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The Effects of Different Storage Temperatures on the Quality of Fresh Bell Pepper (*Capsicum annum* L.)

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Abstract: Bell pepper (*Capsicum annuum* L.) fruit stored for 20 days, on the one hand, at various temperatures such as, 6, 16 and 21°C and on the other one, at ambient temperature (30±2°C), were compared in order to determine not only the impact of such temperatures on the quality, but also the appropriate storage temperature and the shelf life of bell pepper. The shelf life is limited by the effect of microbial proliferation due to a poor initial microbial quality of pepper (4.3 $\log_{10}$ CFU g^{-1}). Microbial proliferation limited *Capsicum annum* shelf life before the limiting effects of the quality properties. The quality of the packages stored at 6°C did not change during the first 12 storage days. The quality of unwrapped control fruit was far better than those stored in perforated sealed bag at air temperature. The storage temperature had major effects on the pH, the proliferation of the micro organisms (from 4.3 to over 9.28 $\log_{10}$ CFU g^{-1}) and the weight loss of bell pepper fruit (*Capsicum annum* L.). In order to guarantee the good quality of fresh *Capsicum annum L.* over a long selling period, it is recommended to keep the product at 6°C.

Key words: *Capsicum annuum*, shelf life, temperature, storage, quality

INTRODUCTION

Fruits and vegetables are important food worldwide (Anonymous, 1971). Bell pepper (*Capsicum annum* L.) is a tropical fruit, originated from South and Central America, disseminated in Europe, Africa and Asia (Reuter, 1950). *Capsicum* Annuum is the best known of all spices in tropical and subtropical areas. It is widely enjoyed and is essential for African and Ivorian dish (Terrible, 1983). In Côte d'Ivoire, *Capsicum Annum* is also used in almost all of the traditional medicine as drink, enema or plaster. It is known to be a medicinal plant (Chenu and Aké, 1987). The best known cultivated species are *Capsicum annuum* and *Capsicum frutescence* (Terrible, 1983). The demand for fresh vegetables led to an increase both in quantity and quality for the consumer. The freshness of these products and the subsequent storage conditions showed indigenous and human pathogenic micro organisms (Francis *et al*., 1999). Post harvest fruit and vegetables are usually exposed to surrounding temperature during transportation, storage and selling (Brecht *et al*., 2003). The best way to maintain the quality of fresh fruits and vegetables is probably by conditioning them in an adequate temperature throughout the post-harvest carriage chain (Brecht *et al*., 2003). It is therefore, significant to avoid quick deterioration of *Capsicum* in order to preserve, as long as possible its organoleptic characteristics, to increase its commercial quality. It was reported that Green *Capsicum* meets the packaging techniques (Ben-Yehosuha *et al*., 1995).

Post harvest losses in bell pepper carriage are a major bane of producers and sellers. The major problems related to fresh *Capsicum* fruit preservation are loss of weight during transport, development of micro-organisms and loss of firmness. The most common methods for post harvest preservation are cold, cooking, sun-drying and grinding, pre-cooking and storing in an oil containing box. Among the factors having impact on bell pepper (*Capsicum annum* L) shelf life, the temperature is probably the most important (Kader *et al*., 1989; Exama *et al*., 1993).

In Côte d'Ivoire, fruits and vegetables are widely used but few studies on the optimum conditions for their quality preserving are published. Therefore, this study is being conduced in order to assess the potential shelf life of bell pepper fruit. An extensive ripening time is

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a critical characteristic in the African selling system where there is no refrigeration and where transportation delay is frequent. A more extensive ripening time offers greater flexibility throughout the selling chain. This study aims at determining the optimum storage temperature of fresh *Capsicum* fruit conservation, in order to be able of extending both fruit ripening time and shelf life, basing upon the assessment of the microbiological spoilage and the quality attributes. In other words, at which temperature fresh *Capsicum* could be preserved longer and keep its quality attributes?

MATERIALS AND METHODS

Plant material: The bell pepper fruits (*Capsicum annum* L.) used for this study, are obtained in Abidjan, Côte d'Ivoire at the market known as "Adjame Gouro" from the retail mature green floor. Fruits were packed and transported the same day to the laboratory (Abobo-Adjamé University). Immediately, after, fruit were sorted out by size, weight, colour (green) and good appearance (fresh). About 22 kg of fruits of same size were stored, washed and distributed into 100 batches; a batch representing a sample of 150 g of fruits. Eighty batches were packed in polyethylene bag.

Storage conditions: To evaluate weight loss, spoilage, changing in colour and pH, according to preservation time, fruits are exposed to various temperatures for 20 days. The following packages (five replicates of each) were examined at each storage temperature and measurement period (0, 4, 8, 12, 16 and 20 days). A total of 80 batches of wrapped fruits were stored at 6, 16, 21°C and air temperature (30±2°C), for 20 days during experiment. Each of the 80 fruit batches was stored in sealed perforated 30 μm Polyethylene (PE) bags (about 20 holes, each 5 mm in diameter), bag of 30 μm thickness. All the sealed and perforated bags were identical in size, weight and in surface area. Fruit weight in the sealed bags was 150 g. Twenty batches of 150 g fruit were kept unwrapped for control measurement. The 20 unwrapped batches and 20 batches of sealed fruit were stored at air temperature. The main purpose of the air-stored control fruit was to indicate how long the experiment in the closed bags had to last before generating maximum differences between storage at different temperatures.

Quality evaluation

Weight loss: All fruit stored were measured at each temperature for initial and final weight to assess the percentage weight loss. Weight loss was calculated as sample weight at the beginning of the experiment, after different storage temperature (6, 16, 21°C and air) for 20 days. Measurements were carried out each 4 days (0, 4, 8, 12, 16 and 20 days).

Colour: Colour assessment was based on five stages of fruit ripening. Each sample was assessed basing upon the colour table. As the colour of *Capsicum* peel changes from green to red during normal ripening, peel colour was evaluated on a 1-5 scale. Scale 1: full green; scale 2: beginning of colour change (from green to yellow); scale 3: colour change (from yellow to light red); scale4: light red and scale 5: red. These stages are the characteristic of a ripe *Capsicum annum* fruit.

$$\text{CI index (between 1-5)} = \frac{\text{(CI level)} \times \text{(no. of fruit at the CI level)}}{\text{Total no. of fruit in the treatment}}$$

pH measurement: pH was measured using a calibrated glass electrode pH meter (PHM85 Precision pH meter, Copenhagen, Danmark). 50 g of bell pepper per replication was homogenised using a mixer (stomacher). A sample of 4 g of juice was diluted with 20 ml of distilled water and pH was measured.

Decay: Bell peppers were regularly examined during the storage period at the following days: 0, 4, 8, 12, 16 and 20 in order to determine the extent of decay. Diseases incidence was determined regarding the percentage of infected fruit per plastic bag.

Microbiological analysis: The growth of total aerobic micro-organisms was followed using the manual enumeration method. After preparation of a dilution series (1/10) in buffered peptone water (Merck, Germany), the number of viable cells was determined by pour-plating 1 mL of each dilution on plate count Agar (Merck, Germany) and incubated at 30°C for 24-48 h. The number of micro organisms was indicated as the $\log_{10}$ of the number of viable cells.

Statistical analysis: The experiments were repeated twice. Since there was no significant difference between the two experiments, the results were pooled and averaged. Experiments were laid out in a completely randomized block design with four replications. Data on weight loss, colour, pH and counts of micro-organisms were submitted to an analysis of variance, followed by Neuwman-Keul's multiple comparison test ($\alpha = 0.05$)

RESULTS AND DISCUSSION

The used of polyethylene seal package with perforation allowed about 12 days storage at 6 and 16°C without undesirable changes (Table 1). Product kept in polyethylene seal package with perforation and stored at 6°C showed no sign of deterioration until 12 days whereas packages without perforations and stored at ambient temperature (30±2°C) also increased the development of the colour and micro-organisms (Table 1 and Fig. 1). Similar observation was reported by others (Shaun *et al.*, 1999). These authors stated that packaged fruit stored at high temperature may have detrimental effects because high temperature effects on the quality of fruit very important than others. Packaged the product favour the excessive relative humidity (Pesis *et al.*, 2000). The quality attributes differed from temperature to temperature. Miller *et al.* (1986) found that packaging product in polyethylene bags reduce weight loss and increase fruits shelf life during storage (Fig. 2). They found that between 7 and 13°C, *Capsicum annum* can be stored for long time similar to results found in this study.

The weight loss in *Capsicum annum* is presented in Fig. 1. It shows that temperature had a significant effect on the weight loss and post harvest life. There is an increase in weight loss from 0% at the beginning of the storage to less than 60% at the end of storage period when *Capsicum* fruit are stored at air temperature (about 30°C) whatever fruit are sealed in perforated polyethylene package or not. Meanwhile, fruits sealed and stored at 6°C show the lowest weight loss of 12.6% after 3 weeks storage time. Therefore, when exposed to lower temperature, changes in weight were not as important as at higher temperature. After 3 weeks storage, the percentage of weight loss is 12.66% when stored at 6°C but more than 60% (64.67 and 62.67%) at air temperature (Fig. 1). Unwrapped control fruits lose about 65 % of their initial weight during the 20 days of storage. Packing fruit and vegetables in plastic bags offers several advantages, such as protecting the produce from mechanical damage and contamination, reducing moisture, loss and allowing modification of the gas atmosphere in the package (Kader *et al.*, 1989). At the end of the 20 days storage period, wrapped fruit stored at 6°C lose less weight than wrapped fruit at other temperatures (Fig. 1). Low temperature is probably the best method to keep quality and extend fresh *Capsicum annum* fruit shelf life according to Raison (1980). The increase in percentage of weight loss with time could also be explained by the effect of transpiration as mentioned by Ben-Yehoshua (1987). Meir *et al.* (1995) stated that sealing fruit in polyethylene bag decreases water loss from 50-40% for fruit store during 2 weeks at 7.5°C and an additional 3 days at 17°C. George *et al.* (1982) reported that after harvest, fruit weight loss is due to water loss. The rate of desiccation due to water loss is negatively correlated with fruit ripening time (George *et al.*, 1982). However, Shaun *et al.* (1999) considered simpler and quicker to monitor fruit ripening by recording changes in peel colour.

Table 1: Effect of storage temperature on colour index of bell pepper (*Capsicum annum*) fruit

	Storage time (days)					
Storage conditions	0	4	8	12	16	20
Air unwrapped	1	1	1	1	2	2
Air wrapped	1	1	2	3	3	4
21°C	1	2	2	3	3	4
16°C	1	2	3	3	4	5
6°C	1	2	3	3	4	4

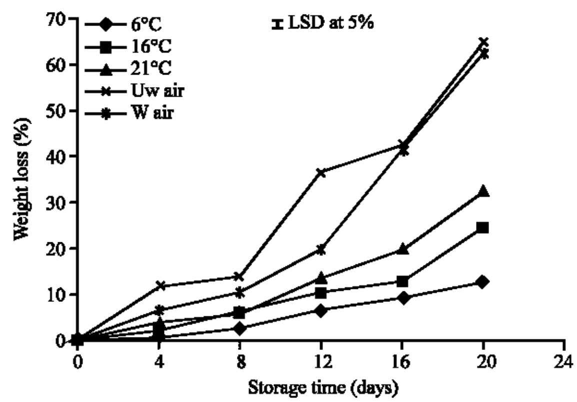

Fig. 1: Effect of storage temperature on bell pepper (*Capsicum annum*) fruit weight loss during postharvest storage

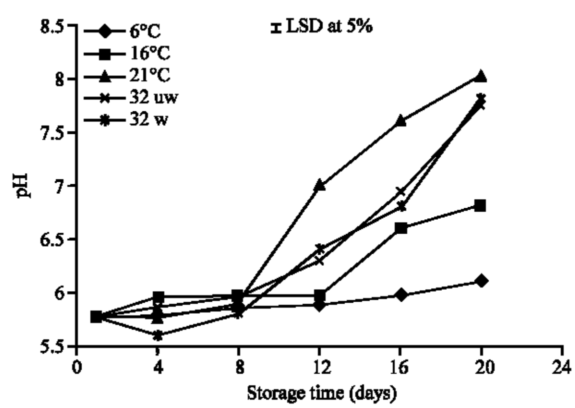

Fig. 2: Effect of storage temperature on the pH of bell pepper (*Capsicum annum*) fruit during postharvest storage

Table 1 presents colour change in Bell pepper fruit at different temperatures. Visual analysis shows that fresh *Capsicum* stored at different temperatures are exposed to colour variation. At the end of the storage period, the scores went from scale 2 (colour change from green to yellow) to scale 5 (red). After 20 days of storage, all Bell pepper fruits reached a colour index of 4-5 at temperatures above 6°C. Wrapped and unwrapped fruit stored at air temperature and wrapped fruit stored at 21 and 16°C show colour change from green to bright red (scale 5) after the end of storage time, similar to results were obtained by Meir *et al.* (1995). Yang (1985) indicated that fruit ripening and senescence are associated with ethylene action and synthesis while Kader (1985) specified that temperature has a high effect on ethylene production and activity. There was little change in fruit colour at 6°C, changing from green (scale 1) to yellow (scale 2) after 3 week storage. Cheftel and Cheftel (1992) got similar results and mentioned that refrigeration temperature delayed and slow down fruit ripening. The shelf-life based on exceeding the score of five for bell pepper colour at specific storage temperature is 20 days.

The effect of different storage temperatures on pH was illustrated by in Fig. 2. Wrapped bell pepper stored in air, at 21 and at 16°C showed acidity variation. For unwrapped pepper stored in air temperature, pH increased from 5.78-5.86 the first days (1st-4th day) and increased after 4 days reaching 7.8. The decrease during the first storage days could be due to effect of air and temperature because many fruits quickly ripened and entered senescence phase (Cheftel and Cheftel, 1992). Variation in fruit acidity is due to the difference in ripening as mentioned by King *et al* (1991). Cheftel and Cheftel (1992) stipulate that fruit acidity decreases with ripening and they confirm the results obtained in this study. From 4-20 day storage, the increase in pH is probably due to ripening because colour change from green to red is observed. At 16°C, pepper pH increased progressively from 5.48 to reach a final pH of about 6.81. During 3 weeks storage, *Capsicum* fruit show slight increase in pH for fruit stored at 6°C from 5.78-6.10. Slow, homogenous and progressive ripening of the fruit could explain this result. Meanwhile at temperature above 16°C, pH tends to be alkaline (7.80-8.01) after 20 days.

Figure 3 illustrates percentage of fruit spoilage during the 20 days of storage period. Spoilage was manifested as colour change of the peel and visual sign of decomposition. For fruit stored at 6, 16 and 21°C for 3 weeks, spoilage percentage is, respectively 35.6, 19.03 and 10.45. For unwrapped control fruit kept at air temperature (30±2°C), spoilage percentage is 81 whereas at the same temperature, wrapped fruit gave 100% spoilage and softening was clearly apparent. Transpiration generates water loss causing undesirable

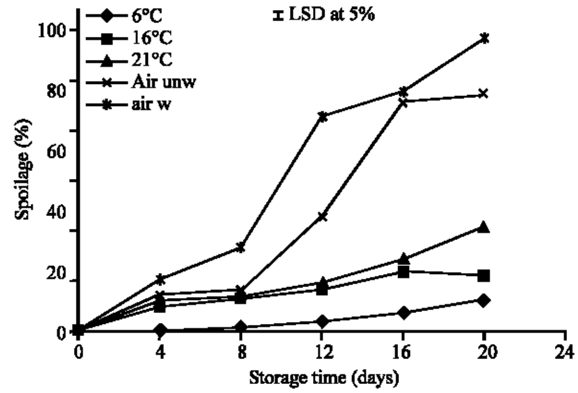

Fig. 3: Effect of storage temperature on the fungal decay in bell pepper (*Capsicum annum*) fruit during postharvest storage

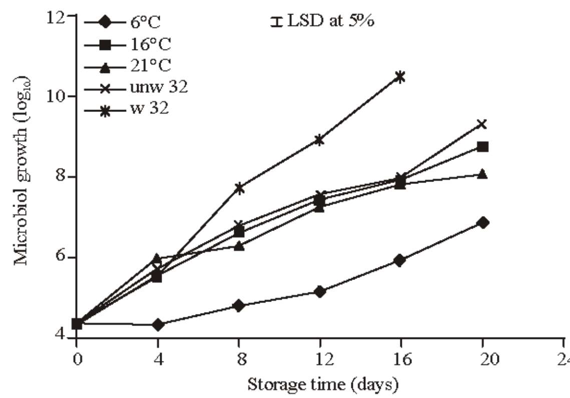

Fig. 4: Effect of storage temperature on the microbial growth in bell pepper (*Capsicum annum*) fruit during postharvest storage

damage such as loss of freshness, desiccation or softening of tissues, weigh loss and quality loss on fruit. The high spoilage obtained at the end of storage time could be explained by air temperature variations increasing fruit senescence process as also reported by Polderdijk *et al.* (1993). The difference in the percentage of fruit spoilage for both wrapped and unwrapped fruit at air temperature could be caused by the condensation in the bag which creates aqueous focuses for the development of micro-organisms such as *Botrytis cinerea* and *Alternaria alternate* (Rodov *et al.*, 1995). Ben-Yehoshua (1987) reported that during storage of *Capsicum annum*, the fruit respires and water from transpiration increases relative humidity in the packages and as a consequence, increases the risk of product spoilage. At air temperature, Bell pepper suffers from spoilage due to growth of micro-organisms. These finding indicated that *Capsicum annum* fruit are perishable but keep metabolic activity after harvest.

Figure 4 shows the effect of different storage temperature on microbial counts and, it also give the summary of the estimation of cell number. Total aerobic count was determined at the beginning and throughout conservation time in order to follow microbial evolution and determine C*apsicum annum* shelf life basing upon the quality attributes and microbial properties determination. Total aerobic count increases, as temperature increases. Since initial microbial count was high (4.3 $\log_{10}$ cfu g^{-1}) it was therefore evident to count great number of total aerobic micro-organisms during storage. Since Bell pepper contains sugar (even more than lettuces and cucumber), it can stimulate growth of yeast and lactic acid bacteria (Babic *et al*., 1992). After 12 days of storage, counts in unwrapped and wrapped fruit stored at ambient temperature were 7.5 $\log_{10}$ cfu g^{-1} and 8.9 $\log_{10}$ cfu g^{-1} and after 20 days, they were 9.28 $\log_{10}$ cfu g^{-1} and numerous enough to be counted. This is due to ripening (Meir *et al*., 1995). The maximum number was reached after a period of storage in which pepper respiration rendered the plant less resistant to microbial attack (King *et al*., 1991). Moreover, Kakiomenou *et al*. (1996) reported that micro-organisms spoilage was dominated by lactic acid bacteria and that type of spoilage has less decomposition character compared to gram negative bacteria. It should also be noticed that *Alternaria* is one of the major mold causing deterioration of mature pepper during storage caused by transpiration and high relative humidity. Storage time acts on micro-organisms development. The quality attributes of fruit at the beginning of storage are the following one: green, pH 5.78, 0% spoilage, 0% weigh loss. But the initial contamination was already high (4.3 $\log_{10}$ cfu g^{-1}). Similar results were reported by Bennik *et al*. (1998). In addition to the effect of storage time, the effect of temperature on microbial counts became very clear during the storage experiment. Growth is accelerated at higher temperature for pepper stored at air temperature wrapped or not. But this growth is slowed down at 6°C because of slowly growing effect of micro-organisms due to cold. Wrapped fruit stored at 6°C are less infected by micro-organisms after 20 days storage (6.85 $\log_{10}$ cfu g^{-1}) than wrapped fruit at 16°C (8.73$\log_{10}$ cfu g^{-1}), 21°C (8.04 $\log_{10}$ cfu g^{-1}) and air temperature (numerous enough to be counted) $\log_{10}$ cfu g^{-1}). After 8-20 days storage at air temperature, wrapped fruit were highly contaminated above values found for unwrapped fruit kept in the same condition. The increase in pH and temperature influence spores germination and favours bacterial growth and could explained the high count obtained for wrapped fruit stored at ambient temperature (30°C). At the end of the storage period, colour variation appeared together with a loss of the fresh look of the fruit because of the growth of Gram negative soft rot causing bacteria (Nguyen-the and Carlin, 1994; Jacques and Morris, 1995). Gram negative bacteria such as *Pseudomonas* sp. or Enterobacteriaceae, dominating spoilage of leafy vegetables are known to have pectinolytic activity (King *et al*., 1991).

CONCLUSION

The increase in weight loss followed by visual signs of microbial spoilage and colour change showing the end of post harvest life was indicated. Exposed to air, unwrapped fruit showed the fastest ripening scenario basing upon the control fruit. The study shows that at 6°C, the shelf life of bell pepper seal in polyethylene package is 12 days. Nevertheless, for producers, cheap carriage and selling shelf life should be better at air temperature without wrapping.

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