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Biomass resources and biofuels potential for the production of transportation fuels in Nigeria

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ABSTRACT

Solid biomass and waste are major sources of energy. They account for about 80% of total primary energy consumed in Nigeria. This paper assesses the biomass resources (agricultural, forest, urban, and other wastes) available in Nigeria and the potential for biofuel production from first, second, third and fourth generation biomass feedstocks. It reviews the scope of biomass conversion technologies tested within the country and the reports on the technology readiness level of each. Currently, most of the emerging biofuels projects in Nigeria utilize first generation biomass feedstock for biofuel production and are typically located many miles away from the petroleum refineries infrastructures. These feedstocks are predominantly food crops and thus in competition with food production. With significant availability of non-food biomass resources, particularly in the Niger Delta region of Nigeria, and the petroleum refineries located in the same area, it is pertinent to consider expanding use of the petroleum refinery's infrastructure to co-process non-food biomass into bio-intermediate oil for blending with petroleum. This not only addresses the potential food versus fuel conflict challenging biofuel production in Nigeria, but also reduces the cost of setting up new bio-refineries thus eliminating the transportation of ethanol to existing petroleum refineries for blending. In view of this, it is recommended that further research be carried out to assess the feasibility of upgrading existing refineries in Nigeria to co-process bio-based fuels and petroleum products thus achieving the targets set by the Nigeria Energy Commission for biofuel production in the country.

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1. Introduction

The combustion of fossil fuels such as coal, oil and natural gas for the conventional method of producing transportation fuels, chemicals, and power, has been established for many years [1]. This method is a significant global concern as it releases greenhouse gases (GHG) particularly carbon dioxide (CO_2) into the atmosphere. Petroleum consumption for road transportation is currently the largest source of CO_2 emissions [2]. It accounts for 23% of CO_2 emissions worldwide [3] and 59.5% of CO_2 emissions in Nigeria [4].

In 2013, world CO_2 emissions from the consumption of petroleum exceeded 11,830 million metric tonnes [5] World total transport energy use and CO_2 emissions are projected to be 80% higher by 2030 than the current levels [3]. The United States Environmental Protection Agency (US-EPA) cited in [6] calculated the amount of CO_2 emissions from the combustion of gasoline and diesel to be about 8.887×10^{-3} and 1.0180×10^{-2} metric tonnes CO_2/gallon respectively. According to Howey et al. [7] unless there is a switch from fossil fuel to low-carbon alternative fuel, CO_2 emissions from vehicles may not reduce below $\sim$8 kg CO_2.

One major method which has been studied to reduce CO_2 emissions from vehicles is the blending of gasoline with ethanol [6]. It is estimated that about 8.908×10^{-3} metric tonnes of CO_2 are emitted from the combustion of a gallon of gasoline that does not contain ethanol, and 1.015×10^{-2} metric tonnes of CO_2 are emitted from the combustion of a gallon of diesel that does not contain ethanol [8]. Increase in the consumption of ethanol fuel has mitigated increases in CO_2 emissions from the transportation sector [9]. To further reduce these emissions, fuel switching to low carbon alternatives such as biomass fuel is essential. This is because, biomass currently offers the only renewable source of energy that can substitute for petroleum fuels as well as reduce CO_2 emissions [10,11].

Globally, biomass fuel is becoming ever more attractive as suitable substitute for fossil fuels due to the increasing demand for clean energy, declining fuel reserves, and its contribution towards reducing dependence on crude oil. The processing of biomass for biofuel, biopower, and bioproducts has important effects on international policy and economy, and on rural development. It reduces the dependence on oil-producing countries and supports rural economies by creating jobs and providing an additional source of income [12]. Hence the purpose of this review.

Despite Nigeria having four petroleum refineries with combined crude distillation capacity of 10.7 million barrels per day (bbl./d) [13], an amount that far exceeds the national demand, the country still imports the majority of refined petroleum products. This is due to the low capacity utilization of existing refineries [13]. At 2013, typical capacity utilization for the four existing refineries was about 22%, with crude oil production of 2367 thousand bbl./d. At the same time, approximately 164,000 bbl./d of petroleum, and 82,000 barrels of fuel ethanol were imported [13]. To reduce the nation's dependence on imported oil it is important to improve refinery utilization and diversify to other energy resources. Therefore the development of alternative fuels particularly biomass-derived fuels from locally available biomass needs investigation.

There is a wide range of biomass conversion processes, at varying stages of technical maturity. Some are commercially available, while others are at demonstration stages. For instance, ethanol production from sugar cane is commercially available in Brazil [14], while biofuel production from algae is at research and development phase [15]. Existing research on biomass resources and the potential for biofuels in Nigeria is focused on power generation and biofuels production from first generation biomass. Typically this substitutes fuel production for food crops. There is currently limited information on the state of biomass conversion technologies for the utilization of non-food crops for transportation fuels production in Nigeria.

This paper reviews biomass resources and biofuel potentials to produce transportation fuels, notably biomass resources available from first, second, third and fourth generation feedstocks in Nigeria. It assesses the biomass conversion technologies tested in the country, and the technology readiness level. It also identifies research gaps alongside the policy targets defined for sustainable biofuel production. In addition, the potential for biofuel contributing towards more sustainable production with improved environmental and socio-economic benefits is discussed. More detailed region-specific evaluation of biomass resources can then be used to define the scope for local production of biofuels within Nigeria.

2. Biomass resources in Nigeria

The term biomass literally means living matter. However, biomass is often used to describe any organic material obtained from plant and animal tissue [16]. This includes agricultural resources, agricultural residues, forest resources, waste including municipal solid waste, industrial waste, and other wastes, as well as algae. These materials are referred to as feedstocks in bio-refining and are classified into four generations: first, second, third, and fourth. First generation refers to the biofuels derived from agricultural products: sugar or starch-based crops and oilseeds, e.g. sugarcane to produce bioethanol or palm oil for the production of biodiesel. Through fermentation or trans-esterification, first generation biomass feedstocks can be processed into bioethanol or biodiesel respectively. Most common uses are as first generation biofuels.

Biomass is abundant in nature and broadly dispersed globally with its distribution being dependent on geographical area. Countries such as Brazil and Nigeria have significant natural resources to produce transportation biofuels, biopower and bioproducts from biomass. Nigeria has substantial biomass potential of about 144