SYNERGISTIC EFFECT OF POLYETHYLENE THICKNESS AND HEAT TREATMENT IN THE CONTROL OF POSTHARVEST ROT IN EGGPLANT (SOLANUM AETHIOPIUM L.) FRUITS

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ABSTRACT

The study demonstrated application of heat treatment together with modified atmosphere storage created by polyethylene pouches of different thicknesses in controlling postharvest rot of eggplant (Solanum aethiopicum L) fruits. Heat was applied as hot air, hot water and steam at 47°, 50°, 53° and 56°C for 30, 40, 50 and 55 mins respectively for hot air and steam only and at 1, 3, 5 and 7 mins respectively for hot water. Control fruits were not heat treated. Treated and untreated fruits were packed in 13.5, 7.5 and 1.25 µm thick polyethylene pouches and stored at 26°±2°C and 98±2% relative humidity (RH). Disease development was assessed at 2 days’ interval for 13 days. Results showed that hot air at 50°C for 30, 40, 50 and 55mins and 56°C for 30 and 40 mins as well as steam at 47°C for 30, 40 and 50mins and 50°C for 50 and 55mins coupled with packaging in 7.5 µm thick polyethylene pouches protected eggplant fruits for 11 days. Hot water was effective at 47°, 50° and 53°C for 1, 3, 5 or 7 mins on fruits packed in 1.25 or 7.5µm thick polyethylene pouches. Heat treatment and packaging in polyethylene enhanced wholesomeness in eggplant fruits and can be incorporated into its market-line in the tropics.

Key words: Solanum aethiopicum, Disease development, Physical heat, Polyethylene

INTRODUCTION

Eggplant (Solanum aethiopicum L.) fruit is an important vegetable crop grown in most tropical countries. Unlike some other species of Solanum, the fruits are eaten raw and are fast becoming more popular in Nigeria than the S. melongena L. common in other regions of the world. Increase in acceptability may be because of the convenience of not having to cook or further processed; coupled with the increasing consumer’s awareness of the health benefits of raw or minimally processed fruits and vegetables (Zink, 2009; Polak, 2010). Generally, consumption of eggplant fruits decreases low-density lipoprotein (LDL) level in human blood due to hypolipidemic effect of its flavonoids, thereby improving heart action (Sudheesh et al., 1997; Kashyap et al., 2002). Extracts from eggplant fruits have been reported to demonstrate high capacities in scavenging superoxide free radicals and inhibition of hydroxyl radical generation (Noda et al., 2000).
Extension of the shelf life of fresh eggplant fruits in the tropics is significantly militated against by rot as a result of moulds, mass loss, shrivelling, enzymic browning and other physiological maladies like ripening and senescence. These factors affect storability, availability and the economics of the produce. As a process, heat treatment has the capacity to eliminate microbial pathogens from fresh fruits and vegetables. It also attenuates enzymic browning and development of chilling injury, delays ripening and senescence thereby extending the shelf life of fruits (Zhao et al., 2009). Heat treatments do not cause significant health risks resulting from chemical residues associated with the chemical method of disease control and, as a result, are appealing to consumers (Lurie, 1998; Fan et al., 2009). Reports on postharvest application of heat treatment on eggplants have mostly been in combination with low temperature storage (Salunkhe and Desai, 1984; Zhao et al., 2009). Low temperature is highly injurious to eggplants fruits originating from the tropics. Below 10°C, such eggplants fruits suffer physiological disorders and development of chilling injury manifested mainly by the appearance of surface pitting, skin scalding, seed darkening and flesh browning (Salunkhe and Desai, 1984; Concellon et al., 2007). Cantwell and Suslow (2013) recommend storage temperature above 10°C. Low temperature may also not be reliable for the postharvest handling and marketing of eggplant fruits in Nigeria because presently the system is in the hands of the small producers and marketers that may not be able to afford the cost.

In Nigeria, eggplant fruits are retailed in open markets and on street sides at ambient temperature in polyethylene bags of varying thicknesses. The use of barrier polyesters is for containment and presentation to the buyers, extension of storage life, reduction of chilling injury, retention of firmness and delay of ripening for the various horticultural products (Aborisade and Ayibiowu, 2010; Li et al., 2014). Materials such as polyolefins for example polyethylene and polypropylene, polystyrene for example polyvinychloride and polyvinlyldene chloride, and polyesters e.g. polyethylene terephthalate and polyethylene naphthalate are of importance (Dhoot, 2004; Aborisade and Ayibiowu, 2010). Leterrier, (2003) and Stracusa (2012) reported that absorption of ambient vapour or liquid can cause an increase of polymer plasticization; resulting in a decrease in its mechanical properties. Relative humidity has a considerable effect on the permeability and sorption characteristics of the most common commercial polymers; the polyethylene. The water vapour transmission rate in barrier polyester is affected by thickness of polymer film, temperature and relative humidity (Anderson, 2008; Kuusipalo and Lahtinen, 2008). This study is therefore aimed at determining the effects of polyethylene thickness together with heat treatment on eggplant (S. aethiopicum) fruits stored in high relative humidity and mesophilic ambient temperature of the tropics.
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MATERIALS AND METHODS

Source and preparation of eggplant fruit: Freshly harvested eggplant (*Solanum aethiopicum* L.) fruits of the Gilo group were purchased from Alade market, Alade via Idanre, Ondo State, Nigeria. The smooth white fruits were sorted, rinsed in running tap water and allowed to drain at ambient temperature (26±2°C) and relative humidity (78 ± 2%). Fruits of uniform colour, size and maturity (white, and an under ripe maturity degree) with green calyx and without any growth defect, disease or injury were selected.

Heat treatment: Selected fruits in triplicates were exposed to hot air, steam and hot water at 47°, 50°, 53° and 56°C for 30, 40, 50 and 55 mins in case of hot air and steam and 1, 3, 5 and 7 mins in case of hot water. Hot air treatment was done in Gallenkhamp oven, while steam and hot water treatments were carried out in Gallenkhamp water baths. Control fruits were not heat treated.

Packaging materials: Polyethylene pouches were made from low density polyethylene films of 1.25, 7.5 and 13.5 µm thicknesses (measured with micrometer screw gauge 543-471B MITUTOYO Instrument, Japan). The films were cut into dimensions (30 cmx30 cm) with sterile blade and thereafter sealed into pouches left with an open end, using impulse sealing machine. Bags were disinfected in hot water at 60°C for 30 minutes before use. Treated and control fruits in triplicates were packed into the polyethylene pouches of different thicknesses. This was done in triplicates. Open ends of the polyethylene bags were thereafter sealed.

Storage: The heat treated and untreated eggplant fruits in sealed polyethylene bags were stored at 26±2°C and 98±2%RH conditions in covered plastic buckets for 13 days. Fruits were observed at two days’ intervals for disease severity. Spoilage of eggplant fruits due to mould development was ranked subjectively from 1 to 5. One represented no spoilage, two represents spoilages on 10% of fruit’s body, three represents spoilages on 20% of fruit’s body, four represents spoilages on 50% of fruit’s body and five represents spoilages on over 70% of fruit’s body.

Statistical Analysis: One-way ANOVA was used to test for significant difference between means and separation was done using New Duncan’s Multiple Range Test where difference was significant.

RESULTS

Effect of hot air and polyethylene thickness on disease severity of eggplant fruits stored at 26±2°C and 98±2% RH: Hot air treatment at 47°C for 55 mins and packaging in 7.5 µm thick polyethylene limited disease severity on eggplant fruits to 1.33 on the 13th day of storage. This value was lower than the severities between 3.00 and 5.00 obtained on the other eggplant fruits treated with hot air at 47°C for 30, 40 and 50 mins when packed in 7.5 µm thick polyethylene.
pouches (Fig. 1). Furthermore, the 1.33 severity was lower and significantly different (P<0.05) from the 1.67 and 4.00 respective severities of eggplant fruits treated with the same hot air at 47°C for 55 mins but packed in 1.25 and 13.5 µm thick polyethylene pouches on the same day of storage (Fig 1). Control fruits packed in 7.5 µm, as well as those packed in 1.25 µm and 13.5 µm thick polyethylene pouches had disease severities of 4.00, 4.00 and 3.00 respectively which were higher than the 1.33 of the eggplant fruits treated with hot air at 47°C for 55mins packed in 7.5 µm thick polyethylene pouches.

Combinations of the respective hot air treatment at 50°C for 30, 50 and 55 mins with packaging also in 7.5 µm thick polyethylene, totally controlled rot on eggplant fruits for 11 days (Fig. 2). The fruits remained at mean 1.00. Disease was also limited to 1.33 when fruits treated with hot air at 50°C for 40 mins were packed in 7.5 µm thick polyethylene. Unlike those treated at the same 50°C for 30, 40, 50 and 55mins but packed in 1.25 µm thick polyethylene pouches with severities between 1.67 and 4.33 and those packed in 13.5 µm pouches with severities between 4.67 and 5.00 (Fig. 2). Furthermore, hot air at 56°C for 30 and 40mins also controlled rot on eggplant fruits stored in 7.5 µm thick polyethylene pouches. The fruits remained disease free at mean 1.00 on the 13th day of storage unlike the control fruits diseased at mean 4.00 and the fruits treated with hot air at same temperature-time combinations but packed in 1.25 and 13.5 µm polyethylene pouches which were also extensively diseased at means between 3.00 and 5.00 (Fig. 4). There was no significant difference (P> 0.05) between fruits treated with hot air at 56°C for 30, 40 and 55minutes packed in 1.25 µm thick polyethylene bags and the control, although the means recorded for the treated fruits were slightly lower. Severity was either 3.00 or 2.33 on the treated fruits and 4.00 on the control (Fig 4).

Generally, the higher the effective hot air temperatures between 47°C and 56°C the shorter the exposure time needed to control rot on eggplant fruits. Similarly, eggplant fruits treated with hot air at 47, 50, 53 and 56°C packed in 13.5 µm thick polyethylene had the greatest disease severities when compared with those packed in 1.25 and 7.5 µm polyethylene pouches. Unlike the 7.5 µm thick polyethylene pouches, the 1.25 µm and 13.5 µm thick pouches did not protect eggplant fruits exposed to all the hot air temperature-time combinations used in the present study.

**Effect of hot water and polyethylene thickness on disease severity of eggplant fruits stored at 26±2°C and 98±2% RH:** Fruits immersed in hot water at 47°C for 1, 3, 5 and 7 mins and packaged in 1.25 µm thick polyethylene bags remained disease free on the 11th day of storage (Fig. 5). Packaging in 7.5 µm thick polyethylene pouches and the hot water treatments at 47°C for 1, 3 and 7 mins also made eggplant fruits to remain disease free on the 11th day of storage (Fig. 5).
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Rot was 2.00 on the fruits treated with hot water at 47°C for 5 mins and packed in 7.5 µm thick polyethylene pouches. Eggplant fruits treated with the hot water temperature-time combinations of 47°C for 1, 3, 5 or 7 mins were however not protected when packaged in 13.5 µm thick polyethylene pouches; the fruits were diseased at severities of 2.00, 2.67, 1.67 and 1.67 respectively (Fig. 5). Eggplant fruits that were immersed in hot water at 50 and 53°C for 1, 3 and 5 mins and packed in 1.25 µm thick polyethylene pouches also remained disease free and were significantly different (P<0.05) from the control on the 11th day of storage. Rot was 1.67 and 2.00 on fruits treated with the hot water at the respective temperatures of 50 and 53°C for 7 mins when packed in the 1.25 µm thick pouches (Figs. 6 and 7).

Polyethylene thicknesses of 7.5 and 13.5 µm did not protect any of the eggplant fruits treated with the hot water at 50 and 53°C for all the exposure periods during storage. Severity was only limited to 1.33 on fruits treated with the hot water at 50°C for 3 mins when packed in 7.5 µm thick polyethylene pouches and ranged between 1.67 and 4.00 on fruits treated the hot water at 50°C for 1, 5 and 7 mins and packed in the same 7.5 µm thick polyethylene (Fig 6). Disease severities were either 3.00 or 4.00 also on fruits treated with the same hot water at 50°C for 1, 3, 5 and 7 mins but packaged in 13.5 µm thick polyethylene pouches and the means were not significantly different (P<0.05). Similar trends were observed on fruits treated with hot water at 53°C (Figs. 6 and 7). Hot water at 56°C for 1, 3, 5 and 7 mins and packaging in 1.25, 7.5 and 13.5 µm polyethylene resulted to rot of eggplant fruits and rot was observed to increase as exposure time increased at 56°C when treated fruits were stored in 7.5 and 13.5 µm polyethylene pouches (Fig 8). Generally, the result showed that the higher the effective hot water temperature between 47°C and 53°C, the shorter the exposure time needed to control rot on the eggplant fruits as observed with the hot air treatments. Similarly, 13.5 µm thick polyethylene did not protect any of the hot water treated eggplant fruits during storage.

Effect of steam and polyethylene thickness on disease severity of eggplant fruits stored at 26±2°C and 98±2% RH: Steam at 47°C for 30, 40 and 50 mins and packaging in 7.5 µm thick polyethylene pouches protected eggplant fruits for 13 days in this study. Fruits treated for 30 and 50 mins remained disease free and severity was 1.33 on fruits exposed for 40 mins. This was lower than the 4.00 of control (Fig. 9). Spoilage was however total on fruits packed in 13.5 µm thick polyethylene pouches after the same treatments as well as on fruits packed in 1.25 µm after 40 mins exposure time (Fig. 9). Other fruits packed in 1.25 µm were also diseased at 2.00, 3.00 and 2.00 on the fruits treated with the steam at 47°C for 30, 50 and 55 mins respectively (Fig. 9). At 50°C, steam protected eggplant fruits exposed for 40, 50 and 55 mins when packed in 7.5 µm thick polyethylene pouches for 13 days in ambient temperature of the tropics.
The eggplant fruits had severities of 1.33, 1.00 and 1.00 respectively and were significantly different (P<0.05) from the control at severity of 4.00 on the 13th day of storage (Fig. 10). Disease severity was also highest generally on the steam treated fruits packed in the 13.5 μm thick polyethylene as was also observed with the hot air and hot water treated fruits. Rot was severe at means between 3.00 and 5.00 on fruits treated with steam at 53 and 56°C packed in all the three polyethylene thicknesses tried (Figs.11 and 12).
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**Fig. 5:** Effect of hot water at 47°C and polyethylene thickness (μm) on severity of rot in eggplant fruits stored for 11 days.

**Fig. 6:** Effect of hot water at 50°C and polyethylene thickness (μm) on severity of rot in eggplant fruits stored for 11 days.

**Fig. 7:** Effect of hot water at 53°C and polyethylene thickness (μm) on severity of rot in eggplant fruits stored for 11 days.

**Fig. 8:** Effect of hot water at 56°C and polyethylene thickness (μm) on severity of rot in eggplant fruits stored for 11 days.

**Fig. 9:** Effect of steam at 47°C and polyethylene thickness (μm) on severity of rot in eggplant fruits stored for 11 days.

**Fig. 10:** Effect of steam at 50°C and polyethylene thickness (μm) on severity of rot in eggplant fruits stored for 11 days.
DISCUSSION
Hot water, steam and hot air provided effective, non-toxic protection against postharvest rot of eggplant fruits stored at 26±2°C and 98±2% RH condition in this study. Hot air and steam were most effective at 50°C, while hot water was effective at 47, 50 and 53°C. These observations are in agreement with the report of Barkai-Golan and Phillips (1991) who noted that many fruits and vegetables are tolerant to water temperature of 50–60°C for up to 10 mins, and many plant pathogens are killed at these temperature regimes. The effectiveness of heat treatments has been reported to be as a result of destruction of pathogen and the activation of antimicrobial compounds in peel of fruits (Burden, 1968; De Caster and Erabadupitiya, 2005). Oladele and Aborisade (2012) reported the efficacy of hot water treatments on citrus fruit against Phytophthora palmivora. Mirshekari et al. (2012) and De Caster and Erabadupitiya (2005) also reported the effectiveness of hot water dip treatment for the control of anthracnose and crown rot respectively on banana during storage. Fan et al. (2008) reported the use of hot water treatment on fresh cut cantaloupe and Mansour et al. (2006) reported on the effect of heat on postharvest quality of mango. The efficacy of steam presently observed is supported by the report of Afek et al. (1999) on the substantial reduction of rot caused by Alternaria alternata, A. radicina and Sclerotinia sclerotiorum on organically grown carrot. Aborisade and Adegoke (2010) also reported the reduction of decay caused by F. verticillioides on tomatoes when treated with steam at 45°C for 3mins.

Of the hot air, hot water and stream treatments tried, hot water treatment was the most effective and may be most appropriate for commercial use. It was effective over the widest temperature range (47 to 53°C) and the exposure periods were for the shortest periods. Furthermore, there was consistency in its effectiveness; temperatures-time combinations were effective at regular intervals.
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At 47°C, the exposure periods of 1, 3, 5 and 7 minutes were all effective and 1, 3 and 5 mins were also effective at 50 and 53°C. The hot air and steam needed as much as 30 to 55mins to be effective and there were inconsistencies in the regularity of effective temperatures. The reports of Shellie and Mangan (1994) and Lurie (1998) showed water as the most efficient heat transfer medium as observed in this study. The study also showed that the higher the effective temperature of air and water media, the lower the exposure period needed for control which supported the report of Burden (1968) and De Coster and Erabadupitiya (2005) on destruction of pathogen.

The result of the present investigation also showed that the interaction between the polyethylene thickness and heat treatment influenced the shelf life of eggplant fruits. Eggplant fruits treated with hot water were best protected in 1.25 µm thick polyethylene film pouches while the hot air and steam treated fruits were best in 7.5 µm thick polyethylene bags, the 13 µm thick polyethylene did not protect eggplant fruits in this present study. The polyethylene and plastic containers used in the study could reduced air circulation around the fruits, thereby causing the accumulation of CO₂ given out by the fruit during respiration (Marriot and Palmer, 1980; Thompson, 1998). Expectedly, the 13µm thick polyethylene films must have caused maximum CO₂ accumulation which would have been aggravated by the initial effect of heat on fruits. The higher CO₂ in the 13 µm thick polyethylene pouches was noticed during this study, it caused the pouch to balloon up. There was also an unpleasant alcoholic smell which might have resulted from anaerobic metabolism occasioning from the high CO₂ concentration. Similar observations have been reported on tomatoes “Beske” sealed in 5-20 µm thick polyethylene bags (Aborisade and Ayibiowu, 2010) and on guavas in vacuum sealed PD 900 Cryovac plastic bags (Lima and Durigan, 2000). De Lapeyre de Bellaire et al. (2010) also reported that, high level of CO₂ is injurious to fruits and might be responsible for the poor quality of fruits stored in the thickest film during this study. Efficacy of the 1.25 and 7.5 µm thick polyethylene may therefore be as a result of their higher levels of porosity which allowed lower accumulation of CO₂ and the micro environment was not toxic to the fruits. Modification of gas composition reduces fruit respiration and production of endogenous ethylene synthesis, which can increase the preclimateric life of fruits and delay senescence (de Lapeyre de Bellaire et al., 2010). Modified atmosphere has also been reported to inhibit the metabolism of some pathogens (Goos and Tschirsch, 1962; Al Zaemey et al., 1994; de Lapeyre de Bellaire et al., 2010). The high relative humidity in this study created pressure on the heat treatments, being a good condition for the growth of microorganism (Badger, 1965). The effectiveness of heat in the control of rot on eggplant fruits in this study is therefore highly promising.
If applied on fruits stored at a lower relative humidity the extent of protection may even be more. The study was conducted at the ambient temperature of the tropics to simulate the current retail and wholesale conditions of the fruits in Nigeria. Therefore, the result can be integrated into the handling and marketing chain of the product in the tropics. Further studies are recommended in the area of effect of the described heat treatments on fruits stored at lower relative humidity and the effects of interaction between the heat and polyethylene thickness on the sugar, ethylene and heat shock proteins contents of the treated fruits.

REFERENCES


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