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Extraction of Biofuels from Water Hyacinth: A Review

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Abstract

At present time sustainable biofuels are attracted much attention because of shortage of fossil fuels. The transformation of lignocellulosic biomass to biofuels, for example, ethanol and other worth added products has attracted much attention. The advancement of a productive, eco-friendly, and cost-effective pretreatment measure is a significant test for the conversion of lignocellulosic biomass to biofuel. Water Hyacinth (WH) is one of the lignocellulosic substances utilized for the production of ethanol because of its fast growing, and unfastened -floating aquatic plant. Hemicellulose is the predominant inside the WH. Biofuel extraction from water hyacinth is a practical interaction as a result of the lesser expense of crude material and its simple accessibility in India.

Keywords: Biofuel Production; Lignocellulosic materials; Water Hyacinth; Pretreatment methods

Introduction

During the last few decades, government's, and researchers have thoughtfulness regarding identifying new fuel sources because of worldwide environmental issues, temperature alteration and also depletion of conventional fuels such as coal, oil, and flammable gas [1]. Biofuels could be considered as a choice to decrease high reliance on diesel fuels [2]. Other than this, the over-usage of conventional fuels and their results on the Earth has expanded the interest for fluid fuels generated from biomass all through the world. As indicated by assessments, the bioenergy creation would be expanded 4.7 occasions (from 9.7 × 106 to 4.6 × 107 GJ/d) somewhere in the range.

of 2016 and 2040. However, it is critical to specify that the biofuel creation measure impacts their ecological effect [3]. Regular fuels represented 80% of the essential energy utilization all through the world in 2019, out of which about 60% were devoured by the vehicle [4]. Biomass is an environmentally friendly energy source which contains oxygen, carbon, traces of nitrogen hydrogen and few minerals. Biomass can be readily shipped and stored (but with a lower energy thickness than petroleum derivatives). Its usage has a benefit over other inexhaustible sources like sunlight-based energy, hydroelectric force, wind energy because of environment as different biomasses can grow in different type of conditions and its low reliance on site. Country territories in under developed nations are reliant upon biomass for fundamental activities like heating and cooking. For instance, India has impressive coal stores of around 223 billion tons, however they are situated in explicit zones like north-east India, in contrast to biomass, which is equitably and extensively spread over the entire nation [5]. Moreover, simple accessibility of waste biomass as an ease fuel make it a promising worldwide fuel source. Developed nations are additionally focusing on biomass as a reasonable energy alternative in view of these advantages [6]. In this situation, sustainable sources may fill in as another option. The renewable resources such as wind, sun, biomass, water and geothermal heat can be hotspots for the energy industry though production of fuel and chemical industry may rely upon biomass as an elective source in near future. Biofuels offer a critical answer for the current challenge since these are delivered through inexhaustible biomass. Nowadays, biofuels are considered as the most positive decision which contrasted with syngas, hydrogen or solar-energy because of their inexhaustibility, biodegradability and cost-adequacy. Recently, a broadly investigated research area is the improvement of economical and clean innovations to use biomass feedstocks to generate biofuels [7].

Biofuels are gaseous or liquid fuels which are generated from biomasses and transcendently utilized in the transportation area. They can be utilized as the feedstock to incorporate significant synthetics and also used to produce power and heat. Liquid biofuels are utilized in the transportation area while gaseous biofuels are ordinarily utilized for power production and heat. Biofuels, includes bioethanol (EtOH), bio-methanol (MeOH), bio-dimethyl ether (DME), Fischer Tropsch (FT) energizes, synthetic gaseous petrol (bio-methane), and H2. Biofuels can be arranged into four primary classes: [8]

- First generation biofuels
- Second generation biofuels
- Third generation biofuels
- fourth-generation biofuels

First generation biofuels are basically derived from agricultural crops such as sugarcane, wheat, sugar beet, rice, sunflower oil, palm oil, soya bean oil, etc. There is an exceptionally mature innovation to changing the agricultural crops over to biofuels [9].

Second generation biofuels generally produced from renewable resources, which could assist with limiting the CO2 emission and petroleum derivative combustion in worry to prevent our “Earth” from an unnatural weather change. Biofuels, for example, bioethanol, biomethane, bio-methanol, biodiesel, biogas, biohydrogen known as “Second generation biofuels” which can be produced from industrial wastes, agricultural wastes, utilized cooking oil, municipal solid wastes, and sewage sludge [9-10].

Third generation biofuels are predominantly generated from algae feedstock. Algae feedstock is known as one of main sustainable renewable energy source, which can be used to generate bioethanol [11].

Fourth generation biofuels are predominantly photo biological natural sun- based fuels & electro fuels and are relied upon to bring fundamentals discoveries in the field of biofuels. Creation of these sunlight-based biofuels is an arising field technology, which depends on the immediate transformation of sun-oriented energy into fuel by utilization of raw materials which are cheap, limitless and generally available. Recently creation of second and third generation biofuels are beneficial over first-generation biofuels as they are obtained from agricultural residues and algal biomass individually. Algal biomass is more bountiful in nature, principally filled in different types of wastewater sources [12-14].

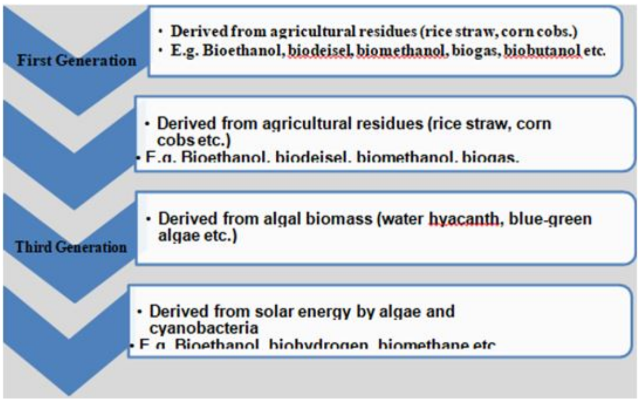

Figure 1: Classification of biofuels.

Lignocellulosic Biomass

Lignocellulosic biomass [14] is the major auxiliary part of all pants and it is a sustainable natural material which comprises of three significant components:

- Cellulose
- Hemicellulose
- Lignin

Cellulose

Cellulose is the most abundant natural molecule on earth, which is a straight biopolymer of anhydroglucopyranose particles, associated by β-1, 4 glycosidic bonds. β-1, 4-glucan or cellulose is a straight polysaccharide polymer of glucose which made of cellobiose units. It is significant constituent of all plant material. Cellulose chains are pressed by hydrogen bonds in supposed 'elementary microfibrils'. These fibrils are connected to one another by hemicelluloses, amorphous polymers of various sugars as well as different polymers such as gelatin,and covered by lignin. The microfibrils are frequently related as groups or microfibrils. This exceptional and convoluted structure makes cellulose impervious to both organic and synthetic medicines. [15].

Hemicellulose

The hemicellulose is the second most important component of lignocellulosic biomass. It is a heterogeneous polymer of hexoses (principally mannose, less galactose and glucose), pentoses (including arabinose and xylose) and sugar acids. The concentration of hemicellulose in lignocellulosic biomass is about 25 to 35%. It is effectively hydrolysable to fermentable sugars [16] as well as less complex. The dominant sugars in hemicelluloses are xylose in agriculture and hardwoods residues and mannose in softwoods [17].

Lignin

In lignocellulosic residues, is the third principle heterogeneous polymer, which generally contains three fragrant alcohols including coniferyl alcohol, sinapyl and p- coumaryl. Lignin serves such ‘glue’ giving the biomass strands its basic strength. Lignin goes about as a barrier for any arrangements or chemicals by connecting to both cellulose and hemicelluloses and also prevents penetration of lignocellulolytic compounds to the inside lignocellulosic structure. Lignin is the most recalcitrant component of lignocellulosic material to debase [15].

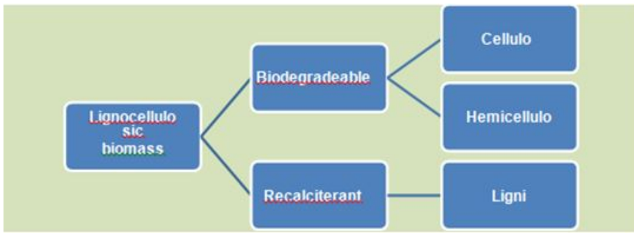

Figure 2: Components of lignocellulose biomass.

Water Hyacinth (WH) is one of the lignocellulosic substances utilized for the assembling of ethanol because of its fast growing, aquatic plant and unfastened - floating. Hemicellulose is the predominant inside the WH.

Water hyacinth (WH)

Water is the main resource on earth which providing various ecological and financial advantages at worldwide scale like industrial, horticultural, domestic, farm and household use. Resources of world's freshwater are, in any case, on a consistent decay, because of expanded pressing factor coming about from poor homegrown garbage removal as well as industrial intensification and rural, which causes eutrophication in lakes, yet in addition reservoirs (initiates by dams), streams, waterways and consequently gigantic spread of aquatic weeds [18]. For example, expanding population pressing factor and land advancement present on-going challenges towards the organization of the climate and the related waterway environments [19-20]. This issue is further exacerbated by

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extreme climate events and anthropogenic activities, which favors obtrusive species spread. Worldwide, water hyacinth is one of the best ten most noticeably harmful weeds [21-22]. At present, the presence of aquatic weed species in freshwater systems is incredible concern to water resource and environmentalists as well as hydrologists. Free- floating plant weed is found to be a genuine danger to freshwater biological systems biodiversity because they affect ecosystems functioning and profitability, human livelihoods, aquatic life as well as biological and hydrological processes [23,24].

Figure 3: WH.

Water hyacinth (WH) is also known as Eichhornia crassipes (fig.3). it is one of the world's most invasive free-floating aquatic plants which could be to a great extent changed in tall from few inches to more than three feet. and is known to cause significant ecological and socio-economic effects. This plant has thick stalks and blue-green leaves with a garish purple flower. Gathering of WH in Nile river and its branches addresses difficult issues which makes obstructing of waterways [25-26]. Also, it extraordinarily the reducing the accessibility of dissolved oxygen levels and seriously corrupts water quality by impeding the air-water interface. Fortunately, it contains biodegradable organics and supplements (phosphorous and nitrogen) which addresses significant feedstock for hydrogen generation through anaerobic digestion method [27]. WH absorb the water content about 70% because these plant achieved the hydrophilic properties. These Eichhornia crassipes separate parts like petioles, stem, and roots were utilized to create different applications and some decorative things. It has the long stalks. These plant essentially called as the high hazardous plant. One water hyacinth plant generated a couple of daughter plants. These daughter sows' seeds withstand the many years. The height of some water hyacinth plants about 2 to 5 m in particular area while these plants grow about 5 to 7 m in some regions because development of these plant consistency wards upon some range of temperature [28]. The high growth level temperature of these plants about 33 to 35 0C, Medium and ideal degree of temperature was 25 to 30 0C, the lower development percentage temperature was 18 0C.

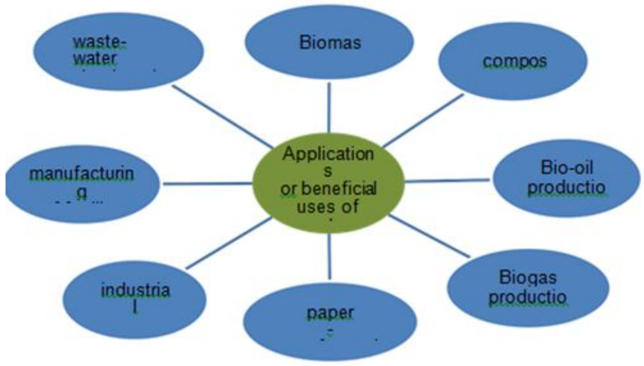


Figure 4: Different applications of water hyacinth [29].

The destinations of this paper are twofold. A brief review of publications during last decade that examine the about water hyacinth and its morphology. We talk about the capability of water hyacinth in energy creation and environmental results has been described as specific illustrations. Second, we distinguish gaps in present scientific understanding, and present thoughts for future exploration.

WH Morphology

WH fulfills the requirement for biofuel generation in view of the accompanying characteristics: non-crop, abundantly, available high sugar content, biodegradable, and perennial bounteously. The dry biomass of water hyacinth chiefly includes cellulose (18%-31%), hemicellulose (18%-43%), and lignin (7%-26%) [30].

Organic components	Percentage (%)
Lignin	3.5
Cellulose	18.2
Hemicellulose	48.7
Crude protein	13.3

Table 1: The percentage composition of WH.

Given its high substance of carbohydrate, which can be effectively hydrolyzed into fermentable sugars, WH is an appropriate and sustainable feedstock to deliver biofuels (e.g., biodiesel, bioethanol and biohydrogen) [31-32]. The develop water hyacinth involves stolon's, leaves, long pendant roots, organic product groups, and leaves. The normal stature of water hyacinth is 40 cm. Nonetheless, sometimes it can grow up to 1 m tallness. WH has 6 to 10 lily-like blossoms, which having 4-7cm breadth. Various pieces of water hyacinth, for example, leaves and stems are produced using air-filled tissues which permits the plant to float on water hyacinth can endure dry season condition due to which it can survive in moist for quite a long time [33]. Four our types of water hyacinth including E. azurea, E. crassipes, E. diversifolia and E. paniculata have been found up until now [34]. Among these it is discovered that E. crassipes has generally attacked to Africa, North America, Europe, and Asia. Lake Victoria, situated in Africa is probably the biggest lake in the word that is being covered with thick layer of water hyacinth [35]. Different nations to be undermined by this weed incorporate Portuga and Spain, alongside the Sundarbans mangrove woods of Bangladesh [36-37]. In China, attack of water hyacinth has become a genuine natural issue Over development of this plant in India has caused extreme siltation in the wetlands of the Kaziranga National Park and Deepor Beel lake. Almost 40,000 ha of water bodies are undermined by this famous weed in Mexico. A few environmental effects in SacramentoeSan Joaquin River

Delta situated in California has been accounted. One of the issues to annihilate WH is a direct result of its seed, which is known to make due as long as 20 years. Although, sufficient examination and endeavors have been made to destroy water hyacinth, this famous weed keeps on engendering overall effectively [38-41]. A portion of the researchers' work was reported for these plants make the deficiency such as triterpenoid and itching [42].

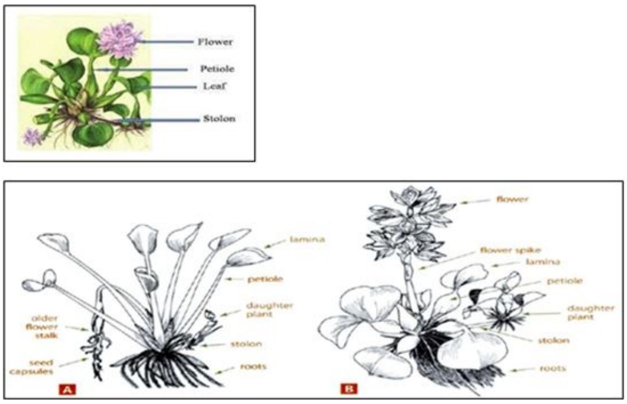


Figure 5: WH morphology.

These WH plants at first appeared in Africa, Europe, North America, and new land. This water hyacinth plants covered the all over ponds, rivers and lakes, if it was not controlled and these plants expanded very quickly due to which it influenced the water stream of the system. Physical and chemical properties of water hyacinth are changed because these plants change the saltiness and pH level of the water

Simultaneously and creates the irregularity. In certain years prior, WH plants introduced in Bengal because of its wonderful leaves and blossoms. But these wide spreading attributes made the annihilation of other water plants of water bodies, fishes and different creatures and [43-45]. In this way, these plant was called as Bengal dread. On 1930s china planted these water hyacinth plants as a feed, because of sewage water control and furthermore ornamental purpose however because of this unique qualities of fast developing these plants hampered and hindered blockage of stream water [46]. This WH plant stopped the river water flows in all over China and genuinely influenced the health and life of the nearby water body peoples as well as the eco system of the water. [47].

Control Process

In water bodies, water hyacinth is controlled by a process known as mechanical harvesting (MH) which recovered its biomass. However, this method is not exceptionally proficient and also costly when the paces of gathering per vessel each day and energy cost per ton of new biomass harvested and distance shipped are taken into consideration [48]. Later, new technologies are found out which improving the productivity during and after harvesting and also focused on cost decrease of collecting processes. (for example, transportation and drying out of new biomass could hypothetically cost around US$40 per ton of dry mass). [49] Traditionally, destroying boat and shaper and expulsion gather system were used. [50] Both machines were fueled by a motor and outfitted with a blade shaper at the outside of the water and could cut floating weeds like WH. However, utilizing a destroying boat could make a huge tangle of plant sections which are hard to eliminate. A cut and eliminate collect system, which has been famously utilized in US since 1950s, comprises of a gatherer (a boat) with a shaper header mounted at the front end, a carrier, shore transport and a truck. A calculation to eliminate 1,000,000 ton of new biomass shows the requirement for 75 full size (40 m3) trucks each day to move the biomass throughout the year around. Additionally, it would require multi-million cubic meters of room at the waste dump site. The calculation also shows that 1,000,000 ton of new biomass need around 20 standard full-size football fields (about 7400 m2) with biomass heaped at a height of two meters if the dry and spoiling turnover rate is 100 days. Besides, the consequence of new biomass saved at waste dump site could include high ecological and socioeconomic expenses because of conceivable high discharges of carbon dioxide, nitrous oxide and methane. This model features that decreases in dehydration cost and harvest cost should be accomplished before the administration issues of water hyacinth are addressed. [51-53]

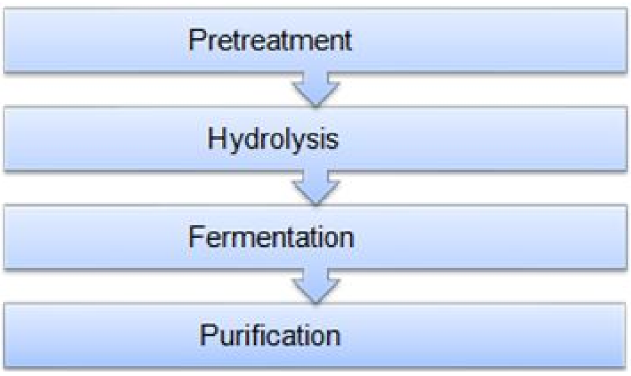
Capability of water hyacinth in energy creation

Generally, biofuel addresses all of liquid and gaseous fuels primarily removed from biomass. For instance, biodiesel, biomethanol, bioethanol and biohydrogen are separated from biofuel [54]. The advantages of biodiesel not just have convinced governments to consider as an energy resource yet additionally have pursued after them to take new methodologies to extend biodiesel generation Use of water hyacinth as a fuel source in type of biogas, production of ethanol, cremation and briquetting. Additionally, biodiesel, bio methanol, bioethanol and biohydrogen as principle biomass products have been applied inconceivably in energy production and huge amount of biofuel assets, change in petroleum derivative costs and harmless to the ecosystem. The qualities of biofuel combustion method have convinced the governments of tropical nations to put resources into the advancement of biofuel industry [55]. Transformation of WH to ethanol or biogas are performed by several pretreatment methods such as biological, alkali, acid treatment. But biological pretreatment has been led for pretreatment of water hyacinth to biogas conversion. The literature about biogas transformation from water hyacinth has been distributed by Barua et al. They applied Bordetella muralis, Paenibacillus and Citrobacter werkmanii to speed up the water hyacinth hydrolysis [56]. Besides, Chanathaworn also studied about activity condition enhancement of biogas creation from water hyacinth within the presence of nitrogen-rich earthworm.

The WH conversion into completed by briquettes machine in which WH aquatic plant was collected, dried and ground into powder prior to being blended with starch binder in physically operated machine. The briquettes derived from sundried and similar cooking tests were done by consuming the briquette in a form [57]. Production of biomethane potential in batch system is expanded by utilizing this earthworm and mesophilic condition (28-32) o C for 15 days. The ideal condition for bio-methane creation (35.50 %) was 8 % of TS substrate, introductory pH 7.0 and molecule size of WH 0.3 cm [58]. Patil et al. applied anaerobic co-absorption condition during 60 days for WH and sheep waste. Alkali method was directed for pretreatment of water hyacinth. Ideal state of fermentation was found by blending proportion of 4:12.01:83.90 of WH: sheep waste: water and yielded most elevated biogas of 0.36/gunstable solids comprises of 60.84 % of CH_4, 21.53 % of CO_2 and 17.63 % of others (H_2, N_2, H_2O and H_2S) [6]. ForhadIbne et al. [59] have shown the capability of biogas production utilizing WH, cow excrement, poultry waste and through anaerobic assimilation. These wastes are consistently accessible in our current circumstance and can be utilized as a source of fuel whenever managed appropriately. Biogas innovation can be a suitable improvement choice for agricultural nations for energy creation and replacement if appropriately oversaw and promoted.

Technique for Extraction of Bio-Fuel

The Biofuel should be extracted by possible following sequential technique as:



Pretreatment Methods

During the pretreatment step, lignocellulosic biomass released some types of decreasing sugars like fructose, galactose, arabinose, mannose. Fermentation depends on the action of microorganisms, which utilizes the sugars as a food source to create bioenergy.

Anca- Couche et al. (2016) showed that a pretreatment step is important for the separation of lignin and carbohydrates. The biochemical change of lignocellulosic biomass to ethanol is as yet restricted because of difficulty as well as high cost. After the separation, the starch portion can be fermented into alcohols. Sun et al. (2016), proof that determination of reasonable pretreatment technique can upgrade the absorbability and reduce the constraints of enzymatic hydrolysis in a possible and affordable manner.A.U. Ofoefule et al. (2009) investigated that, chopped and dried WH joined with cow waste had the most elevated combined biogas yield followed by chopped and dried WH alone, while chemically treated water hyacinth had the briefest beginning of gas combustibility. The general outcomes showed that treating WH with chemical didn't have a critical enhancement for the biogas yield. WH doesn't need chemical pretreatment and also shows that chopping and drying to more modest sizes is a more powerful pretreatment technique and blending with animals' wastes. It also showed that WH is an awesome biogas producer and the yield can be improved by drying and consolidating it with Cow compost. Harun et al. (2011), showed that capacity of physical pretreatment on WH for improving the yield of sugar. The best pretreatment method concludes that combination of gridding and drying produce yield about of

155.13 mg sugar/g dry matter, around 6-fold higher than crude feedstock (24.69 mg sugar/g dry matter). Morphology reviews and thermal investigation had revealed disturbances on the WH structure which clarified the improvement of hydrolysis measure.

Guragain et al. (2011), If there should arise an occurrence of water hyacinth, pretreatment is ordinarily completed utilizing alkali/acid pretreatment. Enzymatic hydrolysis yields of glucose and total reducing sugars, just as fermentation yields of ethanol are considered as proportions of adequacy of these pretreatment processes. Guragain et al. (2011), demonstrated that, crude glycerol pretreatment was the best method as compared to ordinary pretreatment for WH. This method was more effective than ionic fluid pretreatment. Additionally, rough glycerol pretreatment was found as successful as pure glycerol pretreatment and this opens up an alluring elective route for the use of unrefined glycerol which prompting more monetary routes for synchronous production of bioethanol and biodiesel.

Type of pretreatment	Advantages	Disadvantages	References
Combined methods (microwave-assisted)	Effective expulsion of hemicellulose and lignin, Maximum usage of lignocellulosic segments, Improved enzymatic hydrolysis.	Generation of harmful material which can restrict further downstream preparing, High energy requests, Special equipment is required	Sun et al. 2016
Ionic liquid (IL)	Lignin reuse and recover after removal, Less crystallinity of recovered cellulose and open outer and inner surfaces of cellulose, disturbance of lignin and hemicellulose segments.	Recovery of solubilized cellulose/ hemicellulose, Significant expense of synthetic compounds, Sugar division from ILS and reusing and harmfulness of some ionic liquids,	Elgharbawy et al. 2016; Baeyens et al. 2015

Acid(H_2SO_4)	High hemicellulose solvency, High sugar recuperation productivity (> 90%) for both xylose and glucose, Recovery of hemicellulose and lignin, Broadly utilization of dilute acid pretreatment because of its adequacy, Cellulose availability for enzymatic scarification.	Arrangement of inhibitors at low pH, Specific non- metallic developments is required, Concentrated-acid cycle is destructive and dangerous, Losses of sugar substance, balance and salt removal	Sarkar et al. 2012
Alkali (NaOH)	Decrease in polymerization degree and crystallinity, Significant removal of lignin and a part of hemicellulose,	Huge measure of water is required for washing, Low absorbability in softwoods, High substance recovery cost. Long pretreatment inhabitant time,	Bradth et al. 2013; Mood et al. 2013

Table 2: Advantages and Disadvantages of selected pretreatment methods.

Type of pretreatment	Initial biomass concentration (g)	Lignin%	Cellulose%	Hemicellulose%	References
Microwave- alkali	5	38%	44%	7%	Rezania et al. (2019)
Ionic Liquid	5	57%	33%	24%	Gao et al. (2013b)
	5	9%	14%	14%	Rezania et al. (2019)
Alkali	4	17%	43%	36%	Abdel-Fattah et al. (2012)
	5	35%	67%	29%	Abdel Naby et al. (2012)
	10	56%	68%	37%	Singh and Bishnoi (2013)
	10	86%	11%	40%	
Acid(H_2SO_4)	5	19%	48%	6%	Rezania et al. (2019)
	10	25%	26%	31%	Singh and Bishnoi (2013)

Table 3: Synthetic composition of pretreated water hyacinth.

Conclusion

Energy creation by utilizing an infesting plant, for example, WH, ought to be a significant chance to solve related expansion issues. It should be changed over into biomass syngas or bioethanol and briquette which exploited as a biofuel. WH is a special biomass, and its parts have been utilized to consider and build up multitude of products. Sustainable nature makes water hyacinth very attractive as a crude material for different sources as well as their quick growth and potentially low cost. Despite the fact that possibility of utilizing hyacinth for different applications has been illustrated, most investigations have been done as an academic's interests, and no hyacinth-based items or technologies are presently available on market. This literature survey revealed that the utilization of WH as an appropriate biofuel because of

- Biomass yields,
- Less cropping and preparing time
- Solution of wastewater treatment,
- Biogas production,
- High reproduction rate,
- Nutrient uptake

There are not many significant characteristics of WH which can be used to derived biofuel for example biogas to produce power, bioethanol which control vehicles and engine. The ideal advantage could be accomplished from water hyacinth by-product with least processing. It can be considered as the best option to adapt up to progression of territorial and worldwide ecological change as the consumption of fossil fuel exhaustion. Recently, water hyacinth has been basically concentrated as a source of fuel, composites, sorbent for metals and colors and others. It is important to have another viewpoint toward WH as a resource than a weed. Among the different biomasses currently accessible, water hyacinth is seeming to be the most encouraging source for sustainable, inexhaustible, and cheap bioproducts.

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