OPTIMIZATION OF MICROWAVE-ASSISTED DRYING OF JERUSALEM ARTICHOKES (*HELIANTHUS TUBEROSUS* L.) BY RESPONSE SURFACE METHODOLOGY AND GENETIC ALGORITHM

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ABSTRACT

The objective of the present study was to investigate microwave-assisted drying of Jerusalem artichoke tubers to determine the effects of the processing conditions. Drying time (DT) and effective moisture diffusivity (EMD) were determined to evaluate the drying process in terms of dehydration performance, whereas the rehydration ratio (RhR) was considered as a significant quality index. A pretreatment of soaking in a NaCl solution was applied before all trials. The output power of the microwave oven, slice thickness and NaCl concentration of the pretreatment solution were the three investigated parameters. The drying process was accelerated by altering the conditions while obtaining a higher quality product. For optimization of the drying process, response surface methodology (RSM) and genetic algorithms (GA) were used. Model adequacy was evaluated for each corresponding mathematical expression developed for interested responses by RSM. The residual of the model obtained by GA was compared to that of the RSM model. The GA was successful in high-performance prediction and produced results similar to those of RSM. The analysis and results of the present study show that both RSM and GA models can be used in cohesion to gain insight into the bioprocessing system.

1. INTRODUCTION

The Jerusalem artichoke (Helianthus tuberosus L.) has been gaining increasing attention due to the potential use of this plant as a feedstock for the synthesis of new products and the awareness of its significant health benefits. The storage form of carbon in Jerusalem artichokes, inulin, makes this plant attractive compared to the majority of crops that store carbon as starch (KAYS and NOTTINGHAM, 2008; VAN LOO *et al.*, 1995; WATHERHOUSE and CHATTERTON, 1993). In spite of its high potential usage in the food industry, consumption of this plant as a raw material is limited due to changes during its post-harvest period (CABEZAS *et al.*, 2002; MODLER *et al.*, 1993; TAKEUCHI and NAGASHIMA, 2011). Therefore, increasing the Jerusalem artichoke shelf-life by processing is of prime importance, and dehydration of its tubers should also be considered in this regard. Various drying technologies have been extensively used as a preservation technique in the food industry. Specific technologies, such as microwave-assisted drying, for grains, crops and foods have been well documented (AL-HARAHSHEH *et al.*, 2009; GIRI and PRASAD, 2007; SHARMA and PRASAD, 2001).

The main reasons to consider the use of microwave energy are to accelerate the drying process, improve product quality, and reduce costs (AL-HARAHSHEH et al., 2009; GIRI and PRASAD, 2007; MCLOUGHLIN *et al.*, 2003). However, additional effort is required to standardize microwave technology in the drying process. For this reason, microwave-assisted drying requires investigation in terms of the underlying physical phenomena, such as the mechanism of molecular transfer. Effective moisture diffusivity is one of the parameters used to evaluate the drying of food materials from the point of view of intramolecular mass transfer, since transfer of water molecules throughout the solid matrix is generally a rate-controlling step in drying processes (DADALI *et al.*, 2007). Another significant step is to optimize processing variables according to desired targets including faster and more efficient processing and improved product quality. Response surface methodology (RSM) is a statistical procedure frequently used for process optimization. It uses quantitative data from an appropriate experimental design to determine and simultaneously solve multivariate problems. The equations describe the effect of the test variables on the responses, determine interrelationships among test variables and represent the combined effect of all test variables in the response. This approach enables an experimenter to efficiently explore a process or system. In recent years, other optimization techniques have also been developed and adapted to food processes. In process engineering design, genetic algorithms (GAs) are considered a novel technique (GOLDBERG, 2001). For highly complex and nonlinear processes, researchers have reported successful GA applications in analyzing the osmotic dehydration of kiwifruit (FATHI *et al.*, 2011a) and carrot slices (MOHEBBI *et al.*, 2011a), and plant oil extraction from cloves by supercritical CO_2 (HATAMI *et al.*, 2010).

To our knowledge, there are no reported studies on the microwave-assisted drying of Jerusalem artichokes as well as its optimization in terms of drying performance and quality characteristics. Therefore, the objective of this study was to investigate and optimize the processing conditions of microwave-assisted drying of artichoke tubers. Additionally, GA was conducted to evaluate its performance in the optimization of the proposed drying technique.

2. MATERIALS AND METHODS

2.1 Preparation of samples

Fresh Jerusalem artichoke tubers were purchased from the local market and stored at 4°C. The tubers were peeled and sliced at a specified thickness by using a lab-scale slicer on which the thickness was adjusted in the range of 1-10 mm. All slices had the same projected area (30*40 mm, wide*length) to avoid its effect on drying due to any change; the slice thicknesses for each trial were changed as presented in Table 1. Microwave output power was another process variable that was examined at three levels (100, 200, and 300 W), as shown in Table 1. The third variable was the concentration of the pretreatment solution. The experimental design was planned such that there were some trials (run order of trials was 1, 9, 15, and 16; Table 1) excluding the NaCl in pretreatment, and in the remaining trials the slices were treated with NaCl solution (Table 1) to determine the effect of salt on the drying characteristics of interest. The pretreatment was carried out with NaCl solutions of specified concentrations (Table 1) at 25°C with controlled agitation for a period of 2 h. After pretreatment, the samples were removed and rinsed with distilled water to remove the solute that had adhered to the surface and then dried in a microwave oven at the output power specified in Table 1. In the case of samples that were not subjected to pretreatment, aliquots of 50 g of tuber slices were directly dried in the microwave oven (details provided below), whereas pretreated samples were weighted as 50 g after immersion in NaCl solution for 2 h (Table 1). The initial moisture content of Jerusalem artichokes was determined by placing the tubers in a conventional oven at 105°C until no further change in weight of the sample was observed. The average moisture content of fresh Jerusalem artichoke tubers was 81.77 ± 0.89%. The moisture content of any pretreated J. artichoke slice did not vary significantly; even with a 2% (w/v) NaCl

Table 1 - Experimental design of microwave drying and corresponding responses.

Standard order	Run order (W)	Power	Thickness (mm)	NaCl conc. (g/100 mL)	Drying time (min)	Effective diffusivity*10⁻⁸ (m²/s)	Rehydration ratio
9	1	200	2	0	6	0.79	3.27
16	2	200	4	1	8	1.61	2.76
13	3	200	4	1	9	1.58	3.18
2	4	300	2	1	4	0.77	4.47
14	5	200	4	1	14	1.50	3.71
4	6	300	6	1	5	7.62	3.19
3	7	100	6	1	96	0.42	4.28
15	8	200	4	1	12	1.31	3.18
5	9	100	4	0	75	0.26	3.98
12	10	200	6	2	11	3.37	2.97
7	11	100	4	2	83	0.24	3.57
11	12	200	2	2	5	0.68	5.29
1	13	100	2	1	33	0.11	4.45
8	14	300	4	2	4	4.60	3.57
10	15	200	6	0	9	3.77	4.03
6	16	300	4	0	7	3.32	3.19

concentration in the pretreatment solution. This may be due in part to the low temperature level and short duration of the pretreatments.

2.2 Drying equipment and experimental method

A programmable domestic microwave oven (Samsung-MW71E, Malaysia) with a maximum output power of 800 W and wavelength of 2,450 MHz was used for drying. Aliquots of 50 g of pretreated or fresh tuber slices were spread on a glass dish (dried and weighed before use) as a single layer and placed on the center of the turntable of the microwave cavity. Drying was performed for each trial at the microwave output power levels specified in Table 1. Moisture loss was measured periodically (60-s intervals) by taking out and weighing the dish on a digital balance. The drying process continued until the desired moisture content was attained (< 10%, w/w). Trials were carried out according to the experimental design including the processing conditions and run order for each trial (Table 1). The rehydration ratio (RhR) was also determined for J. artichoke slices dried according to each trial specified in Table 1. The RhR is an important quality parameter to evaluate the drying process in terms of product quality. Dried slices were immersed in warm water (50°C) and their weight gain was monitored until it stabilized. The RhR was calculated as a ratio of net weight gain to initial sample amount.

2.3 Theoretical approach to effective moisture diffusivity

The effective moisture diffusivity (EMD) was determined to obtain information about the mechanism of moisture transfer and complexity of the drying process. It was defined by Fick's second law with the assumption that diffusion is the only physical mechanism to control the transfer of water molecules to the surface. Artichoke slices prepared at different thicknesses were assumed to be an infinite slab, since other directions were large enough compared to the thickness. Thus, moisture movement was only throughout thickness. Fick's second law for moisture movement was solved with the following assumptions:

- the particle was homogenous and isotropic
- the material characteristics were constant, and the shrinkage was negligible
- mass transfer was in one direction
- moisture was initially uniformly distributed throughout the mass of a sample
- the pressure variations were negligible
- evaporation occurred only at the surface
- surface diffusion was ended, so the moisture equilibrium arises on the surface
- effective moisture diffusivity was constant versus moisture content during drying
- resistance to mass transfer at the surface was negligible compared to the internal resistance of the sample
- mass transfer was represented by a diffusional mechanism

The following analytical solution of Fick's second law proposed by CRANK (1975) was used to calculate the effective moisture diffusivity.

$$MR = \frac{M_t - M_e}{M_i - M_e} = \frac{8}{\pi^2} \sum_{i=0}^{\infty} \frac{1}{(2i+1)^2} \exp\left(-\frac{(2i+1)^2 \cdot D_{eff} \cdot \pi^2}{4L^2} \cdot t\right) \quad \text{Eq. (1)};$$

where D_{eff} is the effective moisture diffusivity (m²s⁻¹), L is the half thickness (drying from both sides) of slab (m), MR was the fractional mois-

ture ratio, t was the drying time (s). M_t was the moisture content of the material at any time, t; M_i was the initial moisture content of the material before drying; and M_e was the equilibrium moisture content of a dehydrated artichoke slice, all moisture content values were in dry basis.

For long-term drying, only the first term of Eq.(1) was used to explain the drying procedure. The equilibrium moisture content (M_e) was assumed to be zero for microwave-assisted drying. The final equation to calculate the EMD was as follows:

$$MR = \frac{M_t}{M_i} = \frac{8}{\pi^2} \exp\left(-\frac{D_{eff} \cdot \pi^2 \cdot t}{4L^2}\right) \quad \text{Eq. (2)};$$

Further simplification of Eq. (2) resulted in a straight-line equation as Eq. (3);

$$\ln(MR) = \ln\left(\frac{8}{\pi^2}\right) - \left(\frac{D_{eff} \cdot \pi^2}{4L^2} \cdot t\right) \quad \text{Eq. (3)};$$

The effective moisture diffusivity was calculated by fitting Eq. (3) to the curve of ln(MR) vs. time (Fig. 1), and the results are presented in Table 1.

2.4 Experimental design

Drying time (Z_1), effective moisture diffusivity (Z_2), and rehydration ratio (Z_3) were the responses used to optimize the process variables by response surface methodology (RSM). A Box-Behnken design was employed in this regard. Independent process variables (X_1, X_2, and X_3) were microwave output power, slice thickness, and concentration of the pretreatment solution (NaCl); each was specified at three levels with 16 runs including four replicates at the central

point. The ranges and levels of independent variables are presented in Table 1. Minitab (Minitab 15.1.0.0) was used to analyze the experimental data, which were fitted to a second-order polynomial regression model including the coefficients of linear, quadratic and two factors interaction effects. The proposed model was as follows:

$$Z = \beta_0 + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X_i^2 + \sum_{i=1}^{2} \sum_{j=i+1}^{3} \beta_{ij} X_i X_j \quad \text{Eq. (4)}$$

where Z was the response of the equation, b_0 was the constant coefficient, β_i was the linear coefficient (main effect), β_{ii} was the quadratic coefficient, and β_{ij} was the two factors interaction coefficient. The surfaces of the predicted responses were plotted by Sigma Plot (v. 8.02; 2002) (SPSS Inc. Chicago, IL, USA). The values of R^2, adjusted-R^2, and lack-of-fit of models were evaluated to check the model adequacies.

2.5 Optimization by genetic algorithm

The genetic algorithm (GA) is a global search algorithm, which is designed to mimic Charles Darwin's principle of "survival of the fittest" to solve complex optimization problems without falling into local optima (GOLDBERG, 2001; MOHEBBI et al., 2011b; MORIMOTO, 2006). MATLAB version 2010b (MathWorks, Inc.) was used to optimize the interested responses of microwave-assisted drying of Jerusalem artichoke tubers as a function of process conditions by the GA.

3. RESULTS AND DISCUSSION

This study was designed to evaluate microwave-assisted drying of Jerusalem artichokes and to optimize the process using response
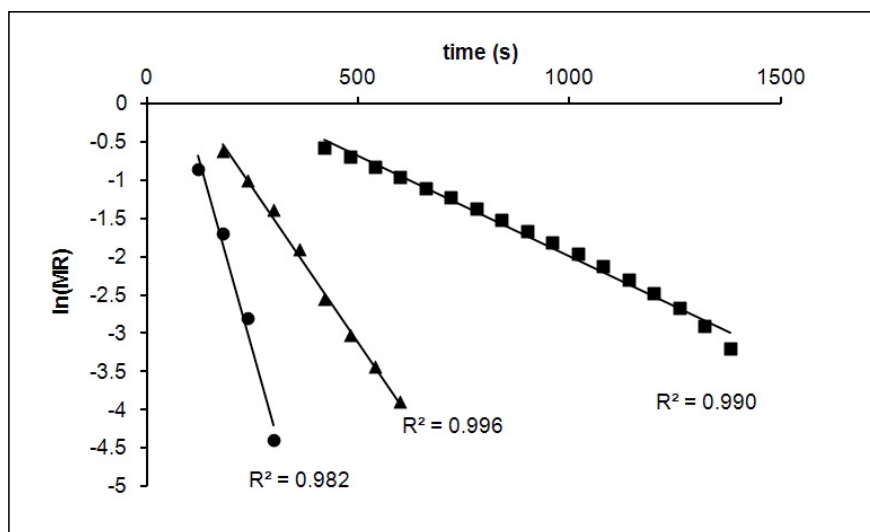

Fig. 1 - Linear relation between ln(MR) and drying time for the slice thickness of 2 mm treated with 1% NaCl and dried at 100 W output power (■), the slice thickness of 2 mm without treatment and dried at 200 W output power (●), the slice thickness of 4 mm treated with 1% NaCl and dried at 200 W output power (▲) and the fitted proposed model line (—).

Table 2 - Regression coefficients of predicted models for the investigated responses of microwave assisted drying of J. artichoke.

Variable[a]	Coefficient		
	Drying time	Effective Moisture Diffusivity	Rehydration Ratio
β_0	130.625*** [e]	4.055999*	5.918046***
β_1	-1.285***	-0.02718*	-0.01159* [c]
β_2	16.562***	-1.60884**	-0.79208** [d]
β_3	0.875ns [b]	-	1.029874*
β_{11}	0.003***	0.0000339ns	3.22E-05**
β_{22}	-	0.096813ns	0.15846***
β_{33}	-	-	0.114851ns
β_{12}	-0.062***	0.008183***	-0.00139*
β_{13}	-	-	0.001977*
β_{23}	-	-	-0.38475***
model	***	***	***
linear	***	**	**
quadratic	***	ns	***
cross-product	***	***	***
R^2	0.98	0.98	0.98
Adj-R^2	0.97	0.96	0.94
Lack-of-fit	0.101	0.312	0.085

[a] Polynomial model $Z = \beta_0 + \sum_{i=1}^{3}\beta_i X_i + \sum_{i=1}^{3}\beta_{ii}X_i^2 + \sum_{i=1}^{2}\sum_{j=i+1}^{3}\beta_{ij}X_i X_j$ adjusted by backward elimination at the level of 0.05% with the lack-of-fit test, where β_0 is the constant coefficient, β_i is the linear coefficient (main effect), β_{ii} is the quadratic coefficient, and β_{ij} is the two factors interaction coefficient. [b] ns, not significant ($p > 0.05$); [c] *, significant at $p \leq 0.05$; [d] **, significant at $p \leq 0.01$; [e] ***, significant at $p \leq 0.001$.

surface methodology (RSM) and genetic algorithms (GA). Drying of J. artichoke tubers resulted in good performance with high quality product in terms of drying time (DT), effective moisture diffusivity (EMD), and rehydration ratio (RhR). Models developed by RSM and GA displayed similar performances to predict the experimental results determined for each interested response.

Multiple linear regression analysis of the experimental data yielded second-order polynomial models for predicting DT, EMD, and RhR. Analysis of variance (ANOVA) was conducted to determine significant effects of process variables on each response and to fit second-order polynomial models to the experimental data. Regression equation coefficients of the proposed models and statistical significance of all main effects calculated for each response were obtained. The effects that were not significant ($p > 0.05$) were stepped down from models without damaging the model hierarchy (Table 2). The ANOVA table also showed that the lack of fit was not significant for all response surface models at a 95% confidence level. On the other hand, R^2 and Adj-R^2 were calculated to check the model adequacy as lack-of-fit > 0.05; $R^2 \geq 0.98$; and Adj-$R^2 \geq 0.94$ (Table 2).

3.1 Drying time

Drying time (DT) is important because it is an index of the drying performance. A reduction in drying time means less energy requirement for the process. Table 2 shows that both microwave power and slice thickness significantly affected DT to decrease the moisture content of slices to less than 10% ($p \leq 0.05$), whereas a change in the salt (NaCl) concentration of the pretreatment solution was not an important factor ($p > 0.05$). The microwave-assisted drying process, which reduced the moisture content of Jerusalem artichoke to less than 10%, took 4-96 min varying based on the process variables. The DT decreased as microwave output power increased due to higher energy transfer for unit process time (Fig. 2). A similar microwave power effect on DT was reported previously (AL-HARAHSHEH et al., 2009; SOYSAL, 2004; SUMNU et al., 2005). The favorable influence of output power on DT may be attributed to the heating mechanism of microwave technology causing high internal pressure and concentration gradients, which increases the flow of liquid throughout the food (AL-HARAHSHEH et al., 2009; SUMNU et al., 2005; WANG and SHENG, 2006). The second factor that had a significant effect on DT values was slice thickness (Fig. 2). However, an increase in DT is not desirable from an economical point of view, and there was a positive relationship between slice thickness and DT (Table 2 and Fig. 2). Drying time to decrease moisture content under a target level (< 10%) increased with thicker slices, especially when a low output power was set (Fig. 2). A similar result related to the effect of slice thickness on DT was obtained by GIRI and PRASAD (2007) studying the drying kinetics and rehydration characteristics of mushrooms that were processed in microwaves.
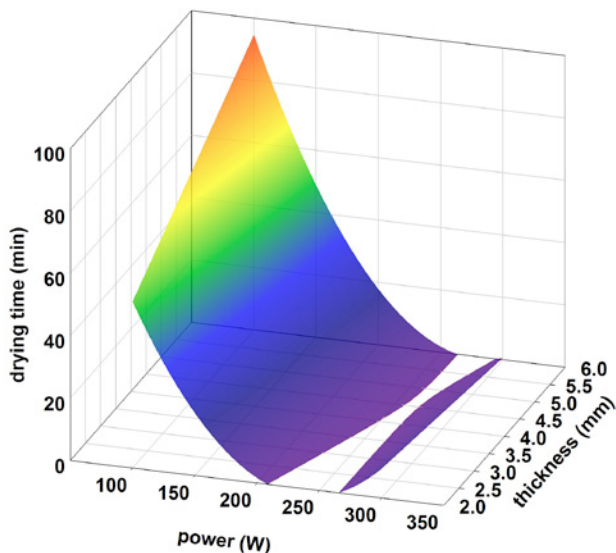
Fig. 2 - Response surface for the effects of power and slice thickness treated with 1% NaCl solution on drying time of Jerusalem artichoke slices.

3.2 Effective moisture diffusivity

Increasing the effective moisture diffusivity (EMD) is desirable in a microwave-assisted drying process, since this technique is expected to create awareness and an improvement in process performance is one of the novelties. The EMD was calculated and used as an index of the rate of the drying process (Table 1). The mass transfer of water molecules in potato matrix dried using different techniques has been previously studied. For microwave application on potatoes, the calculated diffusivities were reported in the range of $1.91*10^{-8}$ $m^2.s^{-1}$ to $3.73*10^{-8}$
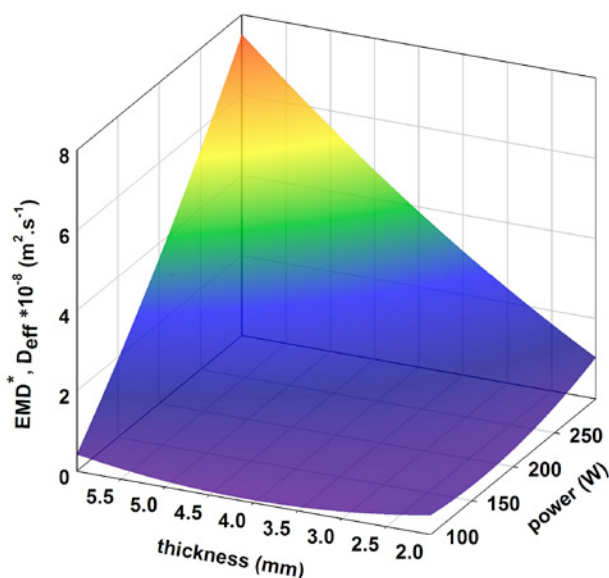

Fig. 3 - Response surface for the effects of power and slice thickness on EMD of Jerusalem artichoke slices irrespective of pretreatment.
* effective moisture diffusivity

$m^2.s^{-1}$ (MCMINN *et al.*, 2003), which were comparable with EMDs ($0.11*10^{-8}$ $m^2.s^{-1}$ to $7.62*10^{-8}$ $m^2.s^{-1}$ depending on processing conditions) of Jerusalem artichoke slices dried in a microwave oven. According to the results of the ANOVA of EMD, the output power and slice thickness are two important factors affecting the EMD of the drying process ($p \leq 0.05$) (Table 2). The EMD remained almost constant with changing slice thickness (2-6 mm) at an output power of 100 W (Fig. 3). Similarly, changing the output power (100-300 W) did not significantly affect the EMD of 2-mm thick tubers. However, there was a significant interaction between both factors (microwave output power and thickness) *(p ≤ 0.05)*, and the EMD increased when higher values of slice thickness and output power were selected (Fig. 3). DATTA and RAKESH (2013) reported that microwave heating is superior compared to conventional heating, since significant internal evaporation inside the microwave-heated material leads to additional mechanisms of moisture transport that enhance moisture loss during heating. Thus, an increase in microwave power results in more energy transfer to the food material during drying and as a result more internal evaporation resulting in a higher EMD.

3.3 Rehydration ratio

Rehydration ratio (RhR) is a widely used quality index for dried products. Rehydration values provide information about the changes in physical and chemical properties of a dried sample attributed to drying and treatments preceding dehydration (MASKAN, 2000). To investigate the effect of drying conditions on final product quality, the RhR of dried tuber slices were determined (Table 1). The effects of drying conditions on RhR were analyzed by ANOVA and showed that all processing conditions were effective on the rehydration capacity of microwave-assisted dried Jerusalem artichoke slices except for the quadratic term of NaCl concentration of the pretreatment solution ($p \leq 0.05$) (Table 2). Figures 4, 5, and 6 display the change of RhR with output power, slice thickness, and NaCl concentration. The RhR of dried samples at an output power around 250 W was smaller than that measured for slices dried at any other power level, when tuber slices were dried without pretreatment. On the other hand, a minimum RhR value was measured for J. artichoke pretreated slices dried at an output power of less than 250 W, and tuber slices dried at 200 W had the lowest RhR when they were treated with the highest concentration (2%) of NaCl solution (Fig. 4). This negative effect of increasing output power on RhR results from quick sample shrinkage due to rapid water loss depending on the internal temperature. The reason for the change in the effect of high output power with the NaCl concentration of the pretreatment solution may
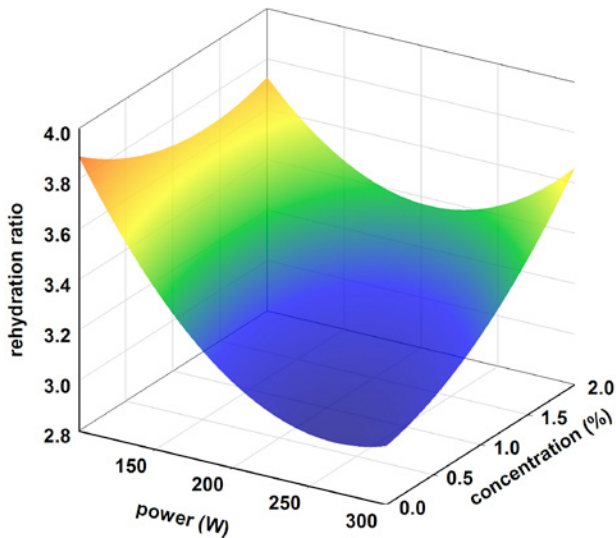
Fig. 4 - Response surface for the effects of power and slice thickness treated with 1% NaCl solution on the rehydration ratio of Jerusalem artichoke slices.

result from partial water loss occurring during pretreatment, although the change in the final moisture content of dried slices pretreated with NaCl solution was not significant compared to the water content of fresh tuber slices (data not shown). In other words, microwave-assisted drying finalized in a shorter period for samples with less moisture content compared to fresh ones. Thus, the internal temperature of a sample never reaches to its level seen at drying of the sample without pretreatment, which means less shrinkage and high RhR. These results are consistent with the changes in RhR with microwave power also observed by WANG and XI (2005). Slice thickness was another factor that had a significant effect on RhR values. Change in RhR was plotted as a function of slice thickness vs. NaCl concentration and slice thickness vs. out-

put power as shown in Figures 5 and 6, respectively. The RhR of the dried products decreased with an increase in slice thickness. The effect of NaCl concentration on this trend was significant when low slice thickness values were conducted (Fig. 5). The RhR increased with increasing NaCl concentration of pretreatment solution when thinner slices were analyzed (Fig. 5). A decrease in RhR was also detected with increasing thickness under the effect of power (Fig. 6). Thickness effects may result from greater volumetric heating, which generates higher pressure inside the Jerusalem artichoke tuber, resulting in boiling and bubbling of the samples and reduced RhRs of the dried products (WANG and XI, 2005).

3.4 Optimal responses

An optimization procedure by RSM was conducted for all responses as a function of processing conditions. The EMD and RhR were maximized, since higher values of these responses means faster drying and better product quality, respectively. The DT response was minimized because a short process length is preferred due to economical considerations. As a consequence of the optimization procedures for these three drying characteristics, the following operating conditions were found to be optimal: power of 235 W; slice thickness of 5.95 mm; and NaCl concentration of 0.081.

3.5 Genetic algorithms

The GAs were used to select the best subset of variables and to build predictive regression models in order to study the relationships between the results obtained from the experimental trials (DT, EMD, RhR) and the pro-
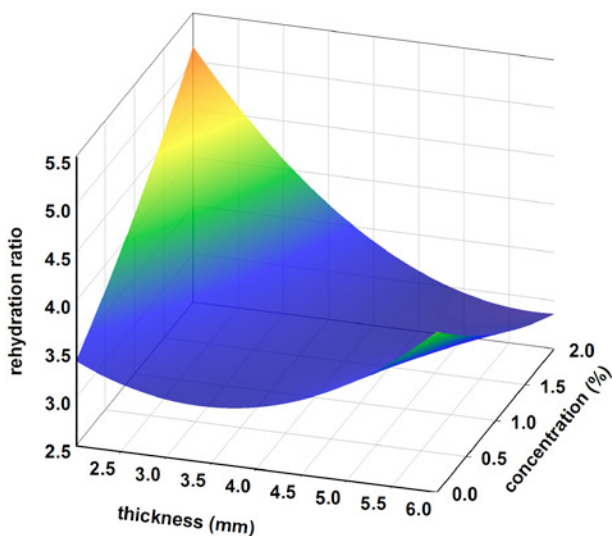

Fig. 5 - Response surface for the effects of power and concentration (slice thickness of 4 mm) on the rehydration ratio of Jerusalem artichoke slices.
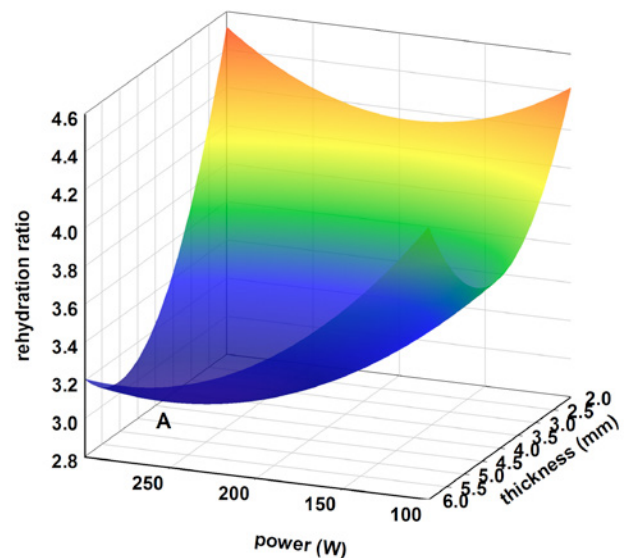

Fig. 6 - Response surface for the effects thickness and concentration (power of 200W) on the rehydration ratio of Jerusalem artichoke slices.

Table 3 - Model coefficients of proposed second order polynomial model[a] obtained by GA.

Variable[a]	Coefficient		
	Drying time	Effective Diffusivity	Rehydration Ratio
β_0	-0.500	0.522	-0.143
β_1	0.118	0.439	-0.267
β_2	0.035	0.024	0.107
β_3	0.488	0.065	0.190
β_{11}	0.253	0.065	0.481
β_{22}	-0.129	0.065	0.024
β_{33}	-0.335	0.439	-0.309
β_{12}	0.047	0.024	0.107
β_{13}	0.076	0.060	-0.600
β_{23}	-0.500	-0.558	0.600

[a] Polynomial model $Z = \beta_0 + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X_i^2 + \sum_{i=1}^{2} \sum_{j=i+1}^{3} \beta_{ij} X_i X_j$, where β_0 is the constant coefficient, β_i is the linear coefficient (main effect), β_{ii} is the quadratic coefficient, and β_{ij} is the two factors interaction coefficient. Independent process variables (X_1, X_2, and X_3) were microwave power, slice thickness, and concentration of pretreatment solution (NaCl).
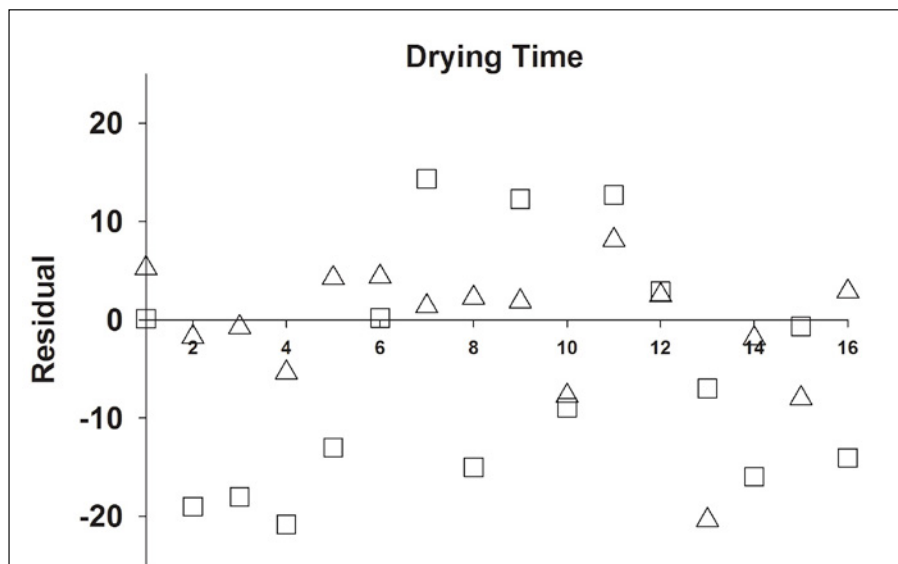

Fig. 7 - Residuals between experimental results and predicted responses by RSM (Δ) and GA (□) models calculated for each trials of drying time in experimental design.

cess parameters. The coefficients of regression models corresponding to DT, EMD, and RhR are presented in Table 3. The residual is an index of model performance where a smaller residual indicates better prediction performance. Thus, residuals between experimental results and predicted values by RSM and GA are shown in Figures 7-9 for each response. Models produced by GA display a similar performance in prediction of EMD and RhR values as those produced by RSM. Figure 7 shows smaller residuals of DT values predicted by models using RSM than GA. Although a performance decrease was seen in the prediction of DT values by GA, this procedure presented in this work can be applied for optimization in microwave-assisted drying of food materials as a rapid and non-destructive inspection method. GAs have been reported as a nov-

el approach in the osmotic drying of kiwifruit by FATHI *et al.* (2011b). Similarly, MOHEBBAT *et al.* (2011) reported genetic algorithms as a method with a high potential for optimization in all food processes.

4. CONCLUSIONS

The experimental results and their analysis demonstrate the possibility of using this innovative method based on microwave technology for the drying of Jerusalem artichoke tubers. To the best of our knowledge, this is the first study on the microwave-assisted drying of Jerusalem artichoke tubers and optimization of process parameters using RSM and GA procedures. The results of the present work demonstrate the feasibility of the DT, EMD,
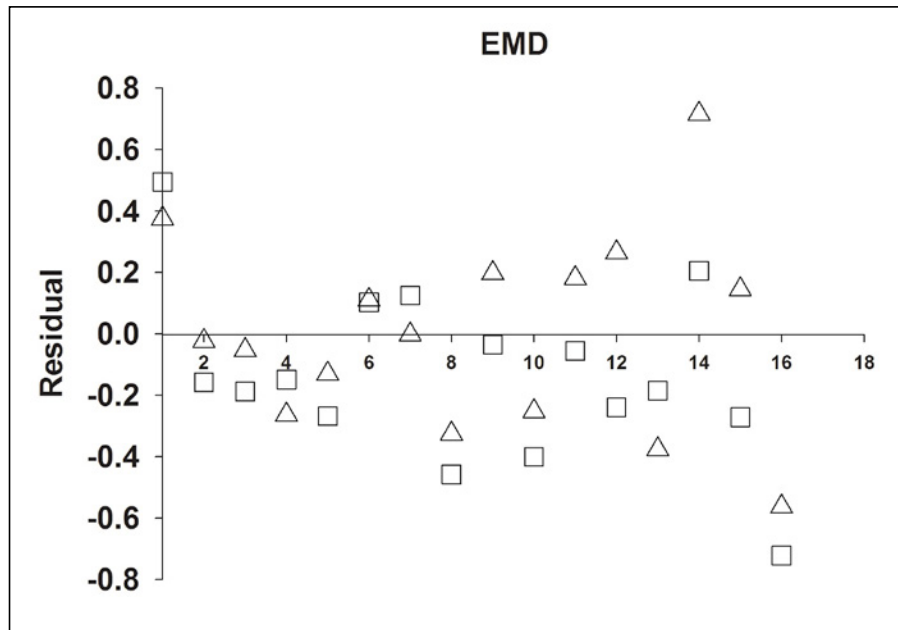
Fig. 8 - Residuals between experimental results and predicted responses by RSM (Δ) and GA (□) models calculated for each trials of effective moisture diffusivity in experimental design.
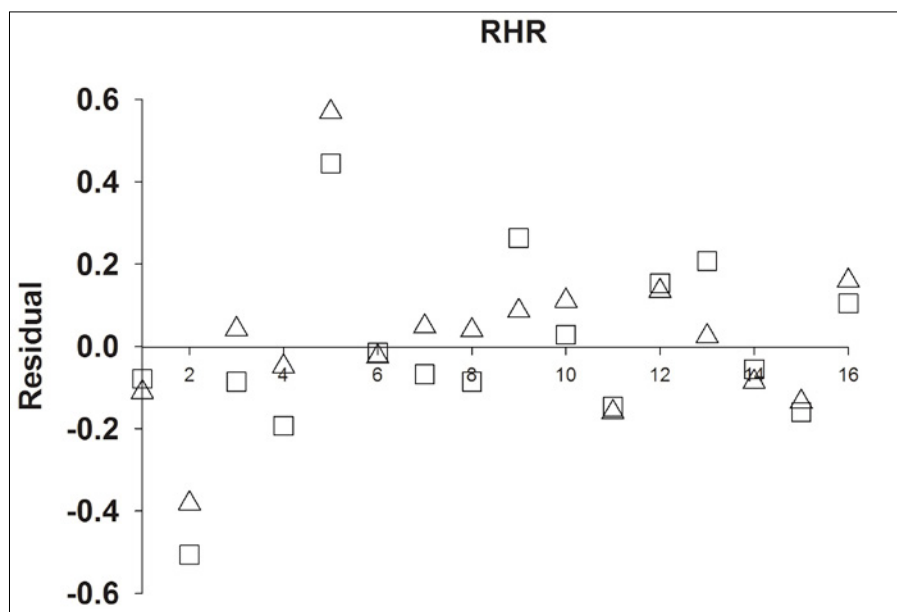

Fig. 9 - Residuals between experimental results and predicted responses by RSM (Δ) and GA (□) models calculated for each trials of rehydration ratio in experimental design.

and RhR determinations for accurate prediction. The performance of RSM with respect to R^2, adj-R^2 and lack-of-fit values was acceptable. The GA and RSM methods produced similar models of performance for microwave-assisted drying of artichoke tubers. The analysis and results from this present study imply that both RSM and GA models can be used in cohesion to gain complete insight into the bioprocessing system.

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