Investigation of the effect of non-thermal plasma on increasing the shelf life of fresh-cut pears

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ABSTRACT

Purpose: Fresh-cut fruits are one of the most popular products. Pear is a highly putrefying fruit that is susceptible to mechanical damage, decay and physiological disorders during storage. Reducing post harvest losses of agricultural products with a view to increasing food security and preventing the loss of capital is one of the major issues facing societies. Research Method: Non-thermal plasma is under research for fruits preservation, especially fresh-cut fruits and vegetables. This study investigates the effects of plasma exposure to delay color changes of fresh-cut pears. Findings: Different treatments for the time of plasma exposure and types of packaging were studied. The results showed that; the parameter $a^*$, $L^*$, Chroma and browning index (BI) was significant at 5% level due to different treatments, but the plasma effect on $b^*$, $ΔE$, $h^*$ and YI were not significant at 5% level. Furthermore, the best acceptability is the direct exposure for two-minutes. Research Limitations: No limitations were founded. Originality/Value: It can be concluded that using non-thermal plasma can be considered as a new approach to increasing the durability and shelf life of fresh-cut pears. In addition, plasma exposure is one of the nondestructive processes that does not have any side effects on the products and can significantly obstruct microorganisms and delayed degradation, discoloration.
INTRODUCTION

Fresh-cut fruits have diverse applications in the food industry such as fruit salad and other low-caloric food stuffs. However, these products cannot preserve quality for over prolonged due to the injuries caused by the slicing action of fresh-cut fruits which induce of biochemical alterations like browning, loss in texture, to diminish the shelf life (Luo et al., 2014). Pyrus communis L., is a member of the family Rosaceae. The fleshy part of pear fruit consists of the fused base of the calyx (sepals), corolla (petals), and stamens, called the receptacle (Manzocco et al., 2000). Pears (and apples) oxidize and turn brown quickly after they’re sliced and exposed to air. Even though they still taste good, they’re just not very appealing that way. For the fresh-cut pear the most important phenomenon accountable for its excellence deprivation is the enzymatic browning. Enzymatic browning is the elaboration of brown color on the sides of fresh-cut fruits and vegetables. Browning is initiated by the interface of polyphenol oxidase (PPO) with the phenolic substrate (Ma et al., 2017).

The common way to keep fresh-cuts from browning is to dip the slices in a solution like brine that contain citric acid. This traditional manner has many limitations so it could not be used in an industrial food factory. There are numerous techniques to prevent the change in the skin pigment of freshly cut pear fruit, such as a light roasting pretreatment (Abreu et al., 2003), atmospheres monitoring (Gorny et al., 2002), exposure to 1-MCP (Arias et al, 2009), dipping fresh-cuts with xantham gum and cinnamic acid (Sharma & Rao, 2015) and Chitosan in combination with rosemary sap used as a pretreatment for fresh-cuts (Xiao et al., 2010). On the other hand, several of these treatments are not economically affordable because of need for validating the efficiency. As a result, it is necessary to create a sufficient and useful procedure for adjusting browning and expanding shelf life of fresh-cut pear fruit. A novel method used to prevent a browning reaction is required. UV-V light (200-280nm) treatment (Pankaj et al., 2013) and short term exposure to nitric oxide (NO) gas have good results in delaying the browning of fresh-cuts (Misra et al., 2011).

Misra et al. (2014) have been studied in package cold plasma treatment for strawberries. This work demonstrated the ability of in package atmospheric cold plasma to reduce the background microflora present on strawberries without inducing a significant effect on color and firmness.

Jiafeng et al. (2014) reported the effect of Cold Plasma Treatment on Seed Germination and Growth of wheat. Results showed that the treatment of cold helium plasma could significantly improve seed germination potential (6.0%) and germination rate (6.7%) compared to the control group. In this research, wheat seeds processed with cold plasma, compared with the control, plant height (20.3%), root length (9.0%) and fresh weight (21.8%) were improved significantly at seedling stage.

Misra et al. (2014) al investigated the effects of cold plasma generated within a sealed package from a dielectric barrier discharge on the physical quality factors and respiration rates of cherry tomatoes. The results showed that cold plasma could be employed as a means for of cherry distillation tomatoes while keeping product quality.

Among high-tech methods, gas plasma is one of the most popular procedures (Niemira, 2012). Plasma is a hot ionized gas consisting of approximately equal numbers of positively charged ions and negatively charged electrons. The characteristics of plasmas are significantly different from those of ordinary neutral gases so that plasmas are considered a fourth state of matter. Plasmas are described by many characteristics such as temperature, degree of ionization, and density that may be classified in different ways. As temperature view plasma
include 4 types of hot plasma, warm plasma, cold plasma and ultra-cold plasma (Perni et al., 2008).

Plasma can be created by revealing many gases such as O₂, N₂, H₂, He, Ne, Ar, NH₃, CH₄ and CF₄ to electric arenas (between two electrodes) ac (sophisticated frequency) or dc, magnetic field, thermal, microwave, and radio frequency (Thirumdas et al., 2015). The plasma system is in equilibrium condition. Parameters like feed gas configuration, moisture, and voltages will change in the plasma quiddities (Sudheesh et al., 2019).

Cold plasma is increasingly under research for decontamination of foods, especially fresh fruits and vegetables (Misra et al., 2014).

The aim of this study is to delay the browning of pear slices by using cold plasma in different treatments for the time of plasma exposure and types of packaging. Specific attention has been given to color alteration, sensory analysis since that enzymatic browning is the greatest cause to decrease the visual quality of pears slice.

Effects of melatonin treatment on the enzymatic browning of fresh-cut pear were studied by Zheng et al. (2019). Fresh-cut fruit flooded with 0, 0.05, 0.1 and 0.5 mM melatonin and kept at 4 °C. Results showed that 0.1 mM melatonin treatment was best one for decreasing the surface browning and sustaining the acidity of the fresh-cut fruit, which expressively reduced MDA contents and the growth of bacteria.

Wang et al. (2012) tested the variation of physiochemical properties of fresh-cut among the atmospheric pressure cold plasma treatment. Results showed that the physiochemical properties changes caused by the plasma were within an acceptable range.

**MATERIALS AND METHODS**

**Plasma DBD device**

Plasma is classified as corona discharge plasma, microwave discharge plasma, dielectric barrier discharge plasma (DBD), radio frequency plasma, and gliding arc discharge plasma (Thirumdas et al., 2015). The non-thermal plasma system that used in this experiment contained a 12 KV pulsed high voltage power supply and a probe which contain quartz as a dielectric layer. The probe was terminated to the high voltage output of power supply. Polytetrafluoroethylene was used at the handhold part of the probe to avoid electric shock. The cold plasma is generated between barrier and samples due to the voltage variance as shown in Figure 1.

**Raw material, handling and storage**

Pears were bought from a local fruit shop and kept at room temperature for just 2 hours before plasma exposure. Samples of 23 cross cut slices were slashed with a penknife sterile with 80% ethanol. Five slices were used as control and the other 18 slices spent for different treatments. Furthermore, the weight of zip locks that used as a package in this study was about 16.2 gr.

**Sample treatment and storage**

After sterilization the test material such as penknife, and hood (work desk) with ethanol 80% and UV rays, treatments of 2 min (1 min for side), 4 min (2 min for side) and 6 min (3 min for side) inside and outside the package were studied. Each treatment (1+1, 2+2 and 3+3) inside and outside the Package was repeated in triplicate. Color, visual quality by image analysis and sensory panel were evaluated for each treatment after one week of storage. Figure 2 shows the results of 4 different treatments after one week. Surface color was dignified on pear slices
before the plasma exposure and one week after the plasma exposure for all treatments, to determining changes in visual quality.

![Schematic of the experimental setup for DBD plasma system](image)

**Fig. 1.** Schematic of the experimental setup for DBD plasma system

![Visual quality of fresh-cut pear under different treatments after one week](image)

**Fig. 2.** Visual quality of fresh-cut pear under different treatments after one week
Table 1. Analysis of variance for effect of plasma treatments on color components

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>df</th>
<th>Mean Square</th>
<th>Sum of Squares</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>L*</td>
<td>6</td>
<td>29.785</td>
<td>178.710</td>
<td>1.902</td>
<td>0.141</td>
</tr>
<tr>
<td>a*</td>
<td>6</td>
<td>21.843</td>
<td>131.056</td>
<td>7.694</td>
<td>0.001 **</td>
</tr>
<tr>
<td>b*</td>
<td>6</td>
<td>20.176</td>
<td>121.055</td>
<td>1.481</td>
<td>0.246</td>
</tr>
<tr>
<td>ΔE</td>
<td>6</td>
<td>121.253</td>
<td>727.518</td>
<td>0.239</td>
<td>0.957</td>
</tr>
<tr>
<td>h*</td>
<td>6</td>
<td>0.23</td>
<td>0.139</td>
<td>0.873</td>
<td>0.536</td>
</tr>
<tr>
<td>C*</td>
<td>6</td>
<td>42.017</td>
<td>252.103</td>
<td>4.642</td>
<td>0.006 **</td>
</tr>
<tr>
<td>BI</td>
<td>6</td>
<td>664550.714</td>
<td>3987304.282</td>
<td>7.948</td>
<td>0.00 **</td>
</tr>
<tr>
<td>YI</td>
<td>6</td>
<td>105.257</td>
<td>631.543</td>
<td>0.898</td>
<td>0.520</td>
</tr>
</tbody>
</table>

** Significant difference (0.05)

Qualitative assessment

Visual quality
In this article, alterations in color parameters as a result of plasma exposure were reviewed. In order to quantify the color differences of fruit slices, the slices were scanned with a colorimeter (TES-135A, TES Electric Electronic Corp., Taiwan) using CIE (L*a*b*) system in it.

Color
In order to determine the effect of plasma on the persistence and changing in the color of the fresh-cut Color parameters (L* for the lightness and a* and b* for the green–red and blue–yellow color components) of the pears was measured before plasma exposure and one week after the plasma was applied in different treatments. The CIE L*a*b* color space provide more uniform color contrasts in connection to human recognition of differences (Fig. 3). Chroma (C*), considered the quantitative property of colorfulness, is utilized to decide the
degree of difference of a color in comparison to a grey color with the same lightness. Chroma
was calculated using Eq. (1) (Barreiro et al., 1997; Lopez et al., 1997).

\[ C^* = \sqrt{a^{*2} + b^{*2}} \]  

(1)

Hue angle (\(h^*\)) represents the differences in absorbance at different wavelengths (Barreiro
et al., 1997; Lopez et al., 1997) (2).

\[ h^* = \tan^{-1}\left(\frac{b^*}{a^*}\right) \]  

(2)

Total color distinction (\(\Delta E\)) demonstrates the color contrast from the standard plate
calculated as (Rhim et al., 1999) (3).

\[ \Delta E = \sqrt{\Delta a^{*2} + \Delta b^{*2} + \Delta L^{*2}} \]  

(3)

Yellowness index (\(YI\)) shows the degree of yellowness (Rhim et al., 1999) (4).

\[ YI = \frac{142.86b^*}{L^*} \]  

(4)

The browning index (\(BI\)) is used to characterize the whole changes in browning color, the
\(BI\) is calculated using the following equation (Maskan 2001; Mohapatra et al., 2010) (5, 6):

\[ BI = 100 \times \left(\frac{X - 0.31}{0.17}\right) \]  

(5)

Where

\[ X = \frac{(a^* + 1.75L^*)}{(5.645L^* + a^* - 3.012b^*)} \]  

(6)

Sensory analysis
Samples have been graded after one week later the plasma exposure. They have been scored
one spot between 1 and 5 (5 was the best) due to their visual quality, smell and the way fresh-
cuts breaks down in the mouth, how this affects the taste and flavor.

Data analysis
Effects of treatments have been investigated by completely randomized analysis of variance
(ANOVA). Significant differences (\(P<0.05\)) between mean values were tested by Duncan’s
multiple range test.

Effects of treatment and scored slices have been investigated by randomized complete
block. Six treatments with three replications were reviewed in this study.
RESULTS

Table 1 shows the Analysis of variance for effect of plasma treatments on color components. Based on the results, the parameter $a^*$, $L^*$, Chroma($C^*$) and browning index (BI) was significant at 5% level due to different treatments, but the plasma effect on $b^*$, $\Delta E$, $h^*$ and YI was not significant at 5% level.

In Figure 4, the comparison of the mean of parameter $a^*$ in different treatments was investigated based on Duncan's multi-domain test at 5% level, which direct plasma (outside the pack) for 6 minutes was significantly different from the other treatments and control treatment at level 5%. In addition, control treatment (no plasma exposure) had a significant difference of 5% with all treatments.

Also, in Figure 5, the comparison of the mean of parameter $C^*$ in different treatments was investigated based on Duncan's multi-domain test at 5% level, which control treatment had the highest value of $c^*$ and direct plasma (outside the pack) for 2 minutes assigned the lowest value.

Furthermore, Figure 6 compared the mean parameter BI (Browning Index) based on Duncan's multi-domain test at 5% level. Control treatment was significantly different from the other treatments and had the highest value of BI, on the other hand direct plasma (outside the pack) for 6 minutes was the best treatment due to had the lowest value of BI in comparison with other treatments and control treatment.

Figure 7 shows the comparison of averages for the general acceptability of freshly cut pears in different treatments based on Duncan's multiple range tests at 5% level. Based on this, the best acceptability is the direct exposure for two-minutes.

![Fig. 4. $a^*$ for pears treated by cold plasma (Direct: D, In-package: P)](image-url)
Fig. 5. $C^*$ (Chroma) for pears treated by cold plasma (Direct: D, In-package: P)

Fig. 6. BI (Browning Index) for pears treated by cold plasma (Direct: D, In-package: P)
**DISCUSSION**

According to our finding, in terms of browned areas, a significant decrease was observed in treated samples compared to control samples. This was in contrast to finding of Pankaj et al. (2017) that mentioned browning of white grape juice was increased. Nevertheless, total acceptability scores for pear slices treated by cold plasma were much higher than controls that are in agreement with the findings of previous studies (Ramazzina et al., 2015; Tappi et al., 2014). They experimented the effect of cold plasma to prevent browning reaction for fresh-cut kiwifruit and fresh-cut apples. According to the obtained results, plasma treatment positively affected the quality maintenance of the product, by improving color retention and reducing the darkened area formation during storage.

**CONCLUSION**

Increasing the time when freshly cut pear is placed under the influence of plasma, in the case of direct plasma exposure, has a significant effect on one of the color parameters (a*), while the fruit is inside the pack, increasing the duration of the plasma effect has no significant effect on any of the color parameters. Generally, plasma exposure decreased the mean value of parameter a* after one week, the lowest amount of a* was in direct treatment for 6 minutes and the highest amount was in the control treatment.

In addition, increasing the time of the freshly cut pear is directly influenced by the plasma has a significant and inverse effect at a level of 5% on overall acceptance, and in the case of freshly cut pears in the package, increasing the duration of the plasma exposure has no significant effect on general acceptability.

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