The effects of dielectric barrier discharge atmospheric air plasma treatment to germination and enhancement growth of sunflower seeds

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Abstract. This research was to study the effectiveness of dielectric barrier atmospheric plasma (DBD) on sunflower seed (Helianthus annuus). The DBD plasma was driven with a power of 90 watts. The samples consisted of five groups; control group, samples 1, 2, 3 and 4 being treated by DBD plasma with time limits of 30 s, 60 s, 90 s and 120 s, respectively. The physical properties and chemical properties were observed using SEM and water contact angle. Growth parameters were studied by the water uptake, seed germination, sprouts length and dry weight. Compared with the control sample the results showed the contact angle decreased and the wettability increased. The surface roughness in all conditions increased with increased power. With bigger power the water absorption decreased and super hydrophilic was achieved with 120 s treatment. The water uptake of plasma produced the best result using the DBD plasma treatment of 120s. The distribution of sprouts length and the dry weight both increased with increased power. The DBD plasma treatment on sunflower seeds improves seed germination rate and lead to a significant change in wettability and growth parameter.

1. Introduction

In the present lifestyle the concept of “clean food and green food” is very popular. Green sprouts have seen an increase in consumers’ demand such as alfalfa (Medicago sativa), broccoli (Brassica oleracea), lentil (Lens culinaris), mung bean (Phaseolus aureus), radish (Raphanus sativus), soybean (Glycine max), sunflower (Helianthus annuus), and other seed sprouts. They are usually eaten fresh or cooked for beverages, soups, appetizers, or main courses. Not only create them delicious menus but the sprouts are also considered to provide health benefits. H. annuus is a folk remedy for chronic diseases such as bronchiectasis, cough, diarrhea, hypertension and infections [1]. Its phytochemical substances are alkaloids, carotenoids, flavonoid, minerals, oils, phenols, tannins, terpene compounds, and vitamins, which all contribute to its remedial properties. Sunflower seed and sprout contain high concentrations of niacin and vitamins A, B, and C. They are also rich in minerals, specifically calcium, iron, magnesium, phosphorus, potassium, selenium, and zinc as well as cholesterol-lowering phytosterols [2]. Notably, sprouts offer magnesium and zinc concentrations in much higher quantities than the seeds. Sprouts are shoots of germinated seeds, which are excellent sources of proteins, vitamins, and minerals.
They have been used as clean foods in salads, soups, stews, and casseroles in the past few decades, especially in Far Eastern countries and the Western world. As the sprouts are consumed at the beginning of the growing phase, their nutrient concentration remains very high. In naturopathy, sprouts have the medicinal benefits as they can promote health benefits and safe evaluation. The U.S. Food and Drug Administration has published several recommendations to consumers regarding consumption of sprouts [3]. The sunflower (Helianthus annuus) is the core of medicinal values which is used as food and medicine worldwide. From all these reasons in order to get the maximum benefits this research is interested in the use of plasma technique for enhancing the quantity and quality of sunflower sprout. Cold plasma processing are powerful techniques for sterilization, functionalization, inactivation of enzymes, altering the hydrophilic/hydrophobic properties and etching. The plasma technologies have been intensively developed for more than three decades. They are successful progress as key manufacturing technologies for a variety of industrial applications such as surface modification and biomaterial processes. Dielectric barrier discharge (DBD) plasma is one types of cold plasma that could be easily operated at atmospheric pressure, which is the strong point and also the DBD plasma could generate ultraviolet radiation, a strong electric field, electrons, and various active species, as well as no rare gas source or vacuum equipment was needed [4]. During the process the gas temperature is maintained as low as the level acceptable for processing of organic materials and biomedical applications. The attractive features of the dielectric barrier discharge (DBD) plasma have led to open intensive research activities that require atmospheric pressure processes in materials in biological and biomedical applications.

2. Materials and method

The sunflower seed samples consisted of five groups; control group, samples 1, 2, 3 and 4 and each sample group has 25 seeds. The samples were arranged on a glass plate. The DBD atmospheric plasma was turned on with energy at 90 watts and treated with time limits of 30 s, 60 s, 90 s and 120 s, respectively. The physical properties and chemical properties were observed using SEM and water contact angle. Growth parameters were studied by the water uptake, seed germination, sprouts length and dry weight.

2.1. Vegetal material

The common sunflower (Helianthus annuus) is a species of the Asteraceae family grown commercially worldwide offering a variety of nutritional and medicinal benefits. The sunflower seed and sprout contain valuable antioxidant, antimicrobial, anti-inflammatory, antihypertensive, wound-healing, and cardiovascular benefits found in its phenolic compounds, flavonoids, polyunsaturated fatty acids, and vitamins. These notable medicinal, nutritional, and culinary benefits have resulted in historical and growing popularity of the sunflower and its constituent parts worldwide.

2.2. DBD plasma source

The discharge voltage, electrode space, and treatment time are extremely important process parameters for atmospheric pressure DBD plasma treatment. A photograph of the DBD plasma is in figure 1. The spacing between DBD and sample is about 1-2 mm and the plasma discharge voltage is 90 watts. The operating condition of 30 s, 60 s, 90 s and 120 s were utilized to achieve different treatment effects. This non-equilibrium state of the DBD discharge leads to the production of reactive species, ion as well as additional electrons through electron-impact dissociation, excitation and ionization of background gas molecules. The reactive oxygen (ROS) and nitrogen (RNS) species are easily produced from the ambient air.

2.3. Germination

The germination percentage reported indicates the proportion by number of seed which have produced normal seeding in temperature room, light/dark (12 hrs./12 hrs.) within 5 days and record the number of germinated seeds every day on the respectively time frame. Calculation follows on this equation.
Total weight and length of seeding were measured on day 5. Plant material for dry weight was dried at 80 °C for 24 hrs. and measured for dry weight. Vigor indexes I and II were calculated according to equation.

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GR(\%) = \left( \frac{\text{Number of germinated seeds in 5 days}}{\text{total number of seeds}} \right) \times 100
\] (1)

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VI = \frac{\text{Seedling length (cm)}}{100} \times GR(\%)
\] (2)

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VII = \frac{\text{Dry weight of seedling (g)}}{100} \times GR(\%)
\] (3)

2.4. Seed imbibition
Dry seeds were weighed \(m_0\) and submerged under water on the plastic plate for 24 hrs. Every 2 hr seed was taken out of the water and dried with tissue paper and weighed \(m_t\). Percentage of water uptake was calculated for each time \(t\) as this equation.

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\text{Water uptake (\%) = } \left( \frac{m_t - m_0}{m_0} \right) \times 100
\] (4)

2.5. Contact angle measurement
The static contact angles measurements employ the fundamentals of liquid spreading to determine the surface energy of a solid. The water contact angle was analyzed by a self-made static contact angles, detail of this was described elsewhere [5]. Deionized water, DI droplets (3 µL) were dropped on top of the seeds at room temperature. Fifth replicates of each condition of treatments were analyzed.

3. Results and discussion

3.1. Seed quality
Using the plasma technique in this work, the exposure time is the main factor for enhancing seed germination and plant growth or for controlling food surface microorganisms. The several beneficial radical doses showed a combination of air gas and time of exposure without provoking damage to the
seed. The result found that all the plasma treatments had significant stimulatory effect on seed germination and vigor. The germination rate (GR%) increased when the exposure time increased; as shown in figures 2 and 3.

3.2. Water uptake
Sunflower seed which treat/untreated DBD plasma in 30 s, 60 s, 90 s and 120 s. The DBD plasma treated sunflower seed effects in the different time exposures. 120 s showed the highest levels of water uptake in time 10 hrs. and suggested the plasma treatment provoked changes on seed permeability to water. The result shown in figure 4.

3.3. Germination and vigor
All the plasma treatments had a significant stimulatory effect on the germination and vigor. This indicates that, with a greater exposure time of the DBD plasma, the seeds germinate better and faster, which produce longer and heavier seedling. The result is shown in figure 5. The growth in length of shoot seedling, treated by plasma, is higher than that of the control. Figure 6 shows the seeding weight and dry weight of sunflower seeds, presenting the same trend as that of the shoot seedling length.
3.4. Contact angle
The contact angle is the quality to its hydrophilic ability, which is relative to the germination seeds. The contact angle was measured when DI water was dropped to the 5 samples seed groups. The apparent contact angle is obviously smaller from 102.3 to 58.5 degree. The water absorption decreased when the time increased and super hydrophilicity was achieved at a 120 s. The Flat water on the surface means...
that the polar and nonpolar surface energy increased being relative to the higher hydrophilicity properties as shown in figure 7.

4. Conclusion
Our study is the first to study the effectiveness of dielectric barrier atmospheric plasma (DBD) on germination and vigor sunflower seed (Helianthus annuus). This work is conducted for samples that are treat/untreated with DBD plasma in 30 s, 60 s, 90 s and 120 s. We used DBD plasma generators voltage at 90 watts. We concluded that plasma treatment: the sunflower seed at different exposure times improved seed health by the plasma produced ROS and RNS and provoked the oxidation lipids present in seed coats. Henceforth leading to promoted seed water uptake, which resulted in decreasing seed coats being hydrophilicity. The exposure time of plasma at 120 s had the best result in the enhancement of sunflower seed germination and vigor.

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References
[1] Yang Y et al 2013 Compr. Rev. Food Sci. F. 12 265–80
[2] Márton M, Mándoki Zs, Csapó-Kiss Zs and Csapó J 2010 Acta Univ. Sapientiae 3 81–117
[3] U.S. Food & Drug 2018 Raw Produce Selecting and Serving it Safely (Maryland: U.S. Food and Drug Administration) Online: https://www.fda.gov/food/educationresourcelibrary
[4] Sarapirom S, Yu L D, Boonyawan D and Chaiwong C 2014 Appl. Surf. Sci. 310 42–55
[5] Guo Q et al 2017 Sci. Rep. 7 16680