International Journal of Scientific Engineering and Science
Volume 1, Issue 8, pp. 1-4, 2017. ISSN (Online): 2456-7361

Comparative Evaluation of Bio-ethanol Production in Selected Palm Tree Species

Ubong David Offiong[1], David Onwe[2]
[1]Department of Agricultural Engineering, Akwa Ibom State University, Ikot Akpaden, Nigeria
[2]Department of Agricultural Engineering, University of Uyo, Nigeria

***Abstract*—** *Palm trees are usually considered as being useful and having economic value, however a particular breed which is referred to as Nypa palm often times found in mangrove biomas sometime become a source of environmental nuisance and concern. The study compared the bioethanol production rate from Oil palm (Ealasis guinesis), Raphia palm (Raphia hookeria) and Nypa palm (Nypa fruticana) which are locally available species in Akwa Ibom state, Nigeria. Results obtained from the study indicates that using both natural and catalysed (using saccharomyces cerevisae) fermentation process the Nypa palm (Nypa fruticana) popularly called "Imo Palm" exhibited the highest bioethanol production level. Bioethanol production followed the trend Nypa palm>Oil palm>Rafia palm for both the natural and catalysed fermentation processes. The peak values of bioethanol content after six days fermentation stood at 40%, 48% and 65% for Raffia, Oil and Nypa palm respectively under natural fermentation process while the peak bioethanol concentration for the catalysed process was observed to be 55%, 71% and 78.5% for Raffia, Oil and Nypa palm respectively. Findings from this could go a long way in changing the perception that this crop could be a nuisance as the use of this palm cell sap could turn out to be a valuable asset in the area of bioethanol production and ultimately renewable energy production and substantial income generation source.*

***Keywords*—** *Bio Ethanol, Evaluation, Palm Sap.*

I. INTRODUCTION

The need to protect our environment in a responsible and proactive manner is becoming more evident by the day. According to [1] the recent trend in change in average climatic conditions and the consequent need to diminish greenhouse gases emissions have encouraged the use of bioethanol as a diesel and gasoline replacement or additive. Bioethanol is a renewable energy source that is produced mainly from the process of fermenting sugar and starch components of plant by-products, although it can also be manufactured by the chemical process of reacting ethylene with steam as observed by [2]. According to [3] it is a microbiological way of converting simple sugar into ethanol and carbon dioxide (CO2). Bioethanol feedstock can contain either sucrose (e.g. sugarcane, sugar beet, cell sap) or starch (e.g. corn, wheat) or be a lignocellulosic material (e.g. sugarcane bagasse, wood and straw). Bioethanol is a principal fuel that can be used as petrol substitute for vehicle [4]. Bioethanol may also be used as raw material for the production of different chemicals, thus driving a full renewable chemical industry. Many countries in the world are currently exploiting the use of plants and plant materials in the generation of bio-ethanol. For example, in Brazil, sugarcane is the primary raw material in bio-ethanol production. The American government is investing lot of money and time to harness ethanol from corn. The Nigerian government is also presently targeting an annual production of over 150 million US dollars' worth of ethanol from cassava once the infrastructure is put in place [5]. As good as these plans are it has come to bare that the utilization of food crops in production of bio-ethanol may result in food scarcity as well as a general increment in food prices. This would likely lead to an increase in the cost of living specifically in developing countries and in the world at large. There is therefore a need to weigh the opportunity cost of producing this fuel from food. This threat can however be reduced or mitigated by considering the use of non-food materials as feedstock. To this end the use of cell sap of palm trees could be explored to help in combating the menace of environmental pollution through the use of fossil fuels and likely rise in general prices of food owing to competition.

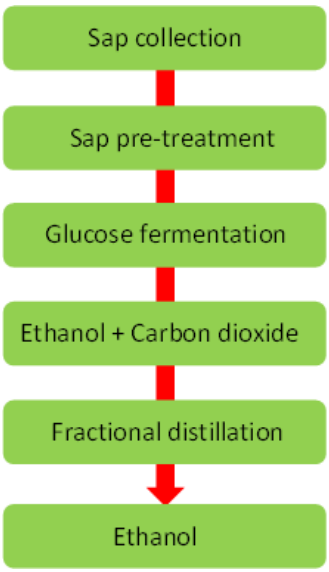

Fig. 1. Flow chart of Bio-ethanol Production from Palm Sap.
Source: [8]

The abundant quantity and supply of palm trees in forest regions of the country provides the raw materials for sustainable production of bio-ethanol [6]. Oil palm (*Elaeis guineensis*) and raphia palm (*Raphia hookeria*) are locally known for the commonly produced local drink called palm wine which produced from its fermented cell sap and usually contains about 4% alcohol by volume [7]. The Nypa palm

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(*Nypa fruticans*) is a species of palm native to the coastlines and estuarine habitats of the west Africa, Indian and Pacific Oceans. It is the only palm considered adapted to the mangrove biome. It has been observed that where Nypa colonizes the mangroves, it completely chokes the mangrove vegetation in which fish breed. There have been concerns that there is the possibility that dense Nypa colonization could affect the breeding of fish in the Niger Delta region of Nigeria, thus contributing to the decline of fish populations throughout the area. Some environmental organizations are beginning to realize that Nypa could be a potential problem. In year the 2000, the Nigerian Conservation Foundation (NCF) began project to assist local communities with the manufacture of jewellery from Nypa. The idea was that utilization would curtail the growth of the palm in the area. It is clear that there is the need to find other uses for this plant that is now being considered an environmental menace

One inherent advantage of the use of palm tree cell sap in production of ethanol is that the raw materials do not require any secondary processing before conversion. Palm trees are perennial plants, this makes them readily available for tapping all year round. Experience has shown that palm trees can be tapped after 4 to 5 years after planting and can produce its sap continuously for 15 to 20 years especially from good species like the nypa palm, coconut palm, oil palm etc. Tapping potentials produce less waste than production from other sources such as fruit, cereals or lignocellulosic materials. The cell sap from palm trees has to be taken through a number of steps (Figure 1) which are also similar to those in other feed stock before ethanol can be obtained. The sap obtained from palm sap has been proven to be rich in sugar concentration (15% to 20%) [8]. From literature a comparison of production rate for nypa palm with other common feed stock shows that it has the highest production rate as shown in table I making it a good feed stock

The main focus of this study is to compare the bioethanol yields of three palm species namely; Oil palm (*Ealasis guinesis*), *Raphia* palm (*Raphia hookeria*) and *Nypa* palm (*Nypa fruticana*) as well as their production variability.

II. METHODOLOGY

Prior to the study a survey was carried out in three locations within Akwa Ibom State to ascertain the availability of these breeds of palm trees. The three selected locations cut across the three geo-political zones of the state and were taken as a fair representation of situation of the whole population. The areas visited were Essien Udim, Itu and Ikot Abasi local government areas.

Information was also collected by conducting personal interviews with palm wine tappers, palm wine producers and gin producers in order to determine the factors affecting ethanol yield from palm sap. A total of thirty questionnaires were later distributed to the wine dealers in each of the areas visited; the distribution is as shown in the table below

2.1 Collection of samples: Ten litres palm sap samples were collected from each of the three species of palm tree in the above mentioned locations. They were collected in sterile, opaque plastic containers and immediately immersed in a freezing mixture of sodium chloride and ice chips before transporting them to the laboratory for analysis. The samples were kept at low temperature was to delay fermentation process from taking place rapidly.

As soon as the samples arrived the sugar concentration was determined by refractometric method by measuring 300 ml of each of the sap into clean beakers and lowering an Abbe hand refractometer into each of the samples.

Two methods were then employed in the fermentation process of the samples; these were the natural and the catalysed fermentation processes.

2.2 Natural anaerobic fermentation: Three litres of each of the samples were placed in a clean rubber container and tightly sealed to prevent the interference of air in the fermentation process. The containers were then kept at temperature of 35 ˚C during the fermentation process, this was to dampen the effect of temperature agitation which may alter the rate of reaction. The samples were left to ferment naturally for a period of six days. The alcohol content of the samples were measured daily by drawing a sample from a drain tap on the containers using an alcoholmeter.

2.3 Catalysed fermentation: yeast cells used for the catalysed fermentation process were prepared by culturing *saccharomyces cerevisiae* ln 500 ml of YPG broth over a 24 hour period. The cultured yeast cells were then separated by centrifuging and then washed in distilled water. The resulting yeast residue was transferred into the three clean plastic containers. A 3 litres sample was drawn from the collected unfermented palm sap and sterilized by autoclaving at 121 ^{0}C for 15 minute. After cooling, the samples were then inoculated with *saccharomyces cerevisiae* and kept for six days at room temperature. Samples were then drawn daily from each of the test medium and tested for alcohol content with the aid of an alcoholmeter.

III. RESULTS AND DISCUSSION

From the survey carried out in the three geo political zones of Akwa Ibom State, it was gathered that three species of palm trees dominates the mangrove swamp forest of the region. They include; Oil palm (*Ealasis guinesis*), *Raphia* palm (*Raphia hookeria*) and *Nypa* palm (*Nypa fruticana*). However of the three spices of palm trees the *Nypa* palm has the least level of utilization and is in some situations regarded as an environmental nuisance due to its nature of forming thick colonies especially in mangrove areas. Results obtained from questionnaires sent out to palm products dealers on their perception of the alcohol yield from the palm species is presented in table III.

The table shows that 83% respondents believed that Nypa palm tree locally called IMO PALM Produces more ethanol, while 17% respondents accepted that oil palm produces more ethanol, however non respondent quoted raphia palm as being an effective source of alcohol production. Since the production of ethanol from bio-agricultural materials depends on the sugar concentration of the materials, the classification agrees with the report from [10] on the growth of palm tree in the Niger Delta.

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International Journal of Scientific Engineering and Science
Volume 1, Issue 8, pp. 1-4, 2017. ISSN (Online): 2456-7361

Results obtained from the refractometric analysis conducted on the raw palm sap at the start of the study are as displayed in figure 2. The figure shows the percentage of sugar concentration in the three varieties of palm sap used in the experiment. From the result obtained, Nypa palm sap had the highest sugar concentration followed by oil palm sap while the raphia palm sap had the least sugar concentration. This proves that Nypa palm sap is would most likely have a higher yield of alcohol as observed by the majority of the sampled palm dealers as indicated in the result of the questionnaires. Results from natural anaerobic laboratory fermentation process as shown in table IV reveals that there is a linear relationship between ethanol yield and number of fermentation days. However taking a comparative look at the three species investigated it can be observed that alcohol production follows the trend Nypa palm>Oil palm>Rafia palm with a peak ethanol content of 40%, 48% and 65% for Raffia, Oil and Nypa palm respectively. This confirms the observations of majority of the palm products dealers who opined that the Nypa palm cell sap yielded more when compared with other species. Table V shows results from fermentation with the aid of cultured yeast (*saccharomyces cerevisae*) as a catalyst. From the table it is observed that there was a very sharp increase in the rate of alcohol production after 48 hours across all species this increased rate of production was sustained until after 60 hours when the rate of increase became drastically reduced till the last day of observation. It can also be noted that the catalysed fermentation process also follows the trend Nypa palm>Oil palm>Rafia palm with a peak ethanol content of 55%, 71% and 78.5% for Raffia, Oil and Nypa palm respectively. This shows that the addition of a catalyst did not alter the trend in production level comparison although it increased the production level of the palm species cell sap.

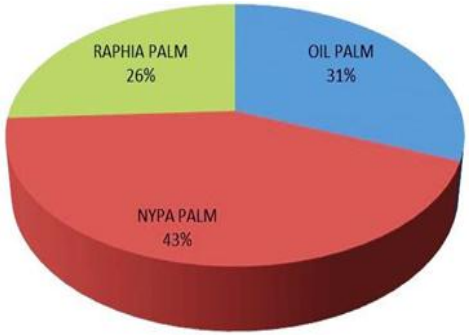

Fig. 2. Pie Chart Showing the Sugar Concentration in Varieties of Palm Sap.

TABLE I. Raw Materials for Bio-ethanol and thier Yeild.

S/n	Feed Stock	Yeild(ton/ha)	Ethanol(L/ton)	Ethanol(L/h)
1	Sugarcane	50-90	7090	5000-8000
2	Wheat	1.5-2.1	340	510-714
3	Berley	1.2-2.5	250	300-625
4	Rice	2.5-5.0	430	1075-2150
5	Maize	1.7-5.4	360	600-1944
6	Sorghum	1.0-3.7	350	350-1295
7	Irish potatoe	10-25	110	1110-2750
8	Cassava	10-65	170	1700-11050
9	Sweet potatoe	8-50	187	1336-8350
10	Grape	10-25	130	1300-3250
11	Nypa palm tree	--	--	15000-20000

Source: [9]

TABLE II. Distribution of questionnaires in each of the visited local government areas.

S/N	Product Dealer	No. of questionnaires
1	Palm wine tappers	10
2	Palm wine Producers	10
3	Gin Producers	10
	Total	**30**

TABLE III. Perception of palm products dealers on effectiveness of alcohol yield based on Palm Tree Species.

Sample size	Palm Specie	Highly Effective (%)
30	Oil Palm	17
	Raphia Palm	--
	Nypa Palm	83

TABLE IV. Ethanol yield from palm sap during Natural fermentation.

Duration of fermentation process (days)	Oil palm sap (%)	Raphia palm sap (%)	Nypa palm sap (%)
1	6.6	4.5	7.4
2	8.9	5.8	10.5
3	16.0	14.0	25.0
4	25.0	20.0	37.0
5	38.0	32.0	53.0
6	48.0	40.0	65.0

TABLE V. Ethanol yield from *Saccharomyces Cerevisae* catalysed palm sap fermentation.

Duration of fermentation process (days)	Oil palm sap (%)	Raphia palm sap (%)	Nypa palm sap (%)
1	8.3	5.2	9.5
2	20.0	17.3	25.0
3	46.0	33.0	50.5
4	68.0	52.0	75.0
5	70.5	53.5	78.0
6	71.0	55.0	78.5

IV. CONCLUSION

Results from the study indicates that at both natural and catalysed fermentation process the Nypa palm (*Nypa fruticana)* popularly called "Imo Palm" exhibited the highest bioethanol production level. This result could go a long way in changing the perception that this crop could be a nuisance as the use of this palm cell sap could turn out to be a valuable asset in the area of bioethanol production and ultimately renewable energy production. The other two species of palm (raffia palm and oil palm) do have a number of uses and have therefore been attributed to one commercial value or another.

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