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Journal of Nutrition and Food Processing
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Research Article

Kinetic characterization of parsley drying (petroselinum sativum var. Latifolium)

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Received date: November 28, 2024; **Accepted date:** December 20, 2024; **Published date:** January 08, 2025

Citation: Yaisely Orquídea H. F., Julia M. S. Pulidob, José M. D. Borgeb, Jany F. Delgadob, and Luis E. Lara, et.al (2025), Kinetic characterization of parsley drying (petroselinum sativum var. Latifolium), *J. Nutrition and Food Processing*, 8(1); **DOI:10.31579/2637-8914/282**

Abstract:

The study addresses the characterization of two parsley drying technologies. To this end, two seasoning dehydration procedures were compared: the artificial method in an oven at 40 °C and an average relative moistureof 50% and natural drying in trays with a metal mesh bottom arranged on cemented plates. The kinetic characterization of both procedures was carried out by fitting three mathematical models. The determination of quality was carried out according to the determinations of: moisture content, appearance and water activity. The results provide the productive base with the technical elements that can be decisive for the selection of artificial or natural technology for the dehydration of this highly perishable condiment species. It was demonstrated that the thermal gradient generated in the artificial technology caused greater dynamics of moisture extraction and better colorimetric quality in the seasoning compared to what was obtained in the natural process.

Key words: quality, dehydration, perishable, seasoning, losses

Introduction

In Cuba, in recent years there has been an increase in the consumption of aromatic herbs, both in the seasoning of food and in the form of infusions or drinks for therapeutic purposes. In this sense, one of the vegetables most used by the industry is parsley to be consumed in instant soups, sauces, spices, creams and soups (Hernández et al., 2024).

Parsley is a very important vegetable due to its nutritional value, characterized by having a high content of vitamin C, β-carotene, thiamine, riboflavin, and vitamin E (Manayay et al., 2019). This herb, both fresh and dried, is widely used as a condiment in various food products due to its powerful aromatic smell.

One of the causes of post-harvest losses in this crop is due to its high respiratory rate (Gordillo and Vega, 2018). Therefore, one of the alternatives to counteract this problem is to transform it into a dehydrated product where its shelf life is extended.

Drying is a widely used process for food preservation and consists fundamentally of removing free water from the solid. This makes it possible to limit the action of factors that cause deterioration such as: chemical reactions and microbial growth (Hernández et al., 2022). In most cases, dehydration is carried out by hot air, where the air conducts heat to the product and it tends to release water vapor (Tucto, 2023).

Research on dehydrated parsley has aimed to verify the effect of different post-harvest operation variables on the properties of the final product and its relationship with the efficiency of the process. However, studies to date are still insufficient, considering the close relationship between drying technology and its influence on post-harvest quality indicators.

Therefore, the objective of this work was to characterize the drying kinetics of parsley (*Petroselinum sativum* var. *latifolium*).

Materials and Methods

The experiments were carried out in the laboratories of Medicinal, Aromatic and Condiment Plants and Post-Harvest Biology and Technology, of the Alejandro de Humboldt Institute for Fundamental Research in Tropical Agriculture (INIFAT).

The parsley (Petroselinum sativum latifolium) foliage used was from the Liliana Dimitrova Horticultural Research Institute (IIHLD) (Table 1) and, depending on the harvesting areas from which the plant material came, it was necessary to separate the sampling for the study and form three groups at the reception stage. Each of them was analyzed as an independent process.

Table 1: Experimental batches of parsley

The work flow was set up as shown in Figure 1.

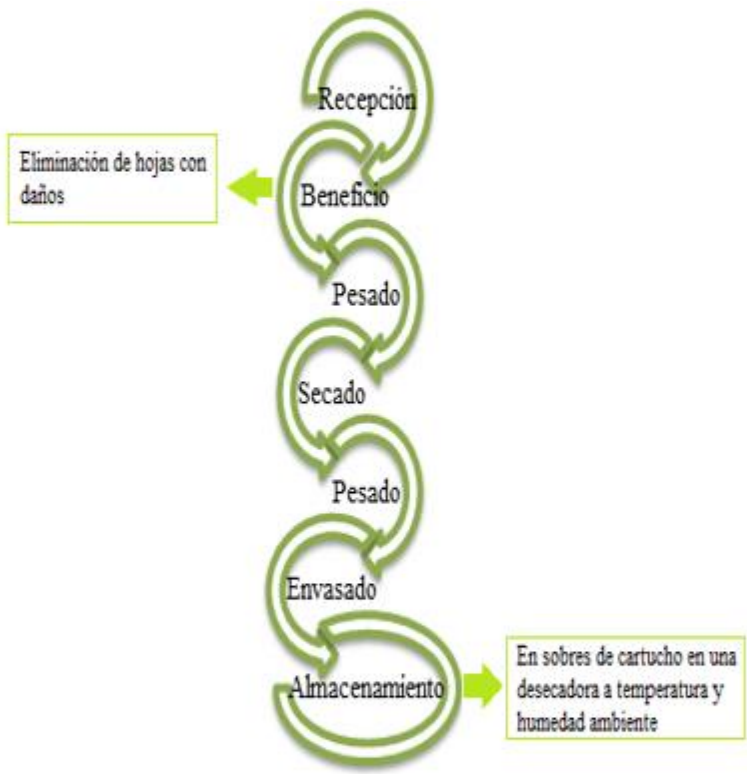


Figure 1. Post-harvest flow

Drying Process

For artificial dehydration, an SPT 200 Vacuum Drier oven was used with axial air flow at 40 °C and an average relative moistureof 50%. The leaves were placed on metal sieves evenly distributed inside the drying chamber. When filling the containers, it was taken into account that the amount of material would facilitate the exchange of mass and energy inside the drying chamber.In the natural drying tests, trays with a metal mesh bottom with 1 mm opening and dimensions of 0.59 x 0.4 x 0.075 m were used.each one, arranged on cemented plateaus. Each of the thermodynamic parameters of each process was monitored by a digital sensor and a thermo-hygrometer respectively.

The initial moistureof the material was determined for all samples.and water activity. During the study, three samples were taken every 24 h per process to evaluate the moisture loss over time. For this purpose, an OHAUS Explorer brand scale with a sensitivity of 0.001 g was used. Time was measured with a stopwatch and was established as the period elapsed from the determination of the initial weight until reaching constant weight.

- *Determination of moisture content:*The moisture content was determined in triplicate, according to the gravimetric method (1 hour at 105 °C) (AOAC, 1990) and for this purpose an OHAUS Explorer brand analytical balance with a precision of 0.0001 g and a MEMMERR brand oven were used.
- *Determination of water activity:*Water activity (aw) was determined by direct measurement with a laboratory water activity meter of the Smart Water Activity Meter brand. With a measurement range between 0 and 0.98 aw, an accuracy of ± 0.015 aw. The activity is dimensionless and takes values between 0 and 1.

The variation in moisture content over time was mathematically modeled using the equations shown in Table 2. The drying constants for each process were obtained from the mathematical model that best fit the moisture loss (MR) values over time. The model was selected based on the highest linear correlation coefficient (R2) and the lowest mean relative error percentage (%E).

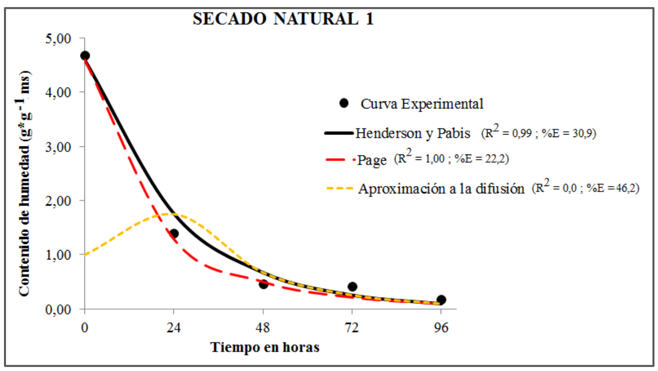
Equation	Mathematical model
$MR = e^{-kt^{n}}$	Page
$MR = ae^{-kt}$	Henderson and Pabis
$MR = ae^{-kt} + (1-a)e^{-kBt}$	Approach to diffusion

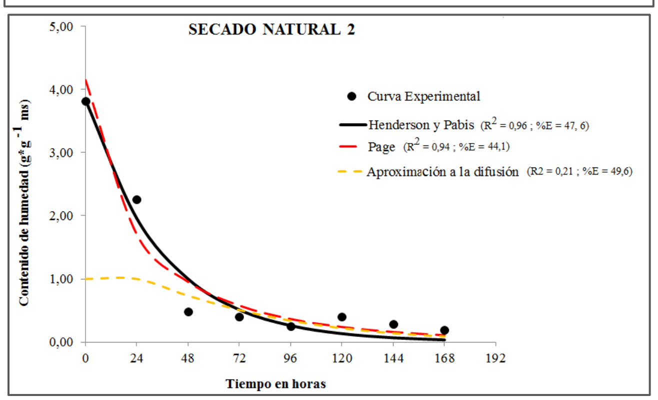
Table 2: Mathematical models used for drying kinetic characterization. Source: Hernández et al. (2022)

All results were processed statistically, through a comparison between the measured and calculated variables. The statistical package used was SPSS.version 11.5 for Windows 2004.

The drying curves obtained from the drying experiments are shown in Figures 1 and 2.

Results





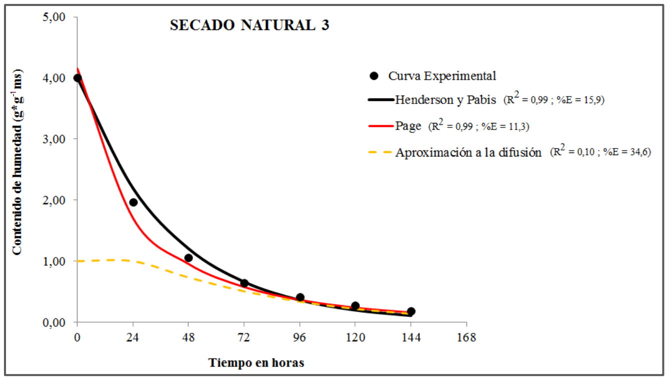


Figure 1: Natural drying curves fitted to different mathematical models.

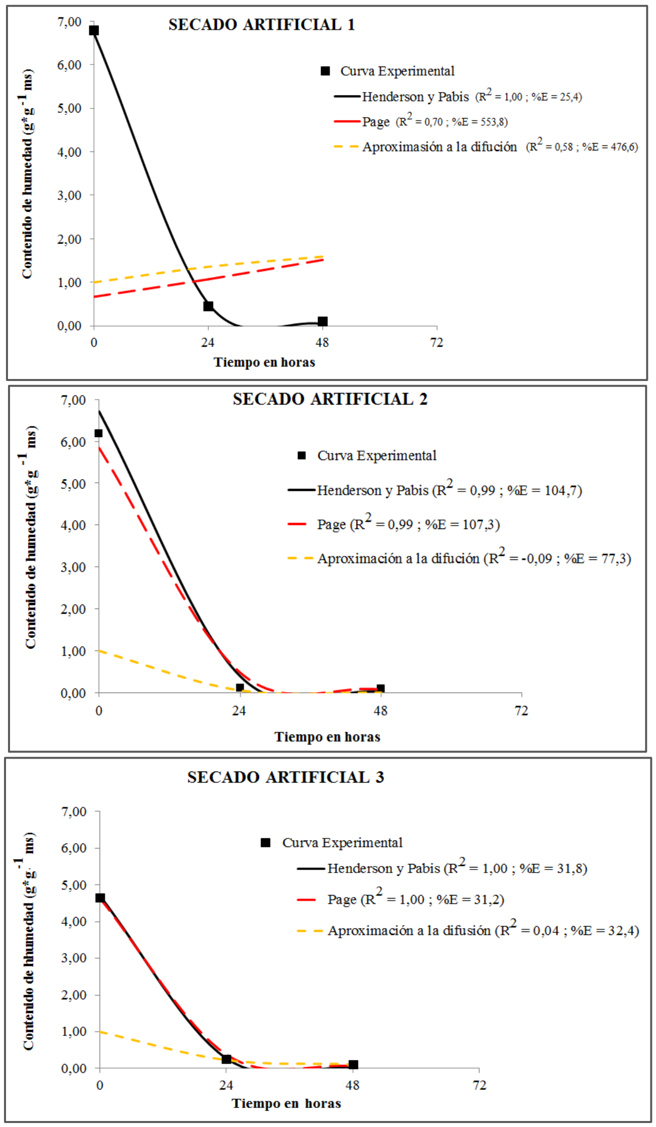


Figure 2: Artificial drying curves fitted to different mathematical models.

Table 3 shows the different coefficients and quality indicators evaluated by each drying process.

Coeficiente	PROCESSES					
	1	2	3	1	2	3
Hi (%bh)	87.16	86.09	82.34	82.36	79.27	80.01

aw	0.994	0.980	0.754	0.945	0.928	0.905
Appearance						
Coefficients	**ARTIFICIAL DRYING**			**NATURAL DRYING**		
H %bs	10,18± 6.6	8.66± 0.0	10.41± 1.8	18.2± 1.9	19.1 ± 6.5	18.6± 0.4
aw	0.508	0.580	0.529	0.533	0.681	0.52
k (h-1)	0.108	0.118	0.118	0.040	0.028	0.025
t (h)	48a			96b	168c	144bc
Appearance						

Table 3: Parsley quality coefficients and indicators

Discussion

Artificial technology, using a drying air temperature higher than ambient, was an effective parameter in substantially reducing drying time. Similar results were obtained by Portin et al. (2008) during the dehydration of this plant. The constant temperature and moistureconditions during artificial drying favored the rapid removal of free water during this process. However, in natural drying, the water vapor pressure in the air at ambient temperature generated a high relative moisturethat led to a lower adsorption capacity of the air. As a result, during the extraction of water from parsley leaves by the natural method, the air became quickly saturated and water removal was slower.

In this sense, authors such as Morsetto et al. (2022) evaluated the effect of air temperature on drying times, finding greater moisture removal with increasing temperature. They suggest that it is possible to achieve homogeneous and uniform drying when parsley is dried without the stems. Guglielmone et al. (2007) obtained the same results for this species during artificial dehydration at 60 °C.

Ceron andGrijalva (2015) carried out thethe application of mathematical models for the drying of parsley leaves in a convective dryer at different process conditions. As in the aforementioned study, the results showed that there is no period of constant speed in the drying curve, the process being carried out entirely in the period of decreasing speed.

Hot air dehydration is more expensive than natural dehydration. However, it has a large number of advantages, including that the process can be carried out without depending on the weather, the drying time is relatively shorter and the quality of the product is much better (García et al., 2010).

The significant differences obtained in time are due to the fact that artificial drying technology is a continuous process, while in natural drying times are increased by intermittent weather conditions because solar energy arrives irregularly. As in what was obtained in research such as that carried out byŁyczko et al. (2019)A stable drying air temperature favours the air's ability to adsorb water molecules from biological material, which results in a reduction in the structure's internal resistance to water removal, i.e. greater diffusion of water in the parsley leaves and therefore shorter processing time.

García et al. (2010) evaluated the effect of air temperature on drying times and color of this plant, showing that drying times decrease with increasing temperature and, as in the present investigation, the drying process is carried out in the period of decreasing speed. In turn, they also state that when the height of the bed is increased, the air speed is reduced and the samples do not have stems, shorter times and energy consumption are obtained.

The parameter k indicates the water output speed associated with the increase in temperature, which may or may not favor the movement of moisture. Therefore, since a higher "k" was obtained in the artificial process, it was the technology in which the greatest amount of water was diffused and therefore the time was shorter.

Portin et al. (2008) stated that the water content of parsley is between 78-82%, while Lema and Morsetto (2020) obtained an average moisturefor this species of 85%. The quality indicators showed that the moisture content was not always close to the values proposed by the literature. This may be associated with the handling during sampling or the production conditions of the crop (Manayay et al., 2019).

In all cases, after natural drying, moisturelevels higher than 12% were obtained. However, the absorption isotherm of this plant obtained by Hernández et al. (2024) establishes that the safe moisturecontent must be between 0.049 and 0.056 gg-1ms. Manayay et al. (2019) suggest that drying should be carried out until the product has a moisturebetween 8 and 12% depending on the plant species; since within these percentages most plant species can be stored without risk of deterioration. What was obtained suggests the existence of air saturation that prevented the absorption of moisture by the material or the development of a hard surface layer that is impermeable to the flow of water vapor, caused by the dragging of soluble materials such as sugars and salts to the surface, thus generating the stoppage of the dehydration process (Rodríguez et al., 2005).

After the two drying processes, the water activity value varied between 0.5 and 0.681, a range in which weakly bound water is found and is characterized by having reduced mobility. This water is more difficult to extract and therefore generally requires more energy. These water activity values were not close to 0.2 (value reported in the literature for dehydrated products), which implies for dried parsley a risk of lipid oxidation, darkening (non-enzymatic browning) and increased enzymatic reactions during the storage stage.

The moisture content and water activity obtained during artificial dehydration were lower. This confirmed that the thermal gradient generated in the oven facilitated moisture removal (Khater et al., 2019).

Color is a perception phenomenon that depends on the observer and the conditions under which a material is observed. In dehydration processes, there are changes and losses of color that are reflected in the appearance, since the characteristics of the surface of the food are modified (Morsetto et al., 2022). Likewise, enzymatic browning, which originates from polyphenol oxidase, can cause rapid darkening mainly on the outer part of the leaves.

The color change observed after the drying processes was visually perceived to a greater extent in the samples dehydrated using natural technology. This could be associated with the photo-oxidation of the pigments by the action of light, which, in combination with oxygen, produces severe discoloration, which, together with the prolongation of the dehydration process and the temperature, caused greater loss of pigments (Chávez et al., 2023). In this sense, the main pigment that is altered during drying is chlorophyll a, since it is less stable than b, forming pheophytin, which is an olive-brown color. What is sought in this type of product is a color with high luminosity (L) values and low a/b ratio values.

Conclusions

1. The thermal gradient generated by artificial technology causes a rapid dynamic of moisture extraction from the parsley and guarantees a colorimetric quality in the condiment superior to that obtained in the natural process.

2. The results provide the production base with the technical elements that can be decisive for the selection of artificial or natural technology for the dehydration of this highly perishable spice species.

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DOI:10.31579/2637-8914/282