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Efficacy of High Voltage Treatment on Tomato Storage

[1]G. Atungulu, [2]E. Atungulu, [3]R. Okada and[4]Y. Nishiyama
[1]Biofunction Sciences, Agro- Bioscience Dept. Iwate University, 3-18-8 Ueda, 020-8550 Morioka, Japan; [2]Biomechanical and Food Process Engineering Dept. Jomo Kenyatta University of Agriculture and Technology, P.O. Box 62000 Nairobi, Kenya; [3]United Graduate School of Agricultural Sciences, Iwate University,3-18-8 Ueda, Morioka, Iwate 020-8550 Japan; [4]Sustainable Bio-Production Engineering Department Iwate University, 3-18-8 Ueda, 020-8550 Morioka, Japan

Abstract: The efficacy of using high voltage treatment to extend post harvest storage life of tomatoes (Mini-tomato Chika variety) was assessed. Continuous and intermittent treatments (2 hours per day) on tomatoes at different voltages (10 kV, 20 kV, 30 kV and 40 kV), storage temperatures (0°C, 4°C, 10°C, and 17°C) and electrode configurations (needle or aluminum plate as cathode electrode) were done. An aluminum plate (inter electrode distance 100 mm) was used as the grounded anode electrode. Using needle electrodes as cathode in the high voltage treatment (10 kV, 20 kV and 30 kV) resulted in higher moisture loss than in the untreated samples. However, intermittent treatment using aluminum plate as cathode electrode did not indicate higher moisture loss in the treated samples when compared to the untreated. In intermittent treatment of tomato stored at 0°C using ionised needle as cathode electrode, respiration rate difference (difference with reference to the initial respiration rate) rapidly declined 48 hours after treatment with 30 kV and 20 kV. Surface characteristics of the tomatoes changed during storage. Abnormal shriveling on the surface of the tomatoes was minimal for the intermittently treated samples.

Key words: High voltage, Parallel plate, Needle electrode, Weight loss, Respiration, Tomato

Introduction

In any age, ever since, there are two fundamental issues in the relationship between humans and their food: the need as individuals to eat and drink, and the challenge to produce and preserve enough food and drink to meet the needs of entire populations. This global consumer demand for high quality foods that are both fresh tasting and nutritious has created considerable interest and investment in the development of new or improved post-harvest storage and food-processing techniques. The competitive struggle for markets, which has resulted from more liberalised trade regimes, has required a much greater emphasis on efficient and effective post-harvest handling, processing and distribution to access markets further and further. Consumers are demanding access to fresher products, no matter where in the world they happen to be located. This demand has generated the incentive to ensure a much wider use of improved controlled-atmosphere storage methods as well as new and emerging non-thermal technologies like high voltage or high electric field treatment.

Beyond the traditional food preservation methods of thermal processing, freezing, salting and drying, new methods of preservation continue to emerge. These can extend the shelf-life and freshness of perishable foods. However, human beings seem to be inherently suspicious of novelty when it comes to food. Throughout history, migrating populations have carried traditional food habits over one or many generations, and new foods or processes have often been received with reservation. The same kind of fear is manifested today regarding currently emerging food technologies. The widespread acceptance of technologies depends very much on public information and education based on conducted research. High voltage or electric field application is a novel non thermal preservation method that has gradually been gaining prominence in agriculture. In this regard, there has been promotion of research into foodstuff preservation technology using negative ions and ozone (both being products of electric field application technology). In the twenty-first century, the food industry in meeting consumers' expectations will have to utilize novel technologies to ensure the all-important and often expected assurance of food safety and also consider energy conserving technologies. High voltage treatment uses low current thus requires low power consumption. In view of these facts, we seek to evaluate the efficacy of high voltage treatments in post harvest preservation of tomatoes. We considered respiration, weight loss as well as surface condition degradation.

Materials and Methods

Equipment Description: The laboratory equipment consisted of an electric field apparatus supplied from a high voltage generator (AKT-0100k02NS, TOWA KEISOKU, Japan), with output 0 to100 kV and 200 /A maximum. A ring (180 mm in diameter) with eleven needles (ASY IC - 500 TEAC, Japan) equidistantly spaced along the circumference was used as the cathode and an aluminum plate (180 mm diameter) was used as the grounded anode in one case and in another case parallel aluminium plates where used as the electrodes. A wooden box (900 mm long, 700 mm wide and 700 mm high) housed the electrodes. The distance between the cathode and the anode was fixed at 100 mm. The grounded aluminium plate held the Petri dish on which the tomatoes were placed. Electric field was applied to the tomatoes by adjusting the voltage. The housing door had two micro switches (VM-21P MULON, Japan) installed in series to cut off power when the door is opened. Between the micro switches and the high voltage generator was a magnetic switch (SC-O FUJI ELECTRIC, Japan). The distance between the cathode and the anode *d* cm was fixed and the voltage adjusted as desired for each experiment.

Experiments: Tomato (Chika variety) raised in a greenhouse were procured immediately after harvest and transported to the laboratory. The tomatoes were selected manually by visual observations on the basis of color, size uniformity and lack of physical damage on the surface after which treatments were done.

High Voltage Treatments: Tomatoes were treated continuously and intermittently with high voltage. In both cases we investigated the effects of using ionised needle and aluminium plate as the cathode electrode while using aluminium plate for the grounded anode electrode. The inter electrode separation was kept at 100 mm.

In the case of intermittent treatments, the tomatoes stored at 0°C, 4°C, 10°C and ambient conditions 17°C were treated with 10 kV, 20 kV and 30 kV using ionised needle as the cathode electrode and at 20 kV, 30 kV and 40 kV using aluminium plate as the cathode electrode. The tomatoes were treated for 2 hours daily during the period of storage.

In continuous treatment, we investigated the effect of continuous treatment with high voltage using ionised needle and aluminium plate as the cathode electrode. Again, we used aluminium plate for the grounded anode electrode in both cases. Tomatoes at ambient condition 17 °C were treated with 20 kV and 30 kV at 100 mm inter electrode distance.

Storage Indices: Weight losses of treated and untreated samples were monitored using an electronic weighing balance (A&D), with an accuracy of up to ± 0.001 g. A cold room and a humidity cabinet (Tabai Laboster, LHU-112) were used for temperature regulation: 0°C, 4°C and 10°C. The humidity cabinet was set at constant humidity and temperature in the treatments.

Apple respiration rate was measured in terms of CO_2 evolution in p.p.m. using a sensor (GMW20 VAISALA, Finland) connected to a nominal 24 Volts DC (MS-H50 KEYENCE, Japan). The sensor had the following operation ranges: -5°C to 45 °C and 0 to 100% relative humidity. Respiration data was converted into moles of CO_2 evolved N as in Eqn (1):

$$N = \frac{\rho v}{R_0 T} \qquad (1)$$

where *ñ* is the partial pressure of CO_2 in Pa, *ı* is the volume of container in which the sample is placed in m³, R_o is the gas constant equal to 8.314 J/mol K and T is the absolute temperature at which measurements were taken in K.

Results

Weight Loss in Intermittent Treatment: Fig. 1 shows the tomato weight loss at 0°C up on intermittent high voltage treatment. Ionised needles were used as the cathode electrode. After some period of storage (72 hours from commencing treatment) we observed that using needle electrodes as cathode in the high voltage treatment (10 kV, 20 kV and 30 kV) resulted in higher moisture loss than the untreated samples. However, in Fig. 2 intermittent treatment using aluminum plate cathode electrode (20 kV, 30 kV and 40 kV) did not indicate higher moisture loss in the treated samples than in the untreated. In all the treatments, using the aluminum plate electrode the moisture loss due to treatment was either smaller or equal to the untreated.

Respiration Rate in Intermittent Treatment: Fig.s 3 to 6 show results of intermittent treatment using ionised needle as cathode electrode. In Fig. 3 it was noted that for tomato stored at 0°C and treated with high voltage, respiration rate difference (difference with reference to the initial respiration rate) rapidly declined 48 hours after treatment with 30 kV and 20 kV compared to the untreated sample. Intermittent high voltage treatment with 10 kV had a gradual and the least effect. After the 48th hour of storage (96th hour for 10 kV treatment) the respiration rate did not change significantly with treatment time. Fig.s 4, 5 and 6 show results of treatments performed at air temperatures of 4°C, 10°C and 17°C respectively. We noted that marginal and regular suppression of respiration occurred for some treatments *i.e.* treatments with 30 kV at 10°C and 20 kV at 17°C.

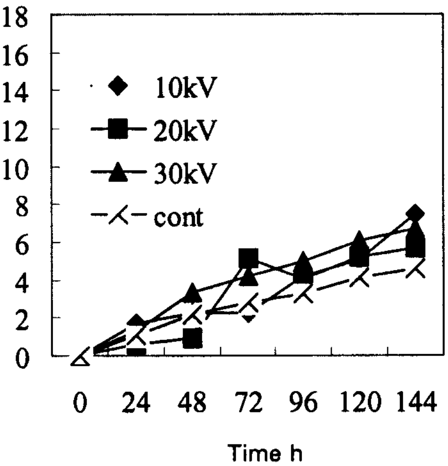

Fig. 1: Tomato weight loss at 0°C, intermittent electric field treatment using needle cathode

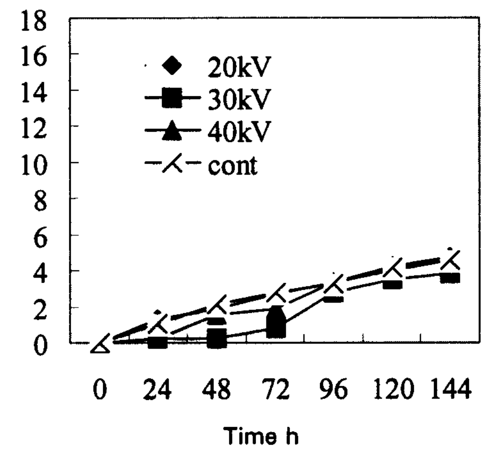

Fig. 2: Tomato weight loss at 0°C, intermittent electric field treatment using plate cathode

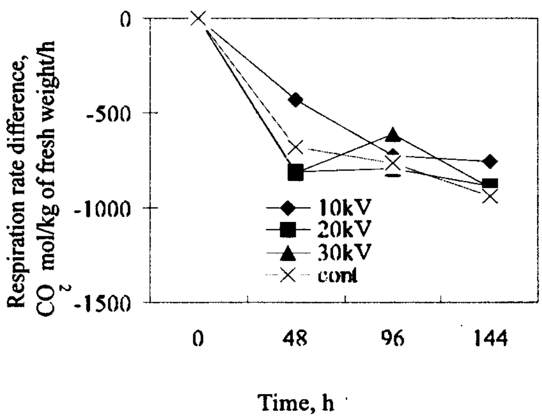

Fig. 3: Tomato respiration rate difference at 10°C, Intermittent electric field treatment using reedle cathode

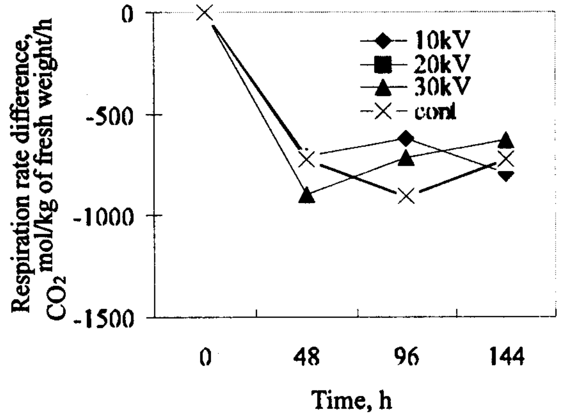

Fig. 4: Tomato respiration rate diference at 4°C, Intermittent electric field treatment using needle cathode

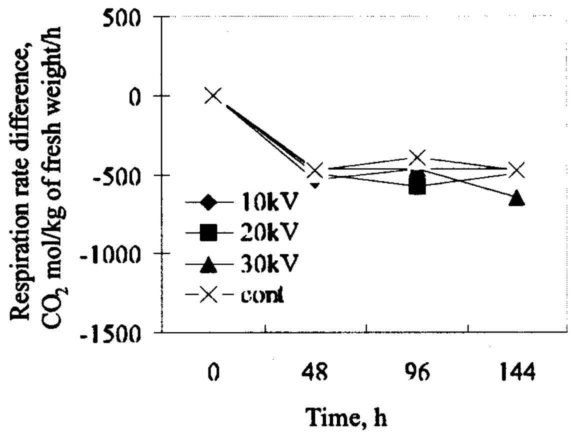

Fig. 5: Tomato respiration rate difference at 10°C, Intermittent electric field treatment using needle cathode

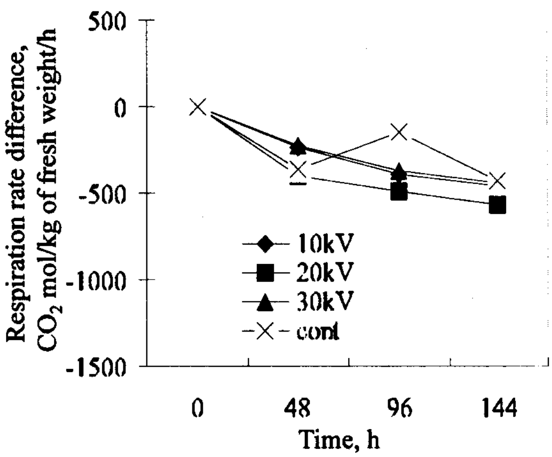

Fig. 6: Tomato respiration rate differencer at 17°C, Intermittent electric field treatment using needle cathode

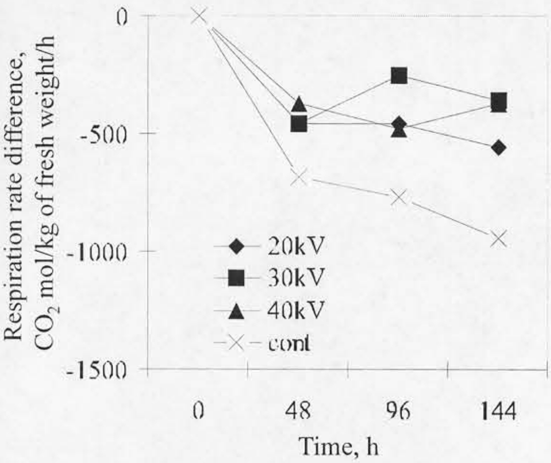

Fig. 7: Tomato respiration rate difference at 0°C, Intermittent electric field treatment using plate cathode

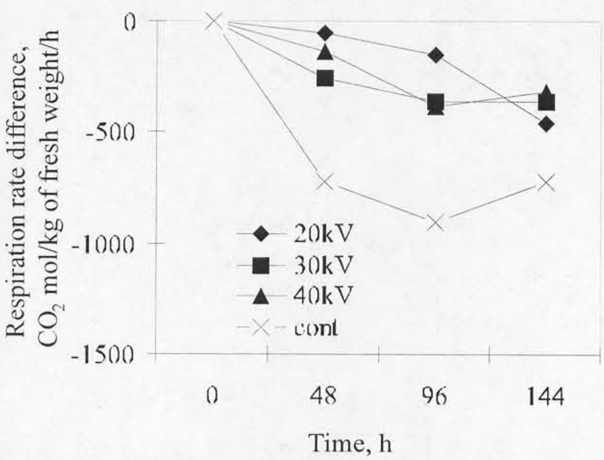

Fig. 8: Tomato respiration rate difference at 4°C, Intermittent electric field treatment using plate cathode

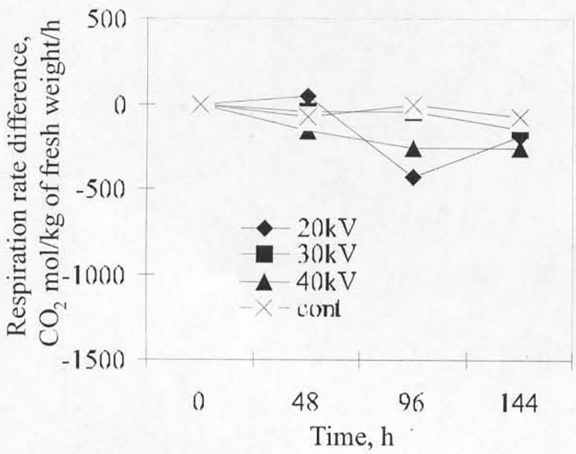

Fig. 9: Tomato respiration rate difference at 10°C, Intermittent electric field treatment using plate cathode

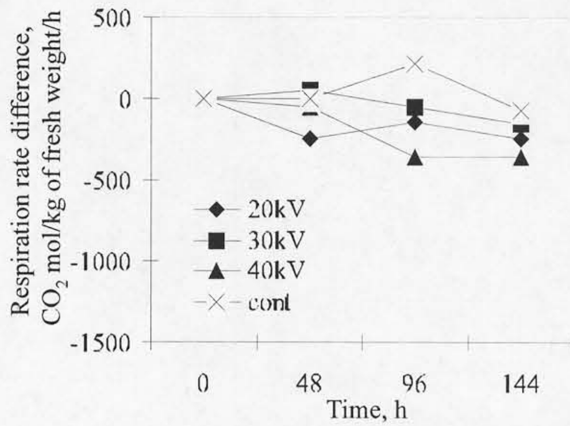

Fig. 10: Tomato respiration rate difference at room temperature 17°C, Intermittent electric field treatment using plate cathode

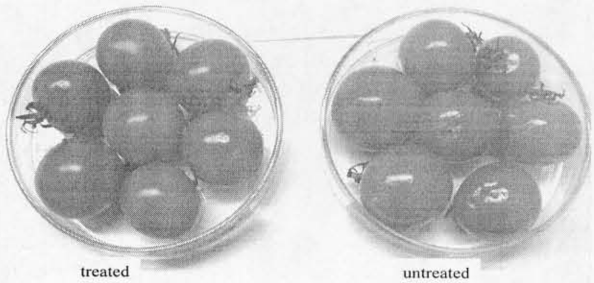

Fig. 11: Tomato surface conditions 5 days after halting 6 days of intermittent treatment (2 h/day) with 20 kV using needle cathode and sample at 10°C

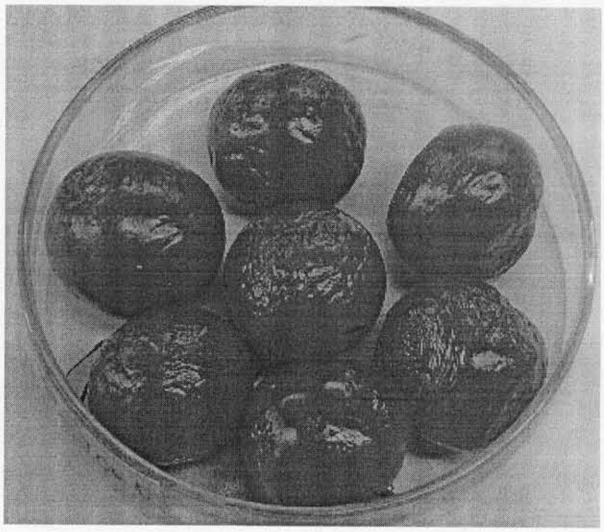

Fig. 12: Treated tomato surface conditions 15 days after halting 6 days of intermittent treatment (2 h/day) with 20 kV using needle cathode and sample at 10°C

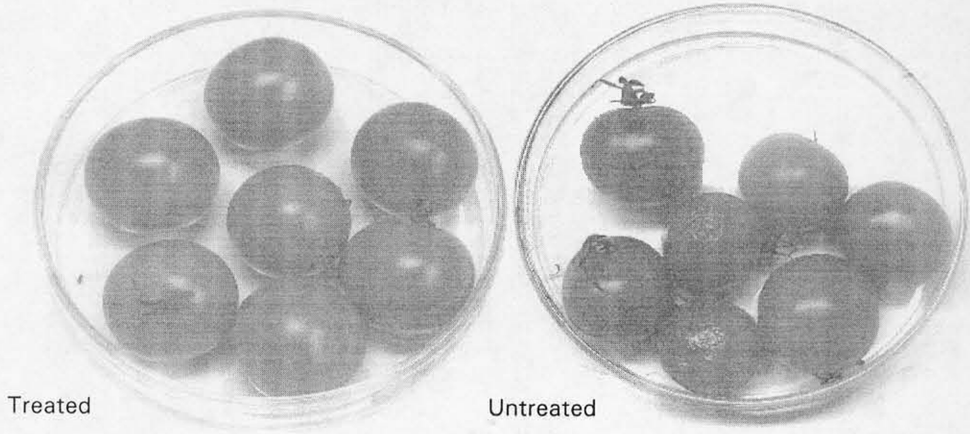

Fig. 13: Tomato surface conditions 5 days after halting 6 days of intermittent treatment (2 h/day) with 20 kV using needle cathode and sample at 17°C

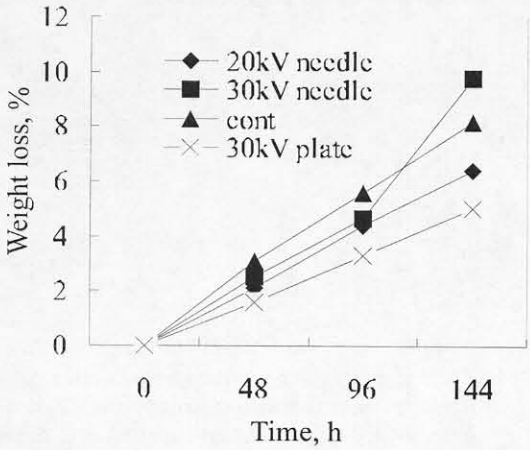

Fig. 14: Tomato weight loss upon continuous electric field treatment using plate and needle Cathode; room temperature 17°C

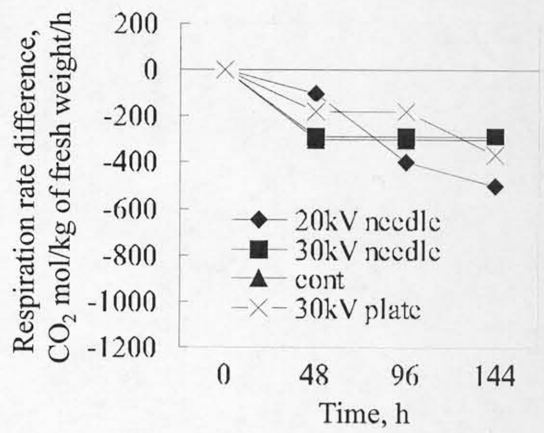

Fig. 15: Tomato respiration rate difference upon continuous electric field treatment using plate and needle cathode; room temperature 17°C

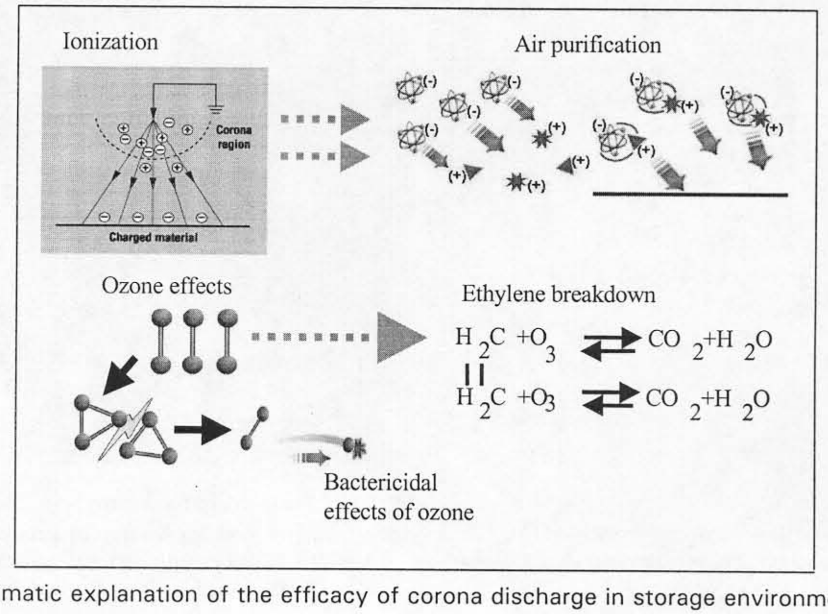

Fig. 16: Diagrammatic explanation of the efficacy of corona discharge in storage environment

Fig.s 7 to 10 show results of intermittent treatment using aluminum plate as cathode electrode. In treatment using aluminum plate as cathode electrode we noted that for tomatoes that were kept at lower temperatures 0°C and 4°C (Fig. 7 and 8) respiration rate difference was lower in the treated sample than in the untreated sample. This phenomenon was not observed in intermittent treatment using ionized needles as cathode electrode. However, at increased storage temperatures of 10°C and 17°C the trend of respiration rate was different. At 10°C and 17°C (Fig. 9 & 10) the treatment had efficacy in suppressing the respiration rate in the tomatoes.
We observed that the surface characteristics of the tomatoes changed during storage. As noted in Fig 11, five days after halting the six days intermittent treatment (2 hours per day treatment using ionised needle as cathode electrode) with 20 kV at 10°C abnormal shriveling on the surface of the tomatoes was minimal for the intermittently treated samples. Initial shriveling on the surface of the treated tomato was observed 15 days (Fig. 12) after halting the six days of intermittent high voltage treatment (20 kV for 2 hours per day of treatment using ionised needle as cathode electrode). A similar phenomenon was observed for tomato stored at 17°C and treated with 20 kV (Fig.13). The surface of the treated sample showed minimal shriveling.

Weight Loss in Continuous Treatment: Fig. 14 shows the weight loss of tomato stored at 17°C up on continuous high voltage treatment using plate and needle as cathode electrodes. Continuous treatment with 30 kV (using aluminum plate cathode electrode) and 20 kV (using ionised needle as cathode electrode) suppressed weight loss compared with the untreated samples. Treatment with 30 kV using ionised needle as cathode electrode, however, suppressed weight loss in the initial four days of treatment after which the weight loss increased higher than that in the untreated ones.

Respiration Rate in Continuous Treatment: Respiration rate difference of tomato up on treatment with continuous high voltage treatment using plate and needle as cathode electrodes is shown in Fig. 15. Six days after treatment with 20 kV (using ionised needle as cathode electrode) and 30 kV (using aluminum plate cathode electrode) we observed suppression of respiration rate compared with the untreated samples.

Discussion

In this research, we noted that weight loss in the treated tomato depended on the electrode configuration used. Ionised needle used as cathode electrode had a tendency to accelerate weight loss while on the other hand aluminium plate when used as the cathode electrode had a tendency to suppress weight loss. Theoretically, it is expected that the electric field treated samples have higher weight loss since evaporation of water remarkably increases under electric field treatment (Asakawa, 1976; Hashinaga, Kharel & Shitani, 1995). Bottcher (1973) deduced from energy considerations the work on a dielectric in an external electric field and explained that the energy of a dielectric in the presence of a field is less than in the absence of the field. And that the escaping tendencies of dielectric molecules, in this case water molecule, is to increase due to decreased molecule to molecule bonding when an external field is applied. During the experiment, however, it could be observed visually that due to the high voltage treatment with aluminium plate used as cathode electrode the outer skin surface of the tomato tended to harden and this probably limited water movement out of the tomato thus reducing weight loss. Electric wind effect can be used to explain the tendency of high weight loss when ionised needles are used as cathode electrodes. When the air ions are subjected to a strong electric field resulting from the high voltage, the charged particles will accelerate. The kinetic energy gained by the particles is partly spent in ionising other molecules *via* the Townsend effect (Townsend, 1914) and partly in colliding with neutral molecules in the drift region of the fluid medium in which they travel. In the process of collisions, momentum is transferred to the molecules and the resulting frictional resistance produces the ion drag phenomenon with the associated electric wind when the air mass between the electrodes moves towards the plate. The generation of this electric wind is responsible for increased mass transfer from the tomato.
It is not clear however, the mechanism by which electric field application (high voltage treatment) affects respiration of tomato post harvest. In other studies, field ionisation, field action associated with polarisation of organic radicals in the plant biosystems and molecular fatigue have been found to affect responses of plants (Murr, 1965) in electric fields. Temperature lowering of materials under electric field treatment has also been reported (Smirnov & Lysenko, 1989). Basically, entropy of materials is decreased under electric field and energy released into the surrounding. On isolation of the material, its temperature decreases due to entropy increase (relaxation of the field). This process may resemble intermittent treatment of tomatoes with electric field (high voltage). Further, it is speculated that the generated high electric field may orient the dipole water molecules in the tomato in the direction of the field. This will create order and reduce entropy in the tomato. Toda (1990) reported that electric field reduced respiration rate in lettuce and spinach. Respiration suppressive effects on apples have also been reported (Atungulu, Nishiyama & Koide, 2003a, Atungulu et al., 2003b, Atungulu et al., 2003c).
It is also expected that the physiological properties of the tomatoes be affected by the presence of negative ions

or corona discharge that arises from ionisation when the ionised needles are used as cathode electrodes. The mechanisms by which corona could affect produce quality include are illustrated in Fig 16: destruction of ethylene and volatile compounds; removal of air-borne fungal spores (air purification); production and release of ozone, negative air ions (NAI), and other reactive substances into the storage environment. Both ozone and NAI have been reported to inhibit or kill pathogenic microbes and reduce decay of fresh produce (Hildebrand *et al.*, 2001). The foregoing phenomena may affect the metabolic activity of the tomato and ultimately suppress respiration rate.

Conclusion

This research sought to establish the efficacy of using high voltage treatment to extend post harvest storage life on tomatoes (Mini-tomato Chika variety). Continuous and intermittent treatments on tomato (2 hours per day) using different voltages, storage temperatures and electrode configurations were done. It was observed that using needle electrodes as cathode in the high voltage treatment (10 kV, 20 kV and 30 kV) resulted in higher moisture loss than the untreated samples. However, intermittent treatment using aluminum plate as cathode electrode (20 kV, 30 kV and 40 kV) did not indicate higher moisture loss in the treated samples when compared to the untreated. Intermittent treatment, using ionised needle as cathode electrode, on tomato stored at 0°C and treated with high voltage, indicated that respiration rate difference (difference with reference to the initial respiration rate) rapidly declined 48 hours after treatment with 30 kV and 20 kV compared to the untreated sample. Intermittent high voltage treatment with 10 kV had a gradual and the least effect. After the 48th hour of storage (96th hour for 10 kV treatment) the respiration rate did not change significantly with treatment time. Surface characteristics of the tomatoes changed during storage. Five days after halting the six days intermittent treatment (2 hours per day treatment using ionised needle as cathode electrode) with 20 kV at 10°C abnormal shriveling on the surface of the tomatoes was minimal for the intermittently treated samples. Initial shriveling on the surface of the treated tomato was observed 15 days (Fig. 12) after halting the six days of intermittent high voltage treatment (20 kV for 2 hours per day treatment using ionised needle as cathode electrode). A similar phenomenon was observed for tomato stored at 17°C and treated with 20 kV. Treated samples showed minimal shriveling. For continuous high voltage treatment, six days after treatment with 20 kV (using ionised needle as cathode electrode) and 30 kV (using aluminum plate cathode electrode) we observed suppression of respiration rate compared with the untreated samples.

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