Case Study of Mixed-Mode Solar Dryer for Drying Fruits

Introduction

This report provides a detailed analysis of a mixed-mode solar dryer used for drying mango slices. The evaluation includes calculation of the total moisture removed, the energy required for moisture evaporation, and the drying efficiency based on given operational parameters. Recommendations for improving the drying process are also presented.

Given Data

Parameter	Value
Dryer Chamber Area	3 m^2
Airflow Rate	0.03 kg/s
Initial Moisture Content of Mango	80% (wet basis)
Final Moisture Content	15% (wet basis)
Solar Radiation	750 W/m^2
Drying Time	6 hours (21,600 seconds)

Task 1: Determination of Total Moisture Removed

To determine the moisture removed, we assume an initial wet mass of 1 kg of mango slices. The moisture content is converted from wet basis to dry basis as follows:

Initial Moisture Content (dry basis):
$X_i = MCi / (1 - MCi) = 0.80 / 0.20 = 4.0$ kg water/kg dry matter

Final Moisture Content (dry basis):
$X_f = MCf / (1 - MCf) = 0.15 / 0.85 \approx 0.176$ kg water/kg dry matter

Dry mass (constant):

$M_d = 1 / (1 + X_i) = 1 / (1 + 4.0) = 0.2$ kg

Final total mass = $M_d \times (1 + X_f) = 0.2 \times 1.176 = 0.2352$ kg

Moisture removed = Initial mass - Final mass = 1 - 0.2352 = 0.7648 kg

Task 2: Energy Required for Moisture Evaporation

To evaporate the moisture, energy input is calculated based on the latent heat of vaporization, which is approximately 2400 kJ/kg at the drying temperature.

Energy required = Moisture removed × Latent heat
$Q_{evap} = 0.7648 \text{ kg} \times 2400 \text{ kJ/kg} = 1835.52 \text{ kJ}$

Therefore, the energy needed to evaporate the removed moisture is approximately 1835.5 kJ per kg of initial mango.

Task 3: Drying Efficiency Evaluation

Solar energy input over the drying time is calculated as:
Q_{solar} = Solar Radiation × Area × Time = 750 × 3 × 21600 = 48,600,000 J = 48,600 kJ

Drying Efficiency (η) is given by:
$\eta = (Q_{evap} / Q_{solar}) \times 100 = (1835.5 / 48600) \times 100 \approx 3.78\%$

Thus, the drying efficiency of the system is approximately 3.78%.

Recommendations for Improvement

To enhance the performance and efficiency of the mixed-mode solar dryer, the following improvements are suggested:

- 1. Improve insulation to reduce thermal losses and retain heat within the drying chamber.
- 2. Incorporate thermal storage materials to store solar energy for use during cloudy periods or at night.

- 3. Optimize airflow distribution to ensure uniform drying across all mango slices.
- 4. Preheat the drying air using a separate solar air heater to increase drying rate.
- 5. Use multi-layer drying trays to increase the drying capacity without enlarging the chamber footprint.

Conclusion

This detailed analysis demonstrates the current performance of a mixed-mode solar dryer for mango slices. With a drying efficiency of 3.78%, there is clear potential for improvement. By implementing the proposed recommendations, energy utilization and drying effectiveness can be significantly enhanced.

Prepared by,

Pawan Kumar (220151010)