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TOP: Analysis of Solar Air-Drying System integrated with Photovoltaic (PV) and Phase Change Material (PCM)

Keywords: Solar air drying, Economic analysis, Phase change materials, fins, photovoltaic

Findings

Solar drying, an ancient technique, has evolved significantly with advancements in technology. Modern research emphasizes the importance of solar dryers in reducing moisture in food, extending shelf life, and promoting sustainability. With rising electricity and fuel costs, solar energy is gaining increased interest as a more sustainable alternative for drying purpose with the integration of PV and PCM system.

The study examines the effect of PCM container thickness (δ) and length (L) on SAH performance, focusing on δ/L ratios. Increasing δ/L improves peak liquid fraction, reduces dead length by up to 99.1%, and delays PCM discharging, storing more energy during non-sunshine hours. At δ/L = 0.04, discharging and exergy efficiencies rise to 39.1% and 3.09%, respectively, while energy and exergy payback times are reduced to 1.09 and 13.53 years. Optimizing δ/L ratios is crucial for enhancing SAH-PCM system performance.

The study further evaluates the economic and enviro-economic aspects of the SAH-PCM system, focusing on the PCM container's thickness-to-length ratio (δ/L). Economic indicators like capital recovery, costs, and maintenance are analyzed, while enviro-economic aspects include CO_2 emission reductions and carbon credits. A δ/L ratio of 0.042 achieves the lowest energy cost (20.824 Rs/kWh), maximizes CO_2 reduction (10.85 tons), and yields the highest carbon credits (Rs. 13,107.9). Optimizing δ/L ratios enhances both economic and environmental performance.

The study now shifts focus to examine how fin length ratios (upper fin length/lower fin length, L_u/L_d) affect PCM melting in the SAH for drying. Five ratios were tested: 1, 4, 1.5, 0.67, and 0.25. The 0.25 ratio (Case V) resulted in the fastest melting time (3696 s), 28.06% quicker than the equal-length fins (Case I), due to improved convection during the strong convection stage. While energy storage was consistent, Case V showed a 36.2% increase in average power and was the most cost-effective (27.5 Rs/W); indicating longer lower fins enhance system performance.

The research further investigates using a PV panel as the absorber plate in a SAH-PCM. It compares three designs: two with copper absorber plates of different thickness ratios (δ/L ratios of 0.0128 and 0.042) and one using a PV absorber with fins (δ/L ratio of 0.042). The PV-based design resulted in complete PCM melting and better charging and discharging efficiencies, showing it's a more effective SAH-PCM system.