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Comparison of Ethanol Production from three Different Tuber Plants *(Manihot esculenta, Ipomoea batata* and *Dioscorea Spp)*

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Abstract

In recent years, the annual energy consumption from petroleum sources has increased many folds resulting not only in continuous depletion of limited fossil fuel stocks but also a cause of concern for the safer, better and greener environment. Further, the high prices of fossil fuel have led to an energy crisis in both developing and developed countries that are oil dependent. Following these challenges, there is need to find alternative sources of producing energy. This study aimed at comparison of ethanol production from three different tuber plants (Manihot Esculenta, Ipomoea Batata and Dioscorea SPP). The cassava, sweet potato and yam peels were collected from the market premises of Jalingo Local Government Area, Taraba State. The collected samples were taken to a convenient place where they were sorted. The peels of cassava, sweet potato and yam were separately sorted to have mainly the peels for drying. The drying was carried out in open air which lasted for a week. The well dried samples were then milled using a hammer mill, Mortar and pestle which reduced the cassava, sweet potato and yam peels to very small particle

sizes and weighed. To 10 g of the powdered wort, distilled water was added, mashed and filtered. Yeast and malt were added to the filtered wort and allowed to stand for three (3) days for fermentation. After fermentation, the fermented wort was distilled to collect a colourless liquid as the distillate. This distillate was neutral to litmus test, soluble in water and indicated the presence of alcohol by Ester, Sodium Metal, Iodoform and Lucas Tests. The result compared from 3 samples showed that cassava peels produced the highest ethanol concentration (6.25) followed by yam peels (6.13) while the minimum ethanol yield was obtained from sweet potato peels (5.01) at temperature 78.4^0C and P^H 7.2 after 72 hours of fermentation. This work has shown that cassava, sweet potato and yam peels which are considered a non-valuable waste are suitable raw materials and could be efficiently utilized for the production of ethanol.

Keywords: Ethanol, *Manihot esculenta, Ipomoea batata, Dioscorea Spp,* Fermentation

INTRODUCTION

Petroleum is the source of about 170 quads of energy out of the total of more than 460 quads used by the world which is far more than derived from other sources (IPCC 2007). Besides the negative global warming impact of fossil fuels, volatile oil price and political unstable in oil exporting countries resulted in a significant increase in international interest in alternative fuels and led policy makers in the world to issues and ambitious goals for substitution of alternative for conventional fuels (Galbe and Zacchi, 2002, Wyman 2007). In recent years, the annual energy consumption from petroleum sources has increased many folds resulting not only in continuous depletion of limited fossil fuel stocks but also a cause of concern for the safer, better and greener environment (Lynd and Wang, 2003). Further, the high prices of fossil fuel have led to an energy crisis in both developing and developed countries that are oil dependent (Oyeleke and Dauda, 2012). Reverse of fossil fuel is going to be depleted fast, leading to the increase in fuel prices and simultaneously unfolding energy crisis (Olayide, 2015). The rapid growth of industries and technological advancement in the world call for development in the chemical sector and the production of industrial chemicals will enhance the economic progress of any nation (Wyman, 2007; Ojewumi, 2018).

Bioethanol, an alcohol produced by fermentation of plant biomass containing starch and sugars by microorganisms, is considered as a dominant form of fuel for future (Akponah and Akpomie, 2011). Production of this renewable fuel, especially from starchy materials such as tuber crops hold a remarkable potential to meet the future energy demand due to its high production and comparatively less demand for use as food and fodder (Mustapha *et al.,* 2019). Bioethanol is widely recognized as a unique transportation fuel and original material of various chemical with powerful economic, environmental and strategic attributes (Olayinka and Isaac, 2018). Ethanol can be produced extensively from biomass such as Cassava peels, sweet Potato peels and Yam peels (Hrudayanath *et al.,* 2014). The main constituents of these classes of crops by-product are cellulose and hemicelluloses making them lignocelluloses that can be excellent energy sources (Duhan *et al.,* 2013). Mechanized farming has led to extensive discharge of agricultural wastes that have had negative effects on the environment (Fadel, 2000). As a result of environmental mess caused the agricultural activities of farmers, the utilization of such wastes has become very important to researchers.

According to Adiotomre et.al. (2015) ethanol is a principal fuel that can be used as petrol substitute for vehicles. It is a renewable energy source produced mainly by sugar fermentation process. It is used in preservation of specimen, food and even as a raw material in the manufacturing of chemicals and pharmaceuticals like trichloromethane. There is need to source for alcohol from plant sources because of its vast use. The aim of this study is to compare ethanol production from three different tuber plants. (*Maihot escolanta, Ipomoea batata* and *Dioscorea SPP*).

MATERIALS AND METHODS

Sample Collection and Preparation

The sources of the samples were cassava, sweet potato and yam tubers. The peels and wastes of the three tubers were collected from the market premises of Jalingo Local Government Area, Taraba State. The collected samples were taken to a convenient place where they were sorted. The peels of cassava, sweet potato and yam were separately sorted and separated for drying. The drying was carried out in open air which lasted for a week. The well dried samples were then milled using a hammer mill, Mortar and pestle to reduce the cassava, sweet potato and yam peels to very small particle sizes.

Ethanol Production from the Tuber Samples

The ethanol was produced using the peels of cassava, sweet potato and yam. The peels were washed, milled and weighed. To 10 g of the powdered wort, distilled water (190mL) was added, mashed and filtered. Yeast and malt were added to the filtered wort and allowed to stand for three (3) days for fermentation. After fermentation, the ethanol and water from the sugar-containing liquid mixture (fermented wort) was separated into their components using distillation method.

The chemical reaction for ethanol production was derived as:

Glucose + yeast → ethanol + carbon dioxide

$C_6H_{12}O_{6(aq)}$ + yeast → $2C_2H_5OH(aq) + 2CO_{2(aq)}$

Confirmatory tests were then carried out for each sample to ascertain that the distillates were actually ethanol (ester test, sodium metal test, iodoform test and lucas test).

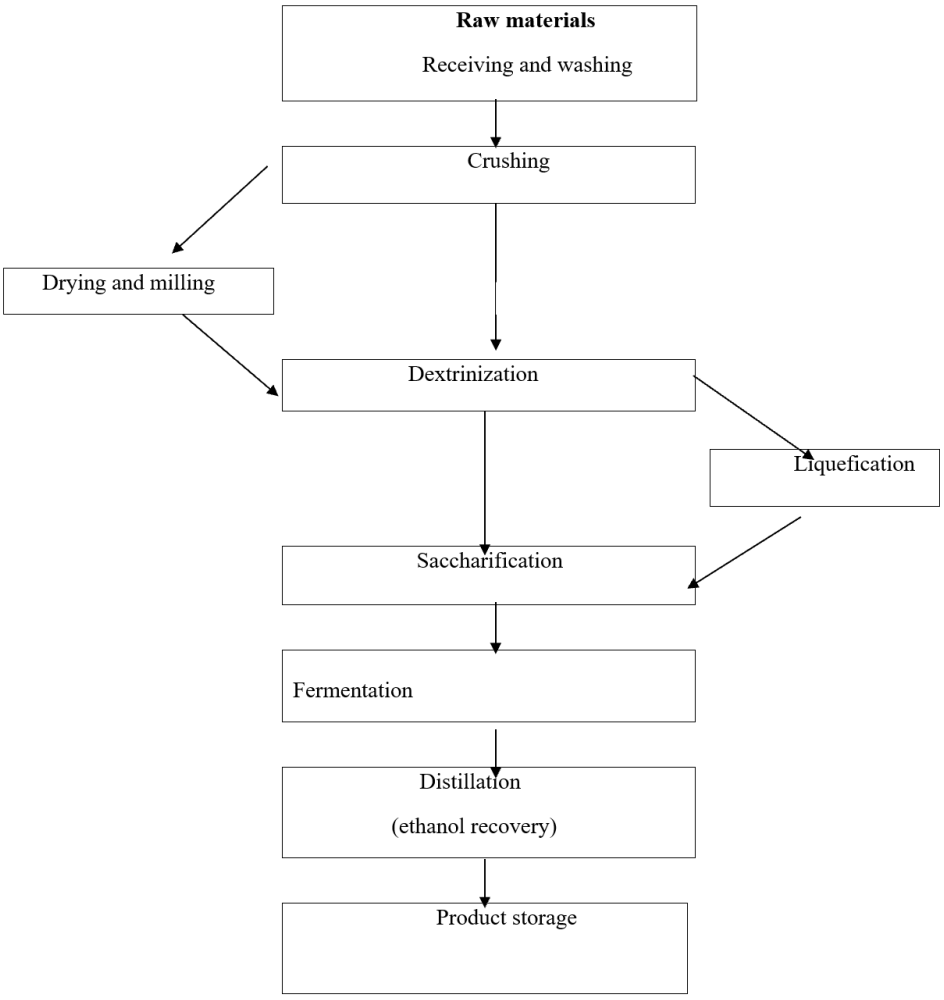

Figure 1. Simple process of ethanol production using peels of tuberous plants

Percentage yield of Ethanol

The data collected for the study was analyzed using percentage frequency. Ethanol yields over total initial sugars (Y1) and average ethanol productivity rate (Y2) were calculated according to equation (2) and (3) as given by Wyman et al. (2007).

$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2C\ O_2$ (1)

$Y1 = ethanol\ produced\ in \frac{ethanol\ produced\ in\ fermentation}{ethanol\ produced\ in\ theoretical}$ x 100 (2)

Y2 = final ethanol concentration/fermentation time (3)

Statistical Analysis

The data obtained from ethanol produced using the three tuber samples was analyzed using SPPS version 23.0. One way ANOVA particularly was used for this analysis. Turkey's post hoc test was used to separate the means at $p \leq 0.05$ (5% significance level).

RESULTS AND DISCUSSION

Quantity of Ethanol Produced from Cassava Peel, Sweet Potato Peel, and Yam Peel

The data for the study were presented in the following tables and interpretation of the result obtained from the experiment given. From table 4 below, the composition analysis revealed that cassava, sweet potato and yam peels using 10g contained 6.25, 5.01, and 6.13. This showed that, in terms of substrate yield, highest ethanol production was from cassava peels, followed by yam peels while sweet potato peels yielded the least ethanol concentration.

Table 1. Quantity of ethanol produced from cassava peel

S/N	**Samples**	**Time (minutes)**	**Initial vol. of distillate(mL)**	**Final vol. of distillate(mL)**	**Quantity of ethanol produced**	**Percentage (%)**
1	10g CP+190mLD.H_2O	140	200	206.25	06.25	3.125
2	10g CP+190mLD.H_2O	140	200	206.40	06.40	3.200

Table 2. Quantity of ethanol produced using sweet potato peel

S/N	**Samples**	**Time (minutes)**	**Initial vol.of distillate(mL)**	**Final vol.of distillate(mL)**	**Quantity of ethanol produced**	**Percentage (%)**
1	10g SP+190mLD.H_2O	140	200	205.01	05.01	2.505
2	10g SP+190mLD.H_2O	140	200	205.10	05.10	2.550

NB: D= Distilled

Table 3. Quantity of ethanol produced using yam peel

S/N	**Samples**	**Time (minutes)**	**Initial vol.of distillate(mL)**	**Final vol. of distillate(mL)**	**Quantity of ethanol produced**	**Percentage (%)**
1	10g YP+190mLD.H_2O	140	200	206.13	06.13	3.065
2	10g YP+190mLD.H_2O	140	200	206.19	06.19	3.095

Table 4. Comparison of ethanol produced between the three tuber samples

Samples	**Sample weight(g)**	**Ethanol produced**	**Percentage (%)**
Cassava peel	10	6.25	86.84
Sweet potato peel	10	5.01	69.60
Yam peel	10	6.13	85.18

Hydrolysis of Starch

$nC_6H_{10}O_5 + nH_2O \rightarrow nC_6H_{12}O_6$

starch water glucose

162g 18g 180g

162g → 180g of glucose

10g → x

X= 180 x $\frac{10}{162}$ =11.11g of glucose

Fermentation of Glucose

$C_6H_{12}O_{6(aq)}$ $\frac{yeast}{zymase}$ $2C_2H_5OH(aq) + 2CO_{2(aq)}$

180g of glucose ⟶ 2moles C_2H_5OH

12 x 2 + 1x5+16+1

24+5+16+1=46

Amount (mole) =$\frac{mass(g)}{molar\ mass}$

Mass(g) = amount(mole) x molar mass $gmol^{-1}$

2 x 46 = 92g

Theoretical Yield of Ethanol

180g of glucose → 92g C_2H_5OH

11.11g of glucose → y

y=$\frac{11.11x92}{180}$ = 5.678g of C_2H_5OH

Percentage Yield of Starch

% yield = $\frac{actual\ yield}{theoritical\ yield}$ X 100

Actual yield (laboratory result) 1cm=1ml

Volume of ethanol 6.25ml

Density of ethanol 0.789gcm^{-3}

Density = $\frac{mass}{volume}$

a) Cassava peel (CP)

Mass (ethanol) = density x volume

=0.789 x 6.25 =4.931 C_2H_5OH

% yield = $\frac{actual\ yield}{theoritical\ yield}$ X 100

= $\frac{4.931}{5.678}$ X 100 =86.84%

b) Sweet potatoes peel (SPP)

Mass (ethanol) = density x volume

=0.789 x 5.01 =3.952 C_2H_5OH

% yield = $\frac{actual\ yield}{theoritical\ yield}$ X 100

= $\frac{3.952}{5.678}$ X 100 =69.60%

c) Yam peel (YP)

Mass (ethanol) = density x volume

=0.789 x 6.13=4.837 C_2H_5OH

% yield = $\frac{actual\ yield}{theoritical\ yield}$ X 100

= $\frac{4.837}{5.678}$ X 100 =85.18%

Table 5. Test for the produced ethanol

Tests	**Procedure**	**Observation**	**Inference**
1. Ester Test	Small quantity of organic liquid produced in a test tube + 2cm^3 of ethanoic acid + few drops of concentrated H_2SO_4 + boil for a while	Fruity smell observed	This indicate the presence of alcohol
2. Sodium Metal Test	1cm^3 of organic liquid produced in a test tube + small quantity of sodium metal	Vigorous effervescence with evolution of gas which is colorless and odorless and has no effect on litmus paper was observed	This indicate the presence of alcohol
3. Iodoform Test	1mL of produced organic liquid in a test tube + 1mL of iodine solution + few drops of dilute NaOH solution, the mixture was then heated gently	Yellow precipitate was formed	This indicate the presence of alcohol
4. Lucas Test	Small amo unt of organic liquid produced in a clean test tube + 8-10 drops of Lucas reagent, the mixture was shake well	Appearance of cloudness was observed	This indicate the presence of alcohol

Table 5. Physical properties of standard ethanol compared with ethanol produced

S/N	Properties	Ethanol produced	Standard Ethanol
1	Melting point	-114.1^{0}C	-114.1^{0}C
2	Boiling point	78.4^{0}C	78^{0}C
3	Density at 15^{0}C g/Ml	0.785	0.789
4	Specific gravity	13	13
5	Viscosity at 20^{0}C	0.0013	0.0012
6	p^H	7.2	7.33
7	Pour point	-39	-40
8	Refractive index, %	1.3803	1.3614

The physical properties of standard ethanol and ethanol produced are compared in the table 5 with the melting and boiling points of both being the same. According to table 4, ethanol can be produced from cassava, sweet potato and yam peels. These shows that their peels can serve as a substitute to other crops that contain starch which are used for ethanol production.

It has been recorded that ethanol can be produced from starch containing substances like cassava, sweet potato and yam (Olayide, 2015). Thus the peels of the crops are regarded as waste but can be another source of ethanol production even though the quality and quantity is small.

The result from the table for confirmatory test showed that, the produced ethanol shows positive result to Ester, Sodium Metal, Iodoform and Lucas test indicating presence of alcohol.

CONCLUSION

It is very evident from the results obtained by the three samples used in this study that cassava peels produced the highest ethanol concentration (53 and 105) while the minimum ethanol yield was obtained from yam peels (36 and 73) at temperature 78.4^{0}C and pH 7.2 after 72 hours of fermentation. Also, the physical and chemical properties of the produced ethanol are similar to the standard ethanol. This work has shown that cassava, sweet potato and yam peels which are considered a non-valuable waste are suitable raw materials and

could be efficiently utilized for the production of ethanol. This is due to their starch contents though the products are low but still manageable.

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Conflicts of Interest

The authors declared that there are no conflicts of interest.

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