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Original Article

Novel Solar Micro Dryer for Aromatic and Medicinal Plants

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ABSTRACT

Background: This paper focuses on an experimental investigation of an indirect solar dryer, specifically designed for drying aromatic and medicinal plants. **Objectives:** The purpose of this study is to utilize solar energy as a sustainable and efficient source of heat for the drying process, ensuring high-quality dried products. **Materials and Methods:** Our project aimed to study, design, implement, and experimentally evaluate an indirect solar micro-dryer. The study involves conducting experiments using different types of aromatic and medicinal plants, analyzing the drying kinetics, and assessing the quality of the dried products. **Results:** The results demonstrate the effectiveness of the micro-solar dryer in achieving rapid and efficient drying while preserving the essential properties of the plants. **Conclusion:** The findings provide valuable insights into the potential application of solar drying technology for aromatic and medicinal plant processing, contributing to the development of sustainable and environmentally friendly drying methods in the agroindustry.

Keywords: Solar energy, Micro-solar dryer, Medicinal plants, Drying kinetics, Drying chamber.

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INTRODUCTION

Drying is considered as the oldest technique to dry various food products, aromatic plants and medicinal herbs of extracting water from a solid, semi-solid, or liquid through evaporation.[1,2] Several techniques are available for drying and preserving crops including sun drying in the field, dehydration cabinets, ensilage for forages and drying in a barn. Throughout the 20th century, solar energy emerged as one of the most prominent techniques for drying, offering benefits such as reduced CO_2 emission and improved storage conditions that prevent loss of color, development of unwanted smells and tastes and undesirable chemical changes that affect product utilization. Additionally, solar drying helps to prevent mold and microorganism development, which can lead to the formation of toxic substances.[3-5] Drying in barns allows for the production of consistently high-quality products in large quantities and frees farmer from weather constraints, at a low operating cost. It opens up new opportunities for drying various products such as forages, aromatic plants, seeds, cereals, fruits and vegetables.[6-8]

The widespread use of solar collectors has become increasingly common, particularly for water heating and air conditioning. The development of solar energy utilization has become a strategic concept for both developed and developing countries.[9-11] Solar energy numerous benefits to humans, including being free, modular, adaptable to various needs, abundant, renewable and a clean energy source with continuously improving technology and low operating costs.[12-14] The availability of solar energy varies depending on the time of day, weather conditions and season.[15-17] Despite these variations, solar energy provides essential resources for life and environmental development in a continuous manner. Given the importance of energy in improving human circumstances and ensuring well-being, solar energy plays a crucial role in meeting these needs.[18-22] In this context, we have constructed indirect micro-dryer and conducted drying kinetics analysis for medicinal and aromatic plants: specifically Mint and Artemisia.

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MATERIALS AND METHODS

Instrumentation

The support was assembled using an aluminum bar with a cross-section of 4 cm^2 and a length of 6.5 m. The advantages of using this support include its foldable nature for convenient storage, easy disassembly and assembly as needed and lightweight construction, achieved through careful weight consideration.

During our experiment, we utilized a sensor consisting of two bars of 40 cm and 2 bars of 60 cm, with a black iron plate at the back to accumulate heat and a glass plate at the front. The sensor has an internal volume of 8300 cm^3 and features holes on two sides, both at the bottom and the top, to ensure the intake of cold air and the outflow of hot air. The advantages of using these conditions include lightweight design, a mounting bracket for easy assembly and disassembly and the ability of the mini sensor can support itself.

Concerning the reservoir, it is covered with 1 mM thick aluminum plates that are folded to form a conical shape with a height of 5 cm. The exterior of the cap was covered with leather. The manufacturing process is based on the information provided. The advantages of using these instruments include facilitating the upward flow of hot air and external covering with black materials to retain and accumulate heat. Therefore, the presence of a glued joint on the reservoir reduces air leaks between the reservoir and the hat.

The instruments used during the experimentation are summarized in Figure 1.

Experimental procedure

To monitor the mass loss of the product during drying, we performed weight measurements every hour using an electronic balance. The temperature was determined by using the thermometer installed in the drying unit. The drying time is defined as the duration required to dry the product until it reaches a constant final mass.

Evaluating parameters

The calculation of the drying rate between two time intervals was based on (t1=9 am, t2=10 am); (t3=12 pm, t4=1 pm) and (t5=3 pm, t6=4 pm).

RESULTS

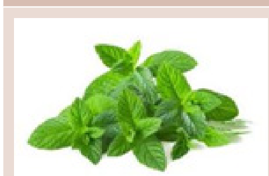
Variations in temperature and sunshine duration in the Gabes Tunisia

Regardless of the season, it's evident that illumination decreases, and temperature drops at sunset compared to the daytime. Light returns each morning at sunrise, accompanied by a rise in temperature. Consequently, the Sun serves as the primary source of light and heat on Earth, with higher positions in the sky correlating to increased illumination and temperature. Temperatures exhibit variability due to factors such as latitude, altitude and notably, proximity to or distance from the Mediterranean. Across the entire country, average temperature hover around 12°C in December and 20°C in July. While winter temperatures can dip a few degrees below zero in the Kroumirie Mountains, summer temperatures can soar around 40°C in shaded areas within desert regions. Sunshine duration stands out as the primary driver behind atmospheric and oceanic circulation. It also fuels evaporation, the process initiating precipitation and underscores the significant potential of solar energy in Gabès, Tunisia. This emphasizes the importance of utilizing solar collectors for various applications.

Operating Principle

Drying serves as both a preservation method and a processing step for various products, finding application in both rural and industrial contexts, notably within the agrofood sector. Traditional drying methods that are reliant on fossil fuels tend to consume substantial energy. However, solar drying emerges as a promising alternative, utilizing only solar energy. In our scenario, the drying process unfolds as follows: Sunlight heats the air trapped between the black plate and the glass of the collector,

Table 1: Experiment on Mint Drying Kinetics.

Plant	Hr (h)	Mint mass (g)	r.t (°C)	R.t (°C)	P_IEW (%)	P_TEW (%)
	9	530	34	50	0	0
	10	490	37	56	11.11	11.11
	11	435	38	58	15.27	26.38
	12	360	39	59	20.77	47.15
	13	300	40	61	16.62	63.77
	14	250	40	60	13.85	77.62
	15	210	38	58	11.11	88.73
	16	170	37	57	11.11	99.84
	17	170	36	54	0	99.84

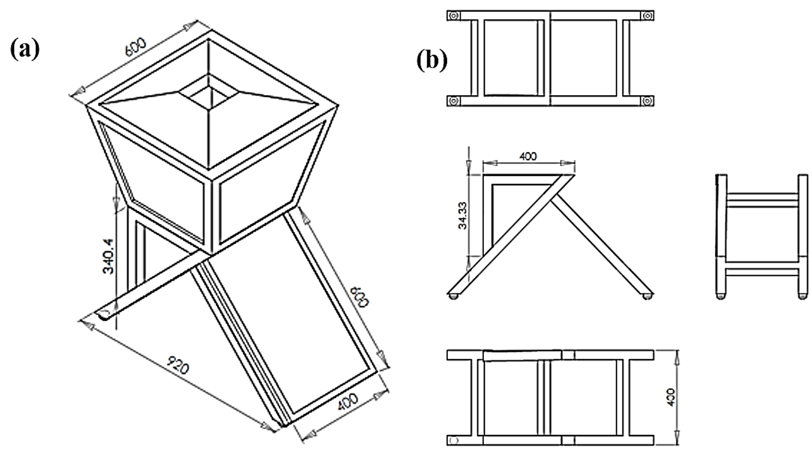


Figure 1: (a): Dimension Micro-dryer system used for medicinal and aromatic plants, (b): Dimension Support.

generating a flow that facilitates drying within the reservoir by leveraging the principle of hot air.

Study of Drying Kinetics

We conducted a drying experiment with mint and lavender, observing the variation in mass over time and taking measurements, every hour and we compared the mass variation results obtained during our experience.

Drying Kinetics Study of Mint

The experiment involved placing 530 g of mint inside the reservoir. was positioned to track the sun's path, while a connector facilitated the movement of heated air towards the reservoir. Subsequently, a thermometer was installed in the dryer to measure the Temperature (T). The experimental procedure aimed to determine various parameters, as detailed in Table 1. The following Table illustrates the variation in mass over time, Temperature (T) and the percentage of water evaporated at each hour during the mint drying experiment. The measurements were taken from 10 am to 2 pm. The values of Table 1 used to generate the curves depicted in Figures 2a-d.

Based on the Table 1, the calculation of the drying rate between two time intervals:

(t1=9 am, t2=10 am); (t3=12 pm, t4=1 pm); (t5=3 pm, t6=4 pm).

M_1=530 g, M_2=435 g, M_3=370 g, M_4=300 g, M_5=210 g, M_6=170 g.

$$V_{1=}\frac{(M1-M2)}{t2-t1} = \frac{530-490}{11-10} = 40 \text{ g/hr}$$

$$V_{2=}\frac{M3-M4}{t4-t3} = \frac{370-300}{13-12} = 70 \text{ g/hr}$$

$$V_{3=}\frac{M5-M6}{t6-t5} = \frac{210-170}{16-15} = 40 \text{ g/hr}$$

Based on the previous curves and Table 1, it can be concluded that the mint takes approximately 7 hr to be completely dried. During this time, its mass decreases from 530 g to 170 g, representing a loss of almost two-thirds of its initial mass.

Drying Kinetics Study of Artemisia

Our experiment involved using 500 g of Artemisia placed it in the reservoir. The solar collector was positioned to track the sun's path, with heated air directed towards the reservoir using a connector. A thermometer was installed to measure the Temperature (T). The experimental procedure aimed to determine various parameters, as summarized in Table 2 and illustrated in Figures 3a-d. The Table displays variations in mass over time, Temperature (T) and the percentage of water evaporated at each hour during the Artemisia drying experiment, commencing from 9 am until 5 pm.

To calculate the drying rate (D_r) between 2 time intervals based on the given Table:

For the interval (t1=9 hr, t2=10 hr): D_r=(M1-M2)/(t2-t1).

For the interval (t3=12 hr, t4=13 hr): D_r=(M3-M4)/(t4-t3).

For the interval (t5=14 hr, t6=15 hr): D_r=(M5-M6)/(t6-t5).

Using the provided values: M1=500 g, M2=480 g, M3=400 g, M4=355 g, M5=310 g, M6=270 g.

$$V_1 = \frac{(M1-M2)}{t2-t1} == \frac{500-480}{11-10} = 20 \text{ g/hr}$$

$$V_2 = \frac{M3-M4}{t4-t3} == \frac{400-355}{13-12} = 45 \text{ g/hr}$$

$$V_{3=}\frac{M5-M6}{t6-t5} == \frac{310-270}{16-15} = 40 \text{ g/hr}$$

Based on the previous curves and Tables, it can be concluded that both the mint and artemisia underwent relatively rapid drying processes. Mint took approximately 7 hr to to achieve a significantly reduced mass, losing almost two-thirds of its initial mass. In contrast, artemisia required about 6 hr to reach a mass reduction of nearly half its initial mass. Throughout our experiments, we observed that the drying process occurred under relatively constant and moderate temperatures within the reservoir, ranging from 50°C to 61°C throughout the day. This temperature range played a crucial role in facilitating the

Table 2: Experiment on Artemisia Drying Kinetics.

Plant	Hour (hr)	Artemisia mass (g)	r.t (°C)	R.t (°C)	P_IEW (%)	P_TEW (%)
	9	500	33	48	0	0
	10	480	36	54	8.69	11.11
	11	450	37	56	13.04	21.73
	12	400	38	59	21.73	43.47
	13	355	39	61	19.56	63.03
	14	310	40	60	19.56	82.59
	15	270	38	58	17.39	99.98
	16	270	37	56	0	99.98
	17	270	35	52	0	99.98

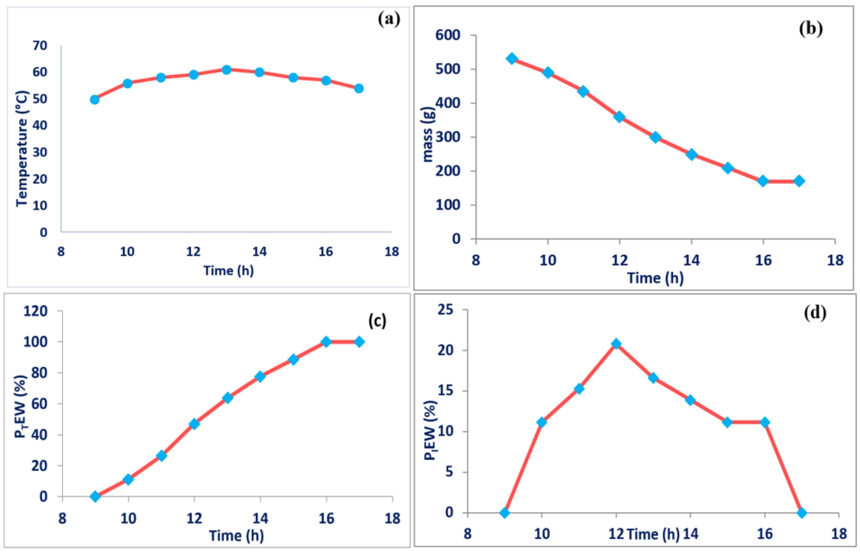


Figure 2: Variation of: (a) temperature as a function of time, (b) Mint mass as a function of temperature, (c) of pourcentage of total water evaporated from mint as a function of time and (d) instantaneous percentage evaporated from mint as a function of time P_IEW.

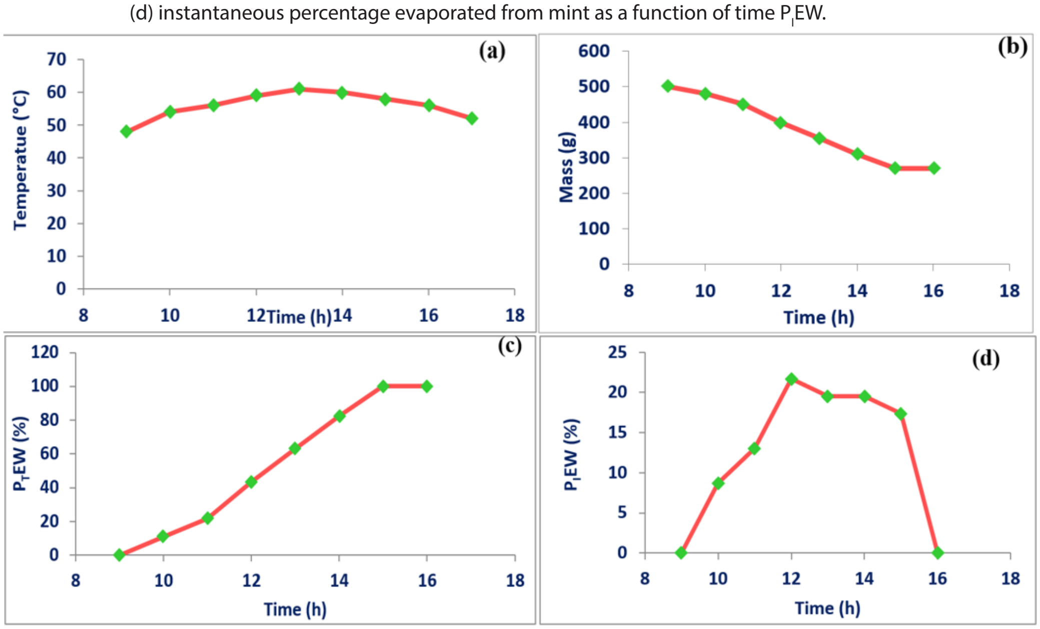


Figure 3: Variation of: (a) temperature of Artemisia as a function of time, (b) Artemisia mass as a function of temperature, (c) pourcentage of total water evaporated from Artemisia as a function of time and (d) instantaneous percentage evaporated from Artemisia as a function of time P_IEW.

successful drying of the products and ensuring the high quality of the dried herbs in both cases.

CONCLUSION

In this study, we investigated the conceptual design, implementation and experimental evaluation of an indirect solar micro-dryer for drying aromatic and medicinal plants. Despite fluctuations in climate, significant solar flux in Gabes, Tunisia was observed, indicating the effective utilization of solar radiation as an energy source for drying agricultural products. The performance of this novel model proved to be very cost-effective and has the potential to serve as an industrial construction prototype for agricultural use and scientific research. Our study utilized an efficient model of the micro-dryer with new properties such as system flexibility, attractive aesthetic design and lightweight construction, which yielded the desired results. Despite climate fluctuations, the significant solar flux in Gabes, Tunisia underscores the potential of solar radiation as an energy source for drying agricultural products. Furthermore, temperature plays a crucial role in reducing moisture content in the products, along with the airflow rate facilitated by natural convection. We observed that the drying rate was higher when the products had higher initial water content. The drying duration varied among different products, as demonstrated by the examples of mint and artemisia. In the given 8-hr period, mint reached a significantly low moisture content, while artemisia achieved a moderate moisture reduction. Overall, our findings underscore the importance of temperature control and airflow in optimizing the drying process for various agricultural products. The use of solar energy for drying purposes emerges as a viable and sustainable solution, offering efficient drying while preserving the quality of the dried products.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

Hr: hours; **P_IEW:** percentage evaporated from mint as a function of time; **V:** values**;** **D_r:** Drying rate; **T:** Temperature.

SUMMARY

An experimental investigation of an indirect solar dryer on the design and evaluation of a micro-solar dryer specifically was designed and discussed for drying aromatic and medicinal plants. This study focused on exploiting the efficient and sustainable solar energy source for the drying process and to involve conducting experiments using different types of aromatic and medicinal plants, examining the drying kinetics and measuring the quality of the dried products. The findings provide valuable insights into the potential application of solar drying technology for aromatic and medicinal plant processing, contributing to the development of sustainable and environmentally friendly drying methods in the agroindustry.

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