EXPERIMENTAL STUDY ON FIGS SUN-DRYING: A TRADITIONAL RENEWABLE, CHEAP AND ENVIRONMENTALLY FRIENDLY TECHNIQUE

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Abstract
This work aims to investigate the drying behavior of figs and the influence of the process on some quality parameters of dried figs. In this study, the drying kinetics and diffusion coefficients were determined experimentally for the Roshnik fig variety, collected in Berat, Albania. Modeling of drying curves was performed for pre-treated samples with bleaching and $K_2S_2O_5$ and untreated samples. Dried fig fruits were evaluated for physico-chemical parameters and antioxidant activity. Results showed that the best fitted model of the drying curve resulted in a two-term model, and the diffusion coefficients for all samples ranged from 1.25 to 3.125 x10-10 m^2/s. The pre-treatments applied played an important role in the drying rate and enhanced the quality of the dried products, from which the best results were achieved for the pre-treated sample bleached plus $K_2S_2O_5$. The total polyphenolic content was in fresh fig fruits at 81.66 gallic acid equivalents (GAE) 100 g^{-1} and ranged in dried fig fruits at 117.88–174.44 mg GAE 100 g^{-1}. The antioxidant activity resulted in 8.87–29.85 mg ascorbic acid equivalents/ 100 g^{-1}. Even under mild drying conditions, a high degradation of vitamin C occurred. This experimental work showed that sun-drying is a sustainable technique and that pretreatment could be beneficial for applications by food processors, providing a shorter drying time and enhancing product quality.

Keywords: fig fruit, sustainable drying technique, pretreatment.

Introduction

The drying of fruit and vegetables is one of the oldest forms of food preservation known to man and is the most important process for preserving food since it has a great effect on the quality of the dried product (Doymaz, 2005). Figs are one of the earliest cultivated fruits, with several varieties that are dried and stored for later consumption (Vinson, 1999). Fig fruit can be dried either by traditional methods (sun drying) or in conventional hot-air dryers (Babalis et al., 2006).

During the drying of solids, two processes occur simultaneously: the transfer of energy from the surrounding environment and the transfer of moisture from within the solid. On comparison of the drying kinetics of fruit and vegetable systems, the nature of the product was found to impart a significant influence on the drying behavior (Perry, 1997).

Recently, there has been much research on the mathematical modeling and experimental studies of the drying behavior of various fruits, such as grapes (Dincer, 1996; Doymaz & Pala, 2002; Kostaropoulos & Saravacos, 1995), apricots (Mahmutoglu, Pala, & Unal, 1995; Togrul & Pehlivan, 2004), figs (Babalis & Belessiotis, 2004), prickly pear (Lahsni, Kouhila, Mahrouz, &

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Jaouhari, 2004), plum (Doymaz, 2004a; Sabarez, Price, Back, & Woolf, 1997), and mulberry (Doymaz, 2004b; Maskan & Gogus, 1998).

Despite the many advances in drying techniques in recent years, much has still to be accomplished before all available raw materials can be successfully dried at an economic cost to give quality products with the required degree of functional.

Studies on the drying of figs are scarce in the literature. Therefore, the present study was undertaken to study the drying behavior of the "Roshnik" fig variety directly exposed to the sun; also, the application of pretreatments and their influence on quality parameters will be investigated.

Materials and Methods

Plant material

For this study, the local variety of Ficus carica named "Roshnik" (yellow skin color and red pulp), traditionally sun-dried, was selected. Its cultivation area is Roshnik village (40°42'51.56" N, 19°58'48.02" E) in the Berat region. Fruits were harvested in the middle of August 2017 at optimal maturity and immediately transported to the laboratory. The selection of fruits was done based on weight in order to ensure uniform size, appearance, maturity, and health conditions.

Sample preparation and drying conditions

Before drying, fruits were pre-treated as follows: blanching in boiling water with 1% NaCl solution for 1 min; cooling to 252 ºC using tap water (blanching water to fruit ratio was 12:1); also, fruit were dipped in 0.2% K2S2O5 (KMS) for 1 min (sample code BS-KMS); only treated with KMS (sample code KMS); and untreated samples were used as controls (sample code C).

Sun-drying process

The fruits were set on a mesh in three repetitions per treatment and exposed directly to sunlight during the day from 8 a.m. to 20 p.m. They were manually turned twice a day, while during the night they were covered in order to avoid absorbing air humidity. The average temperature during the day ranged from 39 to 44 ºC, and the process lasted approximately 5 to 3 days.

Preparation of extracts

Methanol extracts were prepared by extracting 1 ± 0.001 g of grinded fig samples with 10 ml of aqueous methanol 80% (v/v), homogenizing for 1 minute using Ultra-Turrax T-25 (Ika-Labortechnik, GR), with speed set at 11000 1/min, and centrifuged using centrifuge Eba 21 (Hettich, GR) for 15 min at 4500 rpm. This process was repeated three times, and the supernatants were collected and analyzed. Extracts of fresh and dried fig samples were prepared separately. All samples were analyzed in triplicate.

Assessments and determinations

The weight of the material was measured in fixed time intervals using a precision balance with

The weight of the material was measured in fixed time intervals using a precision balance with an accuracy of 0.001 g. The drying data from the different drying tests were then expressed as moisture ratio (MR) versus drying time and drying rate (DR) versus moisture rate in order to determine drying kinetic and diffusion coefficients.

The moisture content was determined, both for the fresh and for the final dried products, according to AOAC (2000); pH was determined using the pH meter UB-10 (UltraBasic, Denver

Instrument) (AOAC 2000); TSS was measured using an ABBE refractometer; and total acidity (expressed as % citric acid) was determined by titrating with 0.1N NaOH (AOAC 2000).

The total phenolic content of the extracts was determined according to the method of Singleton and Rossi (1965) with some modifications, and the results were expressed as gallic acid equivalents (mg GAE 100 g^{-1} DM^{-1} (dry matter of the sample). Total flavonoid content was measured using AlCl3, a colorimetric method (Zubair et al., 2013), and results were expressed as (+) catechin equivalents (mg CE 100 g^{-1} DM^{-1} of sample). Total anthocyanin's content was measured according to the pH differential method (Cheng and Bren, 1991), and results were expressed as cyanidin-3-glucoside equivalents (mg C3G 100 g^{-1} DM^{-1} of sample).

Results and Discussions

The results are given on Table 1 and Figures 1-3. The weight of pre-selected fig fruits was 28.61 ± 1.28 g, with yellow skin colour and red pulp.

Table 1. *Physico-chemical parameters of fresh and dried Roshnik fig varieties*

Roshnik fig variety	Acidity[a] (% citric acid)	Dry matter[a] (%)	pH[a]	Ash (%)
fresh	0.18±0.005	37.31±0.19	5.91±0.01	1.05±0.09
Control	0.61±0.015	77.35±0.15	4.35±0.005	2.15±0.16
Bleached	0.58±0.005	78.85±0.16	4.55±0.005	2.35±0.11
B-KMS	0.55±0.007	77.62±0.10	4.67±0.005	2.25±0.15
KMS	0.56±0.014	76.28±0.02	4.66±0.005	2.1±0.10

(a: mean value ± standard deviation)

Referring to Table 1, the dry matter was 37.31% for fresh figs, while for dried figs it was higher (77.35–78.85%). The ash content was higher than 1%. The total soluble solids (TSS) of fresh fruit were 27 °Brix, and the higher content of total soluble solids makes it more suitable for drying. Titratable acidity, expressed as citric acid, resulted in being concentrated after drying; accordingly, after the drying process, the pH values decreased with an increase in total acidity. The ratio between the analyzed sugars and organic acids in fresh figs is a common quality index and a good indicator of internal fruit quality, which resulted in 150, which is a high ratio. In fact, the higher the ratio, the sweeter the fruits, and the best are for drying. The optimal ratio differs between cultivars, and it is crucial for a harmonious flavor (Slatnar et al. 2011). The above data were in the range reported (Piga et al., 2004; Slatnar et al., 2011) for this fruit species.

In the drying curve in Figure 1, it is obvious that it decreases during drying time. In an attempt to model the drying curve, the moisture ratio (MR) was simplified to M/M0 instead of (M-Me)/(M0-Me), where M0, M, and Me are initial, after time (t), and equilibrium moisture contents, respectively. This was done because the relative humidity of the drying air continuously fluctuated under sundry conditions (Diamante & Munro, 1993). According to the results, the two-term model was best fitted to sun-drying figs. This finding was in accordance with the work of Doymaz (2005). Two-term model: $MR = a\exp(-k_o t) + b\exp(-k_1 t)$, a=0.837497, b=0.164923, k_o=0.024954, k_1=0.314409.

The higher drying time was achieved for control samples (185,217 s), followed by KMS samples (173,868 s), while for bleached samples there was a reduction in drying time (132,657 s (BS) and 139,074 s (B-KMS).

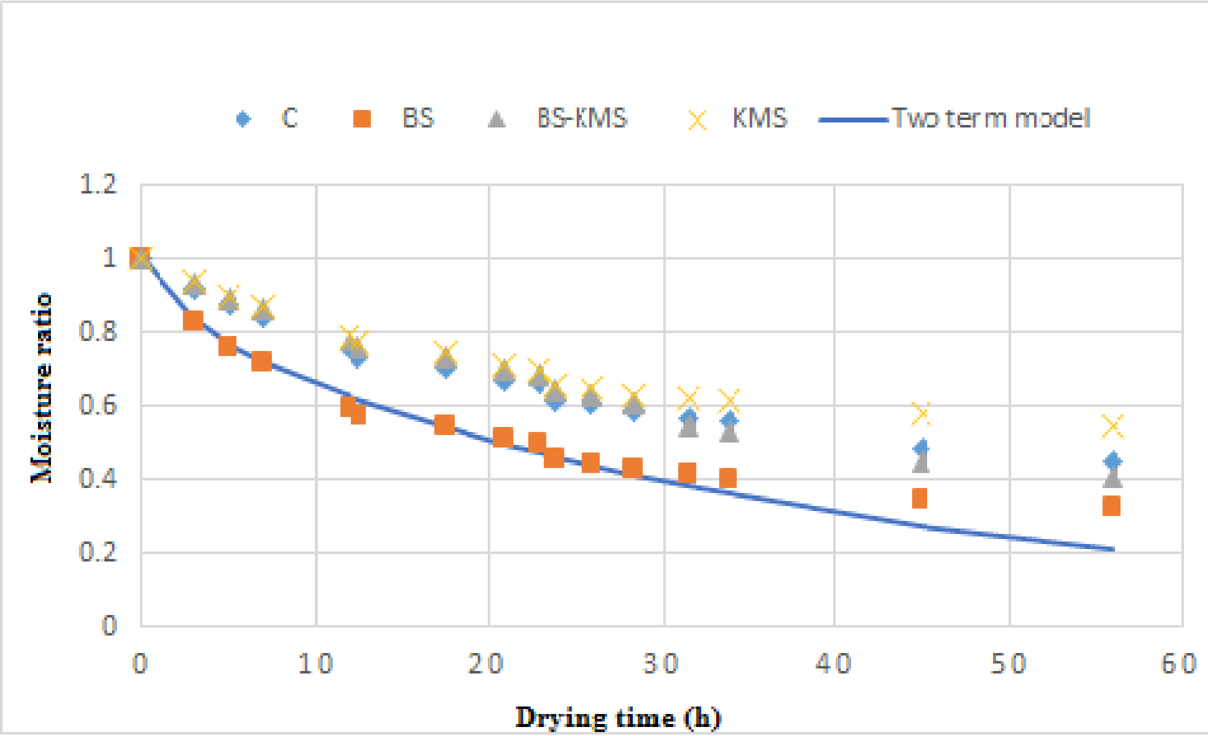

Figure 1: The drying curves of tested samples, relative moisture content, and drying time in minutes

The positive role of pre-treatment applied in drying time reduction was in accordance with other studies (Piga et al., 2004; Lewicki, 2006). Also, the drying process influenced the appearance and quality parameters of the product. The browning resulted in untreated dried samples due to the high amount of sugars, in particular reducing sugars, which have the ability to interact with amino acids (non-enzymatic browning reaction). The application of pre-treatment resulted in a positive effect on the retention of color, shape, and soft structure for samples according to the order: BS < KMS < BSKMS.

From the drying curves of samples in Figure 2, a constant-rate period and a falling-rate period were noted. The drying rate was higher in the constant rate due to the rapid movement of the moisture within the fig fruit, capable of maintaining a saturated condition at the surface, while the rate of mass transfer balanced the rate of heat transfer and the temperature of the saturated surface remained constant. In the falling-rate period, which began at the critical moisture content when the constant-rate period ended, the drying process occurred. Since the critical moisture content is the average moisture through the material, its value depends on the rate of drying, the thickness of the material, and the factors influencing moisture movement and resulting gradients within the solid. During this period, the first zone was shorter than the second one. These results agreed with the observations of earlier researchers (Doymaz, 2005; Lahsasni et al., 2004; Togrul & Pehlivan, 2004).

From the experimental data of drying curves, diffusion coefficients were calculated, and resulted from 1.25 to 3.125 x10^{-10} m^2/s. The estimated diffusion coefficient values lie within the general range of 10^{-11} to 10^{-8} m^2/s of food materials (Zogzas et al., 1996).

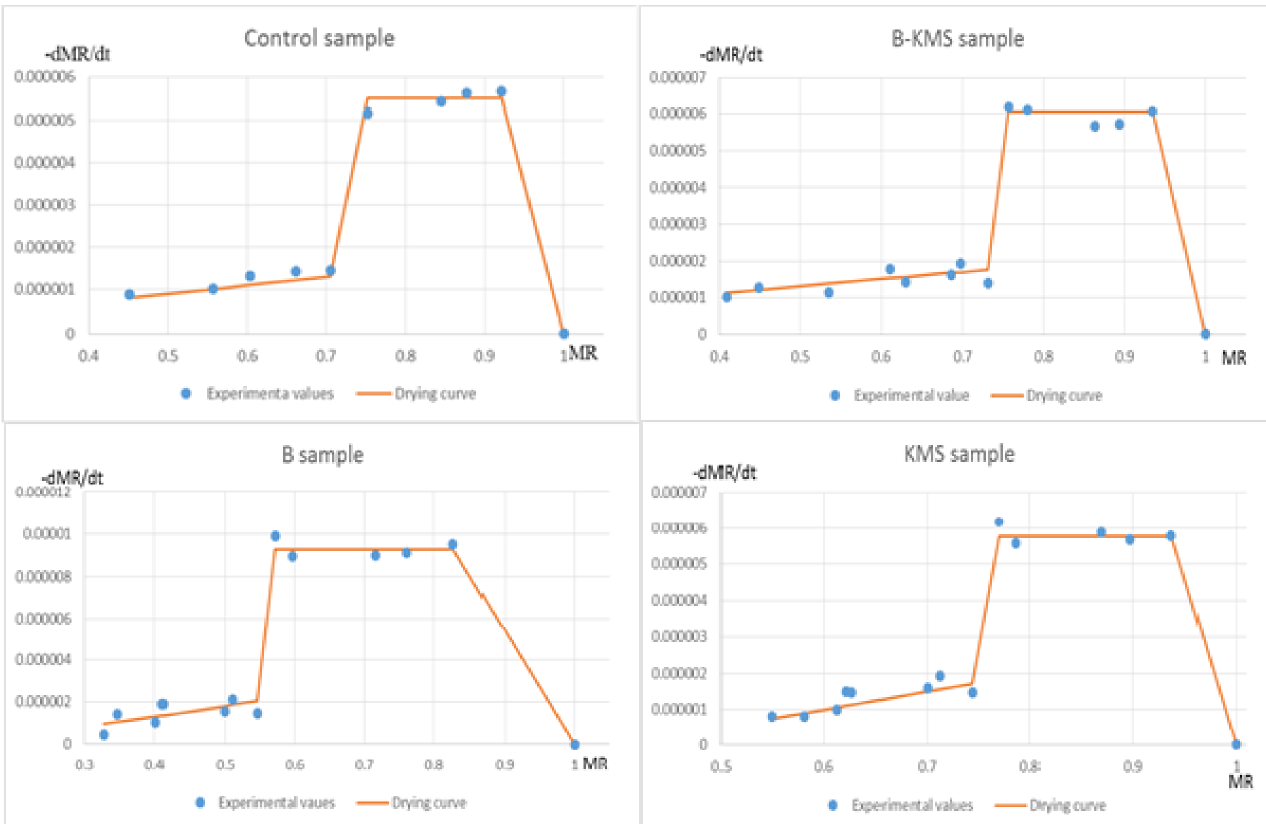

Figure 2: The drying curves of different pre-treated samples: drying rate versus relative moisture.

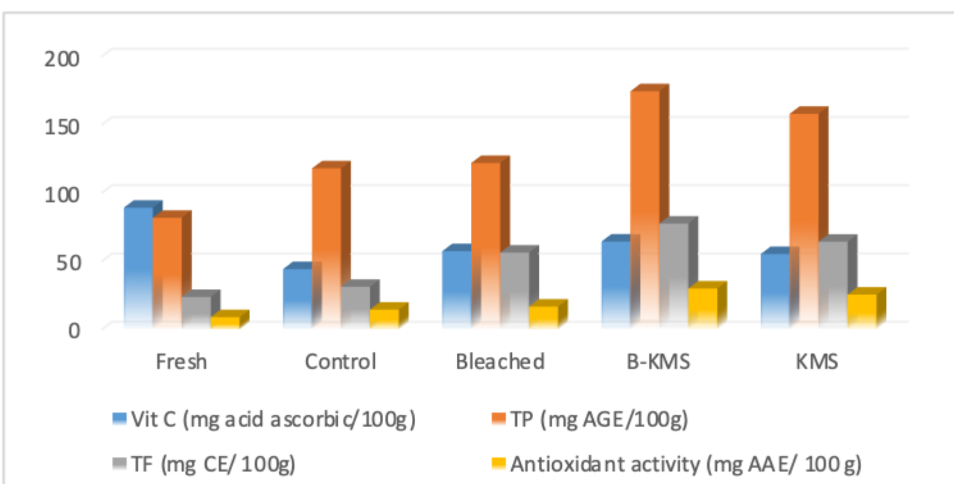

Figure 3: Antioxidant compounds and total antioxidant activity for fig samples.

Figure 3 shows that the total polyphenolic (TP) content of fresh and dried figs before and after pre-treatment was, for fresh figs, 81.66 ± 0.76 GAE per 100 g, and in dried fruits, it ranged between 117.88 and 174.44 mg GAE 100 g^{-1} DM^{-1}. Pre-treated samples had different phenolic content, and it could be said that bleaching plus KMS had a positive effect on the content of polyphenols, as these dried samples resulted in higher content than others. Accordingly, the same trend of values was seen for total flavonoids (23.58–77.43 mg CE 100 g^{-1} DM^{-1}) and antioxidant activity (8.87–29.85 mg AAE g^{-1} DM^{-1}). Anthocyanins were absent in dried figs, as the drying process influenced their degradation. Fresh figs were detected in small amounts due to their red pulp (0.58 mg C3G per 100). Many studies show a good correlation between polyphenolic compounds and antioxidant activity. Antioxidant activity was higher in all dried fig varieties compared to fresh figs. The results for vitamin C given in Figure 3 show that the drying process influences vitamin C degradation, even under mild conditions. In general, the highest values for all antioxidant compounds resulted from the BS-KMS sample, which leads us to the conclusion that the application of dipping in 1% NaCl solution and then in 0.2% KMS solution gives better results and could be recommended as a good alternative for the sun-drying process.

Conclusions

The sun-drying is a cheap method, traditionally applied in Albania for figs drying. Different tests undertaken for pre-treated or not figs, sun-drying behaviour showed that drying took place in the falling rate. The best fitted model for the drying curve resulted Two-term model. Also, from the results was found that application of pre-treatments are necessary, in terms of speeding up the process and positive effect in the product quality including: color, shape, soft texture, and overall acceptability, also for the content of antioxidant compounds, widely known for their beneficial role in human health. The best results in terms of dried figs quality were achieved according to the order: BS < KMS < BSKMS.

Local farmers mostly use sulfur pre-treatment in order to maintain the white peel color, but the final product results in a high amount of SO2, so we could recommend the application of the above-tested pre-treatment as a good, effective, and beneficial alternative.

Despite some disadvantages of sun-drying concerned with safety issues, we recommend the use of solar energy as a potent source of energy that is renewable and non-polluting, but improvements should be made to facilitate the process through pre-treatment involvement, speeding up the process and improving the quality of the final product.

Selected fig variety "Roshnik" showed an Albanian agricultural product with high economic potential, and further attempts should be made for modeling and simulation of fig drying processes at the industrial level in Albania.

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References

AOAC International. 2000. Official methods of analysis of AOAC International. 17th edition. Gaithersburg, MD, USA, Association of Analytical Communities.

Babalis, S.J., Belessiotis, V.G., 2004. Influence of the drying conditions on the drying constants and moisture diffusivity during the thin-layer drying of figs. J Food Eng. 65: 449–458.

Babalis, S.J., Papanicolaou, E., Kyriakis, N., Belessiotis, V.G., 2006. Evaluation of thin-layer drying models for describing drying kinetics of figs (Ficus carica). J Food Eng. 75 (2): 205–214.

Cheng, G.W., Breen, P.J., 1991. Activity of phenylalanine ammonia-lyase (PAL) and concentrations of anthocyanins and phenolics in developing strawberry fruit. J Am Soc Hortic Sci. 116: 865–869.

Determination of Soluble Solids FU Analysis Federation of Fruit No. 8 (Rev. 2005) Refractometric method (UNE-EN 12143)

Diamante, L. M., & Munro, P. A. (1993). Mathematical modelling of thin layer solar drying of sweet potato slices. Solar Energy, 51, 271–276.

Dincer, I. (1996). Sun drying of sultana grapes. Drying Technology, 14(7–8), 1827–1838.

Doymaz, I. (2004a). Effect of dipping treatment on air drying of plums. Journal of Food Engineering, 64, 465–470.

Doymaz, I. (2004b). Pretreatment effect on sun drying kinetics of mulberry fruits (Morus alba L.). Journal of Food Engineering, 65, 205–209.

Doymaz, I., & Pala, M. (2002). The effects of dipping pretreatments on air-drying rates of the seedless grapes. Journal of Food Engineering, 52, 413–417.

Doymaz, I., 2005. Sun drying of figs: an experimental study. J Food Eng. 71: 403–407.

Kostaropoulos, A. E., & Saravacos, G. D. (1995). Microwave pretreatment for sun-dried raisins. Journal of Food Science, 60, 344–347.

Lahsasni, S., Kouhila, M., Mahrouz, M., & Jaouhari, J. J. (2004). Thin layer convective solar drying and mathematical modeling of prickly pear peel (Opuntia ficus indica). Energy, 29, 211–224.

Lewicki, P.P., 2006. Design of hot air drying for better foods. Trends Food Sci. Technol. 17: 153–163

Lewicki, P.P.; (2006). Design of hot air drying for better foods. Trends Food Sci. Technol. 17: 153–163

Mahmutoglu, T., Pala, M., & Unal, M. (1995). Mathematical modelling of moisture, volume and temperature changes during drying of pretreated apricots. Journal of Food Processing and Preservation, 19, 467–490.

Maskan, M., & Gogus, F. (1998). Sorption isotherms and drying characteristics of mulberry (Morus alba). Journal of Food Engineering, 37, 437–449

McMinn W. A. M. and Magee T. R. A. 1999. Principles, methods and applications of the convective drying of foodstuffs. Trans I Chem E, Vol 77, Part C

Perry, R.H.; (1997). Green, D.W. Perry's Chemical Engineers' Handbook, 7th Ed.; McGraw-Hill: New York.

Piga, F., Pinna, I., Özer, K.D., Agabbio, V., Aksoy, U., 2004. Hot air dehydration of figs (Ficus carica L.): drying kinetics and quality loss. Int. J Food Sci. Tech. 39: 793–799.

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

Sabarez, H. T., Price, W. E., Back, P. J., & Woolf, L. A. (1997). Modelling the kinetics of d_Agen plums (Prunus domestica). Food Chemistry, 60(1), 371–382.

Singleton, V. L., Rossi, J. A., 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. Am. J. Enol. Vitic. 16: 144–158.

Slatnar, A., Klancar, U., Stampar, F., Veberic, R., 2011. Effect of Drying of Figs (Ficus carica L.) on the Contents of Sugars, Organic Acids, and Phenolic Compounds. J. Agric. Food Chem. 32: 1-9.

Togrul, I. T., & Pehlivan, D. (2004). Modelling of thin layer drying kinetics of some fruits under open-air sun drying process. Journal of Food Engineering, 65, 413–425.

Vinson, J.A. (1999). The functional food properties of figs. Am. Assoc. Cereal Chem. Inc. 44(2): 82-87.

Zogzas, N.P.; Maroulis, Z.B.; Marinos-Kouris, D. (1996). Moisture diffusivity data compilation in foodstuffs. Drying Technology, 14 (10), 2225–2253.

Zubair, M.; Hassan, S.; Rizwan, K.; Rasool, N.; Riaz, M.; Zia-Ul-Haq, M.; Defeo, V.; (2013). Antioxidant potential and oil composition of Callistemon viminalis leaves. The Sci World J, 2013:1–8.