EFFECT OF FRUIT SIZE AND TEMPERATURE ON THE SHELF LIFE AND QUALITY OF RIPE BANANA FRUIT*

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ABSTRACT

A study was undertaken at Cranfield University, Silso College, UK during 1999. The objective was to investigate the effect of fruit size, ethylene and ripening temperature on the shelf life and quality of ripe banana fruit. It was concluded that ethylene treatment with 1000 ppm for 24 hours proved better to initiate the ripening in both sizes (small and large) of banana. It was observed that there was no difference existed between shelf life of small or large size bananas of similar maturity. Speed of ripening between small and large fruit also did not vary significantly but total soluble solids were greater (22.7% and 22.6%) in smaller bananas than larger ones (22.0 and 21.7%) at 16°C and 18°C. For interaction between fruit size and colour stage, small bananas showed a quicker and greater response to higher temperature at colour stage 3 than larger ones. The difference in ripening temperature used in Britain and other countries of Europe is due to their external appearance rather than internal quality.

KEYWORDS: Bananas; temperature; ethylene; keeping quality; Great Britain.

INTRODUCTION

Banana is an important fruit crop of the world. It has a special place in human diet (10). It is chiefly eaten raw as a dessert fruit, because in the ripe stage it is sweet and easily digestible. It is useful for patients with peptic ulcers, for treatment of infant diarrhoea, celiac disease and colitis (8). It is also ideal for the patients suffering from gout, arthritis, kidney disorders blood pressure and heart problem. It is low in fats, cholesterol and salts (12). It can make a useful contribution to the vitamin A, C and B6 contents of the diet, and is an important and immediate source of energy, being oftenly eaten by sportsmen and women during competition (8). A medium sized banana contains 280 kilojoules, which is significantly more than deciduous or citrus fruits (12).

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The size of individual units of a product can significantly affect consumer appeal, handling practices, storage potential and market selection (5). It has also been shown that moisture loss of fruit depends upon size, maturity, storage temperature and humidity (9). The best commercial ripening temperature in Britain is considered to be 16°C (13). In other countries of Europe, recommended commercial ripening temperature is 18°C. The question arises as to why the variation exists in recommended ripening temperature.

The control of ripening temperature is important to obtain better quality fruit within specific marketable life so the temperature influences the ripening changes in banana.

The present experiment was started to find out the best temperature for the ripening and quality wise differences between small and large bananas.

MATERIALS AND METHODS

This research was conducted in post harvest laboratory of Cranfield University, Silso College, U.K, during 1999. Pre-climacteric Cavendish bananas of two sizes (14 cm and 20 cm) at colour stage-1 were obtained from Wilkinson in Belford, UK. Undamaged bananas of uniform colour were selected and cut into fingers. The cut portions were dipped in 500 ppm thiabendazol (fungicide) and then allowed to dry in the air. Bananas were treated with 1000 ppm ethylene for 24 hours. Ten fingers each of small and large bananas were kept at 16°C and 18°C both with 80-85 percent relative humidity. Layout of the experiment was factorial design with four replications. When fruits kept at both temperatures reached colour stage-3, two fingers from each replication in each treatment were analyzed and remaining fruits transferred to 20°C for ripening. Two fingers were randomly selected from each replication in each treatment for daily analysis. These were earmarked at the start of the experiment. During this period (at 20°C) two fingers of each replication in each treatment were again analyzed daily until these reached colour stage 6. Sensory evaluation data were collected when fruits were fully ripened (colour stage-6).

Assessment of fruit ripening (colour stage) and quality

Ripening of banana fruit was assessed according to peel colour compared with a colour chart as described by Stover and Simmonds (12). For quality

assessment two methods i.e. objective method and subjective method were used.

Objective methods: The peel colour was measured by colorimeter. A positive (a*) values corresponding to the degree of redness while A* negative value corresponding to the degree of greenness. The positive values (b*) represents the degree of yellowness and negative (b) represents the blueness. Peel firmness was measured using an instron universal testing machine (model 2211) with an 8 mm cylindrical probe. TSS were measured using refractometer. Starch percentage was measured by the technique recommended by Blankenship *et al.* (2).

Individual fruit was weighed using a digital balance (precise 60000) and cumulative weight loss was calculated as follows:-

$$\text{Weight loss}(\%) = \frac{Wo\text{-}Wi}{Wo} \times 100$$

where Wo = original weight and Wi = weight at sampling (when banana reached colour stage 6).

Weight loss percentage per day was calculated using the formula: TWP/SC; where TWP stands for total weight loss percentage at colour stage 6 and SC for storage life (total days when banana reached colour stage 6 from pre-climacteric stage).

Subjective methods (sensory evaluation): The fruits were removed from storage at colour score 6. Panel of eight assessors was selected from college and the tests involved individual assessment in isolated testing condition under a standard light source. The Judges were asked to assess pulp flavour, sweetness and acceptance on life point's scale as follows:

1. Low
2. Moderate
3. Moderate high
4. Good/high
5. Very good/very high.

The scores marked by panelists were collected and an average was calculated for each parameter and sub-parameter. The averages were used

for statistical analysis. Means of treatments were calculated and presented in the form of tables.

Statistical analysis

Data were processed and analysis of variance (ANOVA) was carried out based on factorial design using MSTATC programme with four replications. LSD (P= 0.05) was used to test for significant differences of results where applicable.

RESULTS AND DISCUSSION

Storage life (speed of ripening)

The results (Table 1) indicated no significant difference in speed of ripening between smaller and large size fruit. Bananas kept at 18°C reached colour stage 3 earlier than those which were kept at 16°C. Bananas at both temperatures took four days to reach colour stages 3 to 6. The total time needed for fruit to reach colour stage 6 was significantly longer for the fruits transferred from 16°C to 20°C than those transferred from 18°C to 20°C. There was no significant interaction between these factors. It was confirmed, that high temperature accelerated the ripening of banana fruit. There was no difference between speed of ripening in small and large bananas which could be due to the exogenous ethylene treatment. Marriott (6) found that ethylene at 1-ppm for 24 hours was enough to induce prompt initiation of ripening. No evidence could be found in the literature which suggests that either small or large size bananas of similar maturity have any variability in response to exogenous ethylene. So it can be concluded that ethylene treatment with 1000 ppm for 24 hours was sufficient to initiate the ripening in both sizes of banana fruits.

Table 1. Effect of fruit size and temperature on the storage life (days) of banana at different stages).

Colour stage	Temperatures and fruit sizes (days to reach colour stage)				
	16°C		18°C		Mean
	Small	Large	Small	Large	(days)
Colour stage 3	3.0	3.0	2.0	2.0	2.5
Colour stage 3 to 6	4.0	4.0	2.0	2.0	4.1
Colour stage 6	7.0	7.5	6.0	6.0	6.6
Mean (days)	4.6	5.0	4.0	4.0	

P = 0.05%, Temperature = 0.23, Other all are = NS, CV = 9.2%

Weight loss

Smaller bananas showed significantly greater weight loss at colour stage 3 and colour stage 6 than larger bananas (Table 2). Bananas stored at 16°C also showed greater weight loss than those stored at 18°C upto colour stage 3. However, at colour stage 6, trend was changed and total weight loss was greater in bananas, which were transferred from 18°C to 20°C than those transferred from 16°C to 20°C. There was interaction between fruit size and colour stage. The difference in weight loss between both sizes of fruit was higher at colour stage 6. The interaction between temperature and colour stage showed that difference of weight loss between two temperatures was significantly greater between colour stage 3 and 6. The greater weight loss in smaller banana might be due to greater respiration and transpiration rate. This effect has previously been noted in potatoes by Ben-Yehoshua (1), who stated that small potatoes had higher respiration rate than larger ones of the same variety. The findings of Ben-Yehoshua (1) further reported that fruit size affected water loss and transpiration rate was greater in smaller fruit such as oranges compared to large fruit such as grape fruit. The interaction between fruit size and colour stage indicated that small bananas, when transferred from a lower to higher temperature responded immediately to higher temperature. Respiration and transpiration became greater in small bananas than larger ones so more weight loss occurred in small than larger ones at colour stage 3 to 6.

Table 2. Effect of fruit size and temperature on weight loss of banana (%) at different stages.

Colour stage	Temperatures and fruit sizes				
	16°C		18°C		Mean
	Small	Large	Small	Large	percentage
Colour stage 3	1.55	1.27	1.36	1.22	1.35
Colour stage 3 to 6	3.93	3.51	4.56	4.26	4.06
Colour stage 6	5.42	5.86	5.31	5.31	5.33
Mean percentage	3.64	3.17	3.92	43.59	

LSD (P = 0.05)			
Fruit size	= 0.09	Colour stage	= 0.11
Temperature	= 0.09	Fruit size x colour stage	= 0.16
Fruit size x temperature	= NS	Temp. x colour stage	= 0.16
Fruit size x temperature x colour stage	= NS	CV	= 4.7%

Peel colour

The bananas, transferred from 18°C to 20°C were significantly less green than those transferred from 16°C to 20°C at colour stage 6 (Table 3a and 3b). Fruits at an advanced colour stage of ripening were significantly less green and more yellow than those at any early colour stage of ripening.

In terms of peel colour development, it has been observed that breakdown of chlorophyll is temperature dependent. The dark yellow and light green colour at advanced stages of ripening was due to the completion of ripening processes. This is because chlorophyll content decreases slowly during ripening and peel yellowing during ripening is due to chlorophyll breakdown (7).

Table 3(a) Effect of fruit size and temperature on the peel colour values (yellowness) of banana fruit at different stages.

Colour stages	Temperatures and fruit sizes				Mean
	16°C		18°C		
	Small	Large	Small	Large	values
Colour stage 3	-14.68	-14.05	-13.04	-13.94	-13.93
After one day	-9.14	-9.21	-8.58	-8.67	-8.90
After two days	-7.82	-7.90	-6.49	-7.51	-7.45
After three days	-5.45	-6.69	-5.18	-5.56	-5.72
Colour stage 6	-3.61	-3.37	-3.09	-3.30	-3.34
Mean	-8.14	-8.25	-7.22	-7.80	

a* Values (greenness) of banana fruits at beginning of experiment (small = -19.89, large = -19.98).
P = 0.05%

Fruit size	= NS	Colour stage	= 0.71
Temperature	= 0.44	Fruit size x stage	= NS
Fruit size x temperature	= NS	Temp. x colour stage	= NS
Fruit size x temperature x colour stage	= NS	CV	= 12.8%

Table 3(b) Effect of fruit size and temperature on the peel colour values (greenness) of banana fruit at different stages.

Colour stages	Temperatures and fruit sizes				Mean
	16°C		18°C		
	Small	Large	Small	Large	values
Colour stage 3	+41.78	+41.32	+43.37	+43.99	+42.64
After one day	+47.72	+47.03	+48.39	+47.94	+47.77
After two days	+48.21	+47.91	+48.87	+49.84	+48.71
After three days	+50.48	+49.94	+51.77	+50.62	+50.70
Colour stage 6	+51.23	+51.47	+53.13	+52.66	+52.12
Mean	+47.88	+47.53	+49.13	+49.01	

b* Values (yellowness) of banana fruits at beginning of experiment : (Small = + 34.07, large = +34.46)
P = 0.05%

Fruit size	= NS	Colour stage	= 0.64
Temperature	= NS	Fruit size x colour stage	= NS
Fruit size x temperature	= NS	Temp. x colour stage	= NS
Fruit size x temperature x colour stage	= NS	CV	= 7.7%

Peel firmness

The data showed that smaller fruits were significantly softer than large fruit (Table 4). The fruits transferred from higher temperature (18°C) were also significantly softer than those transferred from lower temperature (16°C). Softness was also significant at colour stage 6 than other stages. There was an interaction between fruit size and colour stage. The interaction showed that differences between small and large bananas regarding peel firmness values were significantly greater at one and three days after colour stage 3 but statistically similar to other colour stages. There was also interaction between temperature and colour stage. Bananas of both temperature (16°C and 18°C) showed similar differences regarding firmness values at colour stage 3, two days after colour stage 3 and at colour stage 6. However, the differences were greater after one and three days of colour stage 3.

Table 4. Effect of fruit size and temperature on the peel firmness (Nmm^{-1}) of banana fruit at different stages.

	Temperatures and fruit sizes				
	16°C		18°C		Mean
	Small	Large	Small	Large	(Nmm^{-1})
Colour stage 3	6.68	7.33	6.77	6.67	6.94
After one day	5.92	6.56	5.15	6.39	6.01
After two days	5.33	5.38	4.73	4.98	5.10
After three days	3.11	4.00	2.56	2.60	3.07
Colour stage 6	2.40	2.36	2.00	2.19	2.24
Mean	4.73	5.12	4.24	4.59	

Peel firmness of banana fruits at beginning of experiment : small fruit : 24.16, large fruit : 23.53 (Nmm^{-1})
P = 0.05%

Fruit size	= 0.15	Colour stage	= 0.24
Temperature	= 0.15	Fruit size x colour stage	= 0.34
Fruit size x temperature	= NS	Temp. x colour Stage	= 0.34
Fruit size x temperature x colour stage	= 0.49	CV	= 7.4%

The soft small bananas at colour stage 6 indicated that these ripened earlier than larger bananas. This is because the softening of bananas is associated with degradation of starch. The softer fruit at higher temperature could be due to the fact that these had completed more ripening process than those at lower temperature. The interaction showed that variation in fruit size had greater effect at initial colour stages of ripening than at the final stages. This effect could be attributed to the greater weight loss of smaller fruits when removed from the lower temperature to higher temperature; they suddenly lost more weight and might completed the ripening processes faster than the larger ones. As a result TSS increased from 13.5 to 16.3 percent and 12.5 to 18.4 percent in small bananas at both temperatures, respectively during

ripening from colour stage 3 to one day after colour stage 3 (Table 5). In contrast TSS increased from 11.3 to 14.6 percent and 12.8 and 15.2 percent in large bananas during same period. This indicated that small bananas had completed more ripening processes than larger ones. It has been previously observed (3) that firmness in bananas is closely related to reducing sugar and starch contents during ripening.

Total soluble solids (%)

Analyses of variance showed significant differences for fruit size, temperature and colour stage (P = 0.05) (Table 5). The other factors were non-significant. The results confirmed the previous findings. Smaller bananas showed significantly greater TSS than larger bananas. Bananas transferred from 18°C to 20°C also had higher TSS than those, transferred from 16°C to 20°C. Total soluble solids increased with ripening stage of bananas. No significant interaction was found between any two factors. The higher TSS in small fruit could be due to the higher hydrolysis of starch at full ripe stage. This characteristic had also been observed in tomatoes (9) where small tomato fruits had greater amount of reducing sugars than large ones.

Table 5. Effect of fruit size and temperature on the total soluble solids (%) of banana.

	Temperatures and fruit sizes				
	16°C		18°C		Mean
	Small	Large	Small	Large	TSS (%)
Colour stage 3	13.5	11.3	12.5	12.8	12.5
After one day	16.3	14.6	18.4	15.2	16.1
After two days	21.1	18.5	20.3	18.6	19.6
After three days	21.4	10.7	22.5	20.2	21.0
Colour stage 6	22.7	22.0	22.6	21.7	22.3
Mean	18.8	17.2	19.3	17.7	

TSS percentage of banan fruit beginning of experiment : small fruit = 6.6%, large fruit = 7.2%.
P = 0.05%

Fruit size	= 0.41	Colour stage	= 0.66
Temperature	= 0.41	Fruit size x colour stage	= NS
Fruit size x temperature	= NS	Temp. x colour stage	= NS
Fruit size x temperature x colour stage	= NS	CV	= 5.1%

Starch percentage

Analysis of variance showed the same picture as in TSS. Small fruits had a significantly lower starch percentage than larger ones (Table 6). Bananas transferred from 18°C to 20°C showed significantly reduced percentage of starch compared to those transferred from 16°C to 20°C. Bananas of different

colour stages showed significant differences in starch percentage. The highest reduction in starch was found at colour stage 6. There was no significant interaction between these factors.

Table 6. Effect of fruit size and temperature on starch of banana fruit (%) at different stages.

	Temperatures and fruit sizes				
	16°C		18°C		Mean
	Small	Large	Small	Large	(%)
Colour stage 3	50	43	36	38	41
After one day	37	40	31	32	35
After two days	30	36	25	34	31
After three days	19	28	18	23	22
Colour stage 6	18	17	15	16	17
Mean	31	33	25	29	

Initial starch percentage at the beginning of experiment : small fruit = 95%, large fruit = 95%.
P = 0.05%
Fruit size = 2.37, Temperature = 2.37, Colour stage = 3.74, All others = NS, CV = 8.5%

Sensory evaluation

All fruits showed statistically similar flavour (Table 7). Panelists could not differentiate between bananas in relation to their sweetness (Table 8). Astringency and off-flavour were negligible in all fruits, but astringency was reduced in those which were transferred from 18°C to 20°C (Table 9 and 10). Panelists gave higher scores for acceptability to those, which were transferred from 16°C to 20°C. However, there was an indication that bananas which were transferred from 16°C to 20°C received slightly higher score than those which were transferred from 18°C to 20°C.

Table 7. Effect of fruit size and temperature on flavour of banana fruit at colour stage 6 [5 = maximum scores (very good) 1 = minimum score (low)]

Temperatures	Fruit sizes		Mean
	Small	Large	temperature
16°C	3.0	3.6	3.3
18°C	3.2	3.5	3.4
Mean of size	3.1	3.6	

P = 0.05%, All factors = NS (non-significant), CV = 15.4%

Table 8. Effect of fruit size and temperature on sweetness of banana fruit at colour stage 6 [5 = maximum scores (very good) 1 = minimum score (low)].

	Fruit sizes		Mean of
Temperatures	Small	Large	temperature

16°C	3.5	3.4	3.5
18°C	3.4	3.5	3.5
Mean of size	3.5	3.5	

P = 0.05%, All factors = NS (non-significant), CV = 8.1%

Table 9. Effect of fruit size and temperature on astringency of bananas fruit at colour stage 6 [5 = maximum scores (very high) 1 = minimum score (very low)].

	Fruit sizes		Mean of
Temperatures	Small	Large	temperature
16°C	1.9	2.0	2.0
18°C	1.5	1.6	1.6
Mean of size	1.7	1.8	

P = 0.05%, temperature = 0.22, others = NS, CV = 11.8%

Table 10. Effect of fruit size and temperature on the off-odours of banana fruit at colour stage 6 [5 = maximum scores (very high) 1 = minimum score (very low)].

	Fruit sizes		Mean of
Temperatures	Small	Large	temperature
16°C	1.4	1.5	1.5
18°C	1.5	1.5	1.5
Mean of size	1.5	1.5	

P = 0.05%, All factors = NS (Non-significant), CV = 24.3%

Table 11. Effect of fruit size and temperature on the acceptability of banana fruit at colour stage 6 [5 = maximum scores (very good) 1 = minimum score (low)].

	Fruit sizes		Mean of
Temperatures	Small	Large	temperature
16°C	1.4	1.5	1.5
18°C	1.5	1.5	1.5
Mean of size	1.5	1.5	

P = 0.05%, Fruit size 0.07 = Others = NS, CV = 7.7%

The sensory evaluation regarding the lack of any variation in flavour, sweetness, astringency and off-odours in experiment indicated that all bananas ripened normally. Panelists preferred large size bananas. It can be concluded that panelists preferred the external appearance rather than internal quality in both sizes of banans. This effect has previously been found by Karamura and Karamura (4). They reported that long fingers are generally preferred to short ones. They further added that this statement is true for dessert and matooke bananas because longer ones had a greater domestic value and were easier to peel. Present findings also agree to those of Stover and Simmonds (12) which reported that finger length is the second most

important measurement after finger size in terms of quality specifications. Research conducted by Ssemwanga (11) on 'matooke' also supports the superiority of long fingers.

In terms of shelf life, bananas ripened at both temperatures reached colour stage 6 after same time when transferred from lower temperature to high temperature. The firmness values and panelist scores for acceptability of bananas that were transferred from 18°C to 20°C showed that these lost their quality because these bananas received maximum scores but were only statistically equal to those which were transferred from 16°C to 20°C. This could be due to greater weight loss, greater reduction in firmness or due to the stage of ripeness of pulp. In the light of these results it can safely be assumed that difference between ripening temperature in Britain and the rest of Europe might be due to the taste or preference of people in different countries. The only difference that could be found between the effects of two temperatures was in the stage of ripening. The people in the rest of Europe might prefer softer bananas at a further stage of ripening than British people.

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