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Production and Characterization of Bio-diesel from Water Hyacinth (*Eichhorniacrassipes*) of Lake Koka, Ethiopia

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Abstract: Ethiopia has a large biomass of water hyacinth (*Eichhorniacrassipes*) in Lake Koka and LakeTana during the summer season. Local community of Lake Koka doesn't use this water hyacinth. So the activity is designed to produce biodiesel from water hyacinth and determine its quality parameters. This should be based on the concept of produce renewable energy and discard water hyacinth from the lake. The Specific gravity (g/ml), Acid value (mgKOH/g), Water content (mg/g), kinematic Viscosity (mm^2/sec) and ash% (w/v) content of water hyacinth (*Eichhorniacrassipes*) biodiesel were 0.912, 0.4, 0.004, 2.7 and 0.001 respectively. The Nutrient analysis of water hyacinth from Lake Kokawas takes place in NFLARC laboratory to evaluate for biodiesel purpose. The proximate composition of water hyacinth from Lake Kokawas moisture content % (w/w) 76.2 ± 0.1, lipid content % (w/v) 0.49 ± 0.23%, crude protein % (w/w) 10.23 ± 0.34%, ash content % (w/w) 9.5 ± 0.02%, carbohydrate % (w/w) 3.58 ± 0.6%, and gross energy (kcal/100g) 59.65 ± 0.53%. From the study it can be conclude that the parameters of biodiesel get from water hyacinth is fulfill the requirement set by American and European biodiesel standards. The problem is that the oil content of water hyacinth is too much low and can't economically visible to produce biodieselfrom water hyacinth (*Eichhorniacrassipes*).

Keywords: Water Hyacinth, *Eichhorniacrassipes*, Biodiesel, Nutrient Content

1. Introduction

Water hyacinth is invasive species due to their adaptability to a wide type of fresh water ecosystems and interference with human activities [25]. Thus a huge amount of money and efforts have been invested since then for their management [11]. However, it was recently realized that they could be sustainably managed in their natural ecosystem and used in biodiesel production, generating ample avenues of research, development and marketing of their end product [12]. As the search for alternatives to fossil fuel intensifies in this age of modernization and industrialization, fuelled by increasing energy costs, water hyacinth holds a strong promise in the 21st century biodiesel industry [24]. There have been instances of complete blockage of waterways by water hyacinth making fishing and recreation very difficult [13]. There is a need for sustainability and a new perspective when it comes to managing this species and understanding and implementing their marketability as an ornamental or in their alternative products or as a newly found biofuel crop [8]. The interest in production of biodiesel has started in Ethiopia before hundred years ago [18]. Ethiopia has expense a million dollars to import fuels [1]. Before a decades ago Ethiopia have try to produce biodiesel from vegetables and jatrophacurucas [20]. The biomass of water hyacinth in Ethiopia lakes especially in LakeTana and LakeKoka are covered the half area of the lake [2]. Ethiopian major rivers like Awash rivers are also covered with water hyacinth [22]. Especially in summer reason it spreads fast and covers more than half area of a lake. This is a bottle neck problem for production of fish; to get sustainable water for irrigation of agricultural production because water hyacinth is highly absorbing water and it becomes dry through a time [7]. So in order to save fishes and other aquatic animals the activity is designed to use as biodiesel purpose. Water hyacinth is a promising plant fro biofuel production like bioethanol, biogas and biodiesel [21]. *Eichhorniacrassipes*represents a promising organism for fuel production because of their highavailability and high biomassyield [23]. Water hyacinth is low in lignin contentwith high content of cellulose and hemicelluloses [8]. The combined cellulose andhemicellulose content in water hyacinth reached 58.6%, and the lignin content was very low compared with other biomasses [17]. The most important and beneficial use of *Eichhorniacrassipes*is biofuel production in different countries, mainly in Brazil, India and some African countries. It isfound that 1 kg of cellulose yields 1.1 kg of glucose and 1 kg of cellulose yield 0.56 kg of ethanol [9]. Other consumptionoptions including *Eichhornia*sp based power plantenergy, compost/fertilizer and animal feed production alsomake the engineering feature so important in many commercial ways [10]. The focus on outlook should regard Eichhorniaas power plant energy (as source of biogas, biodiesel, bioethanol etc). It can help to decrease the use of fossilfuels [16] Because of the following characteristics of *Eichhornia*sp (Water hyacinth), it can be used as biodiesel source; Ideal Attributes, Wide availability, Ease of harvesting andcultivation, Frequent harvest cycles, No competition withfood, Easy to extract, non-expensive, Global invasive nuisanceweed, Low-tech processing and Millions of dollarsspent each year to remove / dispose [18]. This study is designed to produce biodiesel from water hyacinth (*Eichhorniacrassipes*) which grows exclusively andextensively in all the Ethiopian water bodies and causingserious problem.

2. Materials and Methods

2.1. Sample Collection and Preparation

Water hyacinth plant with root, stem and leave were collected in October, 2019from Lake Koka, which is located in the Ethiopian Rift valley south-east of Ethiopia and transported to Sebeta National fishery and aquatic life research center for laboratory analysis. Before analysis, the leaf was separated from stem and roots followed by washing with clean water to remove any mud's and dusts. The specimens were chopped and dried at room temperature in greenhouse.

2.2. Laboratory Analysis

Kjledahl apparatus for sample digestion during protein analysis and nitrogen analyzer to isolate nitrogen from other digested organic matters were used in the laboratory. Water activity meter was used to determine of the water content of biodiesel while acidity of biodiesel was determined using titration method.

2.3. Proximate Composition of Water Hyacinth

The moisture, ash, crude protein and fat content of water hyacinth were determined according AOAC (2000) [3-5] standard procedures. The carbohydrate content was derived from moisture, protein, ash and fat content using the following formula:

$$\text{Carbohydrate content} = 100 - (\text{protein} + \text{fat} + \text{ash} + \text{moisture})$$

The gross energy value of water hyacinth was determined using the relationship from fat, carbohydrate and protein contents of the Atwater's Conversion Factors; (4kcal/g) for protein, (9kcal/g) for fat and (4 kcal/g) for carbohydrates and expressed in calories.

$$\text{Gross energy (Kcal/g)} = (4 * \text{protein}) + (4 * \text{carbohydrate}) + (9 * \text{fat})$$

2.4. Biodiesel Production

Biodiesel was produced from water hyacinth through the process of esterification and Trans- esterification according to the method [6].

2.5. Physicochemical Properties of Biodiesel

pH of biodiesel was measured using digital pH meter according to the method [19]. The specific gravity of a substance is a comparison of its density to that of water (1g/cm^3). The density and specific gravity of the biodiesel from water hyacinth was calculated using the formula given below.

$$\text{Density of water hyacinth biodiesel} = \frac{\text{Amass ofwater haycinth biodesiel}}{\text{volume of water hacinth biodesiel}}$$

$$\text{Specific gravity} = \frac{\text{density of water hyacinth biodiesel}}{\text{density of water}}$$

Total pigment, chlorophyl and glycerol were determined according to the procedures and formula indicated by [19]. The water content was determined by using water activity meter and the viscosity was determined by using digital viscosity meter, using spin 1 rotation. The total acidity was determined following the procedures indicated by [6].

3. Result and Discussion

3.1. Evaluation of Extraction Solvents

Table 1 summarizes the mean percentage of crude lipid content of water hyacinth leaf with different extraction solvents.

Table 1. *The crude lipid content % (w/w) of water hyacinth with different solvents.*

Types of solvent used	Oil yield (%)
Hexane	0.60±0.01
Petroleum ether	0.50±0.02
Ethanol	0.33±0.01
hexane: Ethanol	0.50±0.02
hexane: Petroleum ether	0.63±0.01
Ethanol: Petroleum ether	0.40±0.02

The results obtained with different extraction solvents were 0.3-0.6%. The difference of crude lipid content was arises due to the use of different polarity of solvents. The efficiencies of different polarities of solvents hexane, petroleum ether, ethanol and the mixture of different solvents such as hexane: ethanol, Hexane: petroleum ether and ethanol: petroleum ether was evaluated. From the result the highest crude lipid was obtained with mixture of hexane: Petroleum ether and the lowest crude lipid were obtained using ethanol extraction this due to the polarity of ethanol. The polarity strength of ethanol is high than polarity strength of hexane and petroleum ether. The results obtained by [26] are agreed with the current data, they obtained different lipid content with different extraction solvents.

3.2. Evaluation of Crude Lipid Content

Table 2. *Crude lipidcontent % (w/w) of water hyacinth with different extraction methods.*

Methods of extraction	Oil yield (%)
Soxhelet extraction	0.60±0.01
Maceration extraction	0.2±0.02

In table 2 the mean percentage of crude lipid content in water hyacinth leaf collected from lake koka in autumn (October), 2012 in different extraction methods was vary. The result obtained by soxhlet extraction was 0.60 ± 0.01 where as 0.2 ± 0.02 was obtained by maceration extraction methods. From the result obtained soxhlet extraction method has more efficient to extract lipids from water hyacinth. The main problem of soxhlet extraction isn't using for large samples it only uses for small size samples because the sample holder calls thimble can't hold large samples. On the other hand maceration extraction methods use for large samples but the efficient is low.

3.3. Proximate Composition of Water Hyacinth

Table 3. *Proximate composition of water hyacinth leaf collected in Autumn (October) season from lake koka.*

Number	Parameter analysis	Yield
1	Moisture content % (w/w)	76.2±0..1
2	Ash content (w/w)	9.5±0.01
3	Protein content % (w/w)	10.23±0.3
4	Carbohydrate content % (w/w)	3.58±0.21
5	Gross energy content (kcal/g)	59.65±0.32
6	Crude lipid content % (w/w)	0.3-0.6±0.02
7	pH	5.4

The mean percentage of moisture, crude protein, ash, carbohydrate, and gross energy of water hyacinth of Lake Koka is summarized in Table 3.

The mean moisture content % (w/w) lake koka water hyacinth leaf was 76.2 ± 0.1 which is below reported by [15], who was reported that 85.15. These differences may be happen due to the season of sample collection and environmental condition. The other reason is that some water content of water hyacinth was losses due to sample transportation from landing site of koka toSebeta, NFLARC laboratory. The mean percentage of crude lipid content of water hyacinth was 0.3-0.6% (w/w). The difference of crude lipid content was arises due to the use of different polarity of solvents. However the crude lipid content of water hyacinth reported by different authors have significant highest than the current study, whoreported that 6.90% (w/w) by [19].; 1.56% (w/w) by [15]. 4.11% (w/w) by [14]. This may be due to with different agro ecology zone and species of water hyacinth. The mean percentage of total mineral or ash content of water hyacinth was 9.5% ± 0.01, which is less than recorded by [26], who reported that 19.9 ± 0.25; 16.79% by [15]; 4.88%by [14]. The mean percentage of protein content of water hyacinth% (w/w) leaf was 10.23 ± 0.3 which is have less value reported byby [15], who reported that 15.27%, but a close agreement value reported by [27], who reported that 10.01%. The mean percentage of carbohydrate content water hyacinth was 3.58% ± 0.21. The obtained result was less reported by [14], who reported that 33.61%. The main reason that of a big difference of carbohydrate content from the current study is [14] was done from leaf protein concentrate, butthe current study was done on crude leaf of water hyacinth. The mean percentage gross energy of water hyacinth was 59.65kcal/100g ±0.32. To my knowledge the gross energy of water hyacinth wasn't reported before this work.

Table 4 shows that the summery of quality parameters of biodiesel of water hyacinth. From the result most of quality attributes of biodiesel of water hyacinth were within the range limits of American and European fuel standard requirements. In the current study the specific gravity of water hyacinth biodiesel was 0.9129g/ml, According to European standard (EN 14214 standard), the average specific gravity of biodiesel was reported to be 0.8600-0.900 g/ml. The average value obtained from the current study is higher value compared with the required European standard this implies that the energy content of lake koka water hyacinth have high. The specific gravity of the lake koka water hyacinth biodiesel in current study was highest than reported by [19], who reported that 0. 834 g/ml. The cause of difference may be due to variation of agro ecology zone. The mean acid value lake koka water hyacinth biodiesel was 0.4 mg KOH/g. The maximum acid no of biodiesel is 0.8 mg KOH/g (according to ASTM) and 0.5 mgKOH/g (according to EN) standards. The acid value obtained for Lake Koka water hyacinth biodiesel is within the specification limits of international standards and is recommended to be used for biodiesel purpose. The average Kinematic viscosity (mm^2/sec) of Lake Koka water hyacinth biodiesel was 3.12. According to the European standard (EN 14214 standard) the viscosity of the biodiesel should lie between 1.9-6.0mm^2/sec.

The current Kinematic viscosity (mm^2/sec) value of water hyacinth biodiesel was in the range of European standard (EN 14214 standard), but lowest value was obtained than reported by [19], who reported 9.85 mm^2/s. The mean ash content of water hyacinth biodiesel collected from Lake Koka was 0.0012 g/100g. The maximum values of ash content in biodiesel was limited to 0.01 g/100g (according to the American standard D874) and 0.02 (according to EN 14214 standard). From the result, it can be concluded that the ash content values of water hyacinth biodiesel in the current study is closely agree to the values of European standard (EN 14214) and American standard D874. The average water content (mg/g) of water hyacinth biodiesel was 0.04. The tolerable amount of water content of a biodiesel is up to 0.3 mg/g (According to American Standard) and 0.5 mg/g (according to EN 14214 standard). From the result it can be conclude that the water content of Lake water hyacinth biodiesel is within the range of American and European biodiesel standards. The mean percentage of Total Chlorophyll (mg/g) of water hyacinth leaf in production of biodiesel was 0.36. The results are agreed with reported by (Sanaa*et al*., 2017), who reported that 0.36. Chlorophyll a (mg/g) and Chlorophyll b (mg/g) of water hyacinth of Lake Koka was 0.23 and 0.13 respectively. The current value of Chlorophyll a (mg/g) was closely agree than reported by [19], who reported by 0.22, but lower value was obtained in Chlorophyll b (mg/g) than reported by [19] who reported 0.15. The mean percentage of T. Carotenoids (mg/g) for lake koka water hyacinth biodiesel was obtained 1.34 which is higher than reported by [19], who reported that 1.23. The cause of difference may be due to environmental condition of the lake koka and river found in Egypt. The mean result for total pigment content (mg/g) obtained was 2.06 which is also higher reported by [19], who report that 1.60. The cause of pigment difference may be due to environmental condition. From this result it can be conclude that the water hyacinth collected from Lake Koka have better for coloring purpose than the water hyacinth of Egypt river. The glycerolmmol/L and sediment% (w/v) content were 0.39 and 2.45 respectively. [19] reported that the glycerolmmol/L content of Egypt water hyacinth content was 0.41 which is higher than our result.

Table 4. *Biodiesel characteristics of water hyacinth.*

Number	Parameters	Current Value	BiodieselD-6751	Biodiesel (EN14214)	Reports from other authors
1	Specific gravity (g/ml) at 20°C	0.912	-	0.860–0.90	0. 834 by [19]
2	Acid valuemg KOH/g	0.4	Max 0.8	Max 0.5	-
3	Water content (mg/g)	0.04	Max 0.3	Max 0.5	-
4	Kinematic viscositymm^2/sec	2.7	3.5 -5	1.9-6	9.85 [19]
5	Ash% (w/v)	0.001	Max. 0.01	Max 0.02	--
6	pH	5.6	-	-	4.0 by [19]
7	Chlorophyll a (mg/g)	0.23	-	-	0.22 [19]
8	Chlorophyll b (mg/g)	0.13	-	-	0.15 [19]
9	T. Chlorophyll (mg/g)	0.36	-	-	0.36 [19]
10	T. Carotenoids (mg/g)	1.34	-	-	1.23 [19]
11	Total pigment content (mg/g)	2.06	-	-	1.60 [19]
12	glycerolmmol/L	0.39	-	-	0.41 [19]
13	Sediments% (w/v)	2.45	-	-	-

4. Conclusion

From this study it can be conclude that the quality attributes of biodiesel of water hyacinth is fulfill the standards set by American and European standards. Different studies show that oil content of water hyacinth (*Eichhorniacrassipes*) is affected by harvesting age, agro ecology and season. The main challenge or drawback to produce biodiesel from water hyacinth is that very low values of lipid content which have a value of 0.3—0.6% (w/w) on dry based. So in the study it can be conclude that it isn't economically important to use water hyacinth as a biodiesel. Finally I recommended that further study on use of water hyacinth for coloring of substances like food industry will be done.

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