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ALGAE-BASED PLASTIC: PREPARATION OF MOLDABLE BIOPLASTIC FROM *CLADOPHORA*

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Abstract

The research presents a method for converting green algae into a moldable bioplastic. Specifically, the present processes used a green alga *Cladophora* sp. combined with myrrh to obtain the moldable bioplastic. The moldable bioplastic can form a composite, optionally with other environmental friendly materials, to obtain eco-friendly biodegradable products.

Plastics are used in many industries. The vast majority of traditional chemical plastics are non-biodegradable and they pollute environment, unlike algae-based plastics that are biodegradable and maintain environmental sustainability (El Semary *et al*. 2022). Production from nonrenewable resources and their resistance to biodegradation are issues that deter us from relying on conventional petrochemical-based plastics. In this context, bioplastics, or algae-based plastics, derived from natural sources are emerging as sustainable and safe alternatives (Alsuhail 2023). Algae-based bioplastics are increasingly relied upon for their eco-friendly aspects. However, much more work needs to be done to develop suitable algae-based bioplastics that can be used as complete chemical plastic replacements (Abdo and Ali 2019, Amin *et al.* 2019, Ong *et al*. 2019, Filiciotto and Rothenberg 2021, Nikiema and Asiedu 2022). Therefore, researchers have recently focused on novel and potentially eco-friendly control tools.

Algae are a group of photosynthetic organisms which inhabit a wide range of environments and are plentifully available. The development of algae-based bioplastics produced from algae represent potentially safe, applicable, and low-cost alternatives for traditional chemical plastics, which negatively affect the environment and health. Thus, new bioplastics derived from algae solving the aforementioned problems.

Fresh biomass of *Cladophora* sp. was collected from AlUquair beach, Arabian Gulf, Eastern Province, AlAhsa, KSA. The algal biomass was washed thoroughly to clean it from any attached particles and soaked to wash off excess salt. The biomass of the green alga was air-dried. Six gm of dry algal biomass was mixed with ground myrrh with glycerin (50%) and 100 ml water. The mixture was heated at 80°C for half an hrs. then left to dry to form a cohesive algae-based plastic bio-composite or bioplastic. Drying the homogenous thick film to form the moldable bioplastic took a day or more according to room temperature and a complete removal of water was needed in order to allow the shape of the mixture. The *Cladophora* sp. and the ground myrrh were mixed in 2 : 1 ratio, by weight, respectively. It was preferred that the mixture was poured onto a glass Petri dish or container to take the shape of it (Fig. 1). A blend was formed using the combination of algae and plant material in the presence of glycerol (Fig. 2).

Green algae perform photosynthesis and form starch as food reservoir they also have cellulose in their cell wall. These polymers were used for forming the base of bioplastic and other material was added to increase their tensile strength. The cell wall of most marine macro-algal species

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contain cellulose which gives strength to algal cell owing to its unique structure. Its chemical structure is a carbohydrate polymer that is formed of β(1-4)-linked d-anhydroglucopyranose units, with intra- and intermolecular hydrogen bonds resulting in its dense packaging (Zugenmaier 2008) and exceptional mechanical properties (Heinz 2015). In addition, the structure of cellulose has the ability to be modified for more advanced applications such as algae-based bioplastic (Zanchetta *et al*. 2021). Other carbohydrate materials may be present and even form distinct layer in some cases. With regard to green algae, they contain starch as a reserve food material and cellulose in addition to many other polymeric substances. These form the basis for bioplastic

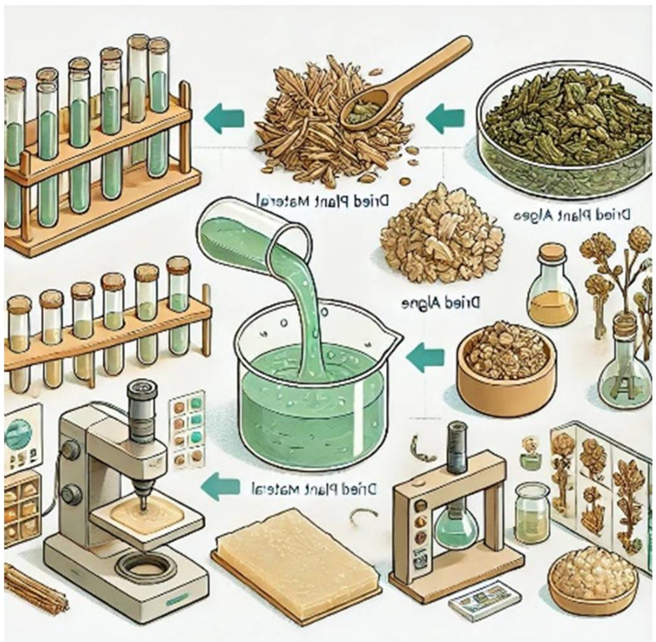

Fig.1. Diagrammatic representation of components and preparation of algae-based plastic using marine green alga, myrrah and glycerol.

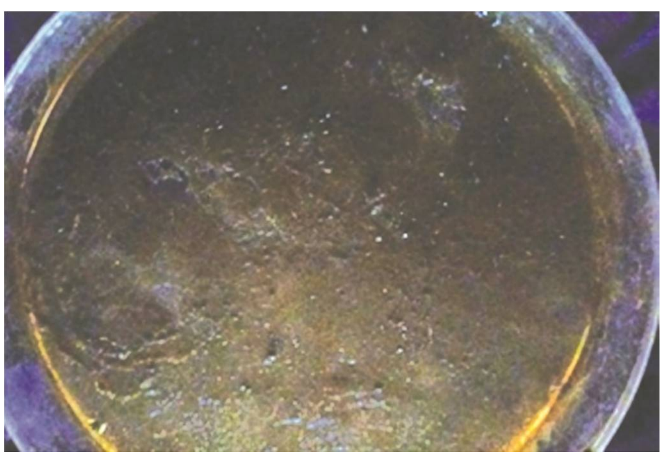

Fig. 2. An algae-based plastic.

production. *Cladophora* sp. in particular was reported to possess many good characteristics that make it a plausible base for algae-based plastic (Steven *et al*. 2022), However, blending this with other materials in order to increase the flexibility and durability myrrah and glycerol was added to improve the physical and chemical properties. Myrrh or *Commiphora abyssinica* gum resin has 26-47% resin in addition to water-soluble matter and volatile oils (Shah *et al.* 2024). Most of gum resins (GR) are composed good foundation for bioplastic formulation. Indeed, resin and its derivatives have been proposed as low-cost, sustainable, and easily obtainable additives for plastic field (Hosseinkhani *et al.* 2017). Another advantage of using gum resin is their antimicrobial properties that makes them safe in manufacturing food films (Shah *et al.* 2024). However, gum resin which consists largely of abietic-type resin acids shows relatively low thermal stability. They have high tendency to oxidize, and crystallizes easily due to its conjugated double bonds and carboxyl groups. Chemical modifications are commonly used to improve these properties, enhancing thermal oxidation stability for applications in adhesives, inks, and coatings (Liu *et al.* 2020). So, some chemical modifications such as hydrogenation and esterification, confer to GR with higher thermal stability. Most common alcohols used to stabilize the GR are glycerol. Glycerol is widely used polyhydric alcohol employed as a stabilizer, plasticizer, and solvent for various gums and resin systems, particularly in food and pharmaceutical applications. For example, due to its high density, glycerol esters help to create a stable, homogeneous mixture. Glycerol is also used to stabilize and plasticize other gum systems, such as gellan gum, where it improves flexibility and prevents brittleness in edible films (Paolicelli *et al.* 2018). This plastic combination is chemical free, 100% natural and biodegradable.

The use of natural resources that are freely available as marine macroalgae for the formation of bioplastic is completely biodegradable, eco-friendly and cost-effective.

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