AJFAND ONLINE
Volume 9 No. 5 2009
August 2009
ISSN 1684-5374
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

DRYING AND BROWNING OF DATE PULP DURING HOT AIR AND MICROWAVE DRYING

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Volume 9 No. 5 2009
August 2009

AJFAND ONLINE
ISSN 1684-5374
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

ABSTRACT

The present work is a part of our scientific project about the valorisation of the common dates grown in southern Algeria. The principal aim was to study the drying ability of the fruit pulp with the view to produce food powders, which can easily take the place of many synthetics ingredients (white sugar, colorant like caramel) in many food preparations. The specific structure of the date pulp was also described: presence of two edible constitutive tissues (outside pigmented and inside white) that can influence the technological proprieties (as drying) of the whole fruit. The pigmented and white part weights were significantly different ($p \leq 0.05$). Results reveal the preponderance of white part, which can favourably influence the heat processing such as drying since the coloured pulp is already pre-browned compared with the white part. Hot air (60°C) and microwave (MW) (350W) drying kinetics of date (*Phoenix dactylifera* L.) pulp pieces from *Mech-Degla* variety were investigated. Colour change (browning) was also analyzed during these drying processes using absorbance measurement at 420nm of the hydro alcoholic extract from pulp pigmented part. The latter has a heterogeneous initial colour in the same fruit. Three shades can be noticed: yellow, beige and brown related to the optic densities (at 420nm) of 0.92, 1.5 and 1.93 respectively. The minimal moisture contents reached by means of MW and hot air drying are about 8 (during 5 min) and 5 % dry basis (during 165 min) respectively. On the other hand, the MW drying could be considered instantaneous but it involves a few scorched spots on pulp pieces what may be due to the non uniformity of the initial date pulp colour or to the inadequacy of the chosen power. In addition, the applied model strongly fit the experimental data for convective air drying (R^2 = 0.995; *MRE* = 6.71%) compared to MW drying (R^2 = 0.94; *MRE* = 18.4%)

Key words: date, hot air, drying, microwave

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INTRODUCTION

There is an important genetic biodiversity of the date (*Phoenix dactylifera L.*) palm in the Maghreb region (Algeria, Tunisia and Morocco) with more than 1000 varieties [1]. Furthermore, the date fruit is the basis food of local population and nomads in the Sahara [2]. The term "common date" is generally used in Algeria and Tunisia to distinguish all other varieties from *Deglet-Nour*, which is widely distributed in both countries. In addition, according to the water content, three date varieties are listed: soft, semi-soft and dried corresponding to the moisture contents of above 30, 26-30 and below 26% dry basis (d.b) respectively [1, 3]. *Mech-Degla* date variety is the vegetable material studied in the present work because of its availability and long shelf-life due to its low moisture content (14-16%) [4]. In addition, common dates are known as low value varieties and their valorisation allows to obtain finished products with high added value.

In previous works, some technologic and physicochemical characteristics as well as drying ability of three common (dried) date varieties were reported [5, 6, 7]. We undertook this work with a view to compare hot air and microwave drying having in mind the colour change in pigmented part of the date pulp. In fact, certain temperature conditions as well as microwave (MW) drying could improve colour deterioration in treated food materials [8]. On the other hand, the first quality judgement made by consumer on a food at the point of sale is its visual appearance [9]. However, there are some circumstances where a certain level of caramelization is desirable, as for example in the case of production of concentrated tomato paste [10] and syrups in pastry and confectionery industries [11]. In our case, the powder from dried dates could easily be used as a natural ingredient: colouring, sweetener, in many preparations including in yogurt [12]. Also, a better knowledge of browning kinetic allows to predict the reaction extension [13], taking into account the caramelization level wished by the consumers. At last, it must be recalled that, the date pulp drying is applied here as finish process in order to reduce the moisture content from 16 to 6% (d.b) on average as that required for fruit powders [10].

MATERIAL AND METHODS

Date sample

Mech-Degla dates investigated in this work were purchased from a local market of Boumerdès (40 km from Algiers) in spring 2007. The initial moisture content of the date pulp, determined according to [14], was found to be 16.28 % dry basis (d.b). Prior to drying, samples were cut into pieces having the dimensions of 15×15×3 (mm). The caramelisation processing was studied through the color change of the pigmented part during drying.

Drying procedure

Fruit pulp pieces (50 g) related to 10 whole dates were dried in laboratory forced-air oven (model Melag, type 405). They were uniformly spread on the unique tray in single layer. The equipment is provided with a fan (maintaining air velocity of about 0.2 m s^{-1}) and temperature control device. The air temperature was (60±2) °C

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considering that temperatures above 65°C involve visual and quality degradation of foods [15]. Moisture loss of the sample was monitored by taking out and weighing the sample (with accuracy of 0.001g) at 15 min interval using an electronic balance (Explorer Pro, Ohans). The drying process was continued until the pulp moisture content did not decrease significantly with increasing drying time and/or the colour change is not visible to the naked eye. The moisture content thus obtained was considered as equilibrium moisture content.

Concerning MW drying, power intensity equal to 350W was applied using a domestic microwave oven (LG Grill). Moisture loss was monitored at intervals of 1min.
After drying, date pieces were subjected to grinding and sieving to obtain fruit powder.

Optical density measurement
Indicators of extent of colour change include, among others, colorimetric evaluation of non-enzymatic browning at 420nm [16] using UV/Visible spectrophotometer (ATI, UNICAM).

The procedure followed in this work is similar to that described by Park and Kim [17] with minor modifications. First, the analysis conditions were optimized. Pulp (0.5g) of pigmented part was mixed with hydro-alcoholic solvent (5ml) (at different water: ethanol ratio). Experimental procedures are summarized in Table 1. Each extraction was carried out in triplicate.

RESULTS

Drying behaviour of date pulp
Figure 1 shows the proportions (%, w/w) of the two constitutive tissues of the date pulp: pigmented (yellow-beige) and white parts.

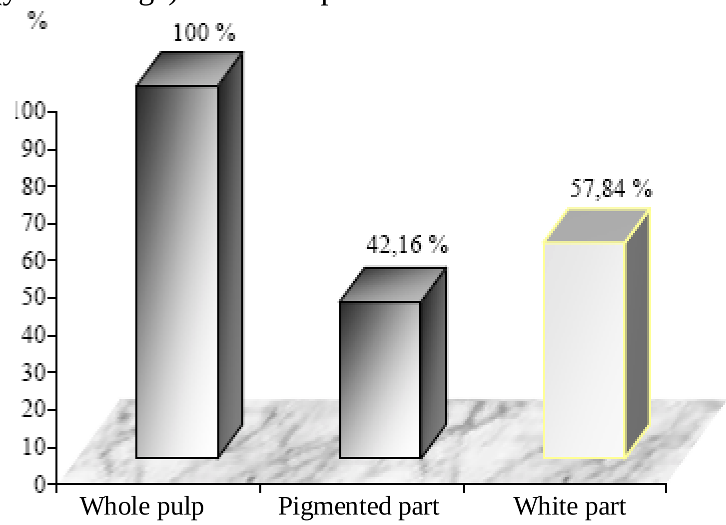

Figure 1: The proportions of pigmented and white parts of the Mech-Degla whole pulp

The results are expressed as the mean of 10 weight measurements on 10 dates chosen at random.

The following diffusion model for an infinite slab was used to describe the drying kinetics of date pulp pieces with assumption that mass transport occurs in one dimension and moisture content uniformly distributed inside the solid matrix [18]:

$$MR = \frac{W - We}{Wo - We} = \frac{8}{\pi^2}\left[\exp\left(-\pi^2 \frac{Dt}{4x^2}\right)\right]$$

where MR = moisture ratio; Wo, We, W are the initial, equilibrium and at time t moisture content (% dry basis) respectively; D = water diffusivity (m^2/s); x = half of thickness (1.5×10^{-3} m) of date pulp piece, with assumption that moisture loss occurs from both sides. Non-linear regression analysis was performed for estimation the model parameters, using Microsoft Excel 2003 (Figures 2 and 3).

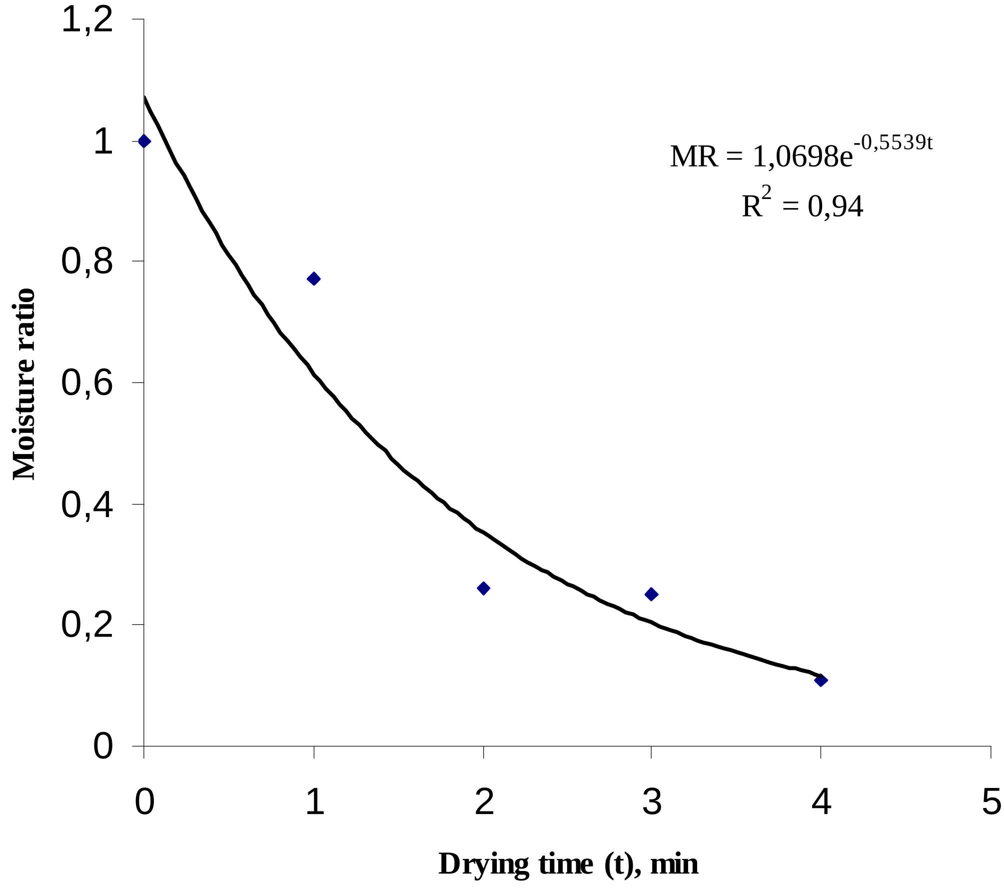

Figure 2: Microwave-drying curves for cut in pieces date pulp

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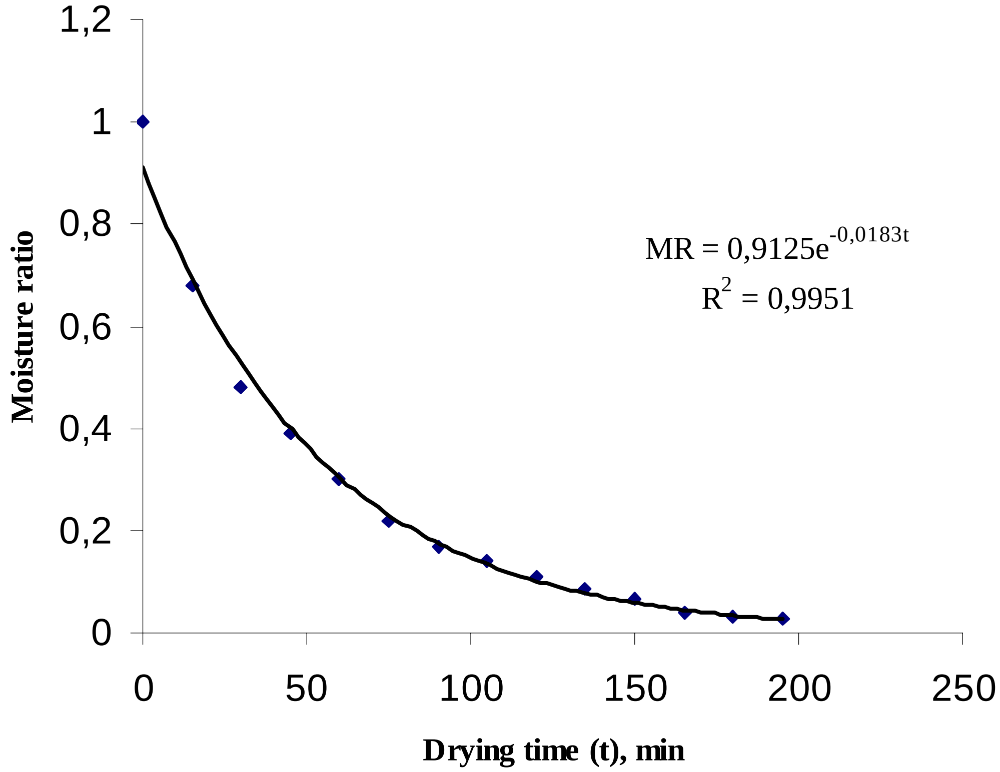

Figure 3: Hot air (60°C) drying curve for cut pieces of date pulp

D values thus deducted are of: 2.78×10^{-10} and $8.43 \times 10^{-9} m^2.s^{-1}$ for hot air and MW drying respectively. To evaluate the goodness of the model fit, two criteria were used: the coefficient of determination (R^2) and the mean relative error (*MRE*) calculated as:

$$MRE = \frac{100}{N} \sum_{i=1}^{N} \frac{|MRei - MRpi|}{MRei}$$

where *MRei* = *MR* experimental value, *MRpi* = predicted value from the model and *N* = number of experimental data points.

Date pulp colour change during drying

Results of preliminary tests, shown in Table 1 guided the choice of a more suitable procedure for analysis of the date pulp browning: (1) water:ethanol ratio (v/v) = 2.5ml:2.5ml; (2) 1 min boiling followed by 30min rest of the mixture, constituted by ground pigmented date pulp (0.5g) and solvent amount (5ml).

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As it has been quoted previously for pulp structure, the initial colour of the date outside tissue (pigmented part) is also heterogeneous, varying from yellow until brown. The absorbance values (at three different wavelengths of the visible spectrum) of three different extract, resulted from three different zones of a single date fruit (chosen at random) are summarised in Table 2.

The results of colour change kinetics obtained from both hot air and microwave drying are illustrated in Figures 4 and 5 respectively using the kinetic equation of zero order through linear regression.

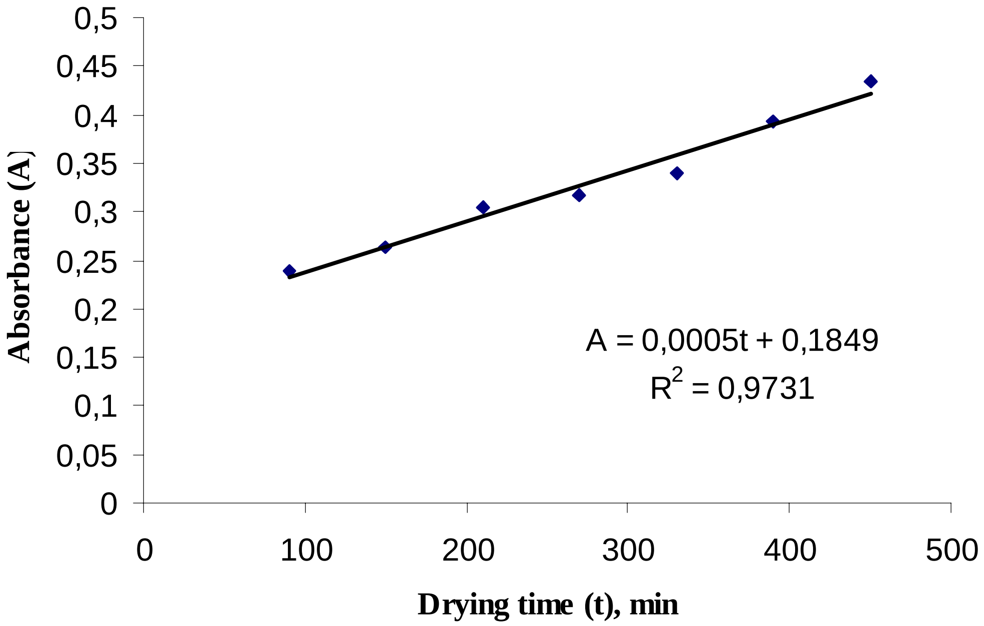

Figure 4: Absorbance (at 420nm) of date pulp pigmented part extract after hot air drying at 60°C

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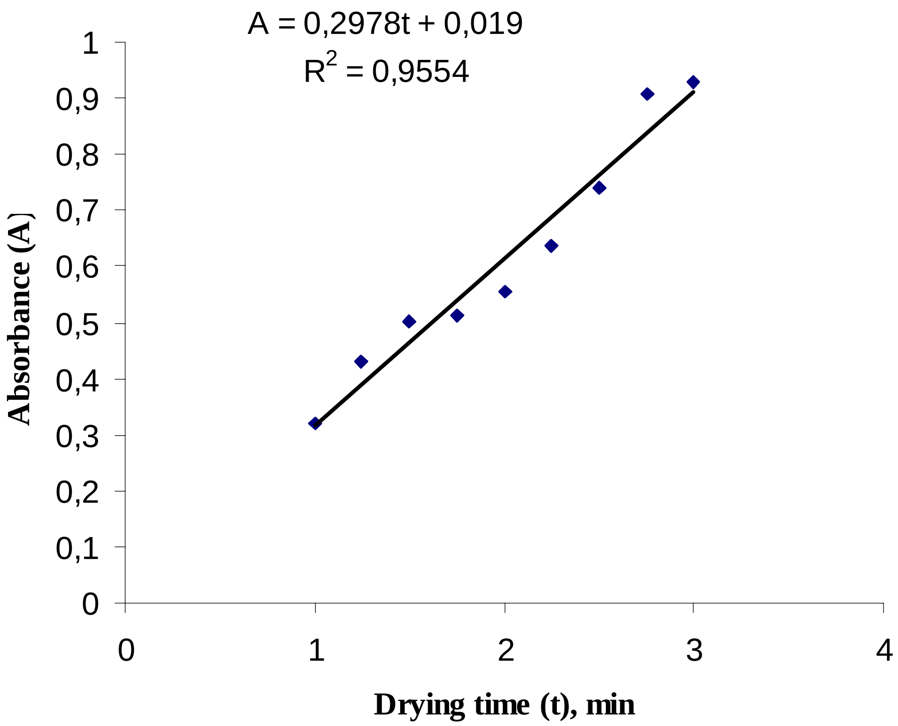

Figure 5: Absorbance (at 420nm) of date pulp pigmented part extract after MW drying.

DISCUSSION

The pigmented and white parts weights are significantly different ($p \leq 0.05$). Results reveal the preponderance of white part, that can favourably influence heat processing as drying since the uncoloured pulp could lead to less caramelized powders compared with the pigmented part. The latter is already partly caramelized and heating will increase the darkening of the fruit powder color.

The *D* values are comparable to the general series of 10-11-10-8 m2.s-1, found for other fruits and legumes [19, 20]. It is evident that MW drying of date pulp (cut in pieces) is much faster than drying by hot air (Figures 2 and 3). The MW drying should be considered as instantaneous, but it generates some scorched spots on pulp pieces, what could be due either to the non uniformity of the initial date pulp colour or the inadequacy of the MW power chosen. In fact, it was already reported that the temperature in the later stages of MW and hot air drying can easily involve scorching and caramelisation in high sugar material [21].

This drawback limits the date pulp equilibrium moisture content to 7% (d.b) in MW drying against <5% for hot air drying. Nevertheless, to reach 7% moisture content, the drying time was reduced by about 95% when the microwave drying was used. Maskan [22] found that MW drying reduced the hot air drying time of kiwifruits by about 89%. This significant reduction of the drying time by MW use was underlined by many authors [23, 24].

The applied model strongly fitted experimental data for convective air drying (R^2 = 0.995; *MRE* = 6.71%) compared to MW drying (R^2 = 0.94; *MRE* = 18.4%). This result reflects the complexity of the MW heating which may take into account other parameters such as the size of the fruit to dry. In fact, it is well known that excessive temperature beside the edges of products may lead to overheating resulting in possible scorching. On the other hand, the fruit temperature during MW drying can easily rise to a critical level which is never reached in hot-air drying [21].

An overall shape of colour change curves is the same in all cases with a dramatically increasing of the absorbance in microwave case unlike the hot air drying.

As it can be seen from Figures 4 and 5, MW gives a browning rate ~ 600 times faster than hot air. This value is 65 times faster than in case of kiwifruits processing for which the colour measurement was performed using Hunter colour parameters [9]. In our view, sugar chemical transformations (dehydration, Maillard condensation) are the principal cause of colour change because of a high sugar content (on average 80% dry basis) [25] taking into account the low phenolic content of date pulp [26]. While there are many investigations dedicated to the kinetics of drying and browning for many fruits, in our knowledge there are no scientific investigations related to these phenomena concerning date pulp. Moreover, there are feasibility studies on the utilization of dates, and among the proposals: the production of caramel colour from date juice [27], [28]. It must be recalled that many chemical transformations such as Maillard reaction, pigment decomposition and other oxidation phenomenon affect colour changes during heat treatments such as drying [29, 30].

CONCLUSION

Both hot air and MW drying of date pulp, cut in small pieces, are efficient to reduce the moisture contents from 16 % (d.b) to about 5 and 7 % (d.b) respectively. These values are generally required for fruit powders. Although, the water removing in MW case is faster compared to convective drying, it becomes imperative to monitor the process without which there is a risk of occurrence of scorching. To avoid this drawback, it is necessary to choose the fruit with homogenous initial color without excessive pigmented pulp. The final fruit powder obtained can be used as multifunctional natural ingredient (coloring, substitute of white sugar.

Table1: Absorbance values of hydro-alcoholic extract at function of water-alcohol ratio and extraction conditions

Water/alcohol ratio, ml/ml	Cold extraction, during: 1 day	2days	One minute boiling+30min rest
4.5/0.5	0.329±0.107	0.338±0.027	0.510±0.040
2.5/2.5	0.674±0.158	0.654±0.151	0.708±0.176
0.5/4.5	0.221±0.085	0.258±0.037	0.342±0.089

Table 2: Absorbance values of the pulp extract obtained from different samples of the pigmented tissue

Wavelength, nm	Absorbance of the sample		
	yellow	beige	brown
420	0.92	1.50	1.93
520	0.40	0.81	0.98
720	0.05	0.40	0.40

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