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Water and Green Energy as the Heart of Sustainable Development – Promoting Sustainable Environment Through Innovate Engineering Technology in Nigeria Economy

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Water and Green Energy as the Heart of Sustainable Development – Promoting Sustainable Environment Through Innovate Engineering Technology in Nigeria Economy

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ABSTRACT
Water for energy, energy for water is an independent sector and through their inextricable linkage, water and energy remains the key driver of economic growth and social development. The benefits water and energy (W-E) provides are: on poverty reductions, economic progress-impairment on the ecosystems, but has quantified costs. In addition, it improves the health and in education, promotes stable society and human dignity and help in realizing basic human rights. When achieving developmental goals on W-E sustainability, it is of disadvantages that there will be an increase on water scarcity, high exposure to environmental degradation, e.g. floods and droughts etc., scaling energy prices which will reduce on access to W-E and in-turn increase poverty and by extension impact on natural ecosystems. By improving the performance optimization on W-E nexus; the resultant increase on energy efficiency; decrease water pollution, reduce costs of energy and water provision, increase access to services and reduce greenhouse gas (GHG) emission. The effective development of renewable energy worldwide would be a stabilizing driver on fossil fuel availability and global climate change.
Water is especially important and used in large volumes in generating electricity, whether through green energy (hydroelectric power), or heat exchange (steam systems), and for cooling (nuclear).
This paper presents some studies on algae formations instead of traditional agro-based raw materials, because it does not compete with food or fodder and is abundantly available in fresh water or marine ecosystem. The studies show that algal species can be used to produce biodiesel (biofuels). A comparative study was conducted using chemically pre-treated with N_aOH and un-treated spirogyra biomass. The spirogyra biomass was subjected to saccharification process by the fungi Aspergillus Niger for hydrolysis, for six (6) days and then followed by the fermentation process by using yeast (Saccharomyces cerevisiae) for another 6 days. The comparative study experimented, and the results recorded showed that high yield of ethanol was obtained for un-treated Spirogyra biomass when compared to chemically pre-treated biomass. Additional studies reveal that inducement of fertilizer and other growth media can be used to increase the growth rate of biofuels production from algae. Oil produced from algae was esterified using CH_3OH as catalyst. The properties of the biodiesel produced clearly show that biodiesel produced from green algae can be used to run engine. The experimental results show that the Flash point was 135^0C, Pour point was 17^0C and Cloud point was 18^0C and are all in agreement with the standard of biodiesel (biofuels). The current production cost of bioethanol plant is \$26,560 US.

Keywords: Energy, water, environment, and sustainability

1.0 INTRODUCTION

Environmental sustainability is responsibly interacting with the planet to maintain natural resources and not jeopardize the ability for future generation meet their needs. In order words, protecting our natural environment, human and ecological health, while doing innovation and not compromising our way of life that affects the ecosystems. Water and energy is a very important aspect of our life that man cannot neglect, because we need them to run our day to day activities. Generation of energy has taken the centre stage and has been the interest of individuals, organizations and countries. Man has since been generating energy from many sources: natural to man-made complex processes, renewable and non-renewable sources. Fossil fuel has been a major source of energy for household (domestic) and industrial uses, but concerns about shortage of fossil fuels, increasing crude oil price, energy security and accumulation of greenhouse gases (GHG) in the atmosphere that bring about global warming have led to growing worldwide interest in renewable energy source. Other renewable energies are solar, wind, hydroelectric (water-energy), biomass (biodiversity) etc. Each of them interacts with one another and earth's system to sustain life.

1.1 Problem Statement

The concern about future oil process, atmospheric pollution of combustion of coal, fossil fuel and other related energy sources causes the releases of greenhouse gases (GHG), these results to global warming, acid rain and decrease in the pH of oceans. Attempts to combat this have led to the use of various renewable source of energy. Biofuel is accepted worldwide as an alternative energy source to fossil fuel. Oil from food crops (Soya beans, rape seed) can be used to produce biodiesel, but other need for food crop is more pressing and also the availability of land to cultivate the crops are reasons why further research was carried out. Using algae to produce biofuel helps conquer the challenge posed by food crop. Bioethanol is an alternative and environmentally friendly fuel that has the potential of transforming environmental problems to environmental benefits in the form of energy to augment the existing amount of fossil fuel used.

1.2 Significance of the Study

The importance of this research work is to demonstrate that biomass (e.g. algae) can be used to produce biodiesel, bio-ethanol and hydrogen for power generation. The production of hydrogen is complex and requires robust and expert capabilities to achieving the desirable objectives. This is a laboratory studies that addressed various and useful aspects of biodiesel production from algae-feed. The end-results can be scale-up industrially.

2.0 BACKGROUND LITERATURES

2.1 Microalgae for biodiesel production

Approx. over 3 billion people have NO access to electricity & many do not have reliable access to electricity. Globally, W&E are unevenly distributed, with 30% world population consuming 75-80% of total primary energy. Many traditional sources of energy like fossil fuel are linked to water stress GHG emission. The world total energy consumption is already eight-times what it was in 2000, and is projected to grow by as much as 55% by the year 2030 as the combined effects on population growth and improvement on living standard (Schuster-Wallace et al., 2014).

Hydropower is an established *renewable technology*, proven & reliable & an important solution to W-E nexus, a s*ustainable energy*. *Globally*, hydropower can generate much more capacity of electricity than all *renewable sources* put-together. *Equally* contribute 3 Gt CO_2 eq/year to mitigate climatic change (UNESCO 2020). However, algae are good source of renewable energy, bcos of its rapid growth rate and its ability to be cultivated in waste water or waste land. Algae are the *fastest growing* plant and *theoretically* have the potential to produce more oil or biomass per acre when compared to other crops and plants. Table 1 represent the summarised version of reviewed investigations.

Table 1 Summarised version of reviewed investigations

Author(s)	**Investigation**	**Research Benefits**	**Remarks**
Jiang et al., 2011	Optimization of parameters like increasing the lipid fraction.	Reducing environmental impact of industries.	**Environmental** assessment.
Chen et al., 2011	Applications of burning biomass.	To produce energy.	Improved studies on its **viability**
Rodolfi et al., 2018	Algae cultivation does not require herbicides or pesticides application	A significant advantage to environment	**Economic viability**
Idris & Owofu 2016	Study inducement of lactose as an enhancer. Established qualitative values of biofuel from algae	Benefits over fodders and agricultural products	**Environmental** and **economic** benefits
Idris & Bello 2021	Though, they are fast growing organism, but growth can be enhanced by inducement of fertilizer and other growth media.	Cultivation rate can be used to increase the growth rate of biofuels production.	**Increase** in **energy production**.

Table 2 Typical oil yields from the various biomass sources in ascending order

S/No.	Crop	Oil yield (Litre/hactre)
1	Corn	172
2	Soybean	446
3	Peanut	1,059
4	Canola	1,190
5	Rapeseed	1,190
6	Jatropha	1,892
7	Karanj (Pongamia pinnata)	2,590
8	Coconut	2,689
9	Oil palm	5,950
10	Microalgae (70% oil by wt.)	136,900
11	Microalgae (30% oil by wt.)	11 58,700

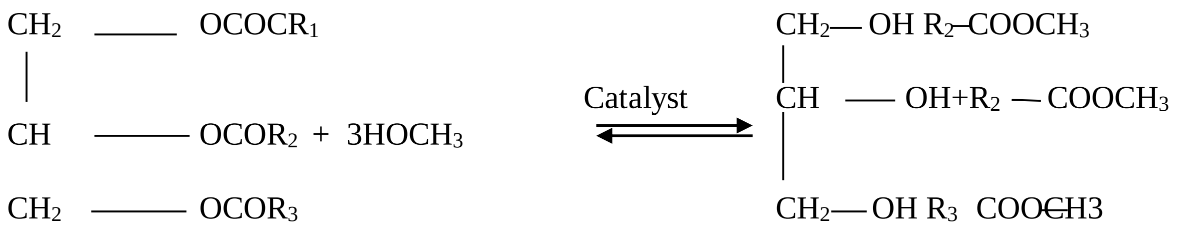
Data sources: (Hill et al., 2006), (Liliana et al., 2008)

2.3 Biodiesel Production

Transesterification of algal oil with simple alcohol has long been the preferred method for producing biodiesel The Transesterification process is most widely use all over the world. The overall Transesterification reaction is given by three consecutive and reversible equations as below:

Triglyceride + ROH = Diglyceride + RCOOR (1)

Diglyceride + ROH = Monoglyceride + RCOOR (2)



Triglyceride Methanol Glycerol Methyl esters

(Parent oil) **(Alcohol)** **(Biodiesel)**

In the first reaction the conversion of triglycerides to diglycerides is, followed by the conversion of triglycerides to monoglycerides, and of monoglycerides to glycerol, yielding one methyl ester molecule per mole of glyceride at each step, Qin (2015). The complete chemical reaction mechanisms of the transesterification process can be found in the open literatures.

3.0 MATERIALS AND METHODS

3.1 Sample collection and Preparation

The first algal *Spirogyra* was collected from pond situated at the orchard in the Faculty of Agriculture, University of Maiduguri, Borno and was identified upon microscopic examination. The second samples were collected from two points at Alaraham fish pond Maiduguri on a clean container. Replicate samples were collected from the two sources. The samples collected served as starter cultures for large biomass generation. The samples were immediately taken to the laboratory for cultivation as depicted from Figures 1-6.

Fig 1: Collection of Algae

Fig 2: Media Preparations

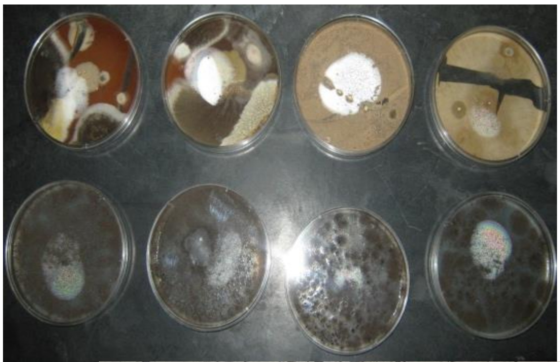


Fig 3: Cultured Aspergillus Niger

Fig 4: Dried biomass

Fig 5: Filtering of biomass Fig 6: Filtered biomass

Figure 7: High rate algal pond in Arizona, USA.
Sources: Renewable Fuel & Energy B.V. (62)

Figure 7 is a pictorial landscape of hundreds of thousand acres of algal pond. It is structural and systematically arranged and is an improved technology for growing algae. The production and processing are low cost effective (much reduced cost). This is a good example of renewable energy source worldwide.

The 3 experimental investigations were carried out as follows:

Biomass + Aspergillus niger + Saccharomyces Cerevisae (3.1)

Biomass + Lactose + Aspergillus niger + Saccharomyces Cerevisae (3.2)

Biomass + Nutrients + Aspergillus niger + Saccharomyces Cerevisae (3.3)

Table 2 Experimental processes

Experiments	**Spirogyra Biomass (untreated)**	**Chemically Treated Spirogyra Biomass**

1.	5g of the biomass + 100ml of distilled water + A. niger + S. Cerevisae	5g of the biomass + 100ml of distilled water + A. niger + S. Cerevisae
2.	5g of the biomass + 100ml distilled water + 0.5% of Lactose + A. niger + S. Cerevisae	5g of the biomass + 100ml distilled water + 0.5% of Lactose + A. niger + S. Cerevisae
3.	5g of the biomass +100ml of synthetic media + A. niger + S. Cerevisae	5g of the biomass + 100ml of synthetic media + A. niger + S. Cerevisae

Source: *Adapted from Fuad Salem Eshaq et.al (2010, 2011).*

Fig 8: inoculated with mycelia A. niger (I)

Fig 9: inoculated with mycelia A. Niger (II)

Fig 10: Experimental Setup

Fig 11: Collections of bioethanol

Fig 12: Measuring the bioethanol

Fig 13: Bioethanol in sample bottles

NOTE! The bioethanol samples were kept under aseptic condition to avoid contamination. Aspergillus niger was used as an enzyme source of cellulase and amylase for saccharification of Spirogyra biomass into simple sugars, since pure commercially available enzymes are very expensive (Idris & Owofu 2016).

4.0 EXPERIMENTAL RESULTS AND DISCUSSIONS

RESEARCH STUDY I

4.1 Saccharification and Ethanol Production from Un-treated *Spirogyra* Biomass

4.1.1 Saccharification of *Spirogyra* biomass by *Aspergillus niger*

Saccharification: Is the process of converting starch to sugar.

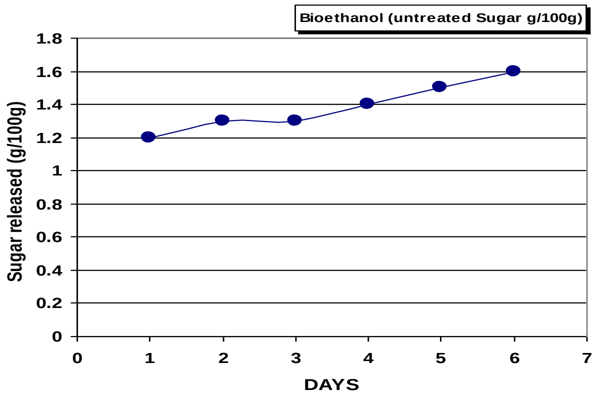


Fig 14: Spirogyra biomass (distilled water)

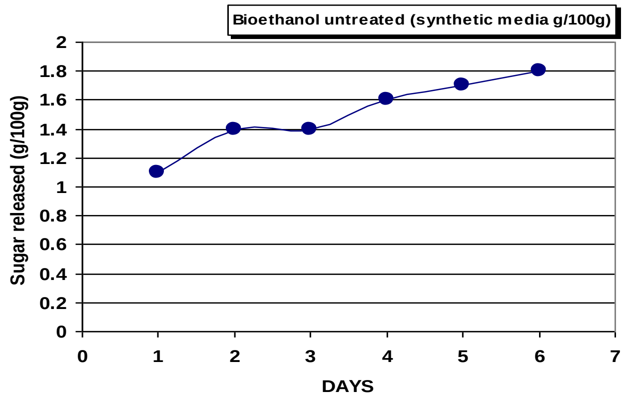


Fig 15: Spirogyra biomass (synthetic media)

In Figure 14, the saccharification of the un-treated spirogyra biomass was carried out for a period of six (6) days at 30^{0}C for sugar released after 24 hours. Linear progression in the sugar release was observed on the 6-days. A differential rate of 0.10 values is recorded on each day. A clear and noticeable release of sugar was recorded. From Figure 15, there are no changes recorded on days 2 & 3. Figure 16 show clearly the inducing effect observed in the lactose.

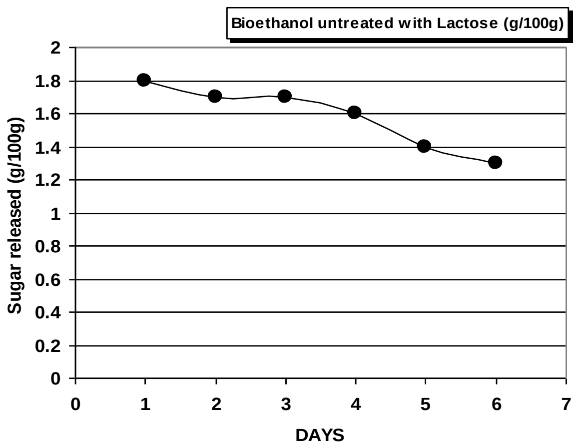


Fig 16: Spirogyra biomass (Lactose)

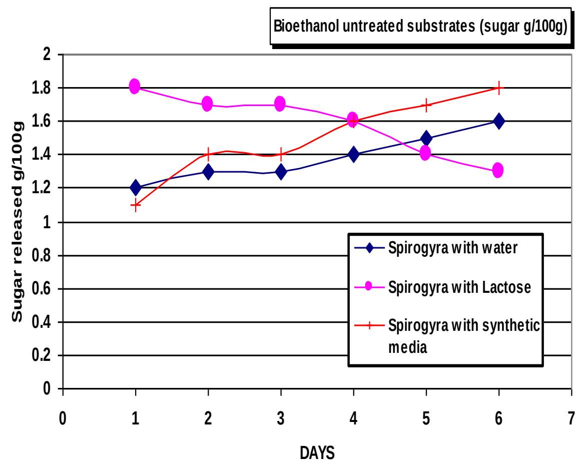
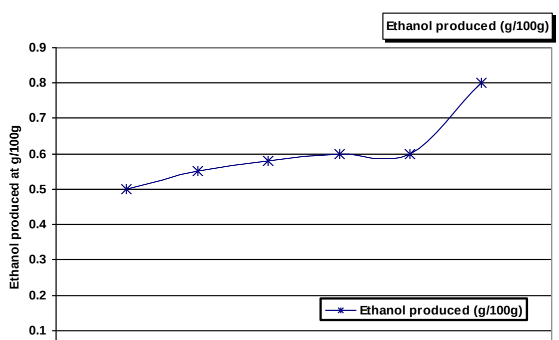


Fig 17: Bioethanol production from un-treated substrate)

From Figure 17, the synthetic media shows an improved production. Production with distilled water is lower than synthetic media. A well noticeable effect of lactose as an inducer was noticed.

4.1.2 Fermentation of *Spirogyra* biomass by *Saccharomyces Cerevisae*



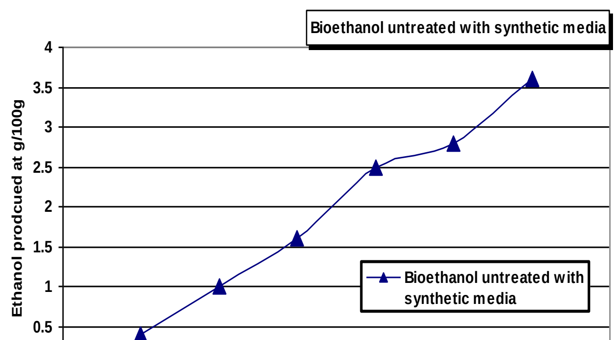
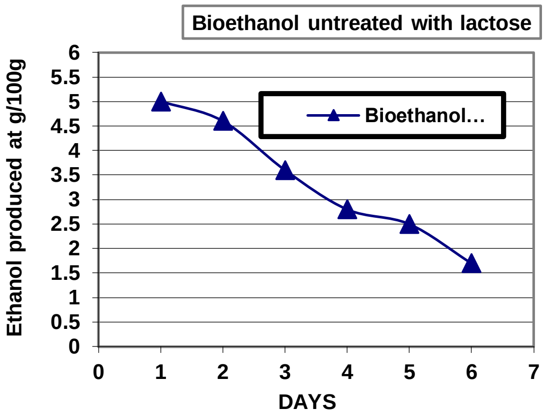


Fig 18: Spirogyra biomass (distilled water)

Fig 19: Spirogyra biomass (synthetic media)

From Figure 18, the systematic progression in the ethanol production in all days. Day 1 started from 0.5 scales and no uniform progression in ethanol in each day. There was noticeable geometrical increase in production on the 5th day. In Figure 19, the ethanol production formed progressively in all days studied. Day 1 started from 0.4 scales and the production rise to 3.6 on the 6th day.



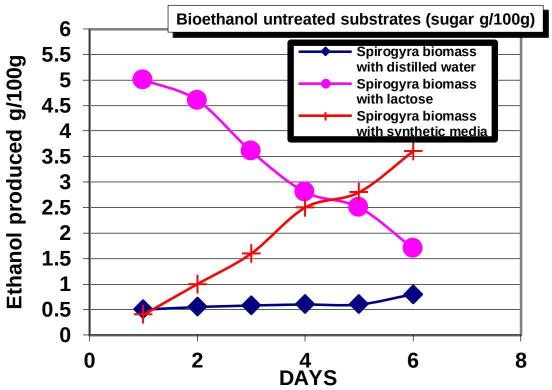


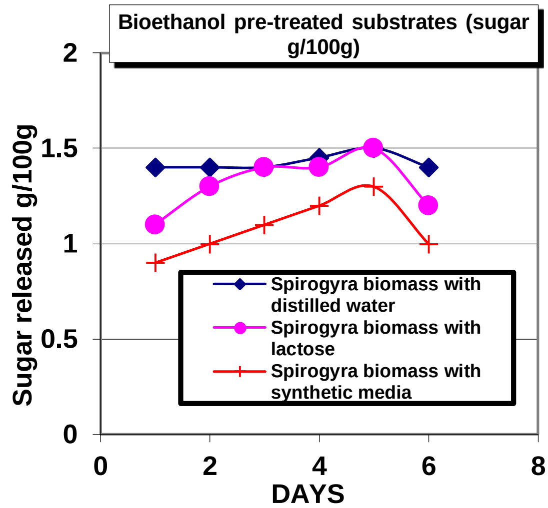
Fig 20: Spirogyra biomass (lactose)

Fig 21: Bioethanol production in submerge

From Figure 20, the ethanol production progressively reduces along the days studied. The lactose steadily show decreasing production of ethanol. The synthetic media (mycelia induced) shows an improved production. The production with distilled water is far lower than synthetic media. In Figure 21, there was noticeable effect of inducing lactose effect. The enzymes converted biomass into sugars, and then the sugars released were fermented by Saccharomyces cerevisiae (Fuad et al., 2011).

4.2 SACCHARIFICATION AND ETHANOL PRODUCTION FROM PRE-TREATED *SPIROGYRA* BIOMASS

4.2.1 Saccharification of *Spirogyra* biomass by *Aspergillus Niger*



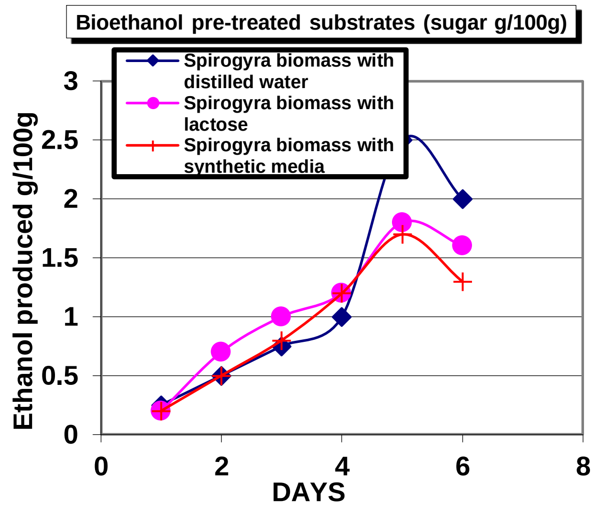


Fig 22: Bioethanol productions in sub-merge fermentation from pre-treated substrate

Fig 23: Bioethanol productions in submerge fermentation from pre-treated substrate

From Figure 22, the synthetic media shows an improved production. Production with distilled water is lower than synthetic media. An established inducing lactose effect was also observed. While from Figure 23, the 3-process showed tremendous increase in production in the 4-days. There was a noticeable drop between the 5th and 6th day in all process. Thus, increased production of ethanol was observed when sugars are more in the suspension and the activity of enzymes decreased gradually when sugars were decreased gradually (Fuad et al., 2010).

<u>RESEARCH STUDY II</u>

4.3 SACCHARIFICATION AND ETHANOL PRODUCTION FROM UN-TREATED *SPIROGYRA* BIOMASS

4.3.1 Media preparation

The modified Bristol media was used in this experiment for algal cultivation. The medium is composed of the following compositions as stated in Table 3.

Table 3 Media composition of algae cultivations

S/No.	Chemical composition	Mass weight	
		grams (g)	milligrams (mg)
1.	$NaNO_3$	0.25	-
2.	$CaCl_2$	0.025	-
3.	$MgSO_4 \cdot 7H_2O$	0.075	-
4.	K_2HPO_4	0.075	-
5.	KH_2PO_4	0.018	-
6.	NaCl	0.25	-
7.	FeCl	-	0.5

4.3.2 Biomass Determination

Figure 24 present the algae growth media from the specimen samples and spectrophotometer device used in the experimental analysis.

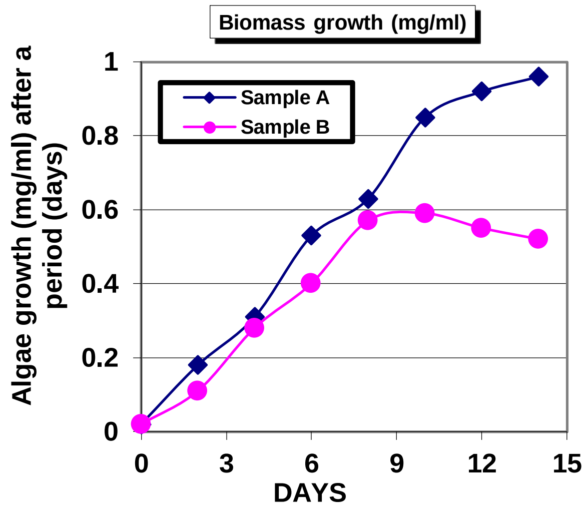
Figure 24 Algae growth media

4.3.3 Comparative analysis of 2-samples of Biofuels

Table 4 Algal biomass

Sample	Algal growth (mg/ml) after a period (days)							
	0	2	4	6	8	10	12	14
A	0.02	0.18	0.31	0.53	0.63	0.85	0.92	0.96
B	0.02	0.11	0.28	0.40	0.57	0.59	0.55	0.52

Table 4 represent algal biomass growth for the 2-samples. Growth parameters in terms of biomass and chlorophyll were monitored for the two weeks (14-days) period of 2-samples. Highest rate of growth was on days 4 to 6 & days 8 to 10 with an increase of 0.22g for 2-days in sample A. Similarly, 0.17g was highest in biomass in sample B. It occurred between days 2 to 4 and 6 to 8.



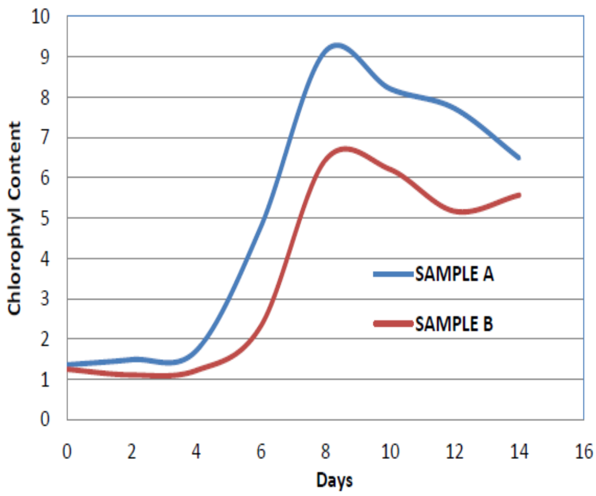


Fig 25: Algal growth for 14-days

Fig 26: Biofuel production within for 14-days

From Figure 25, the high rate of growth within the recorded period (Jiang, L. et al., 2011). Sample A has a higher growth rate compared to Sample B. While from Figure 26, both samples recorded growth till the 8th days. The profile demonstrated in Figure 26 is referered to as Chorophyl content measurement profile. The same trend of decrease in growth after the 8th days for both samples (John et al., 2011), (Idris & Bello 2021).

4.3.4 Costs Analysis of Biofuel Production

Table 5: Production cost in bioethanol plant

Cost	Unit	Cost US ($)
Sugar juice	Tons	5,500
Steam	Tons	9,700
Electricity	Kw	3180
Cooling water	m^3	0150
Process water	m^3	1170

Sulphuric acid	Kg	1700
Salts	Litres	0800
Anti-foam	Litres	1760
Yeast	Kg	2600
TOTAL		**26,560**

Table 5 depicts the total cost of $26,560 US is required for the production of bioethanol plant. The detail was an updated record as at Monday 22th November 2021.

5.0 CONCLUSION

In these studies, it was found that the un-treated biomass has more yields in biofuel production. The use of chemical pre-treatments is not required for the algal material (biomass) particularly for Spirogyra. Chemical treatments are usually employed in practice to remove or denature unwanted materials which are present along with cellulose and starch in agriculturally based raw materials used in bioethanol production. Lactose is an enzyme inducer; it played a vital role in the enhancement of bioethanol production. Finally, biofuel production from algae (Spirogyra) is possible and more beneficial when compared to the fuel produced from: other agro-based raw materials (biomass) and fossil fuels (GHG effects & Costs of processing).
The un-treated Spirogyra biomass is more economical and risk-free than the chemical pre-treatment as it gives room for less expensive method by cutting off the pre-treatment cost.

RECOMMENDATION

- The use of *alga material* (biomass) as a substrate for bioethanol production is advisable than agro-based materials as it's more beneficial and renewable.
- Pre-treatment with chemicals are not required for the algal material particularly for *Spirogyra*. Thus, *un-treated Spirogyra* biomass is strongly recommended for any bioethanol production from *Spirogyra* feedstock as it is more economical.
- The production of bioethanol is dependent on the availability of sugars and the activity of enzymes produced by the *Aspergillus niger,* therefore enhancer like *Lactose* is highly recommended for the saccharification process for more amount of ethanol to be produced; as saccharification and fermentation are moving hand in glove with each other.
- The FGN should take an *active part* in renewable energy and *embark* on this project of *'algal'* on a *large scale*.
- The recent signing of the law on *climatic change* is a welcome development in Nigeria, but a need to its implementation is *highly* encouraged.

In Addition: On Water-Energy Solution:

- A ***comprehensive*** & ***integrate*** W-E plane MUST be instituted
- *Reduce* water dependency
- *Enhance efficiency on* W-E through technology

Legend:

*Gt CO_2 eq/year	=	basis to compare GHG on their GWP
GHG	=	Greenhouse Gas
GWP	=	Global Warming Potential
Nutrients	=	Mycelia (Synthetic media)

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