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# Colour Change During Hot Air and Microwave Complementary Dehydration of Naturally Dried Date (*Phoenix dactylifera* L.) Fruits

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**Abstract:** Both microwave (MW) and conventional drying were analyzed with respect to colour change of obtained date (*Phoenix dactylifera* L.) fruit powder. The total colour difference (TCD) was considered to quantify the colour change applying the full experience design procedure. Among all coded variables (temperature, time, date piece size and sample weight), only the interaction between drying time ($X_2$) and date piece size ($X_3$) is significant concerning the conventional drying. In MW case, all factors, namely time ($X_2$), date piece size ($X_3$), sample weight ($X_4$), power ($X_1$) and all interactions between factors are significant involving the following model: $TCD=24+3.45X_1+2.4X_2+3.23X_3-3.05X_4+1.97X_1X_2+2.18X_1X_3-4.15X_1X_4+0.93X_2X_3-2.64X_2X_4-2.02X_3X_4+0.86X_1X_2X_3-2.73X_1X_2X_4-0.87X_2X_3X_4-2.37X_1X_3X_4$.

**Key words:** Drying · Date · Colour · Modelling

## INTRODUCTION

It is well known that drying processing is one of the oldest methods of food preservation [1]. During drying, the moisture content is reduced to about 5% [2], especially when the processing objective is to obtain fruit powders [3].

Many works were dedicated to the physicochemical and technological characterization of different date fruit varieties. Among them, we can for example cite: compositional and sensory characteristics [4], chemical composition and quality of date syrup [5], water desorption isotherms of certain varieties [6]. Nevertheless, no investigation concerning colour change during thermal processing has been found. Also, factorial designs (full or fractional) are widely used as methodological tool to investigate food processing and bioprocessing: colour and appearance of chilled mousse [7], production of Zeaxanthin by fermentation [8], evaluation of key wine components [9].

In previous works we reported on the possibility to produce date fruit powders from native dried varieties as Mech-Degla, Degla-Beida and Freeza which are considered as low quality varieties because of their hard texture [10-12]. Thus, we visually noted the good stability of the colour related to the final product. On the other hand, the first quality judgement made by consumer on a food is its visual appearance [13]. Moreover, the effect of the process variables on the powder properties are difficult to assess in general terms [14]. In the present paper we report on the date powder colour change quantified by the instrumental analysis when the date pieces are submitted to hot air and microwave (MW) drying. To conduct analysis, full factorial design methodology was followed.

## MATERIAL AND METHODS

**Date Sample:** The date fruits were acquired from local market (Boumerdès city, situated at 40 km from Algiers) in spring 2008 and they were submitted to drying without storage. Before drying, the samples were pitted and then divided on 16 ($D_{1/16}$) and 2 ($D_{1/2}$) approximately equal parts corresponding to low "-" and high "+" levels in the experience matrix respectively. Initial water content of the date pulp is about 10.45 g/100 g dry basis (d.b), whereas initial colour parameters are done in colour measurement section given below.

**Drying Procedure:** Two types of drying processing were applied to obtain date powders.

**Hot Air Drying:** Laboratory oven (Melag) provided with a fan to ensure the air circulation rate of 0.2m/s was used. Table 1 gives the experience conditions (different variables with their levels, as well as responses).

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Table 1: Experience design related to the colour analysis of hot air dried date fruits

| N | $X_0$ | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $TCD_1$ | $TCD_2$ | $TCD_3$ | $TCD_{MEAN}$ | σ2{y} |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | + | - | - | - | - | 8.13 | 7.85 | 7.85 | 7.943 | 0.026 |
| 2 | + | + | - | - | - | 6.59 | 6.47 | 5.81 | 6.290 | 0.176 |
| 3 | + | - | + | - | - | 6.62 | 8.33 | 6.65 | 7.200 | 0.958 |
| 4 | + | + | + | - | - | 3.76 | 2.70 | 2.95 | 3.137 | 0.307 |
| 5 | + | - | - | + | - | 8.74 | 8.44 | 8.28 | 8.487 | 0.054 |
| 6 | + | + | - | + | - | 7.75 | 7.04 | 7.23 | 7.340 | 0.135 |
| 7 | + | - | + | + | - | 7.44 | 9.95 | 7.48 | 8.290 | 2.067 |
| 8 | + | + | + | + | - | 4.39 | 4.53 | 4.67 | 4.530 | 0.020 |
| 9 | + | - | - | - | + | 7.75 | 7.78 | 7.54 | 6.58 | 0.017 |
| 10 | + | + | - | - | + | 6.33 | 5.84 | 5.66 | 5.943 | 0.120 |
| 11 | + | - | + | - | + | 6.30 | 8.28 | 6.58 | 7.053 | 1.148 |
| 12 | + | + | + | - | + | 4.25 | 3.94 | 4.14 | 4.110 | 0.025 |
| 13 | + | - | - | + | + | 8.39 | 8.70 | 8.31 | 8.467 | 0.042 |
| 14 | + | + | - | + | + | 7.28 | 7.55 | 7.50 | 7.443 | 0.021 |
| 15 | + | - | + | + | + | 7.28 | 7.68 | 7.64 | 7.710 | 0.008 |
| 16 | + | + | + | + | + | 5.43 | 7.73 | 5.58 | 6.247 | 1.656 |
| Σ | | | | | | | | | 107.88 | 6.78 |
| Niveau - | 55(°C) | 15 (min) | 1/16 | 5(g) | | | | | | |
| Niveau + | 85 (°C) | 50 (min) | ½ | 50 (g) | | | | | | |

Table 2: Experience design related to the colour analyze of the MW- dried date fruits

| N | $X_0$ | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $TCD_1$ | $TCD_2$ | $TCD_3$ | $TCD_{MEAN}$ | $σ^2${y} |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | + | - | - | - | - | 19.02 | 21.15 | 16.61 | 18.927 | 5.159 |
| 2 | + | + | - | - | - | 15.67 | 18.97 | 19.95 | 18.197 | 5.028 |
| 3 | + | - | + | - | - | 16.81 | 20.23 | 18.71 | 18.583 | 2.936 |
| 4 | + | + | + | - | - | 30.49 | 34.09 | 29.99 | 31.523 | 5.003 |
| 5 | + | - | - | + | - | 23.01 | 20.95 | 13.96 | 19.307 | 22.501 |
| 6 | + | + | - | + | - | 32.37 | 26.96 | 35.52 | 31.617 | 18.744 |
| 7 | + | - | + | + | - | 19.11 | 21.15 | 22.76 | 21.007 | 3.346 |
| 8 | + | + | + | + | - | 50.06 | 61.37 | 60.32 | 57.250 | 39.048 |
| 9 | + | - | - | - | + | 18.73 | 20.87 | 18.58 | 19.393 | 1.641 |
| 10 | + | + | - | - | + | 21.05 | 21.15 | 19.99 | 20.730 | 0.413 |
| 11 | + | - | + | - | + | 22.54 | 21.99 | 18.89 | 21.140 | 3.872 |
| 12 | + | + | + | - | + | 16.85 | 18.84 | 17.57 | 17.753 | 1.015 |
| 13 | + | - | - | + | + | 22.47 | 24.16 | 22.11 | 22.913 | 1.198 |
| 14 | + | + | - | + | + | 22.43 | 19.54 | 23.40 | 21.790 | 4.032 |
| 15 | + | - | + | + | + | 26.42 | 21.48 | 21.70 | 23.200 | 7.788 |
| 16 | + | + | + | + | + | 19.71 | 23.04 | 19.55 | 20.767 | 3.882 |
| Σ | | | | | | | | | | 125.606 |
| Level (-) | 160 (w) | 30 (sec) | 1/16 | 5 (g) | | | | | | |
| Level (+) | 480 (w) | 60 (sec) | 1/2 | 50 (g) | | | | | | |

**Microwave Drying:** A programmable domestic microwave oven (LG) with maximum output of 480 W was used. Details of experiences are also given in Table 2.

**Colour Measurement:** The colorimeter used is CM-2500d MINOLTA provided with Iso colour software. First, the dried date pieces were grinded, sieved (Euromatest 1mm) and finally compacted (force applied = 1.5 tons) to obtain pastilles.

The total colour difference (TCD), colorimetric parameter extensively used to characterize food colour [15,16] is the response investigated in this work and it is defined as:

$$TCD = [(Lo - L)^2 + (a_o - a)^2 + (b_o - b)^2]^{1/2}$$

Where, L (whiteness or brightness/darkness), a (redness/greenness) and b (yellowness/blueness) are

the colour parameters at any time, whereas Lo (83.71), $a_o$ (3.93) and bo (20.11) refer to the initial (before drying) colour parameters of the date powder obtained by lyophilisation. On the other hand, we have defined a critical TCD ($TCD_{cr}$) (= 32.58) calculated with critical values of $L$ = 53.04, $a$ = 14.15 and $b$ = 24.05, corresponding to the date powder for which the hot drying at 55°C during 15 h and then at 140°C, maintained as long as the caramelisation is not visible by naked eye.

The investigation was performed by means of $2^4$ full factorial designs whereas the experimental data were analyzed using SPSS software.

## RESULTS AND DISCUSSION

**Colour Change During Hot Air Drying:** The Lab parameters with corresponding TCD values of lyophilised (natural) and critically hot dried date powders and of commercial cacao are summarized in Table 3. As it can be seen, the critical date browning ($TCD_{cr}$) is smaller than of cacao (TCD). Once TCDcr is reached, the date powder becomes so ostensibly caramelized. It must be recalled that a certain level of caramelisation should be interesting in certain circumstances when caramel colour is wished.

The experience design (Table 1) shows the experience conditions as well as results of colour measurements during date hot drying. The obtained TCD values show that TCDcr is never reached. Cochran criterion Gc calculated is of Gc = 0.1689 < Gt = 0.3346 what signify that variances are homogenous and the experience is reproducible.

From all tests, it can be seen that TCD values increased with time. This is in agreement with results found by [15] studying the various heating methods of pomegranate juice concentration. The large color change observed may be due to the high sugar concentration of the date fruit taking into account their ability to form melanoidin or brown products which are responsible of color alteration [17], [18]. Whereas, all (TCD) values obtained are below (TCD)cr, what confirms the good stability of date color towards hot air drying.

Using the multiple linear regressions, the model parameters and their Student criterion were deduced. Only the $X_2X_3$ interaction is significant since it fit the condition $t_c > t_b(\alpha = 0.025, \nu = N(m-1) = 32) = 2.037$. Consequently, the following model can be written:

$$TCD = 9.5 + 1.38\ X_2X_3$$

According to Fischer criterion (Fc = 1.098 < Ft = 2.01), the model can be considered as adequate. This result confirms those we have obtained by means of spectophotometric measurement (at 420 nm) of color change [12]. The Figure 1 confirms the good correlation ($R^2 > 0.8$) between predicted by the model and experimental TCD values.

The optimal combination of factors is of: temperature = 85°C, time = 60 min, size = $D_{1/16}$, sample weight = 50g, giving as responses: water content = 4.11 g/g (d.b), TCD = 7.82<< $TCD_{cr}$ = 32.58 ˜ cacao TCD = 35.51.

**Colour Change During Microwave Drying:** Results are summarized in the experience matrix (Table 2) from which it can be clearly noted that three factor combinations give TCD values equivalent (tests 4 and 6) or above (test 8) that of TCD cr. These results are in concordance with those reported in the literature. Hence it has been revealed that arcing occurred when the power was increased to above 500 W [19]. In our case, the three TCDcr were obtained at (+) level = 480W. Other authors reported that excessive temperatures along the edges and corners of products may lead to scorching [20, 21]. Cochran criterion Gc calculated is of Gc = 0.3109< Gt = 0.335 what signify that variances are homogenous and the experience is reproducible.

15 parameters are significant since their calculated $t_c > t_b(\alpha = 0.025, \nu = N(m-1) = 32) = 2.037$. The model related to color change can be written in the following form:

$$Y = 24.01 + 3.45X_1 + 2.40X_2 + 3.226X_3 - 3.046X_4 + 1.97X_1X_2 + 2.18X_1X_3 - 4.15X_1X_4 + 0.93X_2X_3 - 2.64X_2X_4 - 2.019X_3X_4 + 0.855X_1X_2X_3 - 2.727X_1X_2X_4 - 0.866X_2X_3X_4 - 2.365X_1X_3X_4$$

Table 3: Lab parameters and TCD values for different powders

| Colour parameter | Lyophilised (natural) date powder | Critically hot air dried date powder | Commercial cacao powder |
|---|---|---|---|
| L | 83.71 | 53.04 | 49.33 |
| a | 3.93 | 14.15 | 12.40 |
| b | 20.11 | 24.05 | 22.74 |
| TCD | 0 | 32.58 | 35.51 |

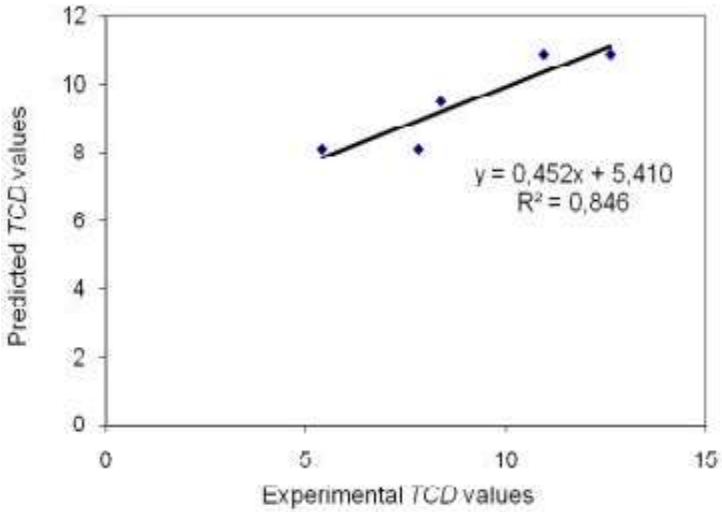


Fig. 1: Correlation between predicted and calculated TCD. Case of hot air-dried date pulp

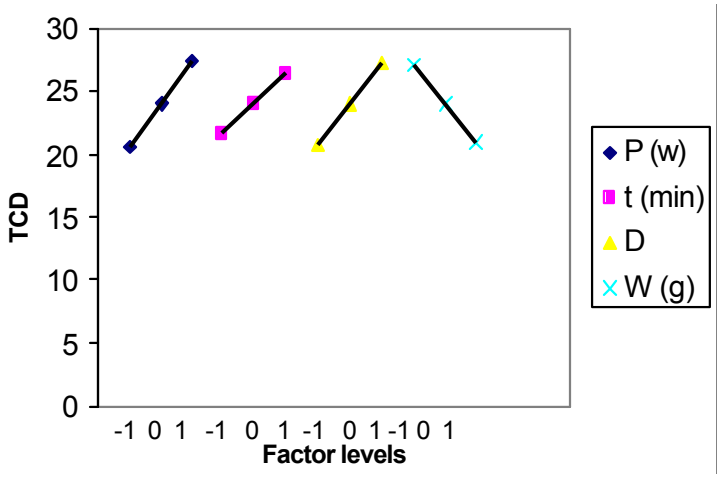


Fig. 2: Graphical representation of the effects related to four factors (P = power, t = time, D = date piece size, W = sample weight). Case of MW- dried date pulp

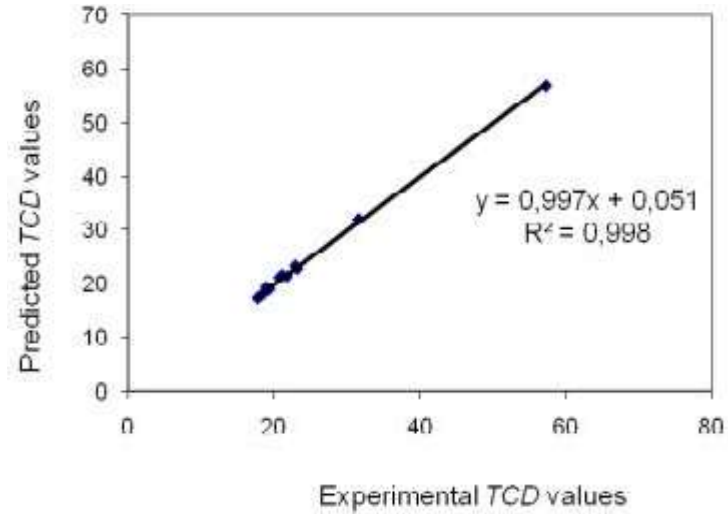


Fig. 3: Correlation between predicted and calculated TCD values. Case of MW-dried date pulp

Here, in opposite with hot drying, the four factors are very significant. As it can be seen (equation above and Figure 2), among all others, the output factor is the most influent with a positive effect. Also, the time and size factors have a positive effect on color change. The influence of the MW drying duration on the caramelisation of kiwi fruits has been already underlined [22]. The validation of the model is confirmed by Fischer criterion since Fc =1.1174 < Ft ($í_1$=1, $í_2$=32) = 4.15. In addition, the goodness of the model is confirmed by the good correlation between TCD values predicted by the model and experimental TCD values (Figure 3). Nevertheless, these results are in contradiction with those found by some researchers concerning the drying of numerous vegetables (rosemary, apple and bananas respectively) [13, 23-25]. They have reported that hot air intensify the browning comparatively to MW drying. We think that, this contradiction may be explained by the initial moisture content of date fruits, their high sugar content as well as their fibrous structure. It must be noted that hot air drying never caused a critical color change in date pulp, whereas a one minute MW drying caused a scorching.

The optimal combination of parameters is of: output = 480W, time = 60 s; sample weight = 50g andcorresponding responses are of: water content = 6.33%, TCD = 20.77< $TCD_{cr}$ = 32.58 ˜ cacao TCD = 35.51.

## CONCLUSION

The date fruit powder could be obtained by both conventional and MW drying. The optimal combinations are of: 1) for conventional drying, as factors: temperature = 85°C, time = 60 min, size = $D_{1/16}$, sample weight = 50g andas responses: water content = 4.11 g/g (d.b), TCD = 7.82; 2) for MW drying, as factors: output = 480W, time = 60 s; size = $D_{1/2}$, sample weight = 50g andas responses: water content = 6.33%, TCD = 20.77. Although, differences in TCD values are observed, the critical TCD value (= 32.58) is not reached. Moreover, MW drying shortened the drying time more than 98% when compared to the conventional drying.

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