Journal of Agricultural Science; Vol. 11, No. 6; 2019
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Drying of Albedo and Whole Peel of Yellow Passion Fruit

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Received: March 5, 2019 Accepted: April 4, 2019 Online Published: May 15, 2019

doi:10.5539/jas.v11n6p501 URL: https://doi.org/10.5539/jas.v11n6p501

The research is financed by Conselho Nacional de Desenvolvimento Científico e Tecnológico-CNPq.

Abstract

The use of waste has been the focus of attention of the agri-food sector, and a fruit with large amount of waste is the passion fruit. Its peel consists of albedo and flavedo, which can be used to manufacture flour, and some studies propose the need to remove the flavedo as well as to perform maceration. The objective of the present work was to study the drying process to produce flour from passion fruit albedo and whole peel, checking the influences of the flavedo removal and maceration steps, as well as the drying temperatures (70 and 80 ºC). Yield after drying was calculated and it was shown to be low. Page, Silva et alii, Henderson and Pabis and Logarithmic mathematical models were fitted to the experimental data using LAB Fit software. The statistical indicators used to identify the best fit were coefficient of determination (R^2) and chi-square (χ^2). The Page model was the one that fitted best to the data, showing the best statistical indicators. Also, it can also be highlighted that the sample composed of peel without maceration and dried at 70 ºC had the best results regarding the statistical indicators.

Keywords: waste use, *Passiflora edulis* f. Flavicarpa, flour

1. Introduction

Yellow passion fruit (*Passiflora edulis*) is among the agricultural products with wide popular acceptance and large quantity of wastes. Its peel represents almost all the waste and is composed of albedo (white part) and flavedo (yellow part). In general, in order to use passion fruit peel in food production, the material is macerated (immersed in water), a procedure which aims to reduce the bitter taste caused by the substance naringin present in its composition (Dias et al., 2011; Yamashita, 2017).

One of the alternative processes that can be used to reduce passion fruit wastes is drying, which can be carried out using artificially moved air, followed by flour production, which can be used in the formulation of other various types of food (Di Domenico et al., 2017; Machado et al., 2013).

Drying allows the determination of the drying kinetics, which tries to define the behavior of the dried solid material and depends on its specific properties, temperature, drying air speed and relative air humidity, represented by the drying curves and drying rate. Depending on the material to be dried, the drying process may require a very long time, which makes it difficult to obtain data for drying kinetics determination. Thus, mathematical simulation becomes fundamental to describe such behavior (Silva et al., 2015; Di Domenico & Conrad, 2015).

Given the above, this study aimed to conduct drying experiments at different temperatures using passion fruit albedo and whole peel with and without maceration, checking the influence of flavedo removal and maceration on the production of flour, besides calculating the mass yield of the samples after the process.

2. Material and Methods

Approximately 600 passion fruits (*Passiflora edulis* f. Flavicarpa) were purchased in the Paraíba state, at full maturity stage (completely yellow peel). Initially, the passion fruits were washed in running water and immersed in sodium hypochlorite solution (50 ppm) for 5 min, then washed again in running water to remove the sanitizing solution.

The passion fruits were cut in half and their pulp was removed. Then, 50% of the peels were cooked for 5 min to facilitate the removal of flavedo (yellow part). The albedo and resulting peels were divided into two equal parts, only one of which underwent the step of maceration.

Maceration was carried out by following the method described by Dias et al. (2011), in which the material was immersed in water for 24 h at a proportion of 400 g of sample for every 2 L of water at room temperature (25±1 °C). The samples were then chopped in a food processor (Figure 1(a)) to uniformize the size of fragments and facilitate the subsequent drying process.

(a) (b)

Figure 1. (a) Food processor; (b) Blades used to chop the samples

The albedo was chopped with an S-blade as shown in Figure 1(b), whereas the peels, for not having been cooked, had a more rigid surface and hence had to be initially reduced with the second blade shown in Figure 1(b) before being chopped with the S-blade.

Figure 2 shows the configuration of the peels after being cut with a knife (Figure 2(a)), chopped with the first blade (Figure 2(b)) and finally chopped with the S-blade (Figure 2(c)).

(a) (b) (c)

Figure 2. Configurations of passion fruit peel during the chopping process: (a) initial; (b) intermediate; (c) final

Then, the samples were placed in polypropylene plastic bags, frozen at -18±1 °C and kept under such condition until 24 h before the experiments, when they were then transferred to the refrigerator to thaw.

For drying and obtaining the flour, the samples were thawed at temperature of approximately 5 °C for 24 hours and only then subjected to drying.

Drying tests were conducted in triplicate in a mechanical air circulation oven (320E model, Fanem, SP, Brazil), at temperatures of 70 and 80±1 ºC. An average mass of 800 g of the thawed waste was weighed on a tray with the material distributed in such a way to form a layer of approximately the same thickness, allowing the drying process to occur as uniformly as possible, until there was no significant variation in the sample mass. The experimental data were expressed in the form of moisture ratio (X^*) using Equation 1.

$$X^* = \frac{X_t - X_e}{X_o - X_e} \quad (1)$$

where, X_t: moisture content at time t, dry basis, d.b.; X_e: equilibrium moisture content, d.b.; X_o: initial moisture content, d.b.

Drying kinetics was described using the nonlinear regression models presented in Table 1. The equations of the models were used for treatment and fitting of the experimental data using LAB Fit Curve Fitting Software.

Table 1. Models used to describe passion fruit flour drying kinetics

Name of the model	Equation	Reference
Page	$X^* = \exp(-at^b)$	Page (1949)
Silva et alii	$X^* = \exp(-at - bt^{0.5})$	Silva et al. (2014)
Henderson and Pabis	$X^* = a \cdot \exp(-bt)$	Henderson and Pabis (1961)
Logarithmic	$X^* = a \cdot \exp(-bt) + c$	Yaldiz et al. (2001)

Note. t: drying time, min; a, b and c: model parameters.

The evaluation criteria used to identify the best fit of the models to the experimental data were the determination coefficient (R^2) and Chi-square (χ^2), calculated by Equation (2):

$$\chi^2 = \frac{\sum_{i=1}^{N} (X^*_{exp,i} - X^*_{pre,i})^2}{N - n} \quad (2)$$

where, χ^2: chi-square; $X^*_{exp,i}$: experimental moisture ratio; $X^*_{pre,i}$: moisture ratio predicted by the model; N: number of experimental data; n: number of coefficients and constants of the model.

Finally, eight samples were collected for physical-chemical analysis, as shown in Table 2.

Table 2. Nomenclature adopted for the samples after drying

	Drying temperature (°C)	With maceration	Without maceration
Albedo	70	MA70	A70
	80	MA80	A80
Whole peel	70	MP70	P70
	80	MP80	P80

3. Results and Discussion

The drying kinetics of yellow passion fruit albedo (white part) and whole peel was studied as influenced by the drying temperature and maceration process. The temperatures used in the drying were 70 and 80±1 °C and the times required for mass equilibrium as well as mass yield of the samples are described in Table 3. In all samples, the mass loss was very expressive after drying, as expected.

Table 3. Drying times required for mass stabilization and mass yield of passion fruit albedo and peel samples after drying at 70 and 80±1 °C

Sample	Time (min)	Yield (%)
A70	1860	7.20
MA70	1380	6.49
P70	1920	10.07
MP70	1440	6.98
A80	1260	7.02
MA80	780	5.94
P80	1260	9.92
MP80	840	6.97

Cristo et al. (2018) elaborated flour with the watermelon peel to produce cupcakes and obtained a lower yield than the peel and passion fruit albedo of this work, of only 5%, a value that approximates only the flour made with the macerated and dry albedo at 80 °C. Vieira et al. (2017) elaborated flour with melon bark also for cupcakes production and obtained a yield of 8.8%, lower only than that found in the flour obtained from the integral shell of dried passion fruit at 70 and 80 °C. Freitas et al. (2017) elaborated flours with green bananas of the varieties silver and nanicão for the production of honey loaves and they describe that the final yield of the flour was 17%, higher than those of this research, certainly because the authors used the pulp of the fruit. Santos et al. (2015) conducted eight treatments for the flour processing using different parts and maturation stages of the banana banana, being: a) green banana pulp; b) mature banana pulp; c) green banana peel; d) ripe banana peel; e) pulp plus bark of green banana; f) pulp plus ripe banana peel and g) pulp plus green banana peel without sanitizing with sodium hypochlorite and obtained yields of 39.4; 23.81; 8.67; 11.24; 23.34; 25.67 and 23.13% for flour a, b, c, d, e, f and g respectively, it was observed that when using the fruit pulp in the flour preparation the yields were higher. However, for the flours c and d (which were made with only peel), the results approximate the values of the dried passion fruit peel flour at 70 °C and the 80 °C.

In relation to the drying temperature, samples dried at 80 °C reached equilibrium in a shorter time than those dried at 70 °C. This is expected, due to the temperature increase of 10 ºC, which causes the water to evaporate faster from the samples (Baptestini et al., 2017; Corrêa et al., 2017; Ferreira & Pena, 2010). Regarding maceration, it was observed that this process contributed to accelerating the drying, possibly because the samples contain higher contents of free water. In addition, water in the maceration process causes bound particles to detach, facilitating mass loss.

Silva et al. (2016), studying the production and characterization of passion fruit albedo flour for food use, observed that the kinetic equilibrium in macerated albedo drying was reached after 1290, 930, 690 and 570 min with the temperatures of 50, 60, 70 and 80 °C, respectively. These periods were shorter than those observed in the present study for albedo samples macerated at the same temperatures; double the time was required for the sample dried at 70 °C and an additional time of 210 min was required for the sample dried at 80 °C. This difference can be explained by the quantity of sample used by these authors in the drying (200 g) and the device used (tray dryer).

Ferreira and Pena (2010) and Spoladore et al. (2014) conducted drying experiments with passion fruit peel and also obtained equilibrium in shorter period. 530 and 390 min were required for the temperature of 70 °C, whereas only 475 and 300 min were required for 80 °C, respectively. The mass used by Ferreira and Pena (2010) was 500 g, which once again reveals that the larger the mass used in the drying of a product, the longer the time required for it to reach equilibrium, considering that the material is arranged on the trays for drying with similar thicknesses. Spoladore et al. (2014) did not describe the mass used in their study, but it was probably even smaller.

Yield values were very low, ranging only from 5.94% for sample of albedo macerated and dried at 80 °C to 10.07% for the sample of peel dried at 70 °C. Such low yield was due to the high moisture content (89.77-94.24%). It was evident that samples dried at the highest temperature (80 °C) obtained lower yield, since water loss is higher in this case. The samples with highest yield are those of peels with no removal of flavedo (yellow part) and which had not undergone maceration. By contrast, the samples with lowest yield were those composed of only albedo and which had undergone maceration, indicating that this process contributed to mass loss in the product.

Table 4 presents the parameters of the mathematical models of Page, Silva et alii, Henderson & Pabis and Logarithmic, respectively.

Table 4. Parameters obtained by fitting Page, Silva et alii, Henderson & Pabis and Logarithmic models to the experimental drying data of passion fruit albedo and whole peel

Page

Sample	Parameters		R^2	χ^2
	a	b		
A70	0.0003	1.3719	0.999	0.0028
MA70	0.0001	1.5813	0.998	0.0138
P70	0.0005	1.3169	0.999	0.0063
MP70	0.0001	1.5432	0.998	0.0143
A80	0.0003	1.4854	0.999	0.0065
MA80	0.0002	1.5697	0.996	0.0193
P80	0.0005	1.3479	0.999	0.0048
MP80	0.0002	1.5353	0.998	0.0106

Silva et alii

Sample	Parameters		R^2	χ^2
	a	b		
A70	0.0040	-0.0198	0.997	0.0296
MA70	0.0047	-0.0269	0.991	0.0742
P70	0.0041	-0.0178	0.997	0.0280
MP70	0.0048	-0.0260	0.991	0.0699
A80	0.0055	-0.0270	0.994	0.0445
MA80	0.0059	-0.0289	0.985	0.0756
P80	0.0051	-0.0212	0.996	0.0272

Table 4 (Cont.)

Sample	a	b	R^2	χ^2
MP80	0.0056	-0.0282	0.989	0.0580

Henderson & Pabis

Sample	Parameters		R^2	χ^2
	a	b		
A70	1.0670	0.0031	0.992	0.0694
MA70	1.0877	0.0034	0.982	0.1426
P70	1.0590	0.0032	0.994	0.0582
MP70	1.0823	0.0035	0.984	0.1315
A80	1.0809	0.0041	0.987	0.0939
MA80	1.0822	0.0042	0.974	0.1324
P80	1.0633	0.0040	0.992	0.0585
MP80	1.0831	0.0041	0.979	0.1127

Logarithmic

Sample	Parameters			R^2	χ^2
	a	B	c		
A70	1.0960	0.0028	-0.0377	0.993	0.0518
MA70	1.1511	0.0029	-0.0783	0.985	0.1021
P70	1.0836	0.0030	-0.0322	0.994	0.0434
MP70	1.1350	0.0030	-0.0650	0.986	0.0978
A80	1.1272	0.0036	-0.0580	0.989	0.0692
MA80	1.2654	0.0030	-0.2106	0.984	0.0664
P80	1.1061	0.0035	-0.0545	0.994	0.0381
MP80	1.2375	0.0030	-0.7978	0.988	0.0547

Note. A70: albedo dried at 70 °C; MA70: macerated albedo dried at 70 °C; P70: peel dried at 70 °C; MP70: macerated peel dried at 70 °C; A80: albedo dried at 80 °C; MA80: macerated albedo dried at 80 °C; P80: peel dried at 80 °C; MP80: macerated peel dried at 80 °C.

Samples constituted of whole peel without maceration and dried at 70 °C showed the best results of R^2 and good results of χ^2 for all models studied. Based on the parameter R^2, the Page model fitted best to the experimental data because, for all samples, it showed values higher than 0.990; the lowest value was observed for the albedo macerated and dried at 80 °C, 0.996, which is close to the best results obtained with the model of Silva et al. (2014). The lowest value of R^2 (0.974) was obtained with the model of Henderson and Pabis in the sample of albedo macerated and dried at 80 °C.

Menezes et al. (2013), studying the drying kinetics and fitting of mathematical model to the experimental drying data of yellow passion fruit bagasse, also found that the Page's equation was the best model for the data obtained within the temperature range from 35 to 65 ºC and air flow speeds of 0.8, 1.0 and 1.3 m s^{-1}. In the present study, the Page model showed R^2 above 0.997, whereas the determination coefficient R^2 was close to 0.996 for the logarithmic model and to 0.995 for the Henderson & Pabis model.

Spoladore et al. (2014) analyzed the mathematical modeling of passion fruit peel drying kinetics and temperature influence on color, phenolic compounds and antioxidant activity, and obtained R^2 values of 0.996, 0.996, 0.996 and 0.998 for the Page model at temperatures of 60, 70, 80 and 90 °C, respectively. For the Henderson & Pabis model, these values were 0.993, 0.992, 0.991 and 0.986 respectively at these same temperatures.

The consulted literature indicates that, for a model to adequately fit to the experimental data, it is essential that R^2 be higher than 0.99 and chi-square (χ^2) be as low as possible. Again, Page model was the one which fitted best to the analyzed data and the highest χ^2 value (0.0193) was obtained in the sample of albedo macerated and dried at 80 °C.

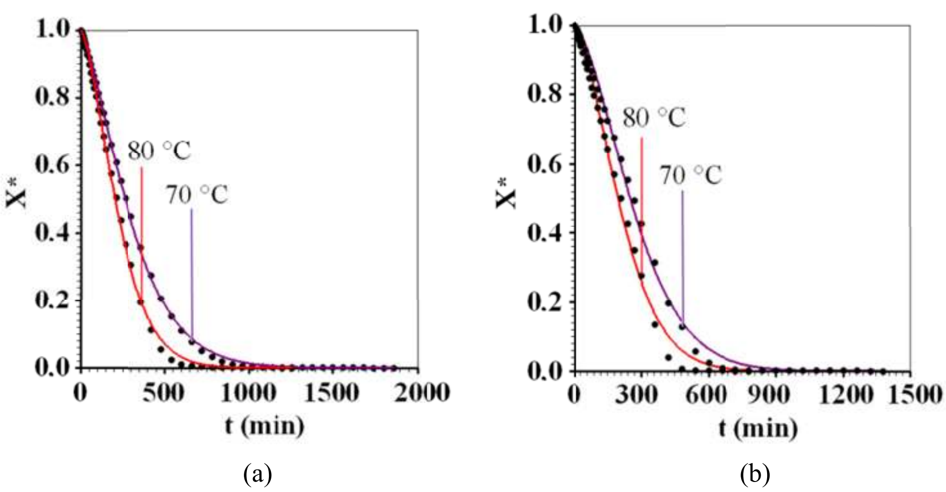
Henderson & Pabis model (Table 4) was the furthest from a good fit to the experimental data, especially in the sample of albedo macerated and dried at 80 °C, with R^2 of 0.9737 and χ^2 of 0.1324.

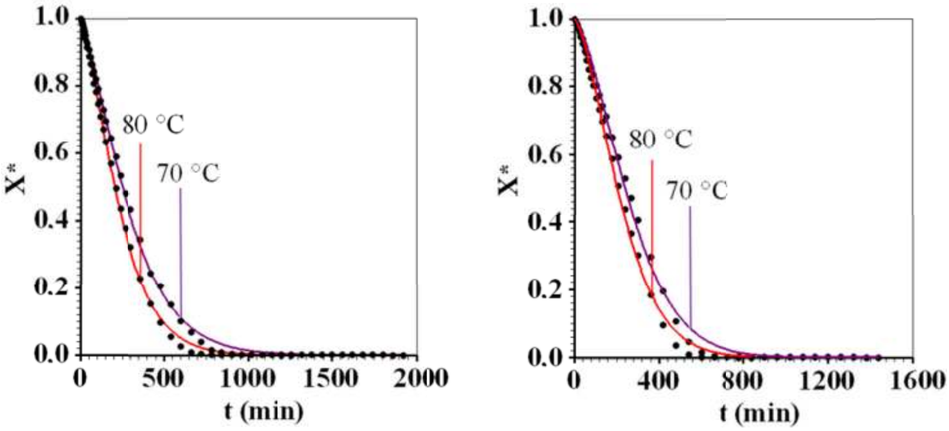
Silva et alii and logarithmic models showed similar values, but the former was the better of the two, because it has fewer data-fitting parameters. The best values of R^2 and χ^2 for Silva et alii model were observed in the drying of albedo and peel at 70 °C: R^2 = 0.996833 and 0.996979, and χ^2 = 0.0296 and 0.0281, respectively.

Silva et alii, assessing mathematical models to describe thin-layer drying and determine the drying rate of whole bananas, after drying at 70 °C, obtained R^2 of 0.999 and χ^2 of 1.35×10^{-3}. In the present study, the best result found using the Silva et alii model was R^2 of 0.996979 for the drying of passion fruit peel at 70 °C.

With the Logarithmic model, the drying of passion fruit peel at 70 °C also stood out as the best, showing R^2 and χ^2 of 0.994 and 0.0434, respectively.

After analyzing the statistical indicators obtained, Page model was selected to represent the graphs of drying kinetics as influenced by temperature, shown in Figure 3.



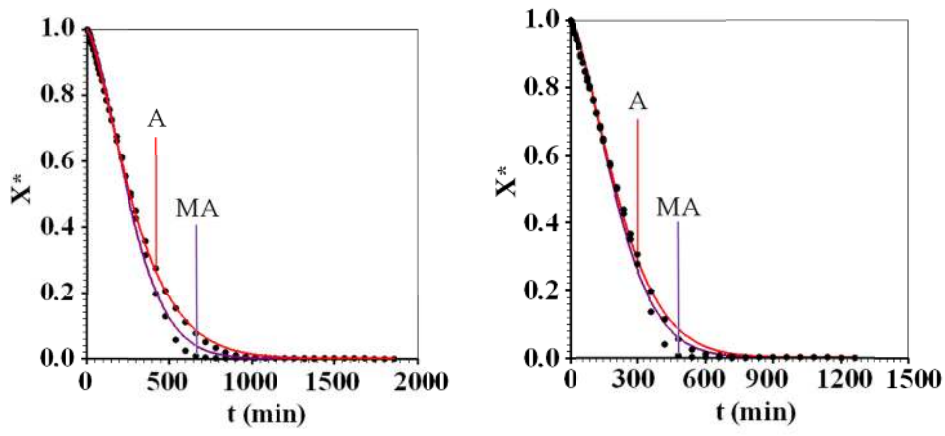


(c) (d)

Figure 3. Passion fruit drying kinetics at 70 and 80 °C using Page model for: (a) albedo; (b) macerated albedo; (c) peel; (d) macerated peel

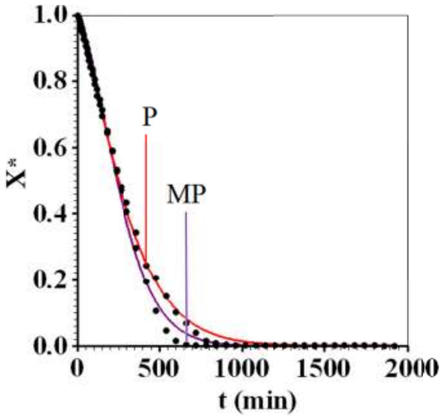
By analyzing all graphs in Figure 3, it can be noted that samples dried at 70 °C required longer time to reach equilibrium, in all cases. Visually, Page model fitted well to the experimental points at the temperature of 80 °C (Figure 3), except for the sample of macerated albedo (Figure 3(b)), in which the points were more dispersed around the respective experimental data. For the temperature of 70 °C, Page model fitted best to the observed data in Figure 3(a), relative to the sample of passion fruit albedo.

The influence of maceration on the drying kinetics is presented in Figures 4 and 5. In all cases shown in Figure 4 and 5, the maceration process tends to reduce the drying time. However, the experimental points showed slightly greater dispersion in the macerated samples. Visually, the best fits were observed in Figure 4(a), relative to albedo with and without maceration dried at temperature of 70 °C.

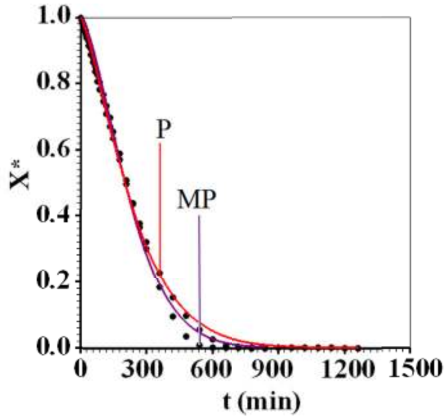


(a) (b)

Figure 4. Passion fruit drying kinetics using Page model for: (a) albedo with and without maceration at 70 ℃; (b) albedo with and without maceration at 80 °C



(a)



(b)

Figure 5. Passion fruit drying kinetics using Page model for: (a) peel with and without maceration at 70 °C; (b) peel with and without maceration at 80 °C

4. Conclusion

The mass yield of the samples after drying can be considered as low and the best result was 10.07%.

The mathematical model of Page was the one which fitted best to the experimental data of drying for all samples. It can also be highlighted that the sample composed of peel without maceration and dried at 70 ºC had the best results of R^2, besides adequate values of χ^2 in the four models.

Both the increase in drying temperature (from 70 to 80 °C) and the maceration process reduced the drying time, but the increase of temperature was the preponderant factor.

Acknowledgement

The second author would like to thank CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) for supporting this study and for his research grant (Process Number 302480/2015-3).

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