INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2006/08–3–377–380
http://www. fspublishers.org

Improvement of Banana Quality in Relation to Storage Humidity, Temperature and Fruit Length

SAEED AHMAD[1], MUHMMAD ASLAM PERVIEZ, ZIA AHMED CHATHA AND A.K. THOMPSON†
Institute of Horticultural Sciences, University of Agriculture Faisalabad– 38040, Pakistan
†*Cranfield University, UK*
[1]Correponding author's e-mail: sandhu100hasan@yahoo.com

ABSTRACT

This investigation was undertaken to find out the effect of fruit size, storage temperature, humidity and their interactions on the quality of ripe fruit. The experiment was laid out according to the factorial design with four replications. It is observed that both humidity levels (80 - 85% & 90 - 95%) and fruit size did not effect the ripening time of bananas so they ripened after 10 days. Bananas stored at 18°C ripened after 9 days (two days earlier) but those stored at 16°C ripened after 11 days. Weight loss percentage was greater (1.31%) in bananas, which were stored at higher temperature (18°C) than those, which were stored at lower temperature (16°C with weight loss 1.09%). Regarding to weight loss percentage temperature showed greater effect at lower humidity levels. Bananas ripened at higher temperature (18°C) were less green (-3.33), softer (2.67 Nmm^{-1}) and with more pulp/peel ratio (1.78) than those ripened at 16°C. Humidity levels showed no difference regarding TSS % but it was greater (22.8%) in bananas, which were ripened at 18°C than those of 16°C. Panelists preferred long bananas, which were ripened at 18°C. In order to attain the best quality ripe fruit bananas (20 cm) should be stored at 18°C and relative humidity during ripening must be 80 - 85%.

Key Words: Bananas; Quality; Fruit ripening; Sensory evaluation; Dessert fruit

INTRODUCTION

Banana is an important fruit crop in the world having a special place in human diets. The size of individual units of a product can significantly affect consumer appeal, handling practice, storage potential, and market selection (Kays, 1991). It has also been shown that moisture loss of fruit depends upon size, maturity, storage temperature and humidity (Salunkhe *et al*., 1991). The best commercial ripening temperature in Britain is considered to be 16°C (Thompson, 1996). In other countries of Europe, recommended commercial ripening temperature is 18°C. The question arises as to why there is variation in the recommended ripening temperature.

The control of the ripening temperature is important to obtain the best quality fruit within in specific marketable life. Temperature influences the ripening changes in banana. Therefore, this experiment was aimed at finding out the best temperatures for the ripening and differences between small and large bananas quality wise.

MATERIALS AND METHODS

This research was conducted in post harvest laboratory of Canfield University, UK during 1999. Bananas of two sizes 14 cm and 20 cm at colour stage 1 were obtained from a banana company in Luton, UK. Un-damaged 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. Ten fingers each of small and large bananas were kept at two humidity levels of 90 - 95% and 80 - 85%. The experiment was set up in two controlled temperature rooms at 16 and 18°C with four replications. Fruit was analyzed when it reached the colour stage 6. Sensory evaluation data were also collected when fruits were fully ripen (colour stage- 6).

Assessment of fruit ripening (Assessment of fruit colour stage). The ripening process has been divided into seven stages by colour changes (Stover & Simmonds, 1987). These are as follows: 1, green; 2, green with a trace of yellow; 3, more green than yellow; 4, more yellow than green; 5, only green tips remaining; 6, all yellow; 7, yellow flecked with brown. The quality of ripe fruit was assessed by two methods.

1. Objective methods. The peel color 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 one represents the blueness. Peel and pulp firmness was measured using an Instron universal testing machine (model 2211) with an 8 mm cylindrical probe. Pulp and peel were separated and weighed individually and expressed as pulp peel ratio as follows:

$$\text{Pulp/peel ratio} = \frac{\text{Pulp weight}}{\text{Peel weight}}$$

Total soluble solids were measured using refractometer. Starch percentage was measured by using the technique

recommended by Blankenship and Herdsman (1993).

Individual fruit was weighed using a digital balance (precise 60000) just before the start of experiment and re-weighed at score 6 (fully ripe) and then cumulative weight loss percentages and weight loss percentage per day was calculated as follows:

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

Where

Wo = Original weight.

Wi = Weight at sampling (when Banana reached at color score 6).

Weight loss percentage per day was calculated as follows:

$$\text{Weight loss percentage per day} = \frac{TWP}{SC}$$

Where

TWP = Total weight loss percentage at color stage 6.

SC = Storage life (total days when Banana reached color store 6 from pre-climacteric stage).

2. Subjective assessments (Sensory evaluation). The fruits were removed from storage when they were at color score 6. Panel of eight assessors was selected and asked to assess pulp flavor, sweetness and acceptance on life point's sale as follows: 1, Low; 2, Moderate; 3, Moderate high; 4, Good/high; 5, Very good/high. An average was calculated for each parameter and sub parameter. There 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, a P.C based programming with four replications. LSD at P = 0.05 was used to test for significant difference of results.

RESULTS AND DISCUSSION

Storage life (Speed of ripening). The time needed to ripen was not significantly (P = 0.05) affected by fruit size and humidity but a significant difference was found by the ripening temperature (Table I). Bananas kept at 18°C reached colour stage 6 two days earlier than those, which were kept at 16°C. There was no interaction between size, humidity and temperature.

It is observed that high temperature accelerates the ripening of banana fruit. It is because higher temperature increased the ethylene production (Lebibet *et al.*, 1995) and ethylene is a natural plant hormone, which brings about the onset of the climacteric peak (Ables, 1973).

Weight loss percentage. Statistical analysis showed significant differences for fruit size, humidity, temperature, fruit size x humidity and temperature X humidity at the p = 0.05 levels (Table I & II). Smaller fruits showed greater (1.36% & 1.65%) weight losses than lagers fruit (1.19% & 1.09%). Bananas kept at low humidity showed greater weight loss than those kept at high humidity. Bananas kept at higher temperature (18°C) also showed greater weight loss than those stored at lower temperature (16°C). There was an interaction between fruit size and humidity. Fruit of both sizes showed greater differences in their weight losses (0.20) at lower humidity levels than those at higher humidity levels (0.10). Temperature showed greater effect at higher humidity levels (Table II). The results of the weight loss per day were broadly the same as those of weight loss percentage (Table I).

The greater weight loss in smaller bananas might be due to the greater respiration and transpiration rate. This effect has previously has been found in potatoes by Day (1993), who stated that small potatoes have a higher reparation rate than larger ones of the same variety. The greater weight losses in bananas at high temperatures and at low humidity might be due to the greater respiration and transpiration rates, which have been reported by the Lebibet *et al.* (1995). These results are the reason of the interaction between fruit size and humidity. This can be concluded that small fruits at low humidity levels lost more weight due to their faster rate of respiration and transpiration than that of larger ones. The interaction between temperature and humidity showed greater effect at high humidity. It could be due to the ability of high humidity to reduce the respiration rate an transpiration processes.

Peel colouur. Statistical analysis showed significant differences for a (greenness) non-significant for b* yellowness (Table I). The bananas ripened at 18°C were significantly less green than those at 16°C.

The less green and more yellow fruit at higher temperature is important in terms of their market appearance because customer use skin colour to decide the optimum eating quality. It has previously been shown (Seymour *et al.*, 1987) that the destruction of the chlorophyll in banana is temperature dependent over the range of 14 to 25°C.

Peel firmness and pulp firmness. The results are shown in Table I. The statistical analysis showed significant differences for the fruit size and temperature at P = 0.05 levels. The other factors are non-significant. Smaller bananas were significantly softer (2.94 Nmm^{-1}) than larger bananas (3.08 Nmm^{-1}). Both small and large bananas, which were ripened at a higher temperature (18°C), were significantly softer than those ripened at the lower temperature (16°C). Bananas of both humidity levels were equally soft in statistical terms. Statistical analysis of pulp firmness showed significant differences for fruit size and temperature at the P = 0.05 levels. The pulp of small bananas was softer than larger ones. The pulp of bananas ripened at higher (18°C) temperature was also softer than the pulp of those ripened at lower (16°C) temperature.

The softer small at colour stage 6 indicated that they were riper than larger bananas. This is because the softening of banana is associated with degradation of starch and with the movement of water (Thompson, 1996). He reported that during ripening of banana fruit water moves from the peel to pulp, which affect the turgidity of the skin.

Table I. Effect of fruit size, humidity and temperature on the ripening and quality of banana

Quality Parameter and Temperature	Relative humidity and Fruit sizes (FR. Reading at the start of experiment)							
	80-85%		90-95%					
	Small	Large	Small	Large	Mean	LSD=(P=0.05)	CV%	FR
Storage life (days)								
16°C	11	11	11	11	11	Temp. = 0.63	6.2	
18°C	8.5	9	9	9	9	All other= NS		
Mean	10	10	10	10				
Weight loss%						Fruit= 0.03		
16°C	1.30	1.14	1.00	0.93	1.09	Hum.=0.03	4.7	
18°C	1.42	1.24	1.33	0.26	1.31	FxH =0.05		
Mean	1.36	119	1.65	1.09		Temp.=0.0		
Weight loss% per day						Fruit= 0.006		
16°C	0.12	0.10	0.09	0.08	0.10	Hum=0.006	7.1	
18°C	0.17	0.14	0.15	0.14	0.15	FxH =0.009		
Mean	0.14	0.12	0.12	0.11		Temp.=0.006		
						HXT=0.009		
Peel colour a* values								
16°C	-3.63	-3.87	-4.01	-4.05	-3.89	Temp.=0.26	9.9	-17.29
18°C	-3.16	-3.31	-3.31	-3.46	-3.33	All other= NS		
Mean	-3.40	-3.59	-3.70	-3.75				
Peelcolour b*values								Small
16°C	+49.89	+49.39	+49.17	+49.18	+49.40	All = NS	8.8	+32.50
18°C	+50.40	+50.49	+50.15	+50.01	+50.26			Large
Mean	+50.40	+49.94	+49.94	+49.59				+33.05
Peelfirmness(Nmm-1						Fruit= 0.10		
16°C	3.27	3.38	3.31	3.43	3.36	Temp.=0.10	4.5	27.51
18°C	2.55	2.73	2.64	2.75	2.67	All other=NS		
Mean	2.91	3.05	2.97	3.11				
Pulpfirmness(Nmm-1						Fruit= 0.07	5.3%	Small
16°C	2.27	2.33	2.38	2.49	2.37	Temp.=0.07		14.75
18°C	1.48	1.67	1.69	1.74	1.64	Humid. =0.07		Large
Mean	1.87	2.00	2.03	2.12		All other=NS		14.52
Pulp/peel ratio						Fruit= 0.07	6.4	Small
16°C	1.73	1.63	1.74	1.51	1.65	Temp.=0.07		1.40
18°C	1.96	1.78	1.74	1.66	1.74	Humid. =0.07		Large
Mean	1.84	1.71	1.71	1.58		All other=NS		1.37
TotalSoluble Solids%								Small
16°C	21.9	20.8	21.5	20.6	21.2	Fruit= 0.52	3.3	6.0%
18°C	23.3	22.8	22.3	22.6	22.8	Temp.=052		Large
Mean	22.6	21.8	21.9	21.6		All other=NS		6.1%
Starch %						Humid.=.772		Small
16°C	20	22	22	23	22	Fruit= 0.72	5.0	95%
18°C	18	19	20	20	19	Temp.=0.72		Large
Mean	19	21	21	21		All other=NS		95%

Humid. = Humidity, Temp. = Temperature, H X T = Humidity X temperature

Pulp/peel ratio. Statistical analysis showed significant differences for fruit size, humidity and temperature at the P = 0.05 levels (Table I). Smaller bananas had a higher (1.84 & 1.74) pulp/peel ratio than larger ones (1.71 & 1.58). Humidity levels also showed a significant effect on pulp/peel ratio of bananas, in that as humidity increased (90 - 95%), the pulp/peel ratio decreased (1.66). Bananas ripened at 18°C showed higher (1.78) pulp/peel ratio than those ripened at 16°C (pulp/peel ratio was 1.65).

The greater pulp/peel ratio in small fruits at higher temperature and at low humidity also confirms that these bananas were at a more advanced stage of ripening because the pulp/peel ratio increased with ripening, because pulp/peel ratio in banana fruit has previously been shown to increase with ripening (Montenegro, 1988). The second reason for the greater pulp/peel ratio at the higher temperature and lower humidity 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 (Lizada *et al.*, 1990).

Total soluble solids and starch percentage. Results regarding TSS % and starch percentages are shown in Table I. Analysis of variances regarding total soluble solids showed significant differences for fruit size and temperature at the P = 0.05 levels. Smaller bananas possessed significantly greater (22.6% & 21.8%) total soluble solids than larger ones (21.9% & 21.6%). Bananas ripened at different humidity levels did not show any statistical differences in their total soluble solids percentages (22.2% & 21.8%). The level of total soluble solids was greater (22.8%), which were ripened at 18°C than those ripened at 16°C (21.2%). Starch percentages were less in small bananas and those, which were ripened at 18°C.

The reduced starch % and greater TSS % in bananas, which were ripened at higher temperature and in smaller bananas indicated that they were riper than those at lower temperature and larger bananas. It could be due to higher starch hydrolysis at the fully ripe stage. This characteristic has also been observed in other crops such as tomatoes (Salunkhe *et al.*, 1991). They state that small tomato fruits have a greater amount of reducing sugars than larger ones.

Table II. Interactions between different parameters

Quality parameters and Interactions between Humidity, Temperature, Fruit size	Humidity Levels 80-85%	95-95%	Mean
Weight loss%			
(Interaction X Humidity)			
Small	1.36	1.19	1.26
Large	1.16	1.09	1.14
Mean	1.27	1.13	
(Temperature X Humidity)			
16°C	1.22	0.96	1.09
18°C	1.33	1.30	1.31
Mean	1.27	1.13	
Weight loss per day			
(Interaction X Humidity)			
Small	0.15	0.12	0.14
Large	0.12	0.11	0.12
Mean	0.13	0.12	
(Temperature X Humidity)			
16°C	0.11	0.09	0.10
18°C	0.15	0.14	0.15
Mean	0.13	0.12	
Peel firmness			
(Interaction X Humidity)			2.94
Small			
Large			3.08
Mean	2.98	3.04	
TSS%			
(Interaction X Humidity)			
Small	22.6	21.9	22.3
Large	21.8	21.6	217
Mean	22.2	21.8	
Starch%			
(Interaction X Humidity)			
Small	19	21	20
Large	21	22	22
Mean	20	21	

Sensory evaluation. Results are shown in Table III. Bananas ripened at 18°C showed significantly better flavour than those, which were ripened at 16°C. The same bananas wee significantly sweeter than others. No significant differences were found between both sizes bananas regarding their flavour and sweetness but there was an indication that larger fruits were slightly better than smaller ones. Off-odour was negligible in all fruits. Bananas ripened at 18°C received higher score (3.6) for acceptability than those ripened at 16°C. Larger bananas also received higher score (3.6) by the panelist for their acceptability.

The lack of any variation in flavour sweetness astringency and off-odour indicated that all bananas ripened normally. Panelist preferred large size bananas. It can be concluded that panelist preferred the external appearance rather than in internal quality in both sizes of bananas. This effect has previously been found by Karamura and Karamura (1995). They reported that long fingers are generally preferred to short ones. They further added that this statement is true for dessert and matoook bananas because longer ones had a greater domestic values and were easier to peel. Ssemwanga (1996) found that the large fingers were mentioned as very attractive in appearance and could be sold for this even if they did not have good eating quality.

In the light of these results it can safely be assumed that the differences between the ripening temperature in Britain and the rest of Europe might be due the taste or preference of people in different countries.

Table III. Effect of fruit size, temperature and humidity on the sensory evaluation of banana fruit

Quality Parameter and Temperature	Relative humidity and Fruit sizes (FR. Reading at the start of experiment) 80-85% Small	Large	90-95% Small	Large	Mean	LSD	CV%
Flavour							
16°C	3.5	3.8	3.5	3.4	3.6	Temperature=0.30	10.6
18°C	4.5	4.5	4.0	4.2	4.3	All others= NS	
Mean	4.0	4.2	3.8	3.8			
Sweetness							
16°C	3.6	3.5	3.5	3.5	3.5	Temperature=0.24	8.7
18°C	4.3	4.2	4.1	4.1	4.2	All others= NS	
Mean	4.0	3.9	3.8	3.8			
Astringency							
16°C	1.4	1.4	1.5	1.5	1.5	Temperature=0.09	10.1
18°C	1.2	1.2	1.2	1.3	1.2	All others= NS	
Mean	1.3	1.3	1.4	1.4			
Off-odour							
16°C	1.1	1.0	1.1	1.1	1.1	All others= NS	8.4
18°C	1.1	1.0	1.1	1.1	1.1		
Mean	1.1	1.0	1.1	1.1			
Acceptability						Fruit size= 0.77	
16°C	3.4	3.6	3.4	3.6	3.5	Temperature=0.24	12.6
18°C	3.5	3.7	3.5	3.6	3.6	All others= NS	
Mean	3.4	3.6	3.4	3.6			

REFERENCES

Ables, F., 1973. Biosynthesis and mechanism of action of ethylene. *Ann. Rev. Pl. Physiol.*, 23: 259–92

Blankenship, S.M. and R.W. Herdsman, 1995. High relative humidity after ethylene gassing is important to banana fruit quality. *Hort. Tech*., 5: 150–1

Day, B.P.F., 1993. Fruit and Vegetables. *In*: Parry, R.T. (1st ed.), *Principles and Applications of Modified Atmosphere Packaging of Food*. Pp: 114–33

Karamura, D.A. and E.D. Karamura, 1995. Bnanas morphology-part: the aerial shoot. *In*: Goven, S. (ed.), *Bananas and Plantains*. Pp: 190–206. Chapman and Hall, London, UK

Kays, J.S., 1991. *Softening. Postharvest Pysiology of Perishable Plant Product*. Van Nastrand Reinhold Avi , NY, USA

Lebibet, D., I. Metzidakis, D. Gerasopoulos and H. Passam, 1995. Effect of storage Temperatures on the ripening response of banana fruit. *Acta Horticulturae*, 379: 521–31

Lizada, M.C.C., B. Panttastico, A.R. Shukor and S.D. Sabari, 1990. Ripening of bananas. Textural changes. *In*: Abdullah, H. and E.B. Pantastico (eds.), *Banana Handling and Marketing in ASEAN*. Pp: 65–7. Published by ASEAN Food Handling Bureau, Kuala Lumpur, Malaysia

Montenegro, E.H., 1988. Post harvest behavior of banana harvested at different stage of maturity. Laguna: *B.Sc Theses*, University of Philippines , Los Banos

Salunkhe, D.K., H.R. Bolin and N.R. Reddy, 1990. *Processing and Nutritional Quality of Fruits and Vegetables. 2nd Edition Vol. 1*. CRC Press, Boca Raton, Florida

Seymour, G.B., A.k. Thompson and P. Johan, 1987. Inhition of degreening in the peel of bananas ripenefd at tropical temperatures. *Annuals of Appl. Biol*., 110: 145–51

Ssemwanga, J.K., 1996. The investigation of post harvest quality of fresh and matooke bananas. *Ph.D Thesis*, Silsoe College, Canfield University Silsoe, UK

Stover, R.H. and N.W. Simmonds, 1987. *Bananas. 3rd Ed.* Longman, London

(Received 05 January 2006; Accepted 04 April 2006)