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Drying Kinetics of Grated Ginger (Zingiber officinale) In a Microwave Oven with Control of Power

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ABSTRACT: The drying of ginger in Mexico is not commercially done, which causes a large amount of product that is not consumed in the form of fresh vegetable, to be wasted. To obtain a more sustainable and profitable presentation of the product, it was proposed to analyze the drying kinetics and the time consumed to perform this operation, having as quality parameters the organoleptic properties, namely, color, taste and smell.
The kinetics of the drying of grated ginger (Zingiber officinale) was analyzed. A microwave oven with power values of 15 and 20 W/ g of product, was used. This energy was lower than that required by other drying methods, the periods of time used were 35 min for 20 W/g and 45 min for 15 W/g. The numerical model that best represents the kinetics was the exponential one. The color variations at the end of the process were greater for the power of 15 W/g, which turned into a product of acceptable appearance, the taste was slightly more acidic, but the smell lasted very little.

KEYWORDS: Control power, Color change drying kinetics, Ginger grated, Microwave drying.

INTRODUCTION

Drying is an important process for preserving the quality of agricultural products. Until recently, they were dried at temperatures between 40 and 70 °C, mainly with the help of natural environment and with hot air in drying tunnels. Some of the active components of these products are temperature sensitive and are not well-preserved by these drying methods, consequently reducing their quality. To accelerate the drying process of the product with a lower cost, the use the microwave oven has been suggested, since it would more quickly eliminate moisture, and better preserve most properties of products [1, 2].

Ginger is an herbaceous plant native to Asia, of the Zingiberaceae family and of genus Zingiber. They are tropical plants with complicated and irregular flowers with a showy labellum. Ginger is cultivated for its rhizome that is used as a spice. National and state Mexican indicators in 1992 reported only 10 cultivated hectares, in the state of Oaxaca; for the years 1999 and 2000, 267 and 100 hectares were registered respectively in the state of Guerrero, with a total production in 2000 of 1,600 tons and a market value of 14.9 million pesos; the average yield was 16 tons/ha. However, there is an important production in small areas in the tropical regions of the country that is not accounted for and is aimed mainly for regional marketing. This production is not enough to meet the needs of the domestic market, for this reason 500 tons were imported in 2010 [3]. Ginger, both in its fresh and dried presentations, is very popular in culinary practice, and, it has been widely used and approved as an edible and medicinal material. It is considered a safe medicinal herb with few side effects [4]. Ginger is used to treat arthritis, rheumatism, muscle aches, the common cold, indigestion, vomiting, and nausea [5]. It has also antipyretic, antimicrobial, hepatoprotective, hypotensive, gastrointestinal prokinetic and antioxidant characteristics [6, 7, 8]. There are three methods with which most of the organoleptic and medicinal properties of ginger are preserved, in a drying tunnel with hot air, in a microwave oven and using silica gel, the latter is the one used to prepare it with suitable properties for the pharmaceutical industry [7]. A report on the drying of 1.0 〖cm〗^3-thick ginger cubes using a microwave oven [2], applied 60 and 70 °C, in extended periods of time of around 300 min. At 60 °C a better retention of the aroma was perceived than at 70 °C, but the color was highly degraded, turning to a dark brown hue [8]. Also, the loss of moisture in ginger in a vacuum microwave oven was analyzed, with a power of 80 W/g and a drying time of 80 min [9]. The present paper analyzes the drying of ginger in a microwave oven, aiming to reduce the drying time and thus achieve good quality product in terms of its organoleptic properties, taste, smell, and color.

KINETICS OF GINGER DRYING

In the process of drying any plant product, it is important to determine the kinetic model that describes it, which is obtained from experimental data. The humidity ratio is calculated with the equation [10,11]:

$$MR = \frac{(M-M_e)}{(M_0-M_e)} = \frac{M}{M_0} \quad (1)$$

where M is the moisture content at time t, M_0 is the initial moisture content and M_e is the equilibrium moisture content, the value of which depends on the relative humidity of the environment. The list of the most used numerical models is presented in Table 1 and are found in [12, 13, 14, 15]. The criteria for selecting the most appropriate one is that correlation coefficient R^2tends to the unit and that χ^2 is as small as possible, the equations used for its calculation are also found in the previous references.

Table 1. Mathematical models to determine drying kinetics of fruits and vegetables.

Model	Equation
Page	$MR = exp\,(-kt^n)$
Newton	$MR = exp\,(-kt)$
Modified Page	$MR = exp\,(-(kt)^n)$
Exponential	$MR = a\,exp\,(-kt)$
Logaritmic	$MR = a\,exp\,(-kt) + c$

COLOR

To evaluate the change of color of ginger in the drying process we used the Hunter method, which determines the proportions between black/white, L; red/green, a, and yellow/blue, b. These ratios allow to define the scale of measurement of the quality of drying of fruits and vegetables. The two parameters that are derived from this method are the color change, ΔE, and the hue or $chroma$, both are defined in [16].

Experimental procedure.

The ginger samples to be evaluated came from the state of Puebla, which is currently the leading producer region in the country, with a contribution of 70% of the national production [17]. They were washed and well undampened and kept in refrigeration at 4 °C. They were exposed for 10 hours to ambient temperature. Finally, with a conventional kitchen grater they were finely grated. The stem from which the 10 samples of 20 g each were obtained for the corresponding evaluations can be observed in Figure 1. Grated ginger used in each evaluation is included in Figure 2.

The oven was programmed so that the power supplied was 15 W/g and that the temperature of the sample was higher than 50 ° C; this program was verified with a water sample. The tray with the product was introduced and the power was applied for a period of 1 min, then, weight, color and temperature were measured. This process was repeated until the difference between two successive measurements was 0.004 g. Five different evaluations were done following the previous procedure. The whole procedure was repeated for the power of 20 W/g.

Figure 1. Ginger stem.

Figure 2. Grated ginger.

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INSTRUMENTATION

We used a MARS 5 microwave oven which has three working power ranges: 0-300 W, 0-600 W and 0-1200 W at a frequency of 2 450 MHz. It has an optic Fiber temperature control with an accuracy of ± 0.1 °C in the range 0 to 200 °C. For temperature measurement, K-type thermocouples (0.5 °C accuracy) were used; the temperature of the samples was determined with a 42540 EXTECH infrared thermometer with an operating range between -50 °C and 538 °C and an accuracy of ± 0.1 °C. The relative humidity of the environment was measured with a EA25 EXTECH digital higro-thermometer, of 0.1 % accuracy; the mass was quantified with a BL1505 SARTORIUS electronic balance of 0.001 g accuracy. A PCM/PSM Color Tec colorimeter with 20 mm sensor was used. It was calibrated with its own ceramic plate whose parameters are X = 93.50, Y = 0.3114, Z = 0.3190. The electrical power consumption was determined with an EXTECH 380803 power analyser, which has a measuring range between 0 and 2000 W and accuracy of ± 0.1 W.

RESULTS

In both tests the initial moisture content was 0.86 kg water/kg dm (dm, dry mass), and the final value was 0.011 kg $_{water}$/kg$_{dm}$. For the power of 15 W/g, 45 min were needed and for 20 W/g, only 35 min. The maximum temperature of the ginger samples was 51 °C, which made the microwave oven continuously stop working due to the imposed condition of maximum permissible temperature of 50 °C; 12 stoppages were counted in the first case and 21 for the higher power. The graph of both curves is presented in Figure 3.

The numerical model of the drying kinetics that best represents it was the exponential type one, models for each power as well as the equation obtained are presented in Figures 4 and 5; the values of the equation and the conditions imposed from R^2 approximate to the unit and χ^2 smaller possible are summarized in table 2.

Table 2. Exponential numerical model and its values.

Power	$MR = aexp(-kt)$		R^2	χ^2
W/g	a	k		
15	0.8540	- 0.0676	0.996	0.000217
20	0.7818	- 0.0907	0.971	0.0075

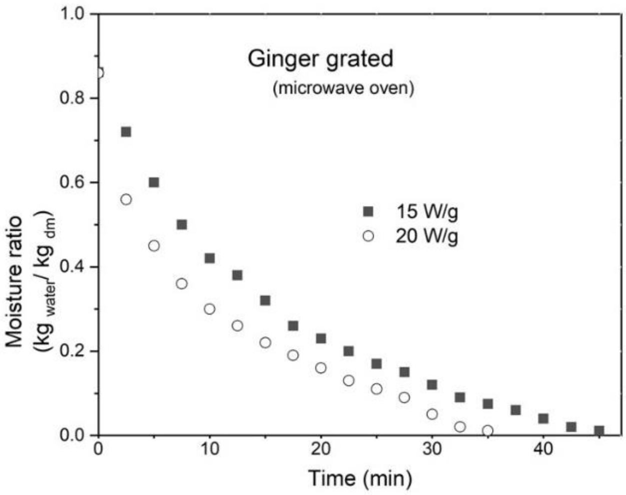

Figure 3. Moisture content of ginger in the microwave oven

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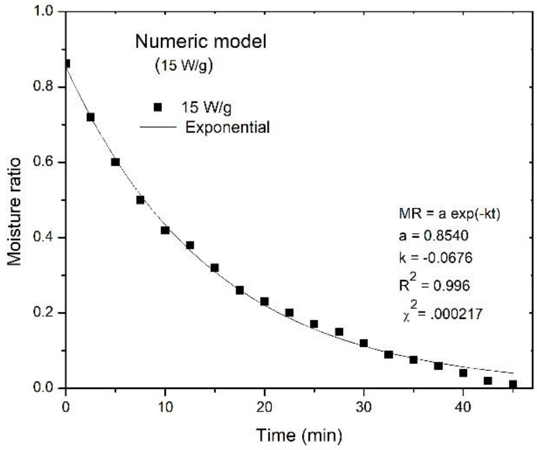

Figure 4. Numerical model of the drying kinetics for 15 W/g.

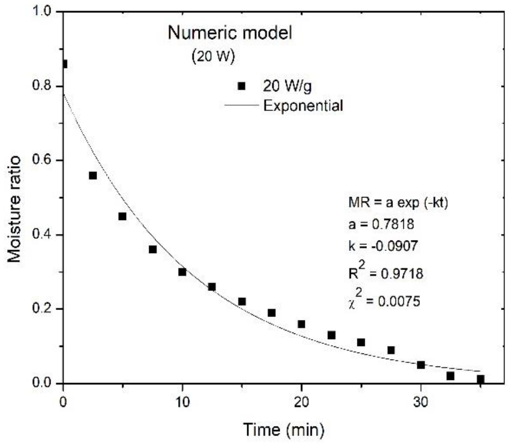

Figure 5. Numerical model of drying kinetics for 20 W/g.

Their equations are, for 15 W/g:

$$MR = 0.8540\exp(-0.067t)$$

And for 20 W/g:

$$MR = 0.7818\exp(-0.00907t)$$

A very irregular behavior of the drying velocity was observed, at the beginning very high values were observed and later they decreased to very small values. For 20 W/g the maximum value was 0.022 $g_{water}/g_{dry\ mass\ min}$ and the minimum, 0.009 $g_{water}/g_{dry\ mass\ min}$, for 15 W/g the highest rate was 0.014 $g_{water}/g_{dry\ mass\ min}$, and the minimum also of 0.009 $g_{water}/g_{dry\ mass\ min}$. Both behaviours can be seen in Figure 6.

By plotting the moisture content against the drying rate, the drying curve of the process is obtained, in this case, in Figure 7 the average of both experiences is shown, the model obtained has the following equation:

$DR = 0.0127 + 0.0828\,MR + 0.145\,MR^2$,
with $R^2 = 0.933$, indicating a good approximation of the process.

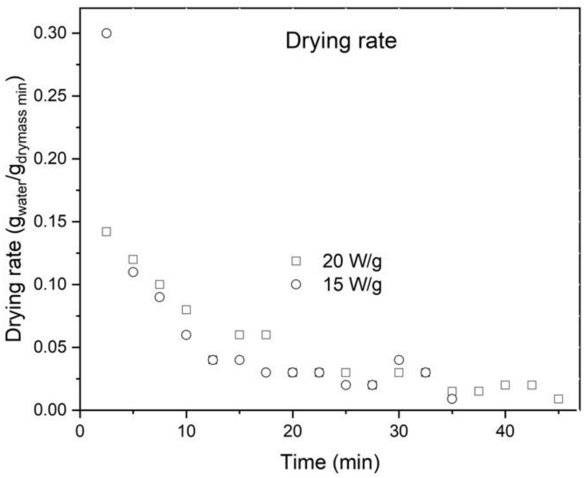

Figure 6. Drying rate versus time.

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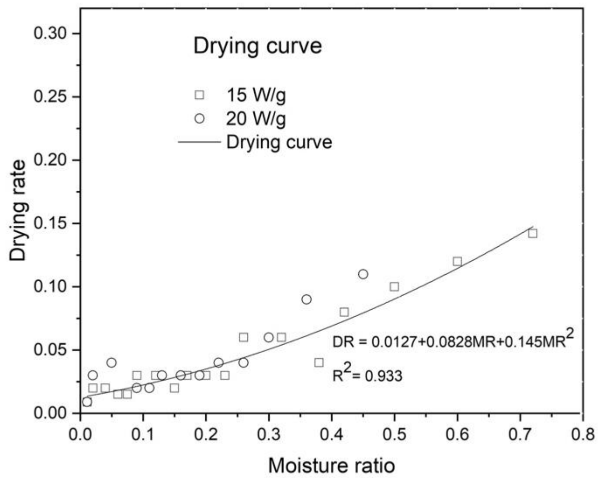

Figure 7. Average drying curve.

For the determination of the quality of the final product, the Hunter method, which is based on the change of color, ΔE, and the hue or $chroma$, has been used. The initial values of $L, a,$ and b variables for ginger were 53.77, 12.02 and 24.01 respectively; for the power of 15 W/g they resulted in 36.05, 6.95, and 16.1 and for 20 W/g they were 30.1, 7.01, and 11.7. Therefore, the color change was ΔE = 20.56 and $chroma$ = 9.39; for 15 W/g and ΔE 27.14 and $chroma$ = 13.20. From these values it is deduced that the product significantly decreased its color as well as the hue under 15 W/g because a longer time was used in the drying process, as compared to the higher power. The summary of these values is presented in Table 3.

With respect to the smell the changes were significant, since, after the process at the higher power this was almost not perceived, and at the lower power it is slightly more preserved in all the evaluations carried out.

CONCLUSIONS

It is possible to dry the grated ginger with the microwave oven at the powers of 15 W/g and 20 W/g.. The numerical model that characterizes the kinetics of the process is the exponential, the model is for 15 W/g $MR = 0.8540\exp(-0.0676t)$ with $R^2 = 0.996$ and $\chi^2 = 0.000217$ and $MR = 0.7818\exp(-0.00907t)$ with $R^2 = 0.971$ and $\chi^2 = 0.0075$ for 20 W/g. The drying equation is, $DR = 0.0127 + 0.0828\,MR + 0.145\,MR^2$. The quality of the final product was acceptable. The color significantly decreased its chroma as well as the hue under 15 W/g because a longer time was used in the drying process, as compared to the higher power. The taste was slightly more acidic; the smell was preserved at the lower power, but at the higher power it was only very slightly perceived.

Table 3. Variation of ginger color.

		15 W/g	20 W/g
	initial	final	final
L	53.77	36.05	30.1
a	12.02	6.95	7.01
b	24.01	16.1	11.7
ΔE		20.56	27.14
$chroma$		9.39	13.20

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