

Effect of Temperature on the Ripening Behavior and Quality of Banana Fruit

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ABSTRACT

The study was conducted to find out the effect of temperature, ethylene and their interaction on the speed of ripening and quality of banana fruit. The interaction between ethylene and temperature showed that ethylene had a greater effect on ripening between the range of 14-18°C than at 20°C. The eating quality of banana fruit was affected by the stage of ripeness rather than the temperature of ripening or storage. All bananas ripened at 20°C, completed their chemical processes faster than their physical processes. 20°C seemed to be the optimum temperature to ripen the fruits to achieve good eating quality in terms of TSS, color development and flavor. Bananas ripened at low temperatures (14 and 16°C) with ethylene had acceptable eating quality with firmer pulp.

Key Words: Banana; Ethylene; Fruit ripening

INTRODUCTION

The dessert banana of international trade is botanically known as *Musa AAA*. It belongs to the family Musaceae. It is one of the most important fruit crops in the world. It is estimated that 100 million people subsist on banana and plantains as their main energy source (Rowe, 1981). Storage temperature influences the ripening changes in bananas (Esguerra *et al.*, 1992). An increase in storage temperatures between 14 and 30°C enhances the rate of ripening and the fruit softens at a faster rate (Smith, 1989). The respiration rate and ethylene production were also shown to increase with an increase of temperature (Weixin *et al.*, 1993). High temperature can also result in damage to ripening fruit (Smith & Thompson, 1987; Semple & Thompson, 1988). Temperatures less than 14°C can cause uneven ripening due to chilling injury (Stover & Simmonds, 1987). Temperature affects the changes that occur during ripening, the quality of ripe fruit and the marketable life of banana fruit. Therefore, this research was initiated from the conversations with the UK retail section to investigate the effect of different ripening temperatures on the ripening behavior and quality of ethylene treated and untreated bananas.

MATERIALS AND METHODS

This research was carried out in the Post harvest lab of Cranfield University UK. Pre-climacteric Cavendish bananas were obtained from C.E. Wilkinson in Bedford UK in 1997. Hands of fruits, which were uniform in color and undamaged were selected and cut into fingers. The cut portions of the fingers were dipped in 500-ppm thiabendazole and then allowed to dry in the air. Half of the bananas were treated with 1000-ppm ethylene for 24 h while the remainder were left untreated. Ethylene treated and untreated bananas were stored at 14, 16, 18 or 20°C at 80-85% RH until they reached color stage 6.

Assessment of Fruit Quality. The quality of ripe fruit was assessed by two methods.

1. Objective methods. The fruits were analyzed when they reached color score of 6 (fully yellow) according to the color chart. The weight of fruits in the bag was taken before and after storage (when ripe). The difference between the initial and final weight was expressed as weight loss as a percentage of initial fruit weight. The peel color was measured using a Minolta color meter. Peel and pulp firmness were measured by an Instron Universal testing machine applying a load of 100 N. Total soluble solids (TSS) were determined with a refractometer (Digital Rafractometer model PRI, Atago Co. Ltd). Starch was estimated by Iodine test.

2. Subjective assessments (sensory evaluation). A panel of eight assessors was selected from the college and the tests involved individual assessment in isolated tasting conditions under a standard light source. The judges were asked to assess pulp flavour, sweetness, off flavour, astringency and acceptance on five points scale as follows:

- **Flavour**

I. Low banana flavour, II. Moderate banana flavour, III. Moderate to high banana flavour, IV. Good banana flavour and V. Very good banana flavour

- **Sweetness**

I. Low sweetness, II. Moderate sweetness, III. Moderate to high sweetness, IV. Good sweetness and V. Very good sweetness

- **Off-odours**

I. No, or very low, off-odour, II. Low off-odour, III. Moderate off-odour, IV. High off-odour and V. Very high off-odour

- **Astringency**

I. No, or very low, astringency, II. Low astringency, III. Moderate astringency, IV. High astringency and V. Very high astringency

- **Acceptance**

I. Low acceptability, II. Moderate acceptability, III. Moderate to high acceptability, IV. High acceptability and V. Very high acceptability

The scores marked by panellists were collected and an average was calculated for each parameter and sub-parameter. These averages were used for statistical analysis. Means of treatments were calculated and presented in the form of tables. Data were processed and analysis of variance was carried out based on factorial using MSTATC, a P.C. based programme. LSD at P= 0.05 was used to test for significant difference of results where applicable.

RESULTS AND DISCUSSION

Storage life (speed of ripening). Statistical analysis showed significant differences for ethylene (Table II) and temperature (Table I) at the P=0.001 level. Analyses of variance showed significant differences for interaction of ethylene and temperature (Table III) at the P= 0.01 level. As expected, ethylene treated bananas ripened earlier than untreated bananas at all temperatures. Ripening temperature was found to influence the rate of ripening. The fruits kept at lower temperatures took a significantly longer time to ripen than the fruits at higher temperatures. The interaction due to ethylene and temperature showed that differences between the ethylene treated and non-treated fruits were statistically similar at 14, 16 and 18°C (3 to 3.5 days) but the difference was smaller at 20°C (only 1.5 days). In this investigation, there was an interaction between temperature and ethylene with ethylene having a greater effect at 14 to 18°C than at 20°C. This is because climacteric fruits give off ethylene during ripening (Sacher, 1973) and this ethylene increases considerably as the ripening processes advance (Rao & Chundawat, 1986). The sensitivity of bananas to ethylene is very low, within the range of 0.01-1.0 ppm (Thompson & Seymour, 1982), and it increases with increasing temperatures (Liu, 1978). Therefore, it can be concluded that internal ethylene was produced by external ethylene treated bananas at 14 to 18°C. This may have been

Table I. Effect of temperature on the different quality parameters of banana fruit

Parameters	Temperature				LSD (P=0.05)	CV
	14°C	16°C	18°C	20°C		
Storage life(day)	9.5	7.8	7.0	4.7	0.59	8.0%
Weight loss %	4.3	4.8	5.1	5.6	0.43	8.6%
Weight loss per day	0.45	0.64	0.74	1.17	0.04	6.3%
Peel colour a*	-3.71	-2.94	-2.16	-1.08	0.71	28.0%
b*	+50.54	+50.39	+50.94	+52.50	NS	3.7%
Fruit firmness	4.85	4.13	3.45	2.41	0.17	6.1%
Pulp/peel ratio	1.79	1.83	2.19	2.27	0.09	4.5%
TSS%	21.6	22.0	22.2	22.5	0.55	2.4%
Starch %	18	16	14	13	2.5	16.3%
Flavour	2.5	2.6	3.0	3.2	0.55	19.0%
Sweetness	2.8	3.0	3.2	3.3	0.35	11.2%
Off-odour	2.0	1.8	1.3	1.3	0.21	13.1%
Astringency	2.3	1.9	1.9	1.3	0.36	19.6%
Acceptability	2.5	2.8	3.3	3.5	0.33	10.8%

Table II. Effect of ethylene treatment on the different quality parameters of banana fruit

Parameters	Ethylene treatment			CV
	0 ppm	1000 ppm	LSD(P=0.05)	
Storage life	8.6	5.9	0.42	8.0%
Weight loss %	5.5	4.4	0.03	6.3%
Weight loss per day	0.69	0.81	0.06	6.3%
Peel coloura*	-2.62	-2.32	NS	28.0%
b*	+50.77	+51.42	NS	3.7%
Fruit firmness	4.23	3.19	0.24	6.2%
Pulp/peel ratio	1.98	2.06	0.06	4.5%
TSS	21.6	22.6	0.55	2.4%
Starch %	18	12	1.8	16.3%
Flavour	2.6	3.1	0.39	19.0%
Sweetness	2.9	3.2	0.25	11.2%
Off-odour	1.8	1.4	0.14	13.1%
Astringency	2.1	1.6	0.26	19.6%
Acceptability	2.9	3.1	0.23	10.8%

insufficient to initiate ripening quickly in untreated bananas, which were kept at these temperatures. In contrast, the internal ethylene produced by ethylene treated bananas at 20°C was sufficient to start the ripening in untreated bananas, which were kept at the same temperature. Therefore, the duration of the ripening process was less in ethylene treated and untreated bananas at 20°C compared to those at other temperatures.

Weight loss percentage. The results are shown in Table I, II and III. Analyses of variance showed significant differences for ethylene and temperature at the P=0.001 level. Ethylene treated bananas showed significantly less weight loss than untreated bananas at color score 6. Bananas kept at higher temperatures showed significantly greater weight loss than those at lower temperatures. A significant difference was also found in bananas due to the interaction of ethylene and temperature. These differences indicated that the difference in total weight loss between ethylene treated and untreated bananas increased with increased temperature. Weight loss per day showed that the differences in weight losses between treated and untreated bananas decreased with increased temperatures (Table III).

The lowest difference in weight loss per day and the biggest difference in total weight losses were observed in ethylene treated and untreated bananas at 20°C. The higher weight loss at higher temperatures could be related to the higher evapo-transpiration rate and respiration rate at the higher temperatures as previously reported by Lebibet *et al.* (1995). The interaction between the effects of ethylene and temperatures showed that ethylene treated bananas at higher temperatures gave off as much ethylene as those at the threshold concentration. Therefore, ripening was initiated quickly in untreated bananas so that their respiration and transpiration processes increased to a similar level to those that were ethylene treated. Thus, the difference in weight loss per day was lowest at 20°C between ethylene treated and untreated bananas. The greater difference in total

weight loss between untreated and treated bananas at 20°C was due to the difference in ripening periods.

Peel color. The results regarding a* and b* values are given in Table I and II, respectively. Statistical analysis showed significant differences for a* (greenness) values at the P=0.001 level but differences for b* (yellowness) were non-significant at the P=0.05 level. No significant difference was found between ethylene treated and non-treated bananas for a* values (greenness). Bananas ripened at higher temperatures were significantly less green than those at lower temperatures. The interaction between ethylene and temperature (Table III) showed non-significant differences for a* values. The trend towards a less green and more yellow fruit at the higher temperatures is important in terms of their market appearance because customers use skin color to decide the optimum eating quality. Although the results proved not to be statistically significant in relation to b* values (yellowness), there was an indication that bananas ripened at higher temperatures were slightly more yellow than those ripened at lower temperatures.

Peel firmness. Statistical analysis showed significant differences for ethylene (Table II) and temperature (Table I) at the P=0.001 level and for interaction (Table III) at the P=0.05 level. Ethylene treated bananas were significantly softer than untreated bananas. Bananas kept at higher temperatures were also significantly softer than those at lower temperatures. The interaction between different treatments of ethylene and temperature indicated that ethylene had a significant effect at different temperatures. The higher the ripening temperature the lower the effect of ethylene on softening of banana fruit was found.

The reduced values of firmness, greater values of TSS and reduced starch percentages of fruit with ethylene treatment and at higher temperatures indicated that chemical processes of these bananas at color stage 6 were at a more advanced stage of ripening. The increased softness of ripe bananas at higher temperatures was due to the greater starch hydrolysis and greater weight loss during ripening. Thompson (1996) states that the softening of banana fruit during ripening is associated with three processes: firstly, the conversion of starch to sugars, since starch granules

have a structural function in the cell; secondly, the breakdown of pectin substances; and the third possibility is the movement of water from the peel of the banana to its pulp during ripening. The later possibility may have affected the turgidity of the skin, which would have been enhanced by transpirational losses. The higher weight loss and greater TSS support the first and third possibilities for the softening of banana fruit in the present research.

The interaction between temperature and ethylene in firmness showed that differences in firmness between ethylene treated and untreated bananas were less at higher temperatures than at lower temperatures. The reason could be starch hydrolysis or conversion of sugars. Bananas, which were ethylene treated and untreated at higher temperatures, were probably at the same stage of ripening. These bananas showed a non-significant difference between TSS at 18 and 20°C. The non-significant interaction for TSS also confirmed that bananas treated with ethylene and untreated at higher temperatures were at an equally advanced stage of ripening so that percentages of TSS were similar.

Pulp/peel ratio. The results are shown in Tables I, II and III. Analyses of variance showed significant differences for ethylene and temperature at the P=0.05 level. Ethylene treated bananas showed greater pulp/peel ratios than untreated bananas. Bananas ripened at higher temperatures (18 and 20°C) showed a significantly higher pulp/peel ratio than those ripened at low temperatures (14 and 16°C). The bananas ripened at 14 and 16°C showed similar pulp/peel ratio. This was due to the advanced stage of ripening because pulp/peel ratio in banana fruit has previously been shown to increase with ripening (Montenegro, 1988; Acedo & Bautista, 1989). The second reason for the greater pulp/peel ratio at higher temperatures could be due to the greater weight loss. Because the pulp mass of banana fruit increases during ripening due to an increase in water content, it could be due to the movement of water from peel to pulp and to the surrounding air.

Total soluble solids (TSS%). The results are shown in Tables I, II and III. Statistical analysis showed significant differences for ethylene and temperatures at the P=0.001

Table III. Interaction ethylene X temperature

Quality parameters	Temperature x Ethylene								LSD (P=0.05)
	0 ppm				1000 ppm				
	14°C	16°C	18°C	20°C	14°C	16°C	18°C	20°C	
Storage life	11.0	9.5	8.5	5.5	8.0	6.0	5.5	4.0	0.84
Weight loss %	4.43	5.27	5.80	6.37	4.08	4.38	4.45	4.75	0.62
Weight loss (pd)	0.40	0.55	0.68	1.15	0.51	0.73	0.81	1.18	0.06
Peel colour a*	-3.85	-3.27	-2.22	-1.15	-3.58	-2.62	-2.09	-1.01	NS
b*	+50.1	+50.1	+50.8	+51.9	+50.9	+50.6	+51.0	+53.0	NS
Fruit firmness N	5.61	4.75	3.83	2.76	4.11	3.51	3.08	2.06	0.34
Pulp/peel ratio	1.71	1.80	2.16	2.25	1.86	1.87	2.22	2.29	NS
TSS	21.1	21.5	21.7	22.1	22.2	22.0	22.8	23.0	NS
Starch %	21	20	18	15	15	13	10	10	NS
Flavour	2.5	2.5	2.5	3.0	2.5	2.8	3.5	3.5	NS
Sweetness	2.5	3.0	3.0	3.1	3.0	3.0	3.5	3.5	NS
Off-odours	2.0	2.0	1.5	1.5	2.0	1.5	1.0	1.0	NS
Astringency	2.5	2.3	2.3	1.3	2.0	1.5	1.6	1.3	NS
Acceptability	2.5	2.5	3.0	3.5	2.5	3.0	3.5	3.5	NS

and $P=0.05$ levels respectively. Ethylene treated bananas possessed significantly greater TSS than untreated bananas. Bananas kept at higher temperatures showed greater TSS than those at lower temperatures. Bananas ripened at 14 and 20°C showed significant differences in their TSS. However, there were no significant differences between bananas ripened at 16, 18 and 20°C. No significant difference could be recorded between the interaction of ethylene and temperature. This was also due to the advanced stage of ripening, because bananas ripened at 14°C could not complete their ripening.

Starch percentage. The results are given in Table I, II and III. Statistical analysis showed significant differences for ethylene and temperature at the $P=0.001$ level. Ethylene treated bananas showed a significantly reduced starch percentage compared to untreated bananas. Bananas at higher temperatures showed a lower starch percentage than those at lower temperatures. Bananas ripened at 18 and 20°C showed similar starch percentages in statistical terms. Bananas ripened at 20°C showed significantly lower starch percentages than those ripened at 16 and 14°C. The interaction between ethylene and temperature showed non significant results at ($P=0.05$) levels.

Sensory evaluation. Ethylene treated bananas had a consistently better flavor than untreated bananas (Table II). Panelists gave higher scores for bananas, which were ripened at higher temperatures (Table I) than those ripened at lower temperatures. The interaction between ethylene and temperature (Table III) showed non-significant results for flavor. Ethylene treated bananas were significantly sweeter than untreated bananas (Table II). Bananas ripened at higher temperatures were also significantly sweeter than those at low temperatures. No significant interaction could be found between ethylene treatments and temperatures. Ethylene treated bananas were significantly less astringent (Table II) than untreated bananas. Bananas ripened at higher temperatures showed lower off odors and astringency than those ripened at lower temperatures. There was no significant interaction between ethylene and temperature for off-odor and astringency. Ethylene treated bananas showed significant differences with untreated bananas regarding acceptability. Panelists gave the highest score for acceptability to the fruit ripened at higher temperatures (18 and 20°C) (Table I). The overall situation indicated that bananas ripened at 20 and 14°C secured the highest and the lowest scores for acceptability. The sensory evaluation in relation to flavor, sweetness, astringency and acceptability of fruits indicated significant superiority of bananas ripened at higher temperatures and with ethylene treatment over those ripened at lower temperatures and without ethylene treatment (untreated). It can safely be assumed that eating quality measured by sensory evaluation was affected by the stage of ripeness rather than temperature and ethylene treatment. This is because that ripeness stage of banana fruit has a very influential effect on their flavor and acceptability

(Esguerra *et al.*, 1992). The bananas ripened at higher temperatures with ethylene treatment achieved the highest score for acceptability. The reason was clear: they had a good flavor, sweetness and less astringency. Bananas ripened at lower temperature were significantly firmer but still had acceptable flavor. Therefore, low temperature (14°C) can be used to achieve firmer bananas which might reduce mechanical damage during handling because a firmer fruit would be better able to withstand rough handling during marketing (Peacock, 1980).

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