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# A comparative study of electrical and conventional pre-treatments for quality assessment of hot air dried green bell pepper

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**Abstract**

In this study, the effect of pretreatments (hot water blanching, microwave blanching and ohmic heating) on drying kinetics and quality characteristics of green bell pepper dried at 60, 70 and 80 °C was investigated. Four mathematical models were fitted to experimental data and *Logarithmic* model was found to be the best for all the samples. Rehydration ability of only ohmic heating pretreated peppers was higher than untreated ones. Total polyphenol (TP) content and antioxidant capacity (AC) of dried peppers varied between 3.21-5.08 mg gallic acid equivalent (GAE)/g dry matter (DM) and 1037.57–2407.40 mmol AAE/100 g DM, respectively. The content of ascorbic acid (AA) in dried samples was in the range of 187.25–722.55 μg/g DM. The bioaccessibility of TP after *in-vitro* digestion varied from 79.44 to 97.73%. Losses of chlorophyll a and b were very high in all samples compared to fresh ones but the most in control samples.

**Keywords**

drying kinetics, ohmic heating, green bell pepper, chlorophylls, total phenolics, bioaccessibility

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## INTRODUCTION

Green bell pepper (*Capsicum annuum* L.) is highly perishable and has limited shelf life in the fresh conditions. Therefore, drying is an alternative to increase its conservation. Dried pepper is mainly used as a food additive and food ingredient for food preparations and products (Darvishi et al., 2014; Łechtańska et al., 2015). Hot air drying is one of the most common methods for food dehydration, but it has some drawbacks such as long drying time (Darvishi et al., 2014; Łechtańska et al., 2015), energy intensive (Fernandes and Rodrigues, 2007) and loss of product quality (Guine and Barroca, 2011). In recent years, much attention has been paid to the quality of foods during drying. Therefore, it is important to find alternatives to minimize drawbacks of hot air drying maintaining quality of green bell pepper such as color and nutritional value during drying. A pretreatment can be used to reduce drying time of products and quality loss of dried products by increasing the permeability of plant cell membranes and thus enhancing water transfer from the plant to the environment (Fernandes and Rodrigues, 2007). Some treatments used prior to drying are hot water blanching (HWB), chemical dipping, microwave blanching (MWB), ohmic heating (OH), ultrasound (US) and pulsed electric fields (PEF). In recent years, growing attention has been given to novel pretreatments such as MWB and OH.

The MWB pretreatment before drying were found to reduce the drying time and nutritional loss for *Centella asiatica* (L.) urban leaves (Trirattanapikul and Phoungchandang, 2014) and for carrot slices (Sabry et al.,

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2016). OH pretreatment increase the drying rate of vegetable tissue (Soghani et al., 2018) because of migration of moisture more easily which result from electroporation of the cell membranes by solubilizing the pectin substances (Deng et al., 2019).

For establishment of suitable drying conditions to produce food materials with the desirable properties, mathematical models describing drying kinetics have been employed (Darvishi et al., 2014) because the modeling is important to obtain a better control of operation (Doymaz, 2012). In literature, numerous studies (Lebovka et al., 2006; Soghani et al., 2018) have been conducted to evaluate the impact of pretreatment and/or temperature on drying kinetics and some quality parameters of fruit and vegetables. However, there is no information regarding the effect of novel pretreatments on various quality properties such as polyphenol content, antioxidant capacity, bioaccessibility, chlorophyll, vitamin C and rehydration behavior of green bell pepper as well as its drying kinetics. Therefore, the objective of this work was to investigate the effect of pretreatments (HWB, MWB and OH) on drying kinetics and quality attributes of green bell pepper under various drying temperatures (60, 70, and 80 °C).

## MATERIALS AND METHODS

### Materials

Ascorbic acid standard, chlorophyll standard, pepsin, pancreatin and bile salt were purchased from Sigma Co. (St Louis, MO, USA). Chemicals used in this study were either HPLC or analytical grade. Fresh, green bell peppers with uniform color and size were purchased from a local market in Bursa, Turkey and stored in a refrigerator at 4 ± 1°C until the experiments were conducted.

### Sample preparation

Before processing, bell peppers were removed from the refrigerator and allowed to reach room temperature (about 20 °C). Then, they washed with tap water and blotted with towel paper to remove excess water on the surface. After, the stems and seeds were removed they were halved. Then, each half was cut into square (12.2 × 12.2 mm) shape with a manual cutter and randomly divided into four groups (about 30 g for each). One group without any pretreatment was taken as control and others were subjected to different treatments prior to drying in triplicate, as detailed below.

### Pretreatments

The parameters of pretreatments were determined on the basis of preliminary study results including peroxidase inactivation test (Icier, 2010). As a blanching medium, 0.25% table salt solution was selected for all pretreatments and blanching time was 90 s. After pretreatments, all samples were drained off rapidly, cooled in running water and then dried with paper towels to remove the excess water.

*HWB.* Pepper was blanched in the salt solution (about 95 °C), 1:10 (w/w), in a beaker on a hot plate.

*OH.* The blanching of the peppers was performed in OH chamber, which consists of a rectangular plexiglass and two stainless steel electrodes. The system of OH chamber was described previously by İncedayi (2020). The distance between electrodes was set at 14 cm. Table salt solution was added to the chamber to assure a better contact between electrodes and sample. The sample to liquid ratio in the treatment chamber was 1:10 (w/w). Green pepper samples were treated with electric field strengths of E = 30 V/cm.

*MWB.* Blanching was carried out in a microwave oven (HMT812B/01, Bosch, India) operating at the 2.450 MHz frequency and 800 W, maximum output power. The product to salt solution ratio (w/w) was 1:5.

### Drying process

Drying experiment was performed at drying temperatures of 60, 70 and 80 °C and 20% relative humidity using a convective drier (Yucebas Machine Analytical Equipment Industry Y35, Izmir, Turkey). The initial moisture content of the green pepper was measured using an infrared moisture analyzer (Sartorius MA150) at 105 °C. Thirty g (on average) of peppers were distributed uniformly on greaseproof paper of known weight as a thin layer. The samples were weighed using a digital balance (Mettler Toledo, MS3002S) with an accuracy of ± 0.01 g every 30 min at the beginning of the drying cycle and then every 10 and 5 min at the later stages of the process. Peppers were dried until their moisture content reached below 10% for their safe storage. The experiment was conducted in triplicate.

### Moisture content

The moisture content of the pepper samples at any time of $t$ during drying at different temperatures, was calculated as follows;

$$Mt = \frac{m - DM}{m} \quad (1)$$

$Mt$: the moisture content at any time of $t$ (g water/g dry matter-DM)
$m$: mass (g)

### Drying rate

The drying rate (g water/g DM min) of samples was calculated by the following equation:

$$Drying\ Rate = \frac{M_{t+dt} - M_t}{dt} \quad (2)$$

$M_{t+dt}$: moisture content at $t + dt$ (g water/g DM)
$dt$: time between two sample weighing (min)

### Moisture ratio

The moisture ratio (MR) of samples during drying was calculated using Eq. (3):

$$MR = \frac{M_t - M_e}{M_o - M_e} \quad (3)$$

$MR$: moisture ratio (dimensionless)
$M_t$: moisture content at any time of $t$ (g water/g DM)
$M_o$: initial moisture content (g water/g DM)
$M_e$: equilibrium moisture content (g water/g DM)

### Mathematical modelling

Four thin layer drying models, commonly cited in the literature, were selected to describe the drying characteristics of pepper samples. These are *Newton* (Eq. 4), *Page* (Eq. 5), *Logarithmic* (Eq. 6), and *Henderson* and *Pabis* (Eq. 7) models.

$$MR = \exp(-k.t) \quad (4)$$

$$MR = \exp(-k.t^n) \quad (5)$$

$$MR = aexp(-kt) + c \quad (6)$$

$$MR = aexp(-kt) \quad (7)$$

The best model describing the thin layer drying characteristics of pepper was chosen as the one with the lowest Chi-square ($\chi 2$) and RMSE, and the highest ($R^2$). The constants k and n of model equations below were evaluated through nonlinear regression analysis using MINITAB (17) software.

Model validation was also performed to determine the suitable model. For this purpose, the averages of two data sets were used to build the model (İncedayi, 2020) and the validation was achieved by applying nonlinear regression method by using the third data set. Model parameters were calculated using equations as follows:

$$\mathrm{RMSE} = \left[\frac{1}{\mathrm{N}}\sum_{\mathrm{i}=1}^{\mathrm{N}}(\mathrm{MR_{pred,i}} - \mathrm{MR_{exp,i}})^2\right]^{1/2} \quad (8)$$

$$\chi^2 = \frac{\sum_{\mathrm{i}=1}^{\mathrm{N}}(\mathrm{MR_{pred,i}} - \mathrm{MR_{exp,i}})^2}{\mathrm{N} - \mathrm{z}} \quad (9)$$

N: the number of observations
z: the number of drying constants
$\mathrm{MR_{exp,i}}$: the experimental moisture ratio of ith dat a
$\mathrm{MR_{pred,i}}$ : the predicted moisture ratio of ith data

### Effective moisture diffusivity *(Deff)*

The Fick's second diffusion equation was used for calculation of the effective diffusivity according to İncedayi (2020).

### Quality parameters

Dried peppers were ground with a coffee grinder (Moulinex Ar1105). The milled samples were used in the analyses of TP, AC, AA, *in-vitro* digestion and chlorophylls.

*Determination of total polyphenol content (TP) and antioxidant capacity (AC).* Extraction of polyphenols was made according to the method of Turkmen et al. (2005). The clear extracts were used for both determinations of TP, *in-vitro* digestion and AC.

TP was determined using the Folin-Ciocalteu method (ISO 14502–1:2005) from a calibration curve of gallic acid ($R^2 = 0.99$) as mg gallic acid equivalents per gram of DM. Antioxidant capacity was determined by the 2, 2, diphenyl-2-picryl-hydrazyl (DPPH) method of Turkmen et al. (2005) and standard curve of reference antioxidant ascorbic acid (0–20 μg/mL) was assayed under identical conditions for affinity to scavenge DPPH. Antioxidant capacity of samples was converted to ascorbic acid equivalent (AAE) defined as mmol of ascorbic acid equivalents per 100 g of DM.

In-vitro *digestion (Bioaccessibility).* *In-vitro* digestion method was applied according to Minekus et al. (2014) to evaluate the bioaccessibility of phenolic compounds of the pepper extracts. It was carried out in two stages as gastric and intestinal. After each stage, the bioaccessibility (%) of TP was calculated as follows.

$$\text{Bioaccessibility } (\%) = (C_{\text{digested}}/C_{\text{undigested}}) \times 100$$

$C_{\text{digested}}$: Concentration in digested sample after gastric/intestinal stage (mg)
$C_{\text{undigested}}$: Concentration in undigested sample (mg)

*Determination of ascorbic acid (AA) content.* AA analysis was carried out as described by Karaca and Velioglu (2020). In summary, AA was extracted with citric acid solution and the extract was filtered, centrifuged and injected into the high performance liquid chromatography (HPLC) equipped with a LC-20 AD Shimadzu pump, a CTO-10 ASVP column oven and SPD-M20A photodiode array detector (242 nm). The column was Nova Select C18 reversed phase column (100A, 5μ, 250 × 4,6 mm).

*Determination of chlorophylls and pheophytins.* Chlorophyll extraction was performed according to the method described by Xie et al. (2019), with some modifications. Dried (0.25 g) and fresh (1.00 g) samples were mixed with 5 mL of cold acetone. The mixture was extracted ultrasonically for 15 min, using an ultrasonic bath operating with a frequency of 50 kHz and a power of 230W, vortexed for one minute and then centrifuged at 10 000 rpm for 10 min at 4 °C. The extract was filtered through a 0.45 μm membrane and injected into the HPLC. Pheophytins were prepared by pheophytinization of chlorophylls adding 1 N HCl, followed by 1N NaOH for neutralization.

HPLC analysis was performed according to the method of Turkmen et al. (2006) with some modifications. Accordingly, the HPLC gradient program was 0–30 min, 95–100% A. The column (Welchrom C8 reversed phase column; 5μ; 250 × 4.6 mm) was re-equilibrated with the initial conditions for 5 min before the next injection. Flow rate was 1 mL/min. Injection volume was 20 μL. The column temperature was maintained at 25 °C. The chromatograms were recorded at 430 nm for chlorophyll a and pheophytin b, 467 nm for chlorophyll b and 408 nm for pheophytin a, which are the wavelengths of their maximum absorption.

### Rehydration ratio *(RR)*

The rehydration analysis was performed according to the method of İncedayi (2020) and determined by the following equation:

$$RR = W_r / W_d \quad (10)$$

Wr: the weight of rehydrated samples (g)
Wd: the weight of dried samples (g)

### Statistical analysis

Experimental results were expressed as means ± standard deviation of triplicate measurements and analyzed by SPSS software (SPSS statistics 23, IBM.2015). Analyses of variance were performed by one-way and two-way ANOVA procedures. Means were compared by using Duncan's multiple comparison test Values of $p < 0.05$ were considered as significantly different.

## RESULTS AND DISCUSSION

### Drying kinetics

*Moisture ratio.* The effect of different pretreatments and temperatures on drying time of green pepper samples is presented in Fig. 1(a). Initial moisture contents of untreated, HWB, MWB and OH treated peppers were 15.03, 14.22, 13.60 and 14.77 g water/g DM, respectively. Green peppers were thin layer dried at 60, 70 and 80 °C in a hot air drier to a final average moisture content of 0.079 g water/g DM. In comparison with pretreatments, control samples dried at 60 °C had longer drying time (315 min). While the longest drying time (270 min) was observed in MWB treated pepper dried at 60 °C, the shortest drying time (175 min) was determined in OH treated sample dried at 80 °C. Results showed that the shortest drying time for all temperatures was observed in OH treated samples. This can be explained by electrical damage of cells during OH and releasing of moisture from damaged cells enhancing transport processes inside in tissue, so more rapid drying process (Lebovka et al., 2006). Also, reduction of drying time by HWB and MWB pretreatments due to their altering the cell wall structure and forming pores in the tissues was reported by Delfiya et al. (2018).

Drying time reduced with the increasing of temperature from 60 to 80 °C for all samples, which can be due to increase in vapor pressure within the product with increase in temperature. The reductions in drying time of control, HWB, MWB and OH pretreated peppers were 38.09%, 28.85%, 31.48% and 31.37%, respectively.

Figure 1(a) shows the changes in MR with time for 60, 70 and 80 °C. It is clear that the MR decreased with increasing of drying temperature as expected. For three temperatures, at the beginning of drying, rapid decrease in MR was observed but in later stages of drying decrease in MR was slow. This could be explained by increasing resistance to moisture diffusion inside the material due to toughening of its outer layers (Nadi and Tzempelikos, 2018). Similar results were observed by Vengaiah and Pandey (2007).

*Drying rate.* As seen in Fig. 1(b), drying rates of green bell pepper ranged from 0.0862 g water/g DM min for control peppers dried at 60 °C to 0.1581 g water/g DM min for OH treated ones dried at 80 °C. For all temperatures, drying rates of pretreated peppers was found to be higher than control ones. Similar result was observed by Mothibe et al. (2011). For each drying temperature, drying rates of pepper samples decreased continuously with the drying time due to decrease in moisture content. Drying of pepper took place only in the falling rate period throughout the drying process and no constant rate period was observed, which is in agreement with previous study (Darvishi et al., 2014). Drying rate of pepper increased with increasing drying temperature (Fig. 1(b)), which resulted in faster reduction in the moisture content thus reducing the total drying time.

### Mathematical modelling

The statistical results from models are illustrated in Table 1. *Logarithmic* model mostly provided the highest $R^2$ values and the lowest $\chi 2$ and RMSE values so, described the

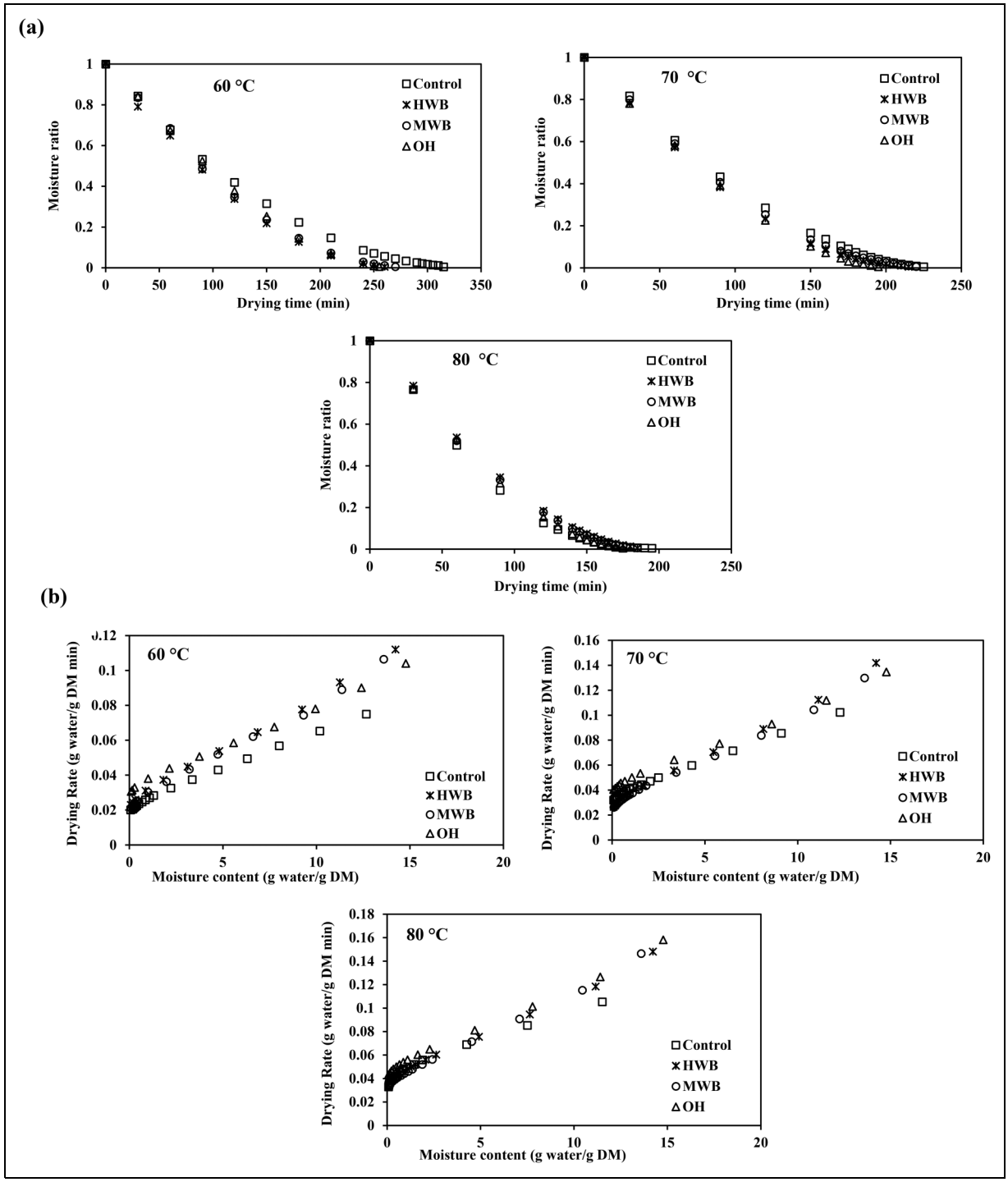



**Figure 1.** Moisture ratio (a) and drying rate (b) of bell pepper samples dried at different temperatures.

best drying characteristics of green pepper samples dried at 60, 70 and 80 °C. Fig. 2 compares experimental data with those predicted with the *Logarithmic* model for pepper samples at all temperatures. The data points closely banded along the straight line, which showed a very good agreement between the calculated and the experimental data ($R^2 > 0.99$). Therefore, the change in the moisture content of the product could be estimated to be close to the experimental data by this model.

## Effective moisture diffusivity

The values of $D_{eff}$ varied from $0.784 \times 10^{-7}$ to $1.903 \times 10^{-7}$ $m^2/s$ for untreated pepper dried at 60 °C and OH treated

**Table 1.** Statistical results obtained from the modelling of dried bell peppers.

| Temp. (°C) | Samples | Model | Coefficient | $R^2$ | RMSE | $\chi^2$ |
|---|---|---|---|---|---|---|
| 60 | Control | *Newton* | k: 0.008627 | 0.9851 | 0.06034 | 0.00384 |
| | | *Page* | k:0.001318, n:1.36669 | 0.9977 | 0.02484 | 0.00069 |
| | | *Logarithmic* | a:1.23056, k:0.005593, c:0.21352 | 0.9977 | 0.02052 | 0.00050 |
| | | *Henderson* and *Pabis* | a:1.07684, k:0.009129 | 0.9807 | 0.05443 | 0.00331 |
| | HWB | *Newton* | k:0.009970 | 0.9772 | 0.06208 | 0.00424 |
| | | *Page* | k:0.001440, n:1.40085 | 0.9927 | 0.02842 | 0.00099 |
| | | *Logarithmic* | a:1.27537, k:0.006308, c:0.26264 | 0.9972 | 0.02004 | 0.00055 |
| | | *Henderson* and *Pabis* | a:1.05915, k:0.010484 | 0.9724 | 0.057769 | 0.00409 |
| | MWB | *Newton* | k:0.009057 | 0.9867 | 0.075414 | 0.00620 |
| | | *Page* | k:0.000632, n:1.54045 | 0.9876 | 0.060835 | 0.00444 |
| | | *Logarithmic* | a:1.4301, k:0.004904, c:0.40332 | 0.9737 | 0.067628 | 0.00610 |
| | | *Henderson* and *Pabis* | a:1.08786, k:0.009729 | 0.9848 | 0.072306 | 0.00627 |
| | OH | *Newton* | k:0.009319 | 0.9714 | 0.073519 | 0.00595 |
| | | *Page* | k:0.000715, n:1.52626 | 0.9937 | 0.026983 | 0.00089 |
| | | *Logarithmic* | a:1.45451, k:0.004914, c:0.43234 | 0.9973 | 0.019625 | 0.00053 |
| | | *Henderson* and *Pabis* | a:1.08104, k:0.009972 | 0.9644 | 0.066979 | 0.00548 |
| 70 | Control | *Newton* | k:0.012171 | 0.9722 | 0.06190 | 0.00405 |
| | | *Page* | k:0.000872, n:1.53836 | 0.9962 | 0.01792 | 0.00036 |
| | | *Logarithmic* | a:1.3664, k:0.006469, c:0.34027 | 0.9971 | 0.01574 | 0.00029 |
| | | *Henderson* and *Pabis* | a:1.09353, k:0.012892 | 0.9662 | 0.05608 | 0.00351 |
| | HWB | *Newton* | k:0.013379 | 0.9706 | 0.06310 | 0.00423 |
| | | *Page* | k:0.001318, n:1.4842 | 0.9953 | 0.02065 | 0.00048 |
| | | *Logarithmic* | a:1.26284, k:0.008083, c:0.24007 | 0.9960 | 0.02096 | 0.00053 |
| | | *Henderson* and *Pabis* | a:1.07847, k:0.014055 | 0.9651 | 0.05801 | 0.00381 |
| | MWB | *Newton* | k:0.012804 | 0.9719 | 0.06297 | 0.00420 |
| | | *Page* | k:0.001073, n:1.51251 | 0.9967 | 0.01698 | 0.00032 |
| | | *Logarithmic* | a:1.29865, k:0.007426, c:0.2721 | 0.9960 | 0.01885 | 0.00043 |
| | | *Henderson* and *Pabis* | a:1.0865, k:0.013510 | 0.9662 | 0.05745 | 0.00371 |
| | OH | *Newton* | k:0.013167 | 0.9697 | 0.07171 | 0.00557 |
| | | *Page* | k:0.000853, n:1.57837 | 0.9960 | 0.02168 | 0.00056 |
| | | *Logarithmic* | a:1.48479, k:0.006107, c:0.47018 | 0.9973 | 0.01665 | 0.00036 |
| | | *Henderson* and *Pabis* | a:1.08099, k:0.013899 | 0.964 | 0.06640 | 0.00521 |
| 80 | Control | *Newton* | k:0.016107 | 0.9761 | 0.05828 | 0.00360 |
| | | *Page* | k:0.001037, n:1.59006 | 0.9992 | 0.01094 | 0.00013 |
| | | *Logarithmic* | a:1.23355, k:0.010410, c:0.1938 | 0.9911 | 0.02676 | 0.00086 |
| | | *Henderson* and *Pabis* | a:1.0856, k:0.016907 | 0.9716 | 0.05403 | 0.00328 |
| | HWB | *Newton* | k:0.014516 | 0.9704 | 0.06203 | 0.00410 |
| | | *Page* | k:0.001001, n:1.5673 | 0.9964 | 0.01768 | 0.00036 |
| | | *Logarithmic* | a:1.3926, k:0.007526, c:0.36536 | 0.9970 | 0.01622 | 0.00032 |
| | | *Henderson* and *Pabis* | a:1.08617, k:0.015229 | 0.9653 | 0.05736 | 0.00376 |
| | MWB | *Newton* | k:0.014751 | 0.9768 | 0.05768 | 0.00355 |
| | | *Page* | k:0.001126, n:1.54652 | 0.9963 | 0.01994 | 0.00045 |
| | | *Logarithmic* | a:1.36621, k:0.007807, c:0.34263 | 0.9977 | 0.01456 | 0.00026 |
| | | *Henderson* and *Pabis* | a:1.08133, k:0.015497 | 0.9721 | 0.05370 | 0.00330 |
| | OH | *Newton* | k:0.015374 | 0.9640 | 0.07244 | 0.00565 |
| | | *Page* | k:0.000935, n:1.60294 | 0.9970 | 0.01728 | 0.00035 |
| | | *Logarithmic* | a:1.43189, k:0.007504, c:0.41026 | 0.9949 | 0.02266 | 0.00065 |
| | | *Henderson* and *Pabis* | a:1.08095, k:0.0161548 | 0.9583 | 0.06715 | 0.00526 |

pepper dried at 80 °C, respectively (Table 2). These values are comparable with the reported values of $8.315 \times 10^{-8}$ - $2.363 \times 10^{-7}$ $m^2/s$ for green pepper (Darvishi et al., 2014) and 4.22–$6.08 \times 10^{-7}$ $m^2/s$ for mushroom (Soghani et al., 2018).

The results showed that for both control and pretreated samples $D_{eff}$ values increased with increase of drying temperature. This could be due to the enhanced evaporation at higher temperatures. For all temperatures, pretreated peppers had higher values of $D_{eff}$ than control samples. Among pretreatments, the maximum $D_{eff}$ values were observed in OH treated samples. Similarly, Won et al. (2015) found that PEF pretreatment for red pepper

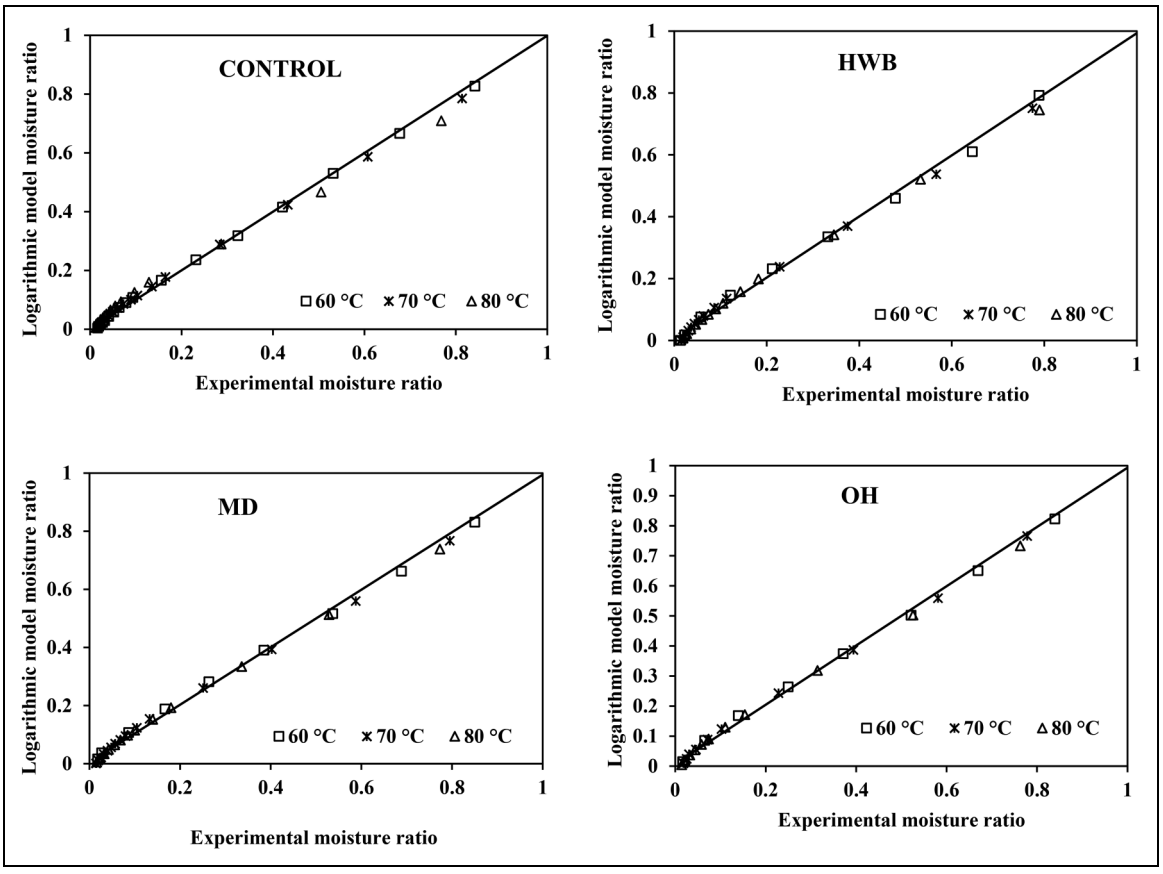



**Figure 2.** Comparison of experimental MR with predicted MR from the model for green bell pepper.

**Table 2.** Deff values of bell pepper dried at different temperatures.

| Pretreatment | Temperature (°C) | $D_{eff}$ ($\times 10^{-7}$ $m^2/s$) |
|---|---|---|
| Control | 60 | 0.784 |
| | 70 | 1.159 |
| | 80 | 1.678 |
| HWB | 60 | 1.262 |
| | 70 | 1.528 |
| | 80 | 1.698 |
| MWB | 60 | 1.228 |
| | 70 | 1.480 |
| | 80 | 1.753 |
| OH | 60 | 1.303 |
| | 70 | 1.671 |
| | 80 | 1.903 |

increased $D_{eff}$ compared to the control due to the higher cell membrane disruption.

## Quality characteristics of dried green bell pepper

Pretreatments, temperatures and their interactions significantly affected TP, AC, AA, chlorophylls and pheophytins ($p < 0.05$) (**Tables 3** and **4**). However, only the pretreatment had a significant influence on RR values of pepper samples. Additionally, for the green peppers dried at 80 °C, the pretreatment had a significant influence on bioaccessibility of TP of pepper samples ($p < 0.05$) (Table 5).

The initial TP values of fresh green pepper was 9.27 mg GAE/g DM, which is within the ranges (7.06–10.87 mg GAE/g DM) found in previous studies for other species of *Capsicum* (Reis et al., 2013; Zhou et al., 2016). TP content of all dehydrated peppers was found to be lower (3.21–5.08 mg GAE/g DM) compared to that of fresh pepper, which is in agreement with the study by Reis et al. (2013). Decrease in TP amounts can be attributed to the degradation of phenolic compounds and alterations in their chemical structures during drying (Zhou et al., 2016).

For a temperature of 60 °C, control peppers presented the lowest content of TP from all dehydrated peppers. OH and HWB treated peppers showed higher TP values. For a temperature of 70 °C, OH treatment caused the highest content of TP among all the treatments. After drying at 80 °C, although there was no significant difference between TP values of all dried peppers ($p > 0.05$), OH treated samples again had the highest TP values. In general, it was observed that as the temperature increased to 80 °C, the content of TP of dried peppers increased.

**Table 3.** Quality attributes of green bell pepper dried at different temperatures.

| Quality parameter | Initial | Pretreatment | 60 °C | 70 °C | 80 °C |
|---|---|---|---|---|---|
| TP (mg GAE/g DM) | 9.27 ± 0.16 | Control | $3.21 \pm 0.07^{aA}$ | $3.52 \pm 0.28^{abA}$ | $4.59 \pm 0.51^{aA}$ |
| | | OH | $5.08 \pm 0.08^{cB}$ | $4.55 \pm 0.09^{bA}$ | $4.73 \pm 0.12^{aA}$ |
| | | HWB | $5.03 \pm 0.11^{cB}$ | $3.73 \pm 0.01^{aA}$ | $3.82 \pm 0.04^{aA}$ |
| | | MWB | $3.94 \pm 0.27^{bB}$ | $3.34 \pm 0.06^{aA}$ | $4.55 \pm 0.09^{aC}$ |
| AC (mmol AAE/100 g DM) | 2880.4 ± 171.95 | Control | $1111.44 \pm 85.22^{aA}$ | $1037.57 \pm 84.89^{aA}$ | $1907.88 \pm 89.43^{aB}$ |
| | | OH | $2407.40 \pm 252.88^{cA}$ | $1992.89 \pm 199.47^{bA}$ | $2193.70 \pm 45.77^{aA}$ |
| | | HWB | $2333.70 \pm 42.75^{cA}$ | $1923.60 \pm 145.01^{bA}$ | $2110.39 \pm 129.44^{aA}$ |
| | | MWB | $1629.20 \pm 85.58^{bA}$ | $1647.91 \pm 9.58^{bA}$ | $1927.66 \pm 41.91^{aB}$ |
| AA (μg/g DM) | 13669.17 ± 155.39 | Control | $218.39 \pm 2.36^{aC}$ | $198.17 \pm 3.77^{aB}$ | $187.25 \pm 3.01^{aA}$ |
| | | OH | $722.55 \pm 36.83^{dB}$ | $683.66 \pm 4.35^{dB}$ | $572.63 \pm 4.98^{cA}$ |
| | | HWB | $407.45 \pm 4.26^{cB}$ | $374.28 \pm 6.11^{cA}$ | $368.66 \pm 11.80^{bA}$ |
| | | MWB | $309.44 \pm 4.30^{bC}$ | $224.21 \pm 8.12^{bB}$ | $195.53 \pm 3.51^{aA}$ |
| Chl a ( μg/g DM) | 813.87 ± 9.20 | Control | $4.55 \pm 0.65^{aA}$ | $4.47 \pm 0.22^{aA}$ | $3.82 \pm 0.71^{aA}$ |
| | | OH | $4.93 \pm 0.42^{aA}$ | $14.50 \pm 1.15^{cC}$ | $8.42 \pm 0.38^{bB}$ |
| | | HWB | $8.19 \pm 0.48^{bA}$ | $11.14 \pm 0.13^{bB}$ | $11.36 \pm 0.30^{cB}$ |
| | | MWB | $17.62 \pm 0.57^{cB}$ | $10.58 \pm 0.17^{bA}$ | $11.48 \pm 0.12^{cA}$ |
| Chl b ( μg/g DM) | 112.28 ± 1.30 | Control | $2.50 \pm 0.06^{aB}$ | $1.55 \pm 0.24^{aA}$ | $1.09 \pm 0.04^{aA}$ |
| | | OH | $2.65 \pm 0.18^{aB}$ | $2.78 \pm 0.16^{bB}$ | $1.72 \pm 0.07^{bA}$ |
| | | HWB | $4.65 \pm 0.25^{bB}$ | $2.75 \pm 0.32^{bA}$ | $2.27 \pm 0.34^{bcA}$ |
| | | MWB | $4.64 \pm 0.21^{bB}$ | $2.18 \pm 0.07^{abA}$ | $2.49 \pm 0.15^{cA}$ |
| Pheo. a (μg/g DM) | 5.17 ± 0.01 | Control | $19.77 \pm 0.19^{aA}$ | $23.51 \pm 1.81^{aA}$ | $22.57 \pm 1.28^{aA}$ |
| | | OH | $37.68 \pm 1.32^{bB}$ | $32.46 \pm 0.77^{bA}$ | $37.92 \pm 0.67^{bB}$ |
| | | HWB | $76.73 \pm 3.32^{dB}$ | $41.74 \pm 2.22^{cA}$ | $38.32 \pm 1.19^{bA}$ |
| | | MWB | $55.47 \pm 1.77^{cC}$ | $43.94 \pm 2.25^{cB}$ | $36.88 \pm 0.78^{bA}$ |
| Pheo. b (μg/g DM ) | 1.05 ± 0.00 | Control | $7.01 \pm 0.15^{aA}$ | $10.11 \pm 0.59^{aB}$ | $15.09 \pm 0.57^{aC}$ |
| | | OH | $20.51 \pm 0.25^{bB}$ | $16.16 \pm 0.58^{bA}$ | $22.54 \pm 0.01^{cC}$ |
| | | HWB | $36.54 \pm 1.12^{dB}$ | $21.27 \pm 1.01^{cA}$ | $19.94 \pm 1.55^{bcA}$ |
| | | MWB | $28.02 \pm 1.24^{cB}$ | $21.37 \pm 2.03^{cA}$ | $17.83 \pm 0.80^{abA}$ |
| RR | - | Control | $6.29 \pm 0.22^{aA}$ | $6.31 \pm 0.23^{abA}$ | $7.06 \pm 0.63^{bcA}$ |
| | | OH | $7.96 \pm 0.42^{bA}$ | $7.79 \pm 0.62^{cA}$ | $8.23 \pm 0.17^{cA}$ |
| | | HWB | $6.26 \pm 0.22^{aA}$ | $7.04 \pm 0.33^{bcA}$ | $6.82 \pm 0.21^{bA}$ |
| | | MWB | $6.05 \pm 0.37^{aA}$ | $5.70 \pm 0.24^{aA}$ | $5.43 \pm 0.43^{aA}$ |

Data are expressed as means ± SE of triplicate experiments. Means in a column (a-c across pretreatment) and in a row (A-C across temperature) not having a common letter are different ($p < 0.05$).

This might be due to the release of phenolic compounds from food matrix or the availability of precursors of phenolic molecules by non-enzymatic interconversion between phenolic molecules at high temperatures (Vega-Gálvez et al., 2009).

Bioaccessibility of the dried green bell peppers at 80 °C was also evaluated (Table 5). The TP of all samples significantly decreased compared to their initial values ($p < 0.05$). The highest decrease was observed in the intestinal phase. This is associated with lower stability of polyphenols due to the alkaline environment during intestinal digestion. The reduction of TP after gastrointestinal digestion was also demonstrated in the previous studies with different foods. Bouayed et al. (2012) stated that the TP content of four different apple cultivars (with an average initial TP level of 44.42 mg/100 g fresh weight) decreased to 35.95 mg/100 g fresh weight after the gastric stage and to 21.84 mg/100 g fresh weight after the pancreatic stage. Similarly, TP values of ten different walnut varieties decreased by an average of 74.1% and 77%, respectively, after *in- vitro* digestion compared to their initial values (Vella et al., 2019). On the other hand, it was seen that the bioaccessibility (79.44–97.73%) of TP in dried green bell peppers after *in-vitro* digestion was higher than those of the other plant materials studied in the previous studies. With respect to pretreatment applied, bioaccessibility of TP in OH and HWB treated peppers was found to be significantly higher than that of the control samples ($p < 0.05$). However, this study showed that bioaccessibility of TP in dried pepper did not decreased so much compared to that (87.03–90.89%, data not shown) of fresh one.

AC of all dried samples (1037.57–2407.40 mmol AAE/100 g DM) was found to be lower than that of fresh one (2880.4 mmol AAE/100 g DM), which could be because

**Table 4.** Variance analysis results on the effect of drying temperature, pretreatment and their interactions on quality parameters of dried bell peppers.

| Sources of variation | Quality parameter (Dependent variable) | DF[a] | MS[b] | F |
|---|---|---|---|---|
| Temperature | TP | 2 | 1.403 | 12.054* |
| | AC | | 446394.473 | 10.083* |
| | AA | | 20914.932 | 48.634* |
| | Chl. a | | 7.551 | 9.084* |
| | Chl. b | | 9.625 | 81.021* |
| | Pheo. a | | 656.152 | 77.460* |
| | Pheo. b | | 107.277 | 35.519* |
| | RR | | 0.192 | 0.458 |
| Pretreatment | TP | 3 | 1.761 | 15.123* |
| | AC | | 1368986.755 | 30.924* |
| | AA | | 385876.679 | 897.290* |
| | Chl. a | | 124.458 | 149.725* |
| | Chl. b | | 4.418 | 37.187* |
| | Pheo. a | | 1550.391 | 183.026* |
| | Pheo. b | | 378.732 | 125.395* |
| | RR | | 7.882 | 18.779* |
| Temperature × pretreatment | TP | 6 | 1.030 | 8.849* |
| | AC | | 197139.764 | 4.453* |
| | AA | | 3279.958 | 7.627* |
| | Chl. a | | 38.873 | 46.765* |
| | Chl. b | | 1.028 | 8.651* |
| | Pheo. a | | 334.438 | 39.481* |
| | Pheo. b | | 103.431 | 34.245* |
| | RR | | 0.432 | 1.030 |

a: Degree of freedom; b: Mean squares; * Significance at $p < 0.05$.

**Table 5.** Bioaccessibility (%) of TP of the green bell peppers dried at 80 °C

| | Initial | Gastric | Intestinal |
|---|---|---|---|
| Control | $100.00 \pm 0.00^{b}$ | $82.53 \pm 1.54^{aA*}$ | $80.43 \pm 2.52^{aA}$ |
| OH | $100.00 \pm 0.00^{c}$ | $95.47 \pm 1.05^{bB}$ | $84.23 \pm 1.35^{aAB}$ |
| HWB | $100.00 \pm 0.00^{b}$ | $97.73 \pm 0.44^{bB}$ | $87.80 \pm 2.05^{aB}$ |
| MWB | $100.00 \pm 0.00^{c}$ | $84.11 \pm 1.29^{bA}$ | $79.44 \pm 1.28^{aA}$ |

For each sample, the differences between means in capital letters (pretreatment) in the same column and in lower case letters (gastrointestinal stage) in the same row are significant ($p < 0.05$).

of the result of oxidation of phenolic compounds. For temperatures of 60 and 70 °C, OH and HWB treated peppers showed higher AC values. However, for a temperature of 80 °C, AC of the dried samples showed a similar trend as that observed in the TP values. The increase in the content of TP after drying at 80 °C might be responsible of the increase in AC as the temperature increased to 80 °C due to significant correlations between TP and AC (Blanco-Rios et al., 2017; Le et al., 2021).

As illustrated in Table 3, regardless of pretreatments and temperatures the content of AA considerably decreased from 13669.17 µg/g DM for fresh sample to 175.86–722.55 µg/g DM in dried samples by drying. Similar findings have been reported by other authors (Vega-Gálvez et al., 2009). The reduction in AA can be explained by its degradation by heat and oxidation in the presence of oxygen (Deng et al., 2018). Furthermore, it was found that increasing the drying temperature from 60 to 80 °C resulted in an increase in the loss of AA regardless of the pretreatment during drying in this study (Table 3), which is consistent with the study of Vega-Gálvez et al. (2009). It was also observed that while control samples had the lowest AA content at the same temperature, OH treated ones recorded the highest AA content. This could be due to the fact that the shortest drying time for all temperatures was obtained by OH pretreated samples thus preventing AA from degradation more.

As expected, chlorophyll a and b contents of all dried samples were very low after drying compared to that of fresh pepper (Table 3). Similar result was observed by Pal et al. (2008) for green pepper. The reduction in chlorophyll a and b contents can be attributed to formation of chlorophyll derivatives such as pheophytins and pheophorbides since chlorophyll is sensitive to heat, enzymes, oxygen, light, pH and heavy metals. The content of chlorophylls in dried samples varied significantly ($p < 0.05$) depending on the temperature and pretreatment applied and showed different trends with increase in temperature. Control samples yielded the lowest chlorophyll a and b contents

for all temperatures. This might be due to their longest drying time (Fig. 1(a)) and the activity of their chlorophyll-degrading enzymes such as chlorophyllase. Similarly, Cui et al. (2004) reported that the loss of chlorophyll during hot air drying of unblanched chive leaves at 60–65 °C was related to high activity of chlorophyllase and lipoxidase at these temperatures. Additionally, for all dried peppers the content of chlorophyll a was found to be higher than that of chlorophyll b as in the fresh one. In the case of pheophytins, from Tables 3 and 4, the content of pheophytin a and b which are major derivatives of chlorophylls changed significantly ($p < 0.05$) depending on the temperature and pretreatment applied and presented different trends with increase in temperature. It was observed that for all samples pheophytin a content was more than pheophytin b content due to the excess of chlorophyll a in the fresh sample. On the other hand, the amount of pheophytins in control samples was the lowest among all samples for three temperatures although the reduction in chlorophylls in control samples was the most This can be explained by the fact that unlike pretreated samples, pheophorbides in addition to pheophytins as chlorophyll derivatives in control samples are formed because of chlorophyllase activity during drying (Gu et al., 2022; Zhang et al., 2015).

Rehydration ability is one of the most important quality parameters for dried products because they need to be further processed or consumed after rehydration (Wang et al., 2018). RR values of dried samples were in the range of 5.43–8.23 depending on the temperature and pretreatment applied (Table 3). Similarly, Pal et al. (2008) found RR of 6.8–7.2 for green pepper. Pretreatment but not temperature and their interaction significantly affected RR values of green bell pepper (Table 4). It was observed that OH treated samples resulted in the highest RR among all samples for three temperatures. This may be due to the fact that more porous structure was developed (Deng et al., 2021; Wiktor and Witrowa-Rajchert, 2020) after drying of the samples pretreated by OH, which promoted rehydration because RR is related to the cellular structure and integrity of the dried product.

## CONCLUSIONS

In this study, the impact of pretreatment on drying kinetics and quality attributes of green bell pepper dried at different temperatures was investigated. Pretreatment and drying temperature significantly affected drying behavior and quality parameters of green bell pepper. The drying time was the highest for control samples and the lowest for OH pretreated samples. *Logarithmic* model described the best drying characteristics of peppers dried at all the selected temperatures. In terms of TP, AC, AA and RR, OH pretreated samples were superior to other ones. Drying process did not affect very much bioaccessibility of TP after *in vitro* digestion. On the other hand, bioaccessibility of TP in HWB and OH treated peppers was higher than that of the control and MWB treated samples. Regarding pigments, control samples have the lowest chlorophylls and pheophytins for all temperatures after drying. On the other hand, the contents of these pigments presented different trend depending on the temperature and pretreatment applied. Consequently, these results showed that drying behavior and quality characteristics of dried green bell pepper depended on drying temperature and the pretreatment applied.

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## DECLARATION OF CONFLICTING INTERESTS

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