Sustainable Biofuel Production Through Multimode Biocatalysis Using Enzymes Extracted and Concentrated From Household Waste

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Biofuels are vital in combating climate change by offering a low-carbon alternative to fossil fuels, thus reducing greenhouse gas emissions. Efficiently converting waste materials into fuel promotes a circular economy and addresses environmental and energy challenges sustainably. This research explores using enzymes from non-microbial waste, such as plant leaves, seeds, and fruit skins, to break down simulated agricultural, household, and coffee waste for biofuel production. Enzymes like amylases, lipases, and cellulases were extracted, enriched via foam fractionation, and studied for enzyme kinetics. These enzymes were immobilized on food-based matrices and characterized using Langmuir and Freundlich adsorption models. After optimizing conditions using a factorial design (5 factors at 2 levels; 90 experiments), oil extraction was examined under aerobic and anaerobic conditions in a controlled bioreactor. The sludge from the waste was clarified using electrocoagulation and electrooxidation, and the clarified oil underwent chemical and enzymatic transesterification. Under aerobic conditions, simulated household waste showed the highest oil extraction efficiency with significant weight gain and oil percentage. Conversely, under anaerobic conditions, coffee waste exhibited the highest weight gain and oil percentage (30% w/w). High-yield enzymatic transesterification was studied with conditions optimized through statistical Response Surface Methodology (RSM) and Central Composite Design (CCD). Oil extraction from waste yielded 14–32% oil, with an 86% conversion to FAAE, a key biodiesel component. FAAE formation was analyzed using Near-Infrared Spectroscopy (NIRS). The final FAAE-rich biodiesel was tested for viability using the ASTM copper oxidation test.

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