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Drying Apricot Optimization's Experimental Design

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Abstract: ***The drying apricot process study through an experiment factorial design allows us to reduce alteration of final product. The targeted variables are sodium metabisulfite concentration (g/l), dipping time (min) and drying temperature (°C). A complete factorial design (2^3) was made in order to determine the factors and their interactions which have a statistically significant influence on the studied response. Hight values sodium metabisulfite concentration, dipping time and drying temperature have a negative effect on alteration reduction. Optimal factor production is 80 g/l of sodium metabisulfite, 45 min of dipping time and 72°C of drying temperature. The later has great impact on the quality of final product.***

Keywords: Apricot, drying, temperature, sodium metabisulfite concentration dipping timeand alteration

1. Introduction

Carotenoids and polyphenolsprovide health benefits tochronic diseases risk decreasing, particularly certain cancers [1]. Therefore, there is a strongtendency in apricots which contain high amount of β-caroteneand polyphenols which beneficial effects are due to their roles as an antioxidant agent [2], [3].

Global apricot production in 2014 was estimated at 4.03 million tonnes[4]. Turkey, Iran, Uzbekistan, Algeria, Italy, Pakistan, France, Morocco, Spain, and Egypt are the top 10 apricot-producing countries in the world. Turkey is the leading exporter of dried apricots, exporting 62% worldwide exports in 2011 [5]. Global market trends for apricot include an increasing trade in fresh fruit, whilst trade in dried apricot is stagnating. Nonetheless, there is an increased interest in dried apricot as an ingredient in health food such as breakfast muesli and cereal/fruit bars [5].

In Morocco the valorization of apricot fruit is limited on the production of jams, frozen syrups and mumps intended mainly for export. Dried apricots are procured totally from import.

In Midelt city (south east of morocco), Canino is the main apricot variety proposed for drying. The fruits are medium-sized (23–31.5 g), oval-shaped, and skin and flesh colors are yellow. Flesh is firm-textured, low in water content, acid and aromatic. This is the best variety that adapts to drying. Thus, this biological material is the subject of drying processoptimization by experimental design.

Apricots have a short harvest season and a limited time of storage even under suitable conditions [6]. To supply the apricots to consumers throughout the year, different preservation methods are commonly applied [7], [8], [9], [10]. SO_2 provides both inhibition of the enzymatic browning during drying and protection from non-enzymatic browning reactions as well as prevention of microbial deterioration during drying and storage [11]. The soaking time is a factor that affects the quality of dried apricots [7]. Drying temperature also plays an important role in dried apricots stabilization [12], [13]. In this study, we intend to study dynamically the effect of these parameters on the dried quality.

2. Material and Methods

2.1 Materials

Before starting this study, we made a screening to select a locality in the region of Midelt (Morocco) that produces apricots from the Canino variety best adapted to drying. With this in mind, five localities were studied in the Midelt region. The choice of the study was focused on the locality "Ait Ali Nitto" because the maximum values in loss of water are recorded in this locality.

Fresh apricots were removed from the storage room (4°C) just before drying; they were washed, cut to create two halves (mumps) and to remove the pit, and then pretreated immediately to minimize undesirable enzymatic activity. After, Mumps is subjected to sulfur treatment in a bath of sodium metabisulphite ($Na_2S_2O_5$). Finally, the apricot mumps were placed in an oven at the laboratory under different temperatures according to experimental deseign. Drying was monitored by weighing the samples to their moisture content. Finished products were evaluated on the basis of visual perception and their browning alteration.

The moisture content of sulfited-DAs (SDAs) was determined in quadruplicate using a vacuum oven (Heraeus VT 6025, Hanau, Germany) according to [14].

Browning alteration was determined by putting a sample of mixed ground dried apricot containing 8 g solids in a 250 mL Erlenmeyer flask containing 100 mL 50% (v/v) ethanol solution. The flask was then covered with parafilm and remained at room temperature (23°C) for 24 hr with occasional shaking. After the solution was filtered using Whatman N°2 filter paper, the optical density of the eluent was read in a Spectrophotometer(RAY LEIGH UV 9200) at 440 nm. The results were recorded in absorbance units using a 50% ethanol solution for zero adjustment [15]. Percentage of alteration was determined by dividing the number of altered fruits on the total one.

2.2 Experimental Design

Many factors can significantly influence apricot drying. Bibliographical data have advised us to study three factors: metabisulfite of sodium concentration X_1 (g/l), dipping time X_2 (min) and drying temperature X_3 (°C). This study was performed according to factorial experiment design where the calculation of polynomial coefficients model has been accomplished through the "least squares" method with the use of coded variables. In fact, the act of replacing the natural variables by coded variables allows for the same domain of variation for each factor (between –1 and +1) and hence being able to compare the effect of factors among themselves. The lowest level is coded–1 while the highest level is coded+1(Table1).

Table 1: Levels of natural variables

Factors	Level	
	-1	+1
C (g/l)	40	80
Time (min)	15	45
T °C	60	80

A complete factorial design with 3 factors and n (number of tries) has been designed which will be equal to 8*3 = (24). In this study, we have conducted 2 replicates for each trial. A summary of the total tests can be seen in Table 2, which we have called "Table of Experiments".

Table 2: Table of experiments

Variables/trial	C (g/l)	Time (min)	T °C
1	40	15	60
2	80	15	60
3	40	45	60
4	80	45	60
5	40	15	80
6	80	15	80
7	40	45	80
8	80	45	80

3) StatisticalAnalysis

The statistical calculations (calculation of coefficients, T-test, analysis of variance, curves were done using the JMP 4 software).

3. Experimental Results

3.1 Validation of the mathematical model relating the studied factors

On the basis of table 3, the mathematical model is written as follows and has the form:

$$Y=b_0+b_1X_1+b_2X_2 +b_3X_3 +b_{12}X_1X_2 + b_{13}X_1X_3+b_{23}X_2X_3+b_{123}X_1X_2X_3$$

To be able to conduct the statistical calculations and prevent that n = p, (n = number of tests and p= the number of estimated parameters starting from the model, in other words, the number of the model's coefficients), it is necessary to make replication. This is the case in this study (Y1, Y2 and Y3). a_0, a_1.... a_3, a_{12} ... a_{123}: are the mathematical coefficients of the model. a_{ij}. X_i. X_j corresponds to the interactions. n = 24 : the number of realized experiments. P=8: the number of estimated parameters from themodel.

Table 3: Factorial design experience of coded variables $C(x_1)$, Time(X_2) and T°(X_3).

Experiments	X_0	X_1	X_2	X_3	X_{12}	X_{13}	X_{23}	X_{123}	Y_1	Y_2	Y_3
E1	1	-1	-1	-1	1	1	1	-1	62,5	50	77,8
E2	1	1	-1	-1	-1	-1	1	1	0	10	22,22
E3	1	-1	1	-1	-1	1	-1	1	12,5	0	11,11
E4	1	1	1	-1	1	-1	-1	-1	0	0	0
E5	1	-1	-1	1	1	-1	-1	1	0	12,5	0
E6	1	1	-1	1	-1	1	-1	-1	0	0	11,1
E7	1	-1	1	1	-1	-1	1	-1	0	0	37,5
E8	1	1	1	1	1	1	1	1	0	12,5	0

Y: The percentage of altered fruits

After the point estimate of effects (table 3), the model is written as:

$Y=14,61-8,94X_1-7,59X_2 -7,67X_3+ 5,17 X_1X_2+ 7,02 X_1X_3 + 9,94 X_2X_3- 6,34X_1X_2X_3$

According to significance effects test, we noticed that at p<0.0001, Sodium metabisulfite concentration, dipping time and temperature have a negative effect on the decrease of alteration (Figure 1 and Table 4),

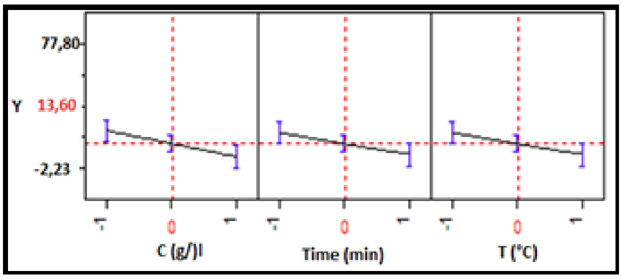

Figure 1: Mean effects of sodium metabisulfite concentration X_1, dipping time $X_2$and drying temperature X_3 on alteration of dried apricots

Table 4: Parameter estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	14,61	2,37	6,15	<.0001
C	-8,94	2,37	-3,76	0,0019
Time	-7,59	2,37	-3,19	0,0061
T	-7,67	2,37	-3.23	0,0057
C *Time	5,17	2,38	2,17	0,0463
C * T	7,02	2,38	2,95	0,01
Time *T	9,94	2,38	4,17	0,0008
C *Time *T	-6,34	2,38	-2,66	0,0179

We also noted that the interactions between the sodium metabisulfite concentration and the time of dipping (c (g/l) *Time (min), between the temperature dipping and the time (T°C*Time (min), between the sodium metabisulfite concentration and the temperature (c (g/l) *T°C) have negative effects on the alteration of dried apricots. So the mathematical model is expressed as follow.

$$Y=14,61-8,94X_1-7,59X_2-7,67X_3+ 5,17 X_1X_2+ 7,02 X_1X_3 + 9,94 X_2X_3- 6,34 X_1X_2X_3$$

Variance analysis (Table 5) which aim is to compare the sum of differences squares due solely to regression (therefore to the model) with the sum of squares of the residues with the help of the F test.

Table 5: Variance analysis

Source	DF	Sum of squares	Mean Square	F Ratio
Model	7	9007.91	1286.85	10.52
Error	16	1956.49	122.28	Prob > F
C. Total	23	10964.40		<0,0001

We noticed that F (observed) > F (0.0001) and therefore we accept model validity. Since Y represents the percentage of alteration, and the aim is to decrease its value. Limited to statistically significant words, we can adopt the mathematical model to find the relationships between the factors studied in pairs to draw iso-response (Contours plot) curves. This allows interactions interpretation of the factors in pairs. These allowed us to draw iso-response curves connecting sodium metabisulfite concentration and dipping time, between (figure 2) temperature and dipping time(figure3), between sodium metabisulfite concentration and temperature (Figures 4). To trace the iso-response curves, we used the JMP software that facilitates the task.

3.2 Study of the interaction between factors

Study of the interaction beteen sodium metabisulfite concentrations (X_1) and dripping time(X_2)

Figure 2 illustrates the interactions between sodium metabisulfite concentrations (X_1)and dipping time (X_2). It shows that the simultaneous increase of the two factors X_1 (C in g / l) and dripping time (X_2) reduces the alteration of the finished product. The optimum is obtained at a maximum value of metabisulphite (80g/l) and dipping time that lasts 45 minutes.These results show that the high concentration of sodium metabisulphite for a long time allows the transfer of sulfur within apricot fruit tissue. This is in agreement with the work of [16]. These authors demonstratedthat the increase in sulfur concentration and soaking time improves the quality of dried apricots and inhibits microbial growth. The same author has mentioned that the sulfur concentration affects the quality of dried apricots with a stabilization of β-carotene [17].

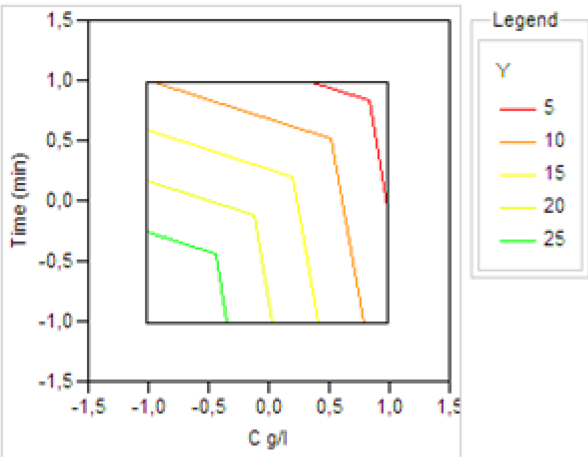

Figure 1: Contour plot of sodium metabisulfite concentrations and dipping time interaction

3.3 Study of the interaction between the concentrations of sodium metabisulfite (X1) and drying temperature (X_3)

The following figure shows the interaction of sodium metabisulfite concentrations and drying temperature. The degree of alteration is very high when the concentration of sodium metabisulfite is at the lowest level (40 g / l) and the temperature factor is also at the low level (60 ° C). When these two factors are increased simultaneously, there is a maximum reduction of the alteration which is more influenced by the temperature which shows an iso-response almost parallel to the temperature axis.

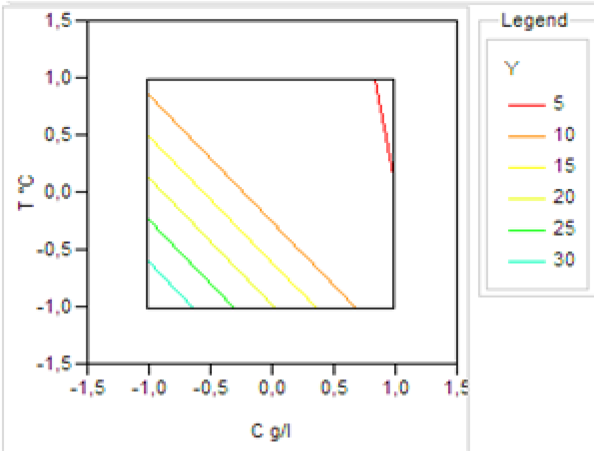

Figure 3: Contour plot of the interaction between the concentrations of sodium metabisulfite and the drying temperature

Figure 3 shows the possibility of using a maximum salt concentration (80g /l) and a temperature of 72° C leading to a significant saving of heat energy. These results concord with those of El Halouat and Labuza[15] who have used response surface analysis which permits the visualization of combination effects which are significant at the 5% level. This analysis shows that using 800-1000 ppm SO_2, at any temperature in the range 50-80°C, was the best treatment. Thus blanching could be excluded which also eliminates a cooked flavor.

Study of the interaction between the drying temperature and dipping time

Figure 4 shows another type of behavior between the drying temperature and the soaking time.Thus, the maximum of alteration is obtained at the minimum values of the temperature and the duration of soaking. The minimum deterioration values are obtained either by an increase of the soaking time and a reduction of the drying temperature (Experiment 4 : E4) ; or by a reduction of the soaking time and an increase of the drying temperature E6. This latter possibility is to be avoided because the experiments (E5, E6, E7 and E8) show that the maximum temperature values give a product which is affected considerably by the alteration.

This confirms the results obtained in experiment E4 are favorable to obtain a product free of alteration.

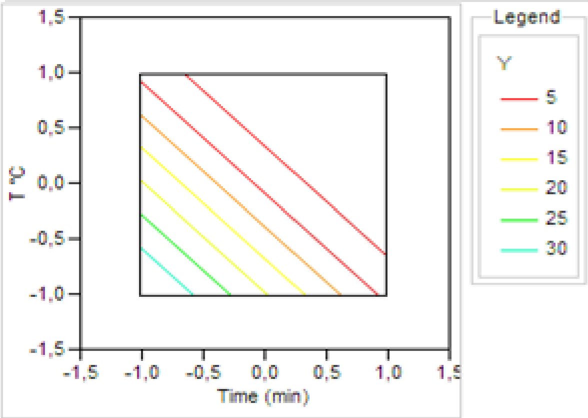

Figure 3: Contour plot of the interaction between drying temperature and soaking duration

The use of the experimental design method has been used by several researchers to study the factors involved in the drying of apricots. But the diversity of the drying process makes the comparison very difficult because of the variability of the systems used. The only common point is compliance with the international standards which state that sulfur levels should not exceed 2000 ppm. In this respect, El Halouat and Labuza [15] found that Sulfiting-drying, using 80-1000 ppm SO_2 at any temperature in the range 50-80°C, was found to be the best treatment. Thus, sulfite was the major factor in controlling dry apricot quality and would be hard to reduce. Drying time was reduced by 50% when apricots were dried at 80°C compared to 50°C, and blanching reduced the time by 10 to 20%.

The main principle of drying is to decrease moisture content to about 10-15 %. As a result, enzymatic reactions and growth of microorganisms are inhibited [18]. However, some fruits, especially apricot, has some problems with the browning reactions. To delay browning reactions, apricots are exposed to sulfur dioxide in sulfuring room by burning sulfur or dipped to the sulfite or bisulfate salt solutions [19]. Sulfur dioxide prevents both enzymatic and non-enzymatic browning reactions [17] . The mechanism is that SO_2 prevents the oxidation of quinones and inhibits the Polyphenol oxidase PPO and also the carbonyl groups in Maillard reactions [20], [21]. The aim of sulfuring is not only to retard browning reactions but also to prevent the microbial growth [22]. Nonetheless, high residual of sulfur dioxide causes undesired taste and bad smell in the apricots [18].

4. Conclusion

The comparison of the results obtainedthrough experimental design with the center of the experimental domain allowed us to highlight the following observations:

- A maximum concentration of sodium metabisulphite (80 g / l),
- A maximum soaking time (45min),
- An average temperature of 72 °C.

The temperature factor could play an pivotal role in controlling alteration. An increase in temperature is responsible for browning (E5 E6 E7 E8).

In view of this work, we intend to move to the pilot scale to compare these results with industrial tests.

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