INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2006/08–6–828–831
http://www.fspublishers.org

Effect of High Humidity and Water on Storage Life and Quality of Bananas

HAMEED ULLAH, SAEED AHMAD[1]†, RAHEEL ANWAR† AND A.K THOMPSON‡
Citrus Research Station, Sahiwal, Pakistan
†*Institute of Horticultural Sciences, University of Agriculture, Faisalabad–38040, Pakistan*
‡*Cranfield University, Silsoe College, UK*
[1]Corresponding author's e-mail: sandhu100hasan@yahoo.com

ABSTRACT

The research was carried out to investigate the effect of high humidity (100%) and water storage on the ripening behaviour and quality of ripe banana fruit. It was observed that high humidity delayed the ripening of bananas and consequently increased their shelf life Water storage delayed the climacteric phase of bananas in a similar way to CA storage but bananas could not complete their ripening processes properly. Water storage resulted in splitting of bananas due to excessive intake of water. Microbial spoilage of water-stored bananas emerged as serious problem against successful application of this technology. Reduced dissolution of O_2 into water affected the ripening process of bananas. In order to attain the best quality and increased shelf life, water storage was found not suitable for banana fruit but high relative humidity (100%) showed better results.

Key Words: Water storage; Shelf life; Humidity; Splitting; Climacteric

INTRODUCTION

The major technical problems in postharvest handling and distribution of fresh fruits and vegetables are associated with their perishability as living organisms. They are subject to various biochemical changes, which lower their quality and finally make them un-acceptable on a commercial basis. Such deterioration may develop as a result of excessive water losses due to evapo-transpiration; the normal respiration cycles resulting in senescence; physiological disorders such as chilling injury in tropical fruits and fruit rot due to the attack of microbes (Farooqi, 1985).

The combination of CA storage and temperature control has proved very successful in extending the postharvest life of fresh fruits but it is expensive and may therefore not be appropriate for use in some rural areas of Pakistan. It has been reported that in certain rural areas of Jamaica, water storage is a practice with bread-fruit, which has been shown to extend their storage life (Thompson *et al.*, 1974a). The reasons for the slower rate of deterioration of water-stored breadfruit (Thompson *et al.*, 1974a) and potatoes (Samotus, 1971) are not clear from the literature but could be related to CO_2/O_2 movement in and out of the product. Relative humidity has a significant effect on the ripening of bananas, which were not treated with ethylene (Ahmad *et al.*, 2006). They further reported that bananas kept at medium and high humidity ripened later with good eating quality. From the literature, a hypothesis was developed that if fruits are permanently coated with a film of water, modified atmosphere conditions could be developed within the fruit, which could result in the extension of their postharvest life. The research was carried out to (i) test the effects of stored bananas under water and to compare them with storage in high humidity air, (ii) study the internal atmosphere of water stored bananas compared with those stored in air, and (iii) identify the problems related to water storage.

MATERIALS AND METHODS

The research was carried out in the laboratory of Cranfield University, Silose College, UK. Pre-climacteric Cavendish bananas were imported from South America and obtained from C.E. Wilkinson in Bedford in the UK. The following treatments were included in the experiment:

1. Fruits stored in high humidity (saturated in water) using an ultrasonic humidifier and in water.
2. Fruit stored by submersion in water.
3. Control fruit stored in normal atmosphere (80 - 85% relative humidity).

For water storage, plastic containers of 60 liter capacity with 25 L of distilled water were used for water storage of bananas. A plastic lid with holes was placed into the water to keep the bananas submerged under water. HY flow pump was used to dissolve air in water (Fig. 1).

The storage temperature for all the treatments was maintained at 13 ± 1°C. Colour stages of banana fruit were assessed according to peel colour changes compared with a standard commercial colour chart as described by Thompson (2003). The colour dark green and fully yellow was assigned the stage 1 and 6, respectively. The fruits were removed from the storage when they were at colour stage 6 for the measurement of quality. Respiration of bananas, were measured during the storage.

The O_2 consumed and CO_2 produced was measured by placing 3 banana fingers in a sealed 3 L glass jar immediately after removal from water. The O_2 consumed and CO_2 produced were measured two hours after placing the fruit into the jar, then related to the weight of fruit. Calculations were made in milligrams (mg) of O_2 or CO_2 per kilogram (kg) of bananas per hour (Fig. 2).

After storage, fruits were weighed, using a Precisa 6000D digital balance with ± 0.01 g resolution, before and after storage. The cumulative weight gain or loss % was calculated as follows:

$$\text{Weight change \%} = \frac{W_0 - W_1}{W_0} \times 100$$

Where:

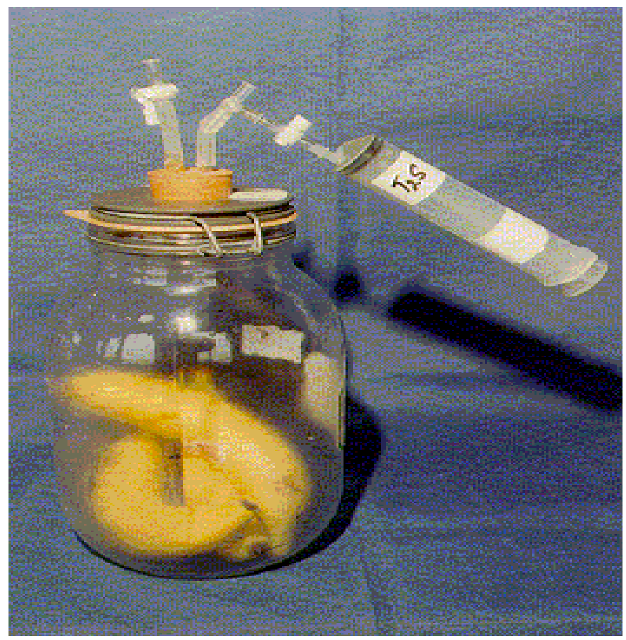
W_0 = Weight before storage.

W_1 = Weight after removal from the storage.

The peel color was measured by colorimeter (Minolta model CR-200/Cr-2006). Positive ‘a’ values corresponding to the degree of redness, while ‘a’ negative value corresponding to the degree of green ness. ‘a’ positive of values represents the degree of yellowness and negative one represents the blueness. Firmness was measured using an Instron Universal Testing Machine (Model 2211) with an 8 mm cylindrical probe. Total soluble solids percentage was measured using a refractometer (Atago Co. Ltd, model PR-1). Randomized complete block design with four replications was used for statistical analysis. Scores related to flavour, sweetness and acceptance were also collected by the taste panel. 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. Judges were asked to assess pulp flavour, sweetness and overall acceptability on the five point scale as follows: 1 = none or very low, 2 = low to medium, 3 = medium to high, 4 = high and 5 = very high. For statistical analysis each of the eight persons was considered to be a replicate.

Fig. 1. Pre-climacteric bananas stored in aerated water

Fig. 2. Measuring the respiration rate of bananas



RESULTS AND DISCUSSION

The data for different parameters were found to be significantly different (P = 0.001). The results are presented in table and discussed as follows:

Storage life. The storage life of bananas was significantly affected, when they were stored under water. Bananas stored in 100% relative humidity also showed a significant increase in storage time compared with control fruit. It was observed that bananas stored as a control or under high humidity started their climacteric phase after two weeks of storage as judged by skin colour changes without any ripening treatment. Delayed ripening of bananas in high humidity storage compared with those held as a control at low humidity confirmed the findings of previous work on bananas (Littman, 1972; Ahmad *et al.*, 2006). A considerable increase in the pre-climacteric life of bananas was observed when they were stored under water. It might be possible that during water storage their climacteric phase was not initiated due to the restricted gaseous exchange. Blockage of intercellular spaces with water might have affected the O_2 tension of the fruit tissue, resulting in the suppression of their ripening. This effect is related to banana storage at reduced O_2 levels. High intake of water might also have reduced the gaseous contents of fruit rather than affecting their concentrations.

Splitting of water stored bananas was undoubtedly attributed to the excessive intake of water. This effect might be due to the influx of water into the banana fruit to maintain equilibrium between the water and water vapour pressure deficit of the fruit. This effect has been reported by Thompson *et al.* (1974a) in the storage of breadfruit under water. Earlier, Thompson *et al.* (1974b) had also reported both splitting of plantains and slower ripening during storage under high humidity conditions. It can be assumed that a major portion of water intake is through the cut portion of the banana hands or through ends of the banana fingers. An increase in weight was also observed, when bananas were stored at 100% relative humidity but to a lesser extent than fruits stored under water.

Weight change. Fruit stored under water showed a significant increased in weight during storage compared with other fruits either held in high humidity or as a control. It was observed that bananas stored in high humidity (100%) also showed a little increase in their initial weight, whereas those kept as a control showed a significant decrease in their weight. Severe splitting was observed on the skin of the fruit stored under water after the fourth week of storage (Fig. 3). Bananas stored as a control, lost weight during ripening and showed under-peel discoloration at stage 6. The greyish yellow peel colour of control fruit might be due to the chilling effects on the fruit during ripening at 13°C. The fruits stored at high humidity gained weight and did not show under-peel discoloration, giving fruits of excellent appearance. The same effect was noticed in previous studies of the effect of humidity on the ripening of plantains (Thompson *et al.*, 1974b). The peel colour values of water stored bananas also support the claim that they had not started their climacteric phase until the fourth week of water storage.

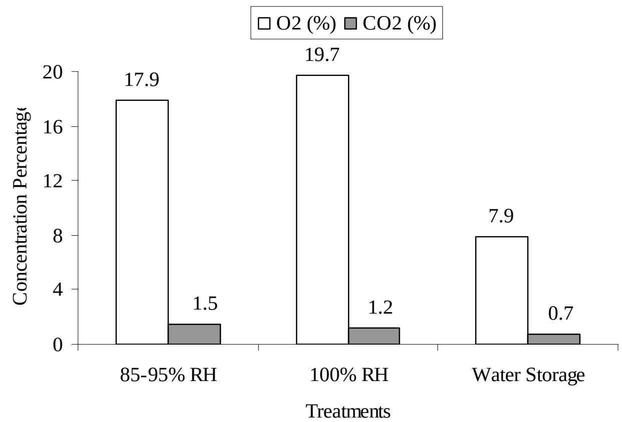
Peel colour. Significant differences in peel colour intensity occurred when bananas were stored under water and at 100% relative humidity compared with those held as a control. It should be noted that bananas stored under water remained green during the whole period of storage but bananas stored at 100% relative humidity exhibited a bright yellow colour.

Firmness. Fruit firmness was significantly lower in control fruit than in fruit stored at 100% relative humidity or under water. The firmness figures for fruit stored under water were much higher than other fruits, which indicate that the bananas stored under water remained firm. The quicker softening of control fruit and those stored under high humidity indicated that these were riper compared with water stored bananas, which were still green. The reason for the lower firmness of the control fruit might also be the higher water losses and the weakening of the tissues of the skin of the fruit.

Total soluble solids (TSS) and starch. The TSS percentage was much lower for bananas stored under water than those stored in control conditions i.e. 85 to 95% relative humidity and at 100% relative humidity. The bananas stored at 100% relative humidity showed no statistically significant difference in TSS to the control fruit, but it was slightly lower. The lower TSS and higher starch contents of water stored bananas also suggested that the ripening process of these bananas was inhibited. Barnell (1941) reported that starch was entirely broken down into sugars during the ripening of bananas. In the light of Barnell's investigations, it can be suggested that the bananas stored under water failed to initiate the ripening process and showed a higher percentage of starch accompanied by less accumulation of sugars. The TSS of the water used for banana storage was 0.4%, when the experiment was discontinued. Sugars are readily soluble in water and could have been leached from the fruit. Bananas immersed under water showed very high starch contents, whereas the bananas either held as a control or in higher humidity showed lower but significantly similar starch contents. However bananas kept in 100% relative humidity showed a higher starch content than control fruit.

Fig. 3. Water stored bananas immediately after removal from water after four weeks

Fig. 4. Effect of high humidity and water storage on internal O_2 and CO_2 concentration of bananas



Internal O_2 and CO_2. Bananas stored at 100% relative humidity accumulated more O_2 than the control fruit (Fig. 4). In contrast, the bananas stored at 85 to 95% and at 100% relative humidity showed statistically no difference in CO_2 accumulation in the internal atmosphere of the fruit. Bananas stored under water showed a considerable reduction in the accumulation of O_2 and CO_2. Bananas stored under water showed very low percentages of O_2 and CO_2 accumulation in the fruit. Burton (1950) showed

Table I. The effect of high humidity and water storage at 13°C on the storage life and the quality of bananas

	Storage life (days)	Colour stage	Weight loss (%)	Peel colour Values a*	Values b*	Peel firmness (N)	TSS (%)	Starch (%)
80-85% RH	21.2	6	-3.5	-1.6	+41.5	3.0	20.1	32
100 % RH	22.6	6	+1.3	-3.2	+48.2	4.4	21.5	26
Water Storage	28	1-2	+4..9	-15.9	+35.3	16.9	7.8	94
LSD	NA		0.6	1.31	2.53	1.04	1.71	3.3
CV	3.05		7.0%	14.0%	4.0%	9.0%	18.0	5.0
Initial Analysis				-17.7	+33.5	19.3	6.5	95-100

Table II. The effect of high humidity and water storage on sensory evaluation quality of bananas

Factors studied	Pulp flavour	Sweet ness	Astringency	Off odour	Acceptability
80-85% RH	3.0	2.9	1.5	1.5	3.2
100 % RH	3.0	2.9	1.6	1.5	3.5
Water Storage	-	-	-	-	-
LSD	NS	NS	NS	NS	NS
CV	17.0%	18.5%	20.0%	19.5%	24.5%
Initial Analysis					

that the diffusion of oxygen through water is 300,000 times slower than in air. This suggests that banana tissues achieved an anaerobic condition during storage under water. This condition could also have slowed down the respiration and thus delayed the ripening of bananas compared with the control fruit. The very low CO_2 accumulation (0.73%) was supported by Kays (1991), who reported that gases such as O_2 and nitrogen are only slightly soluble in water and CO_2 is very soluble (approximately 100 times more soluble than O_2). Due to its high solubility, CO_2 will also diffuse readily in water, allowing it to move within the aqueous medium.

Decay development. During the third week of storage under water, the first symptom of decay, blackening of the surface, was observed. After four weeks of storage the bananas under water started splitting so the experiment had to be discontinued, because microbial spoilage developed rapidly. The splitting of bananas occurred due to the intake of large quantities of water. Further work is needed to study various methods, which could be used to reduce the intake of water during storage under water.

Sensory evaluation. Bananas stored in water did not ripe. Bananas ripened at medium and high relative humidity received the same scores for flavour by panelists. Panelists gave statistically similar scores for sweetness, astringency, off-odors and over all acceptability of both humidity levels bananas. This indicated that bananas of both humidity levels completed their ripening processes normally. The good flavour and sweetness in both humidity due to the increased formation of volatile compounds and grater starch sugar conversion. In previous research by Rahman (1995) it was also mentioned that low humidity caused decline in quality of ripe fruit but he did not mentioned precise reason for this. In contrast, Carvalho *et al*. (1988) reported that the high humidity had no effect on fruit internal quality. It can be concluded from the present research that panelists could not differentiate statistically in the quality of bananas, which were ripened at medium and high relative humidity due to their completion of ripening.

CONCLUSION

Storage of bananas in water for increasing shelf life is not suitable for banana fruit. High humidity can delay the ripening of bananas and consequently increase their shelf life. Water storage resulted in splitting of bananas due to excessive intake of water. Reduced dissolution of O_2 into water affected the ripening process of bananas.

REFERENCES

Ahmad, S., Z.A. Chatha, M.A. Nasir, A. Aziz and M. Mohan, 2006. Effect of humidity on the ripening behavior and quality of ripe fruit. *J. Agric. Soc. Sci*., l.2: 54–7

Barnell, H.R., 1941. Studies in tropical fruits. XI. Carbohydrate metabolism of the banana fruit during ripening under tropical conditions. *Annals of Botany,* 5: 217–50

Burton, W.G., 1950. Studies on dormancy and sprouting of potatoes. I. The oxygen content of potato tuber. *New Phytologist,* 49: 121–34

Carvalho, H.A., M.I.F. Chitarra, A.B. Caralho, V.D. Caralho, H.S. Caralho and D.V.D. Caralho, 1988. Banana ev. Prata ripened under high relative humidity I, loss in weight pulp: peel ratio, correlation and respiration of fruits. *Pesquise Agropecuraio Brasileira,* 23: 1331–8

Farooqi, W.A., 1985. Postharvest technological studies on the conservation of some fresh fruits and vegetables of Pakistan. *Punjab Fruit J.,* 38: 39–52

Kays, S.J., 1991. *Postharvest Physiology of Perishable Plant Products*. Chapman and Hall, London

Littmann, M.D., 1972. Effect of water loss on the ripening of climacteric fruits. *Queenslan J. Agric. Anim. Sci*., 29: 103–13

Rahman, N., W. Yuquing and A.K. Thompson, 1995. Temperature and MA packaging effect on the ripening of banana. *In*: *Proceeding of the International Conference on Postharvest Technology for the Fresh Fruit and Vegetables*, Pp: 313–21

Samotus, B., 1971. Storage of potato tubers under water. Preliminary investigations. *Potato Res.,* 14: 145–9

Thompson, A.K., B.O. Been and P. Perkins, 1974a. Storage of fresh breadfruit. *Tropical Agric. (Trinidad),* 51: 407–15

Thompson, A.K., B.O. Been and C. Perkins, 1974b. Effect of humidity on ripening of plantain bananas. *Experientia*, 30: 35–6

Thompson, A.K., 2003. *Fruit and Vegetables,* P: 459. Oxford, Blackwell's Science

(Received 29 May 2006; Accepted 20 August 2006)