Solar Drying of Onion Scapes: A Sustainable Solution for Agriculture and Industry

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Abstract

This study investigates the use of solar drying for processing onion scapes, a key agricultural product in southern Algeria. The scapes were harvested early, dried, and repurposed for medicinal applications and livestock feed, providing an environmentally friendly and economically viable solution. The experiment was conducted at the Renewable Energy Development Research Unit in Arid Zones (UDERZA) at the University of El Oued, where an indirect solar dryer was used, and solar radiation and temperature data were recorded. Results showed that the Midilli-Kucuk model was the best fit for predicting drying kinetics, with an R^2 value of 0.99978, a chi-square value of 4.3×10^(-5), and an RMSE of 0.00651. The effective moisture diffusivity was calculated at 6.83598E-06 m²/s, confirming that solar drying is a viable and sustainable solution for processing onion scapes.

Keywords: Solar Drying; Onion; Scapes; Diffusivity; Drying Kinetics.

1. Introduction

Solar drying is an economical and sustainable method for drying various products, encompassing agricultural items, food, and building materials [1]. Onions are among the most significant agricultural products in southern Algeria. The formation of scapes is considered a defect that impacts the onions during the later stages of their growth. These scapes weaken the onion bulb by absorbing water and minerals that should be directed primarily to the bulb. Therefore, we decided to turn this defect into an advantage by cutting the scapes early, drying them, and using them in the production of medicines and antibiotics [2], Additionally, these dried scapes are used as feed for livestock. making it an environmentally friendly and economically viable option. Furthermore, dried onions are increasingly becoming part of dietary habits and have evolved into a standard ingredient used as a flavor additive in various agro-industrial products, such as sauces, soups, sausages, meats, fries, and biscuits. The demand for dried onions in the form of flakes or powders is also rising in several countries around the world, including Japan, Russia, Germany, the Netherlands, and Spain [3]. The use of solar drying is one of the effective solutions that helps reduce the cost of processing these products [4], .

2. Materials and Methods

This experiment was conducted at the Renewable Energy Development Research Unit in Arid Zones (UDERZA), University of El Oued, Algeria, during the 2023/2024 season. The onion scapes were harvested from the farm on the morning of the experiment. We selected scapes that were free from defects and sliced them longitudinally to facilitate the drying process after cutting off the flower. The sample was placed in the indirect dryer, which had been preheated half an hour before. The solar radiation and ambient temperature were measured using the weather station of the research unit, while other data such as dryer inlet temperature, dryer mid-section temperature, and dryer outlet temperature were obtained using data acquisition systems. To measure the sample's weight, we used a high-precision electronic scale. After the experiment, we processed the data using Origin 2019 software, and the results are displayed in the corresponding graphs

2. 1. Drying experiments

2.2. Moisture content

The moisture removal was determined by weighing samples at regular intervals until no further weight loss was observed. For moisture content analysis, 2-4 grams of samples were dried in an oven at 105 °C for 24 hours, then cooled in a desiccator for 20 minutes before weighing. The moisture content (Mc) was calculated using the equation [5]:

Eq. (1) was used to calculate the moisture content

$$Mc = \frac{(M0 - Mf)}{M0} \times 100 \quad (1)$$

where M0 is the initial mass before drying, and Mf is the final mass after drying.

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To understand the drying kinetics of onion scapes in the indirect dryer, the experimental results obtained were applied to 7 mathematical models shown in Table 1. The model with the highest value and the lowest RMSE and chi-square values is considered the most suitable for predicting the drying kinetics of tomato slices. Based on the obtained results, the Midilli-Kucuk model is the closest, with a value $R^2 = 0.99978$, a chi-square $\chi = 4.3^{-5}$, and an RMSE = 0.00656.

Table 1: The mathematical models and statistical values for drying onion scapes.

Modèle	K	n	a	b	R^2	x	RMSE
Newton	0.02756				0.98267	0.0019	0.04359
Page	0.10748	0.65509			0.99918	8.93854E-5	0.00945
Modified page	0.03322	0.65505			0.9993	8.93857E-5	8.93857E-5
Henderson and Padis	0.02697		0.97827		0.98329	0.00214	0.04623
Logarithmic	0.03147		0.94803	0.04084	0.98995	0.00154	0.03927
Midilli-Kucuk	0.12773	0.60621	0.99986	-8.32031E-5	0.99978	4.30372E-5	0.00656
Approximation of Diffusion	0.0276		-2.74259E7	1	0.98267	0.00266	0.05157

2.3. Effective moisture diffusion

To determine the effective moisture diffusivity values, we used equations 2, 3, and Fick's law of diffusion. The numerical value of the effective moisture diffusivity was 6.83598E-06.

$$\frac{\partial XR}{\partial t} = D_{eff}\nabla^2 XR \quad (2)$$

Assuming the slab is an infinite, undeformable geometry (with negligible shrinkage or expansion), Crank [6] developed Fick's method, which is expressed as follows:

$$MR = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}exp\left(-(2n+1)^2\pi^2 D_{eff}t/4L^2\right) \quad (3)$$

After simplifying equation 3, it becomes

$$\ln(XR) = \ln\left(\frac{8}{\pi^2}\right) - \frac{\pi^2 D_{eff}}{4L^2} \quad (4)$$

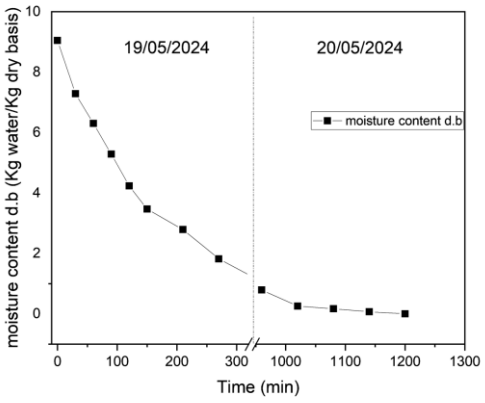

Figure 1. Moisture Content Variation with Drying Time for Onion Scapes

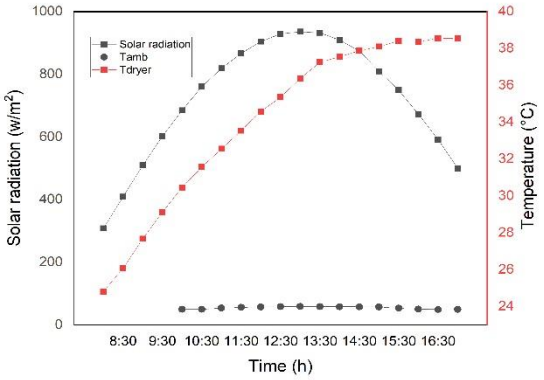

Figure 2. Variation of Solar Radiation and Temperature Over Time During Drying

Figure 1 represents the changes in the dry-basis moisture content of onion scapes. The moisture content of the onion scapes changed from an initial value of 9.1 kg of water/kg of dry matter to 0.073 kg of water/kg of dry matter, which is a suitable

value for storing dry onion stalks. The drying process took 580 minutes.

The figure (Figure 2) represents the changes in external ambient temperature, dryer temperature, and solar radiation intensity. The solar radiation intensity varied from 300 W/m² and reached its peak value of 930 W/m² at 13:00. As for the dryer temperature, it reached its highest value of 59°C at 13:00. The external ambient temperature changed from 24°C at 8:00, reaching a maximum value of 38°C.

3. Conclusions

This study demonstrates the effectiveness of solar drying as a sustainable method for processing onion scapes, highlighting its potential for both agricultural and industrial applications. The results confirm that solar drying not only preserves the nutritional and medicinal qualities of onion scapes but also provides an eco-friendly alternative for utilizing this agricultural byproduct. The successful implementation of the Midilli-Kucuk model, with a high R^2 value, indicates its suitability for accurately predicting the drying kinetics of onion scapes. The calculated effective moisture diffusivity further supports the feasibility of solar drying in achieving optimal moisture removal.

The findings underscore the importance of leveraging renewable energy resources, such as solar power, in enhancing agricultural practices and promoting sustainability. By converting onion scapes, typically regarded as waste, into valuable products for medicinal use and livestock feed, this research contributes to the development of circular economy principles within the agricultural sector. Future research should focus on optimizing the drying process and exploring additional applications for dried onion scapes, thereby fostering sustainable practices in agriculture and industry.

Nomenclature

M_t: The weight at t
X_0: Initial moisture content
Ms: Dry weight of the material
X_t: The moisture content at particular time
X_e: equilibrium moisture content

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