PRODUCTION OF ETHANOL FROM BREADFRUIT (*Artocapus communis)* AND ITS ECONOMIC VIABILITY FOR SMALL-SCALE INDUSTRY

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ABSTRACT

Ethanol (C_2H_5OH) is a primary alcohol which is produced by fermentation, using any of the sources of carbohydrates such as sugarcane, cassava, grains and yam tubers among others. Therefore this study was conducted using breadfruit as alternative source for ethanol production. This is with a view of making ethanol to be available and economically cheap for small-scale industry. The fruits were peeled, cut into bits, sundried and ground into powder with mortar and sieved with a 2 mm size sieve. The starch in breadfruit was hydrolysed into fermentable sugar, using acid hydrolysis. The fermentable sugar was converted into ethanol by fermentation process at pH 4.5 using fermenting brewer`s yeast (*Saccharomyces calsbergensis*). Starch, glucose and ethanol which were obtained were analysed for physicochemical properties. Findings revealed that the powdered breadfruit samples gave a blue-black colouration on addition of few drops of iodine solution. This confirmed that the carbohydrate content is mainly starch. On calculation of viability, findings further showed that, breadfruit is a good raw material for production of ethanol, therefore indigenous production of ethanol obtained from the breadfruit is economically viable. Although, breadfruit cannot be stored for long, but it can be preserved by sun dried and crushed into powdered form which can be used for the preparation of useful materials and chemicals mostly ethanol. This will save the country from lot of money spent annually on the importation of ethanol and it can also provide job opportunity for many wandering and unemployed Nigerians.

KEYWORDS: Breadfruit; Ethanol; Fermentation; Economic viability; Starch; Yeast.

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INTRODUCTION

Alcoholic fermentation of fruits that contain sugar was the earliest application of fermentation with the production of wine and beer in the Middle East, dating back to 6000 BC(Aworh, 2010). The daily increase in demand for ethanol in industries and at home fascinated this study. There are various types of alcohol but the common term used by wine makers is ethyl alcohol or ethanol (C_2H_5OH). Alcohol is classified into primary, secondary and tertiary. C_2H_5OH is a primary alcohol and it is the second member in the alcoholic series while methanol (CH_3OH) called wood spirit is the first member of the series. All primary alcohol is oxidized with solution of potassium – (or sodium) dichromate (vi) or potassium manganate (vii) in dilute sulphuric acid to give aldehyde and with further oxidation will give a carboxylic acid. A secondary alcohol will on oxidation with solution of potassium – (or sodium) dichromate (vi) or potassium manganate (vii.) in dilute sulphuric acid yields ketones; while tertiary alcohol is resistance to oxidation (Roger *et al.*, 1979). Ethanol is produced commercially by fermentation and/or synthetic process. The synthetic process involves direct hydration of ethene, indirect hydration of ethene and hydration of ethyne (acetylene) (Michael, 1982). Fermentation is a term that has been applied to the decomposition of food stuffs and is one of the oldest techniques of food preservation. The best-known example is alcoholic fermentation in which sugar is converted into alcohol and carbon dioxide using yeast as catalyst as given in the reaction equation below.

$$C_6H_{12}O_6\,(aq) \xrightarrow{\text{Yeast}} 2\ C_2H_5OH\,(aq) + 2CO_2\,(g)$$

The fundamental reaction underlying the production of ethanol by fermentation is the catalytic conversion of glucose into alcohol by the enzyme present in yeast (Aworh, 2010). It was Mitscherlich in 1841 who first demonstrated that fermentation occurred in a starch solution only after the introduction of live yeast cells. Any source of carbohydrates such as sugarcane, cassava, grains and yam tubers among others can be fermented for production of alcohol. The industrial production of ethanol utilizing ethene or acetylene is limited due to high cost of equipment and synthetic processes involved. The high demand for ethanol in diverse industries has necessitated research on alternative sources for ethanol production from raw materials like breadfruit. This is with the view of making ethanol to be available and become more economically cheap for small and large scale industries to patronize.

Breadfruit (*Artocapus communis*) one of the most important food crops belongs to the family mulberry. The tree is native to the pacific islands and it is grown all over the tropics. The fruits consist of carbohydrates (40%), protein (17%), water (31%), fat (10 – 16%) and mineral matter (2%) with most of the carbohydrate being starch. Due to its high carbohydrate content, it serves as one of the most abundant sources of carbohydrates in Nigeria especially in the western part of the country as it is substituted for yam. Apart from this after the extraction of the starch from the fruit, the residues are served as food supplement for live stocks. However, the current usage, particularly in developing countries, is limited by the poor storage properties of the fresh fruit (Adebowale *et al*., 2005). It is therefore reasonable to maximize the potentials of this valuable fruit by processing it into different products with better shelf-life.According to Adebowale *et al*. (2005) conversion of the fresh fruit to flour and starch would provide, a more stable form as well as increase its versatility.

MATERIALS AND METHODS

The breadfruit (*Artocapus communis*) used for this study was purchased from the local market (Atikori) in Ijebu-Igbo, Ijebu North Local Government area of Ogun State, Nigeria. In order to obtain a more stable form of the fruits as well as increase its versatility, the fruits were peeled, cut into bits and air dried in the sun for four days. After this, the peeled fruits were ground to fine powder mechanically with mortar and sieved with a 2 mm size sieve. This was kept in a corked bottle for use in the subsequent work in the laboratory. The fermenting brewer`s yeast (*Saccharomyces calsbergensis*) used was obtained from standard breweries, Imagbon Ijebu.

EXPERIMENTAL METHODS

Physicochemical Characterization of the breadfruit samples

Determination of Moisture Content

Cleaned petri dish was dried for 30 minutes in an oven at 104° C and cooled in a dessicator. The petri-dish was weighed and a 10 g mass of milled sample was weighed into it and placed in the oven at 105° C. It was removed and cooled in the dessicator after heating for 2 hours. It was weighed and subsequently heated in the oven until constant mass observed. Percentage moisture was calculated using the formula below.

$$\%\ \text{moisture content} = \frac{\text{Initial mass of sample} - \text{final mass of sample}}{\text{Initial mass of sample}} \times 100$$

Starch test

An amount of0.4 g of the powdered breadfruit samples was dissolved in 5.00 mL of distilled water in a test tube. The solution gives a blue-black colouration on addition of few drops of iodine solution.

Acid Hydrolysis

The method of Christopher Dumazert was used for the acid hydrolysis. An amount of 50.0 g of the powdered breadfruit was treated with 500 mL of 0.2 M HCl in a 1 L round bottom flask. The solution was heated under reflux for 3 hours (Carl, 1992). The mixture was then cooled and filtered. The pH (1.6) obtained for the hydrolysed filtrate was increased to 4.7 with 0.5 M NH_3 solution a slightly acidic state suitable for the action of fermenting microorganism (Adeyemi*et al*., 2019).

Determination of Reducing Sugar

An amount of 5 mL of the hydrolysed filtrate was collected and analyzed for the reducing sugar content. A mixture of equal volume of Fehling's solution A (Copper sulphate solution) and B (Sodium potassium tartarate and sodium hydroxide solution) was added to it in a conical flask. The mixture was then heated at 90° C for 5-15 minutes to develop a red-brown color. Concentration of reduced sugar (g/L) was calculated with the line equation of known glucose concentration (NAL USDA, 2015).

Fermentation Process

The amount of 595 mL of the hydrolysed filtrate left after the test for reducing sugar content was used for fermentation. Fermenting brewer`s yeast (*Saccharomyces calsbergensis*) cell was used to inoculate the hydrolysed filtrate. The fermentation was set up at room temperature, for 5 days. The yeast suspension was removed after the fermentation process. The chemical equation for the fermentation reaction is given in the reaction equation below.

$$C_6H_{12}O_6\,(aq) \xrightarrow[\text{pH 4.7, Temp. } 25^{\circ}C]{\textit{Saccharomyces calsbergensis}} 2C_2H_5OH(aq) + 2CO_2\,(g) + \text{Energy (heat)}$$

Distillation

The clear solution obtained from the fermentation process was distilled to obtain the alcohol. In distilling, the fermented product was poured into a quick fit round bottom flask fitted with condenser. The ethanol was distilled using a sand bath at temperature of (70 – 82)°C and the distillate was collected. The distillate liquor was redistilled for 2-3 times in order to increase the percentage purity of the ethanol.

RESULTS AND DISCUSSION

The Results obtained from the analysis carried out on the starch sample, fermentable sugar and ethanol obtained from the breadfruit (*Artocapus communis*) samples are presented in Table 1.

Table 1: Physico-chemical parameters of starch sample from breadfruit (*Artocapuscommunis*).

Parameters	Values
% Moisture content	12.10
Starch (Iodine test)	Positive
Reducing Sugar (Fehling`s test)	Positive
pH for hydrolysed filtrate	1.6
pH for fermentable sudar	4.7
Volume of fermentable liquor used for fermentation	595 mL
Volume of ethanol obtained	375 mL
Boiling point for ethanol obtained	82° C
Specific gravity for ethanol obtained	0.850

(a) Starch sample

The powdered breadfruit (*Artocapus communis*) sample on addition of few drops of iodine solution gave a blue-black colouration. This confirmed that the carbohydrate content of breadfruit is mainly starch.

(b) Hydolysed filtrate obtained

The hydrolsedfiltrate / fermentable sugar obtained from breadfruit (*Artocapus communis*) sample when tested with Fehling's solution gave a red-brown precipitate. This showed that the hydrolysed filtrate was a reducing sugar (mostly D-glucose).

(c) pH of hydrolysed filtrate obtained

After hydrolysis, the fermentable sugar was found to be too acidic (pH 1.6), thus the pH was adjusted to pH 4.7, since the yeast (*Saccharomyces calsbergensis*) used for this study is active between pH 4.50 to 5.00. This is very close to pH 5.0 reported by Adeyemi *et al*. (2019) to be the slightly acidic condition suitable for the action of fermenting microorganism.

(d) Boiling point for ethanol obtained

The boiling point for ethanol obtained from breadfruit (*Artocapus communis*) was 82°C. This is higher than the boiling point of 78.3°C reported by William (2014). The ethanol obtained after distillation is an azeotropic mixture and its boiling point should be higher than 78.3° C (William, 2014).

(e) Specific Gravity

The specific gravity for ethanol obtained from breadfruit (*Artocapus communis*) was 0.850. This is higher than the specific gravity of 0.789 reported by William (2014). The ethanol obtained after distillation is an azeotropic mixture and should be higher than 0.789 (William, 2014).

(f) Viability Studies

Calculation on viability aspect of the study was found necessary, since one of the objectives of the study was to find out the viability of a small-scale ethanol production industry. The viability studies were calculated as:

(i) Total mass of breadfruit powder obtained = 400 g

(ii) Mass used for this study = 100 g

Since the percentage composition of carbohydrate (40 %) in breadfruit is mostly starch, therefore, every 100 g of breadfruit powder weighed gives almost 40 g of starch. After fermentation and distillation every 100 g of fruit hydrolysed +375 mL of ethanol was obtained. The fermentation of 1 ton (10^6 g) of starch which results to the use of 2,500 Kg powdered breadfruit will give

$$\frac{375\ \text{mL}}{40\ \text{g}} \times 10^6\ \text{g}$$

$= 9.375 \times 10^6$ mL $= 9.4 \times 10^6$ mL

$= 9.4 \times 10^3$ litres.

Therefore, 1 g of starch contained in 2.5 g of breadfruit will give 9.375 mL of ethanol.

This shows that if a small-scale industry can be able to handle 1 tonne (10^6 grammes) of starch in a month, invariably 9.4×10^3 litres of ethanol will be produced by such industry

Fermentation process was the method adopted in this study, since when alcohol is being manufactured by fermentation we can make use of any sources of carbohydrates, such as sugarcane, cassava, yam tubers among others as the raw materials and more so, to achieve high conversion efficiency of sugar to alcohol (Chi *et al*., 1995; WR Abdel-Fattah *et al.*, 2000).

Acidic hydrolysis using dilute HCl was used to convert the starch in powdered breadfruit (*Artocapus communis*) into fermentable sugar and this took about three hours. In comparison to enzymatic hydrolysis which will take about 3 day, acidic hydrolysis was found to produce the fermentable sugar in shorter times.

CONCLUSION

From the foregoing, breadfruit (*Artocapus communis*) is identified in the study as a good raw material for production of ethanol due to its high carbohydrate content. Indigenous production of ethanol is economically viable. The paper argues further that though breadfruit is one of the most important food crops with abundant carbohydrates but due to the poor storage properties of its fresh fruit which has limited its current usage, there is a need to maximize the potential of this valuable fruit and utilize it for the production of ethanol. Efforts in this direction will help in utilizing it for the preparation of useful raw materials and chemicals in both food and non-food industries. This will save the country from a lot of money that is being spent annually on the importation of ethanol and it will also provide job opportunity for employment.

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