Chapter 3
Coconut Shell as a Promising Resource for Future Biofuel Production

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Abstract Production of biofuel is an upcoming and crucial field in environmental biotechnology, due to the rising energy crisis and increase in the cost of the commercially available fossil fuel across the world. This has attracted many researchers to take a series of steps to find a resolution and to develop economically feasible source to produce as an alternative fuel. Many local communities who own small scale industries are not aware of how potential the coconut shell is, used as a biofuel. As the cost of petroleum price is increasing, simultaneously with the increase in demand of the same with depleting energy sources and supply, there arises an urge to go for eco-friendly and sustainable process for the production of biofuel. Coconut shell is being used by farmers as organic fertilizer as it has the capacity to conserve the moisture in the farm land and also it helps in the reduction in the nutrient loss during farming. In the course of time, the coconut shell is modified into compost by which it exhibits the property of fertilizer. So, if the coconut shell is being taken up as a source to produce biofuel, with low cost, it reduces the pollution due to carbon dioxide emission and it's by product can be used as fertilizer.

Keywords Coconut shell · Biofuel · Energy · Fertilizer

3.1 Introduction

Energy is an essential aspect for human being to retain development growth and sustain standard of living. Through worldwide, the transport sector is the second highest energy consuming one next to other fast growing industries and found to account for 30% of the world's total energy. The energy sector has faced a stable development in the past years. It has been estimated that the energy used for transportation is anticipated to rise by 1.8% average per year during the period from 2005 to 2035. Almost all energy consumption in the transport is from fossil fuel in the form of oil i.e. 97.6%.

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Nevertheless, the likely depletion of fossil fuels and the environmental issues related with firing them has made many researchers to involve in research to find alternative fuels (Atabani et al. 2012). To meet the future energy crisis globally energy crops which could be used for the production of biofuels, play a significant role. On the other hand, Energy farming in general refers to the use of agricultural lands for the production of energy instead of agriculture. Production of biofuels from energy crops are ecofriendly, economically feasible and easier to maintain energy production in a sustainable manner. Thus, investigation of substrates for biofuels from energy crops at present and in the past is very much required currently (Kocar and Civa 2013). Due to over consciousness of public towards pollution, rapid degradation of fuel sources, demand for petroleum products pave a way for the generation of biodiesel (Chozhavendhan et al. 2018). Identification of energy crops for production of biofuels is selected mainly on their characteristics as well as the environmental conditions adapted for their growth and development (Tian et al. 2009). Biofuel is a fuel obtained from biologically degradable materials, either from plants or animals. There are three types of biofuel when processed and has three forms such as solid, liquid or gas. The biofuel obtained from farmland biomass directly like rice hull, coconut shell or corn stalk and fuel wood takes solid form (Yerima and Grema 2018). Biofuel can be used in different forms of fuels for transportation. Although all fuels are produced mainly by utilizing plants as the major source, but the method involved in development of biofuels vary from one another. The method of breaking the sugar compounds into ethanol through fermentation process is used for bioethanol production. Similarly, energy dense fuels are obtained from plant biomass which is rich in lignin content by pyrolysis method is adapted for the production of biooil (Sorek et al. 2014). Dumping and removal of organic waste is a threatening issue met by the humans across world wide as there is increasing existence of normal human beings leads to the decrease in mortality. As a result, the population of human is rising quickly and their day to day activities and habitat are the major cause for the enormous production of waste (Jansirani et al. 2012). With respect to the versatile Coconut (*Cocos nucifera*), it is often used in traditional cosmetics (Madakson et al. 2012; Tan et al. 2008).[1] Because of sudden change in the cost of power resources such as fuel oil, natural gas and electricity, in some african countries, the waste from coconut are burnt and has been used as fuel (Madakson et al. 2012).[1] Abundant use of Coconut husk and shell for various purposes, these agro wastes are generated in large amount globally, thus creating pollution to the environment, coconut based biofuels can be used as an swap for the production of fuel and can be utilized in power plants for generation of energy. Because of low ash content, formation of high volatile substance and can be bought at cheap price, pyrolysis method is employed for fuel production from coconut shell (Yerima and Grema 2018). As lignin and cellulose is present in large amount, coconut husk has a high calorific value, lower ash content and moderate moisture content (Yong et al. 2009). The husk of mature coconut is made up of more fibers surrounded by a soft tissue called pith. Usually the fibers are about 15–35 cm

[1] http://www.worldwatch.org/biofuels-make-comeback-despite-tough-economy. Retrieved on 31 Aug 2011.

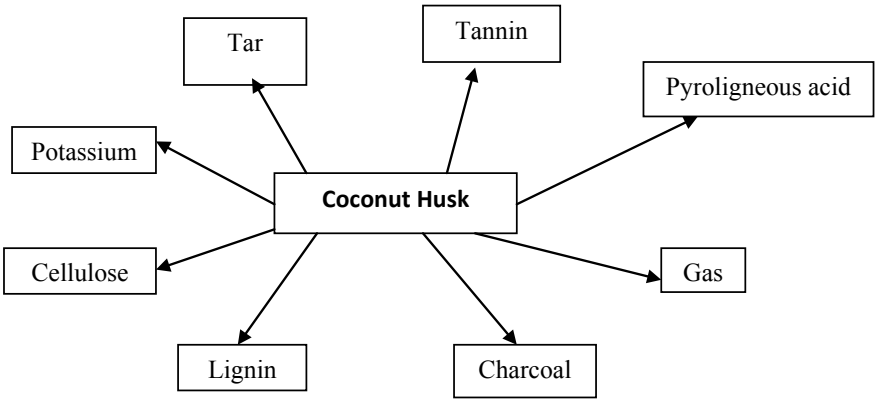

Fig. 3.1 Components of coconut husk

large has large tensile strength, made up of lignin and cellulose. Coconut shell found in the mature coconut is dense material which is in uniform and made up of lignin and cellulose. Nearly 16.7 and 18.2 GJ/Tonne is produced in coconut husk and shell respectively. In general, both the coconut shell and husk are used as fuel for domestic use and for copra drying (Krishna 2010). Major part of the coconut is husk. Till date these husks are used as source of fuels for coconut processing, alternate household fuel and as fiber in the production of ropes and mats (Tan et al. 2008). Coconut is being planted in many countries around the world mainly Indonesia, Philippiness and India that produce nearly 75% of world coconut production nearly. In coconut fruit the fiber content is about 30%, of 40% coconut husk and remaining is of dust (Fig. 3.1).

Among the chemical components listed above, Coconut husk has more lignin and cellulose content when compared to other chemicals. Bacteria and fungi are more resistant in the materials that are obtained during the coconut fibers and husk casting process. Coconut husk and shells, an eye-catching feedstock for biofuels and charcoal, which is a byproduct obtained during processing. Agricultural waste generated from burning of coconut shell, contributes to the emission of CO_2 and CH_4 in many countries. Coconut shells and coconut husks can be classified as with many pros and cons. Coconut shells are processed by using pyrolysis method as it has less percentage of ash content and higher percentage of volatile substances. The most important use of coconut husks through burning in order to produce charcoal; if husks are discarded and it can be harmful but can be transformed into a improvised source which can replace fuel wood and other sources (Yerima and Grema 2018). Energy created from biomass and impact agricultural wastes is considered as cheaper sources for continuously power generate, and these are potential sources of energy which is renewable and ecofriendly (Appels et al. 2011). Though many researchers works for the production of biofuels from coconut husk, this review intends to give focuses on different methods for the same coconut husk as the potential feedstock for

biofuels production which enables the enhancement of the sustainable development of local community (Bolivar-Telleria et al. 2018).

3.2 Transportation Biofuels

Nowadays biofuels are classified into three generations such as first, second and third. Traditional or Conventional chains come under the category of First generation. Second generation involves multifaceted and costly process when compared to first generation. Third generation biofuels are the follow-up of Second generation (Lang 2001).[1]

3.2.1 Biofuels Versus Fossil Fuels

Use of biofuels over fossil fuels seems to be advantageous based on the effects influenced by environment are taken into consideration. If more priority is given to preservation resources from greenhouse gases and fossil fuels, all biofuels favourably plays an effective role when compared with fossil fuels. Impacts brought out by environmental events like acidification, eutrophication or ozone depletion results in opposite effect. In fact, these disadvantages are connected to aggressive agricultural productions that results in emission of nitrogen compounds which creates bad impacts on the environment. Advantages of biofuels vary with one another based on the feedstock (Quirin et al. 2004). Apart from the known sources utilized for biofuel production, waste plastics accumulated in local areas could be used in biofuel production as it has high heat of combustion (Mohana Jeya Valli et al. 2012).

3.2.2 Bioethanol

Energy crops such as sugar beet, maize and Sugarcane are commonly used as substrates for bioethanol production (Kocar and Civa 2013). In 2013, production of Bioethanol from coconut oil accounts for 5.4% coconut oil consumption around worldwide (Moss et al. 2010). At present, sugar crops are paying more attention in the manufacturing of Bioethanol (Kocar and Civa 2013). Pure ethanol can be used as a fuel for transport system, but it is frequently used as a preservative of gasoline to enhance octane and develop automobile emissions. USA and Brazil are the major users of Bioethanol nowadays.[1] The US produces more ethanol than any other country; Brazil is the second most country next to US in ethanol production (Biomass energy data book 2011).

3.2.3 Biodiesel

Biodiesel is an emerging fuel around worldwide. In 2010, European Union, the world′s largest biodiesel producer accounts for 53% of all biodiesel production.[1] The tremendous growth of biofuels industries creates a larger amount of glycerol as the by-product which turn out to be a serious threat to the environment (Chozhavendhan et al. 2016). Raw materials such as canola, corn, soy, palm and rape seed is the most used substrate for the production of biodiesel. Other than these substrates, cotton seed, mustard seed, sunflower and peanut are considered as a raw material for biodiesel production. India accounts for only 4% of soybean production when compared to other countries such as US, Argentina, Brazil and china. Based on the availability of raw materials, different oils have been used as substrates in different countries. US utilize soybean oil and European countries employ rapeseed oil, whereas in Malaysia and Indonesia, coconut oil and palm oils are used for biodiesel production (Demirbas 2009). In India and southeast Asia, the feedstocks that are predominantly used for the production of biodiesel are *Pongamia pinnata*, *M. indica* and *Jatropha cursas* (USDA–FAS 2012).

3.2.4 Biogas

Biogas refers to the method of converting organic waste into an fertilizer, the effective method of disposal of aquatic weeds, agricultural residues, animal, human excreta and other organic materials under anaerobic conditions (Weiland 2003). Biogas, one of the alternative energy source used as a potential fuel in rural areas. The method involved in production process is technology is uncomplicated and become a thriving one across globally in the energy markets. Biodegradable waste materials such as straw, manure, sugarcane, agricultural and industrial processes byproducts and particularly full-grown energy crops can also be used for the energy production (Long et al. 2015). Farmers focus more attention in the biogas production since it is used as a source for generating money. Similarly the environmental and climate condition is well adapted for the production process. Germany, the leading biogas producer introduced new technologies in the biogas production process for the conversion of energy crops (Weiland 2003). Biogas market in many countries is inspired by the use of maize making extra expenses due to methanisation (Eurobserv'ER 2010).

3.3 Biomass Resources

Biomass is defined as the residues that are left over by the biological substances from different wastes such as forest, food, agro and other organic materials. Different forms of substrates that can be used as biomass are available in many types in india.

These resources can be categorized into different types that ranges from grasses to aquatic plants. Among them, algae and jatropha is used in the production of biodiesel. Industrial waste, agricultural crops, municipal waste are the major sources for energy production (Williams et al. 1997). Different components that are used as biomass are carbohydrates such as Monosaccharides, Disaccharides and polysaccharides, Lignin, fat, Crude proteins and crude fibres. Fat has higher percentage of carbon and energy composition of 75 and 39.8% among the various components (Encyclopedia of Energy and Environment 1997). The biomass available in our country is being classified into Energy crops, Agro, Industrial waste, Agricultural waste, Municipal solid waste and forest waste (Kumar et al. 2015).

3.3.1 Bio-Fuels from Biomass

Biomass usually refers to any biodegradable waste material from plant sources such as corn, perennial grasses and sugarcane that can be used as fuel or substrates as a product for industrial production and not including any organic material. It can be measured in terms of dry weight. These fuels can be used as a fuel in different transport systems. Most commonly used biofuel today are ethanol and biodiesel (Encyclopedia of Energy and Environment 1997). Different crops can be used as feedstock for biofuels but the environmental factors restrict the use of such crops and development of novel crops is needed. Predominant feed stocks that are used for fuel production are woody species and crop residues. Currently, the substrates that are used for fuel production are food crops and development of non food crops is still in progress (Long et al. 2015). There is no significant method adapted for the complete utilization of feedstock into sugars in fermented form (Carrijo et al. 2002).

3.3.2 Biomass Use in the Developing World

Biomass which is a part of the carbon cycle, is a renewable fuel source, and is frequently called as "carbon neutral" fuel. The carbon that prevails in the atmospheric environment is converted into organic substance through photosynthesis, emitted back to the same or soil through decomposition or burning. This takes place over a shorter duration and results in zero "net" carbon emissions. It is noted that the percentage of carbon present in biomass is 50 times by its weight (Smith et al. 2003).

The production of bioenergy and bio-based products is an emerging trend. Integrated processes and equipments used in the conversion of biomass into biofuels, power, and chemicals are referred to as biorefineries. Such refineries focus specially on processing biomass feedstock into valuable products like chemicals, fuels, pressboards, biocomposites, and so on. The biorefining from agricultural and plant resources is fast approaching due to the advancements in hydrolysis of the cellulose available in feedstock (Jarvis 2015).

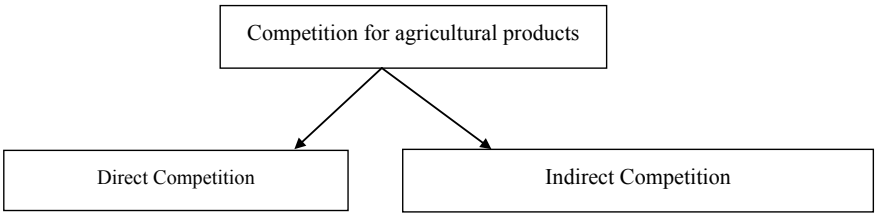

Fig. 3.2 Competition among agricultural products

Recent studies on the process of obtaining energy crops based biofuels shows that there are numerous chances of finding novel potential energy crops that can be used as substrates upon the development of new techniques for conversion and for pretreatment methods with future perspective respectively (Kocar and Civa 2013). In the current situation, many countries are taking significant steps towards a biobased economy. Newer bio-based products have started to act as good replacements for fossil based products. Due to this drastic change, the emission of greenhouse gas are decreasing (de Jong and Jungmeier 2015).

3.4 Biofuel Impact on Agricultural Markets and Food Security

The increase in biofuel demand in turn increases the demand for feedstock. The main feedstock commonly opted for biofuels throughout the universe is crop residues. The more biofuel demand increases, there arises a competition with respect to the use of agricultural products for food, feed, value added food products, and industrial uses. This can have a great impact on human food consumption in domestic areas as well as international level. It also results in greater hit on agricultural and livestock markets (USDA–FAS 2014) (Fig. 3.2).

Production of Bioethanol and Biodiesel may root to indirect land-use change as a result of expanding production (Goldemberg 2008).

3.5 Biofuel Production from Coconut

Coconut (*Cocos nucifera*), a palm tree comes under the group *Arecaceae*, grows well in the atmosphere which is rich in moisture. This fruit can be used as a source to obtain oil and its juice is used in drinks (Egneus and Ellegard 1984). Two important commercial products such as copra and fiber are obtained from the nut present in coconut. Oil and oil cake is extracted from copra. The coconut shell is mainly used as a furnace for firing in large amounts like lime kilns, etc. Using destructive distillation, chemicals such as wood spirit, phenol, etc., gas and charcoal are obtained

during processing of coconut shell. Activated carbon is produced by utilizing the charcoal obtained during the coconut shell processing, which can be used as gas masks alongside its usage in oil refinery and its application in decolorizing sugars. The energy calorie value of shell and shell charcoal are 4794 and 7222 kcal/kg, respectively (Vimal and Tyagi 1984). The mature coconuts are dried for its use in meat, milk and oil (Martins et al. 2016).

During the coconut processing, a lot of residues are left behind such as husk, fiber and shell and as well as pulp residue after extraction of coconut milk, which can be used as feedstock for biofuel production (Mariano et al. 2018). Most seed oils contain the major fatty acids such as lauric acid, palmitic acid, oleic acid, linoeic acid, linolenic acid and stearic acid. In coconut lauric acid is present in the seed of coconut kernel. The lengths of carbon chain present in palmitic, oleic, stearic, linoeic and linolenic acids were found to be 16 and 18 carbons, whereas 12 carbon chain is present in lauric acid (Gunstone et al. 2007; Metzger and Bornscheuer 2006). Good quality oil is produced by coconut and oil palm kernel (Gunstone et al. 2007). On the other hand, while the oil from both the sources together comprises of about 7% of the plant oil used annually worldwide, remaining sources all together represents <1%. This variation is due to high production costs, which leads to limitation in the number of applications (Carlsson 2009).

3.6 Biofuel Production Technology

The production of biofuels comprises of three fundamental stages (Fig. 3.3).

In order to reduce the uprising of the lignocellulosic material so that the accessibility to all polymers in the biomass increases, to reduce the cellulose crystallinity, porosity and surface area of the material, the crucial step of pretreatment should be performed (Cardona et al. 2018). In enzymatic hydrolysis, the enzyme further reduces the cellulose and converts it into fermentable sugars (Aguilar et al. 2018). The previous two stages come in combination to produce increased sugar concentration before fermentation (Su et al. 2015).

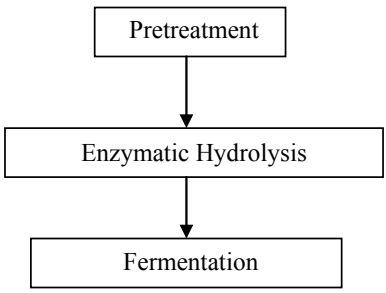

Fig. 3.3 Stages of biofuel production

3.6.1 Pretreatment of Biomass

Conversion of biomass into ethanol as a substrate is a tricky one since the removal of lignin, cellulose and hemicellulose is at risk in hydrolyzing the chemical and biological substances (Sarkar et al. 2012). Pretreatment methods for biomass are classified into three types such as physical, chemical, biological and physicochemical (Park 2010; Wyman 1996).

Physical pretreatment: It involves the disruption of cell wall components that are present in lignocellulosic substances with the help of mechanical process. Commonly used methods for physical treatment are milling, irradiation, heat or steam treatment (Taherzzdeh and Karimi 2008).

Chemical pretreatment: This method makes use of interaction of hemicellulose substances with chemical solutions to release the substances such as lignins, celluloses and hemicelluloses. Examples of this method are alkaline, acid and ozonolysis treatment and wet oxidation (Taherzzdeh and Karimi 2008).

Biological pretreatment: Microoorganisms that are used for the degradation of lignin and hemicelluloses, but this method is not efficient when related to physical and chemical methods (Taherzzdeh and Karimi 2008).

Pretreatment and hydrolysis methods are essential in order to extract fermentable sugars for production of Bioethanol. Investigation of best pretreatment method from coconut husks was studied (Ding et al. 2012). Use of alkali such as sodium hydroxide and calcium hydroxide for the removal of lignin and xylans in pretreatment will boost the saccharification of enzymes (Park 2010). Sodium hydroxide is the most commonly used alkali for the pretreatment of lignocellulosic substrates due to its unique characteristics (Kang et al. 2012). Due to over usage of coconut in brazil, there is an excess disposal of coconut husk. This coconut husk during decomposition release methane gases results in environmental pollution (Brito et al. 2004). Degradation of coconut husk using natural method took long time for the decomposition process.

As a part of enrichment of coconut husk, many optional methods are proposed to diminish the level of lignocellulosic biomass content in the environment (Carrijo et al. 2002). Bioethanol production from coconut husk was done by using alkaline and enzyme and the composition of chemicals was analyzed before and after the alkaline treatment. Based on the study, coconut husk is a good substrate for fuel production (Cabral et al. 2016). Fuels from coconut are less cost than other fuels used in transport which are used to generate revenue to the farmers (Krupa et al. 2018).

3.7 Properties of Coconut Husks and Shells

Calorific value of coconut husks and shells was measured in order to use this as a fuel by replacing the wood. To measure the calorific value, bomb colorimeter is used and the amount of heat generated was recorded. 17.40 and 10.01 MJ/kg calorific

values was found in coconut shells and husks respectively. Hence coconut shell can be used as an alternative for the generation of energy and drying of crop (Amoako and Mensah-Amoah 2019). In order to use coconut shell as a source for fuel in Nigeria, different parameters like calorific value, Moisture content, Density, Ash content, Value Fuel Index, specific heat Capacity was studied. The results revealed that it has higher calorific value and lower ash content, moisture content, CO_2 as well as it does not produce any unpleasant odour when related to fuel generation from wood and rice hull. This will results in decreasing the utilization of natural resources (Yerima and Grema 2018). In Philippiness, coconut shell charcoal is comparatively high than wood due to high energy value and it is used for domestic and industrial use (Tc et al. 2002). Standard methods were used for the determination of physical properties such as Density, viscosity, flash point, GCV and pour point. Elemental analyzer was utilized for the analysis of elements like Carbon, Hydrogen, Nitrogen and Sulphur. From the analysis, it was found that the characteristics of oil is heavy, moderate heating value and viscosity (Joardder et al. 2011).

3.8 Byproducts from Coconut Husks and Shells

Coconut husk has the potential ability to generate silica, which can be used as a substitute for silica. In coconut fruit, the mesocarp is coconut husk which occupies the major percentage of about thirty to thirty five percentage. These husk are used as fuel source for coconut processing, domestic fuel as well as fiber sources in the manufacturing of ropes and mats (Tan et al. 2008). Similar to silica, extraction of SiO_2 was done, which can be a cheap method for production of silica since it is obtained in pure form an also best method for conversion of agricultural waste (Anuar et al. 2018). Coconut husk and shells can act as a good resource for fuel and charcoal. Coconut husk is mainly used for the production of charcoal. Activated carbon, which is produced from coconut shell is used in for eliminating the impurities present in waste water (Yerima and Grema 2018). Fixed bed fire tubing reactor used for the renovation of coconut shell into pyrolytic oil was performed and products like gases, oil and char was obtained (Joardder et al. 2011).

3.9 Conclusions

Biofuels are possible solutions for the present scenario with respect to energy security, reduction of Green house gas emissions and strengthening of agricultural development. The problem of disposal of agricultural and animal waste is overcome by their utilization as substrate for biofuels production, also the solid waste residues post biofuels production has the potential for effective biofertilizers. Among the agricultural products employed in the biofuels production, coconut shell possesses wider range of advantages over the other crop and animal residues due to its unique properties

and its unchanging nature with respect to various environments. The composition and efficiency of biofuels is likely to change when crop and animal residues are employed. This problem is overcome by substituting coconut shell. Increasing the biofuels production will have direct impact on the energy crisis faced globally. It not only addresses the development of agricultural commodities, food security but also provides promising solution for the agricultural and household solid waste disposal. Biorefining this material for the production of biofuels and other end products with greater benefits will enable the countries globally to generate new jobs, income and resolve the present environmental crisis.

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