Chapter 25

A nano-based biofuel: remedy to boost a sustainable and greener environment

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25.1 Introduction

Energy demand has increased tremendously over the past century. The scarcity of fossil fuels and the prominent issue of the increase in greenhouse gas emissions into the atmosphere which leads to global warming are increasing the urgency for the search for alternatives. This scarcity has a major impact across the world (Srivastava & Prasad, 2000). The overdependence on fossil fuels and petroleum and their scarcity are encouraging researchers to discover alternative energy sources, including biofuels like biodiesel and bioethanol (Cherubini, 2010; Kumar & Sharma, 2014; Silva & Chandel, 2014). Biofuels can efficiently replace the petroleum as they can overcome the associated problems, such as by reducing the emissions of greenhouse gases, providing energy security, and strengthening agriculture also as it uses biomass as a resource. Therefore as the production of biofuel utilizes biomass that is agricultural waste left over after harvesting, it eliminates the problem of disposal and also plays a role in solid waste management. The residue of biofuel production can be used as an efficient biofertilizer (Archana et al., 2020). The most common types of biofuels which are gaining attention among researchers are biodiesel, bioethanol, biohydrogen, and biogas. This is due to them being eco-friendly, utilizing substrates that are nonconsumable, low in cost, and easily accessible (Kaparaju, Serrano, Thomsen, Kongjan, & Angelidaki, 2009; Santoro, Arbizzani, Erable, & Ieropoulos, 2017; Sewsynker-Sukai & Gueguim Kana, 2017). In commercial production, substrates such as animal fats, various sugars, carbohydrates, and cooking oils are used in biofuel production through the process of

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fermentation and esterification (mainly transesterification) (Fukuda, Kondo, & Noda, 2001; Mohammad, Bambang, Muhammad, & Anondho, 2009). The most suitable feedstock used in the generation of biofuel is lignocellulosic substances (Rajakumari, Thiruchelvi, Venkataraghavan, & Biswal, 2018). The utilization of inexhaustible waste substrate reduces the waste treatment cost and adds financial gains for bio-based enterprises (Sivasankaran, Ramanujam, Balasubramanian, & Mani, 2016). Biohydrogen is attracting many researchers due to various factors including high energy production, easy removal of carbon dioxide, effective utilization of substrates, and usage of different bacteria found in diverse environments, physicochemical parameters such as pH, pressure, and temperature, and it is the easiest method of production of biofuels (Das, Khanna, & Veziroğlu, 2008). The contribution of biogas to the development of biofuels is based on the nature of its sustainability (Ganzoury & Allam, 2015; Hwang & Gu, 2013). Apart from these applications, biohydrogen is used in the management of wastes (Miltner, Makaruk, & Harasek, 2017). It is produced by various organisms that are diversely present and are rich in animal farms, composts, wastewaters, and landfills. Mostly archaeal and bacterial species are used for biogas generation, taking place by a biochemical process under anaerobic conditions (Bundhoo & Mohee, 2016; Wong, Wu, & Juan, 2014). An important fuel that is used in diesel engines is biodiesel which has several advantages in terms of technical and environmental conditions (Enweremadu, Rutto, & Oladeji, 2011). The advantages of biodiesel are biodegradability, higher flashpoint, low emission, and its lubricant nature (Haas, Scott, Alleman, & McCormcik, 2001). Bioethanol and biodiesel that are generated from feedstock are first-generation biofuels (Antunes et al., 2014; Zabed, et al., 2014). Major feedstocks such as animal fats and vegetable oils are used for the production of biodiesel. Similarly, sugarcane bagasse and corn agro wastes are utilized for the generation of bioethanol (Silwa et al., 2014). Bioethanol also acts as a substitute fuel to meet energy demand (Azhar et al., 2017; Shafiei, Karimi, Zilouei, & Taherzadeh, 2014). Bioethanol production originated in Europe and the United States in the 19th century, and has an annual growth rate of around 3%−7%. (Aditiya, Mahlia, Chong, Nur, & Sebayang, 2016). In 2017 total ethanol production was estimated to be around 100 billion liters. It is expected to double in the next decade (Aditiya et al., 2016).

25.2 Nanotechnology in the conversion of biomass

The world situation requires we be engaged with nonconventional sources. Biomass has risen as one of the most suitable nontraditional feedstocks for the creation of biofuel (Prema, Lakshmi Prabha, & Gnanavel, 2015). Biomass contributes over 10% of energy supply, and therefore is found to be a most capable energy source. It is ranked fourth among all the primary energy resources (Saidur, Abdelaziz, Demirbas, Hossain, & Mekhilef, 2011;

Wu, Tsai, Chen, & Chen, 2012). Since biobased feedstock is available in huge quantities, it is a potential replacement for fossil fuels. It also plays a major part in controlling atmospheric carbon dioxide, as biomass uses carbon dioxide in the atmosphere during growth. It has been estimated that approximately 38% of the fuel supply globally will be provided by biomass by 2050 (Demirbas, 2000). Among the different biofuels, the most commonly and widely used is ethanol (William et al., 2016). For the economical production of bioethanol, preprocessing of biomass is unavoidable. Improvements in the preprocessing methods could lead to efficient biofuel production. Nanoparticles can be incorporated into the preprocessing as an alternative approach to make it more robust (Pena, Ikenberry, Hohn, & Wang, 2012; Razack, Duraiarasan, & Mani, 2016). When nanoparticles are involved in biomass pretreatment they modify the molecular level reaction chemistry. They also increase the specificity of the biocatalysis (Razack et al., 2016). For sustainable energy production or generation, the use of nanomaterials has attracted many researchers. The use of nanotechnology in biofuel production increases the process efficiency through improved pretreatment effect, hydrolytic processes by the enzyme, and an increase in the fermentation process reaction rate. With respect to nanoparticles, the factors which take part in the increased efficiency and generation are morphology, size, area, and characteristics of the nanoparticles used and of the biomass used (Chaturvedi et al., 2012). Nanomaterials are constituents of nanotechnology which have some inimitable characteristics compared with their products in bulk metals. As reported by Verma, Barrow, and Puri (2013), different nanomaterials such as nanofibers, nanoparticles, nanotubes, and nanosheets have many applications directly and indirectly in relation to biofuels. Enzyme hydrolysis of biomasses that are rich in lignocelluloses is also currently practiced. As demonstrated by Ahmad and Sardar (2014) and Goh et al. (2012), magnetic and metal oxide nanoparticles are used as the matrix in the immobilization of enzymes. This is done through various techniques like physical adsorption, cross-linking, and covalent binding. Such materials are referred to as nanocatalysts. They are manufactured by enzyme immobilization with the use of nanomaterials as a carrier of enzymes (Misson, Zhang, & Jin, 2015). The enriched enzymes immobilized on magnetic nanoparticles can be separated by their magnetic property and can be reused for a new reaction of hydrolysis of cellulose with the use of an enzyme (Alftren & Hobley, 2013; Rai et al., 2016).

25.3 Sustainability of biofuel industries

Despite all the definitions of sustainability, the underlying theme is to fulfill the needs of both the present and future generations, where natural reserves are preserved to secure both the communal and environmental benefits. It allows economic and ecosystem balance by conserving renewable and

nonrenewable resources. The crucial determinant of the biofuel economy is feedstock feasibility. The crops for feedstock, especially those which are rich in cellulose, are more profitable for farmers than other alternative fuel crops. Most of the research into the biofuel economy has narrowed down to the supply-side impacts which include fuel crops, land, and total crop produced. Simultaneously, the demand side should also be taken into consideration. In this context, demand depends on the following factors: (1) the presence of compatible vehicles; (2) the biofuel price; (3) the amount of biofuel and blends produced; and (4) the cost of gasoline (United States Department of Energy and United States Department of Agriculture (USDOE and USDA), 2009). The production of sustainable energy from low-cost renewable biomass is drawing attention worldwide. The lignocellulosic material as a resource is a better option as it has cellulose, lignin, and hemicelluloses in a complex form as polymers. From this type of biomass, bioethanol (one of the biofuels) can be produced through the involvement of the sugar polymers present in fermentation (Taherzadeh & Karimi, 2007). Although the increasing price of crops is a major concern, the availability and use of water is another hurdle, as the process of biofuel production needs a large quantity of water. As reported earlier, lignocellulosic biomass processing consumes approximately 6 gallons of water per 1 gallon of ethanol formed (Aden, 2007).

The interest in increasing the production of petroleum-based chemical products and biomass, degradable bioplastic, and biocompatatibles obtained from renewable biomass are considered as profitable replacements for petroleum-derived polymers and also reduce the demand for fossil resources (Brinchi, Cotana, Fortunati, & Kenny, 2013). This sustainable development of biofuel has led to research on nanotechnology in biomass utilization that is one of the desirable options for ecosystem management and environmental development. It differs based on the context of economy, social, and ecological development (Wegner & Jones, 2009). Applying nanotechnology and utilization of biomass can meet the requirements of the public, social, and economic welfare, leading to success in achieving quality of life with both comfort and ecology development (Mäki-Arvela, Salmi, Holmbom, Willför, & Murzin, 2011).

25.4 Eco-friendly green environment

The extensive use of natural resources leads to economic development but also damages the ecosystem and raises more environmental issues (Panwar, Kaushik, & Kothari, 2011; Qi, Shen, Zeng, & Jorge, 2010). To reduce the wastage of energy and carbon emissions, countries around the world have enacted new environment-related regulations, such as the restriction of chlorofluorocarbons in the Johannesburg world summit, and similar rules for the use of dangerous materials (Claver, López, Molina, & Tarí, 2007; Zhu & Sarkis, 2004). The awareness of the necessity for an eco-friendly environment has

grabbed the attention of the public and also creates competition among various companies associated with the fuel industry (Porter & van der Linde, 1995). To meet the requirements of the new regulations, the biofuel industries have moved toward eco-friendly methods of practice and marketing according to the proposed regulations, and have had to come up with practices that are environmentally friendly. They have also used new branding methods and images toward environment sustainability (Chen, 2008; Hillestad, Chunyan, & Haugland, 2010). "Going green" has been the tag line for many industries, giving hope for their sustainability. In this way, they can deal with the environmental concerns that they face in global competition (Davis, 1995; Schiederig, Tietze, & Herstatt, 2012). Silver nanoparticles can be utilized for the management of harmful pollutants that are present in the environment (Muthu Kumara Pandian, Karthikeyan, & Rajasimman, 2016).

25.5 Nanotechnology in bioethanol/biobutanol production

The term nanotechnology is derived from the Greek terminology "nano," which means dwarf. Nanotechnology is used to exploit the nature of materials from mole levels to atomic levels to form new structures called nanomaterials. Nanomaterials exhibit distinct characteristics that they did not possess as the bulk source material they were obtained from (Warad & Dutta, 2007). The size of atoms is very much smaller, in the range of 0.1−1 nm, when compared with viruses and bacteria. Nanotechnology is a technology that can process, form, and produce materials in the atomic to molecular levels (Zhang et al., 2009). Feynman coined the term "nanotechnology" in 1959 to represent the technique used for nano-scale materials production (Jiang, Win, Liu, Teng, & Zheng, 2013). Since then, research has been carried out to study the impacts of nanoparticles in numerous industries ranging from electronics, food, and energy-associated devices (Wu, He, & Jiang, 2008). Studies have shown the effect of nanotechnology in the biofuel industry which has become an efficient tool to produce biofuel with efficient methods and in a cost-effective manner (Sekhon, 2014; Serrano, Rus, & Garcia-Martinez, 2009). The main reason for applying nanotechnology in biofuel production is to bring about the scientific as well as engineering solutions to produce nonpolluting energy resources (Ramsurn & Gupta, 2013). Another application includes using nanoparticles as additives for biofuel to enhance different blends of fuels (Trindade, 2011). As reported by Renn, there is a knowledge gap on the crucial facts, such as the negative effects of nanoparticles on humans. It also passes through different layers of soils and can enter into groundwater (Alargova and Tsujii, 2001). In this way, broad investigations including the assessment of the toxicological concerns about nanotechnology in any uses, including biofuels creation, are required (Justo-Hanani & Dayan, 2015). Nanoparticles play a crucial role in the production of biofuel in light of their uncommon physicochemical properties.

Numerous nanomaterials, for example, TiO_2, Fe_3O_4, SnO_2, ZnO, carbon, graphene, and fullerene, exhibit one-of-a-kind features, which can be manipulated in biofuel synthesis. In addition to these attractive properties, nanoparticles have wide applications in biofuel creation as a result of their increased surface−volume ratio, and atomic properties because of their tiny size (Ahmed and Douek, 2013).

25.6 Nanotechnology in bioenergy production

Nanotechnology is applied in the enhanced production of biofuel as a promising technique using nanoparticles of different sizes. Nanoparticles differ from bulk materials in their important physical, chemical, and electrical properties. Reports have shown that energy production from solar power, water, and biofuel can be increased using nanotechnology (Hussein, 2015).

25.7 Nanotechnology in biogas production

The anaerobic digestion of organic wastes obtained from plants, animals, humans, and agricultural practice produces biogas. This waste contains a high percentage of nitrogen and carbon. The amount of energy produced varies with respect to the ratio of carbon and nitrogen. (Feng, Zhang, Quan, & Chen, 2014). Energy production by methanogenic bacteria needs the action of trace amounts of metal ions which produce a catalytic effect for increased production due to the activity of bacteria. Research has demonstrated that these ions when used in nanoparticles instead of bulky materials, have highly productive results (Feng, Karlsson, Svensson, & Bertilsson, 2010). Nanoparticles have high magnetism and increased coercivity, therefore they can be used to increase the efficiency of methanogenesis. Mainly cobalt and nickel nanoparticles were found to increase gas production. In the case of iron, iron oxide nanoparticles produced greater effects than iron nanoparticles (Abdelsalam, Samer, Abdel-Hadi, Hassan, & Badr, 2015). Abdelsalam et al. (2016) found that when cow dung was used for anaerobic digestion, different nanoparticles such as Fe, Fe_3O_4, nickel (Ni), and cobalt (Co) yielded the highest activity. Casals et al. (2014) reported that when Fe_3O_4 nanoparticles were used in the digestion of organic matter for methane as well as biogas, the anaerobic digestion of organic wastes obtained from plant, animals, humans, and agricultural practice produces biogas. Carbon- and nitrogen-rich waste can be utilized by methanogenic bacteria which require the action of trace amounts of metal. Biofuels were found to be the solution, due to the advantages in reducing the greenhouse gas emissions and supporting increased agricultural development. The leftover waste from agriculture and farm animals has been utilized as the raw material in biofuel production, and the used substrate waste can be used as biofertilizer. Thus biofuel plays a major role in solid waste management.

25.8 Impact of various factors that affect nanoparticles in biofuel production processes

Several factors that influence the performance of nanoparticles in biofuel production processes, including the method of production, pressure, temperature, and pH condition of medium, etc., employed for synthesis (Khan, Saeed, & Khan, 2017). Some of the parameters involved in production are discussed next.

25.8.1 The synthesis approach

Previous findings on the utilization of nanoparticles for biofuel production report different methods are available for the production of nanoparticles which involve microemulsion, thermal decomposition, coprecipitation method, synthesis using biological organisms, and hydrothermal synthesis (Baker et al., 2013; Iravani, Korbekandi, Mirmohammadi, & Zolfaghari, 2014). Each method has its advantages and constraints. On the other hand, natural techniques are enthusiastically prescribed for synthesis because they utilize nonpoisonous and eco-friendly materials, and have been shown to have negligible inhibitory effects on biocatalysts during biofuel creation. Moreover, combining nanoparticles from plants and microscopic organisms is preferred since they utilize less energy and are more affordable (Lu, Salabas, & Schuth, 2007).

25.8.2 Temperature in nanoparticle synthesis

One of the critical parameters involved in the synthesis of nanoparticles is temperature. So-called calcination temperature ranges from 100°C to 700°C dependent on the process of metallic nanoparticles synthesis (Kozhushner et al., 2014). Different methods of synthesis are used for nanoparticles and the temperature for each method differs for chemical and physical methods, where the temperature is greater than 300°C, and for biological synthesis, where it is less than 100°C (Qu, Yang, Fan, Zhu, & Zou, 2006).

25.8.3 Pressure in nanoparticle synthesis

Another important factor in nanoparticle synthesis is pressure. A change in pressure alters the physical and structural properties of nanoparticles. Reports state that increased pressure tends to increase the size of nanoparticles (Yazdani & Edrissi, 2010).

25.8.4 pH in nanoparticle synthesis

At acidic pH, which is below 7, both the stability and accumulation of nanoparticles increase. Hence the nanoparticle shape, geometry, and size can be

increased or decreased by changing the pH while nanoparticles are being synthesized in a process (Sekoai et al., 2019). Metallic nanoparticles like gold, silver, copper, lead, and zinc perform efficiently when the optimum pH is provided (Armendariz et al., 2004).

25.9 Current technologies and their impacts

Nanotechnology, with its extraordinary potential, ensures enhanced synthesis and improved properties of biofuel. The use of nanotechno-components can improve the characteristics of biofuel. It can improve the creation rate, by upgrading response energy, and decrease the creation cost by reducing material expenses and handling time. However, it also has some disadvantages. Size of the catalyst in nanomaterial coating plays a significant role in determining the diffusion. Depends on the catalyst size the diffusion will vary. If the catalyst size is small, diffusion will be more whereas if the if the catalyst size is high, lesser the diffusion. For instance, in protein immobilization forms, a portion of the chemical particles installed in the pores or the inward periphery of mesoporous silica, which confines the dispersion of substrate as well as the product toward the enzyme, results in a lower compound action. During the process, there exists a catalyst loss because of non controllable coating process. In addition, nanotubes and nanoparticles display bulk exchange confinement, where the distribution and regeneration are progressively difficult. The creation of nanoparticle forces may produce adverse health effects to humans who are involved in the production process. The nanocatalysts still have selectivity problems, where the target response is improved but the partnered responses may likewise be quickened. The cost is another reason that this technology is not as effective when new ideas and innovations are developed. There are some issues to be addressed before biofuel cells can become serious realistic applications. Two major issues are reduced lifespan and poor density potential, both of which are identified with chemical security, electron movement rate, and protein stacking. Ongoing advancements in nanobiocatalysis open the likelihood of addressing these perspectives (Zhang, Yan, Tyagi, Surampalli, & Zhang, 2010).

25.10 Future prospects

Nanomaterials have a vital role in the effective production of biofuels in terms of quality and quantity. Nanomaterial types alter the process of producing biofuel through numerous ways including an increase in the cellulose enzyme stability, increase in digestion in both chemical and biological processes, and by improving the formation of biohydrogen through catalysis. This influence is due to the unique catalytic activity acquired because of their shape, structure, and size. These properties must be taken into consideration in utilizing the corresponding method. It is important to know the

molecular mechanism behind how the nanomaterials are altering the production process. The cost of the synthesis of the nanoparticles involved in improved production of biofuels must be addressed. The economically viable synthesis of nanoparticles could be an alternative solution for the effective economic production of biofuels. This technique is in its primary stage and several obstacles need to be cleared, such as the cost and the various molecular interactions between the biological components (Srivastava et al., 2017).

26.11 Conclusion

Biofuels are potential solutions for the present situation in regard to energy security, a decrease of greenhouse gas emissions, and reinforcing of horticultural improvements. The use of nanomaterials in the sector of sustainable power sources is discussed in this chapter. It is clear that nanoparticles are important with a vital role in the development of biofuels from their advantageous properties. Although biofuel industries are utilizing nanoparticles in biofuel production to gain benefits from available resources, nanomaterials are considered as effectual. Therefore much research is required as this is a developing field. This technology has a remarkable role in conquering critical factors which are barriers to other methodologies. The principal advantage of this technique is that the creation of biofuels will be both eco-friendly and economical. In accordance with this, it can be concluded that nanomaterials have the potential to produce a favorable and advantageous end product. In order to quicken their application in bioprocesses, focused investigation and numerous obstacles need to be addressed effectively since the research in this field is very limited.

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