INTISARI

Penyimpanan vaksin pada rentang suhu 2–8 °C masih menjadi tantangan di daerah terpencil Indonesia karena keterbatasan instrumen pendukung *cold chain*. Penelitian ini bertujuan untuk merancang dan menguji performa *portable cold storage* berbasis sistem Peltier *thermoelectric refrigeration* dengan berbagai variasi konfigurasi sebagai alternatif yang efisien energi, bebas refrigeran, dan mudah dibawa. Pengujian dilakukan secara eksperimental terhadap 54 variasi konfigurasi yang meliputi jumlah modul (1, 2, dan 3), tipe *stage* (single *stage* dan *multi-stage*), konfigurasi sambungan listrik (seri, paralel, dan *separated*), jenis *heat exchanger* (*heat sink* dan *water block*), serta tegangan *input* (3 V, 6 V, dan 12 V). Setiap pengujian berlangsung selama 30 menit hingga mencapai kondisi *steady state* dengan beban 120 *vial* vaksin simulasi. Hasil penelitian menunjukkan bahwa suhu ruang pendingin terendah yang dicapai adalah sekitar 18,9 °C, belum memenuhi standar WHO. Konfigurasi optimal diperoleh pada single *stage* TEC-12706 dengan dua modul, sambungan paralel, dan tegangan 6 V. *Single stage* secara konsisten unggul dibandingkan *cascade*, sementara peningkatan tegangan meningkatkan kapasitas pendinginan tetapi menurunkan COP secara signifikan. Penelitian ini memberikan rekomendasi desain awal yang praktis untuk pengembangan sistem penyimpanan vaksin portabel di wilayah dengan akses energi terbatas.

Kata kunci: *cold storage* portabel, Peltier, *thermoelectric refrigeration*, vaksin, COP, *cold chain*

ABSTRACT

Maintaining vaccine storage within the 2–8 °C range remains a major challenge in remote areas of Indonesia due to limited cold instruments. This study aims to design and evaluate the performance of a portable cold storage system based on Peltier thermoelectric refrigeration with different types of configurastions as an energy-efficient, refrigerant-free, and highly portable alternative. Experimental testing was conducted on 54 configuration variations covering the number of modules (1, 2, and 3), stage type (single-stage and multi-stage), electrical connection (series, parallel, and separated), heat exchanger type (heat sink and water block), and input voltage (3 V, 6 V, and 12 V). Each test ran for 30 minutes until steady state was reached under a load of 120 vaccine vials. Results showed that the lowest chamber temperature achieved was approximately 18.9 °C, which has not yet met the WHO standard. The optimal configuration was obtained using a single-stage TEC-12706 with two modules, parallel connection, and 6 V input. Single-stage setups consistently outperformed cascade configurations, while higher voltage increased cooling capacity but significantly reduced COP. This research offers practical design recommendations for developing portable vaccine storage systems in regions with limited energy access.

Keywords: *portable cold storage*, Peltier, *thermoelectric refrigeration*, *vaccine*, *COP*, *cold chain*