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A REVIEW OF BIOFUEL AND BIOCHEMICAL PRODUCTION FROM FOREST AND AGRICULTURAL WASTES

Adekunle E. A[1*], Ayodele O.O[2], Akala A. O[1]. Olorode E.M[1], Agbejinmi B.D[1], Ademola A.A[2] Oyediran R.I[1]

[1]Biotechnology Center, Forestry Research Institute of Nigeria, Dugbe Ibadan, Nigeria
[2]Bioenergy Section, Forest Product and Utilization Department, Forestry Research Institute of Nigeria, Ibadan, Nigeria
***Corresponding author:** *adekunleea@gmail.com,* +234-706-229-5251

ABSTRACT

Utilization of fuels and chemicals from fossil fuel and its derivatives have some disadvantages. Forest and agricultural wastes such as wood wastes are potential resources for the production of chemicals and biofuels. These wastes are lignocellulosic materials which are cheap, renewable and their conversion to bio-based chemicals contributes to resource and environmental conservation. Application of various conversion methods could convert these wastes to myriad of industrial chemical products, platform chemicals, biofuel and other products. The major obstacle in processing these wastes into chemicals is the recalcitrant nature of lignin and the compact structure of these materials. Pretreatment of these waste materials remains a valid option to fracture their recalcitrance and improve the yield of products obtainable from their conversion. In this article, the sources of wastes useable for production of biofuel and biochemicals were discussed. The article also x-rayed the mode of conversion and the types of biofuel and biochemicals obtainable from these wastes. Notably, conversion of these wastes encourages greener environment and lessens the effect of fossil fuel and its derivatives on climate change.

Keywords: Wastes, pretreatment, biofuel, fossil fuel, lignin.

INTRODUCTION

In time past, the world had solely rely on the petro-chemical industry has the main source of energy and platform chemicals for human use. Majority of these products such as fuels, energy, chemical and industrial material were obtainable solely from the petroleum industries (Davis 2011; Massey *et al.*, 2013). The use of forest and agricultural wastes as substitutes for production of fuels and chemical is becoming attractive due to a number of reasons. First, the world crude oil reserves are non-renewable, fast depleting and this is putting pressure on petroleum resources. Likewise, utilization of these wastes for production of biofuel and chemicals will greatly reduce environmental impact concerns such as ozone depletion triggered by the release of greenhouse gas (Berndes 2011, Biilgen *et al.*, 2007). Another important factor is that the materials for biorefineries are cheap and could contribute towards improving the global energy security as biorefineries have shown capability to compete favourably with the petroleum industries (Farmer and Mascal 2015).

Industrialized countries are developing biobased economy in order to meet their energy demands and this will increase the demand for forest biomass as raw material for a wide range of products in preference to fossil fuel (UNEP 2018; Ge and Zhi 2016). African countries should improve their commitment and invest heavily in the development of biobased economy. They ought to capitalize on their advantage of abundant forest resources/wastes and greater availability of land to proffer solution to enormous challenge of power generation. However, forest and agricultural wastes are still subjected to indiscriminate disposal, burnt in the open and vastly underutilized in the developing countries (Anwar *et al.,* 2014; Kaur *et al.,* 2014).

Forest wastes are generated as by-products whenever forest biomass is used to produce forest-based product or during forest operations. Largely, forest and agricultural wastes are lignocellulosic biomass (LCB). The LCB has a 3-Dimensional compact structure whose major chemical components are cellulose, hemicellulose, and lignin in varied concentrations with smaller amounts of proteins, lipids, and ash (Chen and He 2012; Bhatia *et al.*, 2012; Yousuf 2012). The cellulose fibres are attached to each other by a randomly organized hemicelluloses network. These hemicelluloses are lower molecular weight cellulose with little strength; whose main compositions are the pentoses and hexoses (Brodeur *et al.,* 2011). These amorphous polymers are covered by lignin which provides rigidity and resistance against microbial attack to the plant cell wall (Palonen *et al.,* 2004). Lignin is a derivative of wood and one of the most abundant aromatic polymers on earth (Kudanga and Roes-Hill 2014). In plants, it is predominantly a cell wall component and makes up between 15-25 % of woody plant materials, thus, representing a large amount of the world non-fossil carbon reserve (Kudanga and Roes-Hill 2014). Lignin provides mechanical support for wood fibres, regulates water transport through the cell wall xylem and plays a special role in plant defensive system against destructive attacks from insects and destructive enzymes (Lora and Glasser 2002).

In order to encourage more utilization of biomass from forest and agricultural wastes, this article describes the sources of forest wastes, methods used in their conversion, pretreatment methods applicable for enhancing product yield and some products obtainable from these wastes.

Sources of Forest and Agricultural Wastes

Forest and agricultural resources are often not readily useable in their natural state. They have to undergo some processes to turn them to finished products with appreciable values. Examples of these processes include tree felling, de-backing, sawmilling, shelling, harvesting, peeling, strove removal, fruit and vegetable processing. During these processes, forest and agricultural wastes are generated. Often, the waste generated from processing forest and agricultural resources are voluminous than the finished product. A brief summary of the list of the sources of these biomass and wastes and some common examples are given in Table 1.

Table 1: Forest and Agricultural Biomass/wastes useable for biochemical production

Biomass/waste	Description	Ref
Forestry wastes	discarded logs and off-cuts, leaves, wood back, wood chips, wood bark, sawdust and wood shavings	(Kaur *et al.*, 2014; Bloch-Michalik and Gaworski 2017)
Agricultural wastes	Husk, shell, stalk, strove, leaves, hull, bagasse, molasses, shell, fibre, bunches, straw, frond, cob, vegetable wastes, peel, bran	(Yousuf 2012; Portugal-Pereira *et al.,* 2015; Arvanitoyannis and Tserkezou 2008)

Due to the little premium placed on these waste, they are disposed by burning, utilized as wood fuel or packed in dung hill to rot away. These disposal methods give rise to lots of problems. Indiscriminate disposal of these waste in dung hill encourage the growth and infestation of harmful microorganisms that could cause serious health and challenges. Burning, which a global practice, on the other hand is a complex process which generates lots of heat and harmful chemicals into the environment (Yevich and Logan 2003). Few examples of gases and particles released from burning include carbon monoxide, carbon dioxide, methane, organic/inorganic elements and particulate matters (Yadav and Devi 2018). These particles and gasses affect air quality, reduce visibility, release green house gases, contribute to global warming and climate change, and induce some serious health issues (Chan 2017, Smith *et al.,* 2007).

Annually, the volume of forest and agricultural waste generated around the world is in billions of tons (Chen and He 2012). These wastes are rich in constituents that encourage their transformation to chemicals and biofuels. The major constituents of these materials are polymers whose constituents could serve as precursors for platform and industrial chemicals. The LCB materials are made upof 35-50% cellulose, 20-35% hemicellulose, and 5-30% lignin (Amarasekara 2013). These major constituents of LCB enable its utilization for chemical production. Lignin, an abundant polymer, is convertible to a wide range of environmentally friendly products (Balat *et al.,* 2008).

Techniques for valorization of forest/agricultural waste conversion

Efficient utilization of LCB for production of biofuel and chemical can be achieved via two broad techniques: thermochemical and biological conversion. Methods for thermochemical conversion of these wastes into chemicals and biofuel include pyrolyisis, carbonization, gasification, liquefaction, supercritical fluid extraction and supercritical water liquefaction (Balat 2008, Yoder *et al.,* 2011). The thermochemical pretreatment of LCM could require high-energy input, generate toxic compounds and increase cost of production (Brodeur *et al.,* 2011). Biological conversion of lignocellulosic materials involves the use of microorganisms in process described as fermentation. During this process, microorganism utilizes the components (especially the sugar fraction glucose, galactose, mannose, xylose) of these wastes for growth and production of secondary metabolites (Prescott *et al.,* 2008). This process, fermentation of forest and agricultural wastes, can be carried out in solid state, semi-solid state or submerged phases (Tengerdy and Szakacs 2003; Rodriguez-Couto *et al.,* 2002). The metabolites usually produced by organism after at the log phase of the organism's growth for the purposes of signaling, defense, stress response, bioregulation, antibiotics and toxins (Prescott *et al.,* 2008). Often, these substances secreted by the organism for their self-designed purposes are the main substance of interest as industrial enzymes, chemicals and biofuel.

Although forest and agricultural wastes are abundant and rich in constituents that makes them suitable candidate for chemical and biofuel production, their compact structure creates an impediment for its efficient utilization and application of pretreatment is one of the ways of increasing the hydrolysis and microbial fermentability/utilization of these substrates (Galbe, M., Zacchi 2012). However, advances in the field of biotechnology and chemical engineering have created a panacea for this and lot of methods for pretreatments of LCB for enhanced product yield have been well reviewed (Galbe, M., Zacchi 2012; Anwar *et al.,* 2014; Jonsson and Martín 2016). Some of the pretreatment techniques include acid/base hydrolysis, steam explosion, ammonia fiber expansion, ionic/organic solvent, hot liquid treatment, CO_2 explosion, mechanical and biological pretreatment (Jonsson and Martín 2016; Menon and Rao 2012). Currently, there is a shift from the use harmful chemicals to green solvents in the pretreatment of LCB used in biorefineries. Advances in pretreatment include the use of lignin degrading enzymes-laccase; laccase - lignin peroxidise and maganase peroxidise produced by white-rot fungi- to enhance the production of biofuels and high valued chemicals from LCB (Kudanga and Roes-Hill 2014; Singh and Singh 2014). More recent effort by Kubota *et al.,* (2018) described the stepwise use of subcritical water extraction of hemicelluloses, cellulose and lignin from a LCB.

Biofuels and biochemicals obtainable from forest/agricultural waste conversion

Valorization of forest and agricultural waste for production of high-valued products saves the world from many perils. The first is that this makes our world green again and saves us from the perils of global warming and climate change. It also serves as a channel for the production and availability of cheap raw materials for our industries; thus making supplies of chemical and energy cheap and readily available. Categories of compounds that can be produced from these wastes include biofuels, industrial platform chemicals and enzymes, Biofuel production from forest and agricultural wastes is much more advanced and attractive in the developed world which is why there is a pronounced investment in biobased economy (UNEP 2018). Countries such as United States, Brazil and China are the world largest investors and producers of biofuels with millions of litres of biofuel produced annually (FAO 2008).

Industrial chemicals and enzymes produced from renewable LCB are gaining global interest. Such high value chemicals and enzymes include cellulose, succinic acid, lactic acid, pyruvate, lignolytic enzymes. These chemicals serve as key platform chemicals, which in turn act as precursors for the production of other important industrial chemicals. Chemicals obtained from forest and agricultural wastes have vast application in industrial processes, environmental bioremediation and production of pharmaceuticals. Other products obtainable from these wastes are included in Table 2.

Table 2: chemicals obtainable from forest and agricultural biomass/wastes and the biomass source used for production

Chemicals	Biomass	Reference
Industrial chemicals and enzymes		
Succinic acid	Pine wood	Wang *et al.*, 2014
Lactic acid	Potato waste water	Huang *et al.*, 2005
Vanillin	Rice bran	Zheng *et al.*, 2007
Acetaldehyde	Amaranth grain	Bramorski *et al.*, 1998
Acetoin	Molasses and hydrolysate	Xiao *et al.*, 2007
Laccase	Corn stalk	Adekunle *et al.*, 2017
Manganese peroxidase	Agricultural wastes	Yao *et al.*, 2013
Lignin proxidase	Flax fiber	Szabo *et al.*, 2015
Cellulase	wheat bran, husk, saw dust	Vu *et al.*, 2011
Citric acid	apple pomace	Dhillon *et al.*, 2013
Biofuel		
Ethanol	Corn stalk	Rabeya *et al.*, 2020
Hydrogen	Corn stove	Islam *et al.*, 2017
biodiesel	*Jatrophs caucus*	Ayodele and Dawodu 2014
Volatile fatty acid	Corn stalk	Liu and Cheng 2010
Methane	Corn stalk	Cheng and Liu 2012
Briquette	Peanut shells, Mopani leaves	Daniel and Madyira 2017

CONCLUSION

Utilization of forest wastes as alternative source or materials for meeting the demand for important fuels and high-value chemical production has tremendous environmental and economic advantages. Rechanneling biomass wastes for production of indispensable chemicals and biofuels could help meet the world's energy need. Research and advances in development of processes for effective utilization of biomass will continue to be a positive drive towards cleaner and sustainable environment.

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