International Journal of Agricultural Technology 2014 Vol. 10(5):1051-1064
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Effect of Microwave and Solar Drying Methods on the Physico-Chemical Properties of Kiwifruit

Ayadi, A.*, Mechlouch, R. F., Bessaoud, C., Bennour, H. and Debouba, M.

Institut supérieur de biologie appliquée de Médenine (ISBAM), Km 22,5 route el Djorf, 4119, University of Gabès, Tunisia.

Ayadi, A., Mechlouch, R. F., Bessaoud, C., Bennour, H. and Debouba, M. (2014). Effect of microwave and solar drying methods on the physico-chemical properties of kiwifruit. International Journal of Agricultural Technology 10(5):1065-1073.

Abstract Drying kiwifruits by open-air sun drying (OASD) with three samples thickness (4mm; 8mm; 10mm) and microwave drying (MW) with three output powers density (1w/g; 1.5w/g; 2w/g) has been proceeded. The effects of the different drying methods on the physicochemical properties (moisture, pH, °Brix, total phenolics, total flavonoïds, and carotenoïds contents) were assessed. Both drying methods caused decline in Brix and moisture. However, drying kiwifruit by microwave was faster than using OASD method. Whereas fruit pH was decreasing by MW treatments, it was conversely increased by OASD. The highest gain in total phenolics (TP), total flavonoïds (TF) and total carotenoïds (TC) contents was recorded in kiwifruit dried by OASD method.

Keywords: Kiwifruit; Solar drying; Microwave; Physicochemical quality; Phenolics.

Introduction

Kiwifruits have a high antioxidant capacity (Krupa *et al*., 2011) and their regular consumption can reduce DNA fragility (Rush *et al*., 2006). However, this fruit has very short shelf-life because of softening and vitamin loss during storage even at refrigerated conditions (O'Connor-Shaw *et al*., 1994, Agar *et al*., 1999). Drying is a process in which water is removed to halt or slow down the growth of spoilage microorganisms and the occurrence of chemical reactions.

Dehydration plays an important role in extending the shelf life of fleshy agricultural products. In addition to preservation, drying is used to reduce the cost or difficulty of packaging, handling, storage, and transport by converting raw food into a dry solid. This action reduces the weight and sometimes the volume of a food (Orikasa *et al*., 2014).

Maskan (2001) made a comparative study on microwave, hot air and hot air-microwave drying methods of kiwifruits in respect to drying, shrinkage and rehydration characteristics among the three drying techniques. Drying with

* **Corresponding author:** Ayadi, A.**; E-mail:** ayadi.ahlem@gmail.com

microwave energy or assisting hot air-drying with microwave energy resulted in drying rates increase and substantial drying time shortening. Shrinkage of kiwifruits during microwave drying was greater than hot air-drying. Less shrinkage was observed at hot air–microwave drying. Simal *et al*. (2005) evaluated the behavior of kiwifruits at different ripening stages during drying with hot air in order to propose a diffusional model to accurately simulate the drying kinetics at different maturity stages using different air temperatures during dehydration. Regarding to the characteristics of the dried kiwifruits, it was observed that the color of the samples was mainly affected by the drying temperature (Simal *et al.*, 2005).

Erenturk *et al*. (2005) investigated the degradation kinetics of vitamin C for whole rosehip drying using a laboratory dryer at various temperatures. They found that moisture content of solid also decreased with increasing temperature and that C vitamin degradation increased with raising drying air temperature.

Many studies have appeared on the investigation of drying behavior of different fruits. Kaya *et al*. (2007a) determined the effects of drying air temperature, air flow rate and air relative humidity on the drying kinetics of quince, apple Kaya *et al*. (2007b) and pumpkin Kaya *et al*. (2007c) using a convective dryer. Increasing the temperature or velocity of the drying air decreased the total drying time, while decreasing the relative humidity decreased it. Kashaninejad and Tabil (2004) determined the effects of drying air temperature on the drying kinetics of Purslane using an air recirculating dryer. They found that increasing drying temperature decreased drying time but increased drying rate. Nogueira-Terrones *et al*. (2004) evaluated the drying process of Nejayote (a waste product from the tortilla industry) using a hot air cabinet dryer and analyzed the sorption isotherms of the product. They showed that increasing the drying air temperature decreased the equilibrium moisture content and the total drying time.

The objective of the present research is to select an effective drying method that might produce high-quality kiwifruit. Two different drying methods were used (i) micro-wave (MW) with three output powers density (1w/g; 1.5w/g; 2w/g), and (ii) an open-air sun drying (OASD) with three samples thickness (4mm; 8mm; 10mm). Fruit quality was evaluated by determination of moisture, pH, °Brix, acidity, polyphenols, flavonoïds and total carotenoïds content.

Chemicals

All solvents were of reagent grade without any further purification. Gallic acid, rutin and Folin-Ciocalteu's phenol reagents were purchased from Sigma Chemical Co. (St. Louis, MO, USA). The analytical reagent grade methanol

was obtained from Lab-Scan (Labscan Ltd, Dublin, Ireland). The water used in sampling was prepared using a Millipore Simplicity system (Millipore S.A.S., Molsheim, France). Spectrophotometric measurements were performed on a Shimadzu UV-1600 spectrometer (Shimadzu, Kyoto, Japan).

Sample preparation

Kiwifruits have been bought from local producer (Tunis), washed with water and stored at 4℃ for about one day prior to the drying experiment. The average moisture content of the kiwifruit samples was determinate by drying representative samples in a convectional oven at 105-110℃ for 8-10h (AOAC, 1980).

Drying processes

Kiwifruit were subject to two different drying methods, i.e., micro-wave (MW) and open-air sun drying (OASD). In microwave process, Kiwifruit were dried in a programmable domestic microwave oven (HAS-2070M), with maximum output power (700 W) a frequency (2450 MHz) and uncrated weigh (10.5 kg). Samples were subjected to microwaving for 5, 10, 15 and 20 min. Kiwifruit were open-air sun dried for five days at ambient temperature of 25-37℃ and relative humidity of 60 %.

All samples were allowed to cool at room temperature 20℃ for 60 min after thermal treatment and before chemical analysis.

Physical and Chemical Analysis

Determination of titrable acidity, pH and Brix °

Titrable acidity was calculated as percentage of citric acid by titrating 10 ml of the kiwifruit juice with a solution of NaOH (0.1N) till pH 8.1. The pH was measured by a pH meter (InoLab, Germany). The level of sugars was measured as °Brix by a digital refractometer, (Models 10430, 0- 30 ^{o}Brix, Cambridge Instruments Inc, USA).

Methanolic extract preparation

Dried kiwifruit slides (10 g) were stirred with 100 ml MeOH at 30℃ for overnight. The extract was filtered through Whatman no. 1 filter paper for removal of seed particles. The residue was re-extracted with 60 ml methanol.

The obtained extracts were filtered again, pooled and concentrated under vacuum at 40 °C. These methanolic extracts were used for different analysis.

Determination of total phenolic and flavonoïds contents

The Folin-Ciocalteu method was used to measure the total phenolic compounds. For the analysis, from each sample, 0.5 mL of methanolic extract solution was added to 0.5 mL of Folin-Ciocalteu reagent (Prolabo, Paris France), followed by 4 mL of 1M sodium carbonate. Next, the test tubes were incubated at 45 °C for 5 min and then cooled in cold water. Absorbance was measured at 765 nm, using a Shimadzu 1600-UV spectrophotometer (Shimadzu, Kyoto, Japan). The results were compared to a gallic acid calibration curve, and the total phenolic compounds were determined as mg gallic acid equivalents per 100g dry weight (GAE mg/ 100g DW). Determination of each sample was performed in triplicate.

Total flavonoïds were measured spectrophotometrically, in triplicate, following the method described previously (Elfalleh *et al*., 2009). This method based on the formation of a complex flavonoïds-aluminium, having the maximum absorbance at 430 nm. Rutin was used to make a calibration curve. One ml of methanolic extract was mixed with 1 ml of 2% $AlCl_3$ methanolic solution. After incubation at room temperature for 15 min, the absorbance of the reaction mixture was measured at 430 nm using a Shimadzu 1600-UV spectrophotometer. The flavonoïds content was expressed as rutin equivalents in mg per 100 g dry weight (mg RE/100 g DW).

Determination of total carotenoïds contents

The quantification of carotenoïds as xanthophylls and carotenes entail with the determination of chlorophyll (Chl) Chla and Chlb by UV-VIS spectroscopy. Chlorophyll and carotenoïds were extracted from kiwifruit using a method modified by Gitelson et al. (2003). Briefly, samples were put into a pre-chilled tube, and ground for 3 min in 1 ml extraction buffer (80% acetone: Tris-HCl [1%, w/v]). After the pigments were completely extracted by the buffer, an additional 1 ml extraction buffer was used to wash the pestle. All extraction solutions were combined and debris was removed by centrifugation. A volume of 1 ml of the supernatant was diluted to 3 ml final solution. The light absorbance of the final solution was measured at 663, 647 and 470 nm. The concentrations of carotenoïds and chlorophyll were calculated as described by Lichtenthaler (1987). All experiments were done in triplicate and the carotenoïds contents were converted to mg per kg of fresh weight.

Statistical analysis

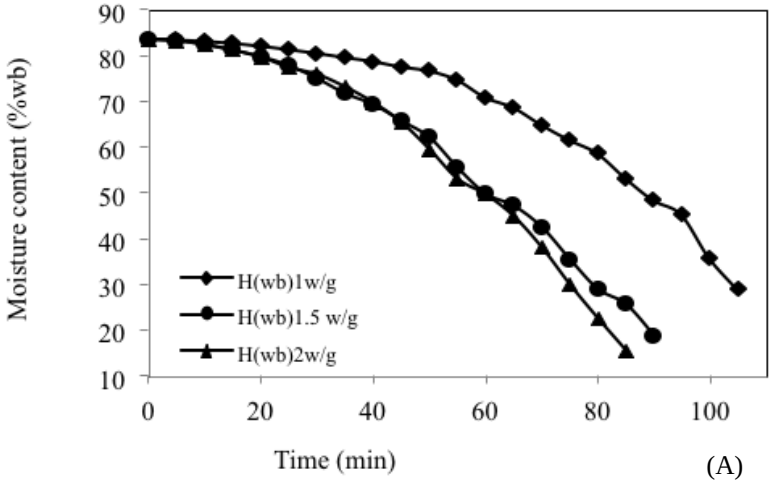
Data were analyzed, using SPSS (Version 17.0) statistical software. SPSS package was used to perform one-way-analysis of variance (ANOVA) and Least Significant Difference test (LSD) at a 95% confidence level ($p < 0.05$) to identify significant differences among samples within the evaluated parameters. The results of compound contents were reported as mean values of three replicates (mean ± standard deviation, n = 3). Data were compared on the basis of standard deviation of the mean values.

Results and discussions

The effect of drying method on the moisture content

We assessed the change in moisture content (wb) with drying time (drying curve) at different microwave output powers densities (1W/g; 1.5W/g; 2W/g) (Fig. 1A). The initial moisture content was 84±0.21% (wb). Similar and faster moisture decrease was recorded in 1.5W/g and 2W/g relative to 1W/g output power density (Fig. 1A). Moisture dropped to 50% after 60 and 95min following kiwifruits exposure to 1.5W/g and 2W/g, respectively.

Slower moisture changes were observed under OASD (Fig. 1B) in comparison to MW methods (Fig. 1A), but microwave still has limited load compared to direct solar dryer and open-air sun drying. Moisture decrease reached 50% after 4 and 12 hours for samples of 4 and 8mm thickness, respectively (Fig. 1B).



(A)

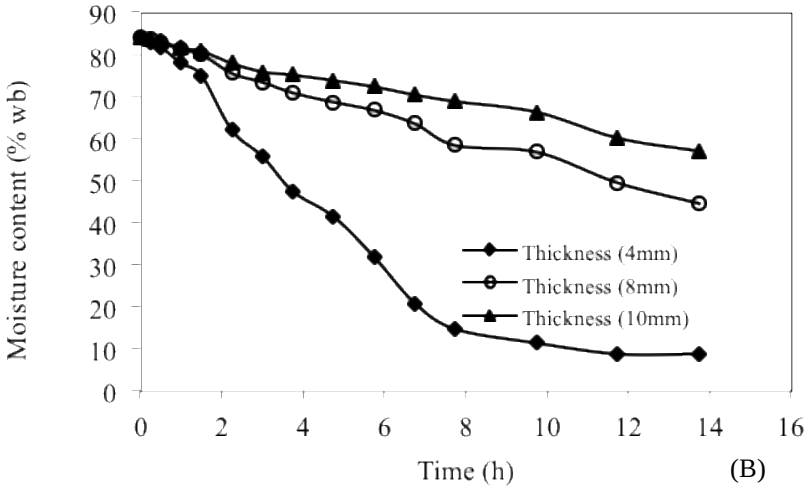


Fig. 1. Effect of (A) microwave output powers density (1w/g; 1.5w/g; 2w/g) and (B) open-air sun drying at three samples thickness (4mm; 8mm; 10mm) on drying time (min).

The effect of drying methods on the quality of kiwifruits

Table 1 shows physicochemical characteristics of dried kiwifruit by microwave and open air sun drying.

Analysis of titrable acidity, pH and Brix

The pH variation were significantly affected by the drying process ($p<0.001$), the lower value was found in kiwifruit samples dried by microwave (2W/g; 60mn). There were no significant differences in pH values between samples dried by MW at 1W/g and 1.5W/g (Table 1). OASD (4mm; 14h) and OASD (8mm;14h) have the same effect on pH and the values were 3.43 ± 0.15 and 3.56 ± 0.30, respectively (Table 1).

Our results showed that the different drying processes caused pronounced decrease in Brix content in dried kiwifruit relative to Fresh one. No significant differences ($p<0.01$) in Brix content could be recorded between treated samples (about 5%).

The titrable acidity values were significantly affected by the drying process ($p<0.01$). The highest value was found in the sample dried by OASD (10mm; 14h). There was no significant difference on the titrable acidity values (about 0.51g/L) for samples treated by MW (1.5W/g;60mn), MW(2W/g; 60mn) and OASD (8mm; 14h). The lowest value of the titrable acidity was observed for fresh sample (0.33 ± 0.06) (Table 1).

Table 1. The effect of drying methods on the pH, Brix, titrable acidity, polyphenol, flavonoïds and carotenoïds content

Drying method	pH	°Brix (%)	Acidity(g/L)	Polyphenols (mg/100g)	Flavonoïds (mg/100 g)	Carotenoïds (µg/100g)
Fresh kiwifruit	3.26^{a} ±0.15	11^{a} ±0.75	0.33^{d} ±0.06	2.24^{f} ±0.21	1.36^{e} ±0.06	0.10^{b} ±0.06
MW (1W/g; 60mn)	2.98^{d} ±0.06	5.52^{b} ±0.09	0.58c^{b} ±0.03	5.51^{d} ±0.30	8.96^{c} ±1.60	0.02^{c} ±0.00
MW (1.5W/g; 60mn)	2.91^{d} ±0.13	5.56^{b} ±0.41	0.52^{c} ±0.03	6.00^{c} ±0.30	7.13^{d} ±1.38	0.09^{b} ±0.04
MW (2W/g; 60mn)	2.73^{e} ±0.30	5.25^{b} ±0.47	0.51^{c} ±0.18	4.82^{e} ±1.02	6.56^{d} ±1.02	0.11^{b} ±0.04
OASD (4mm;14h)	3.43^{b} ±0.15	6.00^{b} ±1.00	0.62^{b} ±0.27	6.80^{b} ±0.60	11.56^{b} ±1.2	0.40^{a} ±0.06
OASD (8mm ; 14h)	3.56^{b} ±0.30	5.23^{b} ±0.50	0.52^{c} ±0.06	6.96^{b} ±0.24	17.54^{a} ±0.9	0.11^{b} ±0.06
OASD (10mm ; 14h)	3.20^{c} ±0.30	5.10^{b} ±0.45	0.76^{a} ±0.03	7.70^{a} ±1.20	9.54c ±1.20	0.12^{b} ±0.06

Values are means ± standard deviations. Values in column with different letter superscripts are significantly different at $p \leq 0.05$. ANOVA applies between drying methods.

Analysis of total phenolics and total flavonoids

In the fresh kiwifruit, total phenolic contents (TPC) were significantly ($p<0.05$) lower (2.24±0.21 mg/ 100g DW), compared to these in dried samples (Table 1). The highest phenolics content were found in kiwifruit dried by OASD (10mm; 14h), OASD (8mm; 14h) and OASD (4mm; 14h). Total phenolic contents in samples treated by Sun Drying are higher than that treated by microwave (Table 1). We can also deduce that no significant ($p<0.05$) differences in total phenolic contents between samples treated by OASD (4mm; 14h) and OASD (8mm; 14h).

Total flavonoïds content (TFC) in different treated kiwifruit samples were significantly ($p<0.05$) higher compared to that in fresh kiwifruit. The highest total flavonoïds contents were measured in samples treated by OASD (8mm; 14h) and OASD (4mm; 14h), respectively. The lowest total flavonoïds content was reported in fresh kiwifruit (Table 1).

The relatively high levels of polyphenols and flavonoïds in sun dried kiwifruit may be due to greater exposure to sunlight.

Analysis of total carotenoïds content (TCC)

Total carotenoïds contents were significantly ($p<0.005$) higher in dried kiwifruit samples except for samples treated by MW at 1W/g and 1.5W/g (Table 1). The highest value was found in the samples dried by OASD (4mm; 14h). It can be seen that TCC was higher for the samples treated by sun than that treated by microwave.

Conclusion

The drying process was investigated for drying kiwifruit by two methods: Open Air Sun Drying (OASD) at different samples thickness (4mm; 8mm; 10mm) and Microwave (MW) with three output power densities (1w/g; 1.5w/g; 2w/g). Experiments were carried out and overall results suggested that drying had a significant impact on the physicochemical properties and the following conclusions can be drawn from this study:

Different drying processes resulted in declines in Brix and moisture.

Microwave drying (1W/g; 60mn) and (1.5W/g; 60mn) had lesser effect on decrease of moisture content compared to (2W/g; 60mn).

Kiwifruit pH was decreased by microwave drying but it was increased by open-air sun drying method.

The highest gain in TPC, TFC and TCC was found at samples dried by open-air sun drying.

As an overall conclusion, compared to open-air sun drying, microwave drying can reduce the drying time and successfully be used to produce good quality dried kiwifruits in terms of TPC, TFC, and TCC. But microwave still has limited load compared to open-air sun drying.

References

Agar, T.I., R. Massantini, B. Hess-Pierce and A.A. Kader (1999). Postharvest CO2 and ethylene production and quality maintenance of fresh-cut kiwifruit slices. Journal of Food Science 64:433-440.

AOAC. (1980). Official methods of analysis, association of analytical chemists Tnc., Washington, DC.

Elfalleh W., Nasri, N., Marzougui, N., Thabti, I., Rabet, I. M., Yahia, Y., Lachiheb, B., Guasmi, F. and Ferchichi, A. (2009). Physico-chemical properties and DPPH-ABTS scavenging activity of some local pomegranate (*Punica granatum*) ecotypes. International Journal of Food Science Nutrition 60:197-210.

Erenturk, S., Gulaboglu, M. S. and Gultekin, S. (2005). The effect of cutting and drying medium on vitamin C content of rosehip during drying. Journal of Food Engineering 68:513-518.

Kashaninejad, M. and Tabil, L. G. (2004). Drying characteristics of purslane (*Portulaca oleraceae* L.) Dry Technology 22:2183-2200.

Kaya, A., Aydin, O. and Demirtas, C. (2007). Concentration boundary conditions in the theoretical analysis of convective drying process. Journal of Food Process Engineering, 30:564-577.

Kaya, A., Aydin, O. and Demirtas, C. (2007). Drying kinetics of red delicious apple. Biosystems Engineering 96:517-524.

Kaya, A., Aydin, O., Demirtas, C. and Akgun, M. (2007). An experimental study on the drying kinetics of quince. Desalination 212:328-343.

Krupa, T. P. and Liwińska, A. (2011). Changes of physicochemical quality, phenolics and vitamin C content in hardy kiwifruit (Actinidia arguta and its hybrid) during storage. Scientia Horticulturae 130:410-417.

Lichtenthaler, H. K. (1987). Chlorophyll florescence signature of leave the autumnal chlorophyll breakdown. Journal of Plant Physiology 131:101–110.

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

Nogueira-Terrones, H., Herman-Lara, E., Garcia-Alvardo, M. A. and Monroy-Rivera, J. A. (2004). Drying kinetics and sorption isotherms of the Nejayote, Dry Technology 22:2173-2182.

O'Connor-Shaw, R. E., Roberts, R., Ford, A. L and Nottingham, S. M. (1994). Shelf-life of minimally processed honeydew, kiwifruit, papaya, pineapple and cantaloupe. Journal of Food Science 59:1202-1206.

Orikasa, T., Koide, S., Okamoto, S., Imaizumi, T., Muramatsu, Y., Takeda, J. I., Shiina, T. and Tagawa, A. A. (2014). Impacts of hot air and vacuum drying on the quality attributes of kiwifruit slices. Journal of Food Engineering 125:51-58.

Rush, E., Ferguson, L. R., Cumin, M., Thakur, V., Karunasinghe, N. and Plank, L. (2006). Kiwifruit consumption reduces DNA fragility: a randomized controlled pilot study in volunteers. Nutrition Research 26:197-201.

Simal, S., Femenia, A., Carcel, J. A. and Rossello, C. (2005). Mathematical modeling of the drying curves of kiwifruits: influence of the ripening stage. Journal of the Science of Food and Agriculture 85:425-432.

(Received 17 April 2014; accepted 31 August 2014)