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Raw *Akamu* wastewater as electrolyte for accumulators (Certificate of Registration of Patent:006419)

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Abstract

The quest for eco-friendly electrolytes for lead-acid accumulators has necessitated this research. Raw *Akamu* wastewater (rAWW), a biowaste effluent, was assessed for its viability as a substitute electrolyte for lead-acid accumulators. Five hundred grams of dent *Zea mays* L. (yellow maize) was weighed for the preparation of the raw *Akamu* using the traditional methods. Raw *Akamu* wastewater (rAWW) got in the process was tested for its pH, microbial and chemical contents. Results indicated that the rAWW had a pH of 1.50 ± 0.00, and contained *Staphylococcus aureus*, *E. coli*, *Bacillus sp.* and *Lactobacillus sp.* The chemical contents include organic acids, alcohols, benzene acetonitrile, uridine, campesterol and D-glucose 2, 3, 4, 5, 6-pentaacetate. To assess its electrolytic potentials, the rAWW was filled into an empty 75 AH lead-acid accumulator with an initial voltage of 11.75 ± 0.05 V. The accumulator was then charged for 12 h thereby significantly ($p < 0.05$) increasing the voltage to 12.20 ± 0.00 V. Afterwards, the accumulator was used to drive a four-cylinder car (1038 kg wt; the maximum power of 104 bhp-77 kw) for twenty-four months. The pH value of rAWW reduced to 1.00 ± 0.00, only *Bacillus sp.* was isolated while organic acids, ketones, taxifolin, riboflavine, L-phenylalanine, isosorbide, lacthydrazide, and glucose benzyloxime pentaacetate were detected during usage. In conclusion, raw *Akamu* wastewater was validated as a viable substitute for the usual sulfuric acid and an eco-friendly electrolyte for lead-acid accumulators.

Keywords: Accumulators; Raw Akamu wastewater; Substitute electrolyte; Maize; Sulfuric acid

1. Introduction

Currently, there is an increasing global transition of energy from the non-renewable sources like coal, uranium, oil, and natural gas which cause climate change, global warming, and other greenhouse gas emissions issues to renewable energy sources like solar energy, wind energy, bioenergy and ocean energy. Offsetting the hazardous effects caused by those non-renewable sources of energy call for the need to conduct research into the opportunity of using renewable energy sources as alternatives [1]. Biomass technology suggests a promising platform for both fuel and chemicals as by-products of biomass found in cities and business areas create wastes that, if effectively managed, can provide employment opportunities and advance the nation's economy instead of constituting environmental pollutants [2]. The consideration on the availability of food strengthened the use of non-edible crops and other biowaste materials to become a more promising option for the processing of these valued renewable products. Substrates with hemicellulose, lignin and cellulose polymers has been responsible for the conversion of biomass to simple sugars and subsequently to biofuels and other chemicals [3].

Maize (*Zea mays* L) is among the most adaptable incipient crops, having wider adaptability under diverse agro-climatic conditions. It is of six major types: dent, flint, pod, popcorn, flour, and sweet, and includes five species, namely: *Z. luxurians*, *Z. perennis*, *Z. diploperennis, Z. nicaraguensis and Z. mays. Zea mays* are the only cultivated species, while the rest are wild grasses [4]. Raw *Akamu* is processed traditionally by soaking clean maize grains in water for 2-3 days. The

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maize grains are washed and ground into a paste. The paste is sifted to smooth slurry which is allowed to settle and the raw *Akamu* wastewater is decanted [5]. Accumulators have been used to generate electricity through a series of chemical reactions which produces an electric current to be used in a car [6]. Sulfuric acid as an accumulator electrolyte, is a highly corrosive, diprotic strong mineral acid. Its corrosiveness on other materials, like metals, living tissues, stones or leakage into the soil, air and underground water can lead to serious damage to humans, plants and the entire ecosystem [7].

To reduce the hazardous environmental impact of sulfuric acid which serves as the electrolyte in the lead-acid accumulators and discharged onto the ecosystem, raw *Akamu* wastewater was evaluated as an alternative eco-friendly substitute.

2. Material and methods

2.1. Materials

2.1.1. Sample collection and identification

The dent *Zea mays* L. (yellow maize) grains used for the study were procured from Eke Ukwu Market, Owerri Municipal Local Government Area, Imo State, Nigeria. They were validated by Prof. F.N. Mbagwu, a taxonomist in the Department of Plant Science and Biotechnology, Imo State University, Owerri; with voucher number IMHB 0045.

2.1.2. Chemicals and reagents

All reagents and chemicals used were of analytical grade/standard, high purity, and were purchased from a local store.

2.2. Methods

2.2.1. Sample preparation and production of raw Akamu wastewater

Five hundred grams of dent *Zea mays* L. (yellow maize) were soaked and fermented for four days in thrice replaced 5,000 ml of water, wet milled using a horse-powered grinding machine and sieved with a muslin cloth to yield raw *Akamu* (pap) slurry. The *Akamu* slurry was bagged and pressed overnight to liberate raw *Akamu* wastewater (rAWW).

2.2.2. Determination of pH

The pH value of the rAWW was determined using a digital pH meter (model LMPH-10) with a glass electrode which had earlier been standardized with standard buffer solutions [8].

2.2.3. Microbial analysis

Bacterial screening of the wastewater was carried out using the spread plate culture and biochemical methods of [9]. The sample was analyzed using the tenfold serial dilution technique.

2.2.4. Gas Chromatography-Mass Spectroscopy analysis of raw Akamu wastewater

The volatile compounds in the raw *Akamu* wastewater were detected using gas chromatography-mass spectroscopy (GC-MS; models Agilent 7890N and 5975B MSD, respectively), where ethyl acetate fractions of the sample were injected into the GC column and helium used as carrier gas (1 ml/min) as described by [10]. Individual peaks were compared with the database of [11].

2.2.5. Determination of voltage produced by raw Akamu wastewater

The cells of a washed and disused 75-amp empty lead-acid accumulator was thoroughly washed nine times with running tap water. They were upturned and allowed to drain overnight. The cells of the washed accumulator were then filled with the rAWW and the voltages across their terminals were determined using a voltmeter. The accumulator was charged for 12 h and the new voltages across their terminals determined using the voltmeter.

2.2.6. Usage of rAWW-containing accumulator

The rAWW was used to fill the cells of a washed and disused 75 AH empty lead-acid accumulator. The charged rAWW-containing accumulator was used to drive a four-cylinder car (curb weight = 1038 kg; maximum power = 105 PS/104

HP; output = 77 kw) for twenty-four months and the pH, microbial flora and chemical contents of the rAWW re-determined.

2.3. Statistical analysis

Data were carried out by using the student's t-test of significance at 95% confidence limit.

3. Results and discussion

Table 1 shows the pH of raw *Akamu* wastewater before and during usage. It can be observed that the rAWW was acidic which may have been due to certain inherent microorganisms fermenting sugars into organic acid and alcohols. The dissociation of the acids may have lowered the pH value of the medium [12].

Table 1 pH of raw *Akamu* wastewater before and during usage

pH of rAWW before usage	pH of rAWW during usage
1.50 ± 0.00	1.00 ± 0.00

Table 2 shows the bacterial isolates of raw *Akamu* wastewater before and during usage. It confirmed that the raw *Akamu* wastewater contained fermentative bacteria which were responsible for the saccharification of maize starch to liberate sugar, conversion of sugars into organic acids. Dilute mineral acids do not contain these microorganisms [5] as determined in the microbial composition of raw *Akamu* wastewater which showed the presence of lactic acid bacteria such as lactobacilli genera (*Bacillus sp*), enterobacteriaceae (*Escherichia coli*), yeast (*Saccharomyces sp.*), mould (*Aspergellius sp.*) and many others during fermentation. These microorganisms and micro flora in maize during fermentation are responsible for the saccharification of maize starch to liberate sugar, conversion of sugars into organic acids, initiating acidification of fermenting maize dough and the release of protons needed for electricity. During the usage of the rAWW-filled and charged accumulator, only the *Bacillus sp.* was detected ostensibly due to its thermophilic nature.

Table 2 Bacterial isolate of raw *Akamu* wastewater before and during usage

Before Usage	During Usage
Staphylococcus aureus	
Staphylococcus sp.	
Bacillus sp.	*Bacillus sp.*
Escherichia coli	
Lactobacillus sp.	

Table 3 Chemical composition of raw *Akamu* wastewater before usage

Before Usage	Chemical Composition
a-D-Glucopyranoside	$C_{29}H_{54}O_{16}$
1-Nitro-2-acetomido-1,2-dideoxy-d-manitol	$C_8H_{16}N_2O_7$
Ethano,2,2-oxybis-, diacetate	$C_8H_{14}O$
Benzene acetonitrile	$C_{14}H_{17}NO_6$
Propanoic acid, 1,1-dimethylethylester	$C_7H_{14}O_2$
Erythorbic acid	$C_6H_8O_6$
n-Hexadecanoic acid	$C_{16}H_{32}O_2$
3,7,11,15-Tetramethyl-2-hexadecen-1-ol	$C_{20}H_{40}O$

D-Glucose,2.3.4.5.6-pentaacetate	$C_{16}H_{22}O_{11}$
Uridine	$C_9H_{12}N_2O_6$
Campesterol	$C_{28}H_{48}O$

The chemical compositions of raw *Akamu* wastewater before usage show that the raw *Akamu* wastewater contained organic acid species, aldehydes, glycosylated pyrimidine analogues, phytosterol, alcohols, and modified glucose among other compounds (Table 3). Again, the chemical compositions of raw *Akamu* wastewater during usage was observed to have carboxylic acids, flavonoids, nitrates, ketones and other compounds with longer chains (Table 4). Glaringly, the aldehydes and alcohols had disappeared; ostensibly being converted to ketones and other compounds.

Table 4 Chemical composition of raw *Akamu* wastewater during usage

During Usage	**Chemical Compositions**
Furantetracarboxylic acid	$C_8H_4O_9$
2H-Pyran-5-carboxylic acid, 2-oxo	$C_6H_4O_4$
Methanone (2,4-dihydroxyphenyl)phenyl)	$C_{13}H_{10}O_3$
Octabenzone	$C_{21}H_{26}O_3$
Acetic acid 7-benzyloxy-2,4-dimethyl 2,3-dihydro-1,9-dioxa-cyclopenta[b]naphthalen-9a-yl ester	$C_{22}H_{22}O_5$
Taxifolin	$C_{15}H_{12}O_7$
Riboflavine	$C_{17}H_{20}N_4O_6$
Acetic acid 7-benzyloxy-2,4-dimethyl-2,3-dihydro-1,9-dioxa-cyclopenta[b]naphthalen-9a-yl ester	$C_{22}H_{22}O_5$
L-Phenylalanine, N-[(3,4-dihydro-8-hydroxy-3-methyl-1-oxo-1H-2-benzopyranyl)carbonyl]-, methyl ester, (R)-	$C_{21}H_{21}NO_6$
Isosorbide	$C_6H_{10}O_4$
Lacthydrazide	$C_3H_8N_2O_2$

Sulfuric acid is a diprotic acid with a dissociation constant, Ka, of 1.00×10^2/ mol dm-3 (as determined), while lactic acid is largely undissociated in aqueous solutions (Ka = 1.30×10^{-5}/ mol dm^{-3}); the higher the Ka value, the stronger the acid [13]. In lead-acid accumulators, lead (II) ions formed during discharge react with SO_4^{2-} ions to form insoluble lead (II) sulphate thereby reducing the efficiency of the accumulator [13]. However, carboxylic acid is largely monoprotic except where there are more than one carboxyl group, which result in second or more dissociation constants. It was presumed that the organic acids in the wastewater would form soluble salts, like lead lactate or any salt of an organic acid, with lead (II) ions at the positive terminal of the experimental accumulator. This soluble lead lactate, for example, would apparently not reduce the efficiency of the accumulator. Lead displaces hydrogen gas from dilute strong acids very slowly [13], but may never displace hydrogen gas from weak (organic) acids since they incompletely dissociate. That way the protons are still available. Microorganisms in the anode compartment are responsible for the breakdown of organic compounds by oxidizing other biodegradable substrates to release electrons, protons and CO_2. Electrons produced from the metabolic activity of organic matters are transported to and collected at the anode electrode surface and then passed to the cathode, which enables the flow of electrons through an external circuit before reaching the cathode thereby producing electricity [14]. Water is produced as the final and clean product during the process by which electrons reacts with protons and oxygen at the cathode. Certainly, the current will continuously flow over a potential difference and trigger the production of power directly through microbial catalytic activities [15].

4. Conclusion

Conclusively, the tested organic electrolyte from waste biomass from maize showed good electrical conductivity and voltage performance, therefore, it has been proven that raw *Akamu* wastewater, which is ecologically friendly, can be used as an alternative to the conventional mineral acid known as sulfuric acid (H_2SO_4). This research work created an avenue to manage waste and convert waste to wealth/energy using a green approach.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed

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