Physics of semiconductor devices & renewable energies journal

Vol. 02 n. 01 (2025); ISSN 2992-040X
Journal homepage: www.psdrej.net

Comparative Study of Drying Methods: Shade, Solar, and Convection on *Phoenicia Juniper* plant

Bendehina Hicham[1*], Abdenbi Asma [2], Dennai Brahim [3], Bennaceur Said [4]

[1,2,3,4] University of Tahri Mohammed, laboratory ENERGARID Bechar. Algeria

*Corresponding author *Email: bendehina.hicham@univ-bechar.dz*

Abstract

In the Mediterranean region, *Phoenicia juniper* is frequently utilized in the culinary and medicinal industries. Despite several studies on alternative drying methods for *Phoenicia juniper*, there isn't much information in the literature about solar drying this herb. Three different drying techniques were used in this study to dry thin layers of Phoenicia juniper plants: convection drying, solar drying, and shade drying. A typical area in southwest Algeria, Béchar is notorious for its hot, dry summers and cold, dry winters. This is where the study was carried out. In terms of drying rates, the findings indicated that convective drying reached 57.82%, shade drying achieved 59.5%, and solar drying achieved 58.23%.

Keywords: *Phoenicia juniper, Solar drying, Shade drying , Convective drying*

1. Introduction

There are traces of the use of medicinal plants in Chinese texts dating back to more than 5000 BC. The Ebers Papyrus (circa 1500 BC) is the first collection dedicated to medicinal plants, providing an index of 12 plants along with their uses. (myrrhe, ricin, ail etc.). The Egyptians already possessed concepts of pharmacy, and more than 200 different plants, brought from Syria by Pharaoh Thutmose III, are depicted on the prominent inscription in the Karnak Temple. (1450 ans avant J.C.). [1,2].

Medicinal plants are used in various galenic forms: plants in nature, powders, powder capsules, sprays, tinctures, extracts, tinctures, essential oils [1]. And to use them, they must be dried because, Drying is a thermal process that can accelerate or inhibit enzymes and reduce biological degradation [3.4]. In our study, we conducted an experiment on the Phoenician juniper where, Juniper is an important species in the landscapes of North Africa, primarily due to their strength and vitality; they are, in fact, pioneer species that do not require special environmental conditions and are found from the coastal front to the peaks of the Atlas. Their strength enables them to withstand the severe human aggression they are subjected to, as in many areas they represent the only tree or shrub element that can be exploited for wood or leaves, or even for industrial or medical purposes [5]. For drying, there are several types and methods, such as Drying is done outdoors in the shade, with natural air circulation. Drying is controlled by natural convection [6]. When a wet product is placed in a stream of sufficiently hot and dry gas (usually air), there is a difference in temperature and partial pressure such that: - The gas provides the product with at least part of the energy required for evaporation - The water evaporates without boiling under the influence of the partial pressure gradient of the water. Water vapor is transferred by conduction and convection from the product to the environment, and then it is carried away by the gas [7]. Or by indirect solar drying, It is simply a matter of heating the product using indirect solar radiation (indirect drying) or using a solar collector to capture and/or concentrate solar radiation to increase the air temperature. (Indirect drying). This drying method is primarily used in the field of agricultural food products. The process of sun drying has widely developed in arid or semi-arid regions with optimal climatic conditions: a dry season with strong sunlight, little rain, and low humidity. Drying is done on the ground, on nuts, on flat rocks, or on rooftops. This system has two main benefits for communities: minimal labor and no need for investment. However, the results achieved are often poor because the products become contaminated with sand and dust, and are exposed to attacks from animals, insects, and microbes, leading to significant losses. Additionally, the products are subject to damage, either by excessive or insufficient drying, which significantly reduces their quality [8].

This study used three different drying methods: shade drying, forced air drying, and solar drying, to dry the medicinal plant Phoenicea juniper for a comparative experimental study to determine the best method for drying this plant and also to prepare the leaves for biological extraction to produce a natural disinfectant.

2. Material and methods

2.1. Preparations and dehydrating methods

Prior to the emergence of dawn, a sample of Phoenician juniper was procured from the central area of Béchar Province, situated in the southwestern part of Algeria. The objective of this undertaking was to examine the desiccation methodologies applied to the medicinal herb commonly referred to as arar. The subsequent techniques were employed in the course of this investigation.

2.2. Shade drying

In this scholarly investigation, a total mass of 300 grams of Phoenicea juniper was systematically chosen for desiccation under controlled shade conditions within a specialized chamber. The desiccation process was scrupulously observed, meticulously documenting both thermal fluctuations and weight alterations at consistent intervals until the Phoenicea juniper attained a stable weight of 178.5 grams. This stabilization threshold was reached after a period of 16 days, signifying the culmination of the drying process.

During the desiccation interval, the chamber was preserved under shade conditions to replicate an environment that mitigates direct solar exposure. Exact temperature measurements were recorded at regular intervals to guarantee optimal desiccation conditions and to avert any drastic temperature variations that could potentially jeopardize the integrity of the desiccated Phoenicea juniper.

2.3. Convective drying

In the course of this investigation, a cumulative mass of 230 grams of freshly harvested Phoenicea juniper was subjected to desiccation employing a hot air-drying methodology. The apparatus utilized for drying was integrated with a computerized monitoring system designed to oversee the drying procedure until a consistent weight of 133 grams was attained.

The desiccation process was executed under conditions of controlled airflow, maintained at a temperature of 40 degrees Fahrenheit. The drying apparatus facilitated a uniform and regulated airflow throughout the duration of the experiment, thereby promoting an effective and homogeneous drying of the Phoenicia juniper.

2.4. Solar drying

In the present investigation, a mass of 600 grams of freshly harvested Phoenicia juniper was subjected to dehydration utilizing an indirect solar dryer apparatus. The solar drying apparatus was outfitted with thermal regulation capabilities through an integrated resistive heater and fans to modulate and direct the circulation of heated air. The mass of the Phoenicia juniper was meticulously documented at regular intervals until it attained a terminal weight of 349.4 grams following a desiccation duration of 24 hours.

The solar dryer was calibrated to function at a temperature of 40 degrees Celsius with an airflow rate of 0.5, thereby ensuring optimal conditions for moisture removal. The solar dryer was positioned to receive direct solar irradiation at 10:45, and its orientation was modified to align southward at an inclination of 31 degrees.

It is pertinent to acknowledge that specific parameters such as the configuration and experimental conditions may fluctuate depending on the particular study and the equipment employed.

2. 5. Specifications for solar dryer

In our study, we utilized an indirect solar dryer, which consists of two main components: a solar collector and a drying chamber.

The solar collector, as shown in Figure 1, is designed with dimensions of 176 cm (length) × 90 cm (width) × 10 cm (height). It incorporates a single circulation system and single glazing. The collector's inclination can be adjusted relative to the horizontal plane and is oriented due south to maximize solar exposure. The materials used for constructing the solar collector include Mishler plates, polystyrene, and glass, which were readily available from the local market.

Moving on to the drying chamber, it is shaped like a parallelepiped and has dimensions of 81 cm (length) × 81 cm (width) × 55 cm (height). The chamber is constructed using Mischler plates. It is connected to another parallelepiped, known as the heating chamber, which measures 80 cm (length) × 26 cm (width) × 53.5 cm (height) and is fabricated from galvanized sheet material.

Figure 1: The actual view of solar drying system [9]

The heating chamber is equipped with a heating unit comprising two electrical resistances, one with a power rating of 1500 kW and the other with 800 kW. To regulate the temperature consistently during the drying process, the resistances are connected to a contactor and a wattmeter. The entire assembly, including the heating chamber and heating unit, is encased within an additional parallelepiped made of galvanized sheet material.

Within the drying chamber, we have incorporated eight rectangular plastic racks, each measuring 50 cm (length) × 30 cm (width) × 4 cm (height). These racks serve as support for the products undergoing drying. By employing this configuration, we aimed to create an effective and efficient indirect solar dryer, allowing for controlled drying operations

Figure**2**: resistance.

Figure 3: The interior view of solar drying system drying chamber

The installation of a rooftop radiation monitoring device within our laboratory premises serves the purpose of meticulously tracking and quantifying the overall radiation levels. This addition has been implemented with the specific intent of enhancing the accuracy and precision of our ongoing experiments. By employing this device, we can effectively monitor and record the cumulative radiation exposure, thereby enabling us to conduct comprehensive analyses and evaluations of our experimental processes. This professional enhancement further bolsters the scientific integrity and reliability of our research endeavors

Figure 4: Centrifugat fan.

Figure 5 : Pyranometre.

The device was positioned in southern orientation at inclination angle of 31 degrees.

2.3 Convective drying

2.3.1 Description

- convection dryer for drying experiments on granular solids
- plotting of drying curves

Convection dryers are commonly employed in the field of food technology to dry solid materials. The CE 130 model serves as a practical tool for investigating and demonstrating the process of convection drying specifically for granular solids.

This dryer consists of a drying channel equipped with four removable plates that are resistant to corrosion. These plates hold the solid material to be dried and are subjected to an airflow within the channel. The airflow serves a dual purpose: it heats the solid material while simultaneously removing any moisture released during the drying process. The speed of a fan can be adjusted to control the air velocity, and an adjustable heater is used to regulate the temperature of the airflow. The drying process can be observed through a transparent door integrated into the drying channel.

To monitor the drying progress, a digital balance is utilized to track any changes in the weight of the solid material caused by the evaporation or vaporization of moisture. Additionally, a combined temperature and humidity sensor measures and digitally displays the air temperature and relative humidity both before and after the airflow passes over the solid material. Another sensor is employed to measure the air velocity.

All the relevant parameters, including changes in weight, humidity, temperature, and air velocity, can be directly transferred to a personal computer (PC) for further analysis and processing.

Figure 6: Convective dryer for our drying experiments

2.3.2 Learning objectives/experiments

- The drying intensity in convection dryers is affected by the air temperature and humidity, which impact the speed and efficiency of moisture removal during the drying process.
- Drying curves can be created under constant external conditions to graphically represent the changes in moisture content of the solid material over time, allowing for visual analysis of the drying behavior.
- The drying rate can be determined by conducting experiments using varying air parameters (temperature, humidity) and different properties of the solid material, providing insights into the speed at which moisture is removed under different conditions.
- Energy and mass balances can be utilized to evaluate drying processes, taking into account the energy input, energy losses, and moisture content entering and leaving the system. This comprehensive assessment helps optimize drying efficiency and understand the overall performance of the drying process.

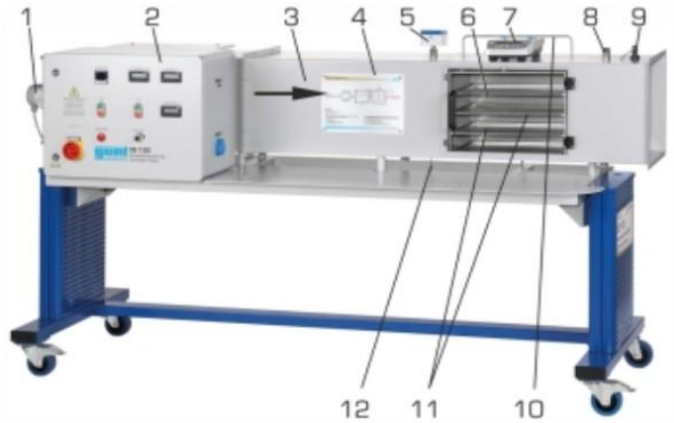

Figure 7: Convective dryers CE 130

1 fan, 2 switch cabinet with digital displays, 3 drying channels, 4 process schematic, 5 measuring point with humidity and temperature sensor, 6 transparent doors,

7 digital balances,

8 measuring point for humidity and temperature, 9 air velocity sensor, 10 bracket for drying plates, 11 drying plates, 12 temperature sensors of the controlled

2.3.3 Specification

1. drier for investigating convection drying of solids
2. drying on 4 corrosion resistant plates in a drying channel with an air flow
3. adjustment of air velocity via speed of fan
4. air heating with controlled heater
5. digital balances for measuring the change of weight during drying
6. combined sensors for measurement of humidity and temperature before and after the solid sample
7. air velocity sensors
8. GUNT software for data acquisition via USB under Windows 10

3. Results and discussion

3.1 Drying. kinetics behavior

In the present investigation, we undertook a series of experiments aimed at evaluating the drying efficacy of Phoenicia juniper plants utilizing various drying methodologies: shade drying, sun drying, and thermal drying. The drying kinetics were meticulously monitored over a duration of 24 hours for both hot air drying and solar drying, whereas the shade drying technique necessitated a protracted period of 16 days for completion.

The data acquired from these drying trials were depicted through graphical representations, which elucidate the drying attributes and effectiveness of each technique. These graphical representations manifest the fluctuations in moisture content of the Phoenicia juniper plants throughout the drying interval.

In the case of the shade drying methodology, we noted a progressive reduction in moisture content spanning the entirety of 16 days. This prolonged drying duration is attributable to the lack of direct solar exposure,which restricts heat transfer and the rate of evaporation .Notwithstanding the extended 134drying duration, shade drying may confer advantages in terms of preserving the pigmentation, fragrance, and overall integrity of the desiccated

Phoenicia juniper due to the moderated drying velocity. Conversely, both sun drying and thermal drying methodologies demonstrated a markedly expedited drying rate, culminating in the completion of the drying process within a 24-hour timeframe.

Sun drying employs indirect solar radiation to furnish thermal energy, thereby facilitating rapid moisture evaporation. This particular technique is both economically viable and readily accessible in regions characterized by plentiful sunlight. Conversely, thermal drying employs heated air produced by electric resistors, thereby expediting the drying process through the provision of regulated thermal energy.

Upon comparing the two swift drying methodologies, namely hot air drying and solar drying, we observed congruent drying durations and moisture reduction rates. This observation implies that both methodologies are efficacious in effectively extracting moisture from the Phoenicia juniper plants within a comparatively brief temporal framework. Nevertheless, it is imperative to acknowledge that solar drying presents the additional advantage of harnessing renewable energy, thus diminishing dependence on electrical power.

The findings from these drying experiments and their associated outcomes yield pertinent insights for the discernment of the most suitable drying methodology for Phoenicia juniper plants, taking into consideration variables such as temporal limitations, desired product quality, and resource availability. Further exploration and examination could be pursued to evaluate the ramifications of drying methodologies on the nutritional profile, sensory characteristics, and overall market viability of the desiccated Phoenicia juniper.

The moisture content of the samples was then expressed in a non-dimensional way using Equation [10]

$$MR = \frac{X(t) - Xeq}{X0 - Xeq} \quad (1)$$

The drying rate (Dr) of Phoenicia juniper plants was calculated using the following equation [11]:

$$Dr = \frac{Xt + dt - Xt}{Dt} \quad (2)$$

where MR is the dimensionless moisture content, X(t) is the moisture content after a drying time (t) (kg water/kg dry matter, d.m.), X0 is the initial moisture content of samples (kg water/kg d.m.) and Xeq (kg water/kg d.m.) is the equilibrium moisture content.

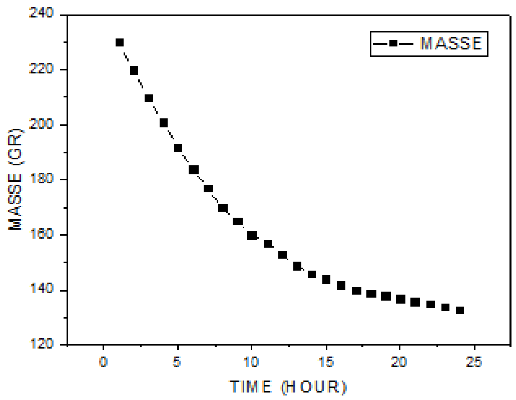

Figure 8: convective drying

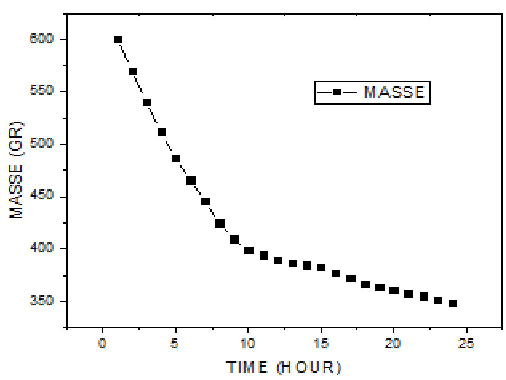

Figure 9: Solar drying

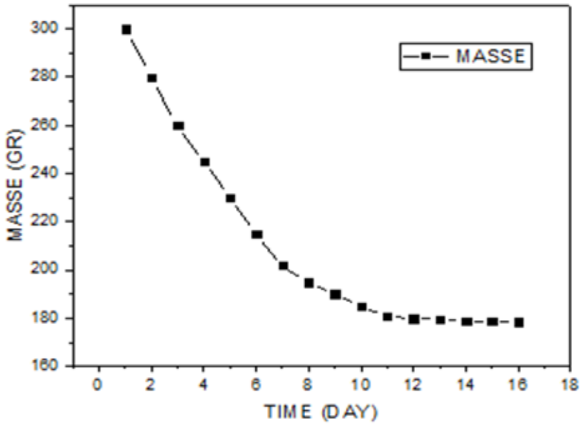

Figure 10: Shade drying

The graph presented herein delineates the operational efficacy of a solar dryer under predetermined working conditions. The dryer was systematically observed to sustain a temperature level nearing 40 degrees Celsius (°C), as evidenced by the recorded air entry and exit temperature metrics at the thermal collector.

The efficiency of the solar dryer in maintaining the intended temperature is manifest in the equilibrium observed between the incoming and outgoing air temperatures, as illustrated in the graph. The air that enters the thermal collector and that which exits it demonstrate a close correlation, thereby accentuating the stability of the system.

Such dependable temperature regulation within a solar dryer is of paramount significance in guaranteeing optimal drying conditions across diverse applications. The capability to consistently uphold a specific temperature range enables the dryer to effectively safeguard the quality and characteristics of the materials undergoing the drying process, while concurrently promoting energy efficiency.

The curve depicted in the graph functions as a crucial representation of the successful operation of the solar dryer, affirming its proficiency in maintaining a stable temperature of approximately 40°C throughout the drying cycle. This achievement highlights the reliability and efficacy of the system, establishing it as a promising solution for a broad spectrum of drying applications.

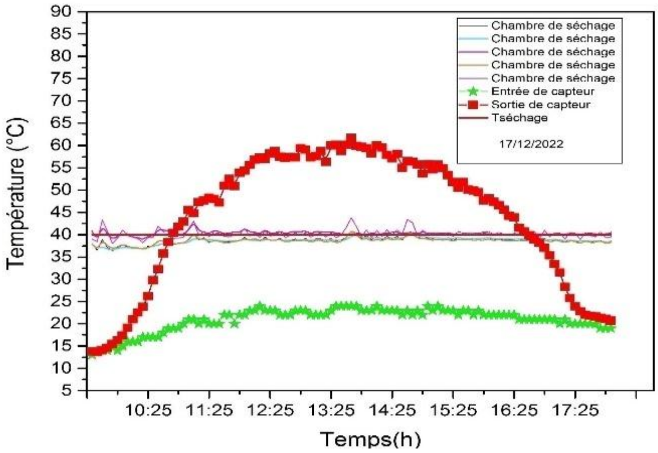

Figure 11: A curve representing how the solar dryer worked over time in terms of temperature

The graph displayed illustrates the temporal variation of total solar radiation, specifically on the day when solar drying was conducted. The graph incorporates experimental data, wherein the observed gradients reflect potential occurrences such as minor cloud cover or an obstruction caused by a bird impeding a portion of the radiation reaching the solar collector. It is important to note that the collector was installed at the surface of the ENERGARID laboratory

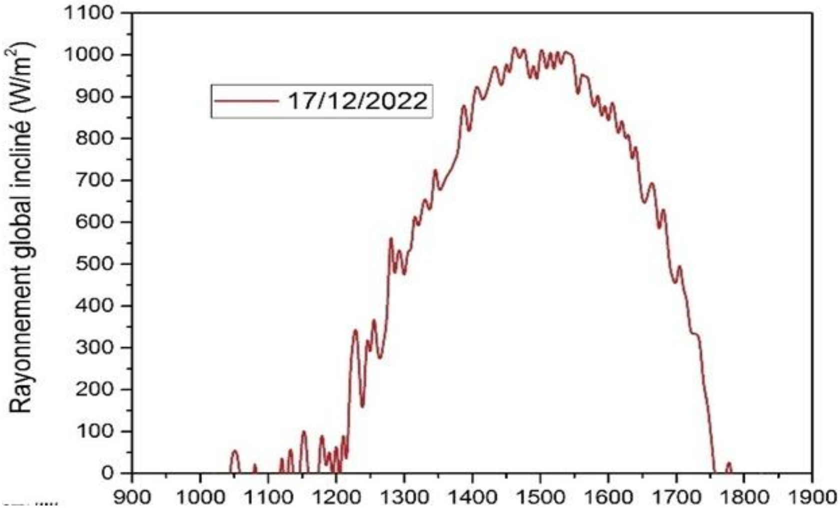

Figure 12: The Following curve represents how the total irradiance of our Solar radiation is one of the most important environmental

Figure 13: fresh plants *Phoenicia juniper*

Figure 14: Tree *Phoenicia juniper*

Figure 15: plants *Phoenicia juniper* convection drying

Figure 16: plants *Phoenicia juniper* Shade drying

Figure 17: plants *Phoenicia juniper* Solar drying

3.2 Air Drying

Air drying is a traditional and natural method of drying herbs. To air dry *Phoenicia juniper*, you would typically gather the fresh sprigs, tie them in small bundles, and hang them upside down in a well-ventilated area. Over time, the moisture within the *Phoenicia juniper* evaporates, resulting in the herb becoming dry and brittle.

In terms of color changes, during the air-drying process, *Phoenicia juniper* tends to experience a gradual transformation. The fresh *Phoenicia juniper* sprigs, which are typically vibrant green in color, gradually fade and darken as the drying progresses. The green color transforms into a muted, pale green or grayish-greenhouse.

This change in color is a natural occurrence as the moisture content decreases and the herb dries out.

3.3 Convective drying

Convective drying is a more rapid method for drying Phoenicia juniper. This method involves spreading the fresh Phoenicia juniper on a sheet and placing them in a preheated convective at a 40° temperature. The heat helps to remove the moisture from the herb, resulting in a dried product.

Regarding color changes, convective drying can lead to a slightly different outcome compared to air-drying. The Phoenicia juniper sprigs exposed to heat tend to undergo a more noticeable color change. Initially, the fresh Phoenicia juniper is vibrant green, and during the convective drying process, the color may darken more significantly.

The green hues might turn into a darker green, brownish-green, or even slightly brown color. The intensity of the color change may vary depending on the duration and temperature of the convective drying process.

In both drying methods, it is important to note that some variation in color can occur due to factors such as the initial color of the fresh *Phoenicia juniper*, the drying conditions, and the overall duration of the drying process. However, the end result should generally be a dried herb with a more subdued color compared to its fresh counterpart.

Table 1: results of deferent drying methods.

Methods	Shade drying	convection drying	solar drying
Fresh masse (grs.)	300	230	600
Dry masse (grs.)	178.5	133	349.4
Percentage (%)	59.5	57.82	58.23
time	16 days	24 hours	24 hours

Considering that each method was executed in duplicate, and the outcomes exhibited consistent trends across both experiments, an average of the results was calculated to ensure accuracy and reliability. By employing this rigorous approach, we aimed to mitigate any potential discrepancies or anomalies that could arise from a single run of each method. This methodology adheres to best practices in scientific research, as it minimizes the influence of random variations and enhances the overall validity of the findings. Consequently, the averaged results offer a robust representation of the performance and effectiveness of each method, providing a more comprehensive and reliable basis for analysis and interpretation.

4. Conclusion

Results of various drying techniques in terms of lowering humidity:

Solar Dryer: Over the course of 24 hours, the application of the solar drying technique effectively lowered the initially elevated humidity levels to 58.23%. This technique made use of solar energy to help with the drying procedure, which effectively lowers the moisture content.

Convective Dryer: By using a thermal drying method, the humidity was significantly reduced, reaching a final moisture level of 57.82% in under 24 hours. By using regulated heat to speed up the drying process, this technique significantly reduced moisture.

Drying Naturally in Shade: The natural drying procedure carried out in a shaded environment demonstrated a lengthy drying time of sixteen days. This approach was successful in bringing humidity levels down to 59.5% despite the prolonged time

Notably, by reaching the lowest humidity level in the shortest amount of time, the convective dryer showed the most effective performance. On the other hand, after a day, the humidity level of the sun drier increased somewhat, but it was still quite efficient. Finally, the drying process that occurs naturally approach produced a good degree of moisture reduction while having a somewhat longer period.

References

1. Verdrager, J., 1978, Ces médicaments qui nous viennent des plantes, Ed. Maloine S.A. p.9- 13.
2. Wichtl, M., Anton, R., 1999, Plantes thérapeutiques, Ed. Tec et Doc. p.4-14.
3. djerroud, D. (2010). Markovian modelling of continuous drying by contact with agitation (in French). Ph.D. Thesis. Toulouse, France: National Institut of Polytechnic (INP).
4. Gevaudan, A. (1989). Study of contact drying of agitated granular medium, application to the cooking-drying operation of cassava (in French). Ph.D. Thesis. Lyon, France: National Institut of Applied Sciences (INSA).
5. Quezel, P., Gast, M. (1998). Genévrier.encyclopedie berbere, Éditeur Peeters Publishers ISBN: 2-7449-0028-

1-ISSN: 2262-7197. http:/encyclopedieberber. revues.org/1863

6. LAHMARI et al, 2012: "Influence des méthodes de séchage sur la qualité des tomates séchées (variété Zahra)."
7. BONAZZI, C., E. DUMOULIN, et al, 2008 : "Le séchage des produits alimentaires." Industrie Alimentaire Agricole 125(03-04): 12-22.
8. NGUYEN, 2016 "Étude expérimentale et modélisation du procédé de séchage des végétaux."
9. BENALI touhami 2023:" study of drying process of apricots grown in bechar by an indirect solar dryer "the 1 st international conference on electrical engineering and renewable energies systems (iceeres'23)
10. LAHSASNI, S.; KOUHILA, M.; MAHROUZ, M.; IDLIMAM, A.; JAMALI, A. Thin layer convective solar drying and mathematical modeling of prickly pear peel (Opuntia ficus indica). Energy 2004, 29, 211–224.
11. CELMA, A.R.; López-Rodríguez, F.; Blázquez, F.C. Experimental modelling of infrared drying of industrial grape by-products. Food Bio prod. Process. 2009, 87, 247–253.