World Journal of Environmental Research
ISSN 2301-2641
Volume 14, Issue 2, (2024) 74-79
www.wjer.eu

Hot red pepper drying with a solar greenhouse dryer

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Suggested Citation:
Metidji**,** N. & Bendjebbas, H. (2024). Hot red pepper drying with a solar greenhouse dryer. *World Journal of Environmental Research*, *14*(2), 74-79. https://doi.org/10.18844/wjer.v14i2.9581

Received from March 20, 2024; revised from June 8, 2024; accepted from December 1, 2024.
Selection and peer review under the responsibility of Prof. Dr. Haluk Soran, Near East University, Cyprus

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Abstract

Pepper, a globally essential ingredient, holds significant demand in the international food industry due to its role as a vital source of vitamins, minerals, and energy in the human diet. Despite its importance, efficient and cost-effective methods for drying agricultural products like pepper remain a challenge. Addressing this gap, this study investigates the efficiency and profitability of utilizing a solar greenhouse for drying hot red peppers. A 300 kg capacity greenhouse dryer was designed and constructed at the Unit Solar Energy Equipment Development (UDES) in Bou Ismail, Algeria. Drying experiments were conducted in June 2020, with hourly measurements of key parameters such as ambient air temperature, humidity, and greenhouse air temperature. These data were analyzed to assess the heat and mass transfer characteristics of the system. The findings provide valuable insights into optimizing greenhouse drying technology, offering potential economic and environmental benefits for sustainable agricultural practices.

Keywords: Drying; greenhouse dryer; greenhouse air temperature; hot red pepper; renewable energy source; solar energy.

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1. INTRODUCTION

This study focuses on the results of an experimental investigation into the solar drying of red peppers, a process with significant potential in both food processing and sustainability. Drying fruits and vegetables on a large scale under controlled environmental conditions has become a focal point in modern food technology research, owing to its ability to preserve agricultural products effectively while maintaining their nutritional and sensory qualities. Recent studies have highlighted how controlled drying processes can revolutionize food preservation by ensuring product consistency, reducing spoilage, and extending shelf life, thereby meeting the growing demand for high-quality food products worldwide (Admass et al., 2024; Joel et al., 2024).

Among the various drying technologies, solar drying has emerged as a particularly promising solution (Mohana et al., 2020). It leverages renewable solar energy, which is abundant and cost-effective, to address the significant environmental challenges posed by conventional drying methods that rely heavily on fossil fuels. By minimizing carbon emissions and energy consumption, solar drying aligns with global efforts to combat climate change and transition toward greener food processing practices (Monicka et al., 2024; Deepak & Behura, 2023).

To further enhance its practicality and adoption, solar drying technology has undergone extensive modifications and advancements (Pandey, Kumar & Sharma, 2024; Yao et al., 2022). Researchers have worked to improve the efficiency of energy transfer, optimize drying parameters, and ensure uniformity in moisture removal. These efforts have led to the development of more efficient designs and systems that not only improve drying performance but also preserve the quality of the dried products, such as maintaining their nutritional value, color, and texture. This progress underscores the relevance of solar drying as a modern, eco-friendly alternative in food processing, with applications that can significantly benefit regions with abundant solar resources (Kidane et al., 2024).

This study builds on this foundation by exploring the application of solar drying technology specifically for red peppers, a widely consumed and nutritionally valuable agricultural product, with the aim of further enhancing its potential in sustainable food processing.

1.1. Purpose of the study

The primary aim of this study is to evaluate the performance and feasibility of a solar greenhouse dryer for processing red peppers, a staple ingredient in Algeria. By systematically analyzing the drying process, the study seeks to optimize drying parameters to improve efficiency, product quality, and economic viability. Additionally, the research aims to contribute to sustainable food processing practices by demonstrating the environmental and economic advantages of solar drying technology.

2. MATERIALS AND METHODS

2.1. Procedure

The drying process in this study was conducted using an indirect solar dryer with forced convection. This type of dryer is cost-effective, user-friendly, and widely applied in food product drying due to its simplicity and reliability. Red pepper was chosen for the study because of its abundance and high consumption in Algeria. The experiments focused on assessing key parameters such as the drying rate, drying time, and the color quality of the final product.

The solar greenhouse dryer used for drying the hot pepper was built in UDES. The structure of the dryer is depicted in Figure 1.

Figure 1
Photograph of the solar greenhouse dryer

For obtaining the various values of temperatures on the level of the tray and at the exit, we used 7 thermocouples (K), connected to a data logger (Hydra) which sends the necessary data to the computer.

A thermo hygrometer (Testo mark) was used to measure relative humidity. Weight losses of hot red peppers in the solar dryer were measured during the drying period in two days. The solar radiation during the operation period of the drying system was measured with a pyrometer.

3. RESULTS

Figure 2 and Figure 2 present the weight loss of hot red pepper dried in a solar dryer. One can note a great reduction in its volume.

Figure 3a shows the variation of the hot air moisture according to time during the two days of drying. One can remark that the values of moisture on the second day of the drying process are lower than those recorded on the first day of the drying operation.

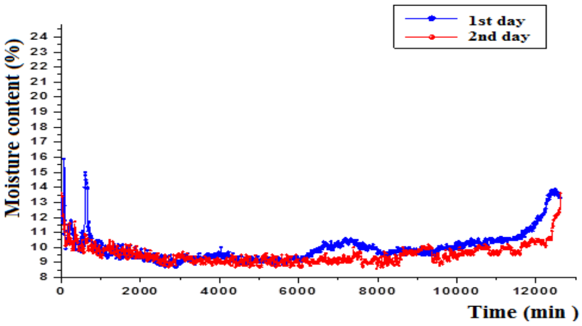
Figure 2
a) - hot red pepper cut and put on the rack, b) –dried hot red pepper.

a)

b)

Figure 3

a) Variation of moisture content with drying time b) Weight loss of hot red pepper dried in a solar dryer



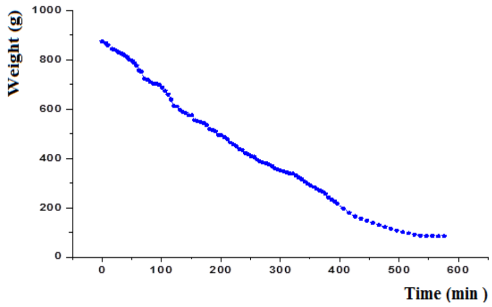


Figure 3(a) depicts the changes in the moisture content of hot red peppers over the drying duration in the solar dryer. During the initial stages of the drying process, a rapid decrease in moisture content is observed. This phase corresponds to the surface moisture being removed quickly under the influence of the heated air provided by the solar dryer. As time progresses, the rate of moisture reduction slows down, reflecting the transition to the removal of bound moisture from within the pepper's cellular structure. The difference in moisture content between the first and second days indicates that most of the drying occurs in the early hours of the process, while subsequent periods involve the gradual release of residual moisture.

Figure 3(b) illustrates the weight loss of hot red peppers overtime during the drying process. A significant weight reduction is observed as the drying progresses, which corresponds to the loss of water content from the peppers. The steep decline in weight during the initial phase is due to the rapid evaporation of free water. Over time, the rate of weight loss diminishes, aligning with the slower removal of internal moisture. The total weight loss recorded at the end of the drying process highlights the effectiveness of the solar dryer in achieving substantial dehydration of the peppers while preserving their physical integrity.

These observations collectively underscore the efficiency of the solar dryer in removing moisture and reducing the weight of agricultural products, demonstrating its suitability for processing hot red peppers and other similar produce.

4. DISCUSSION

The experimental results provide valuable insights into the efficiency and effectiveness of solar drying for hot red peppers. The observed weight loss, as depicted in Figures 2 and 3, highlights a significant reduction in the volume of peppers during the drying process. This outcome demonstrates the capacity of the solar dryer to effectively remove moisture content from the produce.

Figure 3a illustrates the variation in hot air moisture over time during the two-day drying period. Notably, the moisture values on the second day are consistently lower than those recorded on the first day. This trend indicates that the peppers undergo the most substantial moisture removal in the initial drying stages, with a decreasing rate of moisture loss as the drying process progresses. The findings align with known drying kinetics, where the initial phase is dominated by rapid evaporation of surface moisture, followed by a slower internal moisture diffusion phase.

The results also underline the role of the solar dryer in maintaining a consistent drying environment, which is critical for achieving uniform moisture reduction and preserving the quality of the dried product. The use of an indirect forced-convection dryer enhances this process by ensuring even heat distribution and minimizing external contamination risks.

5. CONCLUSION

This study successfully demonstrates the efficiency and practicality of solar drying technology for hot red peppers. The observed significant weight loss and moisture reduction validate the capability of the solar dryer to achieve effective dehydration within a relatively short time frame. The experimental results indicate that the solar drying process is particularly effective during the initial stages, with declining moisture levels on subsequent days.

The findings emphasize the potential of solar drying as a sustainable and economical solution for agricultural product processing, especially in regions with abundant solar energy resources like Algeria. By optimizing drying parameters and improving product quality, this technology could play a pivotal role in reducing reliance on fossil fuel-based drying methods, contributing to environmental sustainability and economic viability in the food processing industry. Future studies could focus on scaling up this technology and exploring its applicability to other agricultural products.

Conflict of interest: No potential conflict of interest was reported by the authors.

Ethical Approval: The study adheres to the ethical guidelines for conducting research.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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