



ORIGINAL RESEARCH ARTICLE

PRODUCTION OF BIO-GEL FROM WASTE OF CASSAVA AND MAIZE

W. B. Asiru¹, A. O. Raji^{2*}, and N. Alausa¹

¹ Federal Institute of Industrial Research, Oshodi, Lagos

² Department of Agricultural and Environmental Engineering, University of Ibadan

*Corresponding author's email address: abdulganiyr@yahoo.com

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ABSTRACT

Bio-ethanol was produced using starch extracted from cassava peel and cellulose from Corn cobs using acid hydrolysis and yeast for fermentation while Bio-gel fuel was produced using a composition of bioethanol and gel from water and Carboxymethyl Cellulose (CMC) in ratio 80%, 20% by volume respectively. The average yield of bioethanol is 757.33ml for cassava peel and 595.56 for corn cobs from 3.55L and 3.35L of filtrates respectively. The properties of bio-ethanol produced from the two samples compared favorably with the commercial ethanol. The bio-gel fuel which is an alternative source for cooking can also support outdoor burning. The formulation is made from 100% recycle of agricultural wastes making it very economical. The research work will have considerable impacts on the vision of bio-economy launched by many African countries, which is to be achieved through the creation and growth of novel industries that generate and develop bio-based services and products. It will also support the local content initiative of Nigeria government. The success of the study has a great impact on the environment being a waste conversion study.

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1.0 Introduction

Large number of wastes are produced from agricultural, forestry and food production/processing activities. It is estimated that globally over 140 billion metric tons of biomass is generated every year from agriculture (Chun, 2015; UNEP, 2015, Tripathi et al., 2019). This volume of biomass can be converted to an enormous amount of energy and raw materials. Equivalent to approximately 50 billion tons of oil, agricultural biomass waste converted to energy can substantially displace fossil fuel, reduce emissions of greenhouse gases and provide renewable energy to some 1.6 billion people in developing countries, which still lack access to electricity (UNEP, 2015.). As raw materials, biomass wastes have attractive potentials for large-scale industries and community-level enterprises that reduces the carbon print. According to the EIA's report on energy (USEIA, 2013), the primary energy consumption worldwide is expected to increase by 0.2% per annum, resulting in an overall increase in consumption of 6% by 2040. However, the global energy consumption growth accelerated in 2023 (+2.2%), much faster than its average 2010-2019 growth rate (+1.5%/year) (WECS, 2024). The rapid growth is linked to factors like post-pandemic economic recovery, increased industrial activity, and rising energy demand in developing countries. However, while global energy demand grew significantly, some developed economies saw slower growth or even declines due to economic factors like inflation.

Studies confirm that the world still relies heavily on fossil fuels to meet growing international energy demands. The negative aspects inherently related to the consumption of fossil fuels include the environmental impact of CO₂ emissions, the depletion of fossil fuel reserves, as well as the economic dependence on countries where political instability is prevalent (Maggio and Cacciola, 2012). In Nigeria, 98 per cent of households lack access to quality clean cooking and lighting fuels. Estimates of 98% of Nigerians are not able to use quality cooking fuels (Biofuels, LPG cooking gas and electricity). Consequent on this, over 95,400 deaths occur per year as a result of the use of traditional fuels such as wood and charcoal, and Nigeria's deforestation rate is one of the highest in the world with 3.3% of its forests lost each year. An average poor household spend 60% of daily earning on energy and Nigeria import 98% of annual ethanol consumption from other countries while \$9m is spent on Kerosene daily in Nigeria. These figures show the estimated income that could be generated from bio-gel if produced in replacement of fossil fuels. There is the potential to generate the bio-fuel form waste

materials from agriculture which are in abundant in Nigeria. Obi et al. (2016) with a host of other researchers estimated over 998 million metric ton of waste is generated from agriculture in Nigeria. Therefore, the main objective of the project is to develop sound technologies for converting cellulosic biomass into energy/biogel and promote the use of biomass. Specifically, the objective is to develop a technology for production of bio-gel from wastes of cassava and maize hence conversion of waste to useful material.

2. Materials and Methods

2.1 Materials

Freshly processed cassava peels were bought at a cassava processing site Eleyele in Ibadan, Oyo state, South-Western Nigeria while the Corn Cobs (CCs) were collected from farmers and Maize merchants in Ibokun and Ibadan in Osun and Oyo States respectively. Chemicals and reagents were purchased in chemical and laboratory stores in Ibadan and Lagos respectively.

2.2 Methods

Cassava peel (CP) and corn cobs (CC) used were both produced from their dried powder using acid conversion method. One kilogram (1000g) of each CC and CP samples were weighed with a Laboratory Scale and transferred into 5L conical flasks each. Four liters (4L) of Sulphuric Acid (1M H₂SO₄) solution was added to each of the sample. The mixture was stirred with glass rod. The hydrolysis process was proceeded in a water bath pre-set at 100°C. The hydrolysis was maintained at 100°C for 2 hours. Four Hundred milliliter (400ml) of Sodium Hydroxide (0.1M NaOH) solution was added to neutralize the slurry, thereafter, the slurries were filtered. The filtrate was further used for ethanol production through fermentation using ethanol tolerance yeast. The filtrate pH was adjusted to 5.2 before fermentation commenced.

The fermentation medium consists of the following in g/L; 10g Peptone, 0.5g MgSO₄.7H₂O, 0.5g KH₂PO₄ and 0.5g (NH₄)₂SO₄. The components were added to the filtrate respectively and sterilized in an Autoclave at 115°C for 20 minutes. The fermentation medium was cooled to room temperature and was subsequently pitched with yeast cell suspension (*Saccharomyces Cerevisiae*) at 50 × 10⁵ cells/L. The inoculated media were incubated at 28±2°C for 7days after which they were was withdrawn for distillation and subsequently purified using rotary evaporator into concentrated ethanol. These samples of ethanol from CP and CC were then analysed.

2.2.1 Production of Biogel from Bio-ethanol produced from Corn cobs and Cassava peel

The Biogel was produced using a composition of ethanol produced from corn cobs and cassava peel, water and Carboxy Methyl Cellulose (CMC) respectively. The CMC acts as gelling agent which needs water to gel before being added to ethanol. The mixture normally results in an inflammable gel often used for cooking. Analysis of the ethanol produced from corn cobs and cassava peel showed that parameters obtained from both are very close and preliminary investigation showed that both formed gel of same quality, hence corn cobs ethanol was produced in large quantity and used for production of bio-gel. The ethanol from corn cobs (200ml each) were then poured into five beakers. Thereafter, 1.5, 2.5, 3.5, 4.5 and 5.5g of CMC were added to 50 ml of water in another set of beakers to form gelled water and were designated as S1, S2, S3, S4 and S5, respectively. These were mixed thoroughly and vigorously with spatula until the CMC dissolved and form gel. Two hundred millilitres (200ml) each of the prepared corn cob ethanol were added gradually to each beaker containing gelled water and mixed continuously. The samples were left for 48 hours before further analysis on the samples. Commercial bio-gel produced by SME Funds (GEB. 2024) purchased from the market was used as the control.

2.2.2 Determination of Yield of Ethanol

A measure of 450ml each of the filtrate was poured in the flask of the distillation apparatus and distillation of the filtrate was done at 78°C using distillation column and rotary evaporator. The distillate collected was poured into a measuring cylinder to determine the volume of the ethanol produced. The percentage yield was calculated using Equation 1.

$$\text{Yield (\%)} = \frac{V_e}{V_f} \times 100$$

where V_e and V_f are the volume of ethanol produced and volume of filtrate used respectively.

2.2.3 Determination of Percentage Ethanol

The percentage ethanol was determined using ethanol by weight through specific gravity (AOAC, 2010). The specific gravity of the ethanol was calculated and checked on ethanol's table. The percentage ethanol values that corresponded with the specific gravity at 25°C was recorded as percentage ethanol for the sample.

2.2.4 Determination of pH (Ionic Concentration)

Glucose syrup (10ml) was measured into a beaker using measuring cylinder. The pH was determined with the aid of previously calibrated pH meter (Model Hanna pH 211) with pH 4.0 and 7.0 buffers.

2.2.5 Determination of Specific gravity

The specific gravity of the glucose syrup was determined using a specific gravity bottle. With a clean and water free gravity bottle. The empty bottle was weighed, and thereafter fills with distilled water and weighed. The bottle was also filled with the glucose syrups from the two samples respectively and their weight taken. The specific gravity of the samples was calculated using Equation 2.

$$SG = \frac{W_s}{W_w} \quad 2$$

where W_s and W_w are the weight of sample and weight of equal volume of water

2.2.6 Determination of Total Soluble Solids (Sugar brix)

The total soluble solids as sugar brix of the glucose syrup were determined using hand refractometer (Abbe Refractometer). Two drops of the glucose syrup from each sample was placed on the refractometer lens surface and reading was observed on the eyepiece of the equipment.

2.2.7 Bio-ethanol Gel Production

Bio-gel is a fuel sourced from biomass to replace fossil fuels. This bio-gel can replace kerosene, gas, wood and charcoal in cooking. The base material for bio-gel production is bio-ethanol while CMC used in the experiments acts as gelling agent which needs water to gel before being added to bio-ethanol.

3. Results and Discussions

3.1 Bio-ethanol from Corn cobs and Cassava Peel

The yield of ethanol produced from the Corn cobs and Cassava peels is as presented in Table 1. The yield of filtrate (Plate 1) from the fermentation process were 3.55 and 3.35 liters respectively for cassava peels and corn cobs. The yield of filtrate from the action of the yeast is higher in cassava peel than the corn cobs which showed that the yeast used is more active on starch than cellulose. The initial pH value of the cassava peel filtrate (6.57) is lower than that of corn cobs (6.90) while the total soluble solid and total titrable acidity for cassava peel is higher than in corn cobs. The yield of cassava peel is 757.33ml which is higher than that of corn cobs of 595.56ml (Plate 2).



Plate 1: Filtrates of Cassava and Corn cob Waste



Plate 2: Ethanol Produced from Filtrate of Cassava and Corn Cob Wastes

As presented in Table 2, the concentration of bio-ethanol produced are 85.34 and 83.71% for cassava peel sample and corn cobs sample respectively. Apart from this the samples parameters like Color, Appearance, Odour, Solubility and flash point were the same and also compared favorably with industrial ethanol. The values for Density, pH, Boiling point, Melting point, and Freezing point were lower slightly in cassava peel than corn cobs bio-ethanol samples.

Table 1: Ethanol Yield and Sugar Conversion by *Saccharomyces Cerevisiae*

Extracts	Cassava Peel	Corn Cobs
Volume of filtrate yield (L)	3.55	3.35
pH value of Filtrate	6.57	6.90
pH value of Filtrate (Adjusted)	5.20	5.20
Total Soluble Solids (TSS) (°Brix)	26	24.5
Total Titratable Acidity (%)	1.86	1.79
Ethanol Yield (mL)	757.33	595.56

Table 2: Properties of Ethanol Produced

Parameter	Cassava Peel	Corn Cobs	Industrial Ethanol**
Ethanol Concentration (%)	85.34	83.71	96
Colour	Colourless	Colourless	Colourless
Appearance	Clear	Clear	Clear
Odour	Burning taste	Burning taste	Burning taste
Solubility	Highly soluble in water	Highly soluble in water	Highly soluble in water
Density @25°C (g/ml)	0.839	0.846	0.789
pH value	6.92	6.95	7.33
Boiling point (°C)	79.5	79.9	78.5
Melting point(°C)	-115.9	-116.4	-114.5
Freezing point(°C)	-116	-116	-114.1
Flash point	Highly flammable	Highly flammable	Highly flammable

**Source: WOM (2024)

3.2 Biogel from Corn cobs and Cassava Peel Bio-ethanols

As earlier observed, the basic material for bio-gel is ethanol, hence due to size of the laboratory equipment used and the fact that there are many researches on use of cassava tuber and cassava peel for bio-ethanol using various enzymes and yeast with positive results. Both corn cobs and cassava peel ethanol above have very closed properties hence both of them can be used for bio-gel. However, the choice of corn cobs for

Corresponding author's email address: abdulganiyr@yahoo.com

further investigation is bore on the fact that there is no literature on bio-gel formation from its bio-ethanol while some work in this area has been done on cassava peel starch. The density of the samples ranged from 0.9308 to 0.9710 but compared favourably with that of the control (0.9336) (Table 3). The specific gravity followed the same trend. As expected, the viscosity of the samples increased with the quantity of CMC added to each sample. Since it is the CMC that forms the gel, the higher the quantity, the more it become viscous and reduction in ability to flow. Hence, sample S1 with 1.5g of CMC has the lowest value of 983cP while the sample with CMC of 5.5g has the highest value of 8,830Cp (See plate 1).



Plate 3: Samples of bio-gel produced

The cloud point did not follow any specific pattern, but sample S4 has value close to the control C. The pour point, flash point, flame point and fire point temperatures decreased with increase in CMC quantity. However, the energy content varies between 18 MJ to 30.5 MJ with control C having 31.5 MJ very close to samples 4 and 5. The burning time for 10ml of samples varies between 4 to 6 minutes while control C burn for 7 minutes. From Table 3, it can be observed that samples S4 and S5 are very close to control sample with S5 the best of the two samples.

Table 3: Properties of Bio-gel from Corn Cobs bio-ethanol (S) compared with commercial Bio-gel (C)

Sample Parameters	S1	S2	S3	S4	S5	C
Density (g/cm ³)	0.9452	0.9308	0.9420	0.9376	0.9710	0.9336
Specific gravity	0.9325	0.9183	0.9293	0.9250	0.9580	0.9210
Viscosity (cP) at 30°C	983.00	1018.20	1,913	3,333.33	8,830.00	8,000.00
Cloud Point Temperature (°C)	-2.5	-4.75	-5.43	-1.37	-3.03	-1.63
Pour Point Temperature (°C)	-10.13	-9.50	-9.27	-5.33	-5.97	-5.40
Flash Point Temperature (°C)	65.27	70.33	63.73	59.43	49.27	52.33
Flame Point Temperature (°C)	65.77	71.33	64.57	59.67	57.27	55.57
Fire Point Temperature (°C)	69.57	71.83	64.87	60.00	59.3	59.40
Energy (MJ)	23	18	20	30	30.5	31.5
Burning Time for 10ml (min)	5	4	6	6	6	7

4. Conclusion

Bio-ethanol was successfully produced using starch extracted from cassava peel and cellulose from Corn cobs by acid hydrolysis and yeast for fermentation. The average yield of bioethanol is 757.33ml for cassava peel and 595.56 for corn cobs from 3.55L and 3.35L of filtrates respectively. The average pHs of the samples are 6.92 and 6.95 for cassava peel and corn cobs bio-ethanol respectively. The properties of bio-ethanol produced from the two samples compared favorably with the commercial ethanol. Bio-gel fuel was produced using a composition of bio-ethanol from corn cob cellulose and gel from water and CMC in ratio 80%, 20% by volume respectively. Samples S4 and S5 compared favorably with commercial sample with sample S5 as the best. The bio-gel fuel which is an alternative source for cooking can also support outdoor burning. The formulation was made from 100% recycle of agricultural wastes making it very economical and environmentally friendly.

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