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Drying technique for local foodstuffs using the uop8-mkii electric dryer: Case of mango and okra in the Guera region of Chad

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ABSTRACT

Drying is one of the most widely used methods for preserving food products in rural areas. Drying staple foods, particularly mango and okra, in the Guera region of Chad using a UOP8-MKII electric dryer is part of an approach to enhancing their value. The method preserves perishable foodstuffs, especially in Chad, where post-harvest losses constitute a significant portion of agricultural production. The experiment was conducted in the Thermal Laboratory of the Polytechnic University of Mongo in Chad. The technique employs a UOP8-MKII material dryer, which allows precise control of drying parameters. Food samples were subjected to varying temperatures, thicknesses, and surface areas to analyze the influence of these parameters on drying kinetics. The results show that high temperatures accelerate drying but can alter organoleptic quality if poorly controlled. A thin layer facilitates faster drying, resulting in better water diffusion. The surface area also significantly influences the rate of moisture removal. Okra dries more slowly than mango at the same thickness due to its fibrous structure. These findings are in partial agreement with previous studies, where only temperature and thickness were primarily examined. The study highlights the importance of the drying surface, which is rarely considered but highly influential. The results were compared with those of earlier research to confirm this hypothesis. This research provides a better understanding of the key factors in drying local products. It opens prospects for optimizing drying processes to reduce post-harvest losses and increase the value of Chad's agricultural products.

Contribution/Originality: This study contributes to the existing literature on variations in temperature, thickness, and surface area of samples using the UOP8-MKII electric drying technique, which significantly affects drying speed. This technique offers better control of these parameters, improved quality of the final product, and increased energy efficiency.

1. INTRODUCTION

1.1. Study Focuses and Motivations

In some heatwave countries, such as Chad, preserving agricultural commodities necessary for food is a major issue [1]. Food products such as okra and mango, widely consumed by the local population, are very abundant during certain periods, but their preservation time is minimal, which causes considerable economic failures and a halt in their availability outside of this period. Drying, being an easy, significant, and important preservation method, thus becomes a solution compatible with local realities [2]. This research aims to determine the state of mango and okra during drying, considering various technical and physical factors affecting this process, such as temperature, thickness, surface area, and drying time. The development is based on improving food preservation systems within the context of combating food insecurity [3].

In Chad, the increasingly high temperatures create many difficulties in preserving okra and mango, which are very abundant during certain seasons of the year. This leads to considerable losses. To address this problem, drying is an ideal solution for preservation. Also, what are the factors that affect the drying speed of this food? And what about the preservation of products by controlling these factors? [4]. The general objective of this work is to study the effect of certain factors on the drying progress of okra and mango to improve their preservation, determine the influence of the parameters that affect the drying speed (temperature, thickness, and surface area), as well as differentiate between the state of these products during drying, determine the amount of water and the organoleptic qualities eliminated during drying, and propose techniques to improve the drying process [5].

The epistemology is based on scientific technique. Drying experiments were conducted in the Laboratory of Heat Transfer and Energy at Polytechnic University of Mongo (UPM) using the UOP8-MKII device, varying physical factors (temperature, thickness, surface area), while monitoring their influence on drying time and drying speed. Parameters such as temperature, thickness, and exposed surface area directly affect the moisture content of the dried sample. Proper control of these factors allows for optimal drying of mango and okra while reducing nutritional losses [6].

1.2. State-of-the-Art

The drying of food products is analyzed by characterizing the drying parameters and the evolution of browning depending on location. The optimal drying temperature for mangoes is close to *70°C*, beyond which heat can alter vitamins and proteins. Maintaining a residual moisture content of *13* to *14%* is necessary to guarantee optimal preservation of dried mangoes [7]. According to the provided technical data sheet, drying okra requires a final moisture content of 4% to 5% and a maximum drying temperature of 66°C. For mangoes, the recommended final moisture content is between 12% and 15%, and the maximum drying temperature should not exceed 70°C [8]. In Nigeria, the Denver Instruments IR-30 dryer was used to analyze the impact of thickness and temperature on okra drying. In the experiment, samples were *5*, *10*, and *15 mm* thick, and temperatures were *90*, *100*, and *110 °C*. In Chad, Passannet et al. [9] conducted a biochemical study of locally grown mangoes. The results showed that the biochemical characteristics of the observed mangoes vary according to the variety and growing region due to climate and soil type. Overall, all mango varieties grown in Chad are high in water and sugar. Furthermore, the Maiduguri, Kent, and Smith mango varieties had higher water content (80.20% to 80.75%) and significantly higher α-carotene (provitamin A) content.

In 2010, Mennouche et al. [10] conducted experimental studies on direct solar drying of tomato pastes at different temperatures of *50°C* and *76°C*. Solar radiation varies daily from $112 W/m^2$ to $420 W/m^2$ and $740 W/m^2$ at the beginning of drying at *9:00 AM* and ends at *6:00 PM*. Solar radiation reaches $685\ W/m^2$ at the end of drying. The authors conclude that temperature has an influence on the drying rate. In the same vein, Lati et al. [11] dried potatoes using solar drying by varying the air inlet temperature from *31.1* to *39.9°C*, the air outlet temperature from *49.9* to *54.9°C* with a maximum radiation of $850 W/m^2$ at noon, and a thickness of *0.3mm*. The experiment lasted 6 hours, and the authors reported that the main factor influencing the drying speed is the drying air temperature. Modern drying techniques, particularly those using electric dryers such as the UOP8-MKII, offer significant advantages: better control of parameters, quality of the final product, and energy efficiency.

1.3. Review of Previous Studies

Many drying techniques, such as conventional drying, have been developed to improve the drying of food products. In 2019, Haryanto et al. [12] used the Armfield tray dryer equipment to dry turmeric and ginger, respectively. For their experiment, they varied the following parameters depending on the drying speed: temperatures of 36°C and 38°C; surfaces of 35 cm² and 52.5 cm²; airflows of 4 cm and 4.5; and thicknesses of 0.1 cm and 0.2 cm, respectively, for ginger and turmeric. They reported that the drying speed is affected by variables such as drying temperature, drying airflow rate, and sample dimensions. According to them, the best drying speed in this study is obtained using a temperature of *39°C* and a drying air flow rate of *4.5 m/s* for drying a ginger sample with dimensions of *4 cm* length, *2 cm* width, and a thickness of *0.1 cm.* [13] Dried peas in an oven dryer were tested by varying different temperatures (*40°C, 50°C,* and *60°C*) and air flow rates (*0.001 kg/s, 0.003 kg/s,* and *0.004 kg/s*). They stated that increasing temperature and air flow rate reduces drying time, leading to optimal conditions at *60°C* and *0.004 kg/s.*

Messaoudi and Fahloul [14], through their study, aimed to estimate the physical-chemical parameters (water content, weight, quality ratio), mass diffusivity, and activation energy. The drying kinetics of dates and two cuts (whole and half) were analyzed to determine the diffusion coefficient at four drying temperatures (40, 50, 60, and 70°C) in a natural convection oven with hot air until the weight was constant. The results showed that the loss of fruit weight and moisture content is influenced by the variation of temperature and cut. The diffusion coefficient varies with the increase in temperature for whole and half dates. The Arrhenius equation provides an activation energy value of 12.00 and 9.54 kJ/mol for whole and half dates, respectively, with the latter decreasing as the thickness decreases [15]. In the few research studies analyzed above, the authors studied the effect of temperature, sample thickness, air flow rate, and sometimes other parameters on the drying rate. Their results highlighted that temperature and sample thickness are determining factors, significantly influencing the drying rate. On the other hand, other parameters such as air flow rate or exposed surface were not reported to have a major influence in these works.

Table 1. Summary of previous studies on drying techniques.

Reference	Study location	Method/Technique used	Outcome/Main findings	Remarks/Limitations
Farouk and Cherif [16]	Ghardaïa, Algeria	Solar dryer, chemical analysis of compounds.	PV solar drying effectively preserves the medicinal properties of plants	Limited sample of plants studied
Fatima Zohra and Yamina [17]	Ghardaïa, Algeria	biochemical analyses drying methods.	Analysis of the effect of drying methods on phenolic compounds in Moringa oleifera leaves	Lack of sensory analysis of dried products.
Slimani and Taouririt [18]	Biskra, Algeria	Solar dryer and efficiency evaluation	Study of the solar drying of various vegetables	Lack of quantitative data on nutrient losses.
Kacimi, et al. [19]	Ain-Temouchent, Algeria	Analysis of traditional drying methods for local processing	Optimizing drying methods could improve product quality	Lack of precise experimental data
Zineb and Manel [20]	Douala, Yaoundé Cameroon	Traditional drying practices	artisanal drying of fruits and vegetables in southern	Data based on self-assessments, potential bias
Ouoba, et al. [21]	Ouagadougou, Burkina Faso	Characterization cutting process of the convective drying of okra.	Study of the influence of cutting and constituents on drying	Study limited to a single type of vegetable.
Themelin and Monkam [4]	Bamako, Mali	A drying unit per feasibility technique of mangoes	Proposals for an economically viable drying unit	No experimental studies on product quality
Kone [22]	Yamoussoukro, Côte d'Ivoire	Hot air assisted drying, specific power control	Improving the quality of dried tomatoes by microwave	Study limited to one type of tomato.
Mwamba, et al. [23]	Kinshasa, DR Congo	Drying by steaming and in the sun of mangoes.	Sun drying better preserves organoleptic qualities	Limited data on nutritional impacts
Kaméni, et al. [24]	Garoua, Northern Cameroon	Drying of mango varieties grown in Cameroon	Drying suitability of cultivated mango varieties	Loss of nutritional quality after analysis

The review articles in Table 1 address various aspects of food drying, highlighting the importance of drying methods on product quality. Maroua and Rayhana [25] explored indirect solar drying in an arid zone, demonstrating its effectiveness in preserving food quality, focusing on the physicochemical characterization of a food product, emphasizing the impact of drying techniques. The study by Garango et al. [26] highlighted the loss of *vitamin C* during direct solar drying of tomatoes, while El Fatmi and Haimoud [27] proposed innovative solar drying solutions adapted to fruits and vegetables. Abdelhamid and Bousmaha [28] compared different drying processes in the Ghardaïa region, revealing variations in efficiency. Bogmis et al. [29] analyzed pineapple drying units, while Adimi et al. [30] diagnosed the production lines of dried tropical fruits. Finally, Kant et al. [31] studied the kinetics of microwave drying of mint leaves, confirming its effectiveness in maintaining organoleptic qualities.

These methods constitute a relevant avenue for strategies to enhance the value and security of perishable agricultural products. This general presentation of the studied products and preservation techniques lays the foundation for the technical and economic study conducted and paves the way for an in-depth analysis of the drying processes applied to mango and okra [32].

1.4. Contributions on Drying Practices

According to the FAO and WFP [33], half of agricultural products deteriorate in some African countries. This is due to poor post-harvest management, inadequate industrialization resources, lack of proper storage (storage, drying), destruction by pests and humidity. These losses cause food insecurity, reduce incomes, and shorten the food chain. Therefore, the application of preservation methods such as solar or mechanical drying can reduce losses, increase the value of agricultural products, and boost the local economy. Mangoes are eaten fresh, processed, or dried, and are known for their high vitamin A and C content [34]. Okra, on the other hand, is a vegetable widely used for its nutritional and medicinal properties, particularly as a source of fiber and minerals [35]. The daily use of these products is recommended by health organizations to ensure physiological health and strengthen the immune system.

In Chad, these products constitute a significant source of income and are also central to the rural economy for local farmers. Thus, in this country where heat is considered an obstacle, natural requirements and a lack of technical means increase the rate of food spoilage [33]. It is therefore imperative to develop a modern and ideal drying method to increase the shelf life of these products outside production periods [36]. Drying is a technique for preserving and preserving products. It helps to extend the shelf life of foodstuffs by reducing their water content, thus limiting the development of micro-organisms [37]. Drying can be traditional or carried out using modern devices, such as the UOP8-MKII electric dryer, offering better control of drying parameters.

2. MATERIAL AND METHOD ON DRYING TECHNIQUE USING UOP8-MKII DRYER

2.1. Foodstuffs to be Dried

The experiment was conducted in a controlled environment using the UOP8-MKII dryer, allowing for variable parameters such as temperature, thickness, product surface area, and drying time. Figure 1 illustrates the product samples selected for drying processing.

Figure 1. Sample of foodstuffs to be dried by UOP8-MKII (Okra and mango).

Table 2 highlights the specific characteristics of the products to be dried. These specific parameters facilitate the drying process and adapt the technique to the nutritional components of the products.

Table 2. Approximate characteristics and nutritional components of the products.

Characteristics	Mango	Okra
Scientific name	Mangifera indica	Abelmoschus esculentus
Botanical family	Anacardiaceae	Malvaceae
Carbohydrate	12 to 17%	7 to 9%
Protein	Approximately 0.8%	1.5 to 2%
Part used	Fruit pulp	Whole or sliced fruit
Color	Green and yellow when ripe	Green
Shape	Ovoid or rounded	Elongated with polygonal cross-section
Water content	80 to 85%	88 to 90%
Vitamins	A, C and E	C and B6
Minerals	Potassium, magnesium	Calcium and iron
Benefits of drying	Storage, processing and valorization	Storage and use out of season
Processing	Dried mango, jam, juice	Dried okra whole or powdered

2.2. Description of the Drying Technique

The UOP8-MKII experimental setup is based on the principle of drying by hot air passing over wet samples placed on fixed trays. This drying technique allows for highly precise control of temperature, airflow, and humidity of the products. A desktop computer is used to record the acquired data in real time, enabling experimental analysis of the drying parameters. The UOP8-MKII is equipped with an axial fan and a heating element to regulate temperature and air circulation in the drying chamber. This uniform distribution of air volume across the trays ensures uniform drying.

Figure 2. Experimental setup of the UOP8-MKII electric dryer.

The measured data are acquired using *ARMSOFT* software for real-time visualization. The *UOP8-MKII* consists of a square-section stainless steel air duct with a variable-speed fan, with an airflow rate between *0.4 m/s* and *3.0 m/s*. It includes an electric heating resistor, whose maximum heating power is limited to *2.7 kW*, to raise the air temperature to *85°C* at low airspeed. The airflow rate through the food to be heated is determined from a speed regulator. Figure 2 describes the experimental device of the electric dryer.

2.3. Experimental Drying Protocol

The first sample is mango cut into strips between *5 mm* and *10 mm* thick for better dehydration. The pieces to be dried have a surface area between *24 cm²* and *32 cm²* to allow for good heat exposure. The second sample, okra, is sliced into strips between *5 mm* and *10 mm* thick to facilitate even and rapid dehydration. Table 3 presents the main drying parameters and physical quantities taken into account for optimal electric drying of mangoes and okra.

Table 3. Typical drying parameters of foodstuffs.

Drying parameters of sample to be dried	Mango	Okra
Initial moisture content (%)	80 to 85	78 to 80
Recommended final moisture content (%)	12 to 15	4 to 5
Maximum drying temperature (°C)	70	66
Slice thickness (mm)	5 to 10	5 to 10
Sample surface area (cm2)	24 to 32	12 to 16
Slice shape	Rectangular	Round

Figure 3 shows the mango samples prepared for drying while following the procedures mentioned above. The initial water content is between *80* and *85%*, reflecting the high relative humidity of fresh fruit, and the final water content must be reduced by *12* to *15%*.

Figure 3. Sample of mango samples before drying.

The maximum temperature, set between *66* and *70°C* in the final drying phase, allows for efficient water evaporation while preserving the product's organoleptic quality. These parameters guarantee a high-quality dried product that is both stable and pleasant to eat. Figure 4 shows okra samples prepared for drying using the above procedures.

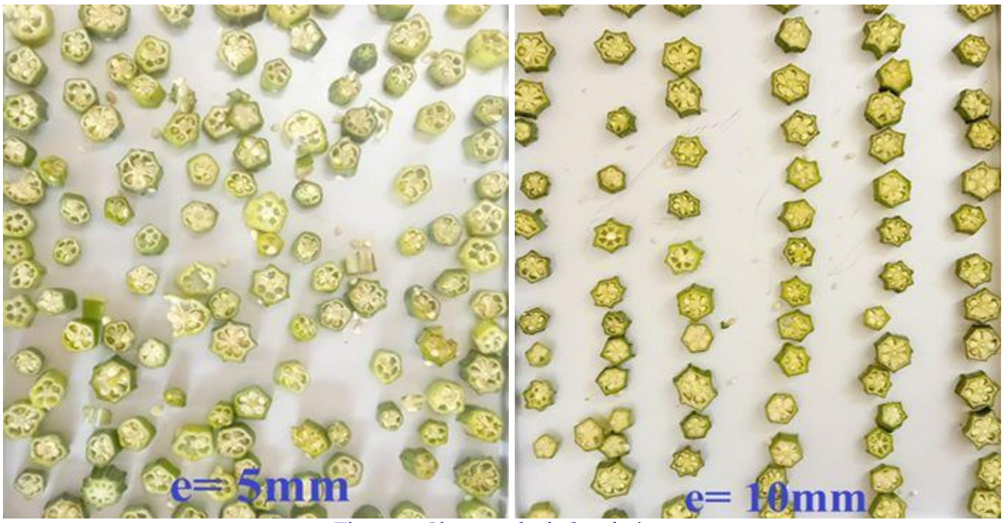

Figure 4. Okra samples before drying.

3. RESULTS AND DISCUSSIONS

3.1. Analysis of the Results from the Dried Mango Sample

Figure 5 illustrates the changes in mango water content over time during drying. It allows for analysis of drying kinetics, identification of the different phases (rapid drying, slowing phase), and evaluation of the effectiveness of the applied process. The drying parameters from the graph are essential elements for assessing the performance of the drying carried out and drawing conclusions on the optimal conditions to be retained.

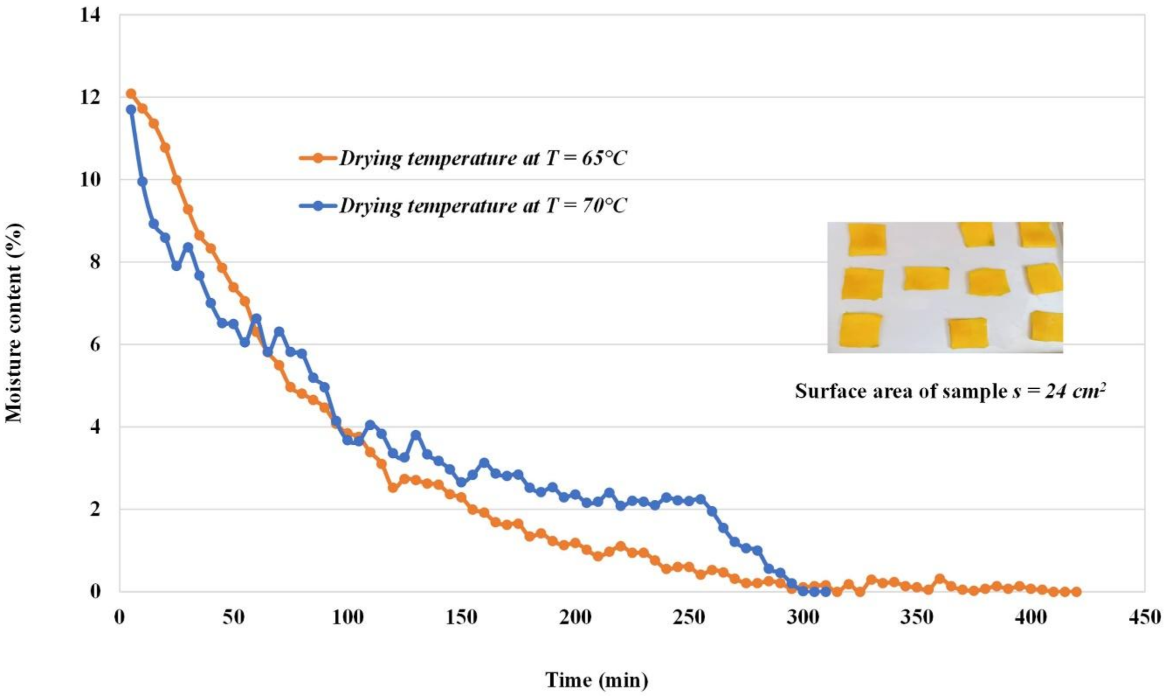

Figure 5. Effect of temperature on drying rate as a function of time for mango.

The Figure 5 shows the evolution of the drying rate as a function of drying time, at a drying temperature of *65°C* (orange curve) and *70°C* (blue curve) with a common surface area of *24cm²*.

- Initial phase (*0* to ≈ *60 min*)

A rapid drop in moisture is observed in both cases. This phase corresponds to the period when free surface water evaporates easily due to temperature. At *70°C*, moisture drops more abruptly than at *65°C*, which is logical: the higher the temperature, the faster the evaporation.

- Intermediate phase (≈ *60* to *200 min*)

At 65°C, the curve continues to decrease steadily, indicating a more stable and progressive drying. At 70°C, significant fluctuations are observed: the moisture content varies with several peaks. This can be explained by excessively rapid evaporation on the surface, which forms a crust (crusting phenomenon), subsequently slowing internal drying.

- Final phase (*200* to *400 min*)

Both curves tend toward a moisture content close to zero. However, the *65°C* curve reaches this level more gradually, allowing for better control of the texture and final product quality.

This led us to conclude that at a high temperature, the drying rate is rapid and reduces drying time. However, drying is not controlled at a high temperature; at a medium temperature, drying is more consistent and therefore better suited to preserving the mango's organoleptic and nutritional qualities.

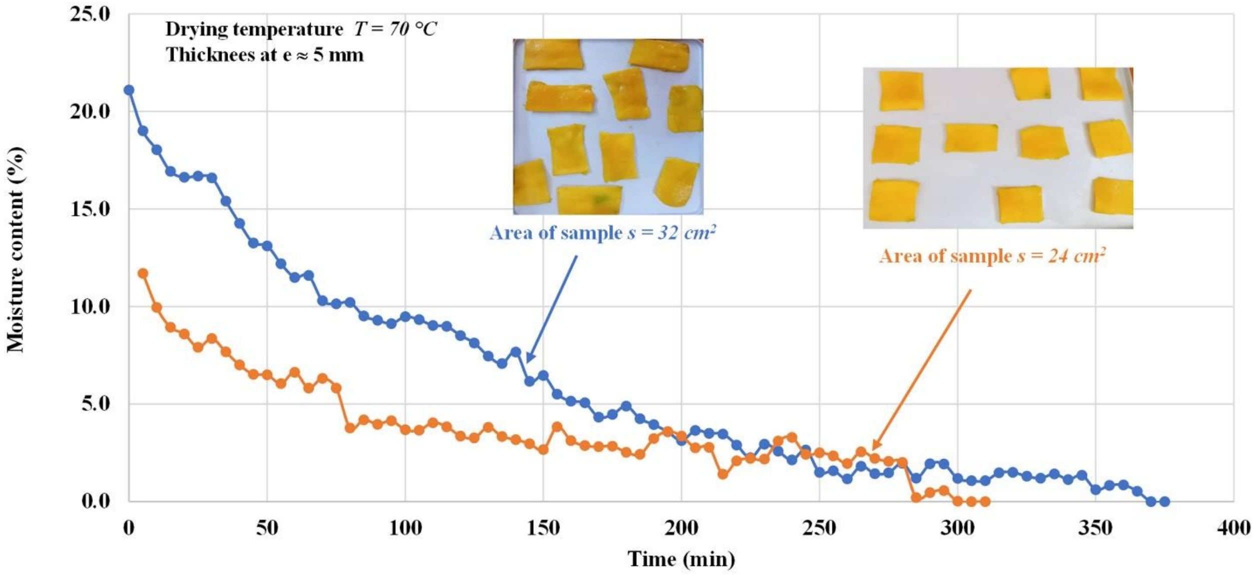

Figure 6. Mango surface area variation curve at 70°C.

Figure 6 compares the drying rate over time for two different surface areas of *32cm²* for the orange curve and *24cm²* for the blue curve, with a common temperature of *70°C*.

- Initial phase (*0* ≈ to *100 min*)

The moisture content averages between *10* and *15%* and gradually decreases. This is explained by the fact that free surface water evaporates easily thanks to the temperature of *70°C*.

- Intermediate phase (≈ *100* to *300 min*)

The blue curve (*24cm²*) shows strong fluctuations, reflecting irregular evaporation. This behavior may be caused by rapid surface evaporation without enough time for internal moisture to migrate efficiently to the surface. The orange curve (*32cm²*) is more stable and descends steadily, indicating controlled drying kinetics.

- Final phase (Approximately 300 min)

The curves converge toward low moisture content, but the *32 cm²* product reaches this level more quickly, demonstrating that increased surface area accelerates drying in this specific case.

This allowed us to conclude that at a constant temperature and thickness, a mango sample with a larger surface area (*32 cm²*) dries faster and more consistently than a smaller sample (*24 cm²*). This can be explained by the fact that a large surface area provides a larger contact area with the drying air.

3.2. Analysis of Dried Okra Results

The analysis of the results obtained is performed. Figure 7 shows the evolution of okra mass over time during drying carried out with the *UOP8-MKII* equipment. It allows us to observe the different phases of the drying process, notably the high drying rate phase followed by a slowing-down phase. This graphic representation highlights the progressive loss of moisture until reaching the recommended final content (*4* to *5%*) and indicates the optimal point at which drying should stop, corresponding to a dark green color of the product. It is essential for assessing drying efficiency and adjusting parameters if necessary.

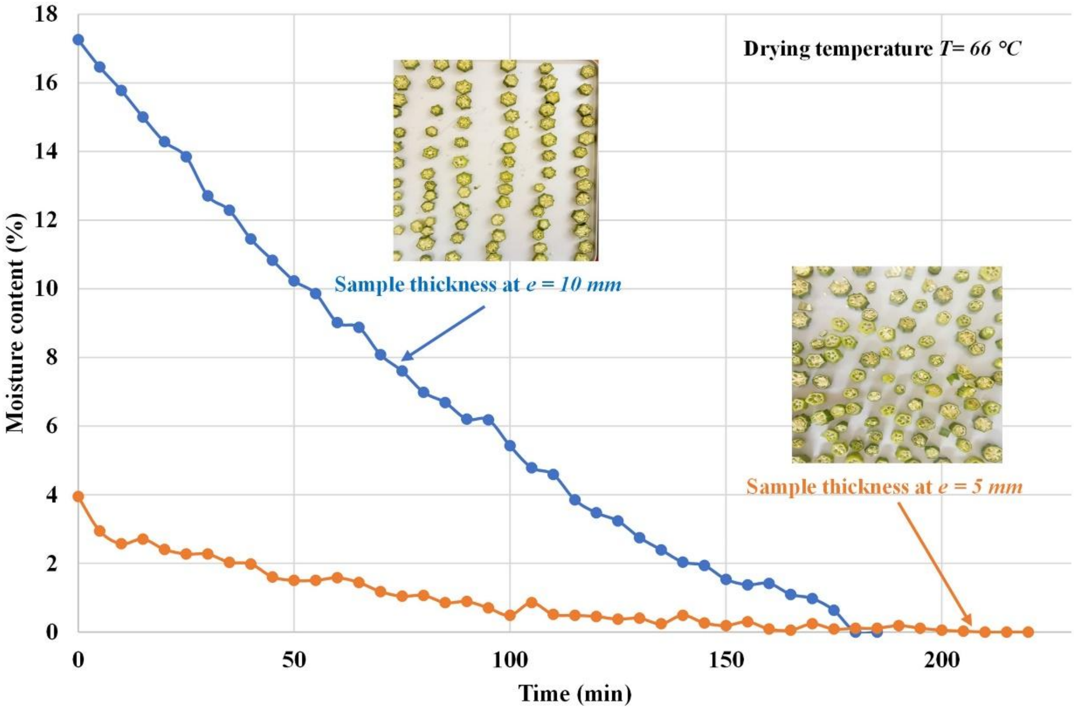

Figure 7. Okra thickness variation curve at 66°C.

Figure 7 shows the change in moisture content as a function of drying time at a constant temperature of *66°C*, for two okra samples with different thicknesses of *10 mm* (blue curve) and *5 mm* (orange curve).

- Initial phase (*0* to *50 min*)

The slice of *10 mm* okra begins with a much higher moisture content (*approximately 17%*) than *5 mm* okra (*approximately 2.8%*), which is logical since greater thickness retains more water. The decrease is faster for *10 mm* okra at the beginning of drying, but this remains insufficient to compensate for the total volume of water to be removed. Intermediate phase (*50* to *150 min*): *5 mm* okra quickly reaches a very low moisture content (*≈ 1%*), indicating that water has evaporated more quickly and evenly. 10 mm okra follows slower drying kinetics, with progressive evaporation throughout the drying period.

- Final phase (*150* to *220 min*)

Both curves converge towards a low residual moisture content, but the time required to reach this level is much shorter for *5mm* samples.

Product thickness has a major impact on drying speed. Thinner samples (*5mm*) dry more quickly and efficiently because the distance water has to travel from the inside to the surface is reduced. Conversely, thicker samples (*10mm*) retain more moisture, which slows the drying process despite a constant temperature. To optimize okra drying, it is best to use a thin layer. The final products obtained after drying are shown in Figure 8: samples of mango and okra.

Figure 8. Sample of okra and mango after drying.

3.3. Overall Analysis of Dried Foodstuffs Results

The experimental results obtained from drying okra and mango using the UOP8-MKII dryer show that the process was generally effective. The reduction in water content was significant for both products, confirming that the chosen parameters (temperature, thickness, and surface area) allowed for adequate dehydration.

- For mango, drying was slower due to its high initial water content and pulpy texture. However, at higher temperatures and with a larger surface area, the drying speed increased considerably.
- For okra, the fibrous structure and lower water content allowed for faster drying, especially when the thickness was reduced.

Drying efficiency is therefore observed through rapid moisture reduction, adherence to optimal times, and consistent results. This demonstrates the proper functioning of the UOP8-MKII device in an experimental setting. However, this thermal efficiency can be accompanied by nutritional losses, including.

- Loss of vitamin C, which is very sensitive to heat (especially in mango).
- Degradation of certain pigments and antioxidants.
- Slight loss of water-soluble minerals during the process.

Losses were more noticeable at higher temperatures. The compromise between drying speed and preservation of nutritional qualities is therefore essential. It would have been ideal to combine post-drying physicochemical analysis (vitamin C content, color, taste) to better quantify these losses.

3.4. Comparative Studies

In June 2025, we carried out drying using the UOP8-MKII dryer in the Heat Transfer Laboratory of the Department of Mechanical Engineering at the Polytechnic University of Mongo. The experiment considered varying temperatures for okra (*60°C*; *66°C*) and for mango (*60°C*; *70°C*), thicknesses for both products (*5mm* and *10mm*), and surface areas for both ($24\ cm^2$ and $32\ cm^2$). The results, as stated in Table 4, show that temperature and thickness have a significant effect on drying speed. Some data are not listed in the Table and are not available in the consulted literature review. However, unlike previous studies, the exposure surface also showed a notable influence in our case. This discrepancy may be explained by the nature of the products used, their different internal structures, or the specific experimental conditions, including the type of dryer, ambient conditions, measurement method, etc.

Table 4. Comparative study with previous work.

Reference (Author)	Device used/ Equipment	Dried product	Temperature of drying (°C)	Set air flow (m^3/s)	Thickness of product (mm)	Area sample (cm^2)	Radiation (W/m^2)	Year
Adel and Elmahdi [38]	Oven dryer	Peas	40, 50, and 60	0.001 to 0.004	10	-	77 and 742	2022
Lati, et al. [11] and Lati, et al. [39]	Indirect dryer	Potato	31.1 to 54.9	0.004	3 and 6	-	850	2015
Messaoudi and Djamel [40]	Oven dryer	Date	40 to 70	-	10.5	70.2	-	2011
Mennouche, et al. [10]	Direct dryer	Tomato	50 and 76	-	10	62	440	2010
Haryanto, et al. [12]	UOP8-MKII	Ginger and Turmeric	36 and 38	0.004 to 0.045	1 and 2	35 and 52.5	-	2019
Our research study	UOP8-MKII	Okra and Mango	65 to 70	-	5 and 10	24 and 32	-	2025

Indeed, okra and mango have particular physical and hygroscopic characteristics that can make the exposure surface more decisive in the heat and mass transfer process. Thus, our results partially confirm previous work, while providing additional analysis on the impact of the surface, which we believe deserves special attention in future research, especially for products with high water content and a porous structure.

4. CONCLUSION

In some, the study investigated the influence of various parameters such as temperature, thickness, product surface area, and drying time on the dehydration rate. The collected data were organized in tabular and run-by-run formats, then interpreted to identify trends and behaviors specific to each food product. The UOP8-MKII material is an electric dryer used during the drying of mango and okra. Particular attention was paid to comparing the results obtained with those of previous studies to highlight the relevance of the experimental conditions adopted. The following discussion helps us understand the observed drying mechanism and evaluate the efficiency of the process, while highlighting any potential nutritional losses or physical degradation suffered by the products. At the end of this study on the drying of two staple foods, mango and okra, several important results were obtained. The experiment, conducted in the Heat Transfer Laboratory of the Department of Mechanical Engineering at the Polytechnic University of Mongo, used the UOP8-MKII dryer to assess the influence of various parameters (temperature, thickness, and surface area) on drying kinetics. The results showed that temperature, product thickness, and surface area significantly influence drying speed. As the temperature increases, drying time decreases, but this can lead to nutritional losses. Similarly, reduced thickness and a larger surface area promote faster and more uniform drying. The optimal parameters for efficient drying of food products in this study have been identified while minimizing nutritional losses. The analysis confirms that the proper adjustment of temperature, airflow, thickness, and surface area is crucial for improving drying quality and ensuring product preservation.

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Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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