



Nipa (*Nypa fruticans*) Palm: The New 'Green Oil' in Nigeria

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ABSTRACT

This study assessed and quantified the bioethanol production potential of nipa (*nypa fruticans*) palm sap in the oil province of Nigeria, the Niger Delta region. The assessment was conducted under three different scenarios of sap yield per palm per day. The potential of bioethanol production from nipa sap was calculated based on assumptions that 1000 palms ha⁻¹ could be tapped for 100 days with a maximum sap yield of 1.0 L d⁻¹, 1.7 L d⁻¹, and 2.5 L d⁻¹ per palm for the low, medium, and high yield scenarios, respectively, containing a minimum sugar content of 150 g kg⁻¹. The estimated area of occurrence of the nipa palm in the four affected states was estimated at 82,100 ha. Results revealed that 0.747, 1.270, and 1.867 billion L of bioethanol can be produced per annum under low, medium, and high sap yield scenarios, respectively. These would provide between 15-36% of the national bioethanol demand per annum. This study sheds new light on the bioethanol potential of nipa (*nypa fruticans*) palm in the Niger Delta. The Nigerian government should therefore, develop and promote suitable biofuels policies, regulations and programmes for production of bioethanol from nipa (*nypa fruticans*) palm sap.

KEYWORDS: Nipa palm, bioethanol, biofuel, biofuel policy, energy potential

1 INTRODUCTION

Biofuel production from renewable biomass feedstock presents a viable substitute for conventional fossil-based fuels that can be produced on a large scale in a sustainable manner. Biofuels plays a key role in limiting global warming and enhancing the security of global energy supply. Over the past decades, many countries have set ambitious targets, and strategic policy goals across the world for the development of biofuels in fighting against climate change. For instance, the *EU Directive 2009/28/EC* for the promotion of renewable energy within the EU sets out the objective of 10% for biofuels in transport and also a minimum 35% reduction in GHG emissions to be achieved by biofuels during their life cycle by 2020 (Biofuels Platform 2011). Similarly, in July 2010, the USA *Renewable Fuel Standard (RFS2)* set out the objective of an aggregate of 36 billion gallons of renewable fuels to be used in transport fuels, and also require producers of advanced and standard biofuels to reduce life cycle GHG emissions

by at least 50% and 20% respectively (Sorda, *et. al.*, 2010).

Bioethanol, made from starch and sugar rich crops such as sugarcane, maize, cassava, sweet sorghum, and wheat; and biodiesel, primarily produced from oil rich seeds such as soybean, *Jatropha Curcas*, palm oil, and animal fats, are currently the most common form of biofuels available in commercial scale (standard, or otherwise called first generation biofuels). Production of these biofuels has also been extensively investigated, and the production methods have proved successful in some part of the world such as USA, Brazil, and China (Sims *et al.*, 2006; Balat and Ayar, 2005; Bellarin *et al.*, 2011). In the US, for example, between the years 2000 to 2009, bioethanol production increased from 16.9 to 72.0 billion liters and is mandated to increase to 136 billion liters by 2022 while biodiesel production increased from 0.8 to 14.7 billion liters (Sorda, *et. al.*, 2010). Table 1 presents the leading bioethanol producers in the world.

Table 1: Global bioethanol production by country in 2008 (Sorda *et al.*, 2010)

Country	Production in million litres (ML)
USA	33,737
Brazil	24,261
EU	2,748
China	1,882
Canada	892
Thailand	337
Columbia	296
India	247
Australia	97
Other	480
World	64,981

Nigeria's transport sector is virtually wholly dependent on fossil-derived fuels such as gasoline and diesel. Bioethanol from renewable biomass can be used in its pure state or as a blend with gasoline in the transport sector. Therefore, changing the fuel mix is of vital importance because though, Nigeria is one of the major oil producers in the world, the country wholly relies on imported refined oil products from other countries, which poses serious economic, social, and environmental problems (Ohimain, 2013a).

Nigeria has developed specific biofuel strategies. The Nigerian biofuel policy and

incentives was released in 2007 with the aim of creating a demand of biofuel products by substituting conventional liquid transportation fuel with 10% ethanol and 20% biodiesel (Ohimain 2013b; Ohimain, 2012). The state of biofuels production in Nigeria is given in Table 2. Recently, the Federal Government initiated an automotive biofuel programme, which involved the construction of 9 plants comprising of 4 sugarcane and 2 cassava bioethanol projects and 3 biodiesel projects for the production of 445 million L of bioethanol and 120 million L of biodiesel annually (Ohimain, 2013a).

Table 2: Biofuel production status in Nigeria (Ishola *et al.*, 2013)

Biofuel	Potential material	raw	Industrial feasibility Nigeria	Proposed use in	Main advantages
Bioethanol	Sugarcane, sorghum, Cassava	sweet	Developing	Transport	Reduced pollution, diversification of fuel mix
Biodiesel	Jatropha, soy beans	palm oil,	Under investigation	Transport	Diversification of fuel mix
Biogas	Manure, sewage	MSW,	Good	Indoor combustion	Improved indoor air quality. Reduced deforestation

Investigations by Ishola *et al.* (2013) showed that bioethanol projects in Nigeria were mainly initiated based on cultivation of sugarcane, cassava and sweet sorghum. But yet, the Nigerian sugarcane sector does not yet satisfy the domestic demand for sugar, while large-scale sugarcane-based ethanol production seems distant, and bioethanol production from cassava would require input of energy and enzymes and would probably be too expensive. However, Ogundari *et al.* (2012) reported that bioethanol production from cassava would be both technically and economically viable. The authors projected that cassava feedstock and landmass requirements for bioethanol production would be in the range of 4.64-14.53 million tons and 4.08-12,800 km², respectively by 2020. Furthermore, sweet sorghum, which is relatively easy to process into bioethanol, has some advantages in a Nigerian context, being widely cultivated. Nasidi *et al.* (2010) investigated the relative merits of sweet sorghum and sugarcane crops as feedstocks for bioethanol production in Nigeria. They found that sweet sorghum is most suited compared to sugarcane, in terms of the resilience to harsh climatic and cultivation conditions, and also in terms of environmental impact, sweet sorghum cultivation is more water efficient, requires less energy input, fertilization and agrochemical application.

Nevertheless, bioethanol from agricultural crops such as maize, sweet sorghum, and sugarcane has been shown to exhibit positive environment performance in terms of net energy balance and greenhouse gases (GHG) emissions reductions throughout its life cycle. However, in spite of all these potential benefits that can be obtained from the production and use of bioethanol from agricultural bioenergy crops, scientific findings have revealed that biofuels from agricultural crops can be anything from good to bad depending on the type and methods used to produce the biomass feedstock, and the conversion process used to produce the fuel when compared with fossil fuels (Fontara *et al.*, 2012; Kaltschmitt *et al.*, 1997; Monti *et al.*, 2009; Molino *et al.*, 2013; Monti *et al.*, 2012; Soimakallio *et al.*, 2009).

Furthermore, the Nigerian biofuel policy did not address the potential food versus fuel conflicts that could arise from the use of food

crops as biofuel feedstock (Ohimain, 2013a). However, according to Amigun *et al.* (2011), developing countries such as Africa need to carefully consider the benefits and detriment of biofuels, particularly in relation to the effects on food production and food prices. Currently, sugar and starch crops account for 61% and 38%, respectively, of the total global bioethanol production (Tamunaidu *et al.*, 2013). In order to avoid competition with food due to bioethanol production currently made from agricultural starch and sugar feedstocks, government should develop and promote biofuels policies, regulations and programmes for production of bioethanol from non-food materials such as nipa (*nypa fruticans*) sap. Nigeria's Niger Delta region being one of the world's largest producers of nipa palm has the potential of producing substantial amount of bioethanol, thereby contributing significantly to the biofuel mix in the country, in a sustainable fashion. Previous study by Okugbo *et al.* (2012), pointed out the need for adopting the use of nipa palm as potential feedstock for bioethanol production in Nigeria. The aim of this study is to assess and quantify the energy potential of nipa palm sap for bioethanol in Nigeria.

2 METHODOLOGY

2.1 Study Area

The Niger Delta is located in the south-south zone and covers five states of Nigeria (Akwa Ibom, Bayelsa, Delta, Edo and Rivers states). It is one of the world's largest wetlands covering an area of approximately 70,000 km² and makes up 7.5% of the country's land mass. It lies between latitude 4° and 6° north of the equator and longitude 5° and 7° East of Greenwich. Along the coast, it stretches from the Benin river in the West to Bonny river in the East, while in land, it begins a few miles below Aboh at a point where river Niger bifurcates into river Nun and Forcados into the Atlantic West at the South, stretching over 160 miles (Mmon and Akoyu, 2010). The Niger Delta zone can be further sub divided into four sub-ecological zones comprising of the coastal barrier Islands, mangrove swamp, fresh water swamp forest, and the lowland rainforest. The mangrove swamp is the largest and dominant sub-ecological zone in the Niger Delta. The Niger Delta mangroves are not only rich in abundant crude oil and natural gas, but also

offer a lot of biological resources such as the nipa (*nypa fruticans*) palm.

2.2 The Nipa Palm (*Nypa Fruticans*)

The nipa (*nypa frutican*) palm is one of the most common, widely distributed, and useful palm found in the mangroves. It thrives well in mangrove environment. It is fast growing plant favoring brackish water environments that grows in clusters, often forming large colonies and without stems above the ground (Tsuiji *et al.*, 2011). It was first introduced in Nigeria in 1906 from Singapore, and since then it has been well established, and is now reported to occur abundantly in the coastal states of the Niger Delta, in the states of Akwa Ibom, Bayelsa, Cross River, and Rivers (Isebor *et al.*, 2003) Nipa palm can be utilized for various traditional purposes such as in basket making and thatching materials. The plant also produces high amount of sap that is very rich in sugar, which can be converted to alcohol.

Nipa palm can be tapped for sap as early as five years old, or even less, and will continue to produce sap for another fifty years. Saps are easily collected from stalks bearing young or mature infructescence with no biomass loss and without any deleterious effect on the palm growth (Tamunaidu *et al.* 2013). The flowering stalk of the palm is cut and inserted into a pot or plastic bag, and the end sliced everyday to stimulate new sap flow and prevent bacterial growth. Beating the base of the stalks with a mallet before tapping and to keep the flow going, longer length of stalks and younger palms have been cited as some of the factors that can contribute to higher sap yields. A study conducted by Tamunaidu *et al.* (2013) showed that nipa palm has the potential to produce sugar saps from 0.4 to 1.3 L d⁻¹ per palm for 80-180 days per year. Sugar composition in the sap can be in the range of 159-214 g kg⁻¹, which is mainly composed of sucrose, glucose, and fructose.

However, saps yield could differ from place to place depending on tapping practices, length of stalks, climate and also the environment. For instance, according to Tamunaidu *et al.* (2013) up to 2.5-3 L of sap can be collected twice per day in Malaysia. It has been reported that nipa can produce more ethanol than sugarcane (4550-6500 L ha⁻¹ yr⁻¹) (Rajagopal *et al.*, 2007; Marris, 2006), cassava (2160 L ha⁻¹ yr⁻¹) (Jansson *et al.*, 2009), sweet sorghum

(2800 L ha⁻¹ yr⁻¹) (Naylor *et al.*, 2007), and corn (3100-3900 L ha⁻¹ yr⁻¹) (Marris, 2006) compared to 4550-9100 L ha⁻¹ yr⁻¹ (Tamunaidu *et al.* 2013). Similarly, Okugbo *et al.* (2012) reported that nipa sap has the potential to allow production of between 6480-15600 L ha⁻¹ yr⁻¹ of ethanol.

2.3 Data Obtained

Our approach involved literature survey from published articles. Data from published literature on area covered by the nipa palm in the Niger Delta, palm population per ha, bioethanol yield per ha, and the calorific value of bioethanol were obtained and utilized to evaluate the total energy potential of the region for production of bioethanol as transportation fuel from the naturally occurring, high-sugar nipa palm that is currently considered as a threat and a nuisance to the region. Analysis was carried out for three scenarios of sap yield per day per palm: (1) low yield scenario (2) medium yield scenario (3) high yield scenario.

The potential of bioethanol production from nipa sap was calculated by adopting the data reported by Tamunaidu *et al.* (2013) based on assumptions that 1000 palms ha⁻¹ could be tapped for 100 days with a maximum sap yield of 1.0 L d⁻¹, 1.7 L d⁻¹, and 2.5 L d⁻¹ per palm for the low, medium, and high yield scenarios respectively, containing a minimum sugar content of 150 g kg⁻¹. The estimated area of occurrence of the nipa palm in the four affected states was estimated at 82,100 ha (Isebor *et al.*, 2003). The total bioethanol production per year in the area (in L) was calculated by the equation below:

$$BOH_{p-liters} = \left(\frac{BOH_{yield}}{ha} \right) \times Occurrence_{area} \quad (1)$$

Where, $BOH_{p-liters}$, is the total amount of bioethanol production in liters per annum (L yr⁻¹); $BOH_{yield/ha}$, is the potential of bioethanol production from the nipa sap in liters per ha per year (L ha⁻¹ yr⁻¹); and $Occurrence_{area}$, is the land area covered by the palm in the mangrove area of the Niger Delta region. In terms of tonnage rather than liters, the value of density of bioethanol was taken to be 790 kg m⁻³ (0.79 kg L⁻¹), and the total bioethanol potential was calculated using the relation given in equation 2.

$$BOH_{p\text{-tons}} = BOH_{p\text{-liters}} \times BOH_{density} \quad (2)$$

Where, $BOH_{p\text{-tons}}$, is the total amount of bioethanol production in tons per annum (tons yr⁻¹); $BOH_{p\text{-liters}}$, is the total amount of bioethanol production in liters per annum (L yr⁻¹); and $BOH_{p\text{-density}}$, is the density of bioethanol. The relative energy potential of the bioethanol produced was also calculated by the relation:

$$BOH_{p\text{-energy}} = BOH_{p\text{-tons}} \times HHV_{bioethanol} \quad (3)$$

Where, $BOH_{p\text{-energy}}$, is the potential energy from the total amount of bioethanol produced in tons, in terajoules per annum (TJ yr⁻¹); $BOH_{p\text{-tons}}$, is the total amount of bioethanol production in tons per annum (tons yr⁻¹); and $HHV_{bioethanol}$, is the higher heating value of bioethanol taken as 29.7 MJ kg⁻¹.

3 RESULTS AND DISCUSSION

Our quantitative analysis, as presented in Table 3, revealed that 747.11, 1,270.09, and 1,867.78 million L of bioethanol could be obtained per annum for the low, medium, and high sap yield scenarios, respectively from the area currently invaded by the nipa palm in the four affected states of the Niger Delta. This is

equivalent to 17,529, 29,800, and 43,824 TJ yr⁻¹, respectively.

If the Nigerian government was to commit to a policy and incentive (for the domestic production of bioethanol) that would initiate and facilitate the development of bioethanol production from nipa palm to meet the national demand of 5.14 billion L yr⁻¹, as reported in (Ohimain, 2010) that would supply 0.747 (about 14.5%), 1.270 (about 24.7%), and 1.867 (about 36.3%) billion L of bioethanol under low, medium, and high sap yield scenarios, respectively. These productions will be more than the current total installed capacity for bioethanol production in Nigeria of about 134 million L per annum as reported in [28], even under low sap yield scenario (747 million L per annum) (Table 3). Therefore, this would make a significant feedstock supply to the existing and emerging 19 bioethanol bio-refineries for the production of over 2.66 billion L of fuel grade bioethanol per annum. At the same time, bioethanol from nipa palm could serve as feedstock for the new bioethanol projects currently initiated by Nigerian automotive biofuel programme that advocates the construction of 4 sugarcane and 2 cassava bioethanol projects for the production of 445 million L of fuel grade bioethanol (Ohimain, 2013a).

Table 3: Bioethanol production under different scenarios of sap yield

Scenario	Sap yield (L d ⁻¹ p ⁻¹)	Bioethanol yield (L ha ⁻¹ yr ⁻¹)	Nipa palm Occurrence (ha)	Bioethanol potential (million L yr ⁻¹)	Bioethanol potential (metric tons yr ⁻¹)	Energy potential (TJ yr ⁻¹)
Low	1	9,100.00	82,100.00	747.11	590,216.90	17,529.44
Medium	1.7	15,470.00	82,100.00	1,270.09	1,003,368.73	29,800.05
High	2.5	22,750.00	82,100.00	1,867.78	1,475,542.25	43,823.60

4 CONCLUSION

Our study quantified the bioethanol production potential from nipa (*nypa fruticans*) in the Niger Delta region of Nigeria. We can therefore, conclude that, if the Nigerian government was to commit to the management and development of 82,100 ha of nipa palm plantation in the Niger Delta, we can expect the production of between 747-1,868 million L of bioethanol per annum, which is between

15-36% of the total country's demand. In addition, in order to avoid competition with food due to bioethanol production currently made from agricultural starch and sugar feedstocks (sugarcane, sweet sorghum, and cassava) in Nigeria, the government should develop and promote biofuels policies, regulations and programmes for production of bioethanol from nipa (*nypa fruticans*) sap, a non-food material, which requires no energy inputs during its cultivation. This would reduce

our dependence on imported crude bioethanol from other countries, enhance the security of energy supply, boost rural infrastructures and enhance the livelihood of the people in the region. We can also conclude that Niger Delta region is not only the 'crude oil province', but also the 'green oil province' of Nigeria. In the context of this research, 'green oil' refers to renewable biofuel (bioethanol).

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