EXTENDING POST-HARVEST LIFE OF SWEET PEPPER (*Capsicum annum* L. 'California Wonder') WITH MODIFIED ATMOSPHERE PACKAGING AND STORAGE TEMPERATURE

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Abstract

The post-harvest performance of sweet pepper 'California Wonder' was tested under three different packages (open trays, non-perforated and perforated polyethylene bags) stored at temperatures of 4°C, 6.5°C and ambient (17°C) for 25 days. Data on weight loss, skin green colour retention, incidences of chilling injury and diseases were collected and subjected to statistical analysis. Fruit weight loss was significantly lowest at storage temperatures of 4°C and 6.5°C and non-perforated packaging. Skin green colour retention was significantly highest on fruits held at 4°C and 6.5°C on day 5 and at 6.5°C on days 10 to 25 compared to ambient storage. However, packaging did not significantly affect colour retention. The interaction of 6.5°C and non-perforated packaging had significantly (p<0.05) highest level of green colour retention throughout the storage period. Storage temperature did not significantly affect the incidence of diseases in sweet pepper, whereas, non-perforated packaging had significantly (p<0.05) highest incidence of disease. The interaction of storage at 4°C and non-perforated packaging had significantly (p<0.05) highest incidence of diseases. Interactions between non-perforated packaging and storage temperatures of 4°C and 6.5°C showed significantly (p<0.05) higher incidences of diseases after exposure to ambient conditions for 2 days. Temperature was the major factor in determining the post-harvest performance of sweet pepper. However, the interaction of storage at 6.5°C and perforated polythene packaging produced the best results.

Key words: Sweet pepper, post-harvest, storage temperature, modified atmosphere packaging, weight loss, skin colour, diseases, chilling injury.

INTRODUCTION

Sweet pepper is increasingly becoming an important fresh vegetable in Kenya. It deteriorates rapidly during handling and storage due to poor post-harvest handling leading to huge losses (Anon. 2003). Generally, the products are handled in batches that subject them to a wide range of environmental shocks. In Kenya, most growers and produce handlers keep the perishables at ambient conditions under which the quality of pepper can be maintained for only a short time (3-4 days) while some store them in cool rooms (4-8°C) that marginally extend their post-harvest life (Anon. 2003).

The purpose of post-harvest handling system is to deliver appealing and nutritious food to the consumer in an economical manner. Handlers and consumers therefore attach a lot of importance to the retention of fruit green colour, freshness and firmness as quality attributes during handling and storage (Sigge *et al*., 2001). In addition, absence of defects, diseases as well as shelf life are also considered. These quality parameters are functions of temperature, relative humidity (Gorini *et al*., 1977; Jobling, 2001) and air composition of the handling or storage environment (Halloran *et al*., 1995).

Controlled atmosphere storage with 3-5% oxygen and high carbon dioxide reduces loss of green colour but results in calyx discolouration (Hardenburg *et al*., 1990) while temperature of 10°C and 90-95% relative humidity maintain sweet pepper quality satisfactorily for a period of up to12 -18 days (Sealand, 1991). Low temperature storage remains the most effective tool for maintaining quality and extending shelf life, but it results in chilling injury. However, seal packaging ameliorates chilling injury in many fresh products by prevention of water loss (Ben-Yoshua *et al*., 1987). In addition, modified atmospheres are designed to slow down respiration and thus senescence by reducing oxygen or increasing CO_2 concentrations (Kader, 1985). Nevertheless, sweet pepper is moderately sensitive to high CO_2 (5-10%) damage. There is need to understand the interactions among the many operations necessary for delivering sweet pepper to consumers in order to be able to predict their impacts on produce quality. Pre-packaging and storage of sweet pepper at ambient conditions are commonly practiced in Kenya but their potential in maintaining produce quality is not well understood. Determining the best pre-packaging and storage temperature for sweet paper may assist the growers, dealers and consumers in maintaining the quality of the sweet pepper. Thus, the aim of this study was to investigate the effects of storage temperatures and modified atmosphere (polyethylene pre-packaging) on post-harvest performance of sweet pepper.

MATERIALS AND METHODS

Sweet pepper 'California Wonder' was conventionally grown at Egerton University (altitude of about 2000m above sea level). Physiologically mature fruits were harvested for the experiment. The fruits were sorted according to uniformity of size and green skin colour and those with defects or diseased were discarded. The fruits were randomly grouped into batches of ten unpackaged or pre-packaged in polyethylene bags (12µm thick – gauge 48). The polyethylene bags were either non-perforated or perforated with a paper-punch. The fruits were then stored at ambient conditions (about 18±5°C) and in refrigerators set at temperatures of 4°C and 6.5°C and relative humidity of 95-100% (monitored by a thermo-hygrometer). The experimental design was a factorial (spilt plot in a completely randomised design) with temperature (3) and pre-packaging (3) as main and sub-treatment factors, respectively. Each treatment was replicated four times. The fruits were stored until the unpackaged ones held at ambient conditions became unmarketable (25 days) due loss in quality. The fruits stored at 4°C and 6.5°C were then transferred to ambient conditions and observed for the incidences of physiological disorders and diseases since symptoms of chilling injury and diseases are well expressed at conducive ambient environments.

Weight loss

Batches of fruits in each replication were weighed (g) at the beginning of the experiment using an electronic balance and then after every 5 days during storage. Percentage changes in weight were calculated.

Colour change

Change in skin colour was rated at intervals of 5 days using a hedonic scale of 1 to 5 (5 - uniformly green; 4 – more green than red; 3 – equally green and red; 2 – more red than green; and 1 – uniformly red).

Incidences of diseases and chilling injury

Fruits showing the symptoms of chilling injury (pitting, water-soaked areas, skin blackening) and incidences of diseases (rots and mycelial growth) were counted and incidences of the disorders calculated as a percentage of the total number of fruits per replication.

Data Analysis

The results were subjected analysis of variance (ANOVA) using SPSS statistical package (Microsoft Corporation, version 9.0) and the means separated by Duncan Multiple range test method at $p<0.05$.

RESULTS

Weight loss was significantly ($p<0.05$) lowest for fruits stored at 4°C and 6.5°C throughout the storage period (Figure 1). Weight losses were significantly ($p<0.05$) lowest, moderate and highest with non-perforated, perforated polyethylene packages and unpacked sweet pepper, respectively (Figure 2). The interaction between storage at ambient conditions and non-packaging resulted in significantly ($p<0.05$) highest weight loss over the storage time (25 days) (Figure 3) followed by perforated packaging at ambient environment.

Skin green colour retention was significantly ($p<0.05$) highest on fruits held at 4°C and 6.5°C on day 5 and at 6.5°C for days 10 to 25 compared to ambient storage (Table 1). Packaging did not significantly affect colour retention (Table 1). The interaction of 6.5°C and non-perforated packaging had significantly ($p<0.05$) highest level of green colour retention throughout the storage period (data not presented).

Storage temperature did not significantly affect the incidence of diseases in sweet pepper, whereas, non-perforated packaging had significantly ($p<0.05$) highest incidence of disease (Table 3). The interaction of storage at 4°C and non-perforated packaging had significantly ($p<0.05$) higher incidence of diseases (Table 3). Interactions between non-perforated packaging and storage temperatures of 4°C and 6.5°C showed significantly ($p<0.05$) higher incidences of diseases after exposure to ambient conditions for 2 days (Table 3).

DISCUSSION

Lower weight loss that coincided with decrease in storage temperature is in agreement with findings of several previous researchers including Tindall (1983); Hardenburg *et al.* (1990) and Sealand (1991). This could be attributed to the slow down of physiological processes such as respiration and transpiration that occur at low temperatures (Kays, 1991). Wide fluctuations in temperature at ambient conditions increased the rates of water loss from sweet pepper possibly by increasing vapour pressure deficit between the tissue and the surrounding air leading to enhancement of transpiration (Ben-Yoshua *et al.*, 1987). In addition, high temperatures increased the rates of respiration and other metabolic processes that caused depletion of substrates like sugars and proteins resulting into further weight loss (Buescher, 1979). As water evaporates from the tissue, turgor pressure decreases and the cells begin to shrink and collapse thus leading to loss of freshness. High weight loss also translates into loss of marketable weight (Wills *et al.*, 1998).

Lowest weight loss from non-perforated packaging is due to the confinement of moisture around the produce by polyethylene bags. This increases the relative humidity and reduces vapour pressure deficit and transpiration. In addition, packaging creates a modified atmosphere with higher concentration of carbon dioxide and reduced oxygen around the produce, which slows down the metabolic processes and transpiration (Thompson, 1996).

The highest weight loss observed at higher temperatures and unpackaged pepper fruits throughout the storage period can be attributed to air movement, which tends to sweep away the unstirred layer of air (at equilibrium vapour pressure with the tissues) adjacent to the surface of the produce thus increasing the vapour pressure deficit (Wills *et al*. 1998).

Higher loss in green colour at ambient temperatures may be caused by increased breakdown of chlorophyll and synthesis of β-carotene and lycopene pigments, which occur during ripening (Grierson and Kader, 1986; Nyalala and Wainwright, 1998). Lowering the temperature of non-climacteric fruits like sweet pepper lowers their rate of ripening and deterioration (Kays, 1991) and hence the high retention of green colour observed on fruits stored at 4°C and 6.5°C.

The highest disease incidence observed with non-perforated packaging may be due to high relative humidity and water condensation around the produce, which promote the development of post-harvest decay (Coates *et. al.* 1995). Pronounced chilling injury observed at 4°C could be as a result of dissociation of enzymes and other proteins into structural sub-units hence changes in the kinetics of enzyme activity and changes in structural proteins (Graham and Patterson, 1982; Morris, 1982; Wang, 1990). The low temperature induces change in the physical properties of cell membrane due to changes in the physical state of membrane lipids. Chilling injury causes the release of metabolites such as amino acids, sugars and mineral salts from cells that together with the degradation of the cell structure provide an excellent substrate for the growth of pathogenic organisms, especially fungi (Wills *et al*. 1998). This supports the high disease incidence observed on sweet pepper in non-perforated package stored at 4°C.

Temperature was the major factor in determining the post-harvest performance of sweet pepper. However, the interaction of storage at 6.5 °C and perforated polythene packaging produced the best results.

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Tab. 1.: The effects of storage temperature or packaging on skin green colour retention of sweet pepper

Treatment s	**Time Days)**				
Storage temperature	**5**	**10**	**15**	**20**	**25**
4°C	97.9a	81.4ab	81.4ab	79.3ab	77.3ab
6.5°C	97.9a	97.9a	97.9a	95.8a	91.7a
Ambient (17°C)	89.6b	75.0b	70.8b	64.5b	37.5b
Packaging					
Unpacked	95.8a	73.1a	71.0a	62.6b	54.3a
Perforated	95.8a	89.6a	89.6a	87.5a	75.0a
Non-perforated	93.8a	91.7a	89.6a	89.6a	77.1a

Means followed by same letters are not significantly ($p<0.05$, Duncan Multiple Range Test) different by column for storage temperature and packaging, respectively.

Tab. 2.: The effects of storage temperature and packaging on the incidence of chilling injury

Storage temperature	**Packaging**			**Temperature Effects**
	Un-packed	**Perforated**	**Non-perforated**	
4°C	70.8ab	79.2ab	83.3a	77.8a
6.5°C	54.2b	87.5a	91.7a	77.8a
Ambient (17°C)	0.0c	8.3c	4.2c	4.2b
Packaging effects	41.7a	58.3a	59.7a	

Storage temperature and packaging interactions followed by the same letters are not significantly different by row and column ($p<0.05$, Duncan Multiple Range Test). Storage temperature or packaging effects followed by same letters are not significantly different by column and row, respectively.

Tab. 3.: The incidences of diseases in sweet pepper as influenced by storage temperature and packaging

Storage temperature	**Packaging**			**Temperature Effects**
	Un-packed	**Perforated**	**Non-perforated**	
4°C	0.0c	12.5bc	45.8a	19.4a
6.5°C	0.0c	4.2c	37.5ab	13.9a
Ambient (17°C)	4.2c	4.2c	20.8abc	9.7a
Packaging effects	1.4b	6.9b	34.7a	

Storage temperature and packaging interactions followed by the same letters are not significantly different by row and column ($p<0.05$, Duncan Multiple Range Test). Storage temperature or packaging effects followed by same letters are not significantly different by column and row, respectively.

Figures

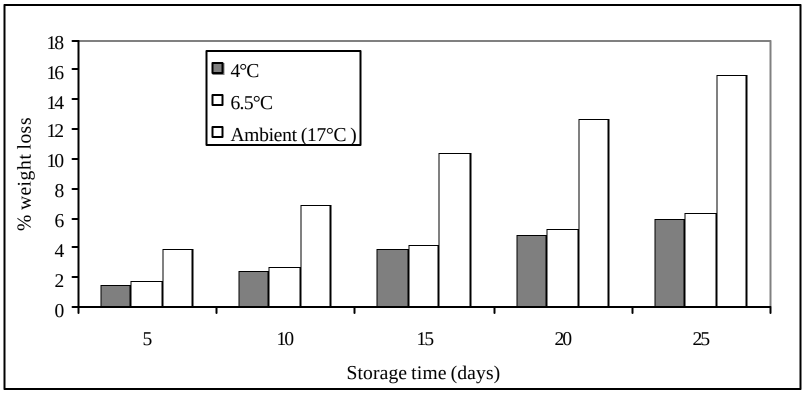

Fig. 1.: The effects of storage temperature on weight loss of sweet pepper.

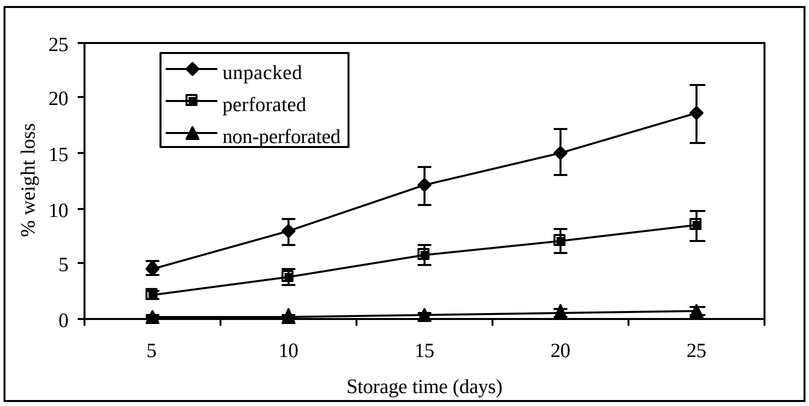

Fig. 2. : The effects of pre-packaging on weight loss of sweet pepper.

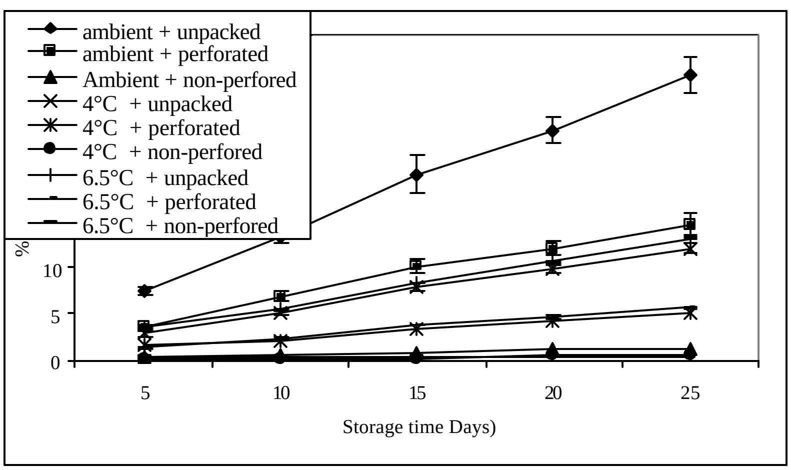

Fig. 3.: The effects of storage temperature and modified atmosphere interaction on weight loss of sweet pepper

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