# Atmospheric pressure cold plasma treatment on quality attributes of groundnut

**K. L. Claudia[1]., S. Ganapathy[2*]., G. Shanmugavelayutham[3]., M. Balakrishnan[4]., S. Karthikeyan[5] and V. Paranidharan[6]**

[1]Ph.D. Scholar, Department of Food Process Engineering, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore
[2]Professor, Department of Food Process Engineering, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.
*corresponding author
[3]Associate Professor, Department of Physics, Bharathiar University, Coimbatore
[4]Professor and Head, Department of Food Process Engineering, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.
[5]Professor and Head, Centre for Post-Harvest Technology, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.
[4]Professor, Department of Plant Pathology, Tamil Nadu Agricultural University, Coimbatore.

## ABSTRACT

Cold plasma technology could be utilized for the safe management of groundnut. Atmospheric cold plasma technique has the advantage of high chemical reactivity which boosts product safety and leads to shelf-life extension with negligible impact on the quality of treated food products. Dielectric barrier discharge (DBD) method of cold plasma was carried out using argon gas for groundnut and the quality characteristics of the groundnuts were determined. The operating parameters were plasma voltage of 12, 15 and 18 kV and a gas flow rate of 15 L/min. Exposure time of groundnut were 5,10 and 15 min. The results showed that the physicochemical characteristics such as protein content, starch content, total phenol content, free fatty acid and color of groundnuts were found to be statistically similar in treated compared to untreated groundnuts. Atmosphere cold plasma treatment resulted in a reduction in protein content and free fatty acid and increment in starch content with increase in plasma voltage and exposure time. Atmospheric cold plasma technology is one of the non-thermal processing methods for food products without effecting the quality.

**Keywords:** *groundnuts, dielectric barrier discharge, cold plasma technology.*

# Atmospheric pressure cold plasma treatment on quality attributes of groundnut

## 1. Introduction

Groundnut is the third largest oilseeds produced in the world. According to International Production Assessment Division USDA, world groundnut production is 49.76 million metric tonnes. As of 2021, China is the largest producer of groundnuts worldwide, producing over 18.3 million metric tonnes. India ranked second producing just over ten million metric tonnes (IPAD, USDA's FAS, 2023). India has exported 514,164 MT of groundnuts to the world worth of Rs. 4,697 Crores (629.27 USD Millions) during 2021-22 (APEDA, 2022). There exists huge international demand for the groundnut because of the high nutritional value including fat, protein, fatty acids and free amino acids. These nuts have potential to delay human aging (Liu *et al*., 2019).

Foods are processed to retain their quality, to extend shelf life and to enhance sensory attributes (Vanga *et al*., 2017). Groundnuts are processed for shelf life extension and to add more value to the products. Conventionally groundnuts are processed by heat treatments such as boiling and roasting. The thermal processing methods encounter losses in organoleptic quality and nutritional quality (Ekezie *et al*., 2019). Increasingly non-thermal preservation methods are attempted to enhance the safety of food materials without affecting their quality.

Several non-thermal methods such as pulsed light processing, pulsed electric field processing, high pressure processing (Dong *et al*., 2020), irradiation (Misra *et al*., 2022) and cold plasma are used currently for different nuts, vegetables and fruits which can retain nutritive value of food materials and extend its shelf life (Ekezie *et al*., 2019).

In the last two decades, the development of cold plasma technology has offered a promising and environmentally friendly solution for addressing global food security problems. Cold plasma technology, a non-thermal processing method, can be utilized to enhance product safety and to extend the shelf-life in food processing (Mravlje, *et al*., 2021). It is generally regarded as reliable and suitable food processing method for use in smallerscale. Cold plasma systems are scalable too, still requiring much more research and development to interpret its food-related interactions (Laroque *et al.,* 2022).

The main advantage of the atmosphere cold plasma treatment of food products is its high chemical reactivity. The activated reactive species of cold plasma can act rapidly against micro-organisms at ambient temperatures without leaving any known chemical residues. Cold plasma has ability to deactivate harmful microbes with almost negligible impact on the treated food products. The technology can be applied to different types of food products in both solid and liquid form. In addition, the low energy consumption and price-value inputs contribute to atmospheric cold plasma system being considered as an economically acceptable method (Misra *et al*., 2019).

Several authors have reported the application of cold plasma for microbial inactivation (Gan *et al*., 2021; Govaert *et al*., 2020 and Feiozollahi *et al*., 2020) and its effect on nutritional components of food (Moutiq *et al*., 2020; Albertos *et al*., 2019 and Hou *et al*., 2019). Further applications include enzyme inactivation (Chutia *et al*., 2019 and Misra *et al*., 2016), inhibition of protein allerginicity (Ekezie *et al*.,2019 and Venkataratnam *et al*., 2019), degradation of mycotoxins and pesticides (Feng *et al*., 2019; Devi *et al*., 2017 and Sarangapani *et al*., 2016) and modification of food packaging materials (Baniya *et al*., 2020).

It appears that individual effect of process parameters of atmospheric cold plasma on groundnuts has not evaluated yet. Hence atmospheric cold plasma has been chosen for groundnut processing in order to retain the quality attributes. The present research envisages evaluation of the effect of process parameters during atmospheric cold plasma treatment on quality characteristics of groundnut and optimization of the process parameters for safety and quality.

## 2. Materials and methods

### 2.1 Materials

Raw groundnuts (Variety: TNAU CO6) were procured from the Department of Oil Seeds, Tamil Nadu Agricultural University, Coimbatore. The groundnuts were stored in the ambient conditions for further studies. Groundnuts were decorticated before cold plasma treatment. All chemicals and reagents used were analytical grade.

### 2.2 Plasma treatment

Atmospheric pressure dielectric barrier discharge system (argon gas) was used for the study. The cold plasma system consists of a plasma chamber (40 cm x 40 cm x 20 cm) with two parallel electrodes (30 cm x 30 cm). Ground electrode was covered with a dielectric material (3 mm thickness) and high voltage electrode with acrylic sheet (10 mm thick). During plasma treatment, the distance between electrodes was fixed at 10 mm. An AC high voltage power supply (Vmax: 40kV) was used to generate plasma between the two electrodes (Fig. 1). Twenty grams of the decorticated groundnuts (TNAU CO6), were exposed to atmospheric pressure dielectric barrier discharge cold plasma (DBD) within the treatment chamber. The operating parameters were plasma voltage of 12,15 and 18 kV along with a flow rate of 15 L/min.

Exposure time of groundnut was maintained as 5, 10 and 15 min. Total nine treatments were used with different combinations. The cold plasma treated groundnuts were stored at room temperature for 24 h. Untreated groundnuts were kept as control samples.

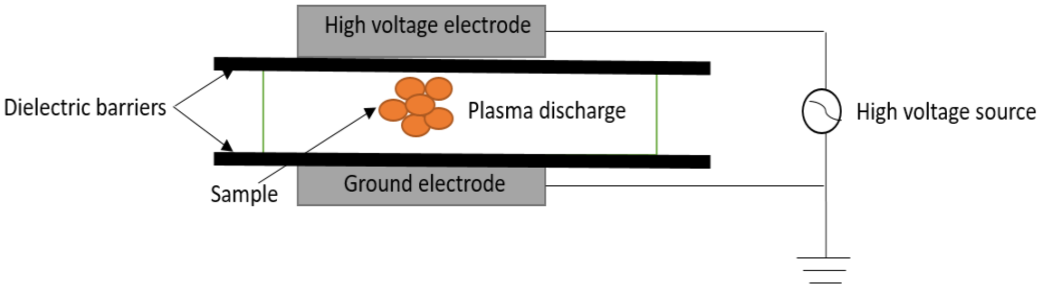

Fig. 1. Experimental setup for plasma treatment

## 2.3 Determination of physico-chemical characteristics of groundnut

### 2.3.1 Protein Content

The protein content was determined using Lowry's method described by Rizvi *et al.*, (2022). Protein content was quantified by hydrolyzation of the protein in the sample and estimation of the amino acid. About 50 mg of sample were ground with 5-10 ml of phosphate buffer solution. The supernatant of the sample was taken for the protein estimation through centrifugation (10,000 rpm/10 min at 4℃). The supernatant (0.1-0.2 ml) was pipetted out and made up to 2 ml. Then 5 ml of alkaline copper solution was added and mixed well. After 10 min of incubation, 0.5 ml of the Folin–Ciocalteu reagent was added, mixed and incubated at room temperature in dark for 30 min. The absorbance of the blue colored solution was read at 660 nm using a spectrophotometer (UV-1800, Shimadzu UV spectrophotometer). The absorbance of all standards was also measured and a standard curve was made of bovine serum albumin. The amount of protein present in the given sample was estimated from the standard graph (Mæhre *et al.*, 2018).

### 2.3.2 Starch Content

Starch content was estimated using acid hydrolysis method described by Yang *et al.*, (2019). The sample (0.1 to 0.5g) was homogenized in 50 ml of 80% hot ethanol for extraction of sugars. The mixture was centrifuged at 3000 rpm for 5 min at room temperature and the supernatant was decanted. The residue was washed thoroughly and then centrifuged. To the residue, 5 ml of water and 6.5 ml of 52% perchloric acid were added and extracted at 0 °C for 20 min. After centrifugation, the supernatant was collected. The extraction was repeated two to three times and made the volume upto 100 ml. About 0.1 to 0.2 ml of the sample was pipetted out and made up the volume to one millilitre with water. Anthrone reagent (4 ml) was added slowly drop by drop and was mixed with the content. It was then kept in boiling water bath for 10 min. After cooling, the absorbance of green colored solution was noted at 630 nm using spectrophotometer (UV-1800, Shimadzu UV spectrophotometer). The amount of glucose present in the given sample was estimated from the standard graph. Glucose content was calculated using the following formula and multiplied by 0.9 to get starch content.

$$\text{Glucose content (\%)} = \frac{\text{Concentration from standard graph of glucose}}{\text{Aliquot taken for estimation}} \text{ x } 100 \text{ x } \frac{100}{\text{Weight of the sample}} \text{ x } \frac{1}{10\text{\^{}}6}$$

### 2.3.3 Total Phenol Content

Total phenol content of sample was determined by the Folin–Ciocalteu method described by Gebremical *et al.*, 2019. Total phenols were extracted in a sample of 250 mg which was ground into two five milliliter portions of 80 percent ethanol. The supernatant obtained after centrifugation at room temperature was made up to 10 ml in standard flask. About 0.2 ml of the solution was mixed with 0.5 mL of the Folin–Ciocalteu solution (diluted in water 1:10). After five min one ml of 20% (w/v) sodium carbonate solution was added. After half an hour the absorbance was read at 660 nm using spectrophotometer (UV-1800, Shimadzu UV spectrophotometer) and total phenolic content was expressed as mg equivalents of pyrocatechol per 100g of sample.

### 2.3.4 Free Fatty acid

The free fatty acid content in groundnut was determined by titrimetric method described by Kupwade *et al*., 2019. Groundnut samples (1-10 g) were ground and 50 ml of ethanol added in a conical flask. Few drops of phenolphthalein indicator were added and titrated against 0.1 N Potassium hydroxide which was taken in burette up to the end point of development of pink color. Free fatty acid content was found by using the following formula.

$$\text{Free fatty acid} = \frac{\text{Titre value x Normality of KOH x 0.028}}{\text{Weight of the sample (g)}} \text{x 100}$$

### 2.3.5 Color

The color of the groundnut was determined using a tintometer (Model LC 100/401100, Lovibond). After calibration, each sample was placed below the camera and values of ‘L*’, ‘a*’ and ‘b*’ were recorded.

### 2.4 Statistical Analysis

Response Surface Methodology (RSM) was adopted in the experimental design as it reduces number of experimental runs needed and provide sufficient information for statistically acceptable results (Montgomery, 2001). A Box–Behnken design was used with two variables and three levels, each with three centre point combinations for the optimization process. Design expert version 13.0 was used for the analysis.

## 3. RESULTS AND DISCUSSION

### 3.1 Protein content

The effect of voltage level of plasma and exposure time on protein content is shown in Fig. 2. The results show that protein content decreased with increase in plasma voltage and exposure time. Proteins may undergo alterations and unfolding in secondary and tertiary structures due to the interactions with reactive species present in cold plasma during treatment (Ekezie *et al*., 2019). No significant difference in protein values were observed between the treated and untreated samples.

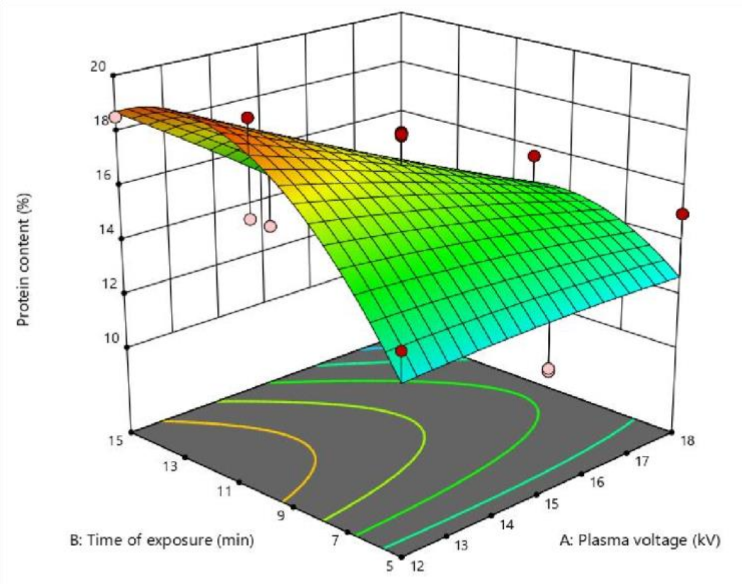

Fig. 2. Effect of process parameters on protein content

### 3.2 Starch content

The relationship between the level of plasma voltage and period of exposure on the retention of starch content is shown in Fig. 3. The plasma voltage and period of exposure have significant effect on starch content. As the plasma voltage increased from 12 kV to 18 kV, the starch content also increased. This might be due to the interactions between starch molecules and reactive species generated through cold plasma. Modifications of starch molecules can be by depolymerization and crosslinking of granules. Cold plasma can be used as a safe technique for modification of starch (Sifuentes-Nieves *et al*., 2021). No significant difference was observed between the starch content of untreated and treated samples.

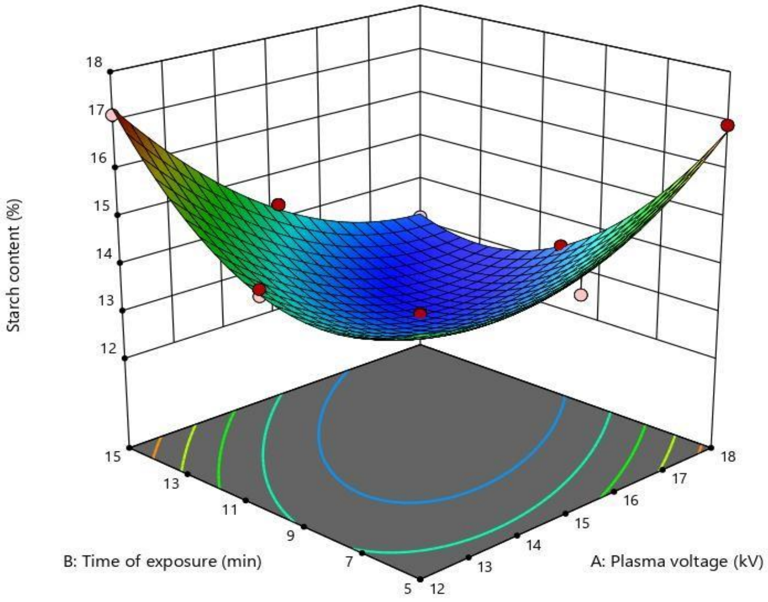

Fig. 3. Effect of process parameters on starch content

### 3.3 Total phenol content

The effect of voltage level of plasma and exposure time on total phenol content is shown in Fig. 3. Independent variables such as plasma voltage and exposure time have positive effect on the total phenol content of groundnut. It showed variation in the phenol content. Maximum value of phenol content was obtained at a plasma voltage of 15kV and 10 min of exposure time (Gebremical *et al*., 2019). The total phenol content values obtained in cold plasma treated groundnuts were statistically similar to untreated control sample.

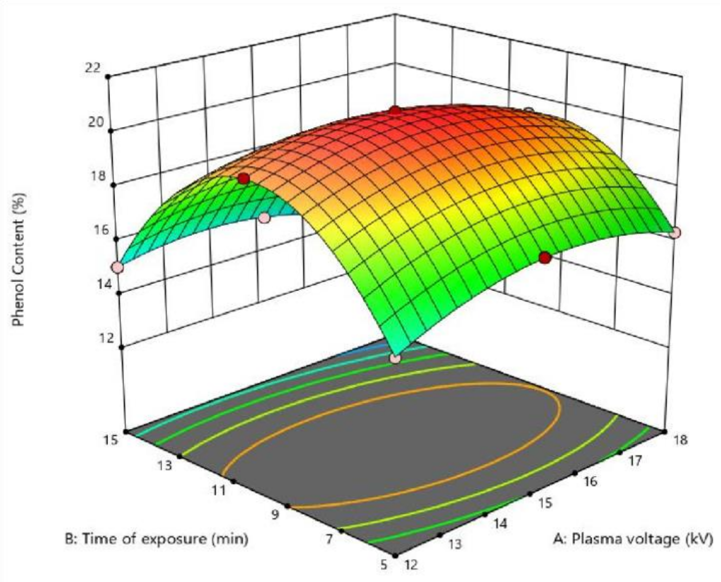

Fig. 3. Effect of process parameters on total phenol content

### 3.4 Free fatty acid

The relationship between the level of plasma voltage and period of exposure on free fatty acid is shown in Fig.4. The values of free fatty acid decreased with increase in plasma voltage and time. Minimum value was obtained at a voltage of 15 kV and 10 min of exposure time. There is slight increase in value after 10 min. It might be due to hydrolysis of triglycerol molecules to free fatty acids and diacylglycerols (Gebremical *et al*., 2019). However, there are no significant differences between the free fatty acid values obtained from treated and untreated samples.

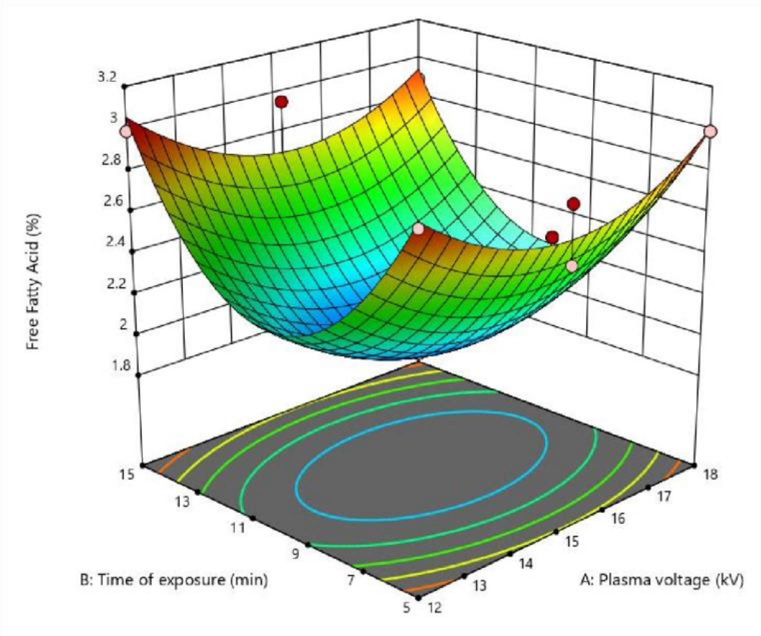

Fig. 4. Effect of process parameters on free fatty acid

### 3.5 Color

The plasma voltage and period of exposure were found to have significant effect on the color values of groundnuts (Fig. 5). As the plasma voltage increased, the L* and b* values decreased while a* values increased slightly. Lightness decreased and groundnuts became slightly darker compared to untreated samples. This might be due to the breakdown of glycosidic and peptide bonds during cold plasma treatment which led to the formation of carbonyl and amino compounds inducing Maillard reactions (Makari *et al*., 2021).

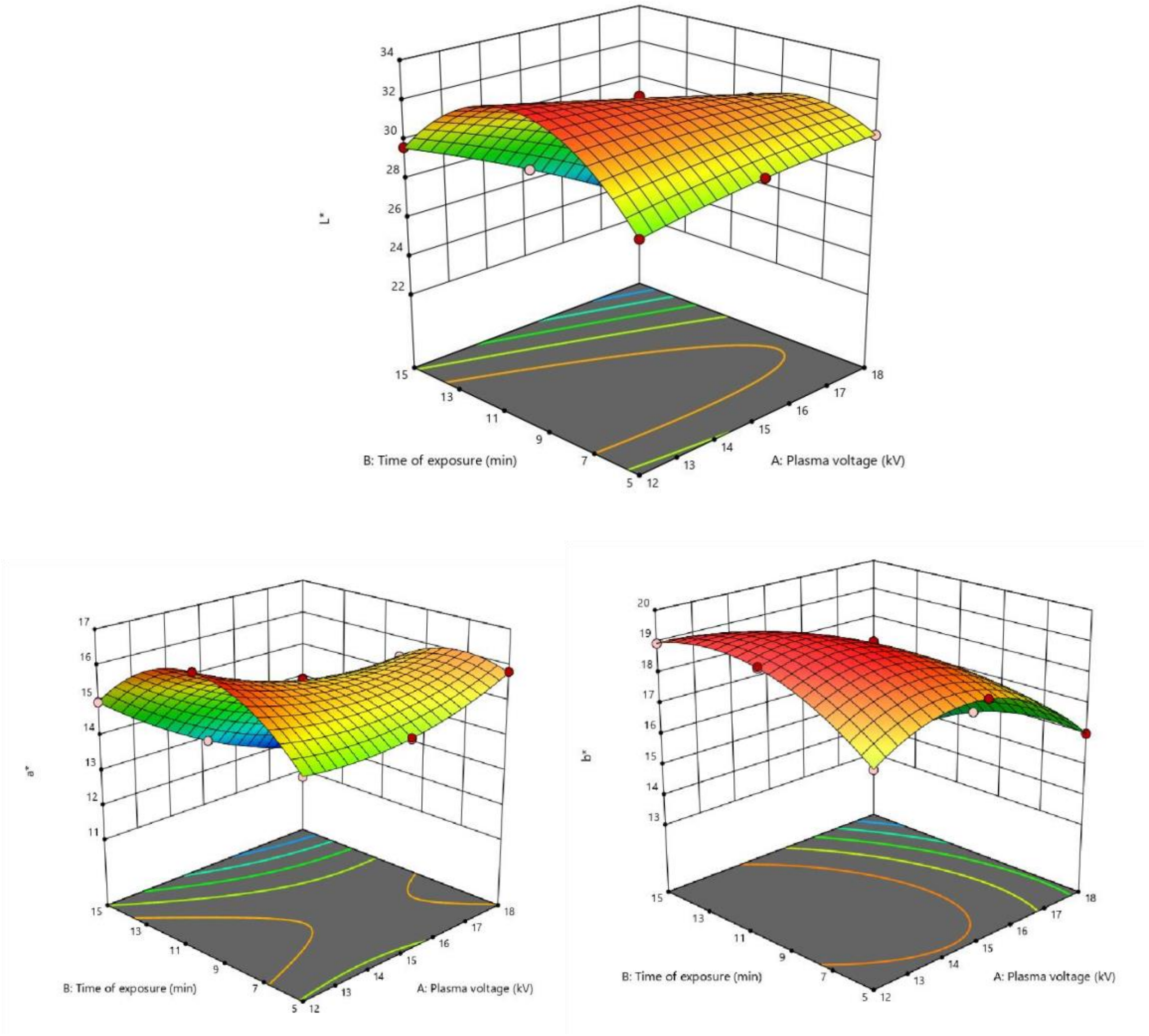

Fig. 5. Effect of process parameters on color

## 4. Conclusion

This work evaluated the effect of process parameters during atmospheric pressure cold plasma treatment on quality characteristics of groundnut. The operating parameters were plasma voltage of 12, 15 and 18 kV and argon gas flow rate of 15 L/min. Exposure time of groundnut were 5,10 and 15 min. Atmosphere cold plasma treatment resulted in a reduction in protein content and improvement in starch content with increase in plasma voltage and exposure time. It was found to result in a plasma voltage and treatment time dependent decrease in the free fatty acid. The L* and b* values decreased whereas a* values increased slightly with applied voltage and treatment time. The results of this study showed that atmospheric pressure cold plasma treatment on groundnut could be considered as a nonthermal technique that results in good quality groundnut. Future work is recommended to research on impact of different working gas and flow rate on quality attributes of nuts and other products.

## Acknowledgments

This reserach has been utilized the atmospheric pressure cold plasma system in Department of Physics, Bharathiar University, Coimbatore.

## References

- Albertos, I., Martin-Diana, A.B., Cullen, P.J., Tiwari, B.K., Ojha, K.S., Bourke, P., Rico, D., 2019. Shelf-life extension of herring (*Clupea harengus*) using in-package atmospheric plasma technology. *Innovat. Food Sci. Emerg. Technol*. 53, 85–91. https://doi.org/10.1016/j.ifset.2017.09.010
- APEDA, APEDA database results, 2022, http://www.apeda.gov.in/apedawebsite/GroundNut/GroundNut.htm.
- Baniya, H.B., Guragain, R.P., Baniya, B., Qin, G., Subedi, D.P., 2020. Improvement of hydrophilicity of polyamide using atmospheric pressure plasma jet. *Bibechana* 17, 133–138. https://doi.org/10.3126/bibechana.v17i0.26869.
- Chutia, H., Kalita, D., Mahanta, C.L., Ojah, N., Choudhury, A.J., 2019. Kinetics of inactivation of peroxidase and polyphenol oxidase in tender coconut water by dielectric barrier discharge plasma. *LWT* 101, 625–629. https://doi.org/10.1016/j. lwt.2018.11.071
- Yamuna Devi, Rohit Thirumdas, C. Sarangapani, R.R. Deshmukh, U.S. Annapure. 2017. Influence of cold plasma on fungal growth and aflatoxins production on groundnuts. *Food Control*. 77: 187-191.
- Xin Dong, Jin Wang and Vijaya Raghavan. 2020. Critical reviews and recent advances of novel non-thermal processing techniques on the modification of food allergens. *Critical Reviews in Food Science and Nutrition.* 61 (2): 196210. https://doi.org/10.1080/10408398.2020.1722942.
- F. G. C. Ekezie, J. H. Cheng, and D.-W. Sun, Effects of atmospheric pressure plasma jet on the conformation and physicochemical properties of myofibrillar proteins from king prawn (*Litopenaeus vannamei*), *Food Chemistry*, vol. 276, pp. 147–156, 2019.
- Feizollahi, E., Misra, N.N., Roopesh, M.S., 2020. Factors influencing the antimicrobial efficacy of dielectric barrier discharge (DBD) atmospheric cold plasma (ACP) in food processing applications. *Crit. Rev. Food Sci. Nutr*. 61, 666–689. https://doi.org/ 10.1080/10408398.2020.1743967.
- Feng, X., Ma, X., Liu, H., Xie, J., He, C. and Fan, R., 2019. Argon plasma effects on maize: pesticide degradation and quality changes. *J. Sci. Food Agric*. 99, 5491–5498. https://doi.org/10.1002/jsfa.9810.
- Gan, Z., Feng, X., Hou, Y., Sun, A. and Wang, R. 2021. Cold plasma jet with dielectric barrier configuration: investigating its effect on the cell membrane of E. coli and S. cerevisiae and its impact on the quality of chokeberry juice. *LWT – Food Sci. Technol*. 136, 110223. https://doi.org/10.1016/j.lwt.2020.110223.
- Gebremical, G. G., Emire, S. A. and Berhanu, T. 2019. Effects of Multihollow Surface Dielectric Barrier Discharge Plasma on Chemical and Antioxidant Properties of Peanut. *Journal of Food Quality*. https://doi.org/10.1155/2019/3702649.
- Govaert, M., Smet, C., Graeffe, A., Walsh, J.L. and Van Impe, J.F.M. 2020. Inactivation of *L. Monocytogenes* and *S. typhimurium* biofilms by means of an air-based cold atmospheric plasma (CAP) system. *Foods*, 9: 157. https://doi.org/10.3390/ foods9020157.
- Mæhre, H. K., Dalheim, L., Edvinsen, G. K., Edel O. Elvevoll, and IdaJohanne Jensen 2018 Protein Determination-Method Matters. *Foods*. 2018 Jan; 7(1): 5. doi: 10.3390/foods7010005
- Hou, Y., Wang, R., Gan, Z., Shao, T., Zhang, X., He, M. and Sun, A., 2019.

Effect of cold plasma on blueberry juice quality. *Food Chem*. 290, 79–86. https://doi.org/10.1016/j.foodchem.2019.03.123.

- Liu, K., Liu, Y. and Chen, F. 2019. Effect of storage temperature on lipid oxidation and changes in nutrient contents in peanuts. *Food Sci Nutr*.
- Kupwade, R.V. and Desai, V. M. 2019. Estimation of acid value, percentage of FFA and cholesterol content in groundnut oil collected from local rural farmers in sangli. *International Journal of Research and Analytical Reviews*. 6(1):516-518.
- Laroque, D. A., Se´o, S. T., Valencia, G. A., Laurindo, J. B., and Carciofi, B.A.M. 2022. Review: cold plasma in food processing: design, Mechanisms and application. *Journal of food engineering*. 312. 110748
- Makari, M., Hojjati, M., Shahbazi, S. and Askari, H. 2021. Elimination of *Aspergillus flavus* from pistachio nuts with Dielectric Barrier Discharge (DBD) Cold Plasma and Its Impacts on Biochemical Indices. *Journal of Food Quality*.
- Misra, N. N., Pankaj, S. K., Segat, A., Ishikawa, K., 2016a. Cold plasma interactions with enzymes in foods and model systems. *Trends Food Sci. Technol.* 55, 39–47. https:// doi.org/10.1016/j.tifs.2016.07.001.
- Misra, N.N., Yadav, B., Roopesh, M.S., Jo, C., 2019. Cold plasma for effective fungal and mycotoxin control in foods: mechanisms, inactivation effects, and applications. *Compr. Rev. Food Sci. Food Saf.* 18, 106–120. https://doi.org/10.1111/1541- 4337.12398.
- Misra, N.N., Yepez, X., Xu, L., Keener, K., 2019b. In-package cold plasma technologies. *J. Food Eng.* 244, 21–31. https://doi.org/10.1016/j.jfoodeng.2018.09.019
- Misra, S., Rayaguru, K., Dash, S.K., Mohanty, S. and Panigrahi, C. 2022. Efficacy of microwave irradiation in enhancing the shelf life of groundnut (*Arachis hypogaea* L.). *Journal of Stored Products Research* Volume 97, 101957.
- Montgomery, D.C. 2001. Design and Analysis of Experiments. New York Wiley, pp.416-419.
- Moutiq, R., Misra, N.N., Mendonça, A., Keener, K., 2020. In-package decontamination of chicken breast using cold plasma technology: microbial, quality and storage studies. *Meat Sci.* 159, 107942. https://doi.org/10.1016/j.meatsci.2019.107942.
- Mravlje, J., Regvar, M. and Vogel-Mikus, K. 2021. Development of cold plasma technologies for surface decontamination of seed fungal pathogens: Present status and perspectives. *J. Fungi.* 7(8), 650; https://doi.org/10.3390/jof7080650.
- Rizvi, N. B., Aleem, S., Khan, M. R., Ashraf, S.,and Busquets, R. 2022. Quantitative Estimation of Protein in Sprouts of *Vigna radiate* (Mung Beans), *Lens culinaris* (Lentils), and *Cicer arietinum* (Chickpeas) by Kjeldahl and Lowry Methods. *Molecules*. 27(3), 814. https://doi.org/10.3390/molecules27030814.
- Sarangapani, C., Misra, N.N., Milosavljevic, V., Bourke, P., O'Regan, F., Cullen, P.J., 2016. Pesticide degradation in water using atmospheric air cold plasma. *J. Water Process Eng*. 9, 225–232. https://doi.org/10.1016/j.jwpe.2016.01.003.
- Sifuentes-Nieves, I., Mendez-Montealvo, G., Flores-Silva, P.C., Nieto-P´erez, M., Neira- Velazquez, G., Rodriguez-Fernandez, O., Hernand´ez-Hernad´ez,

E., Velazquez, G., 2021. Dielectric barrier discharge and radio-frequency plasma effect on structural properties of starches with different amylose content. *Innovat. Food Sci. Emerg. Technol*. 68, 102630. https://doi.org/10.1016/j.ifset.2021.102630.

- IPAD, USDA's FAS, IPAD-USDA's FAS data results, 2023 https://ipad.fas.usda.gov/cropexplorer/cropview/commodityView.aspx?cropid=2221000
- Vanga, S., Singh, A., and Raghavan, V. 2017. Review of conventional and novel food processing methods on food allergens. *Critical Reviews in Food Science and Nutrition*. 57 (10): 2077-2094. https://doi.org/10.1080/10408398.2015.1045965.
- Venkataratnam, H., Sarangapani, C., Cahill, O., Ryan, C.B., 2019. Effect of cold plasma treatment on the antigenicity of peanut allergen Ara h 1. *Innovat. Food Sci. Emerg. Technol.* 52, 368–375. https://doi.org/10.1016/j.ifset.2019.02.00
- Yang, Q., Zhang, W., Luo, Y., Li, J., Gao, P. and Gao, Y. X. 2019. Comparison of structural and physicochemical properties of starches from five coarse grains. *Food chemistry*. 288:283-290.