African Journal of Food Science Vol. 5(7), pp. 446 - 452, July 2011
Available online http://www.academicjournals.org/ajfs
ISSN 1996-0794 ©2011 Academic Journals

Full Length Research Paper

The effects of postharvest handling and storage temperature on the quality and shelf of tomato

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Accepted 7 June, 2011

The experiment was conducted between August and September in 2009 at the laboratories of the Natural Resources Institute (NRI) of the University of Greenwich in the UK to assess the effects of physical impact and storage temperature on ethylene production and quality of tomatoes. A total of 72 red-ripe fruits of the 'encore variety' were used for the experiment. Half (36) were dropped individually from a height of 1 m to simulate rough handling while the remaining half were not dropped. The fruits were then kept in sealed glass jars (six fruits per jar) and stored in two incubators set at 12 and 20°C respectively. This was a 2^2 factorial in a randomised complete block design with three replications. Ethylene production, respiration, ripening and weight loss increased significantly at 20°C with means of 7.85 µl/kg/h, 13.8 mlCO_2/kg-h, 16.80 and 97.08% respectively. However, there was no significant effect of temperature on fruit firmness. Undamaged fruits were slightly firmer with an average of 51.09 while the damaged ones were fewer firms and had an average of 41.14.

Key words: Ethylene, photovac explorer, tristimulus, respiration, carbon dioxide, firmness.

INTRODUCTION

Tomato (*Lycopersicon esculentum*, Mill.) is an important vegetable crop grown in many countries across the globe. It is the second most widely grown vegetable crop in the world other than the white potato (Hanson et al., 2001). The tomato fruit contains about 94.5% water per 100 g of fresh weight, 16% protein per 100 g of dry weight, 71.27% carbohydrate, 21.82 % of total dietary fibre, 15145.45 IU of Vitamin A and 230.91 mg of ascorbic acid (OECD, 2008).

The tomato fruit is a perishable, climacteric fruit whose shelf life can be reduced by ethylene production enhanced by physical impact and high storage temperature. Ethylene is a phytohormone synthesised by all tissues of higher plants. It is involved in regulating many growth and developmental processes in plants (Ishida, 2000).

Ethylene production increases significantly at different growth stages such as flower senescence or fruit ripening or in response to various stresses such as physical wounding, pathogen attack or high temperatures (Abeles et al., 1992 as cited in Chang et al., 2008).

Rough handling (transportation on bad and bumpy roads) under hot conditions characterise tomato handling in most developing tropic regions. Specific reference can be made to the northern part of Ghana where tomato is produced, harvested ripe and transported on bumpy roads to the assembling site (Robinson and Kolavalli, 2010). It is then transported on hot asphalted road over long distances to the southern sector. These conditions lead to faster deterioration of the produce with a lot of the fruits getting softened at the destination. In order to minimise the losses, it is important to understand the biological and environmental factors involved in postharvest deterioration, and to adopt the appropriate postharvest technology or procedures that will slow down deterioration and maintain quality and safety of the commodities (Kader, 2005).

Against this backdrop, this project was carried out to assess the effect of handling and storage temperature on

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ethylene production in tomatoes and also to assess the effect of handling and storage temperature on the quality of tomatoes. The main reason for the simulation of the handling practice was based on the assertion that when fruits, and for that matter plants, are subjected to stress, either physical or biological, which may result in tissue damage, they initiate deteriorative processes. This includes the production of ethylene either as a defence response or to repair the damaged tissues, increased respiration and softening.

MATERIALS AND METHODS

This experiment was conducted at the laboratories of the Natural Resources Institute (NRI) of the University of Greenwich at Medway between August and September 2009.

Simulation of handling

Mechanical impact is known to cause bruises, mar the visual quality and create entry points for spoilage organisms (Kitinoja and Kader, 2003). Various methods such as the discrete element method (Van Zeebroeck, 2005) have been adopted to simulate rough handling of tomatoes and apples during transport and handling. The drop test simulation such as the finite element analysis (Kabas et al., 2008) has also been used to examine the behaviour of tomato upon crashing on a planar surface. In this study, handling was simulated by dropping thirty-six (36) fruits from a height of about one metre. This was done to cause physical damage to the tissues of the fruit in order to assess the response that would result thereafter.

Ethylene measurement

Ethylene was measured employing the static system where the fruits were enclosed in glass jars and kept in the incubators for 2 h. The samples were then removed afterwards and the ethylene produced measured using the portable Photovac Explorer (Photovac Inc. USA) gas chromatograph (GC). The GC was turned on and the ethylene was sucked from the jar. This was done for each sample tagging in appropriately in the GC. The GC was connected to a computer and the sampled ethylene was transmitted and graphically displayed using the SiteChart software package of Photovac Inc. installed on the computer.

The ethylene was measured in parts per million (ppm) but this was converted to micro litre per kilogram per hour (µl/kg/h).

Respiration

As in the ethylene measurement, the static system (Saltveit, n.d) was used to assess respiration of tomato fruits for the various samples. However, the fruits were enclosed in the glass jars and kept for 1 h before sampling. In this case, a hand-held carbon dioxide (CO_2) meter (Anagas CD 98 model, Air and Accoustics, Chesfire. UK) was used to determine the amount of CO_2 produced in each sample. The CO_2 meter recorded the CO_2 produced in percentages and these were converted to respiration rates in millilitres of CO_2 produced per kilogram per hour (ml CO_2/kg/h).

Weight loss (%)

Prior to the separation of the fruits into their respective samples, the fruits obtained at firm ripe and were first mixed together into a composite sample. Six fruits were then randomly picked and placed into each of the labelled twelve boxes to obtain twelve samples. Each sample was then weighed using an electronic scale and the weights recorded manually. The weighing of the samples was done each time they were sampled for ethylene and other quality parameters. The values obtained were then expressed as percentages of the initial treatment weights (Moneruzzaman et al., 2008).

Colour (ripening) measurement

Colour of tomato fruits is used to determine ripeness as the fruits change colour during the process. The colour of tomatoes was determined in terms of the tristimulus colour values L*, a* and b* with a Chroma meter CR 400 model (Konica Minolta Co., Japan). The equipment was calibrated against white Minolta calibration plate (Konica, 2002). It was then held with the spectrum plate on the equatorial plane of the fruit and the push button was depressed to flash the spectrum light onto the fruit. Upon flashing the light, the L*a*b* values where L* represents luminous intensity and hue (a*, redness and b*, greenness) were displayed on the screen of the instrument with an automatic printout of the results. The process was done for all fruits in each sample and repeated each time the other quality assessments were done using the a* value as a determinant for colour change.

Firmness

Fruit firmness was tested using an analogue durometer or Durofel (CTIFL, France) with a probe diameter of 0.25 cm^2 (Ruiz-Altisent et al., 2010). Each fruit in a sample was measured by pushing the central probe against the equatorial plane of the fruit until the central probe flattened. The flattening of the probe caused the needle in the instrument to deflect and the number where the needle stopped was recorded as the value for the fruit firmness (Kitinoja and Hussein, 2005).

Monitoring of storage temperature

The temperature in the storage incubators was monitored during the experimental period using temperature data loggers (Tinytag Talk 2 by Gemini data loggers, UK.). The loggers were programmed to record the temperature at 5 min intervals over the period and were analysed with the Tinytag software. The results indicated that on average, the number of readings was 1770.4 and 1763.7 for the 12°C and 20°C experiments, respectively. The average temperatures recorded for the period were 11.8 and 18.1°C with mean kinetic temperatures of 11.1 and 18.1°C for the incubators set at 12 and 20°C respectively.

Data analysis

The data obtained from the experiment were subjected to analysis of variance (ANOVA) to determine significance or otherwise between means using the Genstat version 9 statistical package.

RESULTS

Ethylene production (µl/kg/h)

From the analysis of variance, there was no significant

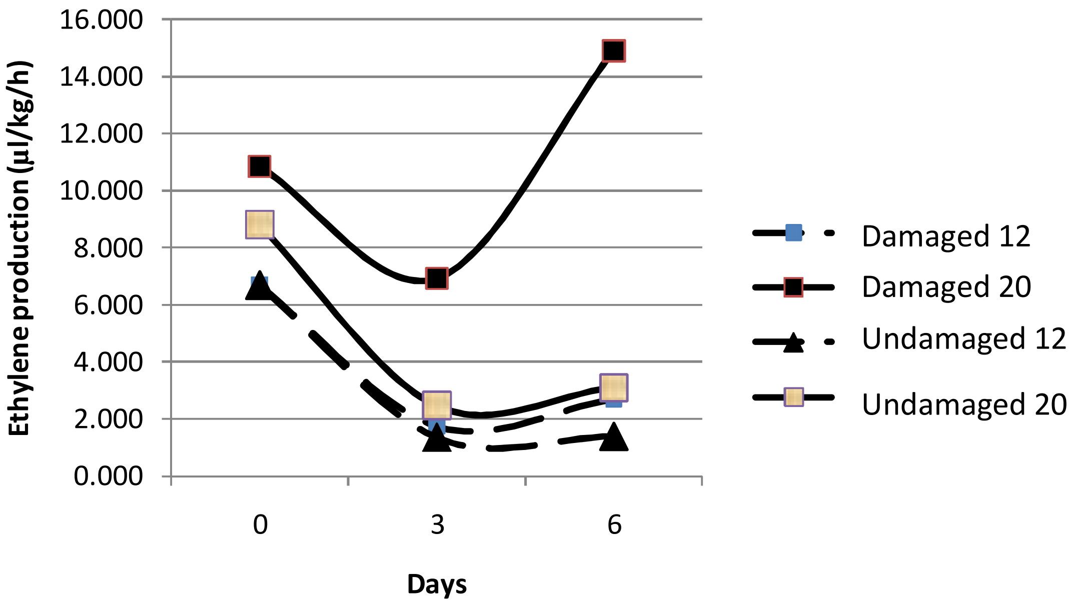

Figure 1. Graph showing the effect of damage and storage temperature (12 and 20℃) on ethylene production in tomatoes.

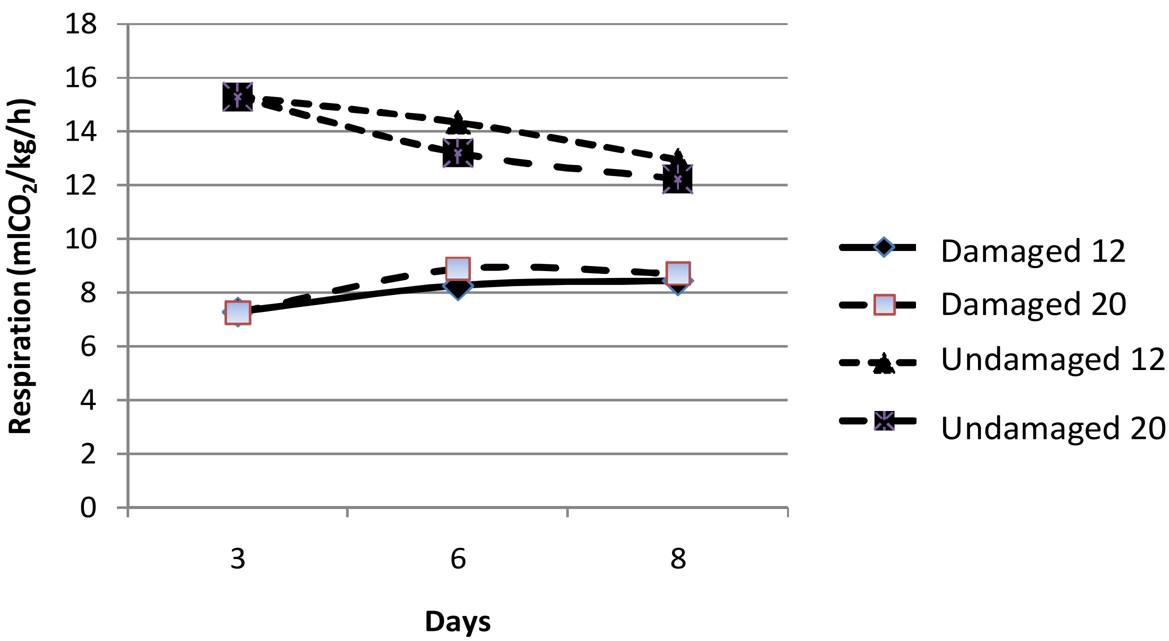

Figure 2. Graph showing the effects of damage and storage temperatures (12 and 20℃) on respiration of tomatoes.

effect ($P < 0.05$) of handling treatment on ethylene production. However, the effect of storage temperature had a significant effect on ethylene production with means higher (Figure 1) at 20℃ than at 12℃. It could be observed that undamaged fruits at 20℃ (Figure 1) produced slightly higher ethylene than undamaged fruits at 12℃.

Respiration in ml CO_2/kg/h

The effects of handling (damaged and the undamaged) and storage temperature (12 and 20℃) on respiration in tomato are presented in Figure 2. From the experiment, it was observed from the analysis of variance that there was no significant effect of handling (damage) on

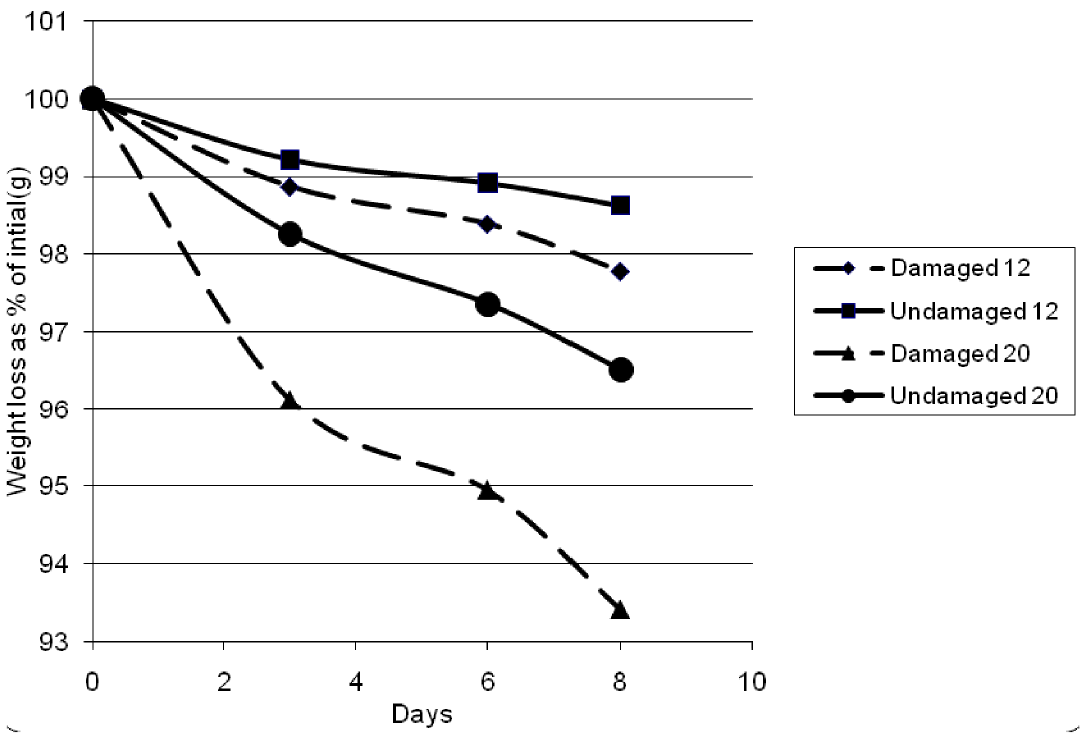

Figure 3. Graph showing the effect of damage and storage temperature (12 and 20°C) on weight loss in tomatoes.

respiration. However, storage temperature (Figure 2) had a statistically significant effect ($P < 0.05$) on respiration with treatment means higher at 20°C than at 12°C.

Weight loss

The mean values for weight loss of samples for the damaged and the undamaged treatments stored at 12 and 20°C are shown in Figure 3. The values are expressed as a percentage of the initial weight of the samples. From the analysis of variance, it was observed that weight loss was not significantly different ($P < 0.05$) for samples that had undergone different handling (damaged and undamaged) treatments. However, storage temperature had a significant effect on weight loss. In both temperatures (Figure 3), there was remarkable drop in weight in the damaged fruits compared to the undamaged ones.

Fruit colour change (ripening)

The means representing colour values of a* for the two storage temperatures and handling treatments are presented in Figure 4. From the analysis of variance, the results of the a* values, which indicate red colour of the fruit, showed that temperature had a significant effect ($P < 0.05$) on colour change indicative of fruit ripening. Handling treatment however did not have any significant effect on colour change.

The a* component of the tristimulus values as recorded by the colour meter were used to indicate the level of redness of the fruits. It was observed that means of a* values were higher at the higher temperature (20°C) than at the lower (12°C) storage temperature.

Fruit firmness

Fruit firmness is indicative of level of softening of the fruit. Means recorded for tomato fruit firmness are presented in Figure 5 for the handling treatments as well as the two storage temperatures. The damaged treatment showed a significant effect ($P < 0.05$) on the firmness of fruit but there was no significant effect of storage temperature on fruit firmness. As shown in Figure 5, undamaged fruit were slightly firmer than the damaged ones.

DISCUSSION

Ethylene production (µl/kg/h)

As was observed in the study, higher storage temperature resulted in increased ethylene production

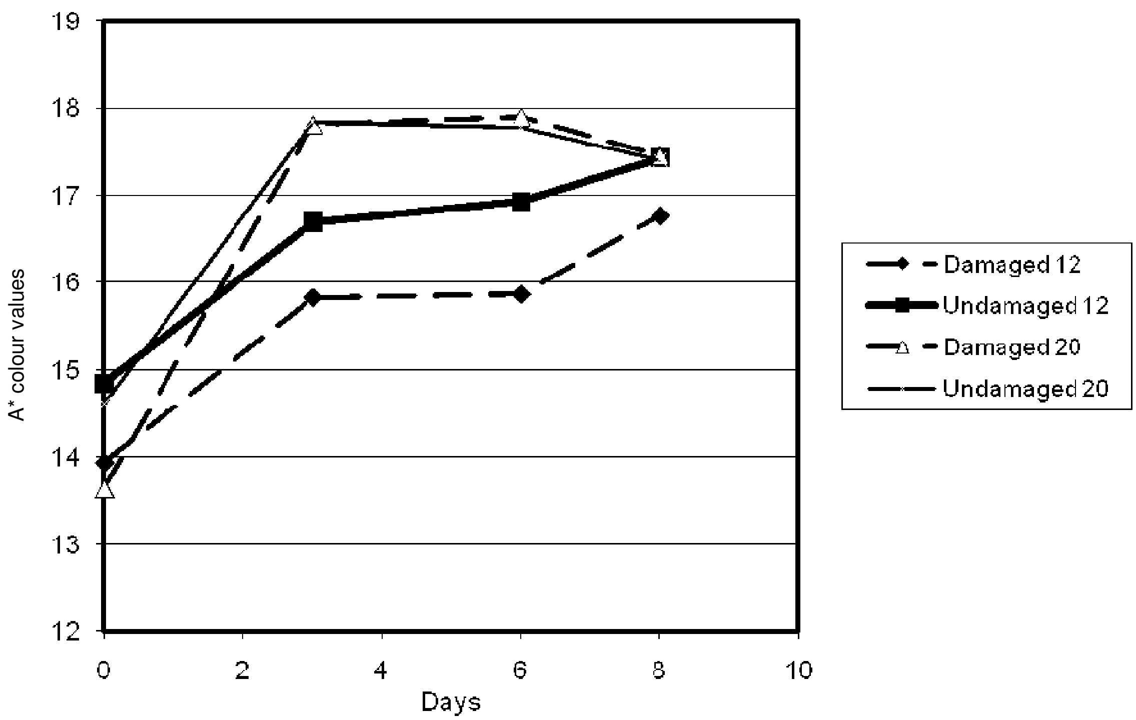

Figure 4. The effect of damage and storage temperature (12and 20℃) on fruit colour changes in tomatoes.

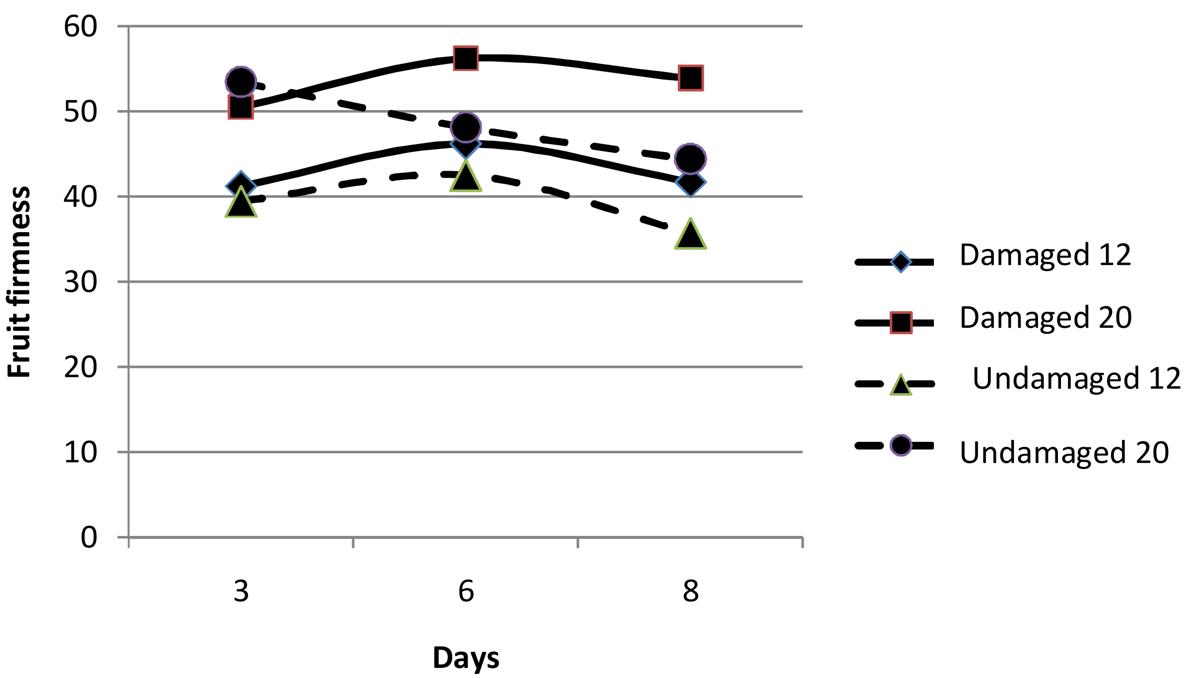

Figure 5. The effect of damage and storage temperature (12 and 20℃) on fruit firmness of tomatoes.

confirming the study by Shams (2003) which indicated that, tomato fruits held at different temperatures from 15 to 35℃ show maximum ethylene production at 20℃.

Respiration in ml CO_2/kg/h

Respiration is a normal metabolic activity of living organisms and involves the intake of oxygen to break down glucose for energy production. This process increases with increased temperature (Ashby, 2000). From the experiment, temperature had a significant effect on the rate of respiration, being higher at 20℃ than at 12℃. As shown by Mordy and Atta (1992), increasing storage temperature from 15 to 30℃ significantly increases carbon dioxide production of tomato fruits. It can also be cited in Thanh (2006) that, the rate of respiration increases two-fold for every 10℃ rise in temperature.

Weight loss

Fruits lose weight when their metabolic rate increases. The metabolic rate accelerates with an increase in temperature around the produce resulting in loss of water and associated reduction in weight. Results from the experiment showed that weight loss (Figure 3) was higher at 20℃ than at 12℃. As indicated in a study by Thanh (2006), temperatures above 20℃ can result in abnormal physiological processes in fresh produce. The major process in this regard is respiration through which water is lost to the immediate surroundings of the produce and hence, a reduction in weight.

Fruit colour change (ripening)

Colour is a human perception by definition, which has long been used in the assessment of fruit quality. In fruits, a decrease in chlorophyll content of the skin is correlated with increasing maturity; this is traditionally used as the criterion for visual assessment of fruit maturity (Crisosto et al., 2007 cited in Ruiz-Altisent, 2010). the experimental results indicated the value of a* which depicts redness had a higher average in the 20℃ storage temperature than in the 12℃ conforming to the study by Roberts et al. (2002) which shows that tomatoes ripenes earlier when stored at 20℃ than those stored at 13, 10 or 5℃ in that respective order.

Fruit firmness

During ripening of fruits and for that matter tomato, they tend to soften either as result of the cells losing water and becoming less turgid or by the breakdown of the cell walls as a result of physical damage (Kashmire and Kader, 1978) The damaged treatment had a significant effect on fruit softening which could be a result of the fruit increasing in metabolic rate and therefore losing water, making the cells flaccid and collapsing upon pressure. It could also be observed as in Kitinoja nad Kader (2003) that warmer fruits (20℃) were less firm compared to the colder ones(12℃).

CONCLUSIONS AND RECOMMENDATION

From the experiments, it could be concluded that rough handling of tomatoes can result in the destruction of the fruit cell wall leading to softening and reduced marketability of the produce. Also, high storage temperature can result in increased respiration and ethylene production as well as accelerate ripening and weight loss. Because these conditions (rough handling and high temperature) accelerate the metabolic rate of tomatoes, they therefore reduce the shelf life of the produce.

Tomato fruits should be transported in shock-absorbing vessels and on smooth roads. The fruits should also be kept within the temperature tolerance zone of the produce. It is also recommended that this experiment be replicated in the future to include varietal response to the various treatments or consider the effects of this treatment at different ripening stages of tomato.

ACKNOWLEDGEMENTS

The authors acknowledge the Department for International Development whose funding through the Strengthening Capacity for Agricultural Research and Development in African (SCARDA) programme administered by CORAF/ WECARD saw me through my MSc. training, the preparation of my thesis and the preparation of this article for publication. They also wish to acknowledge the support of Dr. Debbie Rees who supervised this work, Ms. Linda Nicholaides and Dr. Richard Fuchs all staff of NRI of the University of Greenwich who critiqued and offered guidance to the successful completion of this work. The effort(s) of any person not mentioned which implicitly or explicitly contributed to the success of this work is duly acknowledged.

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