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Experimental analysis and development of novel drying kinetics model for drying grapes in a double slope solar dryer

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ABSTRACT

This experimental study aimed to evaluate the efficacy of natural and forced convective drying techniques in reducing the moisture content of the grapes in comparison with the conventional open sun drying method. Moisture effective diffusivity and activation energy were graphically determined using the Arrhenius equation. In the initial three-day period, forced convection drying significantly reduced moisture from 2000 g to 353 g, with a minimum loss of 14 g. In the next three days, natural convection reduced moisture from 2787 g to 468 g, with a minimum loss of 11 g. These outcomes were then compared to the results of open-sun drying. The investigation showed that open drying and natural convection methods eliminated 25.05 % and 82.35 % of the moisture content, respectively. However, for three days, open-sun drying removed 30.5 % of grape moisture, while forced convection achieved an impressive 83.21 % reduction. The study's innovative mathematical model explained drying curve characteristics, supported by correlation coefficients and parity plots. The comparison shows that the experimental moisture ratios and those predicted by the new correlation exhibit R^2 values ranging from 0.984 to 0.994.

1. Introduction

Solar energy, which is both renewable and environmentally friendly, provides a sustainable means of power generation, minimizing environmental impact and fostering energy independence [1]. Coupled with its cost-effectiveness and continuous technological progress, solar power is a pivotal solution to meet present energy requirements and propel us towards a future marked by environmental sustainability and economic viability [2,3]. Solar drying is one of the most sustainable techniques for preserving fruits and vegetables from post-harvest losses [4]. Dehydration, a method of preserving grapes, holds significant importance in various industries worldwide. Different techniques, depending on the geographic location and grape variety, produce dried grapes or raisins. These techniques include open drying, mechanical drying, and shade drying.

Renewable energy sources offer promising solutions, with solar energy widely accessible in many locales [2,5]. Sun drying, known for its economic viability and effectiveness, particularly in sunny regions, has become an alternative to conventional drying methods [6,7]. For centuries, the tradition of air-drying grapes has been prevalent in Asia and beyond. Major raisin-producing areas in India, such as Sangli, Solapur, Nashik in Maharashtra, and Bijapur in Karnataka, follow the practice of drying grapes under sheds. For grape drying, solar dryers have gained popularity. Research has led to the development of various solar dryer types tailored for grape drying, such as direct, indirect, mixed, and hybrid dryers.

Pangavhane and Sawhney thoroughly reviewed solar dryers for grapes, noting limited adoption by farmers. They assessed technical and cost aspects [8]. Doymaz examined low-density drying for black grapes, observing thin-layer behavior during the process. They dried grapes quickly at 60 °C using airflow and the Page model to find the dehydration curves. The Page model worked well for finding the dehydration

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