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Influence of postharvest ethylene application on spoilage and respiratory activity during ripening of banana

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Abstract
The present investigation was carried out to assess the effect of postharvest ethylene application on spoilage incidence and respiratory behaviour during ripening of banana fruits under ambient conditions. Banana fruits harvested at eighty-five percent physiological maturity were subjected to ethylene treatments at different concentrations, namely fifty, seventy-five, one hundred, and one hundred twenty-five parts per million, in combination with varied pulsing frequencies using a low-cost ripening chamber. The experiment was arranged in a factorial completely randomized design with three replications. Spoilage percentage was monitored throughout the ripening period, while respiratory activity was evaluated by measuring changes in oxygen and carbon dioxide concentrations during storage. The results revealed that spoilage increased progressively with advancement of ripening and was more pronounced in fruits exposed to higher ethylene concentrations. Fruits receiving elevated ethylene doses exhibited an earlier onset of spoilage and higher spoilage levels compared to fruits treated with lower concentrations. Ethylene application significantly altered respiratory behaviour, as evidenced by increased carbon dioxide accumulation and reduced oxygen concentration during ripening. Higher ethylene concentrations coupled with increased pulsing frequency accelerated the climacteric rise in respiration, resulting in rapid ripening and reduced storage life. The findings indicate that although ethylene application is essential for inducing uniform ripening, excessive concentration and improper exposure regimes adversely affect fruit quality. Optimization of ethylene concentration and pulsing frequency is therefore necessary to minimize postharvest losses while maintaining desirable ripening characteristics in banana.

Keywords: Banana, acidity, spoilage, ripening

Introduction
Banana is an economically important fruit crop widely cultivated in tropical and subtropical regions for its nutritional value and consumer demand. As a climacteric fruit, banana undergoes distinct physiological and biochemical transformations during ripening, including peel colour change, pulp softening, conversion of starch to sugars, and development of characteristic flavour and aroma. These changes largely determine fruit acceptability and market quality.

For commercial handling and long-distance transport, banana fruits are harvested at the mature but unripe stage. Ripening is subsequently initiated using ethylene to achieve uniform colour development and synchronized marketing. Ethylene functions as a natural plant regulator that triggers ripening by enhancing respiration and activating enzymes involved in carbohydrate metabolism and cell wall degradation. However, excessive or poorly regulated ethylene exposure can accelerate senescence, increase spoilage, and shorten shelf life.

Postharvest losses in banana are mainly associated with rapid softening and increased susceptibility to mechanical damage and microbial infection during ripening. Elevated respiratory activity during the climacteric phase further hastens deterioration and limits storage potential. Therefore, careful regulation of ethylene application is critical to balance rapid and uniform ripening with preservation of fruit quality.

Although the role of ethylene in fruit ripening is well established, limited information is available on the combined influence of ethylene concentration and pulsing frequency on spoilage development and respiratory behaviour of banana fruits under ambient conditions. A better understanding of these interactions is essential for improving postharvest ripening strategies. Hence, the present study was undertaken to evaluate the effects of different ethylene concentrations and pulsing frequencies on spoilage percentage and respiratory activity during ripening of banana fruits.

Material and Methods

Banana fruits harvested at eighty-five percent physiological maturity were used for the study. The fruits were exposed to four ethylene concentrations, namely fifty, seventy-five, one hundred, and one hundred twenty-five parts per million, combined with different pulsing frequencies in a low-cost ripening chamber. The experiment was conducted using a factorial completely randomized design with three replications.

Spoilage was assessed daily based on visible symptoms such as shrivelling, wrinkling, over-ripening, and decay, and expressed as percentage. Respiratory behaviour was evaluated by measuring oxygen and carbon dioxide concentrations using an oxygen and carbon dioxide analyser. Measurements were taken at regular intervals during storage after proper calibration of the instrument. The recorded data were subjected to statistical analysis following standard procedures.

Results

Postharvest ethylene treatments significantly influenced spoilage development in banana fruits during ripening. Spoilage percentage increased with progression of ripening in all treatments; however, fruits exposed to higher ethylene concentrations exhibited greater spoilage compared to those treated with lower concentrations. The onset of spoilage occurred earlier in fruits receiving higher ethylene doses. Significant interaction effects between ethylene concentration and pulsing frequency indicated that spoilage development was dependent on the combined effect of both factors. Respiratory activity of banana fruits varied significantly among treatments. Ethylene application resulted in increased carbon dioxide concentration accompanied by a decline in oxygen concentration during ripening, confirming the climacteric behaviour of the fruit. Higher ethylene concentrations and increased pulsing frequencies induced an earlier and more pronounced respiratory peak, leading to accelerated ripening and reduced storage life.

Table 1: Spoilage (%) of banana fruits Cv. Grand Naine as influenced by postharvest Ethylene concentrations, and number of pulsings at ambient temperature on 3rd day.

Ethylene concentrations	Number of pulsings in 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 50ppm	0.00	1.26	3.26	2.30	1.70^{c}
Ethylene @ 75 ppm	4.73	4.30	5.20	5.70	4.98^{a}
Ethylene @ 100 ppm	0.00	0.00	0.00	0.00	0.00
Ethylene @ 125 ppm	3.30	3.20	4.20	4.23	3.73^{b}
Mean	2.00^{B}	2.19^{B}	3.16^{A}	3.05^{A}	

FACTORS	CD (5%)	SE (m) ±
Ethylene concentrations (A)	0.99	0.03
Number of pulsings (B)	0.99	0.03
Factor A X B	1.19	0.07

Table 2: Spoilage (%) of banana fruits Cv. Grand Naine as influenced by postharvest Ethylene concentrations, and number of pulsings at ambient temperature on 4thday.

Ethylene concentrations	Number of pulsings in 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 50ppm	0.40	2.26	4.33	3.70	2.67^{c}
Ethylene @ 75 ppm	5.73	5.20	6.23	7.20	6.09^{a}
Ethylene @ 100 ppm	2.20	2.30	2.26	2.13	2.22^{d}
Ethylene @ 125 ppm	4.23	4.70	5.26	6.10	5.07^{b}
Mean	3.14^{D}	3.61^{C}	4.52^{B}	4.78^{A}	

FACTORS	CD (5%)	SE (m) ±
Ethylene concentrations (A)	0.12	0.03
Number of pulsings (B)	0.12	0.03
Factor A X B	0.24	0.06

Table 3: Spoilage (%) of banana fruits Cv. Grand Naine as influenced by postharvest Ethylene concentrations, and number of pulsings at ambient temperature on 5thday.

Ethylene concentrations	Number of pulsings in 24 hrs.			
	6 pulsings	4 pulsings	2 pulsings	1 pulsing
Ethylene @ 50ppm	1.26	-	5.60	5.76
Ethylene @ 75 ppm	-	-	-	-
Ethylene @ 100 ppm	3.40	3.30	3.50	3.23
Ethylene @ 125 ppm	-	-	-	-

The mean values recorded among the bananas treated with ethylene concentrations and number of pulsings during 5th day of storage tabulated at Table 4.9.10. The similar increasing trend in respect of O_2 with advancement of ripening during storage was observed.

Banana is a typical climacteric fruit exhibiting a respiratory rise during ripening. The respiratory rise is induced as fruits are exposed to thresh-hold levels of ethylene, with the subsequent rise in respiration being induced by the autocatalytic production of ethylene after ripening has been initiated. Treatments with ethylene might have triggered the ripening process and resulted in a rise in the respiration rate, which was observed to be proportional to then concentration applied. Higher concentrations of ethylene in the treatments resulted in earlier and higher increase in the respiration rate, and consequently such fruits exhibited higher mean respiration rates in comparison to control fruits. Similar findings have also been reported by Mohamed-Nour and Abu-Goukh (2010) [3] during guava fruit ripening. Ethylene gas has been reported to be many folds effective than ethrel in aqueous solution by many authors (Ibrahim *et al*., 1994). [4]. Similar results were also observed in papaya fruits by Biale, (1975) [5], Pantastico *et al*., (1975) [2] and Selvaraj and Pal, (1982) [7]. Storage of fruits at low temperature resulted in very low respiration rate throughout storage period. The rate of respiration of a fresh produce is a temperature dependent process and is regulated by many enzymes. The low storage temperature results in the reduced enzyme activity, thus lowering the rate of respiration. The rate of respiration is having inverse relationship with the potential storage life of a commodity. The results are in acquiescence with Lam (1990) and Vishnu Prasanna *et al*., (2000) [8, 9].

Table 4: CO_2 (%) of banana fruits Cv. Grand Naine as influenced by postharvest Ethylene concentrations, and number of pulsings at ambient temperature on 1st day.

Ethylene concentrations	Number of pulsings in 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 50ppm	8.80	4.80	4.20	3.70	5.83^c
Ethylene @ 75 ppm	8.66	5.60	11.20	3.70	7.30^a
Ethylene @ 100 ppm	3.70	4.80	5.20	5.30	4.76^d
Ethylene @ 125 ppm	2.80	8.80	8.60	5.60	6.54^b
Mean	5.99^C	6.00^B	7.30^A	4.57^D	

FACTORS	CD (5%)	SE (m) ±
Ethylene concentrations (A)	0.086	0.03
Number of pulsings (B)	0.086	0.03
Factor A X B	0.173	0.06

Table 5: CO_2 (%) of banana fruits Cv. Grand Naine as influenced by postharvest Ethylene concentrations, and number of pulsings at ambient temperature on 2nd day.

Ethylene concentrations	Number of pulsings in 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 50ppm	6.60	3.76	9.63	7.10	6.77^c
Ethylene @ 75 ppm	6.80	5.10	11.23	5.80	7.23^b
Ethylene @ 100 ppm	11.70	7.20	5.60	6.20	7.67^a
Ethylene @ 125 ppm	3.13	7.63	7.80	5.20	5.95^d
Mean	7.06^B	5.92^D	8.56^A	6.08^C	

FACTORS	CD (5%)	SE (m) ±
Ethylene concentrations (A)	0.09	0.03
Number of pulsings (B)	0.09	0.03
Factor A X B	0.18	0.06

Table 6: CO_2 (%) of banana fruits Cv. Grand Naine as influenced by postharvest Ethylene concentrations, and number of pulsings at ambient temperature on 3rd day.

Ethylene concentrations	Number of pulsings in 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 50ppm	8.30	3.60	8.60	5.26	6.44^b
Ethylene @ 75 ppm	9.20	4.30	9.20	4.80	6.87^a
Ethylene @ 100 ppm	4.10	9.66	7.63	6.23	6.10^c
Ethylene @ 125 ppm	3.23	8.86	8.23	3.10	5.84^d
Mean	6.20^C	6.59^B	8.42^A	4.86^D	

FACTORS	CD (5%)	SE (m) ±
Ethylene concentrations (A)	0.10	0.03
Number of pulsings (B)	0.10	0.03
Factor A X B	0.20	0.07

Table 7: CO_2 (%) of banana fruits Cv. Grand Naine as influenced by postharvest Ethylene concentrations, and number of pulsings at ambient temperature on 4th day.

Ethylene concentrations	Number of pulsings in 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 50ppm	7.20	4.60	6.60	4.70	5.77^c
Ethylene @ 75 ppm	6.63	4.73	7.20	8.76	6.83^b
Ethylene @ 100 ppm	14.80	6.20	5.13	4.10	7.56^a
Ethylene @ 125 ppm	2.93	9.23	9.73	5.23	6.78^b
Mean	7.89^A	6.19^C	7.17^B	5.70^D	

FACTORS	CD (5%)	SE (m) ±
Ethylene concentrations (A)	0.11	0.03
Number of pulsings (B)	0.11	0.03
Factor A X B	0.22	0.07

Table 8: CO_2 (%) of banana fruits Cv. Grand Naine as influenced by postharvest Ethylene concentrations, and number of pulsings at ambient temperature on 5th day.

Ethylene concentrations	Number of pulsings in24 hrs.			
	6 pulsings	4 pulsings	2 pulsings	1 pulsing
Ethylene @ 50ppm	3.80	-	5.76	4.60
Ethylene @ 75 ppm	-	-	-	-
Ethylene @ 100 ppm	6.70	7.23	8.30	6.70
Ethylene @ 125 ppm	-	-	-	-

Table 9: O_2 (%) of banana fruits Cv. Grand Naine as influenced by postharvest Ethylene concentrations, and number of pulsings at ambient temperature on 1st day.

Ethylene concentrations	Number of pulsings in 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 50ppm	15.30	16.26	17.26	18.13	16.74^b
Ethylene @ 75 ppm	12.23	15.60	9.20	12.80	12.45^d
Ethylene @ 100 ppm	17.67	15.80	15.30	15.60	16.09^c
Ethylene @ 125 ppm	18.36	14.23	18.53	18.60	17.43^a
Mean	15.89^B	15.47^C	15.07^D	16.28^A	
FACTORS	CD (5%)		SE (m) ±		
Ethylene concentrations (A)	0.10		0.03		
Number of pulsings (B)	0.10		0.03		
Factor A X B	0.21		0.07		

Table 10: O_2 (%) of banana fruits Cv. Grand Naine as influenced by postharvest Ethylene concentrations, and number of pulsings at ambient temperature on 2nd day.

Ethylene concentrations	Number of pulsings in 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 50ppm	16.60	17.80	11.23	14.30	14.98^b
Ethylene @ 75 ppm	14.70	16.60	10.30	15.80	14.35^c
Ethylene @ 100 ppm	9.80	13.30	15.80	14.66	13.39^d
Ethylene @ 125 ppm	17.70	12.70	17.67	17.73	16.47^a
Mean	14.70^C	15.10^B	13.77^D	15.62^A	
FACTORS	CD (5%)		SE (m) ±		
Ethylene concentrations (A)	0.10		0.037		
Number of pulsings (B)	0.10		0.037		
Factor A X B	0.21		0.074		

Table 11: O_2 (%) of banana fruits Cv. Grand Naine as influenced by postharvest Ethylene concentrations, and number of pulsings at ambient temperature on 3rd day.

Ethylene concentrations	Number of pulsings in 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 50ppm	16.60	18.63	13.30	16.20	16.08^b
Ethylene @ 75 ppm	13.30	17.80	16.30	17.10	16.12^b
Ethylene @ 100 ppm	17.50	11.70	13.80	15.70	14.67^c
Ethylene @ 125 ppm	18.60	14.60	15.30	18.30	16.70^a
Mean	16.40^B	15.68^C	14.67^D	16.82^A	
FACTORS	CD (5%)		SE (m) ±		
Ethylene concentrations (A)	0.09		0.03		
Number of pulsings (B)	0.09		0.03		
Factor A X B	0.18		0.06		

Table 12: O_2 (%) of banana fruits Cv. Grand Naine as influenced by postharvest Ethylene concentrations, and number of pulsings at ambient temperature on 4th day

Ethylene concentrations	Number of pulsings in 24 hrs.				
	6 pulsings	4 pulsings	2 pulsings	1 pulsing	Mean
Ethylene @ 50ppm	15.10	18.80	14.30	16.73	16.23^b
Ethylene @ 75 ppm	15.60	17.36	15.20	14.20	15.59^c
Ethylene @ 100 ppm	7.70	15.30	16.733	16.80	14.13^d
Ethylene @ 125 ppm	18.73	14.80	15.80	18.33	16.91^a
Mean	14.28^C	16.56^A	15.50^B	16.51^A	
FACTORS	CD (5%)		SE (m) ±		
Ethylene concentrations (A)	0.09		0.03		
Number of pulsings (B)	0.09		0.03		
Factor A X B	0.18		0.06		

Table 13: O_2 (%) of banana fruits Cv. Grand Naine as influenced by postharvest Ethylene concentrations, and number of pulsings at ambient temperature on 5th day

Ethylene concentrations	Number of pulsings in 24 hrs.			
	6 pulsings	4 pulsings	2 pulsings	1 pulsing
Ethylene @ 50ppm	18.36	-	18.70	17.80
Ethylene @ 75 ppm	-	-	-	-
Ethylene @ 100 ppm	10.70	15.76	16.73	17.56
Ethylene @ 125 ppm	-	-	-	-

Discussion

The findings of the present study demonstrate that postharvest ethylene application plays a crucial role in regulating ripening behaviour, spoilage development, and respiratory metabolism in banana fruits. Increased ethylene concentration accelerated ripening processes, resulting in enhanced softening and tissue breakdown, which subsequently increased susceptibility to spoilage.

The observed rise in carbon dioxide production and reduction in oxygen concentration reflect intensified metabolic activity associated with the climacteric phase of ripening. Excessive respiratory activity caused by higher ethylene exposure may hasten depletion of metabolic reserves, thereby shortening shelf life. The significant interaction between ethylene concentration and pulsing frequency highlights the importance of controlling both factors to avoid excessive ripening and quality deterioration.

These results emphasize that while ethylene is indispensable for initiating uniform ripening, uncontrolled application can negatively impact fruit quality. Therefore, optimization of ethylene exposure is essential for maintaining a balance between ripening efficiency and storage stability.

Conclusion

Banana fruits exhibit a typical climacteric respiratory pattern during ripening, which is markedly influenced by postharvest ethylene application. Higher ethylene concentrations and unsuitable pulsing frequencies accelerate ripening, increase respiratory activity, and enhance spoilage, ultimately reducing storage life. Appropriate regulation of ethylene concentration and pulsing frequency is essential to achieve uniform ripening while minimizing postharvest losses and preserving fruit quality.

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