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Biomass-derived Materials and their Commercial Applications

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Abstract

Recent increases in environmental pollution, combined with the depletion of fossil fuel reserves, have ignited interest in utilizing biomass and waste materials. The development of alternative energy sources has proved to be imperative. Biomass is a rich, abundant, sustainable, and environment-friendly resource making it an excellent raw material for the production of carbon products. Carbon dots (CDs) have gained a lot of interest because of its superior properties such as water solubility, low toxicity, biocompatibility, tiny size, fluorescence, and simplicity of modification and their commercial use in solar cells, drug delivery, bio imaging, and catalysis. Thermal treatment of biomass, such as gasification and pyrolysis, produces bio char, bio-oil, and syngas. The bio char-based materials are used for technologies like fuel cells, super capacitors, and batteries. In this review, the source of nano cellulose, a brief description of the chemical structure of nano cellulose, its type, typical production methods, surface modification, and its applications such as biomedical fields, wastewater treatment, food packaging are summarized. This review paper is expected to help the reader procure concise and systematic information as well as impart novel ideas across a wide range of disciplines.

Keywords: biomass carbon dots, bio-char, nano-cellulose, fuel cell, drug delivery, wastewater treatment

Full length review article **Corresponding Author*, e-mail: faizairshad871@gmail.com

1. Introduction

Carbon dot is a new zero-dimensional carbon-based material that has gained popularity because of their excellent photostability, bioactivity, nontoxicity, excellent biocompatibility, high selectivity, sensitivity for biomolecules high quantum yield, and high stokes shift. Compared to many others, carbon sources from biomass are environmentally beneficial natural sources with various advantages in the creation of biomass carbon dots as being cheap, easy to acquire, green, and abundant. In contrast to carbon dots derived from man-made carbon sources, which require the incorporation of external heteroatoms, biomass comprising heteroatoms is the best raw material for carbon dot production [1]. Carbon dot synthesis techniques are classified into two types top-down techniques that involve breaking larger carbon molecules into nanoparticle and bottom-up techniques that involve fusion of smaller precursor molecules. Top-down methods include oxidizing or reducing cutting, as well as physical grinding combined with cutting. However, their practical applicability is often limited because of difficult experimental conditions complex operational procedures and costly equipment [2]. Bottom-up approaches that are mostly microwave-assisted method such as pyrolysis salvo-thermal and ultrasonic are distinguished by a high quantum yield a cost-effective synthetic process and a simple and environmentally friendly operation and have thus been extensively applied for carbon dot production.

2. Methods for the synthesis of biomass carbon dots

Biomass carbon dots are synthesized by either cutting larger activated carbon molecules top-down or joining smaller precursor molecules bottom-up. The top down method includes oxidizing cutting, reducing cutting, physical grinding, or a combination of grinding. Bottom up approach usually adopt for the preparation of BCDs. Bottom-up method can be obtained via fusing of organic molecules under thermal hydrothermal solvent thermal conditions or carbonization of organic precursors. Hydrothermal carbonization microwave, chemical oxidation, and pyrolysis carbonization procedures are among the most widely used methods for producing biomass carbon dots with biomass as a carbon source.

2.1. Hydrothermal Carbonization Method

HTC is a suitable technique for converting biomass into new carbon compounds with a wide range of applications. The hydrothermal carbonization process is the thermochemical degradation of biomass at high temperatures and pressure in the presence of water. Hydrothermal carbonization has been employed to synthesize novel carbon-based materials from biomass and carbon sources such as sweet pepper, garlic, walnut husks, papaya juice, walnut husks, and other biomass materials. The onion waste has a high concentration of dietary fiber alkyl cysteine sulfoxide and non-structural carbohydrates. In an autoclave, onion residue and ethylene diamine extract was carbonized and passivated, resulting in luminous biomass carbon dots.

The quantum yield of the biomass carbon dots produced was 25%, but the size of the bio carbon dots ranged from a wavelength of 7 to 25 nm [3]. The size distribution of microwave-hydrothermal biomass carbon dots is uniform. The size distribution of biomass carbon dots produced with microwave irradiation eggshell membrane as a source of carbon is approximately 6 nm. Eggshell membrane is a protein-rich material that can be easily synthesized at a low cost and is broken down into fragments by microwaves due to electron rotation in a switching electric field and extreme vibration, culminating in the formation of biomass carbon dots under alkaline environment.

2.2. Microwave Method

Microwave irradiation is a high-potential technique that has seen extensive application in the field of chemical processing. As a carbon source bovine serum albumin has been mixed with urea and microwave treatment produced biomass carbon dots. By using flour as the carbon source, water-soluble fluorescence emission biomass carbon dots with sizes ranging from 2 to 5nm was rapidly produced. Biomass carbon dots were synthesized using a simple and effective microwave technique. In a one-step microwave technique, natural lignocellulose was used as a source of carbon in an ethanol-water co -solvents and an acid catalytic system to produce N doped biomass carbon dots [4].

2.3. Chemical Oxidation Method

A chemical oxidation method is a method of oxidizing a target by causing the new target to lose electrons. It is a method of oxidation that uses a strong oxidizing agent, such as hydrogen peroxide. This technique has the advantage of good selectivity, but it has severe disadvantages: 1) It uses expensive oxidants and affects the environment; 2) it produces intermittent production with limited capacity. The distribution of particle sizes of the biomass carbon dots ranges from 3 to 6 nm [5].

2.4. Pyrolysis Carbonization Method

Pyrolysis is the technique of degrading a material using heat. Pyrolysis has emerged as one of most common procedures for producing bio carbon dots so far. BCDs are prepared from rice husk, plant leaves and gynostemia. The rice husk powder was first treated for three hours in a tube furnace in a nitrogen environment prior to getting react with excessive sodium hydroxide for two hours. This was followed by the addition of H_2SO_4 and HNO_3 sequentially for ultra-sonication treatment. Without any further surface treatment, the produced BCDs showed good fluorescence and the fluorescence intensity of these biomass carbon dots in water and organic solvents was increased after treatment with plasma microwave-assisted technology. The quantum yields of biomass carbon dots generated from oriental plane leaf, orchid leaves, and pine cones are 16.4%, 15.3%, and 11.8%, respectively. Table 1 shows the biomass carbon dots production method, reaction conditions, and applications.

Table 1. Biomass-derived carbon dots production methods and applications.

Biomass	**Production method**	**Applications**
Walnut husk	Hydrothermal carbonization at 180° for 2 hours	Solar cells
Flour as carbon source	Microwave method	Bio imaging
Rice husk	Pyrolysis carbonization method with H_2SO_4 and HNO_3	Super capacitors
Rice husk powder	Pyrolysis with sonication treatment	Photosensitizer
Bamboo	Pyrolysis	Fuel cell

3. Properties of biomass derived carbon dots

The basic component of biomass carbon dots is nitrogen, oxygen, and hydrogen, which are present in several functional groups. Source of carbon for biomass carbon dots are mainly carbohydrates, proteins, and other water-soluble macromolecules. When these carbon sources are utilized to make bio carbon dots the majority of them do not require the inclusion of a doping chemical and instead self-dope. Biomass carbon source have a homogenous and dispersed spherical structure as well as photo luminescent optical characteristics.

3.1. Structural Properties

The presence of surface groups on the biomass carbon dots not only provides significant water solubility to biomass carbon dots, but also allows for a variety of further surface modifications. The combination of scanning and transmission electron microscope characterization can be used to understand the shape and size of a material as well as its size distribution. The different sizes of the nanoparticles cause the excitation-dependent fluorescence characteristic of bio carbon dots [6]. The proposed fluorescence-emitting biomass carbon dots processes comprise surface modification defect impacts and quantum size effects. Surface state impacts, edge state impacts, and carbon nucleus impacts can be used to explain fluorescence emission of biomass carbon dots.

3.2. Optical Properties

The ultraviolet region of the UV-visible spectra of BCDs frequently exhibits the highest peak. The ability of biomass carbon dots to produce up-conversion fluorescence with emission wavelengths shorter than excitation wavelengths. Whereas up-conversion two-photon absorption and anti-Stokes have been recorded, a suitable apparatus to investigate this phenomenon is inadequate. BCDs have numerous intriguing aspects such as the excitation dependency of their emission. This property could be explained by the optical selection of distinct size nanoparticles and separate emission traps or other processes on the surface of biomass carbon dots. Excitation-dependent emission properties of bio carbon dots are common and can be attributed to the variable sizes of BCDs as well as the distribution of varied surface states caused by various functional groups on the surface of biomass carbon dots [7].

4. Application of BCDs

BCDs derived from plant-based carbon materials have been widely used in drug delivery, solar cells, and catalysis due to their higher surface area and porosity.

4.1. BCDs in drug delivery

Because biomass carbon dots are intensely fluorescent and biocompatible, with high cellular absorption and excellent stability, they are suited for use as a versatile drug encapsulation and release vehicle. The presence of chemical groups such as amino or OH groups on biomass carbon dots may facilitate future functionalization. These highly biocompatible biomass carbon dots have the potential to be used as novel fluorescent carriers in drug delivery research. The generated bio carbon dots demonstrated great cellular uptake and sustained antihypertensive release, indicating that bio carbon dots could be a potential drug delivery approach for therapeutic delivery [8].

4.2. BCDs in Solar Cells

Because they possess tunable fluorescence emission, as well as size-dependent fluorescence emission, biomass carbon dots derived from biomass or waste organic materials have been explored for utilization in solar cells. BCDs derived from grasses were utilized as a test project to investigate the hypothesized principle responsible for better fluorescence quenching [9]. The precursor-dependent solar panel revealed an interesting effect of functionalization on biomass carbon dots binding to the zinc oxide surface as well as the type of electrical conduction in the layer, which affects solar cell efficiency. BCDs derived from biomass are employed as sensitizers in TiO_2-based nanostructured solar cells. Harvested crab shells are used in the hydrothermal carbonization technique to generate carbon nan dots.

4.3. BCDs in Bio imaging

BCDs are a promising drug delivery vehicle due to their simplicity of customization minimal toxicity and most importantly exceptional FL characteristics. BCDs can be used as bio imaging agents in addition to transporting medicinal molecules into cells. The precursor's source is extremely rich and easily available. The prepared BCDs could be used in both biosensors and bio imaging. Similarly, lychee seeds and jujube kernels were employed to prepare BCDs for bio imaging. Because of their great water solubility, biomass carbon dots are good detectors for in vitro bio sensing. The newly modified BCDs performed admirably as specific live-cell fluorescent detection probes with high subcellular selectivity [10].

4.4. BCDs in Catalysis

Because of their unique photo luminescent behavior and absorption and emission transfer properties, biomass carbon dots may be recognized an active component in the development of high-performance photo catalysts. Biomass carbon dots can be used as either a photosensitizer photo catalyst spectrum converter or as the sole photocatalytic in a catalytic reaction. Under UV light the sample supernatant exhibits intense blue fluorescence and can be used immediately as a fluorescent ink [11].

5. Biomass-derived Bio char Bio Oil Syngas

Bio char is a highly porous and exceptionally long-lasting carbonaceous byproduct produced by the pyrolysis of widely available biomasses such as wood crop residue, sewage sludge, kitchen trash, and algae. Bio char has a variety of physicochemical features that make it useful in a variety of applications. Surface area with a high porosity , very high stability, outstanding carbon content, incredible cation exchange capacity, and significant water-holding capacity are among these feature. Fig 2 shows schematic representation of bio char, bio-oil and syngas production.

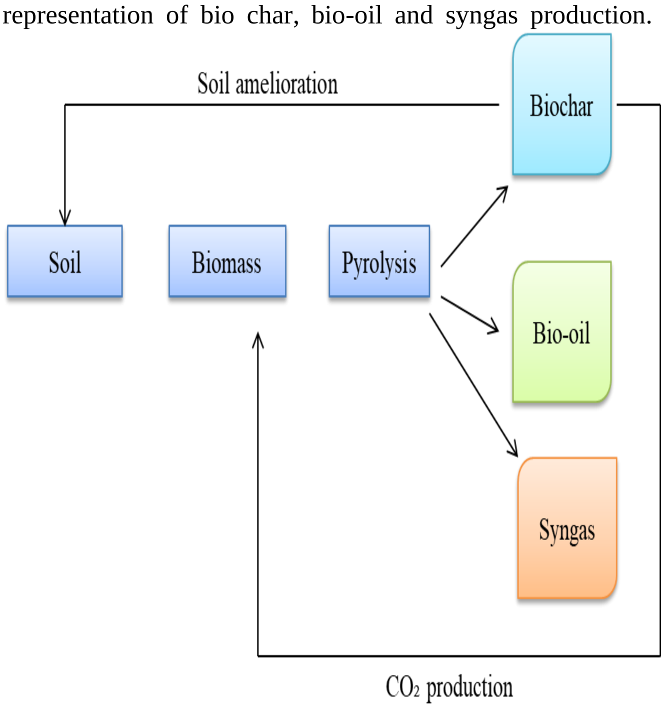

Fig.2. Production of Bio char, Bio-Oil and Syngas from Biomass

Biomass has been used extensively for liquid fuel production and has seen significant progress. The liquid fuel also known as bio-oil is produced through pyrolysis with treatment characteristics such as low temperature short vapor residence time and high heating rate. Bio-oil is another important biofuel that derived from thermochemical conversion of biomass such as pyrolysis and hydrothermal liquefaction. Furthermore, bio-oil is biodegradable and produces significantly fewer NOx and SOx when combusted in a generator than petroleum-based fuel. High temperature leads to large gas residence time and a slower heating rate. The process of pyrolysis increases the production of gaseous fuel, also known as syngas is made from carbon monoxide and hydrogen as well as trace amounts of methane, water and carbon dioxide. Pyrolysis and gasification have been used to synthesize syngas from a variety of feedstock. Syngas is primarily composed of water and carbon dioxide. Bio syngas is syngas produced from biomass feedstock.

6. Production and properties of bio char

The thermal processing of biomass into charcoal and bio-oil involves the processes of pyrolysis process, catalytic cracking, gasification, combustion, and pyrolysis. Torre faction is the term for low-temperature pyrolysis. There are two types of carbonization flash and hydrothermal. Flash carbonization is a half-hour process that produces syngas and bio char in comparable volumes at 350 C° to 650 C° [12]. The process of heating saturated biomass at high temperatures and pressures to produce (hydrothermal carbon) is known as hydrothermal carbonization. Gasification is the partial oxidation of biomass at different temperatures providing ample methane gas syngas while producing less charcoal and bio-oil. The process of heating biomass in the presence of oxygen is known as combustion and it is regarded less efficient for the formation of bio char and bio oil. Pyrolysis is the process of heating biomass in oxygen-depleted circumstances. The heating rate determines whether it is slow or rapid pyrolysis.

Slow pyrolysis produces more charcoal, whereas quick pyrolysis produces more bio-oil. Aside from temperature and pressure, heating rate, vapor pressure residence time and heating technology such as electric heating or fuel combustion all have an impact on the thermal treatment of biomass. Using processes such as pyrolysis and hydrothermal treatment, a diverse range of feedstock have been used in the synthesis of bio-oil. Examples of biomass include food waste, municipal solid waste, and paper [13].

Depending on the reaction temperature vapor residence time and heating rate, pyrolysis produces varying amounts of bio char bio-oil and syngas. Bond breaking, the generation of new functional groups, biomass degradation, and volatilization all occur during pyrolysis. At high temperatures, slow pyrolysis produces charcoal. To achieve complete combustion gasification employs partial oxidation using steam or oxygen. High heat is essential for both practicality and spontaneity as an exothermic process. Syngas is a gaseous mixture produced by gasification. The size of the particles and moisture content of biomass have an impact on the gasification process [14]. Catalysts are useful in thermal treatment because they enhance the effectiveness of biomass-derived products. Catalyst lowers solid product production, allowing for the generation of gaseous and liquid products. Carbon transformation and the amount of reduction of gas produced are affected by alkali metals.

7. Bio char as a catalyst for transesterification

Biodiesel production has risen in popularity in recent years due to the use of waste biomass, lower CO_2 emissions, non-toxicity, and biodegradability [15-16]. Trans-esterification is a chemical process that is accelerated by the application of a heterogeneously or homogeneously catalysis [17-19]. However, heterogeneous catalysts are preferred due to their renewability without neutralizing and ease of separation [20-21]. Solid acid heterogeneous catalysts obtained from bio char sulphonation have been employed in trans-esterification [21-24].

8. Bio char as a catalyst for pyrolysis

Bio char has the potential to be a good catalyst for the pyrolysis of plastic waste. By bonding and complicated synthesis with plastic, the addition of silica, alumina, and aluminum hydroxides to bio char promotes the breakdown process. Bio char is also used as a coagulant in post-treatment activities to increase biofuel quality by removing impurities [25]. Carcinogenesis polyromantic hydrocarbons are generated during the degradation of plastic waste such as polyethylene. Usage of bio char removes these carcinogens.

9. Applications of bio char based materials

Because of their unique properties, bio char-based materials have been used in a variety of applications. Fig 3 illustrates applications and properties of bio char-based materials.

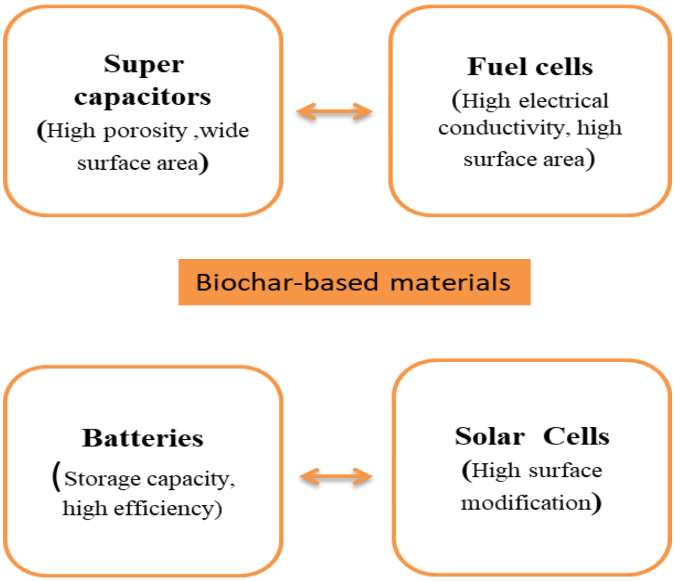

Fig. 3. Applications and properties of bio char-based materials.

9.1. Bio char-based material for fuel cell

In terms of electrical energy production efficiency, fuel cell techniques such as hydrogen storage, microbial hydrogen fuel, and excessive carbon fuel cells have potential. Bio char has the great potential for use in carbon fuel cell technology. Bio char reacts effectively with the melted carbonated electrolyte, boosting charcoal diffusivity in the process [26]. The oxidation of biomass in bio char to oxides stimulates electron transport. Electron transport contributes to the generation of electricity. Bio char strong electrical conductivity makes it suitable for use in fuel cells. Surface area and pores increase reactivity which improves fuel cell performance. The energy created via microbial fuel cells usually utilized to compensate for the power generated during treating wastewater, and it is rarely used for other reasons [27].

9.2. Biochar based material for super capacitors

Because of their high energy density, extended life cycle, and remarkable reversibility, super capacitors have a high energy storage potential. Bio char's conductivity, surface area, permeability, and oxygen-rich surface can be altered to improve energy storage efficiency in super capacitors. Robust electrical conductivity, a large surface area, sufficient porosity, and improved oxygen-rich functional groups are considered necessary for improved super capacitor performance and energy density. However, at high current densities, oxygen-rich functional substituents improve sensitivity while decreasing capacitance, reducing super capacitor performance. This limitation can be overcome by activating biochar using potassium hydroxide, phosphoric acid, or zinc chloride to enhance its surface area and porosity. High porosity, along with an abundance of mesopores,can facilitate ion transport and transfer, resulting in greater capacitance [28].

9.3. Biochar based material for batteries

Because of their great energy density and efficiency, batteries, especially lithium and salt batteries are commercially viable. In lithium and sodium-ion batteries, biochar-based materials with a large concentration of surface functionalities, a small contact area, and a pore structure can be used for ion diffusion and an extended electrode-electrolyte interface, all of which are required for the ongoing electrochemical reactions. The storage capacity could be increased by enhancing the area as well as porosity of the anode and cathode and fine-tuning their conductivity [29]. Nitrogen doping can enhance the carbon oxidation number in biochar, allowing for more active ion storage sites and boosting electrochemical stability. Cycle performance is enhanced by high porosity. Adding nitrogen to biochar increases its specific capacity by providing a surface for charge transfer and reducing inner resistance. Because of its surface characteristics, excellent electrical conductivity, and high specific capacity, metal oxide doped biochar is useful [30].

10. Biomass-derived Nanocellulose

Natural fibers are bio-based material is renewable, biodegradable, and biocompatible. Natural fiber has the greatest potential of any reinforcement or filler to increase the stiffness tensile strength and heat resistance of polymer composites. Natural fiber is mostly composed of hemicellulose, cellulose and lignin. The natural fibers chemical composition and cell structure are quite complex. Cellulose is incorporated in a hemicellulose and lignin matrix. Cellulose is still the crystalline component of natural fiber, while hemicellulose and lignin are amorphous components [31]. Cellulose is a crystalline material that comprises about 36- 50% of the dry weight of biomass whereas hemicellulose and lignocellulose are amorphous regions that account for approximately 20-35% and 10-33% of the dry mass of biomass, respectively. Nano cellulose which is made from cellulosic fiber and has a diameter of less than 100 nm has received a lot of interest. This is due to its higher volume to surface area ratio is lighter in weight, has a higher strength and stiffness than cellulose and is more durable [32] .

10.1. Nanocellulose

Numerous mechanical and chemical treatment methods of natural fiber can yield organic material in the form of cellulose microfibrils and cellulose crystallites on the nanoscale. For specific applications, nanocellulose is categorized as microcrystalline cellulose, cellulose nanocrystals, and bacterial nanocellulose [32].

10.2. Cellulose Nanofibers

Wood pulp and wood saw dust is mechanically and chemically treated to produce lignocellulosic fibrils with nanoscale dimensions. Cellulose nanofibers have crystalline as well as amorphous areas. The resultant cellulose nanofibers have a gel-like appearance and, when formed into a film exhibit excellent tensile strength minimal temperature increases high mechanical integrity and a low oxygen transmission rate. As a result of these unique qualities cellulose nanofibers film can be used in electronic devices pharmaceuticals food packaging and printing applications [33]

10.3. Cellulose Nanocrystals

Cellulose nanocrystals are made from natural materials such as cotton, manila, tunicin and bleached wood pulp paper plastic. The isolation method relies on hydrolysis process which eliminates the amorphous phase from the original source while retaining a crystalline phase domain that is unchanged by acid treatment and has a whisker or road-like structure. Sulphuric acid and hydrochloric acid are the most commonly utilized acids for isolating nanocrystals from the parent material [34]. Sulfate half ester groups are introduced on the cellulose chain during sulphuric acid hydrolysis, which increases intermolecular repulsive force, resulting in improved dispersion of cellulose nanocrystals in the polar solvent. Cellulose nanocrystals have outstanding features such as high surface area, great stability, intriguing mechanical properties (high modulus and greater specific strength), and exceptional optical properties. Cellulose nanocrystals have shown promise in medication delivery, barrier films, antimicrobial films, electrical devices, and hybrid composites [35].

11. Production of Nanocellulose

Numerous approaches for extracting nanocellulose from biological and agricultural residuessuch as coconut fiber fiber cotton fibers rice husks and potato peel have beendeveloped. The parent material and various extraction procedures produced various types and qualities of nanocellulose. The main extraction processes for nanocellulose include acid hydrolysis, enzymatic hydrolysis, and mechanical process [36].

11.1. Acid Hydrolysis

Acid hydrolysis itself is a popular and convenient extraction method for obtaining nanocellulose in the form of microcrystalline cellulose from natural fiber. Natural fiber has both organized and disordered regions (hemicellulose, and lignin). Cellulose nanocrystals are created by eliminating the disordered portion of the fiber and disrupting the local crystalline connections between nano fibrils using high concentration acid hydrolysis followed by extremely power hydraulic or ultrasonic treatments [37].The size and crystalline nature of cellulose nanocrystals are mostly determined by the acid hydrolysis condition temperature duration and acidic reagent concentration are among the conditions. Sulphuric acid is the most commonly used acid for hydrolysis process because it produces single, well-defined cellulose nanocrystals and forms charged stable crystallites that are readily isolated from an acidic solution [38]

11.2. Mechanical Process

Ultrasonication, high-pressure homogenization, and ball miling are the most often utilized mechanical processes for obtaining nanocellulose. The hydrodynamic forces of ultrasound are utilized in the ultrasonication process to defibrillate cellulose fibrils. In this process, liquid molecules absorb ultrasonic energy and generate mechanical oscillating power, which causes small gas bubbles to expand, form, and implode [39]. The high-pressure homogenization procedure involves passing cellulose slurry through a vessel at high velocity and extremely pressure to extract nano cellulose through the effect of shear and impact force in the fluid. Because of intarmolecular and intermolecular hydrogen bonding of lignocellulosic biomass was disrupted during high-pressure homogenization process, the resultant nanocellulose exhibits lower crystallinity and thermal stability than the original cellulose [40].

11.3. Enzymatic Hydrolysis

Acid hydrolysis and enzymatic hydrolysis are two of the most often used hydrolysis methods for extracting nanocellulose. Several studies have utilized different quantities of acids such as hydrogen chloride, sulphuric, nitric acid, and hydrobromic acid to eliminate the amorphous phase of cellulose in order to extract nanocellulose [39]. Furthermore, the acid hydrolysis technique seems to have some drawbacks, including the generation of a large amount of chemical waste and a lack of selectivity in their action [41]. Enzymatic hydrolysis, on the other hand, does not require chemical reagents or special solvents and is energy efficient; their optimum working conditions are practicable and cost-effective. When comparable to native wood fibers, the produced nanocellulose had higher thermal and crystallinity properties [39]. The production method and applications of nanocellulose derived biomass is presented in fig 4.

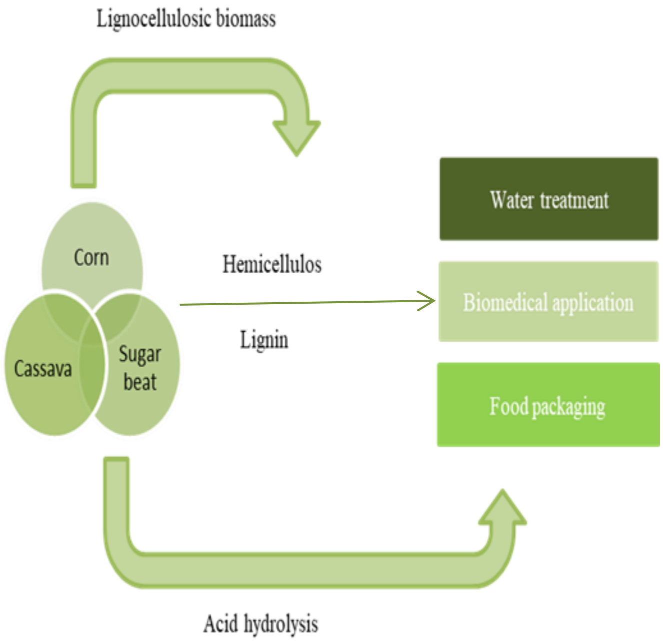

Fig.4. Lignocellulose biomass and their applications

12. Application of Nanocellulose

Nanocellulose has numerous applications in the textile industry due to its light weight, non-toxicity, low thermal expansion, better mechanical qualities, gas impermeability, electrical conductivity, environmentally benign resources, and high resistance. Nano cellulose also has antibacterial properties, which expands its range of applications to include hospital wallpaper, impregnated fabrics, food packaging materials, and water filters [42].

12.1. Water Treatment

Dyes and heavy metal ions in effluents from businesses or natural resources are harmful contaminants in water [43-48]. It has a direct impact on humans or our natural resources, hence pollutant removal is required. Recent advances in nanotechnology have shown that nanoparticles could be used to eliminate many of the hazardous contaminants in water [49-50]. Natural fiber nanocellulose used to have a high surface area solubility in water nano-size and bio-adsorption capability. Heavy metal pollution is a major threat to human health [51-52]. The usage of copper in many sectors has been linked to the water contamination sources particularly groundwater [53-54]. Many procedures have been used in the past to remove heavy metals from water, including chemical coagulation, photocatalytic degradation, ion exchange, physical adsorption and biological treatment with physical adsorption being the most popular due to its ease of use and environmental friendliness [55-59].

Membrane technology has evolved as a preferred treatment and separation method filter extraction and evaporation for recovering water from salty and polluted water streams for human consumption [60]. Because of their low consumption of energy and great selectivity nanocellulose based membranes for water filtration and desalination are a highly environmentally friendly and effective technology [61]. The nanocellulose pores dimensions and surface parameters are critical criteria in determining filter efficiency. Several nanoparticles metals metal oxides and polymeric NPs have already been utilized as disinfectants throughout the last few decades to reduce the toxic disinfection by-products [62].

12.2. Food Packaging

Plastic consumption in the packaging trade is rising in tandem with consumer demand. However, the plastic used in the manufacturing is nonbiodegradable, which has a negative impact on the environment and health impacts. Because of the combustion of plastic increased greenhouse gas emissions and contributed to the growth of landfills To improve consumer food quality, researchers have examined the development of environmentally friendly packaging materials that preserve food while also having a good impact on consumer health [63]. Rather than synthetic non-biodegradable polymers, bio-based materials that are biodegradable, non-toxic, renewable, and abundant in nature may be a superior alternative for packaging material. Cellulose, chitosan, starch, and collagen are the most frequent bio-polymers used in packaging [64]. Cellulose nanofiber-based storage containers have been utilized in a wide range of food categories, including dry goods, drinks, fresh foods, and frozen or liquefied foods.

12.3. Biomedical Application

Because of its unique properties like as low production cost sustainable development biocompatibility availability high specific surface area to volume ratio changed surface chemistry high strength and lack of toxicity nanocellulose has prospective applications in biomedical science [65]. In biomedical applications nanocrystals and nanocellulose fiber made from Plant materials and bacterial cellulose derived from bacteria take a different approach [66]. In plant products, cellulose is found in combination with hemicellulose and lignin. Lignin defends against biological attack in this case, and hemicellulose works as a binder in lignin and cellulose. As a result, mechanical or chemical treatments are required for nanocellulose extraction. Furthermore, the nanocellulose membrane has a high water holding capacity, conformability, and super flexibility, making it an ideal material for wound dressings [67].

13. Conclusions

The fossil fuel depletion and the rise in energy demand have produced a situation of energy security that must be handled with in a sustainable. Because of its renewable nature, biomass must be used for energy production. In this review we described several synthetic processes, characteristics, and applications of biomass carbon dots. The major applications of biomass carbon dots are reviewed, including bio sensing, bioimaging, drug delivery, solar cells, and catalysis. This research is significant to the use of fluorescent biomass carbon dots as a light display material. The uses of BCDs are extremely broad, and we expect that in the future we will be able to research new applications that will benefit human development.

Thermal treatment techniques convert biomass into energy-rich products such as biochar, bio-oil, and syngas. Gasification and pyrolysis have been utilized to create energy-rich goods. For a higher yield of energy-rich products, the impact of thermal treatment temperature, biomass type, vapour residence time, and heating rate must be investigated. Biochar is a good material for use in energy conversion and storage technologies due to its large surface area, high porosity and availability of surface functional groups rich in oxygen high electrical conductivity, and inexpensive cost of manufacturing. This review article emphasizes on the principles, properties, characterisation, and practical applications of nanocellulose.

The use of non-biodegradable and non-renewable materials in a variety of applications has raised concern about pollution. In recent years, cellulose nanoparticles have emerged as a viable alternative to widely utilized nanomaterial due to their low fabrication cost, ease of handling, and outstanding chemical and physical properties. Cellulose developed as the most promising bio-based material for use of water treatment, biodegradable food packaging and biomedical application. Finally, with the advancements in science and technology, nanocellulose-based materials will have a bright future in the nanotechnology. The review will help researchers in the selection, development and use of various kinds of nanocellulose and nanocellulose-based composite materials.

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