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Static drying of yellow onions (Allium cepa): Process monitoring and enumeration of yeasts and moulds in the food

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ABSTRACT

In this work, slices of yellow onions (Allium cape) with a diameter of (6.7 ± 0.05) cm and a thickness of (1 ± 0.05) cm are dehydrated in a drying oven at two temperatures: 40 °C and 90 °C. The average initial mass and water content of the samples are 32.61 g and 92.13%, respectively. The microbial flora in moulds and yeast is also enumerated before and after drying. An experiment plan of two variables, namely drying time and temperature, is followed to optimize the process tests. The moisture content is taken as a response. The interactions between operating variables are shown and a mathematical model is established expressing, thus, the variation of the moisture content of the onion slices as a function of the temperature and the drying time. A correlation of experimental results and calculations is indeed established. The results show that drying duration decreases with increasing temperature and water content of onion slices decreases from 92.13% to 4.5% during 2595 minutes, and from 92.13% to 9.47% during 1245 minutes, at 40 °C and 90 °C, respectively. Also, the experimental results lead to the appropriate choice of the temperature and the drying time in order to reach adequate moisture content. Finally, Oven drying of the yellow onions with determined dimensions eliminates the moulds to desired and encouraging values.

Introduction

In order to preserve foods, drying is considered to be the most widely used technique in the agrifood sector (Vallespir et al. 2018), which consists in removing excess water from an agricultural product (Kumar et al. 2016). The onion is the most produced vegetable in the world and in Algeria in particular (Alabi et al. 2016), and given its high water content, which reaches 90 %, which exposes it to deterioration (Putranto, Samuel, and Koulidiati 2019), has this effect their drying presents a solution for the excess of the production.
Drying is a very complicated phenomenon, and the mastery of the drying condition matrix and the quality of the dried product makes it possible to control the final product acceptability of this process.
Indeed, the monitoring of the drying process and the behavior of the product to be dried with respect to the drying conditions makes it possible to control the final quality of the product.
To this end, we carried out a drying and a statistical analysis to define a suitable mathematical model and a comparison of the microbiological quality, before and after drying.

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Materials and methods

Samples preparation

Fresh and ripe yellow onions are purchased from the local market of the city of Ouargla, Algeria. Once the peels are removed, the vegetable is cut into slices with a diameter of (6.7±0.05) cm and a thickness of (1±0.05) cm.

Experimental materials for drying and incubation

The initial water content of the samples is determined by drying them, in an oven, at 105 °C during 24 hours.

Drying experiments carried out in a same device at two different temperatures (40 °C and 90 °C). The internal volume of the bowl is 29 L, a precision balance of Sartorius brand four decimal places, onion slices are placed in glass capsule of 10 cm diameter and 3 cm height with lid. Weights of samples are measured every 15 minutes until weight stability.

Monitoring the water content

The water content of samples is calculated according to the mathematical relationship following equation. (Shukla, Patel, and Kumar 2019).

$$\%H = \left[\frac{Wts - Wt}{Wts}\right] * 100 \quad (1)$$

Where:
%H : % of moisture on the sample.
Wts : the weight of the test sample.
Wt : the weight at the instant (t).
The initial moisture content is determined after drying the sample at 105 °C during a period of 24 hours according to the equation: [(Shukla, Patel, and Kumar 2019)]

$$\%\boldsymbol{Hi} = \left[\frac{(\boldsymbol{Wts} - \boldsymbol{Wd})}{\boldsymbol{Wts}}\right] * \mathbf{100} \quad (2)$$

Where (Hi) presents the initial moisture of the sample, (Wts) the weight of the test sample and (Wd) is the dry weight of simple after 24 hours of drying.

Enumeration of microbial flora (yeasts and moulds)

The enumeration of the microbial flora of yellow onion slices (yeasts and moulds) before and after drying is carried out according to the standard protocol for microbiological analyzes. In a 10% strength stock solution is prepared in buffered peptone water at 0.5 % of K2SO4; the nutrient medium is glucose agar with PCA yeast extract (Plate Count Agar) incubated at 37 °C reading the incubation results after 48 hours.

Statistical analysis of the experimentation process

The drying of the onion slices in the oven characterized by the monitoring of rates of decrease of the water content by varying two operating variables; the drying time (between 0 and 1245 minutes), the drying temperature (40 and 90 °C), without active air, the thickness and the diameter of the sample set at (1 ± 0.05) cm and (6.7 ± 0.05) cm successively. In this oven the two-level factorial experiment plan, with two variables and one response, is realized with the software start graphics following the tests grouped in Table I.

The response is defined as the percentage of the mass loss of the initial sample; it serves to have a sample with known moisture content according to the 4-point experimental design according to the complete 4-way experimental design given in (Table I), the relationship between the independent variables, drying temperature and time of drying presented mathematically in the form of a polynomial model which gives the rate of water loss of the sample (y) according to these variables. The polynomial equation of first order is presented in the following form equation 3.

$$y = a0 + a1X1 + a2X2 + a1a2X1X2 + e \quad (3)$$

Results and discussions

Moisture content

The measurement of the initial humidity of the samples of yellow onions in an oven set at 105 °C during 24 hours shows an average content of 92.13% in water, other works which are carried out this experiment have found the water-like content of the neighborhood of 89.83%, and the variation of the water content of the yellow onion slices measured at each fifteen minutes, shows a decrease in the moisture ration as a function of drying time for both the drying temperature (40°C and 90°C.), in a manner decreasing from an initial grade of 92.13% to 4.5% for a duration of 2595 minutes, and from 92.13 % to 9.47 % during 1245 minutes at 40 °C and 90 °C respectively, and the results of this study are represented in the moisture ration change curve as a function of drying time (fig. 1), characterized by a slow dehydration rate at the temperature of 40 °C and a more rapid dehydration rate for a drying temperature increase at 90 °C.

Microbiological Analysis

In parallel with this study, the microbiological quality of the yellow onions studied is important in a way, moulds and yeasts are counted, and the results show a diminution of the microbial flora after the drying of onions (Table 2). The microbial flora is not detected in the dried samples and is of 1.1×10^4 before drying.

Table 1. Factorial experiment plan values.

Experience	Variables		Response
	temperature	Time	
1	-1	-1	0 %
2	+1	-1	0 %
3	-1	+1	55,46 %
4	+1	+1	82,66 %
Low level	40 °C	0 minute	
High level	90 °C	1245 minutes	

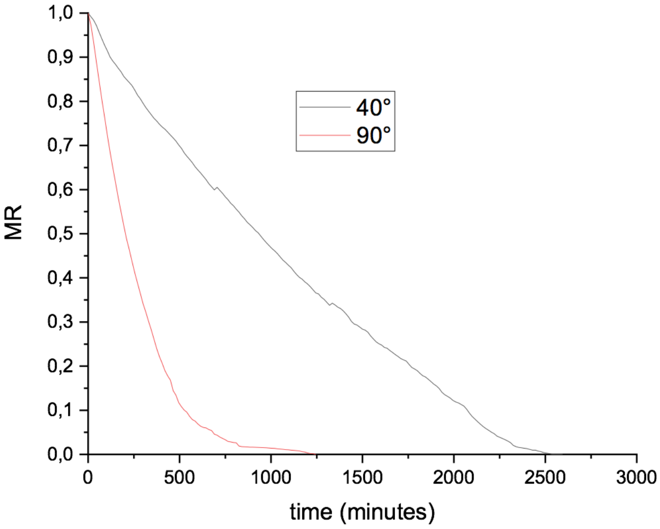

Fig. 1. Variation of moisture ration of yellow onion slices as a function of drying time at 40 °C and 90 °C.

Statistical analysis

The experimentation of this study made possible to obtain the appropriate mathematical model which relates the relation between two factors, namely drying time and drying temperature. The constants computation of the model gives the following mathematical equation.

$$\%H = 34{,}53 + 6{,}8\,x1 + 34{,}53x2 + 234{,}80\,x1x2 \quad (4)$$

This model describes the moisture loss rate of dried onion slices, and the effects of the two factors (factor A: temperature, factor B: time), shows that in these operating conditions described, that the time factor (factor A) has an overall effect of 13.6% and the effect The overall factor of temperature (factor B) is 69.0%, whence the effect of factor B is greater than the factor A of 511.76% (Fig. 2).

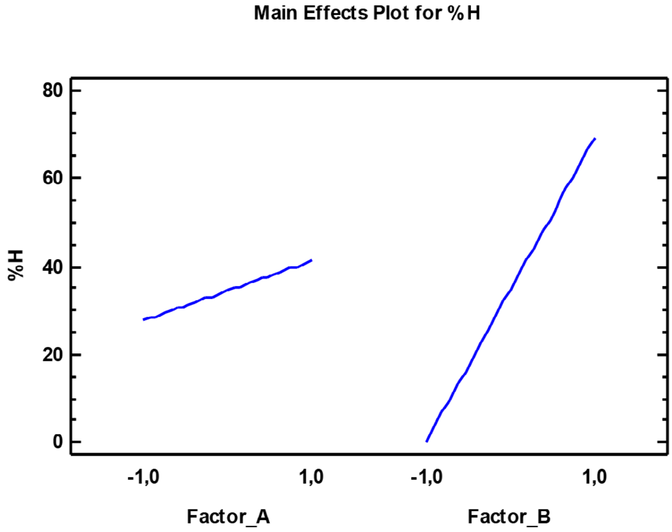

Fig. 6. The main effect of temperature and time of drying.

The correlation between the theoretical results and the experimental ones at a temperature of 40 °C shows a line laniary with a value of R2 = 0,9927 (Fig. 3).

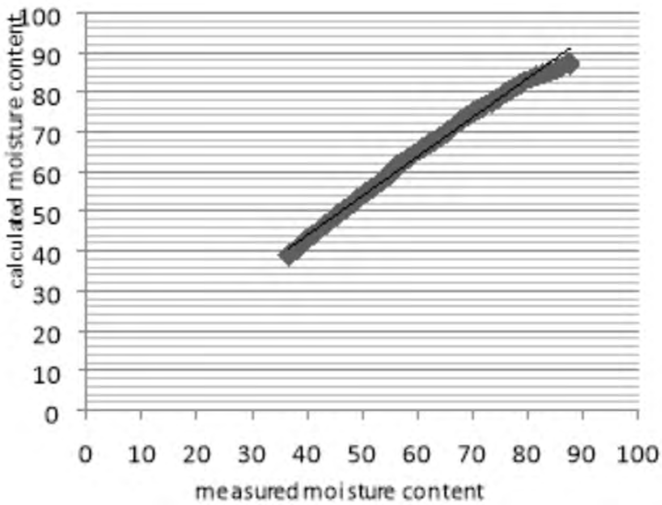

Fig. 3. Correlation between the moisture loss rates found and calculated at 40 °C with linear model.

Table 2. Yeasts and moulds enumeration results.

N	Results	Free onion				Dried onion				
		Plant		Limite		Results	Plant		Limit	
		n	c	m	M	40°C 90°C	n	c	m	M
1	1,1 x 10^4									
2	1,2 x 10^4									
3	1,1 x 10^4	5	2	5 x 10^6	5 x 10^7	ND	5	2	5 x 10^5	5 x 10^6
4	1,1 x 10^4									
5	1,1 x 10^4									

Table 3. Empirical and semi-empirical models close to onion drying kinetics (mazandarani et al. 2017)

Model name	Mathematical expression of model
Page	$MR = \exp(-kt^n)$
Modified Page	$MR=\exp(-(kt^n))$
Newton	$MR= \exp(-kt)$
Two- term	$MR= a \exp(-kt) + b \exp(-k_2t)$
Henderson and Pabis	$MR = a \exp(-kt)$
Wang and Singh	$MR = 1 + at + bt^2$
Midilli-Kucuk	$MR= a \exp(-kt^n) + bt$
Approximation diffusion	$MR=a\exp(-kt)+(1-a)\exp(-k_1bt)$

The moisture loss rate equation of the onion slices under the temperature conditions of 40 °C and the time interval (0 to 1245 minutes) is as follows:

$$\%H = 0{,}9875\ t + 4{,}4905 \quad (5)$$

It corresponds to the constant rate of water content loss. However, the correlation between the results in the temperature of 90 °C case, and the case with the same interval of time (0 to 1245 minutes), gives a non-linear curve (Fig. 4). It shows a divergence between values of the model and the experimental values, with R2 = 0,7361. The mathematical equation for the curve is:

$$\%H = 0{,}8333\ t + 31{,}605 \quad (6)$$

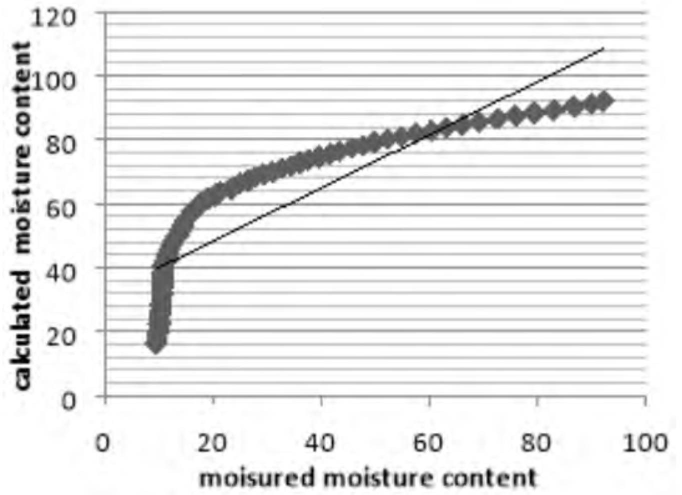

Fig. 4. Correlation between the moisture loss rates found and calculated at 90 °C with linear model.

For the drying temperature 40°C, the linear model obtained for the variable drying time is perfectly corresponding, regarding the temperature of 90°C. The mathematical models corresponding to this kinetics are found in theory (empirical and semi-empirical models). Then, it is possible to obtain better correlations.
Table III shows some empirical and semi-empirical models most answered in drying onions.
The selection of drying model of the corresponding onion slices according to the following parameters (Talla, Mar, and Abdou 2019):
- Coefficient of determination (R2) must be higher.
- The model having a lower value of the mean systematic error (RMSE).
- The lowest value of square khi (χ2).

The corresponding calculations are as follows: (Mang et al. 2019)

$$R^2= \frac{\sum_{i=1}^{N}(MRpri-MRexp)}{\sum_{i=1}^{N}(MRexp-MRmoy)} \quad (7)$$

$$\chi 2= \frac{\sum_{i=1}^{N}(MRexp-MR\ pre)2}{N-n} \quad (8)$$

$$RMSE = \frac{1}{N}\sqrt{\sum_{i=1}^{N}(\,MRexp - MR\ pre)\,2} \quad (9)$$

The moisture ration (MR) is determined by the following mathematical equation:

$$MR = \frac{M\_Me}{Mi-Me} \quad (10)$$

Where: M represents the moisture content of the slice onion and Me is the equilibrium moisture content.
The empirical and semi empirical models are analyzed by the origin 2018 software, and based on the selection criteria (coefficient of determination (R2), mean systematic error (RMSE) and square khi (χ2), the most appropriate model that indicates the best fit is the modified page model with coefficient of determination values of 0.9843, χ2 = 0.00133 and RMSE = 0.03653 for the temperature of 40 °C (Fig. 6) and the six mathematical drying models that were used to describe the drying kinetics of yellow onions samples.
R2 = 0.9843, χ2 = 0.00133, RMSE = 0.03653 for the drying temperature of 90 °C (Fig. 5.).
After determining the evaluation criteria, namely the coefficients of determination (R2), the reduced chi-squares χ2) and the errors systematic average (RMSE), the model page modifier is the most appropriate model to describe the behavior of drying in the experimental conditions studied.

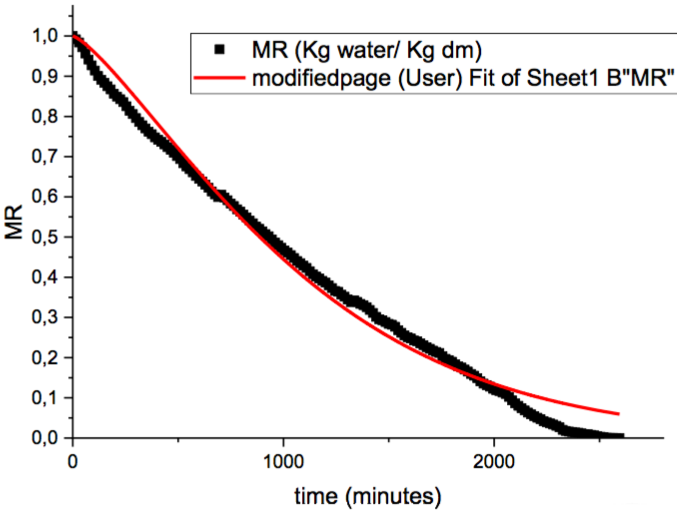

Fig. 5. Presentation of the theoretical and experimental curves of Page modified model at 40 ° C.

The correlation between the values found for the humidity ratio and those calculated by the modified Page model at the drying temperature of 90 °C (Fig. 6) has the following statis-

Table 4. Statistical results obtained from selected models for static drying of onion slices

Model name	T (°C)	Constant and coefficients of model			χ2	RMSE	R^2
Newton	40	k =0,000871			0,00332	0,0576	0,9608
	90	k=0,00376			0,00074	0,02725	0,9904
Approximation diffusion	40	k =0,000938 k1 =20,32391	a=1,07336	b=20,32391	0,00282	0,05306	0,9673
	90	k =0,00409 k1 =19,09596	a=1,09416	b=19,09596	0,00033	0,01828	0,9957
Page	40	k =0,000114	n=1,2836		0,00135	0,03668	0,9842
	90	k=0,00113	n=1,20783			0,00653	0,9994
Modified Page	40	k =0,000851	n=1,3088		0,00133	0,03653	0,9843
	90	k =0,00362	n=1,2093		0,00004	0,00652	0,9994
Henderson and Pabis	40	k =0,000934	a=1,0693		0,00281	0,05303	0,9669
	90	k =0,00402	a=1,07458		0,00041	0,02029	0,9948
Wang and Singh	40	a=- 0,000618	b= 8,833 E-8		0,00018	0,01365	0,9978
	90	a=-0,00237	b=1,3357E-6		0,00287	0,05359	0,9635

tical values:
- Number of Points = 84
- Degrees of Freedom = 82
- Residual Sum of Squares = 0,00616
- Pearson's r = 0,99952
- R-Square (COD) = 0,99904
- Adj. R-Square = 0,99903

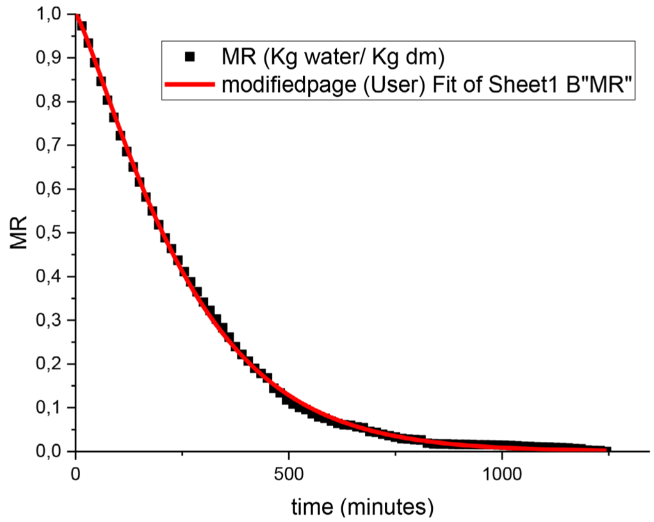

Fig. 6. Presentation of the theoretical and experimental curves of Page modified model at 90 ° C.

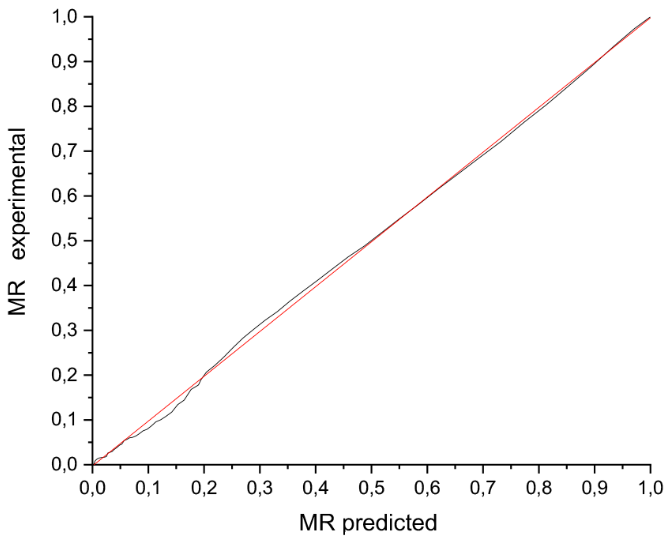

Fig. 7. Correlation between the moisture rate found and calculated at 90 °C with modified page model.

As well as the correlation values between experimental and predicted humidity level by the page model modified at the drying temperature of 40 °C (Fig.7) has the following statistical values :
- Number of Points = 173
- Degrees of Freedom = 171
- Residual Sum of Squares = 0,19531
- Pearson's r = 0,99324
- R-Square (COD) = 0,98652
- Adj. R-Square = 0,98644

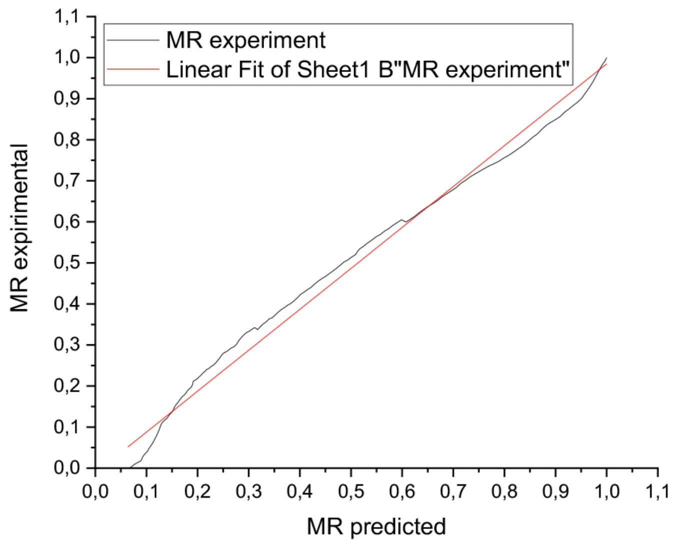

Fig. 8. Correlation between the moisture rates found and calculated at 40 °C with modified Page model.

Conclusion

The main conclusions of this study can be resumed as follows:
- Drying duration decreases with increasing temperature.
- At 40 °C, the water content of onion slices decreased from 92.13% to 4.5% during 2595 minutes.
- At 90 °C, the water content of onion slices decreased from 92.13% to 9.47% during 1245 minutes.
- The Modified Page model is the appropriate mathematical model that can describe the static drying of yellow onion slices.
- The mesophilic flora is not detected after static drying of the

onion slices.
- Oven drying of the yellow onions with determined dimensions eliminates the moulds to desired and encouraging values.

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Conflicts of interest

Authors declare no conflict of interests.

Notes

The authors declare no competing financial interest.

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