Journal of Applied Biosciences (2008), Vol. 6(2): 173 – 179.
ISSN 1997 – 5902: www.biosciences.elewa.org

Effect of storage temperatures and hot water dipping on post-harvest characteristics of Okra

[redacted]

[redacted]

ABSTRACT

Objectives: A post-harvest study was carried out to evaluate the potential benefits of hot water treatment, storage temperatures and any interactive effects of the two in extending the shelf life of okra.

Methodology and Results: The treatments assessed were immersion of Okra pods in hot water dips at 40°C for 7 min, 50°C for 1 min, room temperature (15-20°C) for 10 min and control (no hot water treatment). After treatment pods were stored in refrigerators at 4, 8.5 and 13°C or room temperature conditions to simulate the most common farmer's method of storage. Treatments were replicated six times and the experiment repeated twice. Data were subjected to ANOVA using Genstat (vers. 9). Pods treated in hot water at 50°C for 1 min and stored at room temperature had the least decay and weight loss.

Conclusions and application of findings: Dipping pods in hot water at 50°C for 1 min followed by storage at room temperature (15-20°C) reduced pod weight loss, electrolyte leakage, off odour, decay, and enhanced visual appearance and had no chilling injury. The treatment improved shelf life for 21 days and it can be practical under rural farming conditions. This treatment combination would be easy to adopt and is therefore recommended to farmers for storage of okra. To achieve these storage conditions, okra production in areas with temperatures above 25°C would only require an insulated store built with special cooling material, thereby eliminating the need for electricity. Extending the shelf life of okra, with reduced post-harvest losses, is desirable as it prolongs the marketing period. Use of hot water dips and low temperature storage provides an alternative to chemical treatments, which are harmful and are being shunned by consumers.

Keywords: Okra, hot water dipping, storage conditions, visual appearance, electrolyte leakage, chilling injury, weight loss, decay incidence

[redacted]

Introduction

Okra (*Abelmoschus esculentus* L. Moench) is widely grown in Kenya as an export vegetable (HCDA, 2002). The pods are harvested as immature tender fruits. However, under room conditions (15-20ºC) and without any postharvest care, the pods deteriorate within two days after harvest (Duzyaman, 1997). Temperature is one of the major factors that influence the deterioration rate of harvested commodities. For each 10°C rise in temperature above the optimum, the rate of deterioration for fresh harvested commodities increases two to threefold (Thompson, 1996). When stored at temperatures above 25ºC okra pods lose quality rapidly due to high respiration rates. The pods turn yellow, decay and toughen (Salunkhe & Desai, 1984). Temperature conditions influence the effect of ethylene, oxygen and carbon dioxide levels, and pathogen spore germination and growth rate. Cooling commodities to below 5°C immediately after harvest can greatly reduce the incidence of pathogenic rots (Brackett, 1993).

Chilling injury occurs in okra pods stored between-1.8°C (Penelope, 1997) and 7°C for an extended period (Perkin-Veazie & Collins, 1992). The disruption caused by chilling injury enhances rotting and usually results in immediate collapse of the tissues and total loss (Gasti *et al.,* 1997). Fresh vegetables that are highly sensitive to chilling are generally stored at 10-13ºC (Salunkhe & Desai, 1984). Postharvest heat treatments of fruits and vegetables, applied as hot water dips, vapour or hot dry air (Fallik *et al*., 1996) has been used for many years for disease control (Paull & Chen, 1990). Such non-chemical methods are widely recommended (Bauchmann & Earles, 2000). Treating with hot water treatment at 50 – 55°C for 3 - 5 min controls fungal decay, e.g. grey and black moulds caused by *Botrytis cinerea* and *Alternaria alternata*, respectively, in many fresh fruits and vegetables (Baxter & Waters, 1990).

Most okra farmers in Kenya incur heavy losses especially during periods of market glut because of poor storage practices that are unsuitable for the short shelf life of okra pods. This caused a decline in okra export from 2,600 tons in 2000 to 1,500 tons in 2005 (HCDA, 2006). The objective of this study was to develop postharvest management options using hot water dips and low temperature storage to extend the shelf life of okra pods, and thereby prolong the marketing period.

Materials and Methods

Experimental materials: The okra crop was grown at Egerton University Horticulture Research and Teaching Field. The farm is located approximately 0°23' S; 35° 35' E at 2200 m above sea level. The mean temperature, humidity, evaporation rate and rainfall over a ten year period (1991-2000) were 19.7°C, 62.5%, 3.9 mm day^{-1} and 907 mm yr^{-1}, respectively (Egerton University Meteorological Station, 2000). The soil pH (H_2O) and (0.01M $CaCl_2$) at 0-30 cm depth is 6.3 and 5.4, respectively. The soils are Vintric Mollic Andosols. The postharvest experiment was conducted at the Department of Horticulture Laboratory.

Site preparation and crop management: Okra seeds ('Pusa Sawani') from Kenya Seed Co. Ltd., were sown in beds measuring 1.2 m wide and 20-30 cm high. Drip irrigation tubes and polyethylene mulch were laid on the beds prior to planting. Emergence (95%) was realized within 7 days of planting.

At planting, 120 kg NPK ha^{-1} (2gm $plant^{-1}$) was applied. Top dressings of CAN at 70 kg N ha^{-1} (68 gm $plant^{-1}$) was done when plants were 15 to 20 cm tall and repeated after 2 to 3 weeks (HCDA, 1996). All other management practices including watering, weeding, pest and diseases control were carried out regularly to enhance growth and performance of the crop.

Harvesting commenced within 10 weeks after planting, 4-7 days after flower opening. Well formed, straight, tender pods with a fresh appearance and a colour typical of the cultivar (generally bright green) and free of defects were harvested with at least 1cm long stalk. Sampled pods excluded leaves, stems, broken pods and those with insect damage and mechanical injury. The pods were handled carefully to prevent physical damage such as surface friction, impact and vibration bruising as recommended by Medlicott (1990).

Harvested pods were immediately transferred to a cool room to dissipate heat absorbed in the field. Pods measuring 5 - 8cm long, which are preferred by consumers, were used for the experiment after further sorting to select only those with good appearance (green, fresh, firm, tender tips and free from debris, no dark discoloration, chemical residue, disease, bird or insect damage), and without seeds protruding through the skin (Perkins- Veazie & Collins, 1992).

Postharvest treatments: The selected okra pods were subjected to three levels of hot water dipping treatments and four levels of storage temperatures. Temperature treatments were 50°C for 1 min, 40°C for 7 min, water at room temperature for 10 min and a non-dipping treatment used as the control. Storage temperatures were 4, 8.5, 13°C (in refrigerators) and room temperature (placing pods on tables in the laboratory) (15-20°C). Water was heated in two 30 litre capacity insulated and thermostatically controlled water baths maintained three quarter full for the required time. After treatment, the pods were placed on clean serviettes to air dry.

Experimental design: The experiment was replicated six times in a split plot experiment embedded in a completely randomised design (SPCRD). Storage temperatures treatments were the main factor investigated while the hot water were sub factor. The pods were stored for a maximum of three weeks (21 days). The experiment was repeated twice. The first trial ran from November 25th –December 15th, 2005 and second trial from December 26th – January 15th, 2006.

Variable assessments: The variables measured were weight loss, visual appearance, incidence of decay, incidence of chilling injury, off odour and electrolyte leakage, each assessed as follows:

Weight loss: Weight of pods per bag (B) was determined using an electric weighing balance and weight loss (W) calculated on the basis of the original weight (A) at the start of the experiment and the final weight.(Z) at the end of the experiment W (%) = [(A-Z/A) x100].

Visual appearance was evaluated when green pods started changing colour using a hedonic scale from 7 excellent (bright green), 5 – good (dull green), 3 – acceptable (yellowing) and 1 - not acceptable (dark).

Incidence of decay (I) was calculated based on number of pods showing symptoms of decay (D) to the total number of pods per bag (P) at the end of 21 days. I (%) = [(D/P)*100]..

Incidence of chilling injury (CI) was calculated by counting the number of pods with symptoms (PS) as a percentage of the total number of pods per bag (P). After 21 days pods were first exposed to room conditions for symptoms of discoloration, pitting, water-soaking and increased decay to be expressed. CI (%) = [(PS/P)*100].

Off odour was evaluated using a hedonic scale of 7-Excellent, 5-good, 3-acceptable, and 1-not acceptable. Then percentage average divided by 7 and calculated per package. Off odour = (No of packages in scale/No of total packages) 100%.

Electrolyte leakage was determined by rinsing cut pieces of okra with water. Pieces weighing 5gm were soaked in water for 15 min and the electro-conductivity of the water determined using a Hanna conductivity meter.

All the variables were first assessed when the non-hot water treated pods and those stored at open room conditions started showing signs of wilting or shrivelling. The assessment of weight loss and visual appearance were carried out on the 3rd day (excellent), 7th day (relatively good), 14th day (maximum) and 21st day (not published) of storage (Duzyaman, 1997).

Data Analysis: Data were subjected to analysis of variance (ANOVA) at $p \leq 0.05$ using Genstat (version 9) and the means separated by Duncan Multiple Range Test (DMRT).

Results and Discussion

Effects of treatments on pod weight loss: There was a general increase in weight loss of okra pods with increase of storage temperatures across all water treatments. At the lowest storage temperature of 4°C, weight loss was suppressed at all hot water treatments. The lowest weight loss (19%) was observed in the pods dipped in hot water at 50ºC for 1 min and stored at 4°C (Table 1). This could be due to reduction of metabolism and respiration rates at the lower temperature. In a previous study, fruits stored at 0°C were reported to have increased firmness, better quality and less weight loss (Brackman & Bortoluzzi, 2001), which supports the findings of our study. The largest weight loss of 42% was observed in all the pods that were dipped in water at room temperature for 10 min before storage at room temperature (15-20ºC) for 21 days (Table 1). This loss could be attributed to rapid ripening and senescence due to high temperature (18-20°C). Thompson (1996) has associated increased senescence and deterioration of stored fruits to sustained responsiveness of climacteric fruits to ethylene during and after ripening.

Okra pods that were dipped in water at 50°C for 1 min and then placed at room temperature (15-20°C) had the lowest weight loss of 36% compared to other pods that were dipped in water at different temperatures (Table 1). The reduced weight loss when pods are dipped in water at 50°C for 1 min and placed in a room is consistent with the opinion of Cantwell de Trejo (1998) indicating that the quality of fruits exposed to higher temperatures for shorter duration is less affected than those exposed to shorter temperatures for longer periods. This reaction could be attributed to stress proteins known as dehydrins, which are produced during hot water treatment. According to Neven & Drake (1998) these proteins, along with other physiological mechanisms, help the fruit to prevent water loss and withstand environmental stress.

Table 1: Effects of hot water dipping and storage temperature on okra weight loss after 21 days of storage

Water Treatments	Storage temperatures (°C) 4	8.5	13	RT
	→ Weight loss (%) ←			
No water dipping	22.9h	35.4de	38.5bc	37.4bcd
RT[y] dipping/10mins	24.4h	34.5ef	38.4bc	42.1a
40°C/7mins	23.1h	31.5fg	36.2cde	37.3bcd
50°C/1min	19.4i	31.2g	35.7cde	36.3cde

[z]Means followed by the same suffix are not significantly different in all columns at DMRT P ≤ 0.05
[y]Room temperature (RT) varied between 15-20°C.

Visual appearance and off odour of okra pods: After 21 days of storage the best off odour and visual appearance was expressed by the pods dipped in hot water at 50°C for 1 min before storage at room temperature (Tables 2 & 3). Pods stored at 8.5°C had the worst off odour and visual appearance across all the water treatments except those dipped in water at 50°C for 1 min. The pods had the least blackening on the ridges, a characteristic that is often observed on stored okra pods. It is possible that okra pods respond to heat shock by producing unique heat shock proteins (hsp) that help to prevent further stress. Induction of hsp synthesis is accompanied by a reduction in synthesis of other proteins and compounds, e.g. PAL (phenylalanine ammonia lyase) and reducing phenolic compounds that are sometimes associatec browning in wounded lettuce tissue and other produce (Saltveit, 1998). When stored at 4°C there was no off-odour as the pods were frozen.

Table 2: Visual appearance of okra pods subjected to different hot water treatments and storage temperatures after 21 days of storage.

Water Treatments	Storage temperatures (°C) 4	8.5	13	RT
	→ Visual appearance ←			
No water dipping	3.0e	1.8f	4.0b	5.0bc
RT[y] dipping/10mins	3.0e	1.8f	4.3bcd	4.8abc
40°C/7mins	3.0e	2.3ef	5.1ab	4.6bcd
50°C/1min	3.1e	4.1cd	5.2ab	5.7a

[z]Means followed by the same suffix are not significantly different in all columns at DMRT P ≤ 0.05
[y]Room temperature (RT) varied between 15-20°C. Hedonic scale used is 7 (excellent) to 1 (not acceptable).

Table 3: Effect of hot water dipping and storage temperatures on okra off odour after 21 days of storage.

Water Treatments	Storage temperatures (°C) 4	8.5	13	RT
	→ Off odour ←			
No water dipping	5.0a	2.3d	3.9c	4.3bc
RT[y] dipping/10mins	5.0a	2.4d	4.1bc	4.2bc
40°C/7mins	5.0a	2.6d	4.6ab	4.3bc
50°C/1min	5.0a	3.9c	4.5ab	5.0a

[z]Means followed by the same suffix are not significantly different in all columns at DMRT P ≤ 0.05.

Pod decay incidence: Decay incidence was highest for all the pods stored at 8.5°C irrespective of water treatments (Fig 1). However, pods dipped in water at 50°C for 1 min had significantly lower (21%) decay incidence compared to decay incidences between 59 - 67% for pods that were exposed to other water treatments. There was no decay at 4°C storage temperature as pods were frozen. Dipping okra pods in hot water at 50°C for 1 min and storing them at room temperature (15-20°C) significantly reduced decay incidence (3.3%) compared to the other treatments (Fig 1). This result possibly suggests that pods usually have latent infection from the farm and the hot water treatment decreases the population of microorganisms. Sommer (1992) clearly showed that disease incidence and severity depends on the number of fungal spores or pathogen propagules present.

The results further showed that decay was reduced by only about 6% for pods in older pods, a likely indicator of the presence of more latent infection on older pods than the young ones. Fruits, especially those for export are more likely to be harvested at a stage of maturity where the fungus has not penetrated the fruit but is firmly fixed to its surface. Postharvest treatment with a fungicide is reported to be generally ineffective in controlling fungal diseases but immersing fruits in hot water can give result in effective disease control (Thompson, 1996). Immersing the pods in water probably reduced the fungal spore load on the pods because of the effective surface coverage of the pods by hot water. Furthermore, hot water toughens the tissues within the pods thereby reducing the senescence and vulnerability of the pods to fungal infection.

Chilling injury incidence: No chilling injury occurred when pods were stored at 13°C or room temperature conditions across all the hot water treatments (Table 4). The highest injury (94 to 100%) was observed on pods stored at 4 or 8.5°C. Collins (2003) reported that heat shock protein (hsp) synthesis continued upto 9 days after heat shock, which could explain the reduced chilling injury on pods that were dipped in water at 50°C for 1 min in this study (Table 4). Woolf *et al.* (1995) found that hsp usually confers tolerance to low temperatures. Chilling injury was generally less within the first 14 days of storage, but the tolerance appeared to decline substantially afterwards. It is possible that after hot water treatment fruits loose less weight as a result of melting of natural surface wax, which seals natural openings and invisible cracks on produce, thus increasing resistance to chilling injury.

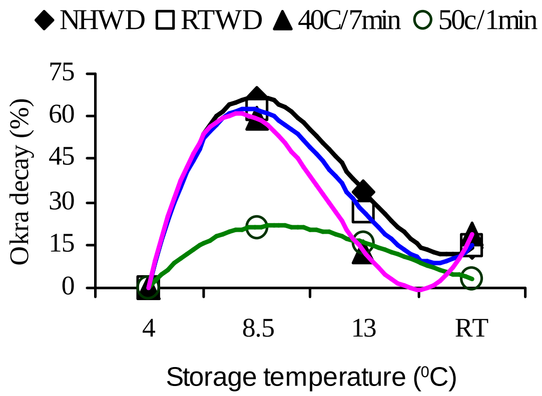

Figure 1: Incidence of decay on okra pods subjected to different hotwater dipping and storage temperature 21days after storage. Room temperature (RTWD) varied between 15-20°C. NHWD=no hot water treatment.

Table 4: Effect of storage temperature and water dipping treatments on okra chilling injury after 21 days of storage.

Dipping Temperatures	Storage temperatures (°C) 4	8.5	13	RT
	Chilling injury (%)			
No water dipping	100a	100a	0.0c	0.0c
RT[y] dipping/10mins	100a	100a	0.0c	0.0c
40°C/7mins	100a	97.6a	0.0c	0.0c
50°C/1min	94.3b	97.4a	0.0c	0.0c

[z]Means followed by the same suffix are not significantly different in all columns at DMRT P ≤ 0.05.
[y]Room temperature (RT) varied between 15-20°C.

Effects of treatments on electrolyte leakage: Electrolyte leakage was highest (15.1 EC.m^S/cm) in pods dipped in water at room temperature before storage at 4 °C, and lowest in all the pods stored at 13°C or room temperature conditions after hot water treatment (Fig. 2). Except for the pods stored at 4°C all the pods dipped in water at 50°C for 1 min had significantly lower electrolyte leakage (2 to 3 EC.m^S/cm) compared to the pods that were exposed to other treatments. Heat treatment could have induced *hsp*, leading to possible suppression of oxidative activity and maintained membrane stability, resulting in enhanced pod quality.

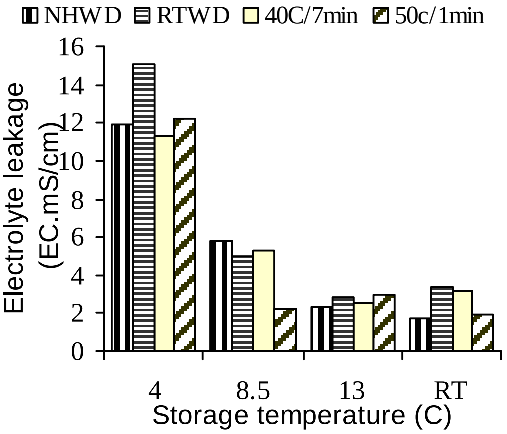

Figure 2: Effect of treatments on electrolyte leakage from okra pods after 21 days of storage. (NHWD-No Hot Water Dipping, RTWD-Room Temperature Water Dipping).

References

Bauchmann J. and Earles R, 2000. Postharvest handling of fruits and vegetables. Appropriate Technology Transfer For Rural Areas (ATTRA). ATTRA Horticulture Technical Note. 19 pp. (http://www.attra.ncat.org).

Baxter L. and Waters L, 1990. Controlled atmosphere effects on physical changes and ethylene development in harvested Okra. HortScience 25 (1): 92– 95

Cantwell de T, 1998. Hot water treatment as alternatives to postharvest use of fungicides on fresh market tomatoes and Cantaloupe melons. University of California Agricultural Research and Educational programme. www. sarep ucdavis.

Collins G, 2003. Heat shock proteins in plants. Faculty of science school of agriculture and wine university of Adelaide. www.agwine adelaide edu. Au /research

Duzyaman E, 1997. Okra botany and horticulture. Horticultural Reviews 21:41-72.

Gasti VD, Madalageri Bb, Dharmatti PR, Ryagi YH, 1997. Studies on response of growth of growth retardants on commercial vegetables. Advances in Agricultural Research in India.

HCDA, 1996. Okra (*Abelmoschus esculentus*). Horticultural Crops Development Authority Export Crop Bulletin, No.9, June Issue, Nairobi.

HCDA, 2006. Horticultural Crops Development Authority Export Crop Bulletin, No.9, June Issue, Nairobi.

Medlicot A, 1990. Postharvest handling of okra: Product specifications and postharvest handling for fruits, vegetables and root crops exported from the Caribbean, Fintrac

Neven LG. and Drake SR, 1998. Quarantine treatments for sweet cherries. Yakima Agricultural Research Laboratories, Wapato, Washington.

Paull RE. and Chen NJ, 1990. Heat shock response in field grown ripening papaya fruit. J. Amer. Soc. Hort. Sci., 115 (4): 623-631.

Perkins-Veazie PM. and Collins JK, 1992. Cultivar, packaging and storage temperature difference in storage temperature differences in postharvest shelf life of okra. HortTechnology 2:350 – 352.

Saltveit ME, 1998. Heat shock and fresh cut lettuce. Mann laboratory department of vegetable crops UCD. Perishables handling quaternary issue no.93 pp 5.

Salunkhe DK. and Desai BB, 1984. Postharvest biotechnology of fruits. Vol.1. CRC. Press Inc., Boca Raton. Florida.

Thompson AK, 1996. Postharvest technology of fruits and vegetables. Hartnolls Ltd. Bodmin Cornwell, Great Britain.

Woolf AB, Ball S, White A, Spooner KJ, Bowen JH, Lay-yee M. and Fergusson IB, 1995. Hot air and hot water treatment reduce chilling injury of Avocados during storage. Proceedings of world avocado congress III pp 348-353.