COLOR AND SELECTED SECONDARY METABOLITES OF CONVECTIVE AND MICROWAVE-DRIED SQUASH (*CUCURBITA PEPO* L.) SLICES

M. BULUT

Igdir University, Faculty of Engineering, Food Engineering Department, Iğdır, Turkey
bulutmenekse2@gmail.com

***Abstract*— This work was undertaken to evaluate the impact of drying techniques (convective and microwave drying) on color and selected secondary metabolites (ascorbic acid, total phenolic substances, and antioxidant capacity) of squash slices. Convective drying at 3 different temperatures (55, 65, and 75 C), and microwave drying at 2 different power levels (100W and 200W) were applied. Significant differences were found among fresh and dried-squash slices. Convective-dried squash samples showed better quality characteristics in comparison with the microwave-dried squash samples. The convective-dried squash samples at 65 C exhibited the highest retention of bioactive components and best color among all convective drying conditions. The microwave-dried squash samples at lower power (100W) showed higher quality characteristics compared to the dried squash samples at 200W.**

***Keywords*— Squash, color, convective drying, microwave drying, secondary metabolites.**

I. INTRODUCTION

Fruits and vegetables are suitable for chemical and microbiological deterioration because of having a high moisture content. Several preservation techniques such as cold storage, freezing and drying are employed for the improvement of shelf-life of these agricultural products (Yıldız and İzli, 2020). Drying is one of the oldest methods that has been used for years to preserve the food products, i.e. fruits and vegetables. Purpose in drying process is to remove the free water in the wet food materials, so prevent the biochemical reactions and microbial growth (İzli and Yildiz, 2021). Drying of agricultural crops improves the shelf-life, lessens losses at storage, and save shipping and transporting expenses. While the drying process was achieved traditionally by natural convection drying of the products laid on the field previously, this method gave its place to faster, more hygienic and homogeneous drying applications with technological developments over time (Yildiz, 2021a).

A squash is perishable because of its high moisture content, causing it to deteriorate within a few weeks of harvest. Preserving the crop with its nutritional, functional, flavor and color characteristics is a difficult task; drying with hot air is one of the more frequent techniques used to achieve this (Yildiz and Izli, 2019a). The drying in microwave and hot-air oven of several fruits and vegetables has been searched by several researchers according to the various conditions (Maskan, 2001; Wang and Shi, 2005; Di Scala *et al*., 2011; Yildiz, 2021a,b). This research has the primary aim of contributing to the works on the use of microwave and convective drying on squash quality. Specifically, the influence of the drying methods and the development of color on dried squash slices in regard to the reduction of the moisture content during drying in microwave and convective dryers will be evaluated. The final features of the squash slices with respect to the retain of selected bioactive compounds including ascorbic acid, total phenolic content, antioxidant capacity and their relationships with the drying techniques and circumstances will also be analyzed.

II. METHODS

A. Sample Preparation

The squashes were obtained at a local market in Iğdır, Turkey. They were washed to remove the dust and attached dirt, and hand-peeled. The squash samples were sliced by dimensions of 10 mm L, 10 mm W and 10 mm thickness by the assist of a food slicer (Nicer Dicer, China). The beginning moisture content of the squash samples was defined as 90.8 ± 0.13 % on a wet basis (w.b.) obtained by drying at 105 ± 5 °C before reaching the stable weight via laboratory oven (AOAC, 1999) (Memmert UN55, Germany).

B. Drying Process

As mentioned previously, the squash samples were exposed to 2 drying methods which were convective and microwave drying. Microwave application was implemented in a microwave oven (Altus ALMD 20, Istanbul, Turkey) at 100 and 200 W power levels. Convective drying operation was implemented in a lab convective oven (Arçelik KMF 833I, Turkey) following the method proposed by İzli *et al*. (2021). The squash samples were located in a thin layer. Air velocity was well-set at 1 m/s along with the temperature of 55, 65 and 75 ºC for the drying process. In the rear of drying period, moisture content of squash samples was achieved as 12 ± 0.78%. About 100 g sample were used for each drying experiment. The analysis was conducted with 3 replications. A short description of the treatments is displayed in Table 1.

Table 1. Treatments used in the study

Sample names	Treatments
FS	Fresh sample, no treatment
MD1	Microwave-dried squash samples at 100 W
MD2	Microwave-dried squash samples at 200 W
CD5	Convective-dried squash samples at 55 ºC
CD6	Convective-dried squash samples at 65 ºC
CD7	Convective-dried squash samples at 75 ºC

C. Color Measurement

The color differences of fresh and dried squash samples were figured out with the help of a Konica Minolta (CR-400, Osaka, Japan) which is assembled by an illuminant D65 and 8 mm scaling region at the CIE *L* a* b** color range. Color attributes were specified in a 3D *L*, a*,* and *b** color zone, where *L** expresses the lightness/darkness of the specimen, *a** presents the redness/greenness, and finally *b** indicates the yellowness/blueness (Yildiz and Izli, 2019b). For each application, colors of ten squash samples were evaluated, and the average *L*, a*,* and *b** values were recorded. Adjustment of the device was handled with a basic white sheet in advance of each analysis.

D. Ascorbic Acid (Vitamin C, AA)

AA amount of the fresh and dried squash pieces was determined by the help of titrimetric technique suggested by AOAC Method 967.21 (Association of Official Analytical Chemist International, 2007) based on the quantative discoloration of 2,6-dichlorophenolic indophenol (Sigma-Aldrich, St. Luis, MO). One gram of standardized squash samples was taken and diluted by the extraction liquid (2 g oxalic acid/100 g) to 100 mL and extracted by 10 min. Following the vacuum filtration phase, collected clear supernatants were titrated with a 2,6-diclorophenol indophenol (0.01 g/100 g). Development of a recognizable pink color is the indicator of the final point of titration process. Vit C findings were defined as mg AA per 100 g on dry weight (d.w.). The procedure was repeated for three times.

E. Total Phenolic Content (TPC)

The procedure proposed in the research of Yıldız *et al*. (2021) by a small change was followed to measure phenolic substances of squash samples. The technique includes the Folin–Ciocalteau reagent degradation by phenolic component. In a short way, the extract obtained from the squash (around 0.25 mL) was blended with 1.25 mL of Folin–Ciacolteu indicator and 15 mL of distilled water by vortexing. Subsequent to waiting in the dark place approximately 8 min, 3.75 mL of 7.5% Na carbon was included into the mixture and the volume was brought up to 25 mL with distilled water. At that point, the absorbance was obtained at 760 nm by using a spectrophotometer (Carry 60 UV–VIS spectrophotometer, USA) succeeding 2 hr incubation at room temperature in a dark place. The findings were demonstrated as mg Gallic acid (GA)/100 g on d.w.

Table 2. Color values in squash samples induced by convective and microwave dryings

Treatments	L^*	a^*	b^*
Fresh sample	76.13 ± 0.2^{a}	14.8 ± 0.8^{d}	42.12 ± 0.3^{a}
MD1	52.11 ± 0.4^{e}	25.3 ± 0.6^{a}	25.21 ± 0.4^{d}
MD2	49.34 ± 0.4^{e}	27.3 ± 0.9^{a}	30.15 ± 0.5^{d}
CD5	65.42 ± 0.2^{b}	17.6 ± 0.1^{c}	37.03 ± 0.9^{b}
CD6	60.83 ± 0.2^{c}	19.5 ± 0.5^{b}	33.08 ± 0.2^{c}
CD7	55.89 ± 0.1^{d}	19.9 ± 0.4^{b}	33.14 ± 0.1^{c}

[a-d]The same letters in each treatment show that treatment means are not significantly different ($p<0.05$).

F. Antioxidant Capacity (ATC)

DPPH was employed for the measurement of ATC of squash extracts by the procedure proposed previously in the work of Yildiz (2021a, b). A 0.1 mL of squash extract was mixed by a 3.9 mL DPPH methanol liquid (25 mM) and shaken 30 seconds and incubated at 25 ºC for 30 min. Subsequent to duration period, the absorbances of the blend were obtained under 515 nm by a spectrophotometer (Carry 60 UV–VIS spectrophotometer) and ATC of the squash samples was identified as μmol Trolox equivalents (TE)/g on d.w.

III. RESULTS

A. Color Measurement

The most and first quality attribute which is assessed by consumers is the surface color of the food products. In addition, this is very important in terms of acceptance of food materials, even earlier the taste the food product. The effect of several drying methods related to the color values of the dried squash samples was tabulated in Table 2. The L^* value of all dried squash samples decreased significantly in comparison with the fresh squash samples ($p<0.05$). At the same time, a significant increase in a^* values for the convective and microwave-dried squash samples when compared with the fresh squash samples was observed. In comparison with the microwave-dried squash samples, the squash samples dried at 55, 65 and 75°C by convective drying were significantly ($P<0.05$) lighter in color. Similar impacts in the case of microwave drying were pointed out earlier by Sumnu *et al*. (2005). Color differences in the squash samples by thermal treatments might be related to the pigment degradation and the occurrence of brown pigments by non-enzymatic (Maillard reactions) and enzymatic reactions. In addition, temperature with the microwave power increase significantly enhanced the reduction in the L^* values which might be caused by non-enzymatic browning. The b^* values of dried squash samples was found out to be lower value than that of fresh squash samples (Table 2). Among the applied 2 drying treatments, the highest b^* value loss was collected with the microwave drying method at 100 W (25.21). Color differences observed in squash samples as a result of drying process could be connected with the pigment degradation, specifically degradation of carotenoids with the occurrence of brown pigments caused by non-enzymatic (Maillard reaction) and enzymatic reactions (Albanese *et al*., 2013).

B. Ascorbic Acid, Total Phenolic Content and Antioxidant Capacity

Figure 1 showed the ascorbic acid content of microwave- and convective-dried squash samples. A significant decline was observed in the ascorbic acid content of the squash samples for all the drying conditions (Fig. 1). While the highest ascorbic acid content was observed in the fresh squash samples (83.12 mg/100 g dry weight (d.w.)), the lowest AA value was reported in the microwave-dried squash samples at 200W (36.38 mg/100 g d.w.).

Figure 1 presents the results of drying on total phenolics of squash samples. Total phenolic content of fresh squash samples was found as 31.67 mg GA/100 g d.w. The drying treatments greatly influenced the total phenolic content. The phenolics in the fresh squash samples was significantly higher than that in the microwave and convective dried squash samples. Increasing microwave power from 100 to 200W reduced the phenolic content. An increase on the drying temperature from 65ºC to 75ºC declined the total phenols significantly. As a result of an increase on drying temperatures, the reduction in the total phenols has also been announced in several works by researchers in pears (Santos *et al*., 2014) and apple samples (Vega-Galvez *et al*., 2012). The reduction on total phenolic value during drying period could be related to the organization of polyphenolics with other compounds (i.e., protein) and/or the differences in the physiochemical occurrence of polyphenols. The effects of drying methods on the phenolic substances of foods were studied previously. In some studies, it was reported that thermal process is very suitable to increase the phenolic content in several food materials including dry raisin (Carranza-Concha *et al*., 2012), and apricot fruits (Sultana *et al*., 2012. In addition, some findings demonstrated a microwave process increased the phenolic content significantly in various food materials such as barley samples (Gallegos-Infante *et al*., 2010). On the other hand, while some studies (Zheng *et al*., 2006; Sultana *et al*., 2012; Mrad *et al*., 2012) showed that total phenolic substances decreased during heat application, some other studies (Dewanto *et al*., 2002) pointed out that no notable differences. So, the influence of drying methods on the phenolic substances from different food products might not produce the same and/or similar results. By taking into account of the findings, we can say that drying application has changeable impacts on the phenolic substances. The highest total phenolic content observed in the dried squash samples could be related to more cell degradation and rupture, so those can lead to more phenolic substances to be released.

The differences in the antioxidant capacity of squash samples by different drying methods is demonstrated in Fig. 1. The antioxidant capacity in the fresh squash samples was determined as 6.13 µmol Trolox/g d.w. A significant decrease was reported in the antioxidant capacity of squash samples in all drying methods (Fig. 1). Several researchers observed a decrease in antioxidant capacity after drying application (Wojdylo *et al*., 2014; Sultana *et al*., 2012; Santos *et al*., 2014) including sour cherries (Wojdylo *et al*., 2014), pineapples (Di Scala *et al*., 2011) and apple pieces (Sultana *et al*., 2012). The decomposition of antioxidant compounds at drying process is the reason of observed reduction. The lowest antioxidant activity value was found for the microwave-dried squash pieces at 200W (2.95 µmol Trolox/ g d.w.). Compared to the microwave-dried squash slices, convective-dried squash samples showed higher antioxidant capacity (Fig. 1). The findings demonstrated that drying applications achieved at lower temperature in convective drying, which results in longer drying periods, may be the reason of more decline in the antioxidant activity. In addition, no statistically significant ($p<0.05$) changes was observed among the antioxidant activity of the microwave (100 and 200 W) dried samples (3.25 and 2.95 µmol Trolox/g d.w., subsequently). There might be a synergistic or antagonistic effect between the antioxidant components and other substances (Di Scala *et al*., 2011). The decrease in antioxidant capacity may be associated with the reduced amount of phenolics complexes. While the dried squash samples demonstrated both lower total phenolic and antioxidant capacity values, the fresh squash samples showed the highest total phenolics and antioxidant capacity. These results show that phenolic substances can contribute to the antioxidant capacity on dried squash samples.

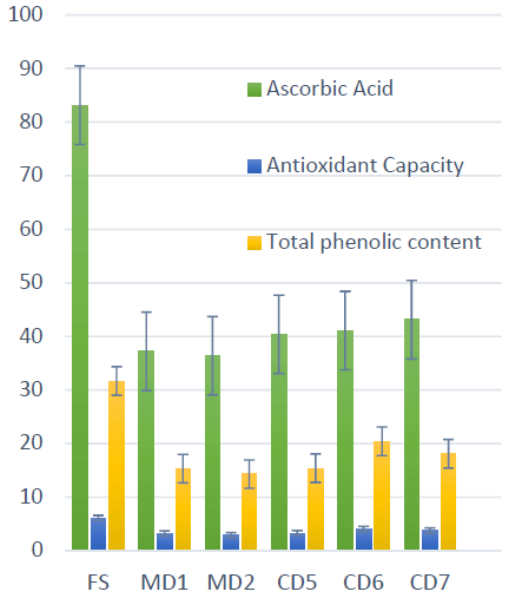

Fig. 1. The differences in secondary metabolites of convective- and microwave-dried squash slices.

V. CONCLUSIONS

In the current work, the impacts of microwave and convective drying methodologies on the color and bioactive compounds including ascorbic acid, TPC and ATC of squash samples were examined. The findings from the analysis demonstrated that convective dried squash samples showed better quality characteristics compared to the squash samples dried with a microwave drying. The

squash slices dried at 65 C with convective drying exhibited the highest retention of bioactive components and best color among all convective drying conditions. The microwave-dried squash slices at lower power (100W) showed a higher quality characteristic compared to the dried-squash samples at 200W. The results from this study are significant for the processing of dried squash samples by optimizing the conditions to obtain a high-quality product.

REFERENCES

Albanese, D., Cinquanta, L., Cuccurullo, G. and Di Matteo, M. (2013) Effects of microwave and hot-air drying methods on colour, β-carotene and radical scavenging activity of apricots. *Int. J. Food Sci. Technol*. **48,** 1327-1333.

AOAC (1999) *Official Method of Analysis*. 2nd edition, Association of Official Analytical Chemists, Washington D.C.

Association of Official Analytical Chemists International (2007) *Official methods of analysis*. 18th ed. 2005; Current through revision 2, 2007 (On-line). AOAC International, Gaithersburg, MD.

Carranza-Concha, J., Benlloch, M., Camacho, M.M and Martínez-Navarrete, N. (2012) Effects of drying and pretreatment on the nutritional and functional quaity of raisins. *Food Bioprod. Process.* **90,** 243-248.

Dewanto, V., Wu, X., Adom, K.K. and Liu, R.H. (2002) Thermal processing enhances the nutritional value of tomatoes by increasing total antioxidant activity. *J. Agric. Food Chem*. **50,** 3010-3014.

Di Scala, K., Vega-Gálvez, A., Uribe, E., Oyanadel, R., Miranda, M., Vergara, J. and Quispe, I. (2011) Changes of quality characteristics of pepino fruit (Solanum muricatum Ait) during convective drying. *Int J Food Sci Technol*. **46**, 746-753.

Gallegos-Infante, J.A., Rocha-Guzman, N.E., Gonzalez-Laredo, R.F. and Pulido-Alonso, J. (2010) Effect of processing on the antioxidant properties of extracts from Mexican barley (Hordeum vulgare) cultivar, *Food Chem.* **119,** 903-906,

Maskan, M. (2001) Drying, shrinkage and rehydration characteristics of kiwifruits during hot air and microwave drying. *J. Food Eng*. **48**, 177-182.

İzli, G. and Yildiz, G. (2021) Evaluation of the high intensity ultrasound pre-treatment effects on the physical properties and bioactive compounds of convective dried quince samples. *Int. J. Fruit Sci.* **21,** 645-656.

İzli, G., Yildiz, G. and Berk, S.E. (2021) Quality retention in pumpkin powder dried by combined microwave-convective drying. *J. Food Sci. Technol.* doi.org/10.1007/s13197-021-05167-5

Mrad, N.D., Boudhrioua, N., Kechaou, N., Courtois, F and Bonazzi, C. (2012) Influence of air drying temperature on kinetics, physicochemical properties, total phenolic content and ascorbic acid of pears. *Food Bioproduct Process.* **9,** 433-441.

Santos, S.C., Guiné, R.P and Barros, A. (2014) Effect of drying temperatures on the phenolic composition and antioxidant activity of pears of Rocha variety (*Pyrus communis L.*). *J. Food Meas. Charact.* **8,** 105-112.

Sultana, B., Anwar, F., Ashraf,M. and Saari, N. (2012) Effect of drying techniques on the total phenolic contents and antioxidant activity of selected fruits. *J. Med. Plants Res.* **6,** 161–167.

Sumnu, G., Turabi, E. and Oztop M. (2005) Drying of Carrots in Microwave and Halogen Lamp-Microwave Combination Ovens. *LWT - Food Sci. Tehnol.*, **38,** 549-553.

Vega-Gálvez, A., Ah-Hen, K., Chacana, M., Vergara, J., Martínez-Monzó, J., García-Segovia, P., Lemus-Mondaca, R. and Di Scala, K. (2012) Effect of temperature and air velocity on drying kinetics antioxidant capacity total phenolic content colour texture and microstructure of apple (var. *Granny Smith*) slices. *Food Chem.* **132,** 51-59.

https://doi.org/10.1021/jf60171a009Wang, J. and Xi, Y.S. (2005) Drying characteristics and quality of carrot using a two-stage process microwave. *J. Food Eng.* **68,** 505-511.

Wojdyło, A., Figiel, A., Lech, K., Nowicka, P. and Oszmiański, J. (2014) Effect of convective and vacuum-microwave drying on the bioactive compounds, color, and antioxidant capacity of sour cherries. *Food Bioprocess Technol.* **7,** 829-841.

Yıldız, G. and İzli G. (2020) *Microwave and Convective Drying Methods on Food Drying*. Ankara, Turkey: Iksad International Publishing House.

Yıldız, G., İzli, G., Çavuş, M. and Ceylan, M.M. (2021) Ultrason Ön İşleminin Kurutulmuş Iğdır Kayısısının Kalite Özellikleri Üzerine Etkisi. *Journal of the Institute of Science and Technology*, **11**, 303-313.

Yildiz, G. and Izli, G. (2019a) Influence of microwave and microwave-convective drying on the drying kinetics and quality characteristics of pomelo. *J. Food Process. Preserv.* **43,** e13812.

Yildiz, G. and Izli, G. (2019b) The effect of ultrasound pretreatment on quality attributes of freeze-dried quince slices: Physical properties and bioactive compounds. *J. Food Process Eng.* **42,** e13223.

Yildiz, G. (2021a) The Effect of Novel Microwave-Convective Drying on the Functional Properties of Dried-Pears (*Pyrus communis*). *Curr. Microw. Chem.* **8,** 22-26.

Yildiz, G. (2021b) The Effect of High Intensity Ultrasound Pre-treatment on the Functional Properties of Microwave-dried Pears (*Pyrus communis*). *Lat. Am. Appl. Res.* **51,**133-137.

Zheng, L. and Sun, D.-W. (2006) Innovative Applications of Power Ultrasound During Food Freezing Processing-a Review. *Trends Food Sci Technol.* **17**, 16-23.

Received: September 15, 2021
Sent to Subject Editor: November 20, 2021
Accepted: December 18, 2021
Recommended by Subject Editor Laura Briand