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Research Article

Convective and Microwave Dryings of Raffia Fruit: Modeling and Effects on Color and Hardness

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Abstract: Biodiversity conservation with the improvement of living conditions requires the efficiency in use of all resources. For instance, A better exploitation of the endemic oleaginous plants of the tropical forests should mitigate the extension of the palm plantations which is one of the greatest threats of the biodiversity in this area. The raffia palm fruit contains edible oil richer in nutrients than oil palm. However, oil raffia production remains weak because entirely based on empirical methods. This study compares the effect of convective and microwave dryings on the drying kinetics, color and hardness of the raffia pulp. Moreover, four drying kinetics models and the concept of characteristic drying curve have been tested for this pulp. To this end, six drying temperatures and four power levels have been used. The results show that the drying time passes from 10 h at 40°C to 3 h at 90°C and from 30 min at 140 W to 5 min at 560 W. The results could be represented by one characteristic drying curve. Among the four models used, the Modified Khazaei model is the best. The coefficient of effective diffusivity varies from 0.63×10^{-10} to 3.8×10^{-10} m^2/s for convective drying and from 10.05×10^{-10} to 88.5×10^{-10} m^2/s for microwave. The activation energy is 34±2 KJ/mol. It is found that convective drying degrades the color and increases the hardness of the pulp more than microwave drying.

Keywords: Color, convective drying, microwave drying, modeling, raffia fruit,hardness

INTRODUCTION

The steady growing of the edible oil and biofuel market led to a great expansion of the oil palm (*Elaeis guineensis)* cultivation, replacing large areas of natural tropical forests (Danielsen *et al*., 2009; Wilcove and Koh, 2010). The nearly exclusive choice of the oil palm is justified by its oil yield, the highest of oleaginous plants (Fitzherbert *et al*., 2008; Sheil *et al*., 2009). Nowadays, the palm oil is the world's largest produced oil and contributes greatly to alleviate poverty in tropics (Murphy, 2007; Fitzherbert *et al*., 2008; Sheil *et al*., 2009; Wilcove and Koh, 2010). But the conversion of natural forests into agricultural lands is now recognized as one of the main causes of the biodiversity erosion (Tilman *et al*., 2001) and the 2012 report of the World Wide Fund for Nature (WWF) reveals that from 1970 to 2008 the biodiversity has decreased by about 60% in the tropics (WWF, 2012). Thus, one of the major challenges about the tropical forests is to find a trade-off between their conservation and the economics growth necessary for the improvement of living conditions in this area.

It is believed that a more rational use of other endemic oleaginous plants that are more wildlife-friendly should contribute to mitigate the expansion of palm oil. Amongst these alternative oleaginous plants, the raffia palm is one of the most abundant. It grows preferentially in the swamp forests and has multiple uses. It provides material for furniture, houses construction, food, clothing... (Obahiagbon, 2009). In addition recent studies report interesting characteristics of the raffia fiber (Elenga *et al*., 2009, 2011).

The raffia fruit is an egg-shaped fruit measuring 6-10 cm long and 3-5 cm in diameter (Fig. 1). It has a pulp of about 3 mm thick between an outer layer made of interlocking hard scales and a very hard ovoid kernel. The oily pulp is edible and contains several nutrients (Edem *et al*., 1984). Chemical analyzes revealed that raffia oil contains as much carotenes and vitamin A as oil palm (about 120 and 40-60 mg/100g, respectively). But, it has more essential unsaturated

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Fig. 1: Raffia fruit

fatty acids and vitamin E (56 versus 30mg/100g) than the latter (Goteni *et al*., 2011). However, unlike oil palm, the production of raffia oil remains weak and is limited by several factors. For instance, the raffia palm remains a wild plant with a big kernel whereas the reduction of the kernel has increased the oil palm yield by a factor 3 (Murphy, 2007; Sheil *et al*., 2009). It should be noticed that the production process is still empiric and has two routes. In the first route, fruit are retted for 6-14 days before to be triturated in water and then the oil is extracted after boiling the mixture. In the second route fruit pulp are sun dried for two days and then they are grinded and mixed with water. Silou *et al*. (2000) have shown that the traditional retting reduces the oil quality. Drying preserves more the oil quality, allows to defer the oil extraction and to collect much pulp.

Studies to improve the quality of dried raffia fruit and its oil are scarce. Dzondo-Gadet *et al.* (2004) reported that solvent and enzymatic extractions increase the yield by a factor 2 comparatively to the mechanical one. In our knowledge, the drying of the raffia fruit is not yet studied for the production efficiency.

Among drying methods, open-air sun drying is known to be simple, low-cost and slow. In addition, it exposes product to dirt. Solar dryer reduces these drawbacks without significantly raising costs, but is weather-dependent and affects the quality of the product. Besides, domestic microwave ovens spread more and more and microwave drying is recognized to shorten the drying time and to less damage the quality (Kardum *et al*., 2001; Jayaraman and Gupta, 2007; Vadivambal and Jayas, 2007; Contreras *et al*., 2008).

In this context, the present study has two main objectives which are:

- To compare the effects of convective and microwave drying on the drying kinetics, color and hardness of the raffia pulp
- To model these drying kinetics and to assess the concept of characteristics drying curve of raffia pulp.

EXPERIMENTAL

Raffia fruit: Ripe raffia fruit were harvested from wild plants at Dolisie in Congo-Brazzaville (latitude: -4.07 S; longitude: 12.88 E). The average fruit weight was 20 g and its color varied from yellow to yellow orange. Prior to drying experiments, the scales were removed manually and the pulp separated from kernel. To accelerate the drying, each pulp was longitudinally cut in nearly two equal parts. Its initial moisture content was determined by drying three samples of 100 g each in an oven (Termosi SR 3000) at 105°C during 24 h. The average value obtained is 78±2%, dry basis.

Drying: After their extraction, the pulps were immediately dried by convective drying or by microwave drying. The convective drying was conducted in a preheated laboratory-scale oven with air velocity of 1m/s, at 40, 50, 60, 70, 80 and 90ºC. The mean air humidity was 60%. To check the necessity to separate pulp from kernel before drying, scaled fruit with kernel were also dried. Sample mass was recorded at 10 min intervals by a digital balance until its variation after three successive records (30 min) became less than 2%. Three replicates were carried out for each experiment.

For microwave drying experiments, a programmable domestic microwave oven Geepas, type GMO 185 with maximum output power of 700 W at 2450MHz is used. The dimensions of the microwave cavity were 135x 458x380 mm^3 and the rotation rate of the turntable was 5 turns per min. Four microwave power intensities were used (140, 280, 420 and 560 W). For an even absorption of microwave energy, each sample was uniformly spread on the plate dish placed on the turntable. The sample mass was measured by taking out and weighing the dish on the digital balance at 1 or 2 min intervals depending on the power intensity. The equilibrium moisture content was assumed to be reached when the sample mass variation was around 2% after 6 min at 140 W and 3 min at the three others powers, according to the preliminary tests. Three replicates were carried out for each experiment.

For all drying experiments, the moisture ratio at time t, $M_r(t)$, is defined as following:

$$M_r(t) = \frac{M(t) - M_e}{M(0) - M_e} \quad (1)$$

where, M(t) and M_e represent the sample mass at time t and at the end of drying, respectively.

Modeling of the drying kinetics: Several drying kinetics of plant materials are successfully fitted by empirical or semi-empirical models, although they do not explain the drying mechanism (Doymaz, 2012; Erbay and Icier, 2009; Menges and Ertekin, 2006). These models have the advantage to be simpler than theoretical ones. For this study, four models having physical meaning constants were chosen that are: Diffusion Approach, Modified Khazaei, Peleg and Weibull models.

The Diffusion Approach model is one of the forms of the Two-term model. Basically, it is a simplified solution of Fick's second law (Crank, 1975; Erbay and Icier, 2009). Thus, it assumes that the sample is uniform and its microstructure does not change during drying:

$$M_r(t) = a\exp(-kt) + (1-a)\exp(-kbt) \tag{2}$$

where, k, a and b are constants. For an infinite slab of half-thickness L and effective moisture diffusivity D_e, k = $\pi^2 D_e/4L^2$. This model was adopted to overcome the shortcomings of the one term approximation. It was applied on several products (Akpinar, 2000; Demir *et al*., 2007; Togrul and Pehlivan, 2003).

The Eq. 3 represents the Peleg model in the form of moisture ratio (Elenga *et al*., 2011; Peleg, 1988). It has been successfully used for sorption and desorption of various products (Corzo and Bracho, 2006; Palou *et al*., 1994):

$$M_r(t) = 1 - \frac{t}{a+bt} \tag{3}$$

where, a is the inverse of the initial drying rate and b could be approximated by $(1-M_r(t))^{-1}$ at the equilibrium. It is approximately equal to 1.

The Weibull distribution (Eq. 4) was originally developed to describe the ultimate strength of materials (Sutherland and Soares, 1997). It is also used to predict the behavior of systems that have some degree of variability such as drying kinetics (Doymaz, 2012; Erbay and Icier, 2009):

$$M_r(t) = \exp\left(-\left(\frac{t}{\alpha}\right)^n\right) \tag{4}$$

α is the scale parameter and is equal to the time at which the removed moisture ratio is equal to 63.2%. α is related to the drying rate. The constant n is a shape parameter and it is higher than 1 if the drying rate increases with the time until its maximal value; after this point the drying rate decreases progressively until the equilibrium is reached. If n is less or equal to 1, the drying rate decreases continuously. In this case, the drying curve has not the constant drying rate period and it is admitted that the drying is governed by the moisture diffusion (Mujumdar, 2007). It could be noticed that the Weibull model looks like the modified Page model. Thus, if we take α^{-n} = b, it becomes the Page model.

The Khazaei model (equation 5) was deduced using an analogy with the viscoelastic model of food (Khazaei and Daneshmandi, 2007). But it could be seen as an extension of the well-known Midilli model (Erbay and Icier, 2009):

$$M_r(t) = a + b\exp(-kt) - ct \tag{5}$$

The constant k is the inverse of the time at which the sample has lost 63.2% of the removable moisture. C is the drying rate near the equilibrium; b is approximately the removable moisture ratio. The constant a is linked to b. Taking account that $M_r(0) = 1$, the model may be rewritten as follows:

$$M_r(t) = 1 - b + b\exp(-kt) - ct \tag{6}$$

Thus, it appears as a correction of the Weibull model (or Page) with the constant n = 1, by adding the linear term, the relaxation term in the viscoelastic model. In this study we extend this addition to the Weibull model for any shape parameter n. The Khazaei model, in this case, may be expressed as:

$$M_r(t) = 1 - b + b\exp\left(-\left(\frac{t}{\alpha}\right)^n\right) - ct \tag{7}$$

All constants keep their meaning. But to distinguish this form from the original Khazaei model in all what follows, it is here referred to as the modified Khazaei model.

Characteristic drying curve: The concept of the drying curve assumes that the normalized drying rate f (quotient of the drying rate at any time to that during the constant drying rate period) of a given material is independent of air temperature, velocity and humidity. It depends only on the nature of the material and its moisture content (Mujumdar, 2007). Despite its simplicity, this concept is verified for many products, especially for thin layer of particles with less than 20 mm in diameter (Coumans, 2000; Langrish, 2008). For drying curve that has not a constant drying period, the normalized drying rate is expressed as: f = V(t)/V(0), where V(t) is the drying rate at the time t.

Statistical analysis of the models: The parameters of the models were determined by the non-linear regression method performed using the software

OriginPro version 8. The agreement between a model and the experimental data is evaluated by the means of the reduced coefficient of determination (R^2), the reduced chi-square (χ^2). The higher is R^2 and lower are χ^2, the better the fit is.

Color measurements: A Minolta spectrocolorimeter 3200 d model with three illuminants (D65, A and F2) was used to measure the color of pulp. The color was expressed by the color coordinates (L*, a*, b*) of the Commission Internationale d'Eclairage color space. The three coordinates characterize the darkness-lightness, greenness-redness and blueness-yellowness of the product, respectively. L* is zero for black, 100 for perfect white; a* is negative for green product, zero for gray and positive for red product; b* is negative for blue product, zero for gray and positive for yellow product. Thus, the increase of L*, a*, b* denotes more light, red chroma and yellow chroma, respectively. The variation of the color ΔE was estimated in comparison to the raw pulp by the formula:

$$\Delta E = \sqrt{(L^* - L_r^*)^2 + (a^* - a_r^*)^2 + (b^* - b_r^*)^2} \quad (8)$$

where, the coordinates without a subscript are those of the dried pulp and those with the subscript are those of the raw pulp.

The hardness measurements: The measures of the pulp hardness were performed using a Facchini penetrometer, model FT011. For each experiment, five pulps are randomly selected and on each pulp, three measures are made. The pulp hardness is the average of the three measures and the hardness value of the experiment is the average of the values of the five pulps.

RESULTS AND DISCUSSION

Drying characteristics: To assess the necessity of stoning fruit before drying, scaled fruit with stone have been dried. For drying temperatures lower than 50°C, the drying is so slow that fungi develop on the pulp. Thus, it is impossible to sun-dry the whole raffia fruit in open air. At 70°C and 90°C, the drying time of non-stoned fruit is about 20 and 15 h, respectively (Fig. 2). These durations are slightly higher than those reported for unshelled candle nut, another oily nut (Tarigan *et al*., 2007). Besides, the drying rate decreases continuously at these drying temperatures, indicating that the drying process is controlled by the moisture diffusion in the fruit (Mujumdar, 2007). Figure 3 shows that the convective drying of pulp is about 5 times faster than that of the fruit with stone at the same temperature. Therefore, drying of fruit with stone is more energy and time consuming than drying of pulp.

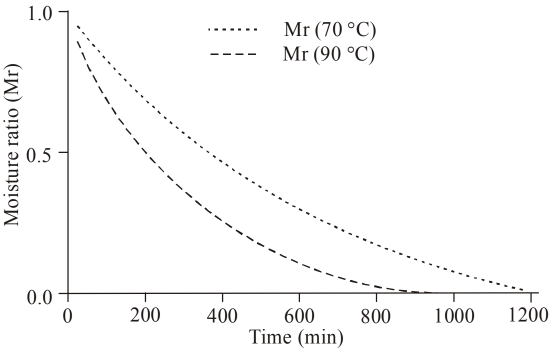

Fig. 2: Evolution of the moisture of the scaled raffia fruit during convective drying

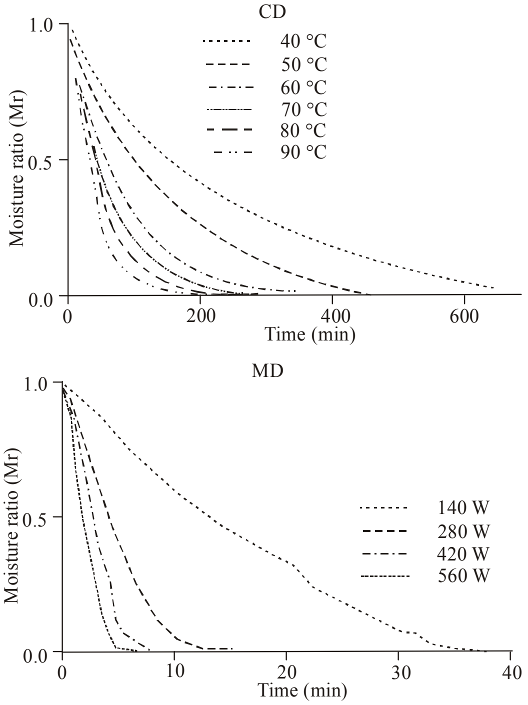

Fig. 3: Evolution of raffia pulp moisture during convective drying (CD) at different temperatures and microwave drying (MD) for different output powers. Air velocity for CD: 1m/s

As with the fruit with kernel, convective drying rates of pulp decrease continuously. But at 40°C, the decrease is slower at the beginning. The absence of the constant drying rate period may be considered as an indication that the diffusion governs the drying of raffia pulp, as already reported for several vegetables and fruit (Karathanos and Belessiotis, 1997; Fernandes *et al*., 2011). The drying length passes from about 10 h at 40°C to 3 h at 90°C. Therefore, the duration of two days observed by farmers is justified. For convective

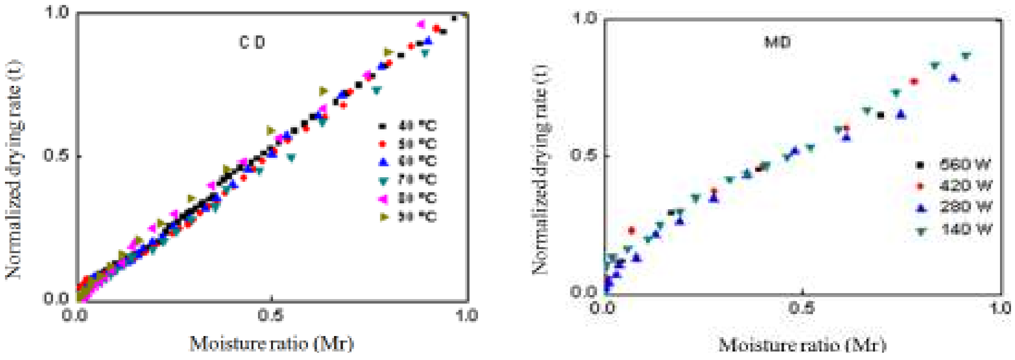

Fig. 4: Characteristics drying curves of the raffia pulp for convective and microwave dryings, CD and MD, respectively

Table 1: Evolution of the parameters of the models with the drying conditions

Dr ying conditions	Kharzaei m n	Approx diffus k	Peleg c	Weibull n
40°C	0.89±0.02	0.00421±7-5	206.8±1.2	0.996±0.012
50°C	0.91±0.02	0.0067±1-4	136±1	1.03±0.02
60°C	0.97±0.02	0.0113±1.7-4	68±1	0.98±0.01
70°C	1.06±0.02	0.0154±2-4	49±2	1.07±0.01
80°C	1.2±0.02	0.0184±6-4	41±3	1.19±0.01
90°C	1.1±0.01	0.0256±6-4	28±2	1.1±0.01
140 W	1.1±0.3	0.067±0.006	19.9±0.5	1.4±0.1
280 W	1.1±0.1	0.24±0.04	4.8±0.5	1.48±0.04
420 W	1.5±0.4	0.3767±0.06	3.4±0.4	1.6±0.1
560 W	1.5±0.1	0.5911±0.13	1.9±0.3	1.5±0.1

drying, the drying duration depends on several factors including the drying temperature, the air velocity and humidity, the product amount, composition, microstructure and size (Mujumdar, 2007). Thus, the comparisons between products are delicate. Taking into account the drying temperature, thin layer shape and air velocity, the durations observed here are comparable to those obtained for apples, but shorter than those of potatoes and longer than those of kiwi (Akpinar, 2000; Orikasa *et al*., 2008). In addition, no presence of fungi was observed for these drying temperatures.

Figure 3 also shows the evolution of pulp moisture ratio as a function of the microwave drying time for different powers. As it can be seen, the drying rate decreases continuously with time. Thus, the microwave drying of the raffia pulp is governed by the moisture diffusion, as for many other fruit (Fernandes *et al*., 2011). Besides, the microwave drying process considerably reduces the drying time. The drying duration passes from 30 min at 140 W to 5 min at 560 W. Thus, microwave drying at 140 W is about 5 and 40 times faster than convective drying at 90 and 40°C, respectively. Similar variations of the duration between the two methods are reported for other products (Maskan, 2001; Jayaraman and Gupta, 2007).

Assessment of the characteristic drying curve: The characteristic drying curves of raffia pulp dried in convective drying and in microwave drying are reported on Fig. 4. Although this empirical concept is criticized because the drying conditions also influence the drying curve as it could be seen from the two figures, the striking effect is that for all drying temperatures or for microwave powers used, the curves have almost the same shape. The linear shape for M_r near 1 reflects the absence of a constant drying rate phase on the drying curve. Indeed, with the drying rate at the beginning equal or slightly lower than the initial drying rate, the shape of the characteristic drying curve should be concave downward. In other words, this shape reflects the absence or, at the most, the weak quantity of free moisture on the product surface (Mujumdar, 2007). For weak moisture contents, the characteristic drying curve for microwave drying is slightly above that for convective drying. This fact is coherent with the observation that microwave drying is more efficient than convective drying for weak moisture ratios (Zhang *et al*., 2006; Jayaraman and Gupta, 2007). For the raffia pulp, the normalized drying rate, f, is nearly equal to M_r.

Evaluation of the thin-layer models: The statistical results of the fitting of the experimental data to the four models are summarized in Table 1. The agreement between the experimental and the models is fairly good as shown in Fig. 5. Indeed, for all experiments, the coefficient of determination is higher than 0.93 and is in average about 0.98. Nevertheless, globally, the Modified Khazaei model is the best, followed by the Weibull model, the Peleg and the Diffusion Approach, respectively. Therefore, the addition of the linear term has enhanced the Weibull model. These results also show that for low temperatures and low microwave powers, the Peleg model is the best whereas the agreement with the other models increases with the increasing the drying temperature or the microwave power. Besides, the fit is better for convective drying than for microwave one.

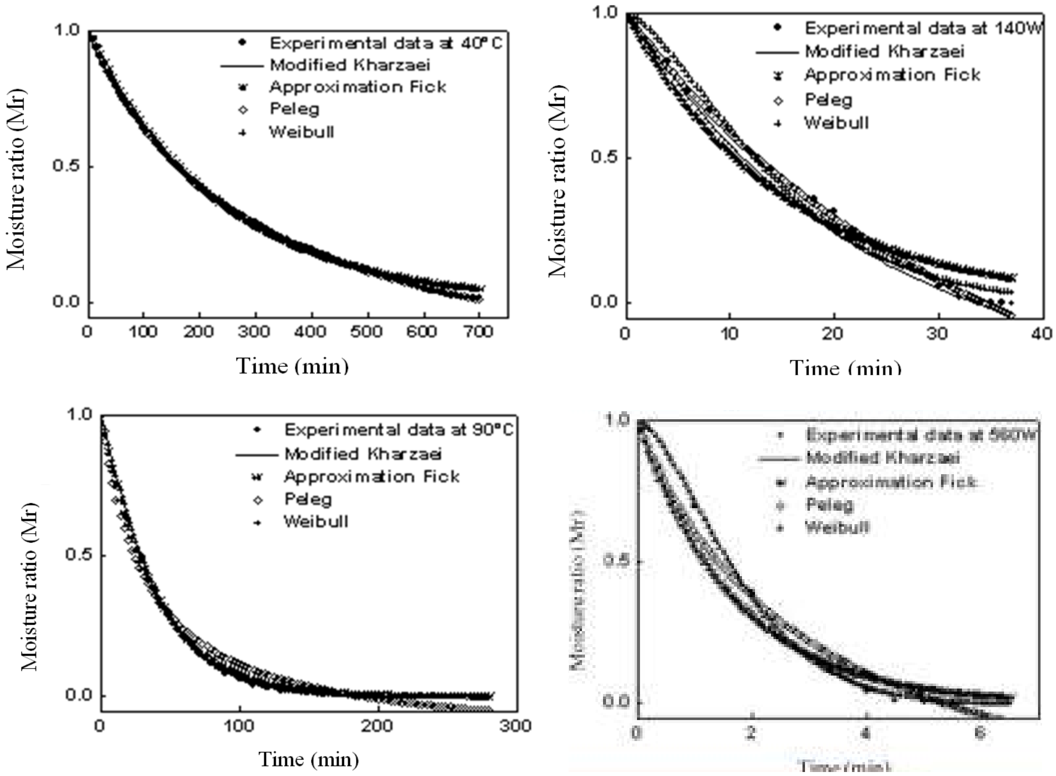

Fig. 5: Modeling convective (left column) and microwave (right column) dryings

The values of the shape parameter (constant n of Weibull and Modified Khazaei models) are around 1 (Table 1), within the range of other vegetables and fruit (Erbay and Icier, 2009). At low drying temperatures or microwave powers, values are less than 1. These values imply that the drying rate decreases continuously until the drying ends, in accordance with the absence of the constant drying rate phase. At higher drying temperatures or microwave powers, n is slightly greater than 1. Basically, this means that the maximal drying rate is not reached immediately at start but later. This could reflect the fact that for high drying temperatures, the sample takes more time to reach the drying temperature. However, as Fig. 5 shows, for high drying temperatures and microwave powers, the Weibull model slightly overestimates the moisture ratio at the beginning of the drying. This overestimation contributes also to the increase of the shape parameter value.

The time to remove about 63% of the removable water (constants α of Modified Khazaei and Weibull models) and the inverse of the initial drying rate (constant C of Peleg model) decrease greatly with increasing temperature or microwave power. Furthermore, the similarity of the evolutions of these constants should be noticed. These constants are related to the drying rate which is reported to increase with the increase of the drying temperature and the microwave power for fruit and vegetables (Zhang *et al*., 2006; Jayaraman and Gupta, 2007; Fernandes *et al*., 2011).

Table 2: Variation of the color, hardness and effective diffusivity with the drying conditions

Drying conditions	L*	a*	b*	ΔE	F(N)	$D_{eff} \times 10^{10}$ (m^2/s)
Fresh pulp	68.57	6.42	49.72	0	19±2	-
40°C	63.21	8.94	40.14	11.26	44±2	0.63
50°C	60.22	10.31	37.65	15.18	50±1	1
60°C	59.31	12.5	35.23	18.24	53±2	1.7
70°C	56.42	12.62	34.33	20.56	52±2	2.3
80°C	48.63	12.54	30.81	28.15	Brittle	2.8
90°C	45.82	12.21	28.25	31.81	Brittle	3.8
140 W	65.44	8.31	44.67	6.24	31±2	10.05
280 W	64.25	8.54	42.81	8.42	37±1	36
420 W	62.43	8.81	41.56	10.49	43±1	57
560 W	63.1	8.72	41.38	10.24	41±1	88.5

The raffia pulp effective diffusivity deduced from the constant k of the Diffusion Approach model is reported in the Table 2. The values lie within the range of foods (10^{-11}-10^{-7} m^2/s) and are comparable to those of persimmon, pumpkin, apple, banana, coconut and mango (Erbay and Icier, 2009; Fernandes *et al*., 2011; Marinos-Kouris and Maroulis, 2007). Besides, these values greatly increase with temperature and microwave power, passing from 0.63×10^{-10} m^2/s at 40°C to 3.8×10^{-10} at 90°C and from 10.05×10^{-10} m^2/s at

Table 3: Performances of the models

Drying conditions	Modified Kharzaei		Diffusional ap		Peleg		Weibull	
	R^2	χ^2	R^2	χ^2	R^2	χ^2	R^2	χ^2
40°C	0.999	0.000067	0.996	0.000284	0.999	0.000042	0.996	0.000289
50°C	0.999	0.000059	0.993	0.000500	0.999	0.000598	0.994	0.000454
60°C	0.999	0.000052	0.999	0.000633	0.997	0.000233	0.999	0.000067
70°C	0.999	0.000066	0.998	0.000150	0.986	0.0010	0.999	0.000062
80°C	0.999	0.000057	0.993	0.00054	0.972	0.0021	0.999	0.00008
90°C	0.999	0.000020	0.997	0.00019	0.976	0.00168	0.999	0.00002
140 W	0.984	0.00016 1	0.949	0.00054	0.997	0.00026	0.987	0.00014
280 W	0.990	0.00012 3	0.962	0.00044	0.983	0.00017	0.999	0.0001
420 W	0.989	0.00013 2	0.933	0.00078	0.978	0.00026	0.988	0.0013
560 W	0.999	0.000017	0.956	0.00739	0.979	0.00030	0.999	0.0002

140W to 88.5×10^{-10} m^2/s at 560W, respectively. These increases are explained by the increase in the energy of the water molecules.

From the effective diffusivity, the constants α and C, the activation energy was deduced assuming that they are in accordance with the Arrhenius law (Fig. 5). The values obtained are 34±2 KJ/mol, 34± 3KJ/mol and 43±4KJ/mol, respectively. These values are in the range of most foods (18-49.5 KJ/mol) (Erbay and Icier, 2009). The coherence of the three values of the activation energy could reflect the relation between the parameters D, α and C with the drying rate which follows the Arrhenius law in this case.

Color and hardness: The color coordinates and variation of the pulp after the different treatments are also reported in Table 2. All treatments decrease the lightness and the yellowness of the pulp while its redness increases. In addition, the color variation increases according to the drying temperature and the microwave power. Therefore, these drying methods affect negatively the pulp color as already reported for many fruit and vegetables (Jayaraman and Gupta, 2007; Marinos-Kouris and Maroulis, 2007; Fernandes *et al*., 2011). The color degradation at 90°C is three times that at 40°C, whereas that at 560W is 1.6 time that at 140 W. However, for the drying temperatures and the microwave powers used, the convective drying is more damaging than the microwave drying, as already reported by many authors (Jayaraman and Gupta, 2007; Vadivambal and Jayas, 2007; Fernandes *et al*., 2011). The increase of the value of the greenness-redness coordinate (a) is considered as indicative of browning reactions (Vadivambal and Jayas, 2007). Non enzymatic browning is recognized to increase with temperature and to be generated by the development of several pigments including melanoidins. The decrease of the blueness-yellowness coordinate (b) which denotes the decrease of the yellow color could be due to the depletion of carotenes. These pigments generate the yellow color of fruit and are degraded at high temperature. Forthcoming study on the dried product quality will elucidate this point.

The hardness values of the fresh pulp and dried pulps are reported in the Table 3. According to these values, drying causes the hardening of the raffia pulp. The higher the drying temperature or the microwave power, the higher the hardening is. This evolution is in agreement with that reported for other products, but the values obtained in this study are higher than most of those reported in the literature (Vadivambal and Jayas, 2007; Fernandes *et al*., 2011). This difference could be explained by the fact that the raffia pulp has a fibrous peel on its inner face (the face in contact with the kernel) which is harder than the pulp itself. For low drying temperatures or microwave powers, the pulp is soft while it becomes brittle at high temperatures or powers. On the other hand, the hardening occurred during the convective drying is higher than that caused by microwave drying.

CONCLUSION

The objectives of this study were, on one hand, to compare the effects of convective drying curve in the range 40-90°C to those of microwave drying in the range 140-560 W on the drying kinetics, color and hardness of the raffia pulp; on other hand to modeling these drying kinetics and to assess the concept of characteristic drying curve for this product. The following results are found:

- Below 50°C, the whole fruit could not be dried. Before the drying end fungi degrade the fruit. Thus, its conservation by sun drying in open air requires the fruit stoning.
- In the range of drying temperatures and microwave powers used, the drying of the pulp is governed by the diffusion. The drying time is reduced from 10 to 3 h when the drying temperature increases from 40 to 90°C. When the microwave power increases from 140 W to 560 W, it is reduced from 30 to 5 min.
- Despite its empirical character, the concept of characteristic drying curve is verified for the two drying methods in the ranges studied.

- In the range of temperatures and powers studied, the agreement is good between the data and the models (R^2>0.93). But, the ordering in the goodness of fit is: Modified Khazaei, Weibull, Peleg and Approach diffusional model. The fit is better for convective drying than for microwave drying.
- The coefficient of effective diffusivity varies from 0.63×10^{-10} m^2/s at 40°C to 3.8×10^{-10} at 90°C and from 10.05×10^{-10} m^2/s at 140W to 88.5×10^{-10} m^2/s at 560 W. These values are in the range of other fruit. The activation energy deduced from these values is 34±2 KJ/mol. The value of the activation energy deduced from the scale parameter of Modified Karzaei model and the initial drying rate of the Peleg model are of the same order of magnitude (34±3 and 43±4 KJ/mol, respectively). This similarity suggests that the coefficient of the effective diffusivity and the scale parameter are strongly related to the drying rate.
- The convective drying degrades more the pulp color than the microwave drying. The degradation increases with the increase of the drying temperature or the microwave power. The pulp turns to brown, suggesting browning reactions or/and depletion of carotenes.
- The pulp hardness increases more during convective drying than microwave drying. At high temperature, the pulp becomes brittle.

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