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# EFFICACY OF PULSED ELECTRIC FIELD PRETREATMENT ON DRYING PROCESS OF GRAPE

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## ABSTRACT

The present study investigated the efficacy of pulsed electric field (PEF) pretreatment on the drying characteristics of black and white grapes during hot air tray drying at 50°C and 70°C. Fresh grape samples were subjected to different PEF intensities (0.3, 1.0, and 2.0 kV/cm) prior to drying to evaluate their effects on drying kinetics, moisture removal, drying time, and product quality. The results revealed that, compared with no treatment, PEF pretreatment enhanced moisture diffusion and accelerated drying. At 50°C, black grapes treated at 2.0 kV/cm presented a reduction in sample weight from 0.103 kg to 0.026 kg after 1600 min, whereas the weight of the control sample reached 0.032 kg. Similarly, white grapes treated with 2.0 kV/cm attained a final weight of 0.022 kg compared with 0.028 kg in the control. At 70°C, the drying time was considerably reduced, and substantial moisture removal was observed in all the PEF-treated samples. Improved color retention, texture, and preservation of quality attributes were also observed in treated grapes due to reduced thermal exposure.

**KEYWORDS:** Pulsed electric field, Grape, Drying, Hot air tray dryer, Electroporation, Moisture, Efficiency.

## 1. INTRODUCTION

Grapes can be eaten fresh as table grapes or can be used for making wine, jam, grape juice, jelly, grape seed extract, raisins, vinegar, and grape seed oil. Venkitasamy et al., 2019. The quality of a dried graph of an important product of a grapevine depends on the size of the berry, the uniformity and brilliance of the berry color, the condition of the berry surface, the texture of the skin and chemical composition of the pulp and the presence of foreign matter. Thakur et al., 2010; Shanmugavelu, K. G. (1989).

Bulk graphs are dried in outdoor yards by spreading clusters on tamped earth floors that are well exposed to sunshine for 7–8 days, after which the clusters are turned by hand to complete drying. Many modifications to the drying and processing of graphs are being carried out to improve their quality. Christensen, L. P. (2000). The yield and quality of the final dried product depend on the Brix of the fresh grape berries taken for drying. Bhutani et al. (1985) reported that drying berries proceeded at a faster rate in a cross-flow dehydrator than under sun drying. The alkali treatment of the berries reduced the drying time. Dried garphs of fairly good quality were produced in a cross-flow dehydrator when the berries were treated with alkali followed by oiling and sulfuring. Esmaiili, et al., 2007, Barbulescu et al. reported that the performance of ‘Perlette’ is high, but it results in low sugar accumulation compared *with that of the black kismis and white kismis* varieties. Sandhu et al. (2001) reported raisins obtained from the ‘Perlette’ variety of grape via soda dip treatment. Ogranoleptic evaluation revealed that when rais was subjected to forced air drying, color was retained during the process of drying because of SO absorption during drying. Berries dried at room temperature had a brown color and poor acceptability. Marisa et al. (2000) described an alternative physical method for increasing the drying rate of seedless grapes. It consists of superficial abrasion of grape peels via the use of an inert abrasive material. The effectiveness of this novel process was compared to that of the traditional ethyl oleate dipping process by analyzing not only their respective drying times but also the peel surfaces by scanning electron microscopy.

Sardar et al. (2019) reported that pretreatments, such as alkali dipping and oil emulsions, significantly improved the drying rate and quality characteristics of raisins prepared from grapes (*Vitis vinifera* L.). Parmar and Sardar (2024) reported that blanching treatment and drying temperature significantly influence the drying kinetics and moisture removal rate of basil (*Ocimum sanctum*) leaves during hot air tray drying. Parmar and Sardar (2024) reported that freshly harvested papaya leaves possess appreciable biochemical constituents, indicating their potential for nutritional and medicinal applications. Parmar and Sardar (2024) reported that natural drying techniques significantly affect the drying behavior and quality attributes of papaya leaves during dehydration. Sardar (2022) developed processing technology for the production of jamun flakes and pulp powder with an emphasis on drying characteristics and retention of quality attributes. Sardar and Akbari (2024) reported that pulp thickness significantly influences the drying behavior and drying time of jamun pulp under natural drying methods. Sardar and Thorat (2012) described various raisin production technologies and highlighted

the importance of pretreatment and drying methods on raisin quality. Tiwari and Sardar (2020) reported that concentration, drying, and dehydration are important food preservation techniques used to reduce moisture content and increase the shelf-life and stability of food products.
The drying of grapes is a more complex process than the dehydration of other agricultural materials because of the necessity of both a pretreatment operation prior to drying and further processing operations after drying (Esmaiili et al., 2007). To date, most researchers have concentrated on pretreatment and drying, where the primary effects of pretreatment on drying have been evaluated. It seems appropriate that a review should now be presented to critically examine all the corresponding published data in the literature and to compare the conditions used in these studies to highlight the grape.
Pulsed electric field (PEF) is an emerging nonthermal food processing technology in which short high-voltage electric pulses are applied to biological materials to increase cell membrane permeability through electroporation. Barba et al., 2015 & Toepfl et al., 2006 In drying applications, PEF pretreatment enhances mass and heat transfer by creating microscopic pores in cellular tissues, thereby facilitating faster moisture migration from the interior to the surface of the product. This results in a reduced drying time, lower energy consumption, and improved drying efficiency. Several studies have reported that PEF pretreatment can improve quality attributes such as color, texture, rehydration capacity, and retention of heat-sensitive bioactive compounds because of reduced thermal exposure during drying. Therefore, PEF has gained considerable attention as an effective pretreatment technique for improving the drying characteristics and overall quality of dried fruits and vegetables (Parniakov et al., 2016; Barba et al., 2015).
There are several food applications of the pulse electric field as a pretreatment in the area of research and development. Alam et al. reported that the drying time of PEF-pretreated parsnip was reduced by up to 28% at 70°C and 21% at 60°C in carrots compared with that of untreated samples. The impact of combined pulsed electric field (PEF) pretreatment on drying kinetics and the quality of dried carrot via the convective method at 70°C was investigated by Wiktor et al. The drying time of the samples subjected to combined treatment ranged from 180--255 min, whereas in the case of untreated carrots, the drying time was 298 min. Ostermeier et al. also evaluated the effects of pulsed electric field (PEF) parameters on the convective drying process of onions and reported drying time reductions of 30.3%, 21.4% and 6.4% at 45°C, 60°C and 75°C, respectively, to reach a residual moisture of 7%.
This study was conducted to investigate the effect of pulsed electric field (PEF) pretreatment on the drying behavior of black and white grapes.

## 2. MATERIALS AND METHODS

### 2.1 Black and white grape samples

In these experiments, black and white grapes **were** procured from a local APMC market, Anand Gujarat. The grapes were washed separately, and the average initial moisture contents of the black and white grape samples were 79.50% and 78.2%, respectively. For each series of experiments, one untreated and three corresponding PEF-treated grape samples were dried.

**Figure 1: White and black grape samples for pulse electric treatment**

### 2.3 Drying process

The drying process of the treated samples, along with the control samples, was carried out in a dry tray at the Department of Food Engineering, College of Food Processing Technology and Bioenergy, Anand Agricultural University, Anand. Drying was carried out at 50°C and 70°C for each treated sample along with the control samples. The dependent drying time and moisture content of each sample were evaluated via standard methods.

***Working principle of the hot air tray dryer***

In a tray dryer, hot air is continuously circulated. Forced convection heating takes place to remove moisture from the solids placed in trays. Simultaneously, the moist air is partially removed. The wet solid is loaded into the trays. The trays

were placed in the chamber. Fresh air, which passes through the heaters and becomes heated, is introduced through the left. The hot air is circulated by means of fans at 2 to 5 meters per second. Turbulent flow lowers the partial vapor pressure in the atmosphere and reduces the thickness of the air boundary layer. The water is picked up by the air. As the water evaporates from the surface, the water diffuses from the interior of the solids via capillary action. These events occur in a single pass of air. The time of contact is short, and the amount of water picked up in a single pass is small. Therefore, the discharged air to the tune of 80 to 90% is circulated back through the fans. Only 10 to 20% fresh air is introduced.
Moist air is discharged through the outlet. Thus, a constant temperature and uniform air flow over the materials can be maintained to achieve uniform drying. In the case of wet granules such as those in tablets and capsules, drying is continued until the desired moisture content is obtained. At the end of the drying, trays or trucks are pulled out of the chamber and taken to a tray dumping station.

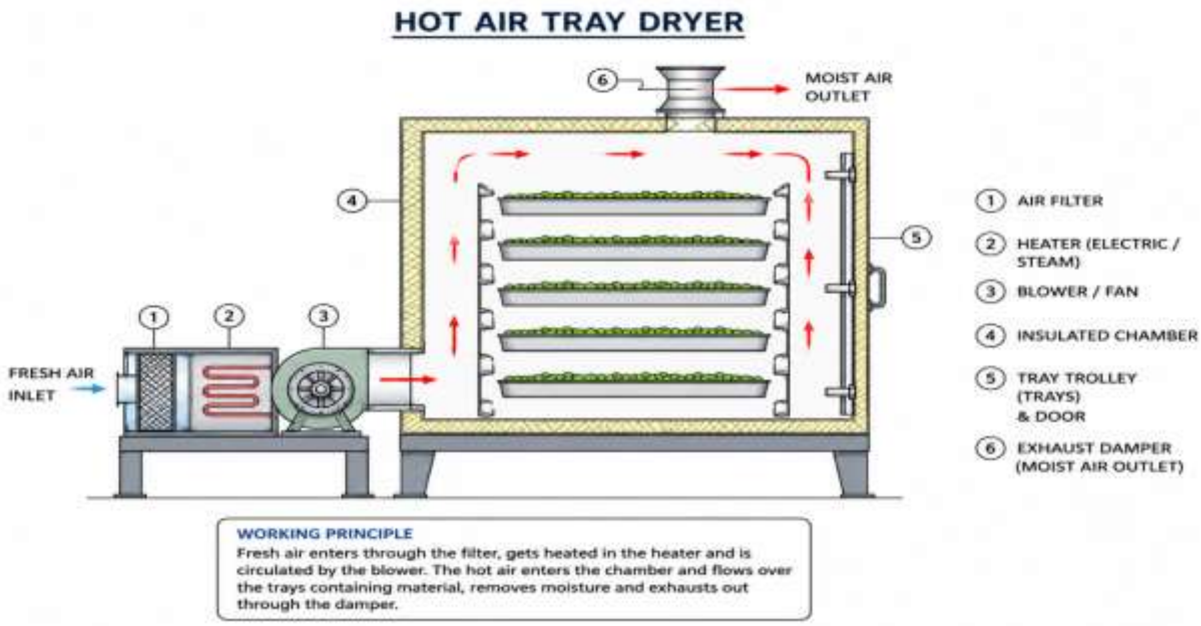


**Figure 3: Hot air tray dryer**

***Pulsed electric field (PEF) treatment***
The PEF-EPELUS®-LBM3A-20 batch system from Energy Pulse Systems, Lda, was used, which includes a BM3A-20 generator connected to a safety box, with the possibility of including batch and continuous treatment chambers, for the PEF treatment experiments. It was equipped with a generator that created a high-voltage exponential decay bipolar matrix. These multiple pulses were applied to the product in a batch treatment chamber consisting of two parallel stainless steel electrodes.


**Figure 2: (a) Parameters for the pulse electric field set on the touch screen display panel and (b) grape sample treated between the two electrodes**

For each experiment, black and white grape samples (100 g) were treated, and the treatment cell was filled with tap water. The total mass inside the cell was set to 200 g. As a consequence of sample quantity variation due to natural fluctuations and the use of whole onions, the mass inside the cell was maintained constant by adjusting the amount of water added. In this study, electrical field strengths between 0.3 kV/cm, 1 kV/cm and 2 kV/cm were applied to each sample, which was treated separately (Fig. 2). The number of applied pulses was set to 10 for every field strength, as shown in Table 1. The treated samples were spread on bloating paper and allowed to rest for 15 min to remove surface moisture.

**Table 1: Parameters used for the treatment of grape samples in a pulsed electric field**

| Parameters | Black grapes | White grapes |
|---|---|---|

| | | |
|---|---|---|
| Voltage (kV/cm) | 0.3, 1 and 2 | 0.3, 1 and 2 |
| Pulse width positive (µs) | 10 | 10 |
| Pulse width negative (µs) | 10 | 10 |
| Frequency (Hz) | 50 | 50 |
| Number of pulses | 10 | 10 |

## 3. RESULTS AND DISCUSSION

The main objectives of the present study were to determine the effect of pretreatment with PEF on the drying rates of black and white grape samples. Different electric field strengths and specific energy input levels have been tested to ascertain their influence on the cell membrane. Afterwards, initial drying trials revealed the specific energy input that results in the most facilitated drying process at a fixed drying temperature. Final drying trials with the investigated PEF parameters were conducted to observe the possible impact of drying at various temperatures as a basis for adjusting the drying process to derive process benefits from the PEF pretreatment and, according to different experiments, the following results and conclusions were reported.

**Effect of Pulsed Electric Field (PEF) Pretreatment on the Weight Reduction of Black Grapes during Drying at 50°C**

The PEF-treated black grape samples (energy densities of 0.3, 1.0 and 2.0 kV/cm), i.e., black and white grapes, were dried in a tray dryer at a constant temperature (50°C). The drying time (min.) was computed for black and white grapes, as shown in Table 4 and Table 5, respectively, compared with that of the untreated (control) sample.

The effects of pulsed electric field (PEF) pretreatment on the drying behavior of black grapes dried in a hot air tray dryer at 50°C are presented in Table 4. The weight of the grape samples gradually decreased with increasing drying time for all the treatments, indicating continuous moisture removal during the drying process. Similar observations during the drying of PEF-treated fruits have been reported by Parniakov, Oleg et al. (2016) and Barba, Francisco J. et al. (2015).

The initial sample weight of the black grapes ranged from 0.100 to 0.103 kg. During drying, a progressive reduction in sample weight was observed due to evaporation of moisture from the grape tissues. The weight of the control sample decreased from 0.100 kg to 0.032 kg after 1600 min of drying. Similarly, grapes treated with 0.3 kV and 1.0 kV PEFs presented final weights of 0.034 kg and 0.036 kg, respectively. However, the 2.0 kV PEF-treated sample presented the maximum reduction in weight, reaching 0.026 kg at the end of drying. Similar findings regarding improved drying efficiency after PEF pretreatment were also reported by Wiktor, Anna et al. (2013).

The enhanced moisture removal in the PEF-treated samples may be attributed to electroporation caused by the electric field treatment, which increases the cell membrane permeability and facilitates the migration of intracellular moisture toward the surface during drying. Among the treatments, the 2.0 kV PEF treatment resulted in faster moisture removal, particularly after 800 min of drying, indicating improved mass transfer characteristics. Similar observations regarding increased moisture diffusivity in electrically treated plant tissues were reported by Lebovka, Nikolai et al. (2007).

At a lower drying temperature (50°C), drying occurred at a slower rate because of the lower thermal energy available for moisture evaporation. Nevertheless, PEF pretreatment improved the drying efficiency by reducing the internal resistance to moisture diffusion. The results suggest that higher PEF intensities positively influence the drying characteristics of black grapes and contribute to greater weight reduction during the drying process. This study revealed that the application of PEF pretreatment prior to hot air drying can enhance drying performance and accelerate moisture removal in black grapes, especially at relatively high electric field strengths.

**Table 4: Weights of black grapes during the drying process in a tray dryer at 50°C**

| Drying Time (min.) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Treatment** | **Sampleweight (kg)** | **200** | **400** | **600** | **800** | **1000** | **1200** | **1400** | **1600** |
| Control | 0.100 | 0.100 | 0.097 | 0.093 | 0.080 | 0.078 | 0.071 | 0.035 | 0.032 |
| 0.3 kV | 0.101 | 0.101 | 0.096 | 0.092 | 0.080 | 0.079 | 0.071 | 0.036 | 0.034 |
| 1.0kV | 0.103 | 0.103 | 0.101 | 0.095 | 0.084 | 0.082 | 0.074 | 0.040 | 0.036 |
| 2.0kV | 0.103 | 0.103 | 0.097 | 0.090 | 0.073 | 0.070 | 0.060 | 0.036 | 0.026 |

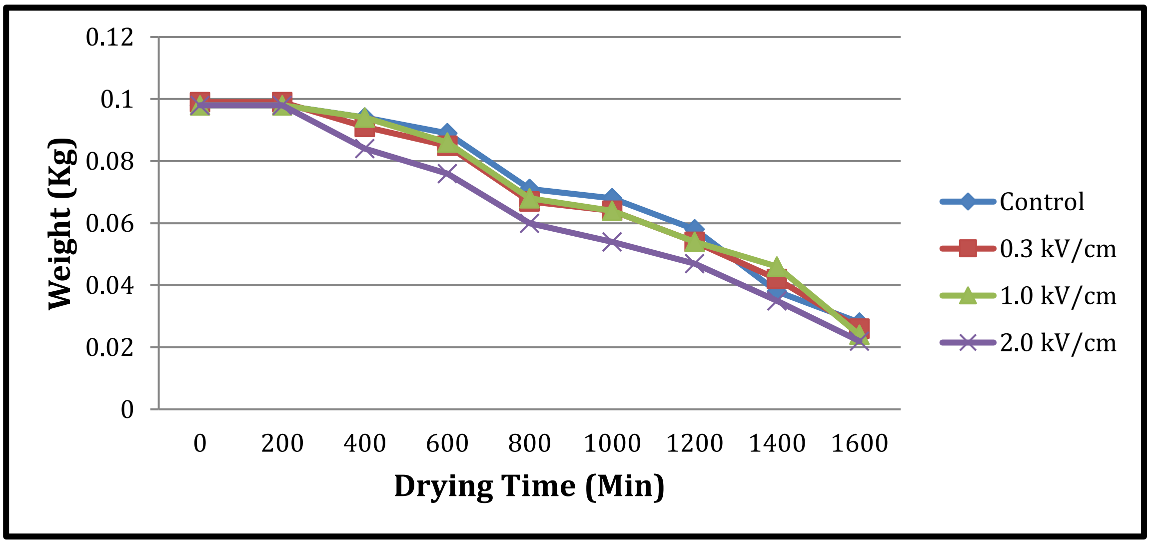


**Figure 3: Effects of drying black grapes in a tray dryer**

**Effect of Pulsed Electric Field (PEF) Pretreatment on the Weight Reduction of White Grapes during Drying at 50°C**

The effects of pulsed electric field (PEF) pretreatment on the drying characteristics of white grapes dried in a hot air tray dryer at 50°C are presented in Table 5. A gradual decrease in sample weight was observed with increasing drying time for all the treatments, indicating continuous moisture removal throughout the drying process. Similar drying trends in PEF-treated fruits and vegetables have been reported by Parniakov, Oleg et al. (2016) and Barba, Francisco J. et al. (2015). The initial weights of the white grape samples ranged from 0.098 to 0.099 kg. The control sample showed a reduction in weight from 0.098 kg to 0.028 kg after 1600 min of drying. Similarly, samples treated with 0.3 kV, 1.0 kV, and 2.0 kV PEFs had final weights of 0.026 kg, 0.024 kg, and 0.022 kg, respectively. A similar increase in the drying rate due to PEF-induced electroporation was also reported by Wiktor, Anna et al. (2013).

The enhanced moisture removal in the PEF-treated samples may be attributed to electroporation caused by the electric field treatment, which increases the cell membrane permeability and facilitates the migration of intracellular moisture toward the surface during drying. Among the treatments, the 2.0 kV PEF treatment resulted in faster moisture removal, particularly after 800 min of drying, indicating improved mass transfer characteristics. Similar observations regarding increased moisture diffusivity in electrically treated plant tissues were reported by Lebovka, Nikolai et al. (2007).

Among all the treatments, the 2.0 kV PEF-treated sample presented the maximum reduction in weight, indicating enhanced moisture removal and improved drying efficiency. The higher rate of moisture loss in the PEF-treated samples may be attributed to electroporation, which increases the permeability of the cell membranes and facilitates the migration of intracellular moisture to the surface during drying.

At 50°C, drying occurred gradually because of the lower thermal energy available for moisture evaporation. However, PEF pretreatment improved the drying performance by reducing the internal resistance to moisture diffusion. A noticeable reduction in sample weight was observed after 600 min of drying, particularly in samples treated with higher electric field strengths. The results showed that PEF pretreatment positively influenced the drying behavior of white grapes and enhanced moisture removal during hot air drying. The application of higher PEF intensities resulted in faster drying and lower final sample weights, suggesting improved mass transfer characteristics and drying efficiency.

**Table 5: Weights of white grapes during the drying process in a tray dryer at 50°C**

| **Drying time(min.)** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Treatment** | **Sample Weight (kg)** | **200** | **400** | **600** | **800** | **1000** | **1200** | **1400** | **1600** |
| Control | 0.098 | 0.098 | 0.094 | 0.089 | 0.071 | 0.068 | 0.058 | 0.038 | 0.028 |
| 0.3kV | 0.099 | 0.099 | 0.091 | 0.085 | 0.067 | 0.064 | 0.054 | 0.042 | 0.026 |
| 1.0 kV | 0.098 | 0.098 | 0.094 | 0.086 | 0.068 | 0.064 | 0.054 | 0.046 | 0.024 |
| 2.0 kV | 0.098 | 0.098 | 0.084 | 0.076 | 0.060 | 0.054 | 0.047 | 0.035 | 0.022 |

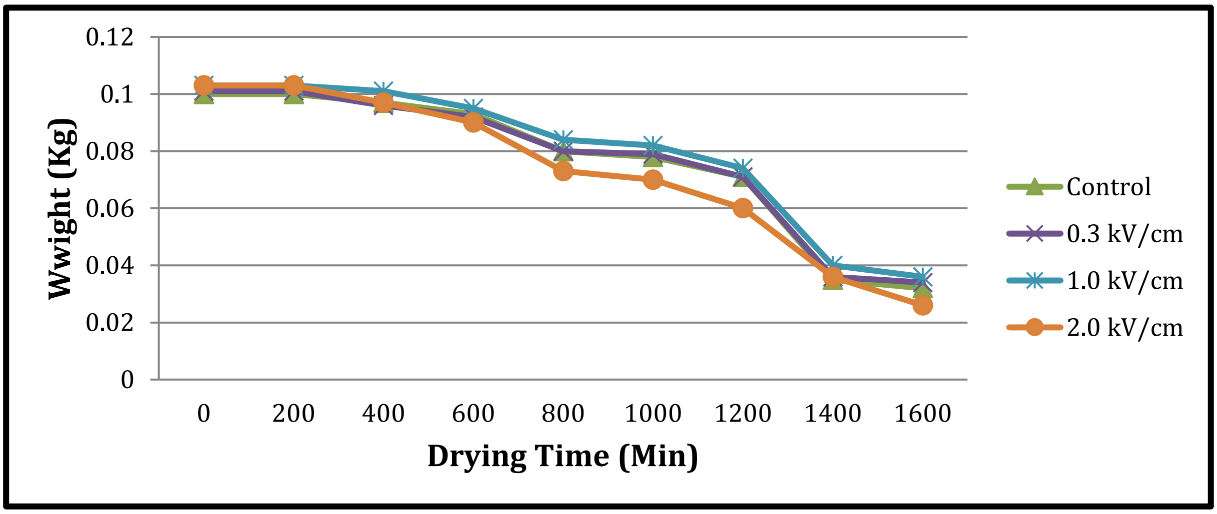


**Figure 4: Effects of drying white grapes in a tray dryer at 50°C**

With increasing drying time, the moisture content greatly decreased after 200 min of drying, and the moisture from the black and white grapes continuously rose until a constant moisture content was reached. A constant moisture content was observed for the control and treated samples at 0.3, 1.0 and 2.0 kV/cm, and the weight of the samples decreased as the drying time increased from 200 min to 1600 min (Figure 3 and Figure 4) at 50°C. Compared with that of the control samples, the moisture content of the PEF-treated samples decreased at a faster rate. Similar findings were demonstrated for dried carrot via the convective method at 70°C (Wiktor et al.). The drying time of the samples subjected to the combined treatment ranged from 180--255 min, whereas for the untreated carrots, the drying time was 298 min.

**Effect of Pulsed Electric Field (PEF) Pretreatment on the Weight Reduction of Black Grapes during Drying at 70°C**

The PEF-treated black grape samples (energy densities of 0.3, 1.0 and 2.0 kV/cm), i.e., black and white grapes, were dried in a tray dryer at a constant temperature (70°C). The drying time (min) was computed for black and white grapes, as shown in Table 7 and Table 8, respectively, compared with that of the untreated (control) sample.

The effects of pulsed electric field (PEF) pretreatment on the drying characteristics of black grapes at 70°C in a hot air tray dryer are presented in Table 6. A continuous decrease in sample weight was observed with increasing drying time for all the treatments, indicating progressive moisture loss during drying. Similar drying trends in PEF-treated fruits have been reported by Parniakov, Oleg et al. (2016) and Barba, Francisco J. et al. (2015).

The initial weight of the black grape samples ranged from 0.098 to 0.099 kg. The control sample showed a reduction in weight from 0.098 kg to 0.022 kg after 1000 min of drying. Similarly, the samples treated at 0.3 kV/cm and 2.0 kV/cm reached a final weight of 0.024 kg, whereas the 1.0 kV/cm-treated sample reached a final weight of 0.023 kg. The rapid decrease in sample weight at higher temperatures indicated accelerated moisture evaporation and improved drying kinetics. A similar increase in drying efficiency after PEF pretreatment was reported by Wiktor, Anna et al. (2013).

Compared with drying at 50°C, drying at 70°C significantly accelerated moisture evaporation, thereby reducing the total drying duration. PEF pretreatment facilitated moisture migration by increasing cell membrane permeability through electroporation, which enhanced internal moisture diffusion during drying. The treated samples exhibited comparatively rapid moisture removal during intermediate stages of drying, indicating improved mass transfer characteristics. Similar observations regarding increased moisture diffusivity and reduced drying resistance in electrically treated plant tissues were reported by Lebovka, Nikolai et al. (2007).

Although the differences among the treatments at 70°C were relatively small, the PEF-treated samples generally presented more efficient drying behavior and lower residual moisture contents than did the untreated samples. The combined effect of elevated temperature and PEF pretreatment contributed to increased drying efficiency and faster weight reduction in black grapes.

**Table 6: Weights of black grapes during the drying process in a 70°C drying oven**

| Drying Time (Min) | | | | | | |
|---|---|---|---|---|---|---|
| **Treatment** | **Sample weight (kg)** | **200** | **400** | **800** | **800** | **1000** |
| Control | 0.098 | 0.098 | 0.078 | 0.063 | 0.024 | 0.022 |
| 0.3 kV/cm | 0.098 | 0.098 | 0.079 | 0.066 | 0.025 | 0.024 |
| 1.0 kV/cm | 0.099 | 0.099 | 0.078 | 0.064 | 0.023 | 0.023 |
| 2.0 kV/cm | 0.099 | 0.099 | 0.079 | 0.064 | 0.025 | 0.024 |

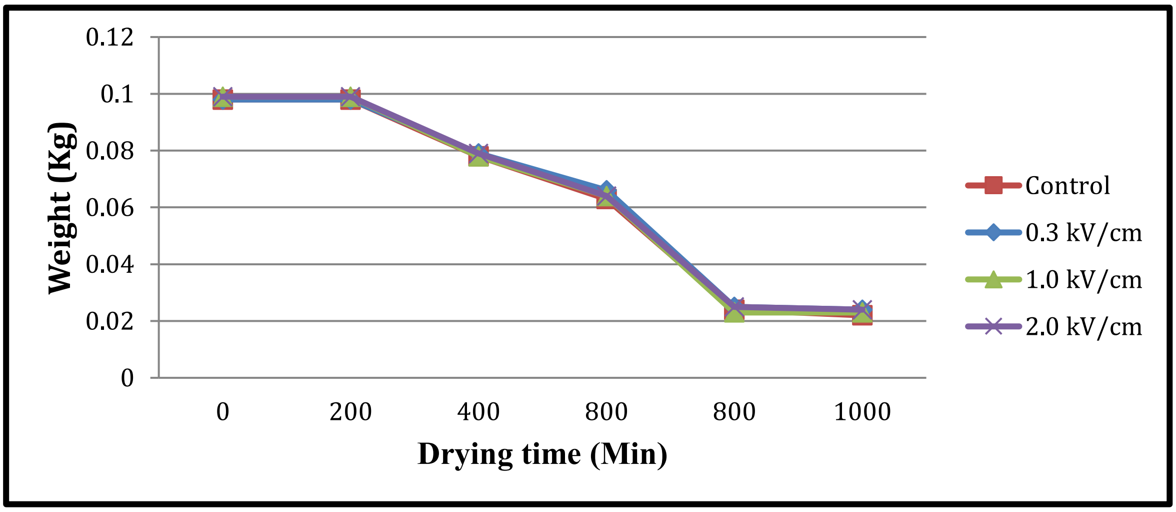


**Figure 5: Effects of drying on black grapes in a tray dryer at 70°C**

**Effect of Pulsed Electric Field (PEF) Pretreatment on the Weight Reduction of White Grapes during Drying at 70°C**

The influence of pulsed electric field (PEF) pretreatment on the drying behavior of white grapes dried at 70°C is presented in Table 7. The weights of all the samples continuously decreased with increasing drying time due to the removal of moisture from the grape tissues. Similar drying behavior in PEF-treated agricultural products has been reported by Parniakov, Oleg et al. (2016) and Barba, Francisco J. et al. (2015).

The initial sample weight ranged from 0.099 to 0.100 kg. The control sample weight decreased from 0.099 kg to 0.016 kg after 1000 min of drying. The samples treated with 0.3 kV/cm, 1.0 kV/cm, and 2.0 kV/cm attained final weights of 0.017 kg, 0.018 kg, and 0.019 kg, respectively. The rapid decrease in weight observed during drying indicated effective moisture evaporation at higher drying temperatures. Similar results for enhanced drying kinetics after PEF pretreatment were also reported by Wiktor, Anna et al. (2013).

Compared with drying at a lower drying temperature, drying at 70°C resulted in rapid moisture evaporation and a shorter drying time. PEF pretreatment enhanced the drying process by increasing the moisture diffusivity within grape tissues. The electroporation effect produced by electric field treatment disrupted the cellular structure, thereby facilitating the movement of water from the interior to the surface of the grapes. Similar observations regarding increased mass transfer and reduced drying resistance in electrically treated plant tissues were reported by Lebovka, Nikolai et al. (2007).

The results indicated that white grapes presented substantial weight reduction throughout the drying process under all the treatments. The combined effect of hot air drying at elevated temperatures and PEF pretreatment improved drying efficiency and accelerated moisture removal. Therefore, PEF pretreatment can be considered a useful technique for enhancing drying performance and reducing drying time in grape processing operations.

**Table 7: Weights of white grapes during the drying process in a 70°C drying oven**

| **Drying time (Min)** | | | | | | |
|---|---|---|---|---|---|---|
| **Treatment** | **Sample weight (kg)** | **200** | **400** | **600** | **800** | **1000** |
| Control | 0.099 | 0.099 | 0.058 | 0.037 | 0.020 | 0.016 |
| 0.3 kV/cm | 0.099 | 0.099 | 0.056 | 0.037 | 0.021 | 0.017 |
| 1.0 kV/cm | 0.100 | 0.100 | 0.056 | 0.039 | 0.018 | 0.018 |
| 2.0 kV/cm | 0.099 | 0.099 | 0.059 | 0.042 | 0.020 | 0.019 |

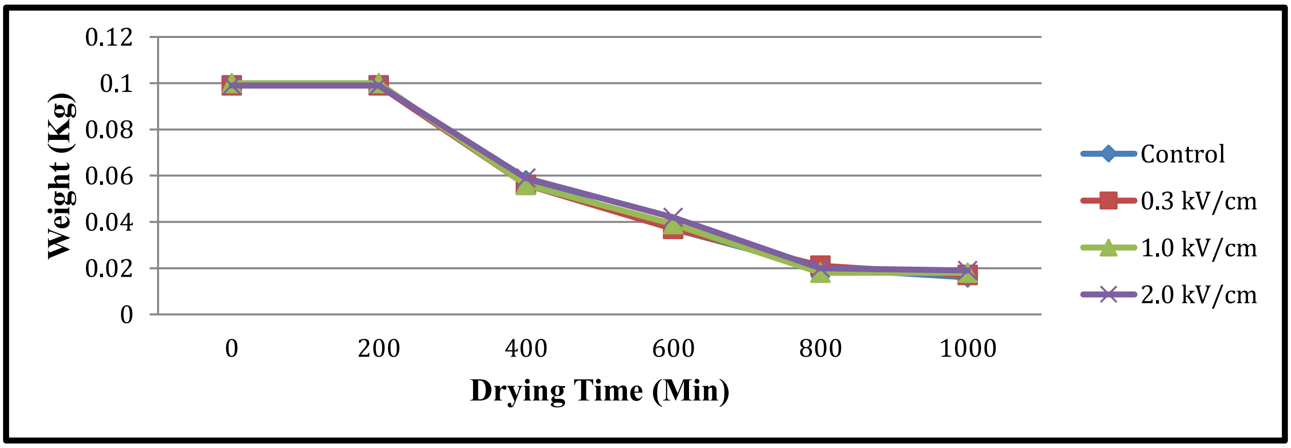


**Figure 6: Effects of drying white grapes in a tray dryer at 70°C.**

With increasing drying time, the moisture content greatly decreased after 200 min of drying, and the moisture from the black and white grapes continuously rose until a constant moisture content was reached. The constant moisture content for the control and treated samples at 0.3, 1.0 and 2.0 kV/cm decreased as the drying time increased from 200 min to 1000 min (figure. 5 and Figure 6) at 70°C. Compared with that of the control samples, the moisture content of the PEF-treated samples decreased at a faster rate. Similar findings were demonstrated for dried carrot via the convective method at 70°C (Wiktor et al.). The drying time of the samples subjected to the combined treatment ranged from 180--255 min, whereas for the untreated carrots, the drying time was 298 min.

**Figure 7: Changes during the drying of black and white grapes**

## 4. CONCLUSIONS

The present study demonstrated that pulsed electric field (PEF) pretreatment significantly influenced the drying characteristics of grapes during hot air tray drying. A continuous reduction in sample weight was observed with increasing drying time for all the treatments, indicating progressive moisture removal. Among the different PEF intensities, a higher electric field strength resulted in faster drying and greater weight reduction. Compared with the control, the 2.0 kV treatment resulted in improved moisture removal efficiency and lower PEF treatment. PEF pretreatment enhanced mass transfer during drying by increasing cell membrane permeability, thereby facilitating moisture diffusion from grape tissues. Furthermore, a higher drying temperature (70°C) reduced the drying time compared with 50°C because of the increased evaporation rate. Overall, the results of this study indicate that PEF pretreatment is a promising nonthermal technique for improving drying efficiency and reducing drying duration in grape drying operations while potentially maintaining product quality. The effect of pulse electric treatment for the drying of black and white grapes has a very small effect on the moisture content; as the drying time increases, the weight of the sample decreases.

**Competing Interest declaration**

Authors declare that there are no competing interests

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