Bioethanol Potential from Oil Palm Sap in Ghana

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Abstract- Ghana has a competitive geographical location for oil palm development when compared with its immediate neighbors and other global producers. In 2010, a total of 336,000 hectares of oil palm plantation was cultivated in Ghana and this is expected to increase as part of the roadmap stipulated in the introduction of 'Master Plan Study on the Oil Palm industry in Ghana' in July 2012. In cognizance with the improvement of oil palm development, Ghana can develop biofuel plan and its implementation through the production of ethanol from palm sap. In this study, four leading cultivators of oil palm were examined for the potential palm sap that can be derived. An estimated amount of 447.5 million litres of bioethanol can be obtained from these four producers which could be used to support E10 and E20 as stipulated in the Strategic National Energy Plan (SNEP) (2006-2020).

Keywords Ghana, Oil Palm, biofuel, bioethanol

1. Introduction

Ghana currently produces 90, 000 barrel of crude oil per day and there are discoveries of new wells which are yet to commence production. However, Ghana is fully dependent on imported fuel for transportation, power generation and other purposes. The concern about escalating cost of these fuels due to their depletion and also their negative effects on climate change have necessitated the shift to the use of biofuels [1,2]. Ghana has the capacity to replace part of fossil fuel based fuels with biofuels through a comprehensive biofuel program.

Currently there is a biofuel program embedded in the Strategic National Energy Plan (SNEP) up to 2020 which considers the roadmap for the introduction of biofuels into the Ghana oil market, however, it is yet to be implemented. At the moment, the introduction of biofuel has received the necessary legal backing which was passed in to law in 2011. The feedstocks that are being considered for the production of bioethanol are cassava and sugarcane which are first generation. However, first generation ethanol has been criticized that depending on the feedstock used can increase greenhouse gases (GHG) and the feedstock used can create competition with food. Some studies [3, 4] have shown that the conventional fuels replacement by ethanol can be sustained by the use of cassava as the feedstock for ethanol production without comprising on the domestic supply of food.

This study aims at investigating potential suitable feedstock for the production of ethanol. The study seeks to disabuse the general notion that first generation ethanol production competes with food production that is usually perpetuated.

2. Figures Status Quo of Palm Oil Development in Ghana

Oil palm is indigenous to Ghana and was the leading foreign exchange earner for Ghana from about the mid-nineteenth century to the beginning of the twentieth century [5,6]. According MOFA [5] and Gyasi E A [7], during this period, the cultivation was based on small scale farming until 1960 when the government of Ghana began to promote the industry.

Through the Ministry of Food and Agriculture (MOFA), the government of Ghana outdoored a working document in July 2012 to raise Ghana's competitiveness in the global oil palm commodity sector. The document is to ensure large scale plantation and small scale independent small-holder plantation development by proposing a minimum of 10,000 and 5,000 hectare per year nucleus estate and processing mills respectively. This will result in the development of 40,000 hectares of large scale estates and 11,000 hectares outgrowers in the village sector through motivation of outgrowers to cultivate a minimum of two hectares per farmer of oil palm [5,8]. The document, 'Master Plan Study

on the Oil Palm industry in Ghana', is ultimately aimed at attracting foreign investment to expand the oil palm industry [5].

Ghana has a competitive geographical location for oil palm development compared to its immediate neighbours and global producers. Approximately 336,000 hectares of oil palm plantation is already being cultivated in Ghana as of 2010 with an additional 20,000 hectares of oil palm farm needed to meet the current deficit as a result of increasing demand for palm oil [9]. Eastern Region-one of the ten regions in Ghana-accounts for 32% of total area cultivated, followed by the Western Region (28%) with the least developed being the Volta Region (4%). Nearly 80% of the land is cultivated by private small scale farmers [9].

Oil palm are used mainly for palm oil production, palm kernel oil and palm wine extraction; palm oil accounts for more than 50 % of the global import and export trade of vegetable oils [9,10]. The increasing demand for palm oil for biofuel production and for domestic and industrial use coupled with the lucrative nature of palm oil commodity prices, both locally and internationally will lead to increase in palm oil production in Ghana [9]. Major cultivators of oil palms are Ghana Oil Palm Development Limited (GOPD), Norpalm Ghana Limited, Benso Oil Palm Plantation Limited (BOPP), Twifo Oil Palm Plantatation Limited (TOPP), Juabeng Oil Mills Limited, Ashanti Oil Mills Limited, Ameen Sangari Limited and Adansi Oil Mills [6].

There are two main species of oil palm cultivated globally: Eleais guineensis (African oil palm) commonly grown globally with high oil content (25% [10]) which is extensively cultivated in Africa and tropical countries outside Africa and Elaeis oleifera (America Oil Palm) native to Central and South America. Oil Palm takes between 90 to 100 days to sprout and is nursed for 4 – 5 months before transplanting into a nursery for one year before transplanting into a palm grove. The oil palm begins to bear fruits when about 3 – 4 years after transplanting in the palm grove. Commercial oil palms have an economic lifespan from 20 to 30 years [11]. In Ghana, the recommended plant density of oil palm is 143 trees per hectare [12].

Sap from palm species has been tapped to produce fresh juice, fermented drinks, syrup, brown sugar or refined sugar throughout the tropics for centuries [13]. There are two techniques for producing palm wine from oil palm. One is destructive technique where there is incision of the stem apex of a felled palm and the other non-destructive technique is where there is excision of male inflorescence [14]. The first technique leads to total destruction of the tree and it is the main method for palm wine production in Ghana while the latter was developed to preserve the palm trees because of economic consideration. This method is used in Eastern Nigeria [9,13]. The destructive method can be used for oil palm grown purposely for oil extraction and have reached the end of the economic lifespan.

According to Delibard [13], the site of excision affects the nature of the palm tree after tapping of the sap when applying the non-destructive technique in that it can hinder the growth of the oil palm. The perforation of the terminal buds may also lead to the palm showing malformation in subsequent leaves, flowers and trunk growth. However, the most advanced method of tapping which is applied to inflorescence spadix guarantees high yield of wine for a long periods and still maintaining the welfare of the tree. It entails a sacrifice of a bunch of fruit in case of a female inflorescence is tapped.

Two features are common in non-destructive tapping: manipulative treatment or preparation is necessary as prelude to profuse and sustained sap flow, and the other shaving off a thin slice tissue once or twice a day. Most of the palm trees have to be climbed for trapping since the inflorescences are located at the summit of the truck.

Sap production from palm trees can be done at an early age depending on the palm species. The Elaeis guineensis species grown in Ghana can be tapped as early as 6 years and can produce sap all year round for the next 10 to 15 years [10, 13]. For this species, the sap tapped for palm wine contains about1.2 tonnes sugar per hectare of palm trees [13]. According to Delibard [13], sap production is at its maximum just before or during fruit formation and this will result in competition between sap production and palm fruit production. However, the encouraging aspect is that the sap production stimulates palm fruit production. The sap is left to ferment to produce a weak alcohol juice known as 'palm wine'. Natural fermentation starts immediately after collection of the sap from the palm tree. The sap contains 4% alcohol but upon fermentation, the alcohol content increases to about 5-8% [15]. This can further be distilled to 96.5% azeotropic alcohol using fractional distillation and 99.5% or more using molecular sieves [16].

3. Fuel Consumption Pattern in Ghana

The main transportation fuels used in Ghana are petrol and diesel which are either processed from the imported crude oil or are imported in their refined state. Recently, there is an emerging use of Liquefied Petroleum Gas (LPG) especially among taxi vehicles which is increasing the demand of fuel from the transportation sub-sector. Ghana depends largely on Nigeria and Equatorial Guinea for its oil importation [17] and the expenditure on crude oil importation alone was US$520 million in 2000 and this increased to about US$1.5 billion in 2009 representing about 186% increment [18]. Meanwhile, the importation of crude oil increased from 1,284,928 tonnes in 2000 to 1,976,155 tonnes in 2008. [19].This quantity shows that the demand for oil has increased and has affected the government's expenditure on importation of crude oil. Crude oil imported into Ghana is used for generation of electric power and for refinery use. The share of crude oil used for refinery is generally higher compared to that used for power generation [19].

Currently, there is only one crude oil refinery that is responsible for refining imported crude oil except for consignments meant for power generation. In 1990, the maximum production capacity of the refinery was 28,000 barrels per day which was expanded to 45,000 barrels per day in 2000 to meet the increasing demand [20]. In recent

years, the refinery's production has been sporadic. For example, due to maintenance works and crude oil supply disruption, the refinery was shut down for most part of 2009 [21, 22]. The refinery owed US$660 million to its creditors at the end of 2009 [21] and at some point, repairs to a water pipeline disrupted water supply to the refinery [23] which generally resulted to refined oil supply disruptions.

Currently, Ghana is an oil producing country having an initial estimate of crude oil reserve of about 660 million barrels [24]. However, with the recent oil discoveries and appraisals, the fields have shown to contain about 800 million barrels of light crude oil with upper limit of 3 billion barrels [25]. Ghana started its oil lifting in 2011 with its first share of 995,259 barrels [17].The production is expected to reach 120, 000 barrels per day and later increased to 250,000 barrels per day in 2012. If it is assumed that the production peaks at 250,000 barrels and that the oil reserve is around 3 billion barrels it means reserves-to- production ratio is around 32 years. The oil produced at one of the major fields is exported since it has a higher premium compared to the oil imported. Part of the oil proceeds is used to mitigate the impact of consequential high product prices locally [17].

Table 1. Fuel consumption in the transport sector of Ghana (kilotonnes) [26]

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
LPG	45	42.5	50	56.7	65.7	70.5	88	93.3	117.6	220.6	178.4
Gasoline	524.4	535.1	570.2	479.8	575.6	537.8	511.9	544.2	545	701.4	737.8
Gas Oil	665.8	685.4	717.8	755.3	848.9	880.4	934	1,147.00	1,092.10	1,280.00	1,271.90

Table 1 shows the quantity of different fuels consumed by the road transport sub-sector in Ghana. It can be observed that the most consumed fuel by this sub-sector is diesel followed by gasoline and LPG. Diesel has extended uses in the mining sector and in power generation and this results in high consumption pattern of diesel fuel in Ghana. Gasoline consumption pattern increased from 524,400 tonnes in 2000 to 737,800 tonnes in 2010 with dip in consumption in 2003 and 2006. The dips were due to supply disruptions as mentioned earlier and gasoline was imported to meet the demand. LPG was introduced into the Ghanaian market to curb the use of wood as fuel. However, some taxis that originally run on gasoline, are converted to use LPG. According to a Ghana Energy Commission survey, in 2008 about 37% of the total LPG was consumed in road transport sector [27]. This has resulted in high demand for LPG from 2008 and gives rise to frequent LPG shortages since there is always competition for domestic use and as a fuel in road transport. The shift for LPG usage in road transport can be attributed to the price differential between gasoline and LPG due to the high government subsidy on LPG.

The increase in all the fuel consumption patterns are symptomatic of growing road transport which require an increase in existing fuel supply or identification of sustainable alternative fuels to support this sector. Continuous importation of crude or refined fuels will only increase the government's expenditure. An approach to deal with the problem of inadequate fuel supply in Ghana is to commence the implementation of the existing biofuel plan and to address the production of biofuels and utilization as well as infrastructure to support the plan. Implementation of such a plan will have socio-economic and environmental benefits.

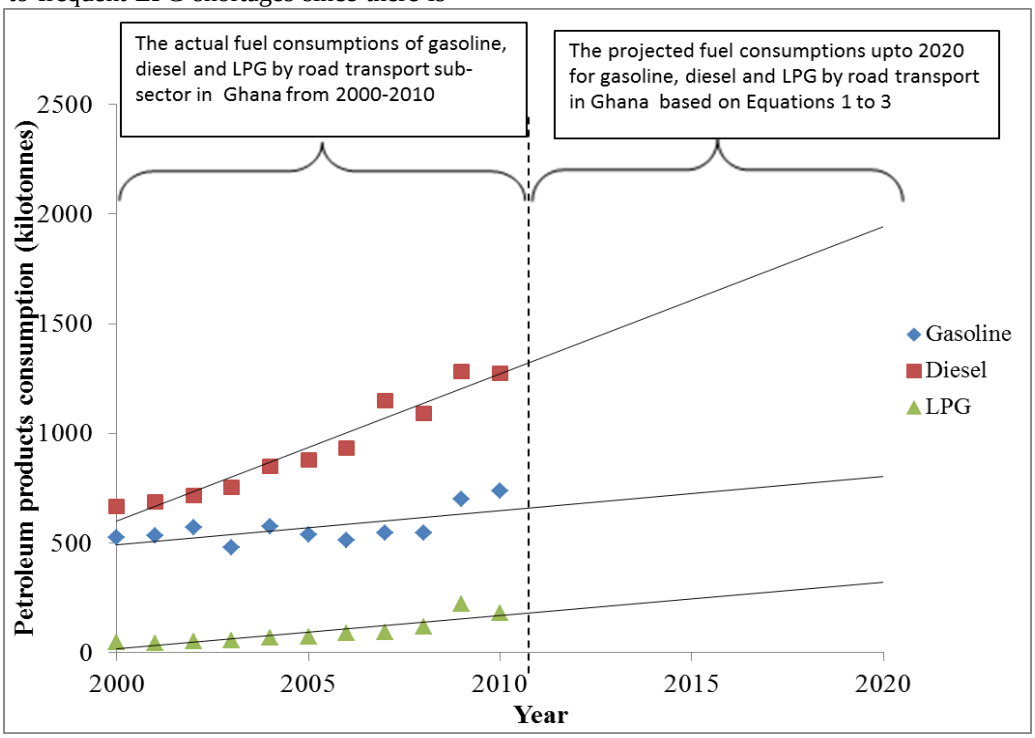

Fig. 1. Petrol, diesel and LPG consumption patterns and projections in Ghana

Equations (1) to (3) are models formulated from a linear curve fitting of the consumption patterns of diesel, petrol and LPG. The R2 values generated are the corresponding coefficients of determination. The coefficients of determination are the indication of predictability of future consumptions of the fuels and it can be seen that it is easier to predict the future consumption of diesel (R2=0.95) than petrol (R2= 0.43).

$$DC=67.28(year-2000) + 530.77;\ R2=0.95 \quad (1)$$

$$PC=15.65(year-2000) + 475.47;\ R2=0.43 \quad (2)$$

$$LC=15.25(year-2000) + 1.97;\quad R2=0.76 \quad (3)$$

Where DC, PC and LC are diesel, petrol and LPG consumptions in kilotons respectively.

4. Biofuel Policy and Plan

In 2010, more than 50 countries globally adopted biofuel policy, however, biofuel blending targets and mandates differ from country to country [28]. The two countries which are dominant in the production of biofuels are Brazil and the US and in 2008 they were able to meet 21% and 4% of the total road transport fuel with biofuel respectively. Brazil has adopted E20-25 (E20 is a mixture of 20% ethanol and 80% gasoline), B5 (5% biodiesel and 95% diesel) and currently there are vehicles known as Flexi Fuel Vehicles (FFV) that can run on E85 and 100% ethanol [28]. In 2011, the mandate on biofuel policy in US was to produce 48 billion litres of biofuels to support the road transport sector [28]. In 2012; USEPA approved the use of E15 as fuel for year 2001 models and newer vehicles [29].

In Ghana, the roadmap of introducing biofuel has been stipulated as part of the Strategic National Energy Plan (SNEP) up to 2020. To support biofuel policy in terms of feed stocks, jatropha, cassava and sugarcane plantations will be encouraged to support the production of biodiesel and bioethanol. The Private sector, the Ministry of Energy and Energy Commission will be responsible for the initiatives. The Komenda and Asutuare sugar factories will be re-activated to start the commercial production of alcohol and this will be done through the joint action of government-private sector. While a commercial biodiesel distillation plant will be commissioned for refining biodiesel, blending centres are expected to be installed for gasohol and biodiesel in Tema and Takoradi for the southern sector and similar plants to be installed in Bolgatanga and Tamale for the northern sector. In addition, blending centres will be extended to the remaining regional capitals which will be done through the joint action of Energy Commission, National Petroleum Authority (NPA), Bulk Oil Storage Transportation Company (BOST) and Oil Marketing Companies (OMCs). The B5 and E10 should have been introduced into the country's oil market by 2008 while B10 and E20 to be introduced by 2012. In 2020 B5, B10 and E10 is expected to be mandatory for dispensation at all fuel filling stations and up to E85 voluntary throughout the country.

Assuming all the different types of biofuels were to be introduced by the timelines as stipulated in the SNEP document, and using equations (1) and (2) to estimate future petrol and diesel fuels, the bioethanol and biodiesel fuels needed to meet the biofuel policy are summarized in Table 2. Table 3 shows the calorific values and densities that were used to estimate the amount of bioethanol and biodiesel fuels on energy basis.

Table 2. Fuel needed to meet biofuel policy (litres equivalent)

	B5	B10	E10	E20	E85
2008	65,573,690	131,147,380	113,859,873	227,719,745	967,808,917
2012	84,385,972	168,771,943	141,838,064	283,676,127	1,205,623,541
2020	116,703,876	233,407,751	167,994,497	335,988,994	1,427,953,223

Table 3. Properties of fuels

	LHV(MJ/kg)	Density(kg/m3)
Diesel[30]	42.5	880
Ethanol[30]	26.9	785
Petrol[30]	44	780
Biodiesel[31]	38.5	916

5. Estimation of Bioethanol from Oil Palm Sap

Elaeisguineensis is predominantly caltivated by the palm oil producing companies in Ghana [32]. This species is solely grown for the production of palm oil while palm sap is produced in small quantities which are meant for the production of palm wine. Palm sap is produced in Ghana mainly by destructive method which involves the incision of stem of felled palm [13] as a result, the yield of sugar is around 1.2 tonne per hectare in a year [33]. To produce palm sap in a sustained manner, the non-destructive method should be employed because there is a potential to increase the yield to 7.2 tonne per hectare annually when the palm trees are tapped every other month in a year. In addition, the strategies for producing ethanol from palm sap is either to integrate ethanol production to the major oil producing companies or central plants separated from the mills. The fermented sap will only be transported from the various sources to the central plants where they will be converted to ethanol. . These strategies are similar to that used in Brazil where there are two types of production facilities for ethanol-independent distilleries only producing ethanol and mills with distillery plants producing sugar and ethanol [34]. Some of the major companies producing palm oil in Ghana and their locations are listed in Table 4 and four of these companies will be considered since those were the data within the reach of the authors.

Table 4. The major oil producing companies in Ghana

Company	Location [32,35]	Area planted(ha)[5]
Benso Oil Palm Plantation (BOPP) Ltd.	Benso	6322
Twifo Oil Palm Plantation (TOPP) Ltd.	Twifo Praso	11000
Ghana Oil Palm Development Corporation Ltd. (GOPDC)	Akim Oda	35078
National Oil Palm Plantation	New Juaben	NA
Norpalm Ghana Ltd.	Prestea	5000
National Oil Palm Plantation Ltd.	Ayiem	NA

Assuming 85% conversion rate of ethanol from palm sap, then from Table 4 the potential ethanol for the different companies will be as presented in Table 5. It can be seen that a total of 447.5 million litres of ethanol can be derived from the four oil palm plantations with a maximum of 273.5 million litres of ethanol potential from GOPDC whilst almost 40 million litres of ethanol potential from Norpalm Ghana Ltd.

Table 5. Ethanol potential from the existing oil palm plantations

Company	Sugar yield (tonnes/yr)	Ethanol yield(million Litre/yr)
GOPDC	252561.6	274
BOPP	45518.4	50
TOPP	79200	86
Norpalm Ghana Ltd.	36000	39

GOPDC: Ghana Oil Palm Development Corporation Ltd
BOPP: Benso Oil Palm Plantation Ltd.
TOPP: Twifo Oil Palm Plantation Ltd

6. Results and Discussion

The analysis made is based on ethanol potential from just four oil palm plantations from well established companies. This is also based on the assumption that the oil palm plantations will not expand. The results obtained give a good indication that the ethanol required for fully implementing the biofuel plan can be produced using the palm sap as the potential feedstock.

Figure 2 shows the percent of bioethanol needed for the petrol replacement scenarios from the bioethanol potential from the four oil palm plantations. Assuming the biofuel plan was implemented for the timelines in indicated the policy, then it can be seen from Figure 2 that about 25% and 51% of the annual ethanol potential would have been needed to meet the required ethanol for E10 and E20 respectively in 2008. This would have increased to 32% and 63% in 2012 and further increase to 38 % and 75% in 2020 for E10 and E20 respectively when the use of E10 and E20 will be mandatory. However, the implementation of E85 seems unsustainable since the ethanol potential will not meet the required ethanol to replace 85% of petrol consumed according to the biofuel implementation timelines.

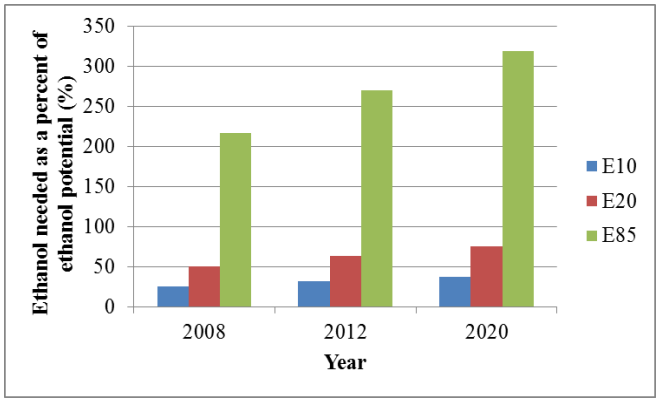

Fig. 2. The amount of ethanol required as a percentage of ethanol potential from four palm oil plantations in Ghana

Palm oil production was the leading foreign exchange earner for Ghana and significant efforts have been made to boost the palm oil industries. There is need for a re-evaluation at the production of ethanol not only from cassava as stipulated in the SNEP document but investigation into suitable feedstocks such as oil palm sap. Integrating ethanol production to the existing palm oil mills should not necessarily be complex and this should further boost the palm oil industry.

Ethanol production from palm sap is not new in Ghana. Traditionally the ethanol produced is locally known as akpeteshie. The traditional method of producing ethanol in Ghana is not energy efficient, however, this method could be improved upon thereby serving as the nucleus for ethanol production in Ghana.

One of the benefits of producing ethanol from sap collected from palm trees is that the since sap will ferment naturally, the preparatory stage of processing the raw feedstock and the hydrolysis stage, usually associated with some feedstocks such as starchy feedstocks will require relatively less overall energy input. The major setback of using ethanol as road transport fuel is that the emissions resulting from both direct and indirect land use change during the production of first generation ethanol are concerns to policy makers. This is one of the main reasons why the use of bioethanol as fuel constitute 3% of the total road transport fuels [28] and has not been rapid globally as one would expect. Another concern with bioethanol is that the land meant for food production is converted for the cultivation of feedstocks which are used for the production of ethanol and this has led to increase in prices of some food commodities. However, promoting oil palm as a source of feedstock for ethanol production will have a huge advantage since the ethanol produced is only a by-product which means that land meant for food production will not be compromised.

The socio-economic and environmental gains from implementing a sustainable biofuel plan should be a core

business of every government and most especially in developing countries such as Ghana where there are hopes of transforming the economy through industrialization and job creation. Ghana relies on proceeds from oil produced and the economy grew by 14.4% in 2011 from 8% in 2010 which largely depended on the level oil production. However, it is important to note that oil is finite and based on the oil production, the oil reserve might last for 32 years, therefore, Ghana must begin to look for alternative source of energy in order reduce the over reliance on oil imports.

Integrating ethanol production plants with palm oil mills will be one of the strategies and this will strengthen the industry since the ethanol produced is a by-product. This will increase revenues and further boost palm oil production. The costs of setting up and running plants to convert palm sap to ethanol will not be expensive since the sap produced will not undergo certain stages of ethanol production. This will be one the channels for creation of sustainable development in developing countries while tackling climate change through biofuel utilization.

7. Conclusion

The production of ethanol from palm sap as the one of the feedstocks in Ghana to sustain the biofuel policy is auspicious. Based on the four oil palm plantations own by the well established companies in Ghana, the total amount of ethanol that can be produced is around 447.5 million litres annually and considering the yield of sugar of 7.2 tonnes per hectare in a year if these plantations do not expand. Figures from biofuel plan indicate that, the ethanol potential from palm sap is enough to replace 10% and 20% of petrol consumed in Ghana up to 2020.

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