JOURNAL OF HORTICULTURE AND POSTHARVEST RESEARCH
2021, VOL. 4 (SPECIAL ISSUE: FRESH-CUT PRODUCTS), 91-102

Journal of Horticulture and Postharvest Research

Journal homepage: www.jhpr.birjand.ac.ir

University of Birjand

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

Ali Hajizadeh Namin[1*], Rouzbeh Abbaszadeh[2] and Arezo Pouraghdam[3]

1, *Department of Mechanic, Iranian Research Organization for Science and Technology (IROST), Tehran, Iran*
2, *Department of Agriculture, Iranian Research Organization for Science and Technology (IROST), Tehran, Iran*
3, *Department of Agriculture, University of Tehran, Karaj, Iran*

ARTICLE INFO

Short Communication

Article history:
Received 17 March 2021
Revised 19 October 2021
Accepted 20 October 2021
Available online 22 October 2021

Keywords:
Food preservation
In package
Non-thermal plasma
Pear fresh-cut
Sensory analysis

DOI: 10.22077/jhpr.2021.3907.1185
P-ISSN: 2588-4883
E-ISSN: 2588-6169

***Corresponding author:**
Department of Mechanic, Iranian Research Organization for Science and Technology (IROST), Tehran, Iran.
Email: a.hajizadeh@irost.ir

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 O_2, N_2, H_2, He, Ne, Ar, NH_3, CH_4 and CF_4 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 treatment, to determining changes in visual quality.

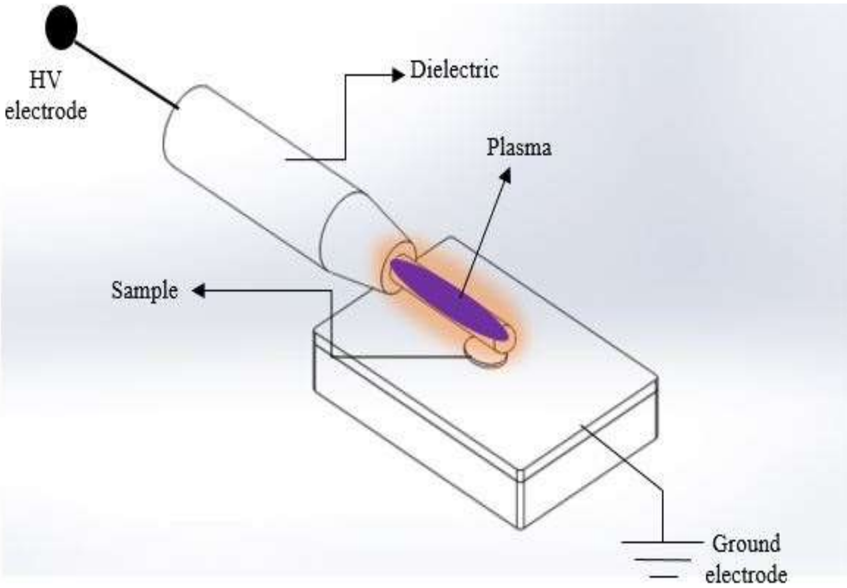

Fig. 1. Schematic of the experimental setup for DBD plasma system

A) Control
B) 4 minutes exposure of plasma in package
C) 6 minutes exposure of the direct plasma
D) 2 minutes exposure of plasma in package

Fig. 2. Visual quality of fresh-cut pear under different treatments after one week

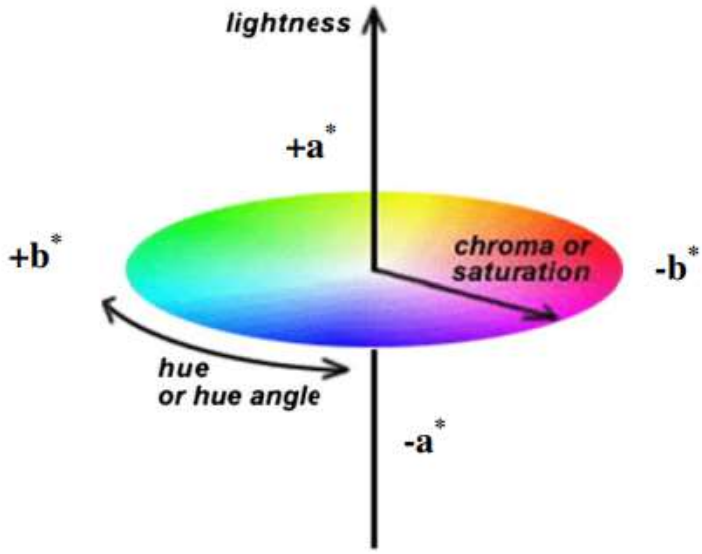

Fig. 3. CIELAB color space

Table 1. Analysis of variance for effect of plasma treatments on color components

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

** 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).

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad (1)$$

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

$$h^* = \tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (2)$$

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

$$\Delta E = \sqrt{\Delta a^{*2} + \Delta b^{*2} + \Delta L^{*2}} \quad (3)$$

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

$$YI = \frac{142.86b^*}{L^*} \quad (4)$$

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):

$$BI = 100 \times \left(\frac{X - 0.31}{0.17}\right) \quad (5)$$

Where

$$X = \frac{(a^* + 1.75L^*)}{(5.645L^* + a^* - 3.012b^*)} \quad (6)$$

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**, ΔE, *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.

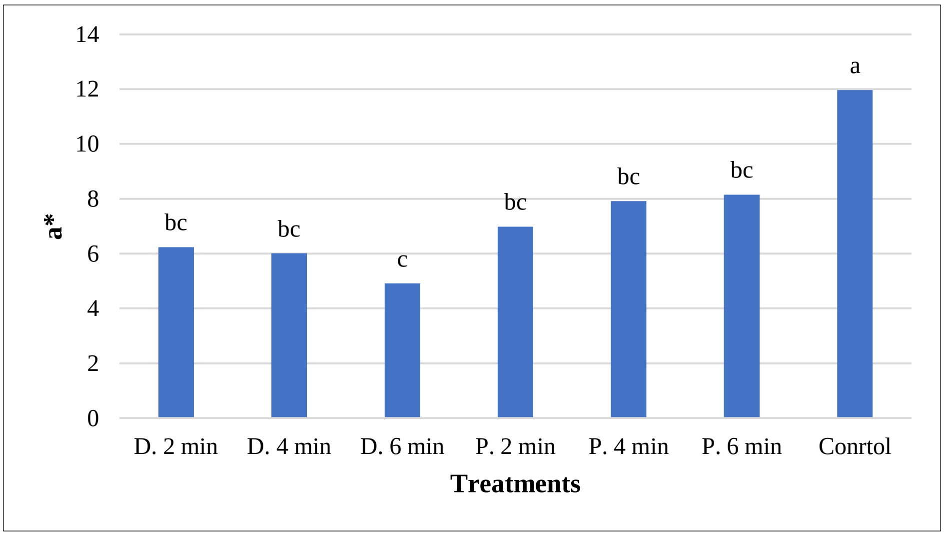

Fig. 4. *a** for pears treated by cold plasma (Direct: D, In-package: P)

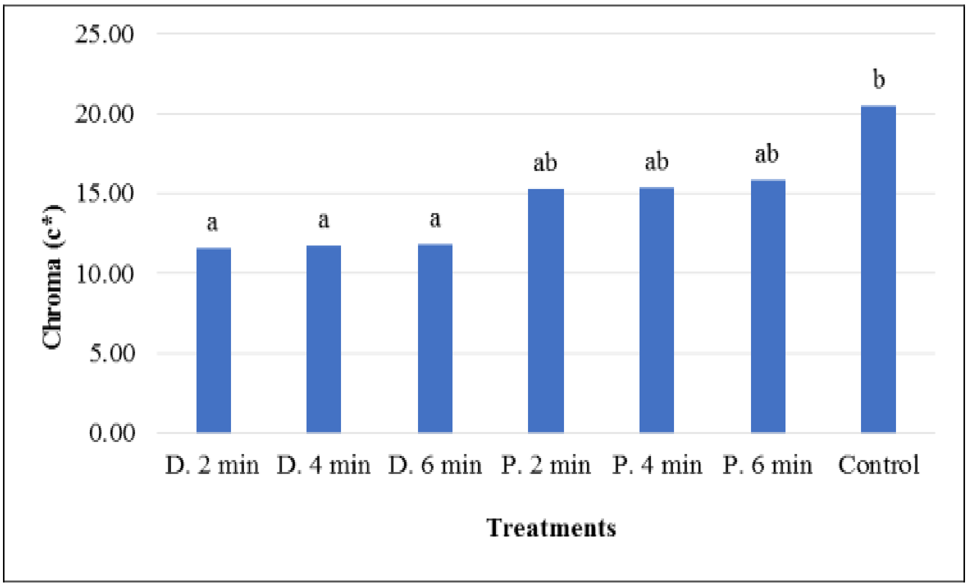

Fig. 5. *C** (Chroma) for pears treated by cold plasma (Direct: D, In-package: P)

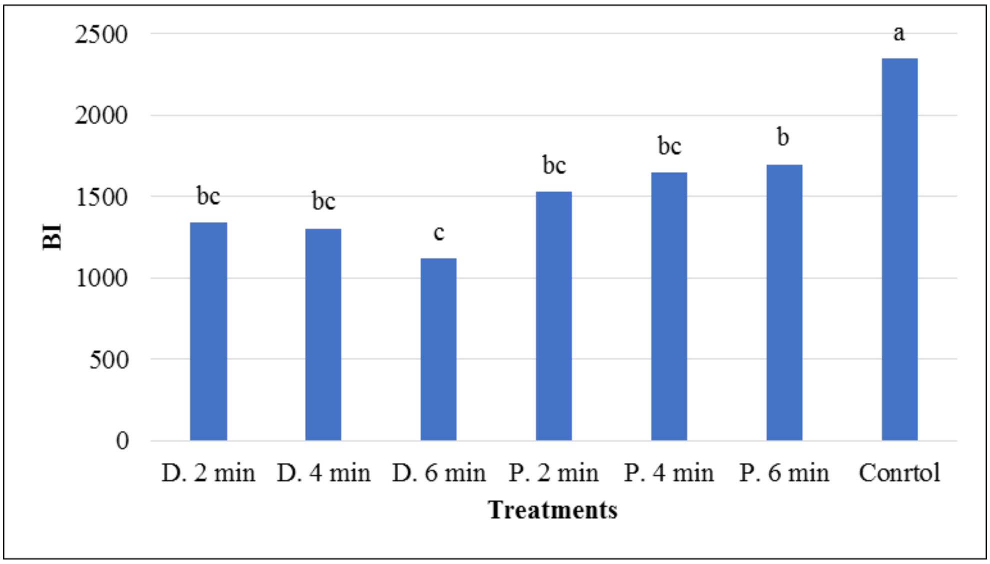

Fig. 6. BI (Browning Index) for pears treated by cold plasma (Direct: D, In-package: P)

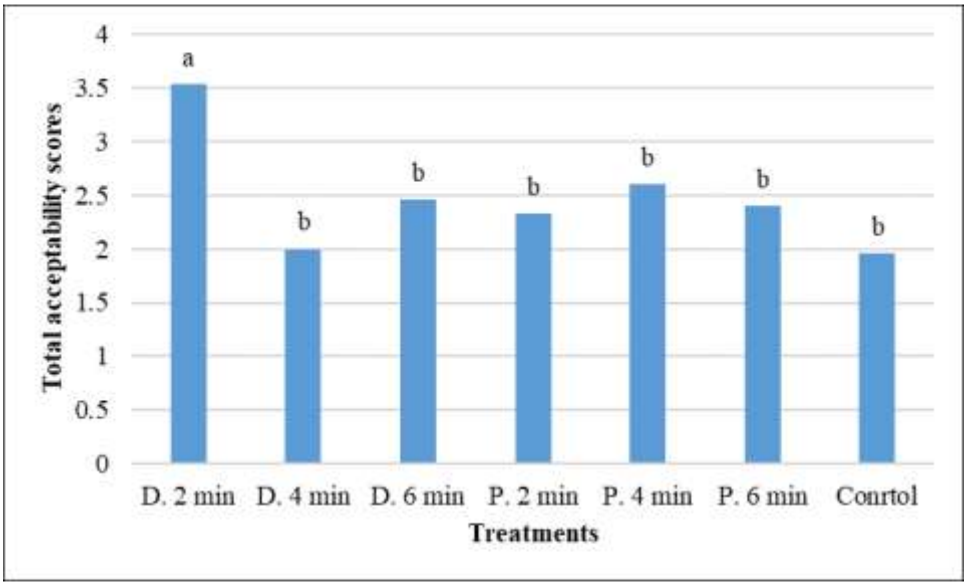

Fig. 7. Total acceptability scores for pear slices treated by cold plasma (Direct: D, In-package: P)

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.

Acknowledgements

This study was supported by the Post-Harvest Laboratory of the Iranian Research Organization for Science and Technology.

REFERENCES

Abreu, M., Beirao-da-Costa, S., Gonçalves, E. M., Beirão-da-Costa, M. L., & Moldão-Martins, M. (2003). Use of mild heat pre-treatments for quality retention of fresh-cut 'Rocha'pear. *Postharvest Biology and Technology*, *30*(2), 153-160. https://doi.org/10.1016/s0925-5214(03)00105-4

Arias, E., López-Buesa, P., & Oria, R. (2009). Extension of fresh-cut "Blanquilla" pear (Pyrus communis L.) shelf-life by 1-MCP treatment after harvest. *Postharvest Biology and Technology*, *54*(1), 53-58. https://doi.org/10.1016/j.postharvbio.2009.04.009

Barreiro, J., Milano, M., & Sandoval, A. (1997). Kinetics of color change of double concentrated tomato paste during thermal treatment. *Journal of Food Engineering*, *33*(3–4), 359–371. https://doi.org/10.1016/s0260-8774(97)00035-6

Gorny, J. R., Hess-Pierce, B., Cifuentes, R. A., & Kader, A. A. (2002). Quality changes in fresh-cut pear slices as affected by controlled atmospheres and chemical preservatives. *Postharvest Biology and Technology*, *24*(3), 271-278. https://doi.org/10.1016/s0925-5214 (01)00139-9

Jiafeng, J., Xin, H., Ling, L. I., Jiangang, L., Hanliang, S., Qilai, X., & Yuanhua, D. (2014). Effect of cold plasma treatment on seed germination and growth of wheat. *Plasma Science and Technology*, *16*(1), 54. https://doi.org/10.1088/1009-0630/16/1/12

Lopez, A., Pique, M., Boatella, J., Romero, A., Ferran, A., & Garcia, J. (1997). Influence drying conditions on the hazelnut quality. III. Browning. *Drying Technology*, *15*(3–4), 989–1002. https://doi.org/10.1080/07373939708917273

Luo, Z., Wang, Y., Wang, H., & Feng, S. (2014). Impact of nano-CaCO 3-LDPE packaging on quality of fresh-cut sugarcane. *Journal of the Science of Food and Agriculture*, *94*(15), 3273-3280. https://doi.org/10.1002/jsfa.6680

Ma, L., Zhang, M., Bhandari, B., & Gao, Z. (2017). Recent developments in novel shelf life extension technologies of fresh-cut fruits and vegetables. *Trends in Food Science & Technology*, *64*, 23-38. https://doi.org/10.1016/j.tifs.2017.03.005

Manzocco, L., Calligaris, S., Mastrocola, D., Nicoli, M. C., & Lerici, C. R. (2000). Review of non-enzymatic browning and antioxidant capacity in processed foods. *Trends in Food Science & Technology*, *11*(9-10), 340-346. https://doi.org/10.1016/s0924-2244(01)00014-0

Maskan, M. (2001). Kinetics of colour change of kiwifruits during hot air and microwave drying. *Journal of Food Engineering*, *48*(2), 169–175. https://doi.org/10.1016/s0260-8774(00)00154-0

Misra, N. N., Tiwari, B. K., Raghavarao, K. S. M. S., & Cullen, P. J. (2011). Nonthermal plasma inactivation of food-borne pathogens. *Food Engineering Reviews*, *3*(3-4), 159-170. https://doi.org/10.1007/s12393-011-9041-9

Misra, N. N., Keener, K. M., Bourke, P., Mosnier, J. P., & Cullen, P. J. (2014). In-package atmospheric pressure cold plasma treatment of cherry tomatoes. *Journal of Bioscience and Bioengineering*, *118*(2), 177-182. https://doi.org/10.1016/j.jbiosc.2014.02.005

Misra, N. N., Patil, S., Moiseev, T., Bourke, P., Mosnier, J. P., Keener, K. M., & Cullen, P. J. (2014). In-package atmospheric pressure cold plasma treatment of strawberries. *Journal of Food Engineering*, *125*, 131-138. https://doi.org/10.1016/j.jfoodeng.2013.10.023

Mohapatra, D., Bira, Z. M., Kerry, J. P., Frías, J. M., & Rodrigues, F. A. (2010). Postharvest hardness and color evolution of white button mushrooms (*Agaricus bisporus*). *Journal of Food Science*, *75*(3), E146-E152. https://doi.org/10.1111/j.1750-3841.2010.01518.x

Niemira, B. A. (2012). Cold plasma decontamination of foods. *Annual Review of Food Science and Technology*, *3*, 125-142. https://doi.org/10.1146/annurev-food-022811-101132

Perni, S., Liu, D. W., Shama, G., & Kong, M. G. (2008). Cold atmospheric plasma decontamination of the pericarps of fruit. *Journal of Food Protection*, *71*(2), 302-308. https://doi.org/10.4315/0362-028x-71.2.302

Ramazzina, I., Berardinelli, A., Rizzi, F., Tappi, S., Ragni, L., Sacchetti, G., & Rocculi, P. (2015). Effect of cold plasma treatment on physio-chemical parameters and antioxidant activity of minimally processed kiwifruit. *Postharvest Biology and Technology*, *107*, 55-65. https://doi.org/10.1016/j.postharvbio.2015.04.008

Pankaj, S. K., Misra, N. N., & Cullen, P. J. (2013). Kinetics of tomato peroxidase inactivation by atmospheric pressure cold plasma based on dielectric barrier discharge. *Innovative Food Science & Emerging Technologies*, *19*, 153-157. https://doi.org/10.1016/j.ifset.2013.03.001

Pankaj, S.K.; Wan, Z.; Colonna, W.; Keener, K.M. Effect of high voltage atmospheric cold plasma on white
grape juice quality. J. Sci. Food Agric. 2017, 97, 4016–4021. http://dx.doi.org/10.1002/jsfa.8268

Rhim, J., Wu, Y., Weller, C., & Schnepf, M. (1999). Physical characteristics of a composite film of soy protein isolate and propyleneglycol alginate. *Journal of Food Science*, *64*(1), 149–152. https://doi.org/10.1111/j.1365-2621.1999.tb09880.x

Sharma, S., & Rao, T. V. R. (2015). Xanthan gum based edible coating enriched with cinnamic acid prevents browning and extends the shelf-life of fresh-cut pears. *LWT –Food Science and Technology*, *62*, 791–800. https://doi.org/10.1016/j.lwt.2014.11.050

Sudheesh, C., Sunooj, K. V., Sinha, S. K., George, J., Kumar, S., Murugesan, P., & Kumar, V. A. S. (2019). Impact of energetic neutral nitrogen atoms created by glow discharge air plasma on the physico-chemical and rheological properties of kithul starch. *Food Chemistry*, *294*, 194-202. https://doi.org/10.1016/j.foodchem.2019.05.067

Tappi, S., Berardinelli, A., Ragni, L., Dalla Rosa, M., Guarnieri, A., & Rocculi, P. (2014). Atmospheric gas plasma treatment of fresh-cut apples. *Innovative Food Science & Emerging Technologies*, *21*, 114-122. https://doi.org/10.1016/j.ifset.2013.09.012

Thirumdas, R., Sarangapani, C., & Annapure, U. S. (2015). Cold plasma: a novel non-thermal technology for food processing. *Food Biophysics*, *10*(1), 1-11. https://doi.org/10.1007/s11483-014-9382-z

Wang, R. X., Nian, W. F., Wu, H. Y., Feng, H. Q., Zhang, K., Zhang, J., ... & Fang, J. (2012). Atmospheric-pressure cold plasma treatment of contaminated fresh fruit and vegetable slices: inactivation and physiochemical properties evaluation. *The European Physical Journal D*, *66*(10), 276. https://doi.org/10.1140/epjd/e2012-30053-1

Xiao, C., Zhu, L., Luo, W., Song, X., & Deng, Y. (2010). Combined action of pure oxygen pretreatment and chitosan coating incorporated with rosemary extracts on the quality of fresh-cut pears. *Food Chemistry*, *121*(4), 1003-1009. https://doi.org/10.1016/j.foodchem.2010.01.038

Zheng, H., Liu, W., Liu, S., Liu, C., & Zheng, L. (2019). Effects of melatonin treatment on the enzymatic browning and nutritional quality of fresh-cut pear fruit. *Food Chemistry*, *299*, 125116. https://doi.org/10.1016/j.foodchem.2019.125116