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Performance Evaluation of an Indirect Natural Convection Solar Dryer for Okra Drying in Abéché, Chad

This study presents the design, construction, and performance evaluation of an indirect natural-convection solar dryer used for drying okra under the Sahelian climatic conditions of Abéché, Chad. Post-harvest losses of vegetables remain a major challenge in the region due to inadequate preservation techniques. Experimental drying tests were conducted to monitor temperature, relative humidity, moisture content, and drying time. The results show that the solar dryer achieved higher drying temperatures than ambient conditions, leading to **1 a significant reduction in moisture content** from fresh okra to safe storage levels within a reduced drying time **compared to open sun drying**. The developed system demonstrates an efficient, low-cost, and environmentally friendly solution suitable for rural areas in arid regions.

Key words:-Solar dryer; Okra drying; Natural convection; Renewable energy; Food preservation; Chad

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Introduction

Okra (*Abelmoschus esculentus*) is a vegetable widely consumed in Chad, particularly in Abéché, due to its nutritional value and economic importance. However, its high water content makes it highly perishable, resulting in significant post-harvest losses. Drying is one of the most effective methods of extending the shelf life of agricultural products.

Traditional sun drying, although widely practiced, has several disadvantages: contamination by dust and insects, dependence on climatic conditions and variable final quality. Indirect solar dryers with natural convection offer an interesting alternative, protecting the product from direct sunlight while ensuring hot air circulation without the need for an external energy source.

The main objective of this study is to evaluate the performance of an indirect solar dryer with natural convection for drying okra under the climatic conditions of Abéché.

1. Literature Review

1.1 Principle of Solar Drying

Drying is a preservation technique based on reducing the moisture content of food to inhibit microbial growth. Solar energy, abundant in Sahelian regions, is a renewable and cost-free resource commonly used for drying agricultural and animal products. [19]

1.2 Types of Solar Dryers

Solar dryers are generally classified into direct, indirect, mixed, and hybrid systems.

Indirect solar dryers are particularly suitable for food products as they offer better control of drying conditions and preserve color, texture, and nutritional quality. [19]

1.3 Natural Convection

In natural-convection dryers, airflow is driven by buoyancy forces caused by temperature differences, eliminating the need for electrical fans. This makes such systems especially appropriate for rural areas without reliable electricity access. [19]

2. Materials and Methods

2.1 Study Area

The experimental study was conducted in Abéché, located in eastern Chad. The city is characterized by a Sahelian climate with high solar radiation, elevated ambient temperatures, and low relative humidity during most of the year. These conditions are favorable for solar drying applications.

2.2 Description of the Solar Dryer

The solar dryer used in this study is an indirect natural-convection type. It consists of three main components:

- A solar air collector covered with transparent glass,
- A drying chamber equipped with perforated trays for product placement,
- An air outlet chimney to enhance natural air circulation.

Dimensions of natural convection solar dryer in centimeters

The structure was constructed using locally available materials such as wood, metal sheets, and glass, making the system affordable and easy to replicate in rural areas.

2.3 Preparation of Okra Samples

Fresh okra pods were selected, washed with clean water, and sliced uniformly to ensure

homogeneous drying. The slices were weighed before drying and evenly distributed on the drying trays.

2.4 Experimental Procedure

Drying experiments were carried out during daylight hours. The following parameters were measured at regular intervals:

- Ambient air temperature,
- Drying chamber temperature,
- Relative humidity,
- Mass of okra samples.

Standard measuring instruments such as thermometers, hygrometers, and digital scales were used for data collection.

Comparative table of okra drying methods

Drying method

Temperature (°C)

Drying time (h)

Final moisture content (%)

Product quality

Advantages

Disadvantages

Open-air drying (direct sunlight)

30 – 40

48 – 72

15 – 20

Average (discoloration possible)

No cost, simple

Contamination, depends on climate

Direct solar dryer

40 – 55

24 – 36

10 – 15

Good

Free energy, reduced time

Possible overheating

Indirect Solar dryer (Natural convection))

45 – 60

18 – 30

8 – 12

Very good (color and nutrients preserved)

Even, hygienic drying

Limited air flow

Indirect solar dryer (with forced ventilation))

50 – 65

12 – 24

7 – 10

Excellent

Fast and uniform drying

Cost and electricity consumption

Electric dryer

55 – 70

8 – 12

5 – 8

Excellent

Precise control

Remarks

- The initial moisture content of fresh okra is generally 85–90% (wet basis).
- A final moisture content of less than 10–12% ensures good preservation.
- The indirect solar dryer with natural convection is a good compromise between quality, cost and performance in Abéché.

2.5 Moisture Content Determination

The moisture content of okra was calculated using the wet basis method, expressed as a percentage of the initial mass. The drying process continued until the moisture content reached a safe level for storage.

The initial and final moisture content was calculated using the following formula:

: Meat Mass before Drying

: Meat Mass after Complete Drying

3. Results and Discussion

3.1 Temperature and Humidity Variation

The temperature inside the drying chamber was consistently higher than the ambient temperature, indicating effective solar energy capture by the collector. Relative humidity inside the dryer was significantly reduced, enhancing moisture removal from the okra slices.

3.2 Drying Characteristics

² The moisture content of okra decreased progressively with drying time. Compared to traditional open sun drying, ³ the solar dryer reduced the drying time considerably while maintaining better product quality in terms of color and cleanliness.

3.3 Performance Evaluation

The improved performance of the solar dryer is attributed to indirect heating and controlled airflow by natural convection. The climatic conditions of Abéché played a significant role in achieving high drying efficiency.

The results obtained are consistent with similar studies conducted ⁴ in arid and semi-arid regions, confirming the suitability of solar drying technology for vegetable preservation.

4. Conclusion

This study demonstrates that the indirect natural-convection solar dryer is an effective and sustainable solution for drying okra in Abéché, Chad. The system significantly reduces drying time and moisture content compared to open sun drying while ensuring improved product quality. Due to its low cost and use of local materials, the dryer is well suited for rural communities and small-scale farmers.

5. Future Perspectives

Future work may focus on:

- Integrating a small fan powered by photovoltaic panels,
- Improving thermal insulation of the solar collector,
- Conducting economic and social impact assessments,
- Extending the application to other agricultural products such as onions and meat.

Acknowledgements

The authors gratefully acknowledge the Islamic Development Bank, through the Ministry of Higher Education, Scientific Research, and Innovation of Chad, for financial support provided for this research

Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this paper.

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URL: <http://dx.doi.org/10.21474/IJAR01/22428>

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