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Experimental Investigation of Novel Phase Change Composites Based on Utilization of Waste Pork Fat and Thermal Paste

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Abstract

Thermal energy storage (TES) is a key technology for improving energy efficiency and enabling the integration of renewable energy sources. In this context, the development of novel, environmentally more favorable materials from waste food-based resources has attracted increasing attention for engineering applications. Among these materials, animal fats represent an abundant and low-cost class of bio-based phase change materials (PCMs) with promising thermal properties. Furthermore, the use waste of pork fat as PCM supports also circular economy aspect. In this study, a naturally aged pork fat sample was investigated and it can be considered as waste material. The sample was stored in an uncontrolled outdoor environment on a building rooftop and exposed to long-term environmental conditions and repeated natural thermal cycling over four years, and where conditions are very similar like in the case of thermal management of photovoltaic (PV-PCM) systems, where thermal cycling, i.e. aging also occurs. The sample of waste-based pork fat was compared with commercially fresh pork fat to evaluate effects of prolonged aging and uncontrolled melting–solidification cycles on thermal behavior, as well as thermal properties. Furthermore, the aged pork fat was modified to improve its thermal performance by incorporating a high-conductivity thermal paste at different weight fractions (5%, 10% and 20%). The thermal properties of these newly developed phase change composite materials were analyzed using the transient hot-wire (THW) method in the temperature range from 10 °C to 60 °C with a temperature step of 5 °C, under both heating and cooling regimes. Results showed that aged pork fat has slightly higher thermal conductivity and diffusivity compared to fresh pork fat across the investigated temperature range, specifically in the liquid phase. At 40 °C (cooling regime), the thermal conductivity increased from 0.164 $W \cdot m^{-1} \cdot K^{-1}$ for fresh pork fat to 0.168 $W \cdot m^{-1} \cdot K^{-1}$ for the aged material, while thermal diffusivity increased by approximately 0.6%. The addition of thermally conductive paste further improved performance, however limited, resulting in increases of approximately 1.5%, 3.9%, and 6.9% for thermal conductivity and 0.4%, 1.5%, and 3.1% for thermal diffusivity at 5%, 10%, and 20% additives, respectively, compared to aged pork fat. However, key problem was segregation at specific temperatures, which has affected overall improvement of thermal properties of the examined samples. This highlights importance of suitable surfactants or targeted additives in order to limit segregation, which needs further investigation. Finally, these findings demonstrate that waste pork fat can be considered useful waste-based material with potential applications in thermal management. However, more research efforts should be provided to investigate suitable combinations of waste pork fat as well as other phase change materials in order to form novel phase change composites based on waste materials.

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Keywords: pork fat, waste material, phase change composites (PCM), thermal energy storage, thermal conductivity

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