Effect of Non-Thermal Plasma on Post-Harvest Quality of Tomato

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ABSTRACT

The goal of this experiment is to study the effect of NTP on the shelf life and quality of tomato. A new method of food preservation that is environmentally friendly is provided by NTP, a fourth state of matter that uses ionized gasses to destroy bacteria on fresh produce. There are two stages to the experiment. During the first stage, tomatoes are treated with NTP at different power levels and times: 5 kv 1 min, 5 kv 2 min, 5 kv 5 min,15 kv 5 min, 15 kv 10 min and 20 kv 5 min. Then, to determine the ideal power level and time for plasma treatment, 56 tomatoes are analyzed visually and by using colorimeter.In the second phase, destructive and non-destructive analyses are conducted using the selected power level and time from the first phase. In both the control and treatment groups, the non-destructive analyses include disease incidence, taking pictures, color changes and the destructive analysis includes Total soluble solids (TSS), firmness, pH, total lycopene content, and total phenol content.

Keyword: Non- thermal plasma/ Shelf life/ Tomato quality/ Food preservation

1. INTRODUCTION

Due to its distinct flavor, vivid color, and abundance of antioxidants such as lycopene, carotenoids, and chlorophyll, tomatoes are a favorite food in many countries. But as the storage period is extended, the high moisture content and respiration of postharvest tomatoes reduce their chlorophyll concentration and physical quality, causing the tomatoes to soften and turn red and causing financial losses. Traditional chemical preservatives can extend the shelf life of postharvest tomatoes, but they have little effect on tomatoes' ability to turn red, and their residue poses a risk to food safety [3].

The mechanisms of NTP technology used for microbial inactivation, is vital for extending the shelf life of fruits and vegetables. Reactive oxygen and nitrogen species (ROS and RNS), including hydroxyl radicals, nitric oxide, and ozone, are produced by NTP by ionizing air or gases that include oxygen [4].

DBD is generated by applying high voltage AC across the electrode, then ionization of the gas occurs in between the electrode which generates NTP near dielectric barrier [2]. In this experiment the tomato is indirectly exposed to the NTP. During indirect exposure the target is positioned away from the plasma discharge, as opposed to having plasma applied directly to the food items. This configuration makes sure that only reactive species with longer life cycles get to the target [10].

2. METHODOLOGY

Mid-ripe 56 tomato is used for this experiment. There are 6 treatment group with 5 kv 1 min, 5 kv 2 min, 5 kv 5 min, 15 kv 5 min, 20 kv 5 min, 15 kv 10 min and a control group (C) with each group having 4 replicates with 2 tomatoes on each replicate. In this experiment, argon was used as the working gas for all treatment group. The color of tomato was measured using colorimeter on day 0, 7, 14, 21, 28, 35, 46, 53, 60, and 67. The disease incidence and photo was clicked on day 0, 7, 14, 21, 28, 35, 46, 53, 60, 67, and 72. The average temperature and humidity were recorded using a data logger, with the temperature being 29.18°C and the relative humidity 93.83%. The result from this analysis is used to select appropriate power level and time for the main experiment.

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2.1 Disease incidence

Fungal growth symptoms on the fruit's surface were observed visually using a scale [9]. The percentage of DI was formulated using the following equation:

$$\text{Diseaseincidence } (\%) = \frac{\sum (\text{DI scale} \times \text{Number o f tomato fruit at the DI level})}{\text{Total number o f tomato f ruit in the treatment} \times \text{The highest score } (5)} \times 100$$

2.2 Fruit marketability

The marketable tomato is given score 1 while the non-marketable are given 0. The marketability is analyzed using the formula [1]:

$$\text{Percentage marketability} = \frac{\text{Number of marketable fruits}}{\text{Total number of fruits}} \times 100$$

2.3 Color analysis

All fruit samples were allowed to ripen and monitored by taking optical measurements to track the progress of the color change. Color measurements will be taken using a MiniScan XE PLUS colorimeter at three positions per side (head, middle, and tip). Calibration of the colorimeter is important [7].

3. RESULTS AND DISCUSSION

3.1 Disease incidence

The treatments 15 kv 10 min and 20 kv 5 min are the most effective in reducing disease incidence in tomatoes, whereas the control samples and 15 kv 5 min have the highest disease incidence. The 20 kv 5 min treatment shows a mean disease incidence of 8.86%, which is comparable to the 15 kv 10 min treatment's lower value of 3.18%.

Table 1. LSD Test for disease incidence (%) comparing control and treatment groups (showing only significant comparisons $p < 0.05$)

Comparison	Mean difference	Std. error	Sig. (p-value)	95% Confidence interval
CONTROL vs. 15 kv 10 min	16.1364*	6.75	0.02	2.67 to 29.6
5 kv 5 min vs. 15 kv 5 min	-15.2273*	6.75	0.03	-28.7 to -1.76
15 kv 5 min vs. 20 kv 5 min	16.1364*	6.75	0.02	2.67 to 29.6
15 kv 5 min vs. 15 kv 10 min	21.8182*	6.75	0.00	8.36 to 35.3
15 kv 10 min vs. 5 kv 2 min	-14.3182*	6.75	0.04	-27.8 to -0.86

(* indicates significance at $p < 0.05$)

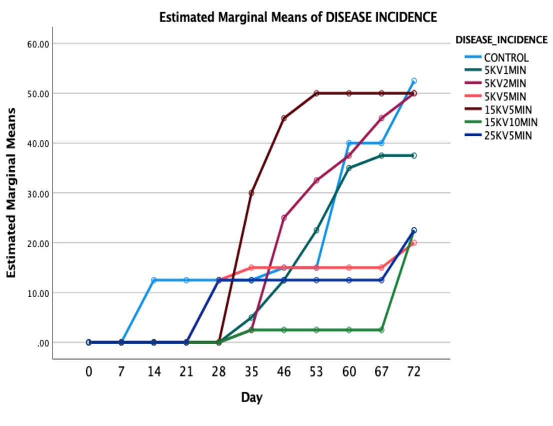

Figure 1. Disease incidence on tomato over 72 days

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The fungal growth was detected in tomatoes of both treatment and control group. The limited fungal growth on the higher voltage 20 kv could be due to the antifungal effects of plasma. According to a study in 2023, Reactive oxygen species (ROS) and Reactive nitrogen species (RNS) are the primary chemicals that give NTP its antifungal properties. The main sterol of the fungus cytoplasmic membrane, ergosterol, is essential for preserving the integrity of the cell. NTP lowers the concentration of ergosterol, which inhibits the growth and spread of fungus [8]. During plasma operation, the degree of microbial inactivation rises with increasing input power. High input voltage and frequency improve NTP microbial inactivation efficiency. The length of treatment is one of the key variables affecting how well plasma processing works. The efficiency of NTP can be affected by the type of gas used, how it is exposed, how the generator is set up, and the working environment. Noble gases such as argon cause bacterial cell death due to their high thermal conductivity and UV emission spectrum [5]. In the control group, one tomato showed signs of insect growth, while none of the tomatoes in the plasma-treated groups showed any signs of insect growth. This suggest that the plasma treatment may have prevented insect growth on the tomatoes.

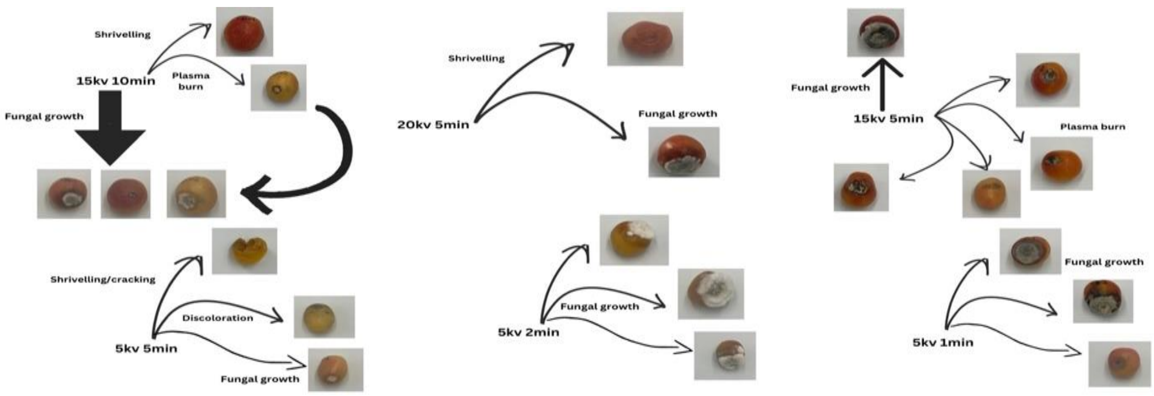

Figure 2. Effects of NTP treatment on tomato disease incidence and marketability over 72 days. Discoloration (not indicative of disease) is shown alongside symptoms of disease incidence (fungal growth, shriveling) and plasma-induced burns affecting marketability. Treatments: 5 kv/1 min, 5 kv/2 min, 5 kv/5 min, 15 kv/5 min, 15 kv/10 min, and 20 kv/5 min.

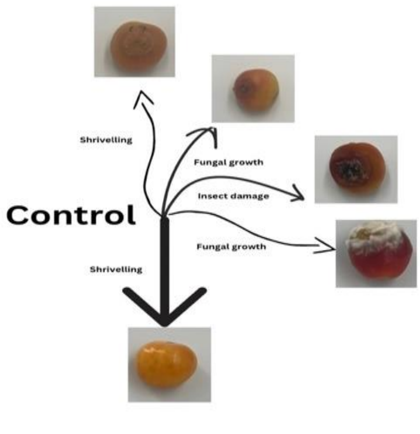

Figure 3. Visual representation of fungal growth, insect damage and shriveling in Control group.

3.2 Fruit Marketability

The marketability of all treatment group and control sample was 100 % on day 0 expect 15 kv 5 min with 87.5% due to visible plasma burn. The treatment group 20 kv 5 min has shown the highest marketability over time.

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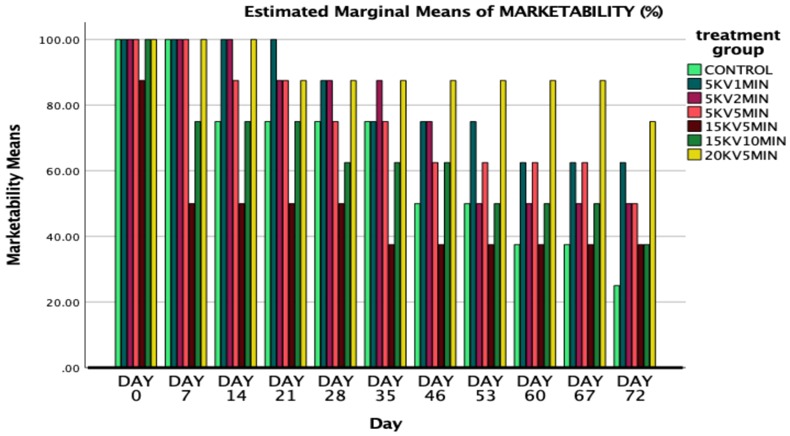

Figure 4. Estimated marginal means of marketability across 72 days

The tomatoes in the 15 kv treatments had visible plasma burns while the tomatoes in the 20 kv and 5 kv treatments did not show this type of damage. The reason for it can be the interaction between reactive species produced at varying power levels and treatment times. Higher plasma voltages have a capacity to produce more reactive oxygen species (ROS), which may increase oxidative stress and damage cell structure, which can result in burns [3]. The absence of burn in the higher concentration of 20kv could be due to having less reactive species concentration over time.

Table 2. Marketability of tomatoes at day 0 and day 72 across different treatments

Treatment	Day 0 (%)	Day 72 (%)
CONTROL	100	25
5 kv 1 min	100	62.5
5 kv 2 min	100	50
5 kv 5 min	100	50
15 kv 5 min	87.5	37.5
15 kv 10 min	100	37.5
20 kv 5 min	100	75

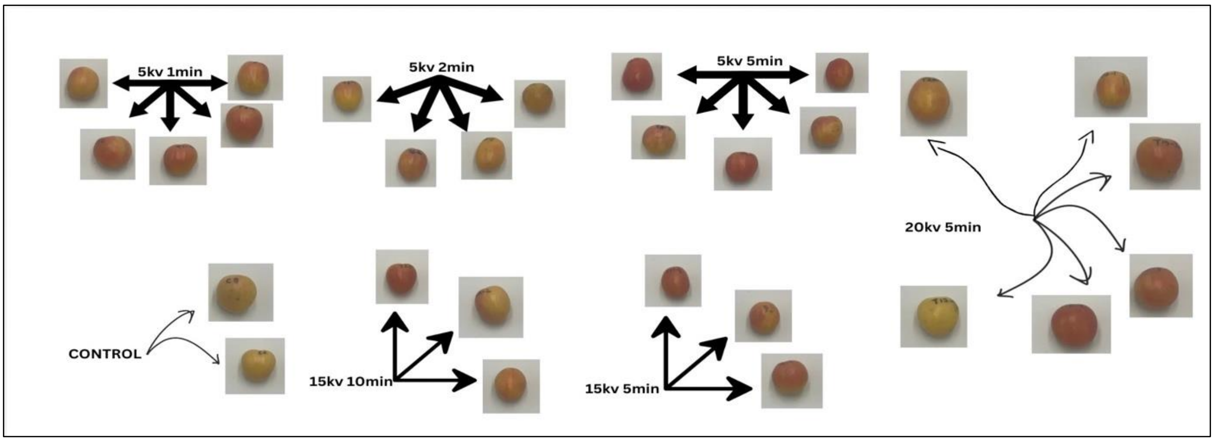

Figure 5. Marketable tomatoes from all cold plasma-treated groups and untreated control group at 72 days.

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3.3 Color analysis (chroma and hue angle)

The Tukey HSD comparisons indicate that no treatment pairs have statistically significant differences in chroma (all p-values are > 0.05). The control sample has the lowest chroma mean at 26.4541.

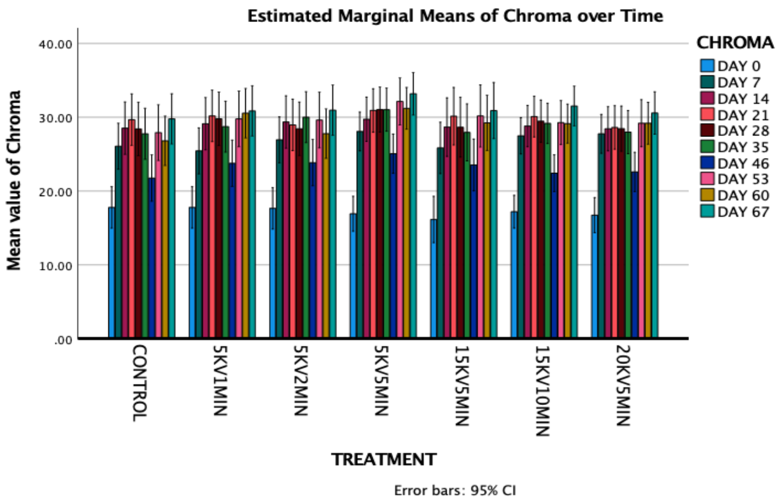

Figure 6. Chroma changes over time for different treatments

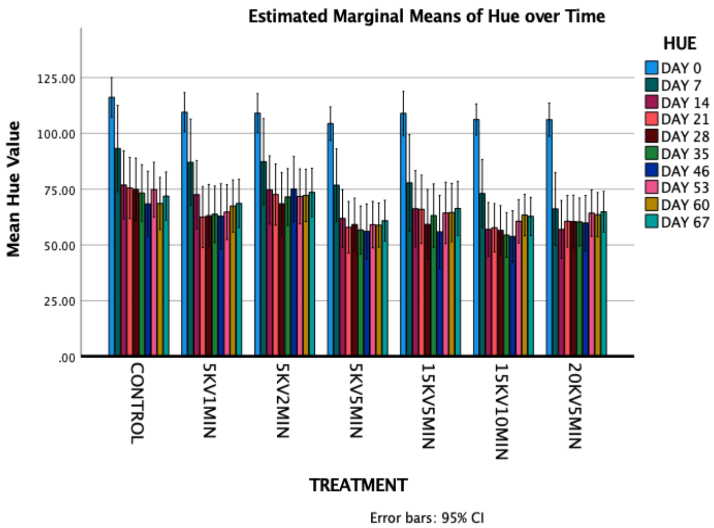

Figure 7. Hue changes over time for different treatments

At the beginning, every tomato in every treatment had a high hue value over 100. Based on the LSD post-hoc test results, there are no statistically significant differences between most treatment pairs for hue changes, given that all the p-values are above 0.05.

The color analysis showed the treatment group and control group's chroma and hue values did not differ significantly ($p > 0.05$). This result is similar with previous study, which found that cherry tomatoes treated with DBD in-package ambient pressure showed only slight changes in color [6]. According to the study conducted in 2016 [11], the L*, a*, and b* values of tomatoes treated with NTP did not show any significant changes. Moreover, there were no noticeable alterations in the tomatoes' color.

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4. CONCLUSIONS

In conclusion, while the NTP treatments influence the disease incidence of tomato, but it doesn't have a strong impact on the hue angle and chroma of the tomatoes. For the main experiment, 20KV 5MIN is selected because it offers effective disease incidence control and have no plasma burn and requires significantly less time. Due to this, it is the best option for industrial applications where speed and throughput are crucial.

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