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3D-Printed Bioplastics from Fish Protein and Green Solvents

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Extended Abstract

Annually, approximately 500 billion single-use plastic bags are consumed worldwide. More than one million bags are used every minute. A plastic bag has an average “working life” of 15 minutes. In the United Arab Emirates (UAE), for example, 11 billion plastic bags are used annually, which is the equivalent of 1,182 plastic bags per person per year [1]. This is considered a very high rate compared to the global average of 307 bags per person per year. In the UAE, for example, plastic wastes contribute significantly to the total municipal solid waste. To address this situation, levies are being imposed on single-use plastic bags for packaging of items bought from malls and grocery stores. Other single-use plastics, including beverage cups and lids, plastic cutlery, straws, stirrers and food containers, will also be phased out in the coming years in the UAE [2]. Bioplastics are suggested as alternatives to fossil-based, single-use plastics because they are more biodegradable. Some bioplastics can biodegrade in a year whereas their counterparts from petroleum-based plastics may take hundreds of years to biodegrade [3,4].

In addition, according to the World Economic Forum, up to 35% of fish harvested is wasted. The seafood sector can become more circular and put by-products to use. Edible food resources have been used mainly to produce bioplastics [5,6]. This practice could lead to food vs. plastic competition if bioplastics are produced on a massive scale from food waste.

Therefore, this research presents a comprehensive methodological framework for the sustainable production and assessment of 3D-printed bioplastic sheets synthesized from fish waste-derived protein isolates. The study is structured into four main tasks addressing material synthesis, technical evaluation, economic viability, and environmental sustainability, with the overarching goal of demonstrating a green and scalable alternative to petroleum-based plastics. The first task involves the synthesis of bioplastic sheets through a three-stage process. Proteins are first isolated from dehydrated fish waste using a sequence of steps including pulverization, alkaline hydrolysis, centrifugation, and pH adjustment, followed by drying and structural characterization. The protein isolates are then dissolved in the green solvent 1-ethyl-3-methylimidazolium acetate ([Emim][Ac]) and modified using glyoxal as a crosslinker and glycerol as a plasticizer. The resulting polymer suspension is processed into printable filaments. These filaments are subsequently used to fabricate bioplastic sheets.

The second task focuses on evaluating the technical performance of the bioplastics. The sheets are characterized by measuring tensile strength, thermal stability, UV resistance, chemical resistance, moisture absorption, and biodegradability. The optimum formulation is identified using Minitab software for statistical analysis. The third task involves economic assessment. The fourth task conducts a cradle-to-gate life cycle assessment (LCA) following ISO 14040 and ISO 14044 standards. The LCA is implemented in SimaPro software and covers inventory analysis, midpoint and endpoint impact categories, and interpretation based on the Hierarchist approach. This approach integrates food waste valorization, green chemistry, and advanced manufacturing technologies, while aligning with several UN Sustainable Development Goals, including SDG 2, 12, 13, and 14.

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