

TUGAS AKHIR

Studi Eksperimental Pengaruh Penggunaan *Fully Refined Paraffin Wax* - FRW-52, Temperatur Inlet, dan Laju Aliran terhadap Distribusi Temperatur, Aktivasi *Mist Maker*, dan Konsumsi Energi Inkubator Telur

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PADANG**

2026

ABSTRAK

Penelitian ini mengevaluasi integrasi *Fully Refined Paraffin Wax* (FRW-52) sebagai *phase change material* (PCM) pada penukar panas tipe tabung bersirip untuk meningkatkan karakteristik termal inkubator telur ayam. Penelitian bertujuan menganalisis pengaruh PCM terhadap distribusi temperatur, stabilitas temperatur, kelembaban relatif (RH), konsumsi energi inkubator, serta karakteristik *charging* dan *discharging* PCM. Pengujian dilakukan pada tiga konfigurasi sistem, yaitu inkubator konvensional, inkubator berbasis PCM, dan sistem PCM dengan penukar panas, menggunakan variasi temperatur inlet 60, 65, dan 70°C serta bukaan katup penuh, $\frac{3}{4}$, dan $\frac{1}{2}$. Parameter yang diamati meliputi temperatur multi-titik ruang inkubasi, RH, serta konsumsi energi lampu dan *mist maker*. Hasil penelitian menunjukkan bahwa integrasi PCM meningkatkan homogenitas distribusi temperatur hingga deviasi 0,39°C, namun menghasilkan fluktuasi temperatur dan RH yang lebih tinggi dibandingkan inkubator konvensional. PCM mampu menurunkan konsumsi energi lampu selama fase stabil hingga 78,8%, tetapi pengurangan konsumsi energi total sistem hanya sekitar 1 kJ akibat meningkatnya konsumsi energi *mist maker*. Selain itu, peningkatan temperatur inlet mempercepat proses *charging* PCM, dimana temperatur inlet 70°C menghasilkan waktu *charging* sekitar 47–50 menit dengan estimasi energi tersimpan sebesar 650–730 kJ, sedangkan variasi laju aliran air panas menunjukkan pengaruh yang relatif kecil terhadap karakteristik *charging*. Temperatur inlet dan laju aliran air panas tidak mempengaruhi performa inkubator secara langsung, tetapi melalui karakteristik *charging* PCM yang menentukan energi tersimpan dan selanjutnya dilepaskan selama proses *discharging*. Secara keseluruhan, integrasi PCM mampu meningkatkan homogenitas distribusi temperatur, namun di sisi lain meningkatkan fluktuasi kelembaban relatif (RH), sehingga pengurangan konsumsi energi total sistem menjadi relatif kecil.

Kata kunci: *Fully Refined Paraffin Wax* (FRW-52), PCM, penukar panas tipe tabung bersirip, inkubator telur ayam, distribusi temperatur, kelembaban, konsumsi energi, temperatur inlet, laju aliran.

ABSTRACT

*This study evaluates the integration of **Fully Refined Paraffin Wax (FRW-52)** as a **phase change material (PCM)** in a **finned-tube heat exchanger** to improve the thermal performance of a chicken egg incubator. The study aims to investigate the effects of PCM on temperature distribution, temperature stability, relative humidity (RH), incubator energy consumption, and the charging and discharging characteristics of the PCM. Experiments were conducted using three system configurations, namely a conventional incubator, a PCM-based incubator, and a PCM-integrated heat exchanger system, with inlet temperatures of 60, 65, and 70°C and valve openings of fully open, three-quarters, and one-half. The measured parameters included multi-point temperature distribution inside the incubation chamber, relative humidity (RH), and the energy consumption of the heating lamp and mist maker. The results indicate that PCM integration improved temperature distribution uniformity, achieving a maximum temperature deviation of **0.39°C**. However, it also resulted in greater temperature and RH fluctuations compared with the conventional incubator. During the steady-state period, the PCM reduced the heating lamp energy consumption by up to **78.8%**, although the overall system energy consumption decreased by only approximately **1 kJ** due to the increased operation of the mist maker. Furthermore, increasing the inlet temperature accelerated the PCM charging process, with an inlet temperature of **70°C** achieving a charging time of approximately **47–50 minutes** and an estimated stored thermal energy of **650–730 kJ**, while the hot water flow rate showed only a minor influence on the charging characteristics. The inlet temperature and hot water flow rate did not directly affect the incubator performance but instead influenced the PCM charging characteristics, which determined the amount of thermal energy stored and subsequently released during the discharging process. Overall, PCM integration provides improved temperature uniformity at the expense of increased RH fluctuations, resulting in only marginal reductions in overall energy consumption.*

Keywords: *Fully Refined Paraffin Wax (FRW-52), PCM, finned-tube heat exchanger, egg incubator, temperature distribution, humidity, power consumption, inlet temperature, mass flow rate.*