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# Humidity Effects on Physiological Quality of Stored Tomatos and Bananas

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## Abstract

Tomatoes harvested at both green and pink stages of maturity and bananas harvested at the three quarter green mature stage were stored at 20°C and relative humidity of 62%, 78% and 94% until full ripening. Bananas ripening was initiated by exposure to 10 ppm ethylene for 24 h at beginning of the study. The number of days to ripe, skin colour, firmness, titratable acidity, total soluble solid and weight loss of fruits were measured. The organoleptic characteristic of bananas was also evaluated. Ripening time was shorter in banana than in tomato; and in pink tomatoes than in green tomatoes. Whereas increasing air RH increased ripening time of tomatoes with less water loss and without effect on fruit color; the reverse was true in banana where ripening time was reduced with less weight loss, less firm and good eating quality fruits of high soluble solids content and flavor despite of the less yellow peel colour. Fruit firmness was in general higher in green than in pink tomatoes and in both it was maximum at medium RH; while that of bananas was maximum at low RH. The concentration of total soluble solids was about 4 times higher in bananas than in tomatoes; and in the latter it was comparable in pink and green tomatoes. Total soluble solids were non-significantly affected by RH in pink tomatoes; but peaked at medium RH in green tomatoes and bananas. Titratable acidity was comparable in pink and green tomatoes and was non-significantly affected by RH in pink tomatoes but increased by increasing RH in green tomatoes. Weight loss during storage was in general higher in bananas than in tomatoes and in both species it exhibited progressive decrease with the increase in RH with stronger effect in bananas than in tomatoes.

*Keywords*: Humidity, fruit quality, bananas, tomatoes, storage.

## Introduction

Humidity is an important environmental factor influencing the shelf life of fresh fruits and vegetables in both long and short term storage (Frith, 1991). Moisture loss is related to air humidity and losses can result in softening (Risse, 1987), wilting and toughing of plant parts (Salunkhe and Wu, 1974). Rate of water loss depends on nature of the skin, size and shape of the plant organ and humidity of the atmosphere (Paine and Paine, 1992). In low-humidity environments moisture loss can be hastened, which is associated with structural and transpiration damage in fruits (Shewfelt, 1986). An effective method for reducing water loss from fruits and vegetables is to increase the relative humidity of the air in the storage environment (Shewfelt, 1986). Nevertheless, if the air relative

humidity is high (over 95%) there is a danger of moisture condensation on the produce, which may favor microbial growth and decay of the commodity (Zagory and Kader, 1988). Van den Berg and Lentz (1977) reported less disease in many crops held at very high (98-100 % RH) compared with crops held at 90-95% RH and they recommended RH of 98-100 % for vegetable crops. However, Paine and Paine (1992) recommended RH of around 85-90 % for fruits and most vegetables. McKeown and Lougheed (1980) reported that traditionally, the recommended range of RH for vegetables is 90 to 95%; and > 90 % for leafy vegetables. Generally, levels between 90% and 95% RH are recommended for fresh vegetables and up to 98% for root crops. For fresh fruits recommended levels vary but are generally between 85% and 95% depending on the fruit species and variety (Frith, 1991; Ahmed et. al., 2006). The aim of this study is to investigate the effect of RH on quality of ripening bananas and tomatoes during storage in relation to stage of maturation at picking.

**Materials and methods**

Fruits of tomato (***Lycopersicum esculentum* Mill.**) freshly harvested at both green and pink stages of maturity were obtained from the greenhouse at Silsoe Research Institute. Banana fruits (***Musa acuminata***) had been harvested at three quarter grade maturity in the Windward Islands and transported by sea for some 9 days at 13˚C to UK and obtained through th local market in Great Britain.

Bananas ripening was initiated by exposure to 10 ppm ethylene for 24 h at beginning of the study. Tomatoes and bananas were placed separately into 3-litre air tight glass jars with inlets and outlets. Air with three levels of RH was passed through the inlets into the jars continuously. The output air was passed over the sensor head of a Michell dew point meter to measure the RH every 6 hours. The inlet of each jar was connected to a 500 ml conical flask to feed air with a specified level of RH. A group of flasks was filled with water to provide high (92-96 %) RH; a second group was filled with dried silica gel to provide low (60-65 %) RH and a third group was left empty to provide ambient air with 76-80 % RH. The experiment was set up in a controlled temperature room at 20˚C. Skin colour values were measured using a Minolta Chromometer Model CR 200 and the average reading at three pre-determined points on the circumference of the fruits was calculated. The instrument was calibrated against a standard white colour plate (Y=93.9, x=0.313, y=0.321). In Minolta chromometer positive a* value corresponds to the degree of redness while a negative value corresponds to the degree of greenness; whereas positive b* value refers to the degree of yellowness and the negative value to the blueness. Therefore, redness values of tomatoes were recorded in the a*/b* ratio **(Anonymous, 1993)**.

For tomatoes, a non-destructive deformation test was used to evaluate fruit firmness according to **Floros *et al* (1987).** A maximum compression force of 1 N was applied to the fruit surface with a 6 mm diameter round stainless steel probe in an Instron Universal Testing Machine, model 1122. An appropriate full scale compression load deflection was chosen. The chart speed was 50 mm minute$^{-1}$ and the cross-head speed was 1 mm minute$^{-1}$. Measurements were made on each fruit at 3 positions around its equator. The deformation (mm) due to application of the 1 N compression force was measured. For bananas, the same instrument was used to measure the force required to penetrate the skin of the intact fruit. This force was applied to each finger using the same probe, and a cross head speed of 10 mm minute$^{-1}$.

Weight of fruit was recorded using a Mettle balance Model P1200 and the rate of weight loss was calculated as % FW. Soluble solids content was determined with a bench top A tago Digital Refractometer, model PR-1. Titratable acidity was determined by titrating the fruit juice to pH 8.1 with 0.3 N NaOH using a Jenway Digital pH meter, model 3020.

Sensory evaluation was only carried out on bananas. Pieces of pulp were served randomly to eight judges, who were asked to assess sweetness, strength of flavour and acceptability on a five point scale (1= low or week to 5= very high or strong). Off-flavour was assessed on six point scale (0 = no off-

flavour to 5 = very high). The results were presented as percentage of the maximum score.

Results of the sensory evaluation showed that, bananas ripened at high RH had the highest score for flavor, pulp sweetness and acceptability whilst those ripened at medium RH had no off-flavour. (Table 3).The experiment was conducted in the completely randomized design and analyses of variance was carried out by using SPSS program version 22. Comparison of means was performed according to the Duncan's multiple range test.

**Results and Discussion**

Ripening time was generally shorter in banana than in tomato; and in the latter it was lower in pink tomatoes than in green tomatoes. Whereas the ripening time of tomato increased with the increase in air RH the reverse was true in banana. In tomatoes picked at the pink stage ripening time was 5 d at low RH and was doubled at medium and high RH. The extent of change was relatively low for green tomatoes where ripening time increased from 13 d at low RH to 15 d (only 15% increase) at medium and high RH (Table 1). On the contrary, ripening time of banana decreased from 6.3 days at low air RH to about 4 days at medium and high RH (37% reduction).

The effect of air RH on color of tomatoes varied according to maturation stage at picking. Color of pink tomatoes was non-significantly affected by RH of air; but that of green tomatoes was non-significantly affected by increasing RH from low to medium levels with marked reduction in fruit redness (50% reduction in the Minolta a*/b* ratio) upon further increase in RH from medium to high levels. Bananas ripened at the three humidity levels showed a similar degree of skin yellowing expressed as non-significantly different Minolta b* values, whilst fruits ripened at low humidity were less green than those ripened at medium and high RH as the Minolta a* value increased from -20.57 at low RH to about -5.88 at medium and high RH (Table 2). **Shirazi and Cameron (1992)** reported highly significant effect of air RH on shelf life of fruits. **Sharkey and Peggie (1984)** extended the shelf life of cherries and lemons by a week and month respectively by applying high humidity (95-99%) storage. Ripening time of bananas stored at low RH (62%) was prolonged in association with high weight loss and poor eating quality despite of the nice yellow peel colour. In agreement with our results, **Haard and Hultin (1969)** reported suppression of fruit ripening under conditions which cause rapid weight loss.

The present results suggest that colour of the skin is not always a good measure of fruit ripening. Nevertheless, this is not always the case since **Broughton *et al*. (1978)** and **Broughton and Wu (1979)** found that the fruits ripened at low RH shrivel and turn black faster and had inferior flavor, which they termed "flat taste" compared with those stored at high RH. However, the literature on the effect of RH on the co-ordination of banana ripening is somewhat conflicting. Whereas **Broughton and Wu (1979)** reported that low RH had no effect on the respiratory rate at the climacteric peak, other workers **(Littmann, 1972; Lizana, 1975** and **Haard and Hultin, 1969)** found that different varieties of banana, maintained at RH less than 80% did not exhibit a climacteric rise in respiration which means abnormal ripening. There are also conflicting reports on the influence of air RH on ethylene production by climacteric banana fruits; where low RH either depress ethylene evolution at the climacteric peak **(Lizana, 1975)**, increase rate of respiration and ethylene production **(George *et al*., 1982)** or was without effect **(Broughton and Wu, 1979).** Since ripening in this experiment was initiated by exogenous ethylene application. It has been hypothesized by **Thompson *et al*. (1974)** that the effect of low RH was to create tension in the fruits which in turn would initiate system II ethylene production resulting in initiation of ripening. This is confirmed by the findings of **Broughton and Wu (1979)** that high humidity repress ethylene production by banana fruits. The mechanism of this effect was hypothesized by

**Wilkinson (1970)** as that low production of ethylene at high RH was due to saturation of intercellular spaces within the fruit and this could account for the slight delay in ripening. However, in their experiments **Broughton and Wu (1979)** did not use exogenous ethylene to initiate ripening as is the case in this study. Therefore, the influence of air RH on endogenous ethylene production during ripening seems not the only reason for the variability in the speed of ripening and the subsequent eating quality of ripe banana. Alteration in RH of air can modify the action of exogenous ethylene, in that, high humidity accelerates ripening as recognized by pulp softening. Although medium RH also accelerated ripening of bananas (softening of pulp) this was associated with enhanced weight loss. This could be due to rapid losses in moisture at RH less than 80% **(Day, 1993)**. Although low RH increased weight loss of bananas due to rapid transpiration, it also delayed fruit ripening and led to more firm, poor eating quality fruits with lower soluble solids content. However, it seems that other factors in addition to ethylene production might play important roles in fruit ripening under varying RH and further work is necessary to resolve this point.

Fruit firmness was in general higher in green than in pink tomatoes. Both pink and green tomatoes attained maximum firmness at medium RH, with 41% reduction below the maximum at low RH in pink tomatoes and 28% reduction at high RH in green tomatoes. In bananas firmness was maximum at low RH and was reduced by 28% as RH increased to medium levels with non-significant effect of further increase up to high RH. The concentration of total soluble solids was about 4 times higher in bananas than in tomatoes; and in the latter it was comparable in pink and green tomatoes. Total soluble solids were non-significantly affected by RH in pink tomatoes; but in green tomatoes they peaked at medium RH with 5% reduction at high RH and a non-significant effect of low RH. Similar to green tomatoes, total soluble solids of bananas peaked at medium RH but were reduced by 16% at low RH with a non-significant effect of high RH.

Titratable acidity was assayed only in tomatoes. Titratable acidity was comparable in pink and green tomatoes and was non-significantly affected by RH in pink tomatoes but was increased by 35% in green tomatoes upon increasing RH from low to high levels. Weight loss during storage was in general higher in bananas than in tomatoes and in both species it exhibited progressive decrease with the increase in RH with stronger effect in bananas than in tomatoes. Increasing RH from low to high levels reduced the amount of weight loss in fruit by 55%, 68% and 74% in pink tomatoes, green tomatoes and bananas respectively.

Pink tomatoes ripened at low RH were firmer and had higher titratable acidity than those ripened at medium and high humidity, probably because the time taken to ripen was shorter. Since fruits and vegetables have 80-95 % water, they lose moisture rapidly whenever the RH is less than 80-95 %. Moisture loses of 5.6 % are usually enough to cause market deterioration of quality for many kinds of plants **(Day, 1993; Risse, 1987)**.

As would be expected the magnitude of weight loss in both tomatoes and bananas significantly decreased as RH increased. Weight loss of tomatoes is inversely related to RH of the storage environment **(Riquelme *et al*., 1994)**. Dennis *at al.* (1979) showed that weight loss (excluding that due to fungal decay) from the fruit during 4 weeks of storage was approximately 5% at 90% RH compared with 2% and 1% respectively at 95% and 98% RH. **Risse (1987)** reported that film wrapped (approximately 100% RH) tomatoes had less fresh weight loss and longer storage shelf life and also were much firmer than non-wrapped tomatoes during storage (**Kawada and Hale, 1980)**. On the other hand high RH favors growth of microorganism which increases the possibility of product deterioration **(Gorris and Peppelenbos, 1992; Riquelme *et al*., 1994)**.

**Table I.** Effect of air relative humidity on quality of tomatoes picked at green and pink stages and stored at 20°C until ripening. Each value is the mean of five replicates ± SE. weight loss was non-statistically analyzed

| Relative humidity (%) | Ripening time (days) | Colour Minolta a/b ratio | Firmness (deformation, mm) | Titratable acidity (%) | Total soluble solids (%) | Weight loss (% /day) |
|---|---|---|---|---|---|---|
| Pink tomatoes | | | | | | |
| High (94%) | 10 ± $^{a}$ | 0.81$^{a}$ | 35.34$^{a}$ | 0.261$^{a}$ | 4.60$^{a}$ | 0.42 |
| Medium (78%) | 10 ±$^{a}$ | 0.83$^{a}$ | 47.65$^{b}$ | 0.235$^{ab}$ | 4.70$^{a}$ | 0.51 |
| Low (62%) | 5 ±$^{b}$ | 0.83$^{a}$ | 28.05$^{c}$ | 0.265$^{a}$ | 4.55$^{a}$ | 0.93 |
| Green tomatoes | | | | | | |
| High (94%) | >15$^{a}$ | 0.42$^{a}$ | 32.70$^{a}$ | 0.345$^{a}$ | 4.72$^{a}$ | 0.19 |
| Medium (78%) | 15$^{a}$ | 0.82$^{b}$ | 45.07$^{b}$ | 0.274$^{b}$ | 4.95$^{b}$ | 0.44 |
| Low (62%) | 13$^{b}$ | 0.83$^{b}$ | 41.39$^{bc}$ | 0.255$^{bc}$ | 4.85$^{bc}$ | 0.59 |

**Table 2** Effect of air relative humidity on quality of bananas picked at green stage and stored at 20ºC until full ripening. Each value is the mean of five replicates ± SE.

| Quality criterion | Relative Humidity (%) | | |
|---|---|---|---|
| | High (94%) | Medium (78%) | Low (62%) |
| Ripening time (days) | 4.0$^{a}$ | 4.2$^{ab}$ | 6.3$^{c}$ |
| Colour Minolta a* | -5.48$^{a}$ | -6.28$^{ab}$ | -20.57$^{c}$ |
| Colour Minolta b* | 46.77$^{a}$ | 48.39$^{ab}$ | 49.61$^{abc}$ |
| Colour Minolta a*/b* ratio | -0.12$^{a}$ | -0.13$^{a}$ | -0.41$^{b}$ |
| Firmness (kg) | 2.02$^{a}$ | 2.48$^{a}$ | 3.08$^{b}$ |
| Total soluble solids (%) | 25.9$^{a}$ | 26.7$^{a}$ | 22.5$^{b}$ |
| Weight loss (%/day) | 0.39$^{a}$ | 1.00$^{ab}$ | 1.49$^{b}$ |

**Table 3.** Effect of air relative humidity on sensory assessment of bananas picked at green stage and stored at 20 °C until full yellowing.

| Sensory evaluations (arbitrary units) | Relative Humidity (%) | | |
|---|---|---|---|
| | High (94%) | Medium (78%) | Low (62%) |
| Flavour (weak-strong) | 82$^{a}$ | 68$^{b}$ | 69.8$^{bc}$ |
| Sweetness (low-high) | 85$^{a}$ | 71$^{b}$ | 67$^{bc}$ |
| Off-Flavour (low-high) | 0.8$^{a}$ | 0.0$^{ab}$ | 2.5$^{abc}$ |
| Acceptability (low-high) | 84$^{a}$ | 75$^{b}$ | 72$^{bc}$ |

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## الملخص العربي

## عنوان البحث: تأثير الرطوبة خلال التخزين على الجودة الفسيولوجية لثمار الطماطم والموز المخزن

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**تمثل تم تخزين ثمار الطماطم فى طوري النضج الأخضر والوردى وثمار الموز فى مرحلة ثلاثة ارباع النضج عند درجة حرارة 20° م وثلاثة مستويات من الرطوبة النسبية: 62% ،78% و94% حتى تمام النضج مع وضع ثمار الموز قبل التخزين فى 10 جزء من المليون من غاز الأثيلين لمدة 24 ساعة لتنشيط النضج. تم تقدير بعض صفات جودة الثمار المتمثلة فى صلابة الثمار، الحموضة الكلية، المواد الصلبة الذائبة ، الفقد في الوزن، تقدير سطوع، درجة وكمية الكثافة اللونية لكلا نوعي الثمار والأيام اللازمة للوصول الى النضج التام بالإضافة الى تطبيق اختبار الجودة عن طريق المذاق الحسي لثمار الموز فقط. أظهرت النتائج أن الوقت اللازم لنضج ثمار الطماطم ازداد مع زيادة الرطوبة النسبية وعلى العكس من ذلك، الوقت اللازم لنضج ثمار الموز قل مع زيادة الرطوبة في حين لم توجد فروق معنوية بين مستويا الرطوبة المتوسط والمنخفض على جودة ثمار الطماطم الخضراء بعد النضج. ثمار الطماطم التي تم نضجها في مستوي عالي من الرطوبة تميزت بجودة اللون وصلابة الثمار وزيادة الحموضة وانخفاض الفقد في الوزن مقارنة بتلك الثمار التي تمت نضجها في مستوى منخفض من الرطوبة. أما الثمار المخزنة في مرحلة النضج الوردي والتي تم نضجها في مستوى منخفض من الرطوبة النسبية كانت أكثر صلابة مقارنة بتلك الثمار المخزنة في المستويين المتوسط والمرتفع من الرطوبة. ربما يعود ذلك لزمن الوصول لنضج الثمار كان أقل. بالنسبة لثمار الموز التي تم نضجها في مستوى منخفض من الرطوبة النسبية كانت أكثر ليونة وذات محتوى قليل من المواد الصلبة الكلية الذائبة مقارنة بتلك التي نضجت في المستويين المتوسط والمرتفع من الرطوبة النسبية والذي توافقت نتائجه مع نتائج اختبار الجودة الحسى.**