02	8.87	11.06	12.70
S_2C_4	4.51	8.26	11.89	15.85	18.27
S_2C_5	4.14	7.54	10.14	14.69	17.62
S.E(m) ±	0.157	0.123	0.135	0.124	0.133
CD at 5%	NS	0.364	0.400	0.368	0.397

(NS - Non-significant, C.D – Critical Difference, S.E – Standard Error)

Rapid moisture loss, which results in shrivelling, loss of turgidity, an early climacteric peak, and a subsequent increase in respiration in comparison to low temperature, may be the cause of weight loss at higher temperatures. Gibberellic acid slows down the rate of respiration, which in turn slows down the physiological weight loss. Gibberellic acid also delays the appearance of the climacteric peak in a concentration-dependent manner, which slows down the ripening of banana fruits.

Fruit Firmness

Table 3's findings showed that, when it came to fruit firmness on the fourth and eighth day, the interaction between storage conditions and chemical treatment was found to be non-significant. Fruit firmness on the 12th, 16th and 20th day was found to be at its highest in the treatment combination (S_2C_1: Refrigerated Storage + GA_3 @ 150 ppm), which showed (4.47 kg/cm^2, 4.12 kg/cm^2 and 3.82 kg/cm^2 respectively). This was followed by the treatment combination (S_2C_2: Refrigerated Storage + BA @ 50 ppm, i.e., 4.28 kg/cm^2, 3.93 kg/cm^2 and 3.57 kg/cm^2 respectively), while fruit firmness was found to be at its lowest in the treatment combination (S_1C_4: Ambient Storage + Hexanal @ 1% viz. 2.40 kg/cm^2, 2.00 kg/cm^2 and 1.87 kg/cm^2 respectively). Similar results were reported by Padmavati (1999) in banana, and Santha Krishnamurthy (1989).

Table 3 : Effect of different storage condition and chemical treatments on fruit firmness of banana

Treatments	Storage Period (No. of Days)				
	4th Day	8th Day	12th Day	16th Day	20th Day
S_1C_1	5.12	4.67	4.04	3.45	3.13
S_1C_2	4.93	4.14	3.57	3.16	2.82
S_1C_3	4.55	3.97	3.26	2.80	2.54
S_1C_4	4.00	3.35	2.40	2.00	1.87
S_1C_5	4.12	3.45	2.90	2.34	1.95
S_2C_1	5.55	5.03	4.47	4.12	3.82
S_2C_2	4.72	4.45	4.28	3.93	3.57
S_2C_3	4.61	4.29	3.82	3.55	3.25
S_2C_4	4.26	3.82	3.34	2.80	2.45
S_2C_5	4.47	3.95	3.50	3.00	2.73
S.E(m) ±	0.115	0.087	0.058	0.025	0.025
CD at 5%	NS	NS	0.172	0.074	0.074

(NS - Non-significant, C.D – Critical Difference, S.E – Standard Error)

Fruits stored in cold conditions had the highest levels of fruit firmness. This can be because the hydrolysis of starch and hemicellulose in fruit is slower at low temperatures, which reflects how slowly fruit ripens there. Gibberellic acid treatment may increase fruit firmness by delaying the breakdown of starch, cellulose, and hemicellulose. It may possibly be because of its antagonistic action on IAA, which boosts oxidative and hydrolytic enzymes such peroxidase, catalase, phosphatase, phosphorylase, and amylase (Desai *et al*., 1984).

Peel Thickness

According to table 4's data, peel thickness on the 4th and 8th day was not found to be significantly affected by the interaction between storage conditions and chemical treatment. The treatment combination S_2C_1: Refrigerated Storage + GA_3 @ 150 ppm showed the maximum peel thickness on 12th, 16th and 20th day. It showed 4.59 mm, 4.27 mm, and 3.75 mm, respectively). Treatment combination S_2C_2: Refrigerated Storage + BA @ 50 ppm showed the second-highest peel thickness, measuring 4.16 mm, 3.81 mm and 3.56 mm, respectively. Treatment combination S_1C_4: Ambient Storage + Hexanal @ 1% recorded the lowest peel thickness, measuring 2.99 mm, 2.49 mm and 1.92 mm, respectively. Similar results were found by Ramana *et al.* (1971).

Table 4: Effect of different storage condition and chemical treatments on peel thickness of banana

Treatments	Storage Period (No. of Days)				
	4th Day	**8th Day**	**12th Day**	**16th Day**	**20th Day**
S_1C_1	4.43	4.23	3.93	3.43	3.00
S_1C_2	4.32	4.09	3.76	3.26	2.97
S_1C_3	4.15	3.87	3.49	2.99	2.43
S_1C_4	4.07	3.52	2.99	2.49	1.92
S_1C_5	4.27	3.69	3.19	2.69	2.23
S_2C_1	5.23	4.91	4.59	4.27	3.75
S_2C_2	4.86	4.51	4.16	3.81	3.56
S_2C_3	4.65	4.28	3.91	3.64	3.27
S_2C_4	4.30	3.94	3.62	3.21	2.78
S_2C_5	4.34	4.00	3.74	3.33	2.92
S.E(m) ±	0.144	0.115	0.046	0.042	0.034
CD at 5%	NS	NS	0.137	0.124	0.100

(NS - Non-significant, C.D – Critical Difference, S.E – Standard Error)

Fruit kept in a chilly environment was shown to have thicker peels than fruit kept in an ambient environment. Environmental factors led to a greater drop in peel thickness, which may have been caused by a faster metabolic rate and consequent rise in the hydrolytic enzyme in the peel. In comparison to other chemical treatments, the GA_3 treated fruits had the thickest peels, which may be because their metabolisms were slower and their hydrolytic enzyme concentration was lower than with other treatments.

Pulp to Peel Ratio

The data in Table 5 showed that, with regard to the pulp to peel ratio on the 4th, 8th and 12th day, the interaction between storage conditions and chemical treatment was found to be non-significant. The results indicate that on the 16th and 20th day, the pulp to peel ratio was lowest in treatment combination S_2C_1: Refrigerated Storage + GA_3 @ 150 ppm, showing 1.84 and 1.96 respectively followed by treatment combination S_2C_2: Refrigerated Storage + BA @ 50 ppm, i.e., 1.93 and 2.13 respectively. Treatment combination S_1C_4: Ambient Storage + Hexanal @ 1%, i.e., 2.92 and 3.10 respectively had the highest value. Similar results were obtained by Krishnamurthy (1989).

When compared to fruits maintained at low temperatures, bananas stored at room temperature showed the highest pulp to peel ratio. This result may be attributed to a faster metabolic rate and therefore higher peel hydrolytic enzyme levels. Fruits treated with gibberellic acid have a decreased pulp to peel ratio. In the presence of gibberellic acid, the pulp to peel ratio indicated a delay in the ripening of banana fruit. The increased sugar concentration of the pulp in comparison to the peel causes a rise in the pulp to peel ratio, which is caused by the displacement of water from the peel towards the pulp during the ripening process as a result of the osmotic pressure gradient.

Table 5: Effect of different storage condition and chemical treatments on pulp to peel ratio of banana

Treatments	Storage Period (No. of Days)				
	4^{th} Day	8^{th} Day	12^{th} Day	16^{th} Day	20^{th} Day
S_1C_1	1.71	1.93	2.11	2.30	2.63
S_1C_2	1.79	1.97	2.26	2.52	2.71
S_1C_3	1.81	2.01	2.34	2.56	2.78
S_1C_4	1.96	2.25	2.61	2.92	3.10
S_1C_5	1.87	2.05	2.37	2.86	3.03
S_2C_1	1.44	1.55	1.67	1.84	1.96
S_2C_2	1.47	1.56	1.79	1.93	2.13
S_2C_3	1.57	1.78	1.93	2.13	2.35
S_2C_4	1.70	1.95	2.22	2.56	2.75
S_2C_5	1.67	1.86	2.10	2.32	2.64
S.E(m) ±	0.062	0.052	0.038	0.033	0.027
CD at 5%	NS	NS	NS	0.099	0.080

(NS - Non-significant, C.D – Critical Difference, S.E – Standard Error)

Shelf Life

The data given in table 6 indicate significant interaction effect of chemicals and storage conditions with regarding to shelf life. The shelf life at entire period of fruit storage was observed significantly maximum in treatment combination (S_2C_1 : Refrigerated Storage + GA_3 @ 150 ppm) i.e., 33.89 days which was followed by treatment combination (S_2C_2 : Refrigerated Storage + BA @ 50 ppm) i.e., 32.30 days and the minimum shelf life (20.00 days) was observed in treatment combination (S_1C_4 : Ambient Storage + Hexanal @ 1%).

At ambient temperature, shelf life decreased more quickly than at low temperature. The increased metabolic activity at room temperature may be the cause of this. Enzymatic activity and the generation of ethylene may have been regulated by gibberellic acid. It's possible that decreased respiration and transpiration activities slowed the ripening process. The GA_3 treatment may have contributed to the fruits' longer shelf life by preventing the climacteric increase in respiration.

Table 6 : Effect of different storage condition and chemical treatments on shelf life of banana

Treatments	Storage Period (No. of Days)
S_1C_1	24.33
S_1C_2	23.00
S_1C_3	21.73
S_1C_4	20.00
S_1C_5	20.98
S_2C_1	33.89
S_2C_2	32.30
S_2C_3	30.50
S_2C_4	28.00
S_2C_5	29.15
S.E(m) ±	0.156
CD at 5%	0.463

(C.D – Critical Difference, S.E – Standard Error)

Organoleptic Evaluation

The experimental results shows that the organoleptic score for appearance was significantly higher (3.46) in treatment combination (S_2C_1 : Refrigerated Storage + GA_3 @ 150 ppm) followed by treatment combination (S_1C_1 : Ambient Storage + GA_3 @ 150 ppm) i.e., 3.37. Minimum organoleptic score for appearance (2.63) was recorded in treatment combination (S_1C_4 : Ambient Storage + Hexanal @ 1%).

Treatment combinations S_1C_1 (ambient storage + GA_3 @ 150 ppm) and S_1C_2 (ambient storage + BA @

50 ppm) had significantly higher organoleptic scores for flavor (3.27) and 3.25, respectively, while S_2C_4 (refrigerated storage + hexanal @ 1%) had the lowest organoleptic score for flavor (3.10).

Significantly higher organoleptic score for fruit taste (3.42) was observed in treatment combination (S_1C_1 : Ambient Storage + GA_3 @ 150 ppm) followed by treatment combination (S_1C_2 : Ambient Storage + BA @ 50 ppm) i.e., 3.37, while minimum organoleptic score for flavour (2.68) was recorded in treatment combination (S_2C_4 : Refrigerated Storage + Hexanal @ 1%).

Table 7: Effect of different storage condition and chemical treatments on organoleptic evaluation of banana

Treatments	Appearance	Flavour	Taste	Overall Acceptability
S_1C_1	3.37	3.27	3.42	3.38
S_1C_2	3.24	3.25	3.37	3.25
S_1C_3	3.20	3.25	3.35	3.21
S_1C_4	2.63	3.15	2.82	2.66
S_1C_5	2.87	3.19	2.95	2.89
S_2C_1	3.46	3.20	3.23	3.44
S_2C_2	3.34	3.18	3.13	3.39
S_2C_3	3.31	3.16	3.12	3.34
S_2C_4	2.66	3.10	2.68	2.69
S_2C_5	2.93	3.12	2.83	2.90
S.E(m) ±	0.006	0.006	0.005	0.005
CD at 5%	0.017	0.017	0.015	0.014

(C.D – Critical Difference, S.E – Standard Error)

According to the experimental results, the treatment combination (S_2C_1: Refrigerated Storage + GA_3 @ 150 ppm) had a considerably higher organoleptic score for overall acceptability (3.44) than the treatment combination (S_2C_2: Refrigerated Storage + BA @ 50 ppm), which was 3.39. In the treatment combination (S_1C_4: Ambient Storage + Hexanal @ 1%), the minimum organoleptic score for overall acceptability (2.66) was noted.

Respiration Rate

The data in Table 8 showed that, with regard to the respiration rate on the fourth and eighth day, the interaction between storage conditions and chemical treatment was found to be nonsignificant. Respiration rate on 12th, 16th and 20th day was found minimum in treatment combination (S_2C_1 : Refrigerated Storage + GA_3 @ 150 ppm) showed (33.13 ml CO_2 kg^{-1} h^{-1}, 45.40 ml CO_2 kg^{-1} h^{-1} and 62.38 ml CO_2 kg^{-1} h^{-1} respectively) followed by treatment combination (S_2C_2 : Refrigerated Storage + BA @ 50 ppm i.e., 35.07 ml CO_2 kg^{-1} h^{-1} , 47.30 ml CO_2 kg^{-1} h^{-1} and 64.47 ml CO_2 kg^{-1} h^{-1} respectively), while maximum respiration rate recorded in treatment combination (S_1C_4 : Ambient Storage + Hexanal @ 1% i.e., 58.22 ml CO_2 kg^{-1} h^{-1} , 76.50 ml CO_2 kg^{-1} h^{-1} and 74.44 ml CO_2 kg^{-1} h^{-1} respectively).

According to Martins and Resende (2013), it was found in the current study that the respiration rate of the banana fruits increased as ripening progressed, peaked during the climacteric stage, and then began to fall at the later phases of ripening. The rising CO_2 levels in the storage have a direct impact on the respiration rate of bananas. This observation conflicts with those of Mazhar and Freebairn (1970), who found that increased CO_2 generation slows down the ripening of fruits by inhibiting endogenous ethylene synthesis and lowering respiration rates.

Table 8: Effect of different storage condition and chemical treatments on respiration rate of banana

Treatments	Storage Period (No. of Days)				
	4th Day	8th Day	12th Day	16th Day	20th Day
S_1C_1	28.09	35.27	48.41	66.28	64.00
S_1C_2	30.12	37.85	50.35	69.71	67.60
S_1C_3	33.57	40.05	53.67	72.33	70.53
S_1C_4	37.43	44.59	58.22	76.50	74.44
S_1C_5	35.33	42.38	55.11	74.39	71.35

S_2C_1	21.38	26.20	33.13	45.40	62.38
S_2C_2	23.25	28.37	35.07	47.30	64.47
S_2C_3	25.67	30.45	38.19	51.24	68.36
S_2C_4	30.47	35.62	43.73	56.20	73.15
S_2C_5	28.69	33.25	40.89	52.34	70.25
S.E(m) ±	0.231	0.202	0.173	0.144	0.115
CD at 5%	NS	NS	0.514	0.428	0.342

(NS - Non-significant, C.D – Critical Difference, S.E – Standard Error)

According to the current study, it was found that banana fruit stored in a refrigerator showed a lower respiration rate than fruit stored in an ambient environment, which may be related to the fact that less CO_2 is produced and that the endogenous ethylene level of banana fruit is maintained at a low temperature. The fruits treated with GA_3 demonstrated a minimum respiration rate by producing less CO_2 than other fruits, according to the findings of the current study.

Conclusion

It was concluded that the fruits stored in refrigerated storage treated with GA_3 @ 150 ppm result in maintenance of good physical quality followed by BA @ 50 ppm along with refrigerated storage condition. Shelf life can be effectively regulated by application of GA_3 @ 150 ppm with treated fruits stored in refrigerated condition as compared to other treatments. Thus, the current study found that postharvest interventions and appropriate storage conditions could prolong the Grand Naine banana's shelf life by delaying ripening with the least amount of nutritional loss. After being tested in the current market system, the produced technology can be commercialised as a new field of endeavour that will aid in reducing post-harvest losses and providing a higher return for farmers.

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Conflict of Interest

The authors declare no conflicts of interest. They bear sole responsibility for the content and composition of the paper.

References

Bhusan, L.P., Dash, D.K. and Das, A.K. (2022). Pre harvest application of GA_3 and $CaCl_2$ on physiological loss in weight and storage life of banana cv. Grand Naine. *The Pharma Innovation*. 11(1): 675-679.

Desai, B.B., Sangal, P.B. and Deshpande, P.B. (1984). Hormonal regulation of hydrolytic and oxidative enzymes during ripening of three cultivars of banana. *J. of Maharashtra Agriculture University*, 9(1): 24-26.

Ghimire, R., Yadav, P.K., Khanal, S., Shrestha, A.K., Devkota, A.R. and Shrestha, J. (2021). Effect of different levels of gibberellic acid and kinetin on quality and shelf life of banana (*Musa spp*.). *Heliyon*. 7(9). https://doi.org /10.1016/j.heliyon.2021.e08019

Huang, H., Jing, G., Guod, L., Zhanga, D., Yanga, B., Duana, X., Ashrafe, M. and Jianga, Y. (2013). Effect of oxalic acid on ripening attributes of banana fruit during storage. *Postharvest Biol. Technol*., 84, 22-27.

Kader, A.A. and Saltveit, M.E. (2003). Respiration and gas exchange. *Postharvest Physiol. Pathol. Veg*. 2, 7-29.

Krishnamurthy, S. (1989). Storage life and quality of Robusta banana in relation to their stage of maturity and storage temperature. *J. Fd. Sci. Technol.*, 92(2), 87-89.

Martins, D.R. and Resende, E.D. (2013). Quality of Golden papaya stored under controlled atmosphere conditions. *Food Sci. Tech*., 19, 473-481.

Mazhar, H.Q. and Freebairn, H.T. (1970). The influence of Ethylene, Oxygen, and Carbon Dioxide on the Ripening of Bananas. *Bot. Gaz*., 131(1), 5-14.

NHB Database (2021-22) published by National Horticultural Board Department of Agriculture and Co-operation, Government of India.

Padmavathi (1999). Post harvest storage studies in banana cv. Dwarf Cavendish (Musa AAA). *M.Sc. Thesis* submitted to Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad.

Panse, V.G. and Sukhatme, P.V. (1987). Statistical methods for agricultural workers. ICAR, New Delhi.

Patil, S.N. and Hulamani, N.C. (1998). Effect of postharvest treatments on physical characters and shelf life of banana fruits. *Karnataka J. Agril. Sci*., 11(2), 535-537.

Peryam, D.R. and Piligrim, J.F. (1957). Hedonic scale method for measuring food preferences.

Ramana, S.V., Mohan Kumar, B.L. and Jayaraman, K.S. (1971). Effect of post-harvest treatments and modified atmosphere on the storage life of fresh banana and guava under ambient temperature. *Indian Food Packer.*, 26(1), 29-35.

Ramana, S.V., Mohan Kumar, B.L. and Jayaraman, K.S. (1989). Effect of post-harvest treatments and modified atmosphere on the storage life of fresh banana and guava under ambient temperature. *Indian Food Packer*, 26(1), 29-35.

Rao, P.V. and Chundawat, B.S. (1984a). Chemical regulation of ripening in Basrai banana at ambient temperature. *Progressive Horticulture*, 16(1-2), 58-68.

Rao, P.V. and Chundawat, B.S. (1984b). A note on retardation of ripening in Basrai bananas stored in cartons. *Progressive Horticulture*, 16(3-4), 295-297.

Shantha Krishnamurthy (1989). Storage life and quality of Robusta banana in relation to their stage, maturity and storage temperature. *Journal of Food Science Technology*. 26(2), 87-89.