

Influence of the Aerothermal Parameters of an Indirect Solar Dryer on the Intermittency of Bioproduct Drying: The Case of Fruits and Tubers

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Abstract

This study examines the impact of the aerothermal factors of an indirect solar dryer on the intermittent and continuous drying dynamics of four crops: mango, banana, potato, and sweet potato. The experiment was conducted under sustained global solar radiation reaching $1000 \text{ W} \cdot \text{m}^{-2}$, with drying temperatures ranging from 55°C and controlled forced convection airflow to stabilize the airstreams. The study of thermal profiles and drying kinetics shows that intermittent processing controls mass transfer by promoting internal water redistribution during pause phases, preventing hardening and maintaining a steady evaporation process. The dynamics of moisture migration are quantified by contrasting effective diffusion coefficients D_{eff} : $2.67 \times 10^{-9} \text{ m}^2 \cdot \text{s}^{-1}$ for mango, $9.08 \times 10^{-10} \text{ m}^2 \cdot \text{s}^{-1}$ for banana, $8.39 \times 10^{-10} \text{ m}^2 \cdot \text{s}^{-1}$ for potatoes, and $7.63 \times 10^{-10} \text{ m}^2 \cdot \text{s}^{-1}$ for sweet potatoes. These figures, which are higher for mangoes due to their more porous structure, are consistent with the standards established in the literature for horticultural and starchy products. During theoretical validation, the Page and Logarithmic models show excellent agreement with the experimental data. Page model proved to be optimal for mangoes ($R^2 = 0.9968$), while the logarithmic model better described the drying of bananas ($R^2 = 0.9979$), as well as that of potatoes and sweet potatoes ($R^2 = 0.9988$). These results show that controlling the aerothermal parameters and implementing an intermittent drying regimen improve drying efficiency while ensuring a rigorous mathematical prediction of the process.

Keywords

Intermittent Drying, Continuous Drying, Effective Diffusivity, Drying Kinetics, Aerothermal Parameters

1. Introduction

Drying is an essential process for preserving perishable products and minimizing post-harvest losses, particularly for tropical fruits such as mangoes and bananas, as well as root vegetables like potatoes and sweet potatoes [1]. Unlike natural air-drying, the use of indirect solar dryers with forced convection allows for better control of hygiene conditions and optimizes heat transfer [2]. In these systems, the temperature of the drying air and total radiation are the dominant aerothermal parameters that directly influence the drying kinetics [3]. Managing intermittency, whether driven by natural cycles or by a thermal regulation strategy, is one of the main challenges of solar drying. Research has shown that cyclic temperature fluctuations can not only optimize energy efficiency but also preserve the organoleptic characteristics of products by facilitating internal moisture distribution [4] [5]. This process is closely linked to effective diffusivity, a key coefficient that determines how quickly water moves from the center to the surface of the product [6]. This study aims to examine, both experimentally and theoretically, the effects of aerodynamic factors on drying intermittency for four different types of produce (mango, banana, potato, and sweet potato) under solar radiation of up to 1000 W/m² and a setpoint temperature of 50°C. Specifically, the aim will be, on the one hand, to quantify the evolution of drying kinetics under intermittent and continuous conditions, as well as the effective diffusion rate. On the other hand, it will involve theoretically validating the results using semi-empirical models, which are widely recognized in the literature for their ability to accurately characterize the behavior of food products in thin layers [7]-[9].

2. Materials and Methods

2.1. Experimental Characterization of Solar Drying

2.1.1. Equipment and Experimental Protocol for the Solar Dryer

The experimental setup shown in **Figure 1(a)** and **Figure 1(b)** is an indirect solar dryer with forced convection, enhanced by the addition of an auxiliary solar collector specifically designed to increase the airflow and heat transfer to the drying chamber. To ensure consistent test conditions, such as the target temperature of 55°C, the system is controlled by an automatic temperature controller, as shown in **Figure 1(e)**. A METEON solarimeter shown in **Figure 1(g)** was used to measure total incident solar radiation, and an anemometer (**Figure 1(f)**) was used to accurately measure the wind speed at the inlet. A handheld thermometer (**Figure 1(g)**) is used to monitor temperature changes in the racks. A thermo-hygrometer (**Figure 1(c)**) was used to monitor the internal environment, simultaneously

measuring changes in temperature and relative humidity of the drying air. The water content of the products was quantified using a precision balance shown in **Figure 1(d)**. This allowed us to determine the drying rates and effective diffusion coefficients necessary to validate the mathematical models.

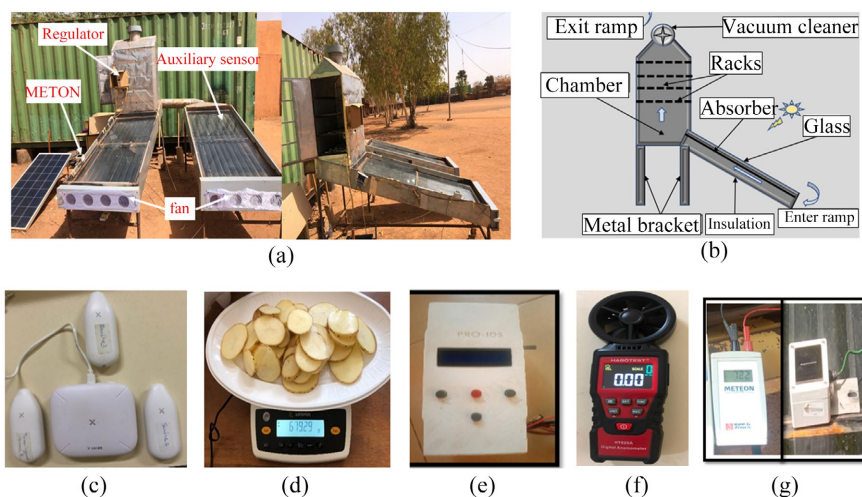


Figure 1. Materials and experimental setup.

2.1.2. Product Preparation

The products were selected based on their economic importance and local availability, and the experiments were conducted using samples harvested at commercial maturity, ensuring consistent initial drying conditions. The preparation process for products such as mangoes, bananas, potatoes, and sweet potatoes (**Figure 2(a)**) begins with thorough washing using potable water. This is followed by peeling and slicing into uniform 5 mm thick slices. This thin-layer structure is essential for reducing internal resistance during mass transfer and ensuring uniform drying dynamics. The prepared samples were placed on the reracks in the drying chamber (**Figure 2(b)**), with each rack holding a load of 0.5 kg, for a total weight of 1.5 kg, in order to optimize their exposure to the drying airflow. The initial moisture content of the samples was 3.02, 1.41, 4.04, and 2.64 kg of water per kg of dry matter for mango, banana, potato, and sweet potato, respectively, as determined by the gravimetric method. The drying air circulated through the forced-convection dryer at an average velocity of 2.5 m/s, measured using a digital anemometer placed at the inlet of the drying chamber. Temperature and relative humidity sensors were positioned at the hot air inlet and outlet, respectively, in the center and at the outlet of the drying chamber, and near the products to monitor thermal changes during the process. Experimental data were recorded at 10-minute intervals throughout the drying process. To determine dry matter content, representative samples were dried in a ventilated oven at 105 °C for 24 hours until a constant mass was achieved. The tests were conducted under average ambient temperature conditions ranging from 30 °C to 37 °C with relative humidity varying from 20% to 40%.



Figure 2. Experimental products.

2.1.3. Intermittent Ans Continuous Condition

The intermittent ratios used in this study were selected based on preliminary tests conducted prior to the main experiments, in combination with data reported in the literature on the intermittent drying of agricultural products. A 3/4 ratio was chosen for mango drying, while a 1/2 ratio was applied to the banana, potato and sweet potato studied. These choices were made based on criteria related to the product's thermal stability and the reduction of drying time. For each test, the mass of product introduced per batch, the air flow conditions, and the criteria for determining the end of drying were specified.

For each test, the mass of product introduced per batch, the airflow conditions, and the criteria for determining the end of the drying process were specified. In continuous mode, heating and ventilation were maintained without interruption until the desired final moisture content was reached. In intermittent mode, alternating cycles of heating and rest were applied according to defined ratios (3/4 for mango and 1/2 for banana, potato and sweet potato). During rest periods, the heat supply was interrupted while the product remained in the drying chamber to promote internal moisture redistribution. The operating parameters were kept identical between the two modes to allow for a reliable comparison of drying performance.

2.2. Theoretical Approach to Drying Kinetics

The study of the drying of fruits and tubers is based on observing changes in water content and mass transfer rates over time.

The moisture content on a dry basis at time t , denoted by X_t and expressed by Equation (1), is calculated from the mass of the wet sample m_t and the mass of the dry matter m_s obtained after drying in an oven [10]:

$$X_t = \frac{m_t - m_s}{m_s} \quad (1)$$

In the study of thin-film drying kinetics, the reduced moisture content MR from Equation (2) is used, which normalizes the experimental data based on the initial and equilibrium conditions X_0 and X_{eq} [8] [11]:

$$MR = \frac{X_t - X_{eq}}{X_0 - X_{eq}} \quad (2)$$

The drying rate X^* in Equation (3) represents the temporal variation in moisture content. It serves as the primary indicator of the product's responsiveness to temperature changes and total irradiance [12]:

$$X^* = -\frac{dX}{dt} \approx -\frac{X_{t+\Delta t} - X_t}{\Delta t} \quad (3)$$

Fick second law is used to model the internal flow of water during the deceleration phase in a lamellar flow configuration [13]. For relatively long drying periods, the simplified approach allows the effective diffusion coefficient D_{eff} to be estimated using Equation (4) [14]:

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

where L represents half the thickness of the slices. This method is commonly used to describe moisture migration in plant tissues such as those of mangoes or bananas [10] [11].

To mathematically model the behavior of certain products (such as mangoes, bananas, potatoes, and sweet potatoes) during the drying process, we correlated experimental data on moisture reduction (MR) with four semi-empirical models commonly cited in the agri-food literature. Of all the models listed in **Table 1**, we selected and used only those by Newton, Page, Henderson, and Pabis, as well as the logarithmic model, for our experimental study.

Table 1. Semi-empirical model of drying kinetics.

Models	Expression	References
Newton	$MR = \exp(-kt)$	[15]
Page	$MR = \exp(-kt^n)$	[16]
Page modifié	$MR = \exp(-(kt)^n)$	[17]
Henderson and Pabis	$MR = a \exp(-kt)$	[18]
Logarithmic	$MR = a \exp(-kt) + c$	[19]
Two-term	$MR = a \exp(-k_0 t) + a \exp(-k_1 t)$	[20]
Wang and Singh	$MR = 1 + at + bt^2$	[21]
Approximation de diffusion	$MR = a \exp(-kt) + (1-a) \exp(-kbt)$	[22]
Verma	$MR = a \exp(-kt) + (1-a) \exp(-gt)$	[23]
Modified Henderson and Pabis	$MR = a \exp(-kt) + b \exp(-gt) + c \exp(-ht)$	[24]
Two term exponential	$MR = a \exp(-kt) + (1-a) \exp(-kat)$	[25]
Page modifié equation II	$MR = \exp\left(-k\left(t/L^2\right)^n\right)$	[26]

The correlation between the experimental data and the R^2 model, as illustrated by Equation (5), was determined. The closer its value is to 1, the better the quality of the fit [27]

$$R^2 = \frac{\sum_{i=1}^N (MR_{exp,i} - \overline{MR}_{pre,i})^2}{\sum_{i=1}^N (MR_{exp,i} - \overline{MR}_{exp,i})^2} \quad (5)$$

The difference between the experimental values and the values calculated by the χ^2 model was calculated using Equation (6). A χ^2 value close to zero indicates an excellent fit [8]. It is expressed as follows [11]:

$$\chi^2 = \frac{\sum_{i=1}^N (MR_{exp,i} - MR_{pre,i})^2}{N - z} \quad (6)$$

where N is the number of observations and Z is the number of model parameters. The root mean square error ($RMSE$) shown in Equation (7) was used to demonstrate the overall accuracy of the model. The lower the $RMSE$ value, the more accurate the model is [10]:

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (MR_{pre,i} - MR_{exp,i})^2} \quad (7)$$

2.3. Intermittent Approach Condition

The efficiency of intermittent drying is characterized by the intermittency ratio α from Equation (8), defined as the ratio of the active period duration t_{on} to the total cycle duration t_{cycle} , and is expressed as [28] [29]:

$$\alpha = \frac{t_{on}}{t_{on} + t_{off}} \quad (8)$$

where t_{off} represents the duration of the rest period.

The optimal rates shown in **Table 2** were applied to the indirect solar dryer for drying fruits and tubers.

Table 2. Optimal intermittency rates applied to different products.

	Ratio α	Active time (min)	Rest time (min)	Cycle duration (min)
Mango	3/4	180	60	240
Banana	1/2	60	60	120
Potato	1/2	60	60	120
Sweet potato	1/2	60	60	120

3. Results and Discussion

3.1. Thermal Profiles of the Solar Dryer in Intermittent Operation and Global Radiation

The analysis of the experimental data, presented in **Figure 3** for the drying of fruits and tubers, highlights a close correlation between global solar radiation G and temperature changes within the indirect solar dryer. For all dried products (such

as sweet potatoes, bananas, mangoes, and potatoes), it is observed that the temperatures measured at the sensor outlet $T_{\text{Sensor_output}}$ and those of the drying chamber T_{Chamber} correlate closely with variations in incident radiation. Irradiance peaks reach values close to $1000 \text{ W}\cdot\text{m}^{-2}$ between noon and 2.00 p.m. , causing the drying air temperature to rise well above the ambient temperature T_{ambient} [30]. This temperature difference is crucial because it provides the thermal energy needed to evaporate the water contained in the products [31]. For example, when it comes to bananas, internal temperatures typically range between 50°C and 55°C . This temperature range is considered ideal for preserving nutritional value while ensuring an efficient drying process [30] [32].

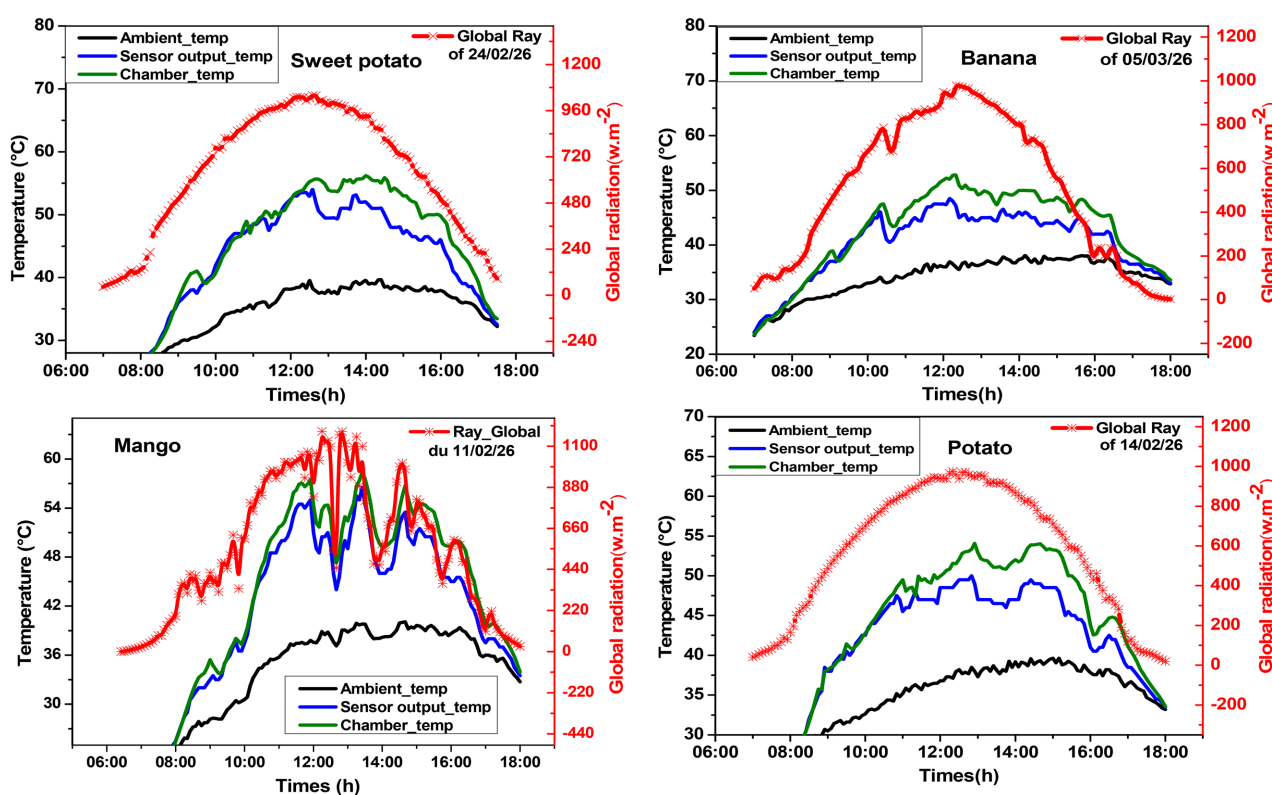


Figure 3. Changes in the thermal profiles and radiation of the solar dryer.

Rapid variations in global radiation are observed in the mango and banana curves, attributed to cloud cover. These fluctuations immediately affect the sensor's output temperature $T_{\text{Sensor_output}}$, even though the thermal inertia of the drying cabinet seems to slightly dampen these peaks [30]. This behavior demonstrates that the indirect solar dryer, despite its efficiency, is dependent on local climatic variability. This underscores the importance of examining aerothermal parameters to optimize the drying process under real-world conditions [33].

3.2. Thermal Kinetics of the Racks and the Product under Intermittent Conditions

Figure 4 shows the evolution of the rack temperature T_{rack} and the average in-

ternal product temperature $T_{product}$ over time for the optimal intermittent drying rates adopted (a $3/4$ ratio for mangoes and a $1/2$ ratio for bananas and tubers). The results indicate alternating periods of heating and distinct periods of rest. During the heating phase, the temperatures T_{rack} and $T_{product}$ rise rapidly. Temperature peaks of approximately 55°C to 60°C are observed on the trays, while the product appears to be slightly cooler, with a difference of 5°C to 10°C . During the rest period, opening the drying chamber for one hour causes a sudden simultaneous drop in both temperatures. During this period, the temperature of the racks T_{rack} and that of the product $T_{product}$ almost completely overlap, tending toward values close to room temperature. This heat buildup during the rest phase is caused by a disruption of the internal thermodynamic equilibrium. When the chamber is opened, forced convection with the outside air dissipates the accumulated sensible heat inside the cabinet as well as on the surface of the product. Mangoes, with a duty cycle of $3/4$, provide a longer heating time compared to the $1/2$ duty cycle used for bananas and sweet potatoes. This results in a higher cumulative energy exposure, which is necessary for products that contain a high water content from the outset. The fact that temperatures converge during the resting phase indicates that the thermal gradient between the air and the product has completely disappeared. However, this phase is not wasted; it serves to halt surface evaporation and promote the migration of water from the interior to the surface [28] [34]. This oscillatory behavior is characteristic of intermittent drying.

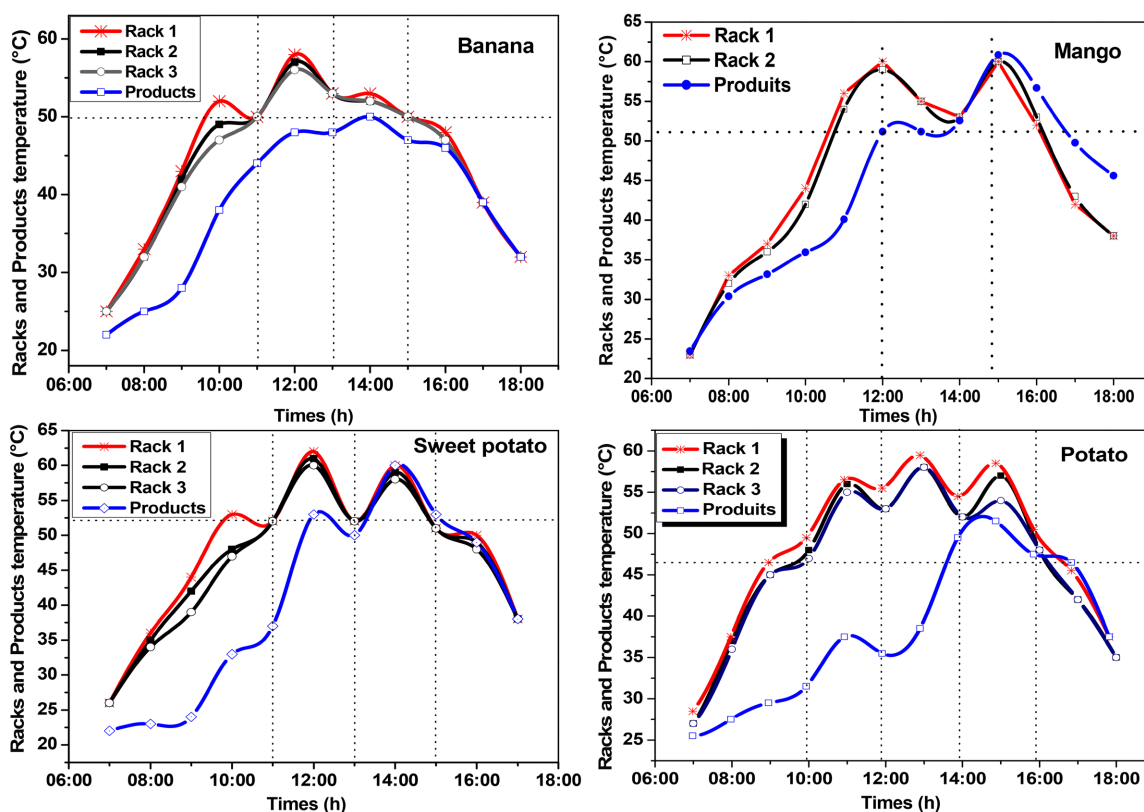


Figure 4. Thermal profile of the racks and the product under intermittent conditions.

According to Kowalski and Pawłowski, rest periods promote the distribution of internal moisture, thereby preventing the cracking or formation of a surface crust that is frequently observed during continuous drying [34]. Furthermore, although the drop in product temperature when the chamber is opened slows down the process, this is offset by a more efficient resumption of evaporation as soon as the next heating phase begins. Moisture migration to the surface can be further reduced, which could shorten the total drying time compared to a steady-state condition at a fixed temperature [28]. The temperature readings observed between 50°C and 60°C remain within the standards for indirect drying of tropical products, ensuring a reduction in water activity without excessive nutrient degradation [30] [32].

3.3. Relative Humidity and Drying Temperature during Intermittent Condition

Figure 5 shows the changes in relative humidity and drying temperature over time for the four products dried using an intermittent drying process. Kinetics analysis reveals a constant inverse relationship between drying temperature and relative humidity (*HR*), with temperature peaks ranging from 52°C to 56°C depending on the product, resulting in a sharp drop in relative humidity to critical levels of 7% for sweet potatoes and 15% for mangoes. This phenomenon is due to the increased ability of the air heated by the absorber to absorb water vapor, creating a strong vapor pressure gradient that acts as the primary driving force behind mass transfer [31] [35]. The intermittent cycle, characterized by the opening of the chamber, causes fluctuations in which the relative humidity rises slightly during the rest phases, indicating an internal movement of water from the interior to the surface of the product. These results support the findings of Mendyl *et al.*, who state that a humidity level below 20% ensures optimal drying performance in an indirect solar system while preventing microbial degradation [30].

3.4. Reduced Moisture Content and Drying Temperature during Intermittent Condition

The graphs shown in **Figure 6** illustrate the changes in reduced moisture content and drying temperature over time for the four products dried using an intermittent drying process. An examination of the curves for reduced moisture content *X_r* over time shows a constant exponential decrease for all products, influenced by variations in drying temperature and the arrangement of the drying racks. Racks 1, positioned at the inlet of the hot air, exhibits the fastest drying rate, reaching an *X_r* value of approximately 0.1 in just 300 minutes for mangoes and potatoes. The average drying time obtained was 360 ± 60 min for all products, indicating a variation of approximately ±1 hour around the mean value. This variability is acceptable given the experimental drying conditions and the natural differences between samples. The small deviations observed in the kinetic parameters indicate good repeatability of the tests and satisfactory stability of the experimental setup.

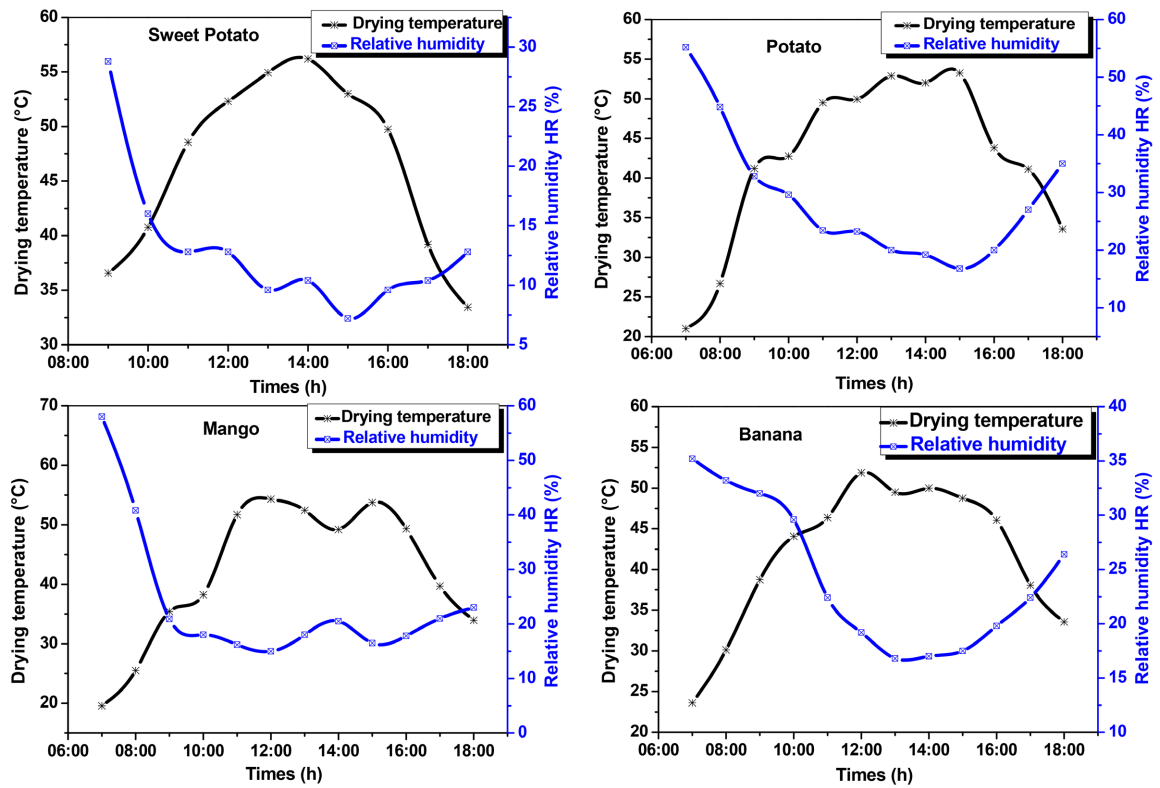


Figure 5. Drying temperature and air relative humidity in intermittent solar drying mode.

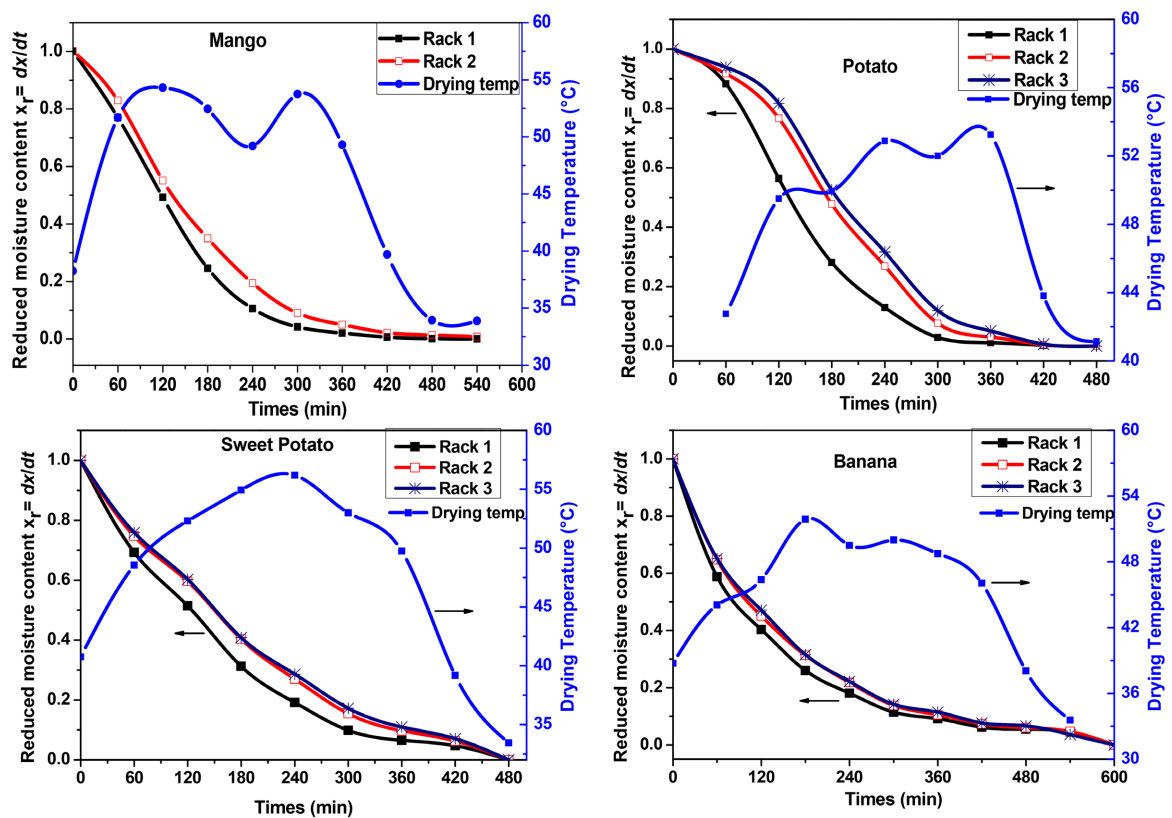


Figure 6. Changes in reduced moisture content and drying temperature during intermittent operation.

In contrast, a moisture gradient is evident on Racks 2 and 3, which show slower drying. This stratification is caused by the gradual decrease in the air's evaporation potential; as the air passes through the first layers of the product, it absorbs moisture and cools slightly, thereby reducing its ability to remove water from the upper trays. Drying curves are directly influenced by temperature, which peaks at between 51°C for bananas and 56°C for sweet potatoes: rising temperatures accelerate surface evaporation, while the rest periods associated with the intermittent cycle promote internal water distribution. This analysis is scientifically supported by the work of Kowalski and Pawłowski, who demonstrate that thermal intermittency prevents surface crusting by allowing moisture to migrate from the interior to the surface during temperature drops, thereby promoting more uniform final drying and preserving the porous structure of the products [28] [34].

3.5. Changes in Drying Rate under Intermittent and Continuous Conditions

Figure 7(a) and **Figure 7(b)** illustrate the evolution of the drying rate of the products over time under intermittent and continuous conditions. A comparative analysis of the kinetics shows that, in continuous mode, drying reaches a single initial peak, amounting to approximately $6.8 \text{ g}_{\text{water}}/\text{g}_{\text{ms}}\cdot\text{min}$ for potatoes and $6.3 \text{ g}_{\text{water}}/\text{g}_{\text{ms}}\cdot\text{min}$ for sweet potatoes, before continuing to decline until the end of the cycle at around 480 minutes. In contrast, the 3/4 and 1/2 intermittent condition is characterized by a multi-peaked profile in which the rate decreases sharply during rest phases (when the chamber is open) and then rises sharply during heating phases, reaching, for example, a second peak of $4.2 \text{ g}_{\text{water}}/\text{g}_{\text{ms}}\cdot\text{min}$ at 180 minutes for sweet potatoes. This process reflects effective management of mass transfer: while continuous operation risks causing surface hardening due to the sudden removal of surface water, the rest phases in intermittent mode promote the migration of internal moisture to the surface through diffusion. This surface re-humidification justifies increasing the speed with each new heating cycle, ensuring more uniform evaporation even though the total drying time can be as long as 600 minutes. Korobka *et al.* confirm this behavior, noting that the intermittent flow prolongs the constant-velocity phase by preventing the saturation of surface pores [36]. According to El'Houyoune, this thermal cycling is essential for products with complex structures, as it helps to harmonize vapor pressure gradients [37]. Finally, research by Boroze *et al.* confirms that this intermittent approach, despite its staggered timing, optimizes the overall energy efficiency and technological performance of dried products in a tropical setting compared to a continuous process [35].

3.6. Analysis of Effective Diffusion Coefficients

Figure 8 shows the trend in effective diffusion coefficients for each type of dried product. An examination of the effective diffusion coefficients (D_{eff}) reveals a significantly higher mass transfer capacity for mango, which reaches a value of $2.67 \times 10^{-9} \text{ m}^2\cdot\text{s}^{-1}$, in contrast to the results obtained for bananas, $9.08 \times 10^{-10} \text{ m}^2\cdot\text{s}^{-1}$,

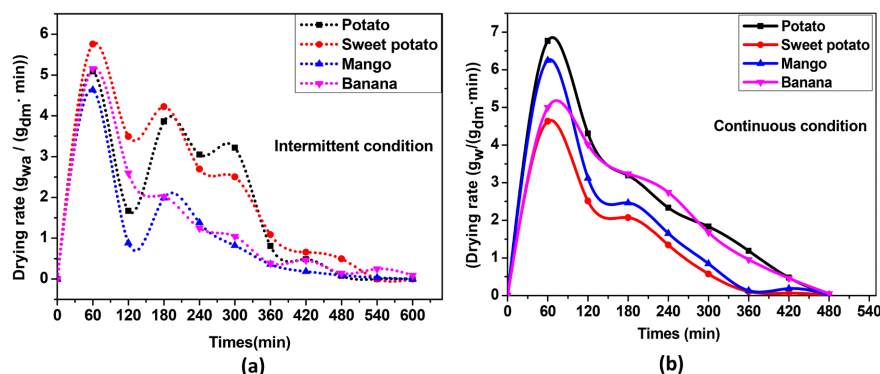


Figure 7. Changes in drying rate under intermittent and continuous conditions.

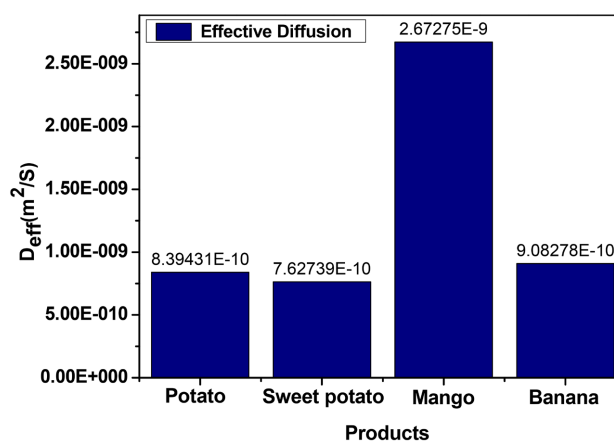


Figure 8. Effective diffusion coefficients of different products.

the potato $8.39 \times 10^{-10} m^2 \cdot s^{-1}$ and $7.63 \times 10^{-10} m^2 \cdot s^{-1}$ for sweet potato. The prevalence of mangoes can be explained by their more porous cellular structure and biochemical composition, which, unlike the dense starchy matrices of tubers, facilitate the movement of water molecules toward the periphery. With regard to potatoes and sweet potatoes, their high starch content and thermal gelatinization processes could increase their internal resistance, thereby limiting the movement of moisture through the parenchyma. These observations are supported by Muthuvairavan *et al.*, who found the thermal diffusivity of potatoes to be between 4.22×10^{-10} and $11.67 \times 10^{-10} m^2 \cdot s^{-1}$ under similar thermal conditions [38]. Furthermore, the research by Elangovan and Natarajan confirms that the D_{eff} values for horticultural products and fruits generally range between 10^{-10} and $10^{-9} m^2 \cdot s^{-1}$ thereby confirming the accuracy of our experimental results [39] [40]. This hierarchy of coefficients indicates that the primary limiting factor affecting the overall drying rate is related to the nature of the product and its initial porosity.

The effective diffusivity calculations were performed assuming an infinite flat plate geometry, one-dimensional moisture diffusion, a uniform initial moisture content, a constant diffusivity during drying, and negligible shrinkage effects. The half-thickness used corresponds to half the average thickness of the product slices. The estimate was based on the linear portion of the curve of the logarithm of the

reduced moisture ratio as a function of drying time.

3.7. Theoretical Validation of Drying Kinetics

Figure 9 illustrates the mathematical validation of the experimental data using four semi-empirical models of drying kinetics for dried fruits and tubers. The mathematical simulation of drying kinetics for fruits and tubers reveals a rigorous statistical fit, as illustrated in **Table 3** and **Table 4**, with coefficients of determination R^2 ranging from 0.984 to 0.999 and extremely low root mean square errors ($RMSE < 0.02$). It is noted that the Page and Logarithmic models consistently outperform the Newton model; specifically, for potatoes, the Logarithmic model has an R^2 of 0.999 and an $RMSE$ of 0.01467. These four specific models were selected because they are capable of encompassing the entire phenomenological spectrum of thin-layer drying. This hierarchy stems from the complexity of plant matrices, where water movement is not solely diffusive but is also influenced by the internal resistance of the pores, particularly in starch-rich tubers. These results are consistent with those of Elangovan and Natarajan, whose work on bananas confirms the accuracy of the logarithmic model ($R^2 = 0.9936$) and Page model ($R^2 = 0.9882$) in describing the drying rate reduction phases [39] [40]. Furthermore, the use of Henderson and Pabis is validated by Muthuvairavan *et al.* as one of the most reliable methods for modeling the moisture ratio (MR) in indirect solar systems [38].

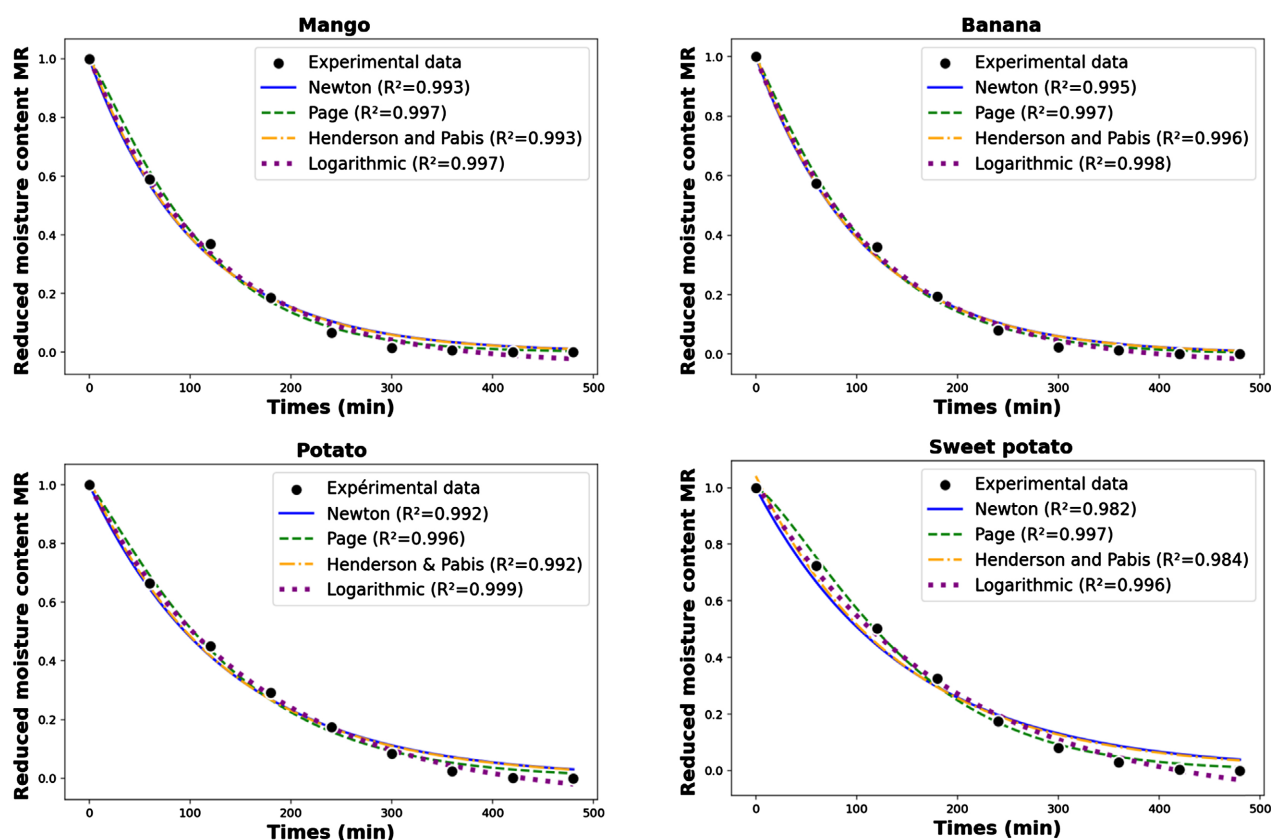


Figure 9. Theoretical analysis of drying kinetics using semi-empirical models.

Table 3. Statistical analysis of the models for fruit.

Models	Banana			Mango		
	R^2	RMSE	Paramètres	R^2	RMSE	Paramètres
Newton	0.99543	0.02187	$k = 0.0093$	0.99277	0.02789	$k = 0.0093$
Page	0.99704	0.01760	$k = 0.0055$ $n = 1.1059$	0.99681	0.01851	$k = 0.0039$ $n = 1.1757$
Henderson and Pabis	0.99551	0.02169	$a = 1.0079$ $k = 0.0094$	0.9930	0.02737	$a = 1.0149$ $k = 0.0094$
Logarithmic	0.99794	0.01467	$a = 1.0330$ $k = 0.0085$ $C = -0.0329$	0.99671	0.01879	$a = 1.0466$ $k = 0.0084$ $C = -0.0408$

Table 4. Statistical analysis of the models for tubers.

Models	Sweet potato			Potato		
	R^2	RMSE	Paramètres	R^2	RMSE	Paramètres
Newton	0.98162	0.04576	$k = 0.00677$	0.99175	0.02969	$k = 0.00729$
Page	0.99725	0.01768	$k = 1.26029683e-03$ $n = 1.32253173e+00$	0.99623	0.02006	$k = 0.00320$ $n = 1.15907$
Henderson and Pabis	0.98370	0.04310	$a = 1.04080$ $k = 0.00700$	0.99216	0.02893	$a = 1.01798$ $k = 0.00741$
Logarithmic	0.99612	0.02101	$a = 1.13937$ $k = 0.00530$ $C = -0.12266$	0.99889	0.01084	$a = 1.07823$ $k = 0.00608$ $C = -0.07828$

4. Conclusion

This research has thoroughly described the drying dynamics of fruits and tubers, demonstrating that a carefully calibrated intermittent cycle optimizes heat and moisture exchange while preserving product quality. The kinetic analysis indicates that while continuous drying yields high initial velocity peaks of up to $6.8 \text{ g}_{\text{water}}/\text{g}_{\text{ms}}\cdot\text{min}$, Intermittent drying, at setpoint temperatures below 60°C , prevents the formation of a hard crust by allowing pause periods that facilitate the movement of internal moisture to the outside. This high mass transfer efficiency is demonstrated by particularly high effective diffusion coefficients for mango ($2.67 \times 10^{-9} \text{ m}^2\cdot\text{s}^{-1}$), confirming its superior porosity compared to the denser starchy matrices of tubers such as sweet potato ($7.63 \times 10^{-10} \text{ m}^2\cdot\text{s}^{-1}$). The robustness of the semi-empirical models used, as evidenced by R^2 values greater than 0.99 for the Page and Logarithmic models, confirms the high predictive power of these processes under various operating conditions. Finally, the approach combining intermittent operation and stratification using racks is an effective strategy for processing tropical products, minimizing moisture gradients and ensuring uniform and energy-efficient drying.

Authors' Contributions

Sawadogo Emmanuel Sidwaya: Investigation, conceptualization, methodology, formal analysis, writing original draft. **Salmwendé Eloi Tiendrebeogo:** Scientific and methodological guidance, Overall supervision of the work, Final validation of the manuscript, Ongoing scientific supervision. **Guy Christian Tubreoumya:** Technical and scientific support, Targeted methodological advice, Contribution to analysis, Critical review of the manuscript. **Alfa Oumar Dissa :** Team leader, technical and scientific support, Targeted methodological advice. **André Luc Batiana:** help with setting up the experimental equipment and carrying out the tests. **Zoungrana Windnigda:** Language and editorial assistance, Translation and proofreading support, Spelling and grammar correction. **Desire Zerbo:** help with setting up the experimental equipment and carrying out the tests. **Antoine Béré:** laboratory director, make the laboratory's experimental equipment available.

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Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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