ABSTRACT

The unsustainable nature of current energy storage methods and the abundance of biomass waste such as fruit peels and brown algae along the Indonesian coast present significant environmental challenges. The utilization of natural materials as sources of active compounds in supercapacitor electrode fabrication has demonstrated promising potential in previous studies. Putri (2022) reported that electrodes derived from mangosteen peels achieved a specific capacitance of 41.6 F/g, while Dhelipan et al. (2016) recorded a value of 275 F/g from orange peels. Sasongko (2023) also showed that brown algae-based electrodes reached 20.86 F/g. Utami (2020) reported a specific capacitance of 43.1 F/g for banana peel-based electrodes, and Ajeng et al. (2020) found 37,842 F/g from white ginger. Wibowo et al. (2020) noted that bilimbi fruit (Averrhoa bilimbi) juice could generate voltage through electrochemical processes; however, its application in supercapacitor electrodes remains largely unexplored. The main problem addressed in this study is how to enhance the capacitance of manganese-based supercapacitor electrodes through the incorporation of bioactive-rich natural materials as pseudocapacitive agents.

The proposed solution involves the synthesis of MnO_x-based supercapacitor electrodes using natural materials such as orange peels, banana peels, mangosteen peels, white ginger, bilimbi fruit, and brown algae. In addition, Carboxymethyl Cellulose (CMC) was used as a binder to improve the structural stability of the electrodes, and loofah was introduced as a natural porous template. This study focused not only on the morphological and elemental characterization of the electrodes but also on electrochemical performance evaluations, including Cyclic Voltammetry (CV) and Endurance tests.

The EDS characterization of elemental distribution revealed that the bioactives from brown algae, starfruit, and banana peel bound manganese above 20%, whereas white ginger, mangosteen peel, and orange peel exhibited less than 2%. The specific capacitance of electrodes synthesized with TETA was found to be 113.32 F/g for brown algae, 11.58 F/g for starfruit, and 8.97 F/g for banana peel. The addition of CMC as a binder resulted in a significant improvement, yielding 420.18 F/g for brown algae, 108.15 F/g for starfruit, and 225.74 F/g for banana peel. The performance was further influenced by composition ratios, with $MnCl_2$+extract:CMC = 1:9 achieving the highest specific capacitance of 420.45 F/g. Moreover, the variation employing loofah as a porous medium demonstrated that the ratio of brown algae $MnCl_2$+CMC:loofah = 1:5 produced a capacitance of 215 F/g.

Keywords: Supercapacitor, Specific Capacitance, MnO_x, Natural Materials