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Combined effects of drying method and variety on the quality of dried figs

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Abstract

Tunisian environmental conditions permitted perfect adaptation of fig trees (*Ficus carica* L.). However, fresh figs are very perishable due to their high-water content and considerable losses are recorded. Drying is one of the practical technologies and helps to preserve product's quality and increase the availability of figs throughout the year. This study concerned the effect of two solar drying techniques (open air and greenhouse) on the physicochemical and biochemical characteristics of two local varieties Bither Abiadh (*San pedro* type) and Bidhi (*Smyrna* type). The results showed that the moisture content of dried figs was around 18% indicating no significant effect of the drying type and the variety. The observed variation in water activity was attributed mainly to varietal effect. Bither Abiadh showed the highest moisture content and water activity. Compared to open air drying, greenhouse improved the external color of figs of the two varieties which showed the highest values of yellowness and brightness. Drying in a greenhouse allowed also having total phenolic content approximately twice as high as that drying at open air for both varieties. Bidhi revealed the highest content (1098 mg GA / 100g DM). The variations of major mineral compounds (Mg, P, K, Ca) were also mainly due to the varietal effect. Bidhi showed the highest amounts. While the type of drying had a significant effect on the content of traces elements (Mn, Fe, Cu, Zn). High temperatures of the greenhouse generated a decrease of the levels of trace elements. These results demonstrated several advantages of tunnel drying over traditional air drying. This technique deserves further research in the local conditions of farmers.

1. Introduction

The fig tree (*Ficus carica* L.) has been cultivated since a very long time in several regions of the world. Fig production is mainly located around the Mediterranean basin or in regions with similar climatic conditions. It is also widely cultivated in tropical and subtropical countries for its commercial value [1]. Fig is a seasonal fruit and three types are grown commercially: the *Common* type, which develops fruits parthenocarpically, the *Smyrna* type, non-parthenocarpic, which requires pollination and the *San Pedro* type, which produces parthenocarpically fruits and the main crop after pollination [2]. Fruits can be consumed fresh, either peeled or not, dried, as jam and also as juice [3]. Fresh and dried figs, considered as a traditional food, provide high amounts of calcium, potassium and dietary fibres, and bioactive compounds compared to other fruits [4]. They are important sources of vitamins (thiamin and riboflavin) and containing over than 17 types of amino acids [5, 6, 7]. Besides its nutritional value, fig fruits are widely consumed for its therapeutic properties confirmed by epidemiological studies [8]. They are exploited in traditional medicine [9, 10]. Figs are rich in phenolic compounds and contain antioxidants, which prevent pathogenic processes associated with cancer, cardiovascular diseases; diabetes and can enhance immune function [11]. However, fig is very perishable and conducive to various degradations. This can lead to very high losses. Hence, conservation techniques are used as an alternative for the preservation of its nutrients. Drying is one of the ways commonly used for effective preservation of figs [8]. Sun drying has been practiced widely since ancient times [12]. The main objective of drying is to increase the shelf life of the product by means of a reduction in the moisture content and water activity in order to inhibit microbial growth and enzymatic activity [13, 14]. The advantage of using drying is not only technically convenient, but the costs of processing, packaging, transportation, and storage are less for dried products than canned and frozen foods [15]. Dried figs have economic benefits and are widely appreciated by both industrial users and individual consumers [16]. In Tunisia, fig tree has a very important value and represents a tradition inherited since many generations. A wide diversity of fig varieties adapted to the different regions has been investigated by several authors [17, 18]. Despite its high potentialities, fig crop remains under-valued. Drying techniques increases the availability of figs throughout the year. The aim of this study was to evaluate the effect of two drying techniques: direct solar drying (open air) and solar drying in a greenhouse, on the quality of dried figs of two local varieties.

2. Material and Methods

2.1. Plant material

Fig varieties selected for this study were 'Bither Abiadh' (*San Pedro* type) (average diameter= 39.89 mm± 4.7) and 'Bidhi' (*Smyrna* type) (average diameter= 47.31 mm± 4.42). Fruits (main crop) of both varieties were collected from the governorate of Mahdia in Central-Eastern of Tunisia.

2.2. Drying methods

Two types of drying system have been studied: direct solar drying (open air) and solar drying in a greenhouse. Fresh figs are put (10 kg /variety for each type of drying) on perforated wooden tables with nets on the inside, raised from the ground and covered by an insect proof (Fig.1). Drying started in august. The drying period at open air was 18 days, while in a greenhouse it was 10 days.

Figure 1. Drying process of Bither Abiadh and Bidhi figs

2.3. Physico-chemical analysis

Dried fruits have been analyzed for several parameters. Moisture content was determined according to the AOAC method [19]. Water activity of dried figs was determined with a Novasina aw Sprint TH 500 analyzer. Fruit skin color parameters (L*(darkness/lightness), a*(green/ red) and b*(blue/yellow)) were measured using a colorimeter CM Minolta 508i (Osaka, Japan). Mineral analysis was carried out according to the official method [20]. The mineral elements (Mg, K, Ca, Mn, Fe, Co, Cu, Zn) were analyzed by atomic absorption spectrometry, whereas phosphorus (P) was determined by a colorimetric reaction using a spectrophotometer at 430 nm. All measurements were carried out for three replications except the color which was measured on a dozen fruits.

2.4. Biochemical analysis

Total phenolic content (TPC) was determined using the method described by Singleton and al. (1999) [21]. The absorbance of the solution was measured at 760 nm on a UV-VIS spectrophotometer. Results were expressed as mg of gallic acid equivalents (GAE) on a dry weight (DW) (mg GAE/100 g DW). The antioxidant activity of dried figs was measured by the DPPH method using spectrophotometer (Biochrom Libra S60) at 515 nm [22]. Three replications were made for these analyzes.

2.5. Statistical analysis

Statistical analysis of the data was carried out using SPSS 20. For each parameter, analysis of variance was carried out in order to determine the level of significance of the differences between the varieties and between the drying methods by applying the general multivariate linear model. Mean values relative to drying methods were submitted to one-way analysis of variance (ANOVA) and separated by Duncan's test ($P \leqslant 0.05$).

3. Results and discussion

2.1. Dried fig color

Color is an important characteristic that is especially important in products that contain considerable amount of total sugars, particularly reducing sugars which have the ability to interact with amino acids resulting in non-enzymatic browning reaction [23]. 'Bither Abiadh' and 'Bidhi' provided clear fruits for which a yellow or clear color is a sign of good quality. Compared to open drying, greenhouse drying improved the external color of figs (Fig.2) with the highest yellowness (b*) and brightness (L*) values (Table 1).

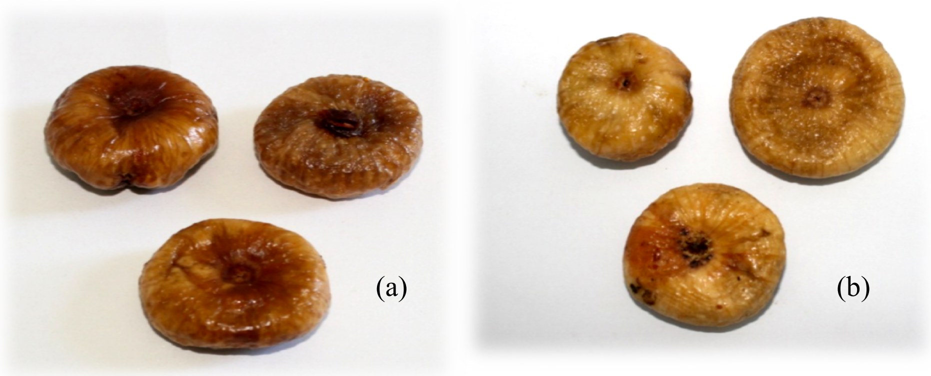

Figure 2. Color of 'Bither Abiadh' dried figs: (a): at open air; (b): in greenhouse

In direct sun-drying, climatic conditions and light intensity exert significant impact on product color [24]. This result is similar to those found by Chimi et al. [25] who indicated that direct sun drying of figs destroyed color, vitamins and flavor.

Table 1: Effect of drying systems on the external color of dried figs

	Bidhi		Bither Abiadh		Effect of variety (V)	Effect of drying type (DT)	Interaction VxDT
	Open air	Greenhouse	Open air	Greenhouse			
CEL*	29.93±6.5	53.34±7.17	34.92±8.96	45.75±7.06	**	**	ns
CEa*	7.41±1.65	9.35±1.76	9.41±2.96	8.31±1.79	ns	ns	ns
CEb*	16.63±4.35	27.49±4.81	19.88±7.44	28.25±5.58	ns	**	ns
CEC	18.28±4.35	29.13±4.55	22.12±7.62	29.49±5.59	ns	**	ns
CEh	1.14±0.1	1.24±0.09	1.11±0.12	1.28±0.06	ns	**	ns

ns: not significant, ** : highly significant (P< 0,01)

2.2. Moisture and water activity

The purpose of the drying operation is to reduce considerably the water present in an initially wet product. It is therefore a question of achieving a product capable of being preserved considering the main microbiological and enzymatic activities. The activity of water (*aw*) is an important parameter to follow during drying, it characterizes the availability of "free" water. This is the part of water which actively participates in exchanges with the ambient environment which will have an influence on the microbiological stability of the product, allowing the growth or the inhibition of the microorganisms.

The results showed no significant effect of drying type or variety on the moisture content of dried figs which was around 17-18% (Table 2). The variations observed were attributed mainly to the varietal effect. Bither Abiadh showed the highest activity and moisture content (Table 2). The changes in *aw* values were similar to the loss of water content due to the significant relationships between these two parameters [26].

Table 2: Effect of drying systems on moisture and water activity of dried figs.

	Bidhi		Bither Abiadh		Effect of variety (V)	Effect of drying type (DT)	Interaction VxTS
	Open air	Greenhouse	Open air	Greenhouse			
Moisture (%)	16.72±1.87	17.87±3.02	18.82±1.21	18.74±1.9	ns	ns	ns
Water activity (aw)	0.65±0.01	0.66±0.01	0.68±0	0.7±0.01	**	**	ns

ns: not significant, ** : highly significant (P< 0,01)

2.3. Total phenolic content (TPC) and antioxidant activity (AA)

Highly significant differences were recorded between the two varieties for total phenolic content and antioxidant activity. Drying in a greenhouse permitted to have total phenols content higher two times than that recorded with open air drying for both varieties. Bidhi exhibited the highest content (1098 mg GA / 100g DM) (Table 3). The decrease in the total phenol content with open air drying may be due to the degradation of phenolic compounds by enzymes. Madrau et al. [27] reported that drying apricots for a long time in the presence of oxygen promotes the degradation of polyphenols through polyphenoloxidase (PPO). This enzyme was responsible for the oxidation of phenolic compounds and their polymerisation into dark brown polymers called melanins [28]. During drying, the activity of PPO remained high for a long time if the drying temperature is below 55°C. On the other hand, exposure to a higher temperature (75 °C) inactivated this enzyme [29]. The variation of the antioxidant activity was mainly attributed to variety effect. Values of AA ranged between 69.91 and 75.16% and Bidhi variety exhibited the highest value.

Table 3: Effect of drying systems on Total phenolic content (TPC) and antioxidant activity (AA)of dried figs

	Bidhi		Bither Abiadh		Effect of variety (V)	Effect of drying type (DT)	Interactio VxTS
	Open air	Greenhouse	Open air	Greenhouse			
TPC (mgGAE/100gDM)	767.22±182.67	1098±90.22	434.33±81.88	605.22±116.15	**	**	ns
AA (%)	75.16±0.56	72.56±2.16	69.91±2.1	70.52±1.65	**	ns	ns

ns: not significant, ** : highly significant (P< 0,01)

2.4. Minerals content

The results showed significant differences between the two varieties for mineral content. The major mineral compound for both varieties was potassium (K: 11.3-10.16g/l) and calcium (Ca: 3.3-2.5g/l) respectively, in Bidhi and Bither Abiadh (Table 4). These results were comparable to those found by Aljane et al. [30] who showed that Tunisian figs were rich mostly in potassium, calcium and magnesium. The variation of major mineral compounds (Mg, P, K, Ca) were mainly due to the varietal effect. Bidhi showed the highest amounts. While the type of drying had a greater influence on the levels of trace elements (Mn, Fe, Cu, Zn) (Table 4). These findings highlight that the mineral level found in different research on dried figs made on Italian, Greek and Tunisian samples [31].

Table 4: Effect of drying systems on mineral content of dried figs

	Bidhi		BitherAbiadh		Effect of variety (V)	Effect of drying type (DT)	Interaction VxTS
	Open air	Greenhouse	Open air	Greenhouse			
Mg (g/l)	1.27±0.15	1.16±0.03	0.98±0.38	0.64±0.02	**	ns	ns
P (g/l)	1.42±0.41	1.26±0	0.98±0.29	0.58±0.04	**	ns	ns
K (g/l)	10.21±2.09	11.37±0.26	10.16±3.96	5.98±0.52	ns	ns	ns
Ca (g/l)	3.38±0.31	3.13±0.33	2.49±1.01	1.52±0.13	**	ns	ns
Mn (mg/l)	1.95±0.26	1.55±0.14	2.33±1.17	1.21±0.02	ns	ns	ns
Fe (mg/l)	43.02±5.98	23.02±0.28	26.82±10.47	13.56±0.91	**	**	ns
Cu (mg/l)	5.23±1.13	5.04±0.23	5.18±2.63	2.69±0.27	ns	ns	ns
Zn (mg/l)	18.77±2.06	10.09±0.57	13.52±3.91	5.84±0.51	**	**	ns

ns: not significant, ** : highly significant (P< 0,01)

Conclusion

Drying was a reliable way to preserve figs, in terms of technical feasibility and nutritional quality. The results showed several advantages of drying in a greenhouse over sun drying in open air: improvement the external color of figs and preservation of total phenols and antioxidant activity. This technique deserves further research in the local conditions of farmers.

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