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Effect of oven and microwave drying on phenolic compounds and antioxidant capacity of coriander leaves

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Abstract

In the present study, the effects of two drying methods on antioxidant properties of coriander leaves were investigated. For the rate of drying, results showed that sample weight stability was reached faster in microwave (900 W/70 s) than in oven drying (120°C/290 s). Concerning antioxidants, results showed that the highest total polyphenols and total flavonoids contents were recorded by leaves dried in microwave (48.44 mg GAE/g and 20.28 mg RE/g, respectively) than those dried in oven (26.64 mg GAE/g and 19.60 mg RE/g, respectively). At the end, the assessment of radical scavenging activity against stable radical ABTS and DPPH showed an increase in scavenging effect particularly when microwave technology was used.

Introduction

Fruits and vegetables play an important role in human nutrition, as they are important source of vitamins, minerals as well as phytochemical substances (Craig *et al.*, 1999; Boudries *et al.*, 2015). Fresh coriander leaves are perishable in nature and a considerable amount of the produce is wasted due to lack of post-harvest processing facilities. Drying is the most widely used primary method of food preservation (Ahmed *et al.*, 2001). It is the process of removing the moisture in the product up to certain threshold value by evaporation. In this way, the products can be stored for a long period (Alibas Ozkan *et al.*, 2007).

The increasing demand for high-quality shelf-stable dried vegetables requires the design, simulation and further optimization of the drying process with the purpose of accomplishing not only the efficiency of the process but also the final quality of the dried product. Conventional drying involves the exposure of food and agricultural products to high temperature and long treatment times, which can result in serious damage of flavour, colour, rehydration capacity and nutrients of the treated material as well as low energy efficiency (Drouzas *et al.*, 1999; Sharma *et al.*, 2004; Ozbek and Dadalli, 2007). Owing to these reasons, development of new methods of drying for such perishable vegetables is essential for food preservation, which can save time and energy and minimize quality degradation.

Over the last two decades, microwave drying has gained popularity as an alternative to conventional one (Bouraoui *et al.*, 1994; Tulasidas *et al.*, 1995); it has several advantages over conventional hot air drying, such as higher drying rate, minimal heating at locations with less water, thus reducing overheating of atmosphere (Sharma *et al.*, 2004).

Several studies concerning the drying effect of agricultural crops have been done through the world (Turhan *et al.*, 1997; Ramesh *et al.*, 2001; Doymaz and Pala, 2002); however, in Algeria, this field is still new because there is few published articles. The aim of this study was to determine the effect of drying method on antioxidant properties of coriander leaves.

Materials and Methods

Chemicals

ABTS and DPPH reagents were purchased from Sigma Chemical (Sigma–Aldrich GmbH, Germany), Folin–Ciocalteu phenol reagent from Biochem, Chemopharma (Montreal, Quebec). All chemicals and solvents used were of analytical grade.

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Plant material

Three bunches of fresh coriander plants (*Coriandrum sativum* L.) were purchased from a market (Bejaia, Algeria). The leaves which length varied from 1.5 to 2 cm were separated from theirs stems and used immediately.

Oven drying

One hundred grams of coriander leaves were dried in oven (MEMMERT, Germany) at 40, 60, 80, 100 and 120°C. The mass was periodically measured (each one hour) until stability. Three replications of each experiment were performed and the weight loss (%) was calculated using the following equation:

$$\text{Weight loss } (\%) = \frac{w_t \, . \, 100}{w_0} \qquad (1)$$

w_0 and w_t are initial weight and the weight at specific time, respectively.

Microwave drying

Five grams of coriander leaves were dried in a domestic digital microwave oven (NN-S674MF, Kuala Lumpur, Malaysia). Five different microwave powers (100, 300, 500, 700 and 900 W) were used. The mass was periodically measured (each five seconds) until stability. Three replications of each experiment were performed and the weight loss (%) was calculated using equation 1.

Grinding and sieving

Dried samples were grounded with an electrical grinder (IKA A11 basic) and sieved. The fraction with particle size <125 µm was used. The powder was stored in glass jars, sealed and kept in dark until needed.

Microwave assisted extraction

One gram of powder was extracted with 60 mL of ethanol 50%. The extraction was carried out using a domestic microwave oven. The microwave assisted extraction parameters obtained by Dahmoune *et al* (2013) (400 W and 123 s for microwave power and extraction time, respectively) were used and the extracts filtered through Whatman paper n° 1.

Total polyphenols

The method used for determination of total polyphenols content (TPC) was that described by Singleton and Rossi (1965) with slight modifications. Aliquots of 500 µL of extract were mixed with 2.5 mL of Folin–Ciocalteau reagent (10%). After incubation for two minutes, 2 mL of sodium carbonate solution (7.5%) was added and again incubated at 50°C for 15 min in darkness. The absorbance was recorded at 760 nm using a UV–Vis spectrophotometer (Model: SpectroScan 50, Nicosia, Cyprus) and result expressed as mg gallic acid equivalents (GAE) per g.

Total flavonoids

The total flavonoids content (TFC) was determined according to the method reported by Djeridane *et al.* (2006), which consist to mix two equal volumes of extracts and Aluminium chlorides ($AlCl_3$, 2% in methanol). The mixture was rested for 15 min in darkness at room temperature. After incubation, the absorbance was measured at 430 nm and result expressed as mg rutin equivalent (RE) per g.

ABTS radical scavenging capacity

The ABTS radical scavenging capacity was determined according to the method described by Re *et al.* (1999), which is based on the ability of antioxidants to interact with the ABTS radical, and hence decreasing its absorbance at 734 nm. Briefly, ABTS radical solution (7 mM ABTS and 2.45 mM potassium persulfate) was prepared in ethanol and left to stand in the dark at room temperature (27°C) for 12-16 h before use. This solution was then diluted with ethanol to get an absorbance of 0.70 ± 0.02 at 734 nm. For the antioxidant activity analysis, 2 mL of the diluted radical solution were mixed with 100 µL of extract and incubated in darkness for 6 min and the absorbance was read at 734 nm against ethanol. The inhibition percentage was calculated using the following equation:

$$\text{Inhibition } (\%) = \left(\frac{A_C - A_S}{A_S}\right).100 \qquad (2)$$

A_c and A_s are absorbances of control and sample, respectively.

DPPH radical scavenging capacity

The DPPH radical scavenging capacity was evaluated according to the method described by Brand and Williams (1995) with slight modifications. Equal volumes of DPPH radical solution (70 µM in methanol) and extracts were mixed. The absorbance was measured at 517 nm after incubation (20 min at 37°C). The inhibition percentage was calculated using equation (2).

Statistical analysis

All analyses were carried out in triplicate and the experimental data were expressed as means ± standard deviation. The software STATISTICA®5.5 was used to compare the different results by the analysis of variance with one factor (ANOVA). Differences between the means at 5, 1 and 0.1% levels ($p<0.05$ or 0.01 or 0.001) were considered statistically significant.

Results and Discussion

Impact of drying on samples weight

Because the water represents a source of degradation of the phenolic compounds by enzymatic oxidation such as the polyphenols-oxydase, which modifies their structures (Tomas-Barberan and Espin, 2001), the drying allows eliminating water while protecting bioactive compounds content of the sample.

For oven drying, the effect of temperature on coriander leaves dehydration is presented in Table 1a. It was observed that weight loss had proportional relationship with temperature drying and non-proportional one with time drying. At 40°C, the drying time takes 264 min while 48 min at 120°C; hence, the total time of drying was reduced substantially with the increase of temperature. In this line, Ahmed *et al.* (2001), when studying drying coriander leaves using a cabinet dryer at 45, 50, 55, 60 and 65°C, reported similar results (drying times up to 4 hours); however, Silva *et al*., (2005) reported 10 hours as time drying when they dried coriander leaves in fixed bed dryer.

Concerning the microwave drying, the effect of power output on coriander leaves weight is presented in Table 1b. It can be observed that the increasing microwave power output increases substantially the weight loss and thus decreasing drying time. This observation indicates that moisture content was affected by microwave power input and drying time (345 to 70 s as the power input increased).

Table 1. Temperature, end weight loss and time of Oven drying (a) and power, end weight loss and time of Microwave drying (b)

(a)

Temperature (°C)	End weight loss (%)	Drying times (min)
40	59.48	264
60	48.52	160
80	48.96	88
100	42.98	72
120	33.62	48

(b)

Power (watt)	End weight loss (%)	Drying times (s)
100	14.50	960
300	10.27	765
500	9.60	430
700	9.23	335
900	8.78	290

Total polyphenols

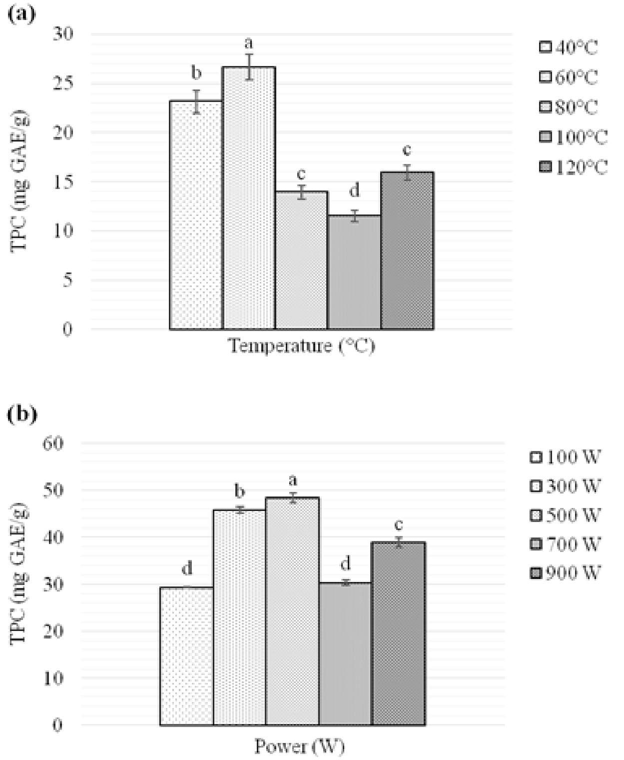
The TPC results of coriander leaves dried in oven and microwave are presented in Figures 1a-b. For oven drying, temperature had a significant influence ($p<0.05$) on TPC, obtaining the highest content (26.64 mg GAE/g) at 60°C, while 100°C led to the lower TPC (11.53 mg GAE/g) (Figure 1a). These results were in line with those reported by Vega-Gálvez *et al.* (2009) who studied the effect of air-drying temperature on physico-chemical properties, antioxidant capacity, colour and TPC of red pepper (*Capsicum annuum* L); these authors reported that the highest TPC, which was reached at 60°C, decreased in high temperatures (70 and 80°C).

Concerning microwave drying, results of TPC are presented in Figure 1b. The highest TPC was recorded at 500 W (48.44 mg GAE/g) while the lowest one was at 100 and 700 W (29.33 and 30.39 mg GAE/g). According to Inchuen *et al.* (2010), the highest TPC in microwave-dried sage plants could be explained by the fact that the intense heat generated from the microwaves creates a high vapour pressure and temperature inside plant tissue, resulting in the disruption of plant cell wall polymers thus causing more phenolics to be extracted. However, excessive output power (or temperature) led to the decrease of antioxidant compounds (Dong *et al*., 2011).

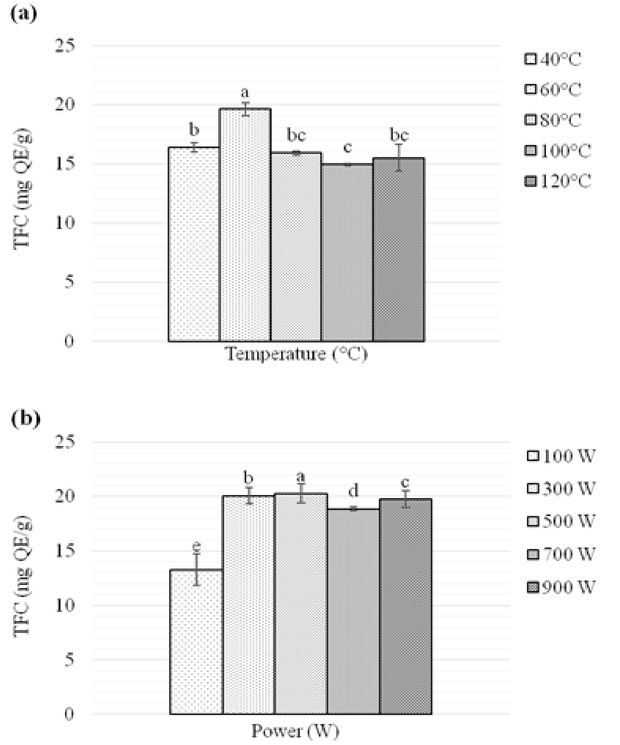
In order to appreciate the coriander TPC level, the amount of this antioxidant in some foods were mentioned. It was reported the amount of 64.5 mg/100 g FW of red pepper (Zhang and Hamauzu, 2003), 38.5 to 50.7 and 35.4 to 43.1 mg/100 g FW of watermelon rind and flesh, respectively (Tarazona-Díaz *et al*., 2011), 670.9, 303.6, 244.1, 59.0 and 50.9 mg/100g FW of blueberry, plum, strawberry, fig and peach, respectively (Marinova *et al*., 2005).

Total flavonoids

The TFC results of coriander leaves dried in oven and microwave are presented in Figures 2a-b. From the Figure 2a, it can be seen that TFC of samples dried in oven were ranked from 14.92 to 19.60 mg RE/g; the drying temperature of 60 and 100°C allowed recording the highest and the lowest contents, respectively. Furthermore, TFC of samples dried in oven did not show any significant differences ($p<0.05$) at temperature of 40°C (16.36



Different letters means there is a significant effect at $p < 0.05$.
Figure 1. Total polyphenols content of coriander leaves dried in oven (a) and microwave (b)



Different letters means there is a significant effect at $p < 0.05$.
Figure 2. Total flavonoids content of coriander leaves dried in oven (a) and microwave (b)

mg RE/g), 80°C (15.89 mg RE/g) and 120°C (15.50 mg RE/g). According to Schieber (2001), the loss of macromolecules like flavonoids during heat treatment might be due to the harsh drying conditions, in particular, the temperature and duration used.

Concerning TFC of samples dried in microwave, the results are shown in Figure 2b. Samples treated by high output power 300 - 500 W recorded the highest TFC (20.07-20.28 mg RE/g); whereas, 100 W displayed the lowest amount. In this line, Dong *et al*. (2011) reported that the contents of TFC in samples treated by high output power (560 -700 W) were higher than those treated by lower output power (140 - 430 W). As for TPC, temperature (or output power) lower than that displayed high amount of TFC did not allow enough disruption of plant cell wall polymers causing better extracted; however, higher than optimal temperature (or output power) led to the decrease of TFC.

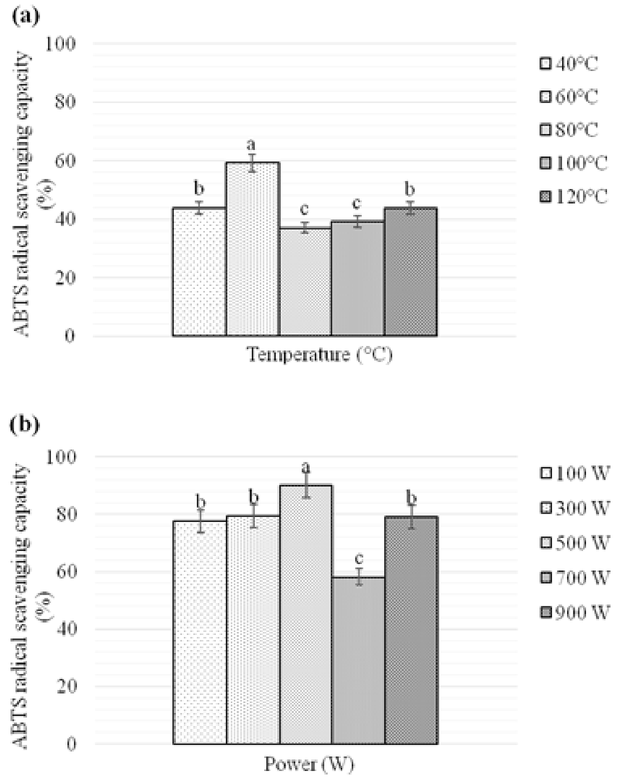
In order to appreciate the coriander TFC level, the amount of this antioxidant in some foods were mentioned. It was reported the amount of 190.3, 136.2, 69.7, 20.2 and 15.0 mg/100g FW of blueberry, plum, strawberry, fig and peach, respectively (Marinova *et al*., 2005).

ABTS radical scavenging capacity

The ABTS radical scavenging capacity results of coriander leaves dried in oven and microwave expressed in terms of inhibition percentage are shown in Figures 3a-b. As can be seen in Figure 3a, the highest ABTS radical scavenging capacity was obtained at 60°C with an inhibition of 59.30% followed by the sample dried at 40, 100, 80, and 120°C (43.86, 39.19, 37.10 and 43.84%, respectively).

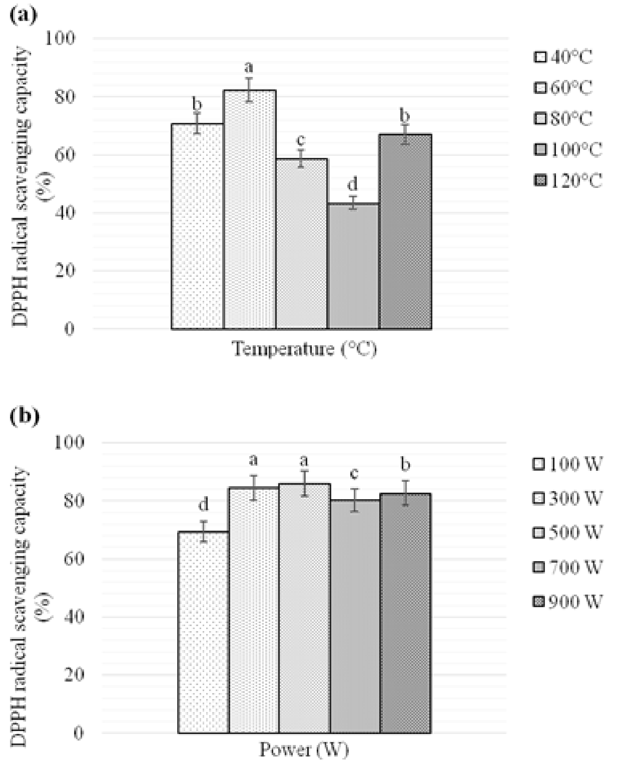
Concerning samples dried in microwave, ABTS radical scavenging capacity results were ranged from 58.16 to 90.18% (Figure 3b). The highest activity was obtained at 500 W with 90.18% while the lowest one was at 700 W with only 58.16%. The results were in agreement with those obtained by Sim and Sil (2008) who studied the antiradical efficiency of pericarp of red pepper extracts against the ABTS radical; these authors found a strong antiradical activity.

The tendency of ABTS radical scavenging capacity of coriander leaves dried in oven and microwave displayed the increase of the activity until reaching the highest value by increasing temperature or output power. This fact maybe due to the release of antioxidant compounds from plant cells. Nevertheless, over than optimal condition of temperature or output power, the antioxidant activity decreased because of the antioxidant compounds deterioration. Moreover, the noted increase of the antioxidant activity under extreme condition of temperature or output power might be due to generation and accumulation of



Different letters means there is a significant effect at $p < 0.05$.

Figure 3. ABTS radical scavenging capacity of coriander leaves dried in oven (a) and microwave (b)



Different letters means there is a significant effect at $p < 0.05$.

Figure 4. DPPH radical scavenging capacity of coriander leaves dried in oven (a) and microwave (b)

Maillard derived melanoidins, which have a varying degree of antioxidant activity, and then enhance antioxidant properties (Miranda *et al*., 2009).

DPPH radical scavenging capacity

The DPPH radical scavenging capacity results of samples dried in oven and microwave expressed in terms of inhibition percentage are shown in Figures 4a-b. As for ABTS radical scavenging capacity, samples displayed a same tendency for the DPPH scavenging capacity. For samples dried in oven (Figure 4a), DPPH scavenging capacity results showed significant differences ($p<0.05$) for the samples dried under various temperatures. The sample dried at 60°C showed the highest capacity to neutralize the radical (82.21%) followed by that dried at 40°C (70,79%) ; however, the increase of temperature decreased the activity to 58.76 and 43.42% at drying temperature of 80 and 100°C, respectively. Our result was in concordance with that reported by Hamrouni-Sellami *et al.* (2013) who observed that temperature of 65°C led to the highest radical scavenging activity of plante. Moreover, the inhibition of 67.02% at drying temperature of 120°C might be due to generation and accumulation of Maillard derived melanoidins, which have a varying degree of antioxidant activity, and then enhance antioxidant properties (Miranda *et al*., 2009). In another study, Vega-Gálvez *et al*. (2009) reported that dehydration at high temperatures (80 or 90°C) gave a higher antioxidant activity rather than at low temperatures like 50, 60 or 70°C.

Concerning samples dried in microwave, DPPH radical scavenging capacity results are shown in Figure 4b. The high inhibitions capacity were obtained at microwave output power of 300 and 500 W (84.5 and 84.59%, respectively); while the lowest one (69.50%) was at 100 W. Hamrouni-Sellami *et al.* (2013) observed that output power of 800 W gave the highest radical scavenging activity of plants.

Conclusions

The conventional drying of coriander leaves could reduce moisture content below the maximum value in 48 min at 120°C, whereas it took 264 min at 40°C; while for non-conventional drying, 290 and 960 s were needed to reach the requirement at 100 and 900 W, respectively. Moreover, it was found that the highest TPC and TFC were recorded by leaves dried in microwave (48.44 mg GAE/g and 20.28 mg RE/g, respectively) than those dried in oven (26.64 mg GAE/g and 19.60 mg RE/g, respectively). In other words, non-conventional drying remains better the antioxidant compounds. Finally, the obtained results in the present study demonstrated that there is a non-proportional relationship between drying conditions and both antioxidant compounds and antioxidant capacity.

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References

Ahmed, J., Shivhare, U. S. and Singh, G. 2001. Shorter Communication: Drying characteristics and product quality of coriander leaves. Food and Bioproducts Processing 79: 103-106.

Alibas Ozkan, I., Akbudak, B. and Akbudak, N. 2007. Microwave drying characteristics of spinach. Journal of Food Engineering 78: 577-583.

Boudries, H., Souagui, S., Nabet, N., Ydjedd, S., Kefalas, P., Madani, K. and Chibane, M. 2015. Valorisation of Clementine peels for the recovery of minerals and antioxidants: Evaluation and characterisation by LC-DAD-MS of solvent extracts. International Food Research Journal 22: 1218-1226.

Bouraoui, M, Richard, P. and Durance, T. 1994. Microwave and convective drying of potato slices. Journal of Food Process Engineering 17: 353-363.

Brand-Williams, W., Cuvelier, M. E. and Berset, C. 1995. Use of a free radical method to evaluate antioxidant activity. Food Science and Technology 28: 25-30.

Craig, W. and Beck, L. 1999. Phytochemicals: health protective effects. Canadian Journal of Dietetic Practice and Research 60: 78-84.

Dahmoune, F., Boulekbache, L., Moussi, K., Aoun, O., Spigno, G. and Madani, K. 2013. Valorisation of citrus limon residues for the recovery of antioxidants: Evaluation and optimization of microwave and ultrasound application to solvent extraction. Industrial Crops and Products 50: 77-87.

Deng, G.F., Lin, X., Xu, X.R., Gao, L.L., Xie, J.F. and Li, H.B. 2013. Antioxidant capacities and total phenolic contents of 56 vegetables. Journal of Functional Foods 5: 260-266.

Djeridane, A., Yousfi, M., Nadjemi, B., Boutassouna, D., Stocker, P. and Vidal N. 2006. Antioxidant activity of some Algerian medicinal plants extracts containing phenolic compounds. Food Chemistry 97: 654-660.

Dong, J., Ma, X., Fu, Z. and Guo, Y. 2011. Effects of microwave drying on the contents of functional constituents of *Eucommia ulmoides* flower tea. Industrial crops and products 34: 1102-1110.

Doymaz, I. and Pala, M. 2002. Hot-air drying characteristics of red pepper. Journal of Food Engineering 55: 331-335.

Drouzas, A. E., Tsami, E. and Saravacos, G. D. 1999. Microwave/vacuum drying of model fruit gels. Journal of Food Engineering 39: 117-122.

Hamrouni-Sellami, I., Rahali, F. Z., Rebey, I. B., Bourgou, S., Limam, F. and Marzouk B. 2013. Total phenolics, flavonoids, and antioxidant activity of sage (*Salvia officinalis* L.) plants as affected by different drying methods. Food Bioprocess Technology 6: 806-817.

Inchuen, S., Narkrugsa, W. and Pornchaloempong, P. 2010. Effect of drying methods on chemical composition, color and antioxidant properties of Thai red curry powder. Kasetsart Journal of Natural Science 44: 142-151.

Marinova, D., Ribarova, F. and Atanassova, M. 2005. Total phenolics and total flavonoids in bulgarian fruits and vegetables. Journal of the University of Chemical Technology and Metallurgy 40: 255-260.

Miranda, M., Maureira, H., Rodriguez, K. and Vega-Gálvez, A. 2009. Influence of temperature on the drying kinetics, physicochemical properties, and antioxidant capacity of Aloe Vera (*Aloe Barbadensis* Miller) gel. Journal of Food Engineering 91: 297-304.

Özbek, B. and Dadali, G. 2007. Thin-layer drying characteristics and modelling of mint leaves undergoing microwave treatment. Journal of Food Engineering 83: 541-549.

Ramesh, M. N., Wolf, W., Tevini, D. and Jung, G. 2001. Influence of processing parameters on the drying of spice paprika. Journal of Food Engineering 49: 63-72.

Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M. and Rice-Evans, C. 1999. Antioxidant activity applying an improved ABTS radic al cation decolorization assay. Free Radical Biology and Medicine 26: 1231-1237.

Schieber, A., Keller, P. and Carle, R. 2001. Determination of phenolic acids and flavonoids of apple and pear by high-performance liquid chromatography Journal of Chromatography A 910: 265-273.

Sharma, G. P. and Prasad, S. 2004. Effective moisture diffusivity of garlic cloves undergoing microwave-convective drying. Journal of Food Engineering 65: 609-617.

Silva, A. S., Almeida, F. A. C., Gouveia, J. P. G. and Lima, E. E. 2005. Cinética de secagem das folhas do coentro variedade verdão, p 4. En XXXIV Congresso Brasileiro de Engenharia Agrícola, Canoas, Anais.

Sim, K. H. and Sil, H. Y. 2008. Antioxidant activities of red pepper *(Capsicum annuum)* pericarp and seed extracts. International Journal of Food Science and Technology 43: 1813-1823.

Singleton, V. L. and Rossi, J. A. J. R. 1965. Colorimetry of total phenolics with phosphomolybdic phosphotungstic acid reagents. American Journal of Enology and Viticulture 16: 144-158.

Tarazona-Díaz, M. P., Viegas, J., Moldao-Martins, M. and Aguayo, E. 2011. Bioactive compounds from flesh and by-product of fresh-cut watermelon cultivars. Journal Science Food Agriculture 91: 805-812.

Tomas-Barberan, F. and Espin., J. C. 2001. Phenolic compounds and related enzymes as determinants of quality of fruits and vegetables, Journal of the Science of Food and Agriculture 81: 853-876.

Tulasidas, T. N., Raghavan, G. S. V. and Mujumdar, A. S. 1995. Microwave drying of grapes in a single mode cavity at 2450 MHz: drying kinetics. Drying Technology 13: 1949-1972.

Turhan, M., Turhan, K. N. and Sahbaz, F. 1997. Drying kinetics of red pepper. Journal of Food Processing and Preservation 21: 209-223.

Vega-Gálvez, A., Scala K. D., Rodríguez, K., Lemus-Mondaca, R., Miranda, M. and Perez-Won, P. 2009. Effect of air-drying temperature on physico-chemical properties, antioxidant capacity, colour and total phenolic content of red pepper (*Capsicum annuum*, L. var. Hungarian). Food Chemistry 117: 647-653.