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REVIEW ARTICLE

Bioprospecting of microalgae for biofuel and PHA production

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Abstract

Microalgae are significant primary producers of organic matter in the marine environment, producing half of the world's oxygen. In the food, feed, pharmaceutical, cosmetic, nutraceutical, and biofuel sectors, marine microalgae and PHA are sources of a variety of bioactive substances. Only with a drop in manufacturing costs is it conceivable for the PHA to have wider commercial use. Numerous research has shown that microalgae may be able to generate PHAs at a reduced cost since they need very few nutrients and are photoautotrophs, which means they get their energy from light and CO_2.It is still clear, nevertheless, that microalgae can make biopolymers at a cheap cost and can be utilized to improve the environment. The main objective of this paper is to learn more about the use of microalgae for the production of Biofuel and PHA. In the future, this study will help to understand the importance of microalgae for biofuel and PHA production.

Keywords: Biofuel, Bioplastics, Microalgae, Polymer, Polyhydroxyalkanoate (PHA).

Introduction

Due to their extensive pollution of both terrestrial and marine life, plastics have a severe effect on the ecosystem and environment. The conceivable substitute is biodegradable goods made from renewable resources. One such prospective option is bioplastics, which have qualities comparable to those of polymers obtained from fossil fuels but with improved biodegradability and mixing capabilities. Bioplastics, which can be molded, are made up of renewable biomass sources (Dong et al., 2020; Kaparapu et al., 2018). Depending on the availability of carbon sources, bacterial and algal systems acquire Polyhydroxyalkanoate (PHA) as part of their metabolic activities. Although PHA produced by bacterial systems is effective in accumulating, commercializing it is difficult because of the high cost. Scaling up is costly for bacterial systems because they need essential process parameters. Utilizing microalgae biomass that collects PHA may solve the problems with commercializing bacterial PHA. The cultivation of various resources is made possible by the flexibility in carbon source usage (Fig. 1).

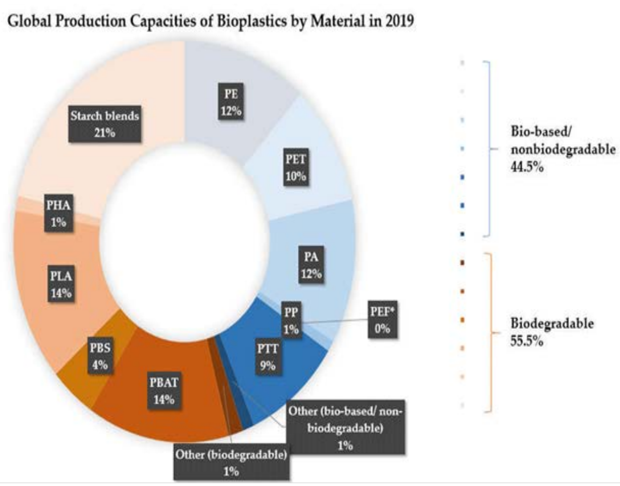

Figure 1. Global production capacities of Bioplastics material in 2019.

PHAs are polyesters of hydroxyalkanoates that are made by bacterial and algal cells from sugar and/or lipids as an internal carbon source. PHAs are considered viable substitutes for petrochemical-based polymers like polypropylene in plastic bags or containers due to their similar physical properties. Repeated ester units with an R-group, two oxygen atoms, and a carbon chain makeup the structure of PHAs. They have limited solubility in water as a consequence of their high hydrophobicity characteristics (Arias et al., 2020; Pradesh et al., 2018). They are thought to be inert, harmless, and air-indefinitely stable. PHAs may exhibit thermoplastic and elastomeric characteristics, very high cell purity, strong UV light degradation resistance, poor solvent resistance, biodegradability, and biocompatibility. These special qualities make them suitable materials for a variety of applications. PHA was first used in coatings for paper and packaging films for bags and containers. Fig. 1, shows the 2019 bioplastics production capacity on a global scale. Disposable medical supplies include surgical instruments such repair patches, bone plates, screws, and orthopedic pins as well as wound dressings, vein valves, bone marrow scaffolds, tendon repair devices, and replacements or scaffolds for damaged tissue. Razors, utensils, feminine hygiene products, diapers, shampoo bottles, cosmetic containers, and mugs are more disposable goods. The present study is an attempt to explore the possibilities of bioprospecting of microalgae for biofuel and PHA production.

Literature Review

Lakhan Kumar et al. studied an environmentally friendly way to extract lipids from microalgae by using its waste products for a variety of commercial uses. The economy based on algae cannot be supported only by the generation of lipids for biofuels like biodiesel. As a result, utilizing biomass that have the lipids removed for different other uses may provide a solution. One of the numerous applications for biomass is the production of biofuels, such as biohydrogen or biogas, biochar, carbon quantum dots, bio-composites, or polythene with different densities. It may also be used as manure to improve soil fertility, animal feed, and clean effluent (Kumar et al., 2022).

Gang Li et al. studied the use of wastewater as the culture medium for nutrient recovery, generation of renewable energy and wastewater treatment are current breakthroughs in microalgae technology. Even though recent studies have supported the practicality of this method, it is still challenging to maintain high-quality microalgae-derived biofuel production in real wastewater when nutrient levels vary. This study examined a method for altering the nutritional composition of the wastewater used for feeding microalgae culture (*Desmodesmus sp.*) and the generation of biofuel. This study showed that adjusting wastewater might be a possible strategy for raising the caliber of microalgal biofuel production, which will have a smaller negative environmental impact (Li et al., 2022).

Chandan Mahata et al. studied creating marine microalgae biomass-based foods, feeds, and fuels: viable routes, related difficulties, and future directions. However, a freshwater microalgae strain's high-water need is a serious issue, particularly if the biomass is used for non-food uses. Therefore, if marine microalgae were able to produce biomass of the proper grade, they would enjoy a comparative benefit over freshwater microalgae. In addition to biofuels, microalgal biomass has lately drawn a lot of attention as a source of ingredients for both human and animal food as well as a feedstock for other bulk chemicals. To address this, various technologies are being developed that utilize marine microalgae to produce feed, food, as well as biofuels (Mahata et al., 2022).

Senem Onen Cinar et al. studied to analyze the present condition of microalgae species used to produce bioplastics and highlight potential areas for process and application optimization. The creation of plastic garbage is growing worldwide, which contributes to the degradation of the planet with plastic waste. It is unavoidable that we need an original method to lower this pollution. A whole solution does not consist just of increasing the recycling of plastic garbage for consumption; Bio-based plastics are becoming more and more common as a replacement for fossil-based plastics in the marketplace. Studies have shown that items may be produced utilizing biological feedstocks rather than fossil fuels and yet have products with comparable performance attributes (Onen et al., 2020).

DISCUSSION

According to their group and the make-up of the monomer units, PHA bioplastics may be divided into three main groups. The R-group is made up of hydrogen or hydrocarbon chains up to C15 in length. More than 15 carbon atoms make up "long-chain hydroxy alkanoic acids, 6 carbon atoms-14 carbon atoms" make up "Medium-Chain 3-Hydroxy Alkenoates" (MCL-3HA), and 3-5 carbon atoms make up "Short-Chain 3-Hydroxy Alkenoates (scl-3HA)". The composition of five of the 27 monomer units in PHAs may vary from one PHA to the next, which might have an impact on their mechanical properties, such as their hard crystalline and elastic behavior (Jiang., 2016). The condition of the polymer, which can range from rigid and brittle thermoplastics to rubbers and elastomers, is determined by the monomer's makeup. The elasticity of a PHA can be increased by increasing its co-monomer concentration or chain length. Also included are PHAs with short chains, such as "Poly-3-Hydroxypropionate (P-3HP)", "Poly(3-Hydroxybutyrate) (P(3HB), or Poly (3-Hydroxy valerate)" as examples. These materials have a wide range of characteristics, including low water solubility, strong moisture resistance, or hydrolytic breakdown. P (3HP) is known for having high crystallinity, however, P3HB, which has a crystallinity of about 60%, might be regarded as a more ecologically friendly substitute for PP. They stand out due to their robust thermos plasticity as well as UV light resistance. The high polymer flexibility required for use in the production of biomaterials is incompatible with the brittle behavior and high crystallinity levels found in the majority of PHAs. PHAs are widely mixed with biodegradable polymers such cellulose, poly (lactic acid), amylose, lignin, or polycaprolactone to improve their properties (Arias et al., 2020; Riaz et al., 2021). A well-known method for enhancing the performance of the majority of biobased polymers uses PHAs in conjunction with plasticizers. To reduce the dispersion forces and hydrogen bonds, raw polymers such as glycerol triacetate, polyethylene glycol, acetylsalicylic acid ester, acetyl tributyl citrate, 4-nonylphenol, and salicylic ester are coupled with them. This process is known as plasticization. By lowering the glass transition temperature, mineral fillers, plasticizers, and conventional impact modifiers can be used to boost the material's flexibility and toughness (Talan et al., 2020; Winnacker et al., 2019).

In contrast to polymers generated from petroleum, PHA may biodegrade. PHA begins to degrade when it comes into contact with soil, compost, or marine trash. The quantity of exposed surface area, pH, moisture, temperature, and molecular weight are only a few of the factors that influence how rapidly something degrades in the environment. Additional important PHA-related parameters include crystallinity and polymer composition. The characteristics of the monomer units affect degradation as well. Copolymer PHB monomer units degrade more quickly than "PHB or 3HB-co-3HV" monomer units. The polymer is broken down by microorganisms into its molecular hydroxy acid components, which are then used as a carbon source for growth. Since its first discovery, PHB is the first member of the PHA family to get significant attention as a potential plastic replacement. PHB possesses qualities that are comparable to those of petroleum-based polymers. Although normally, short-chain PHA is very brittle and has poor elastic characteristics, whereas medium-chain PHA is more flexible and simpler to shape, PHB may be extruded, molded, spun into fibers, made as films, and utilized to build heteropolymers. Less brittle than PHB is one copolymer, Polyhydroxy Butyrate Co-Hydroxy Valerate (PHBV), which may make it more useful. The piezoelectricity of HBV makes it useful. The fact that 3-

Hydroxybutyrate (HB), a substance that is naturally present in human blood, degrades PHB is advantageous. This homopolymer can thus be used in biological applications like drug transporters and scaffolds for tissue engineering. PHB has been utilized in packaging and little throw-away goods. The author compares polyethylene plastics to PHB as they look at how PHB is used in food packaging (Gao et al., 2011).

PP typically outperforms PHB under typical freezing conditions. PHB fared better than PP at higher temperatures. PHB is a material with a significant amount of crystallinity and a high melting point. Although it is totally biodegradable, optically active, piezoelectric, and has high barrier properties, it is not water soluble. Young's modulus, tensile strength, and elongation at break of PHB are comparable to those of PP, however elongation is much lower. Therefore, it is theorized that internal tension causes fractures inside the PHB, which are triggered by its rigidity. With extended room temperature storage, brittleness increases. Since bacteria serve as the primary catalysts throughout production, PHB doesn't include any leftover catalysts. There is no chain branching and the grammar is isotactic. Because of this, processing proceeds without any problems. PHB possesses the same properties as synthetic thermoplastics, but due to its high cost and limited melt processing window as a result of its brittleness or poor thermal stability in the molten state, its usage has been restricted. Due to its poor heat stability during processing, it loses molar mass and viscosity. About 40% of overall operating costs are attributable to the cost of the carbon source. There are reports of PHB production from a variety of cheap carbon sources (de et al., 2022; Chen et al., 2009). Due to the homopolymer's subpar mechanical properties, the copolymer is used in PHA applications all over the world. To create a microalgae/cyanobacteria-based PHA production system that is economically viable, the PHA content must be adjusted. Numerous research has attempted to increase the amount of PHA by using genetic engineering methods or by improving a manufacturing process parameter. Numerous factors, including as light (quantity or quality), pH, temperature, salinity, and the amount and kind of nutrients in the culture medium, can affect the development of microalgae. Although saline stress does not directly influence PHA synthesis, it may have an impact on the production of carotenoids and lipids. Despite pH's significance in promoting microalgal growth and lipid build up, its impact on PHA generation has not yet been well investigated. Numerous studies have suggested that heat stress or dietary restrictions might raise the PHA level of microalgae. When nutrients like phosphorus and nitrogen are scarce in the growth media, certain microalgae species suffer an increase in PHA content and other intracellular compounds (up to 20% in terms of dry cell weight). This is so that fewer nitrogen compounds are formed (like proteins). When exposed to environmental challenges, such as nutrient-limited growth conditions, cyanobacteria usually have a high propensity for producing PHA.

Biodiesel

Biodiesel is a tried-and-true fuel that has the potential to replace fossil fuels. In contrast to fossil fuels, biodiesel is produced from renewable biomass, which has a reduced impact on the environment. Biodiesel production and use technology has been around for more than 50 years. Investigations on the use of microalgae as a biodiesel source have been conducted on this topic. Microalgae are the best source of biodiesel because they grow rapidly, use little freshwater, and possess a high photosynthetic rate, among other factors.

Microalgae appear to be the only biodiesel source with the ability to displace fossil fuels. In contrast to other oil crops, microalgae develop extremely fast and contain enormous amounts of oil. Usually, microalgae triple their biomass in 24 hours. Biomass may quadruple during exponential growth in as little as 3.5 hours. More than 80% of the dry biomass weight of microalgae may be made up of oil. The high lipid content and quick growth of microalgae are well recognized. Microalgal cultivation can provide adequate feedstock for large-scale biodiesel synthesis and its proliferation doesn't affect food production because it doesn't require arable land. However, to cultivate microalgae with 30% oil in their biomass, which can also produce equivalent biodiesel, just 2.5% of the currently used agricultural land would be required. Similar to larger plants, microalgal cells employ a photosynthetic mechanism to fix CO_2 in the air and transform it into carbohydrates and lipids. Triacylglycerides (TAGs), which are the perfect material for producing biodiesel, are also accumulated in significant quantities by several microalgal species. Therefore, it's possible that the required cropping area% will be less. The photosynthetic mechanism used by microalgae is more cost-effective than that used by heterotrophic bacteria, which produce oil from materials like glucose and other organic compounds. The amount of carbon dioxide emitted by industries, power plants, as well as other industrial sources may be greatly decreased by microalgae. It's excellent news for the environment because certain microalgae can efficiently clean up severely polluted urban and agricultural wastewater that includes too much nitrogen and phosphorus (de et al., 2018) (Choonut et al., 2022). Microalgae may produce beneficial byproducts as a bioreactor system, such as long-chain polyunsaturated fatty acids or carotenoids for food, as well as other chemicals used in the cosmetic and pharmaceutical industries. The total cost of manufacturing will be significantly reduced by the integrated use of these byproducts. Microalgae may produce various fuels such as alkanes, butane, ethanol, and hydrogen through some additional processing stages. Utilizing biodiesel made from microalgae resulted in the least amount of nitrous oxide, sulfur dioxide, and other pollutants produced when compared to diesel made from petroleum.

Microalgal cells have the capacity to synthesize a wide range of lipids. These lipids are categorized into 23 neutral and 11 polar lipids based on their chemical makeup and polarity. Polar lipids, which typically comprise phospholipids (such as phosphatidylinositol, phosphatidylcholine, or phosphatidylethanolamine) as well as glycolipids, serve as structural components of membranes in the majority of situations (e.g. galactosyl diacylglycerol and monogalactosyldiacylglycerol). Wax, isoprenoid-type lipids (like carotenoids), diacylglycerols, Triacylglycerols (TAGs), and monoacylglycerols are examples of neutral lipids. Under various stress conditions, Triacylglycerols (TAGs) are frequently reported to build as a kind of energy storage. In contrast to other vegetable oils, microalgal oils are distinguished by their concentration of polyunsaturated fatty acids with four or more double bonds. For instance, algal oils usually include omega-3 fatty acids and omega-3 fatty acids. Because they are more likely to oxidize when stored, Fatty Acids and Carboxylic Acid Methyl Esters (FAME), which contain four or more double bonds, are less appropriate for use in biodiesel. This issue is also caused by several vegetable oils. For instance, high-oleic vegetable oil contains significant amounts of linoleic acid as well as other omega-6 fatty acids. The iodine value indicates the overall unsaturation level of the oil. The iodine value of biodiesel cannot be higher than 120 iodine/100g and 130g iodine/100g biodiesel, respectively, as per Standards EN 14214 or EN 14213. Furthermore, only 1% mol of FAME may have four or more double bonds in accordance with European biodiesel regulations. Light, water, CO_2, and inorganic salts are necessary for photosynthesis to occur. A temperature of between 20°C and 30°C must be maintained. Inorganic ions, carbon dioxide, light, or water are all necessary for photosynthetic growth. To cut costs, biodiesel production must rely on easily accessible sunshine despite seasonal and daily fluctuations in light. The inorganic components required to produce an algal cell must be present in the growing media. Iron, Phosphorus (P), Nitrogen (N), and, in uncommon cases, silicon, are a few of the essential elements. Determine the bare minimum nutrient needs by using the approximation of microalgal biomass. Not all of the extra P is available because the extra phosphates interact with metal ions, therefore nutrients like phosphorus must be given in sufficient quantities. In addition to a few other micronutrients, commercial fertilizers such as nitrate and phosphate are frequently added to saltwater to enrich it for the growth of marine microalgae (Lee et al., 2012; Choonut et al., 2017).

Microalgal biomass has a carbon content of around 50% by dry weight. Normally, carbon dioxide is the source of all of this carbon. 183 tons of carbon dioxide are fixed for every 100 t of algal biomass produced. All day long, carbon dioxide must be continuously supplied. Reduced carbon dioxide loss or pH changes can be achieved through feeding management in response to pH sensor inputs. Some of the carbon dioxide that is generated in power plants from the combustion of fossil fuels may be used in the creation of biodiesel. Typically, getting this carbon dioxide is inexpensive or free. Despite the fact that microalgal biodiesel is typically carbon neutral, burning fossil fuels won't be significantly reduced as a result of its use. Continuous daytime cultivation is often used in large-scale production of microalgal biomass. The fresh medium is continually introduced while the same volume of microalgal broth is continuously removed while utilizing this technique of operation. Even when feeding stops at night, it is still necessary to stir the soup to keep the biomass from settling. Through respiration, up to 25% of the biomass created during the day might well be exhaled at night. The quantity lost is influenced by a number of variables, including the temperature at night as well as the amount of sunlight needed to grow the biomass. Thermochemical liquefaction is a common method for turning wet microalgal biomass with high water content straight into liquid fuel.

This technique has the advantage of not requiring a drying step, which makes it a possible substitute for many conventional extraction processes. However, biomass drying is an additional step that is always required to include in many lipid extraction methods. Sun drying is the most efficient and economical way to dehydrate microalgal biomass. Drum, spray, fluidized bed, freeze, and reflectance window dehydration technologies are a few effective yet expensive drying techniques. Presses, traditional solvent extraction, enzymatic extraction, and additional techniques used only at the laboratory scale, including such ultrasonic-assisted extraction, and supercritical carbon dioxide extraction, are some of the methods used to extract lipids from dewatered microalgal biomass. Each microalgal strain must be taken into account when designing a press since it mechanically ruptures algae cells. Screw, piston, and expeller presses are only a few examples of the various press designs. Many different oilseeds may be extracted of their oils using screw presses. Although there haven't been any research that extract microalgal oils from cells using this technique, it should be taken into account as a prospective option. Lipids may be quickly and effectively removed from whole cells using solvents (like hexane or chloroform). Sometimes a solvent extraction is paired with a press. The broad use of the solvent approach has drawbacks, too, since it uses more energy and puts more people at danger of fire and explosion because distillation is required to separate the solvent from the extracted lipids. But now days, solvent extraction is the most cost-effective technique. A fast drop in osmotic pressure can result in osmotic shock, which can cause microalgal cells to rupture in solution and release cellular oil and other substances. Some marine microalgae, such *Dunaliella sp.*, which lack strong cell walls, may endure osmotic shock with ease. Oils can be extracted using the potent technique of supercritical CO_2 extraction. Supercritical carbon dioxide's low viscosity and high diffusivity may increase the efficiency of extraction and permit carbon dioxide recycling. Enzymes break down the cell walls while water serves as the solvent during enzymatic extraction. The most crucial factors to take into account when selecting an efficient oil extraction technique are cost, toxicity, efficiency, and simplicity of the extraction process. Due to their high operating costs, supercritical carbon dioxide extraction or osmotic shock are currently ineffective technologies for large-scale microalgal oil production. Commercially speaking, enzymatic extraction of microalgal oils is possible, but significant cost-cutting measures are needed. In order to lower costs, restrict the co-extraction of non-lipid contaminants, and optimize the necessary lipid fractions for the synthesis of microalgal biodiesel, new commercially viable technologies must yet be developed. Few approaches can be employed for large-scale extraction of microalgal oils.

Microalgae

A type of creature called algae may be found in almost any environment. They may colonize different environments such as deserts, volcanic waters, very acidic soils, and frozen soils, albeit the bulk of them prefer aquatic settings. In all ecosystems on Earth, they form the basis of food chains. Additionally, they account for 40% of all worldwide photosynthesis and are the primary oxygen generators. The term "algae" refers to tiny organisms that may be found in both freshwater and marine habitats as well as macroalgae, sometimes referred to as seaweed since they are macroscopic and multicellular. Algae are systematically divided into nine groups, primarily according to the pigments they contain.

Lipid in microalgae cells

Unicellular Microscopic Algae (MSA) are extensively found in nature and live in all of the world's water basins. One of the most crucial elements of living biological substances, lipids greatly influence the energy potential and unique structural-functional characteristics of both the cell and the organism as a whole. There is a class of substances (polyunsaturated fatty acids) found in the composition of lipids that can only be produced by MSA and are essential for both human and animal diets. Since phytoplankton is essentially the only source of Polyunsaturated Fatty Acids (PUFA), which are physiologically significant active components, a study of the fatty acid content of lipids in MSA and, in particular, of phytoplankton, is of great interest. The most crucial elements of cellular membranes, lipids serve as an energy, transport, and defensive component in living things.

Microalgae are a potential source of biomass for the production of alternative fuels due to their capacity to collect large amounts of neutral lipids that are stored as cytosolic lipid bodies. Wide variations in lipid patterns are determined by the diversity of algae, which is likely a result of the algae's ability to adapt to their surroundings. For instance, in response to ecological variables, certain microalgae may synthesize significant quantities of long-chain polyunsaturated fatty acids.

Microalgae as a suitable source for biofuel and bioplastic production

Energy will be one of the biggest problems of the 21st century. Global climate change worries and high energy usage have led researchers and politicians to search for new renewable energy sources. The demand for biofuel has increased significantly over the past few years as a consequence of the fact that it is frequently thought of as the safest and most ecologically friendly of these. However, the substitution of fuel crops for food crops has led to a food crisis in some regions of the world and disagreement regarding the fuel *vs.* food trade-off. Algae have been suggested as a potential source of feedstock for the manufacture of biofuels and other valuable goods, and they can absorb carbon dioxide in an algal bio-refinery.

Up to 250 times, as much oil may be generated by microalgae per acre as by soybeans. In general, manufacturing enough biodiesel from microalgae to meet the current gasoline demand is probably the best option. Microalgae generate 7 times -31 times more oil than palm oil does. Microalgae are the most practical and appropriate kind of algae for biodiesel systems, and they are simple to produce and extract biodiesel from.

The generation of biodiesel from microalgae is also investigated, taking into account their numerous environmental benefits for both water and air. Despite their quick development and high lipid content, microalgal biodiesel synthesis is a costly and energy-intensive process. One of the main challenges is effective oil extraction, and microalgae need specific consideration to make the biodiesel manufacturing process more affordable and doable. Because it reduces the amount of poisonous and damaging gases in the atmosphere, biodiesel made from microalgae has been hailed as a renewable and sustainable energy source with the potential to replace fossil fuels. A novel bio-refinery idea was created using de-oiled algae cake as a bio-resource for the production of Polyhydroxyalkanoates (PHB), making the biorefinery process more affordable and sustainable by fully using the algal biomass without creating waste algal left overs (Fig. 2).

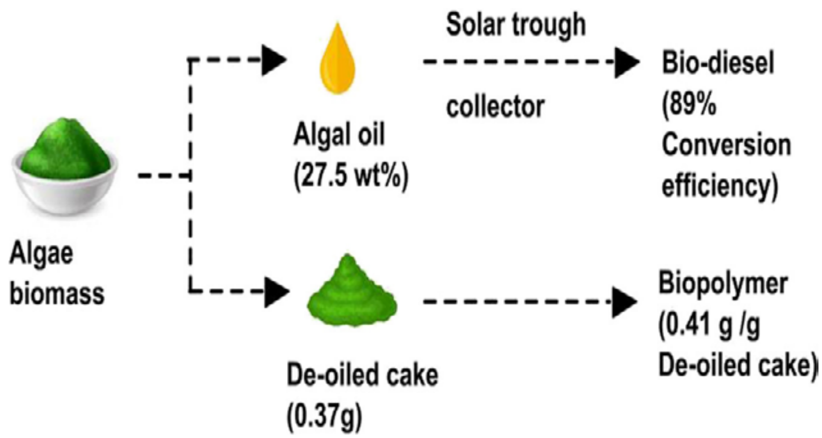

Figure 2. **Microalgae source for biofuel and bioplastic production.**

PHA

In place of petroleum-based plastics, Polyhydroxyalkanoates (PHA) are biopolymers created by a variety of microorganisms that have similar mechanical properties, can be processed similarly, and are biodegradable. The production of commercial PHAs currently takes place in fermenters with bacteria, a significant amount of organic carbon sources, and salts in the culture media, and it costs roughly half as much to do so. The PHA's expanded commercial application is only possible with lower production costs. According to various studies, microalgae are a type of microbe that may be utilized to obtain PHAs at a lower cost since they require little in the way of nutrients for development and are photoautotrophic.

Industrial waste should be regarded as an alternative carbon source for microalgae mixotrophic growing and co-generation of high-value compounds in order to boost bioprocess income and allow large-scale synthesis of microalgae Polyhydroxyalkanoates (PHAs). Potentially replacing traditional polymers like Polypropylene (PP) or "High-Density Polyethylene" (HDPE) are these biopolymers (HDPE). Growing demand for biodegradable plastics, which is being fueled by stringent government regulations and policies against single-use plastics as well as trends related to sustainable development and the circular economy, is driving the PHA industry. The high production cost of PHA, which is up to four times more than that of PP and Low-Density Polyethylene (LDPE) fabrication, is the biggest barrier to its practical implementation, though. PHAs are divided into two groups based on the quantity of carbon atoms in their monomeric unit. Short-chain PHAs (scl-PHAs) have three to five carbon atoms, whereas Medium-Chain PHAs (MCL-PHAs) have 6-14. PHB, the most famous scl-PHA component, is a hard, brittle material that is difficult to handle due to its crystalline structure. By adding 3-Hydroxy Valerate (HV) units to PHB, the copolymer poly ("3-hydroxybutyrate-co-3-hydroxy valerate, or PHBV") is produced. The material becomes more durable, flexible, and heat-resistant as the molar proportion of PHBV in the copolymer increases. SCL-PHAs are mostly used in the production of disposable goods and food packaging materials. As elastomers, the MCL-PHAs are suitable for high-value applications including implantable devices and biodegradable matrices for drug delivery, among others (Riedel et al., 2014).

PHAs accumulate as complex inclusion bodies or granules inside cells. PHA synthase, regulatory proteins, depolymerizing enzymes, and structural proteins known as phases are some of the proteins that are connected to the granules. Recently, this multi-component structure was created as carbon, a term that symbolizes its versatility. These polymers can be thought of as appropriate substitutes for plastics made from fossil fuels, but some issues with their industrial manufacture must be taken into account, such as the high cost of PHA manufacturing and the unreliability of the fermentation process.

Future scope

Biodiesel and PHA are seen as potential substitutes for conventional fuels and conventional plastics, respectively, in response to the growing global demand for biobased goods. These biobased goods reduce environmental pollution and are sustainable and biodegradable. The main barrier to the development of biobased goods is the higher production cost. Microalgae may be used to combat this as they are inexpensive. The manufacturing cost will be further decreased by improving the microalgal strain and optimizing growing factors (such as light intensity, pH, and temperature). By subjecting microalgae to nutritional and environmental stress, their lipid content and PHB may be further improved. Through the transesterification procedure, the recovered lipids may be transformed into biodiesel. The emerging algal-based business is anticipated to expand quickly and soon provide unique products, markets, and employment despite significant bottlenecks and difficulties. Furthermore, the potential for algae-based goods is still quite high given the vast variety and recent developments in systems biology, genetic engineering, and bio-refining.

Conclusions

One important strategy for reducing the cost of acquiring polymers and, as a consequence, improving competitiveness vs synthetic polymers, is to get PHAs from microalgae. Since microalgae are the only bacteria that utilize photosynthesis to get PHAs, they are a reliable supply of PHAs due to their low nutritional requirements for development and the fact that they use CO_2 or light as their main sources of energy. To lessen the warming effect brought on by industrial CO_2 emissions, microbes eat CO_2. These bacteria are crucial to the preservation of the ecosystem. In essence, the production of PHAs from microalgae diminishes the need for fossil fuels and lowers CO_2 emissions, which lessens the process' effect on the environment. The growing conditions, species, and extraction techniques of these polymers all impact their features, which are essential for their commercialization, even though it is still unknown how PHAs are formed in microalgae. Research on microalgae-stimulated PHA synthesis is still in its early phases, as well as the PHAs synthesized are not yet offered for sale. However, microalgae have the great potential to produce biopolymers at a lower cost and are crucial to the environment.

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