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Corn cob pyrolysis for sustainable bio-oil production; a review of pretreatment, conversion, and improvement techniques

Sakina Bello^{a,b}, Adekunle Adeleke^c, Petrus Nzerem^d and Taofik Olatunde Uthman^e

^aDepartment of Industrial Chemistry, Nile University of Nigeria, Abuja, Nigeria; ^bDepartment of Pure and Applied Chemistry, Kaduna State University, Kaduna, Nigeria; ^cDepartment of Mechanical Engineering, Nile University of Nigeria, Abuja, Nigeria; ^dDepartment of Petroleum Engineering, Nile University of Nigeria, Abuja, Nigeria; ^eDepartment of Biochemistry, Nile University of Nigeria, Abuja, Nigeria

ABSTRACT

The growing demand for renewable energy has intensified research into biomass conversion for sustainable fuel production. This review examines corn cob as a promising feedstock for bio-oil production with specific focus on its pretreatment, processing, pyrolysis, prospects, and challenges. Findings revealed that corn cob contains cellulose, hemicellulose, lignin, with a moisture content in the range of 3–11%. The biomass also exhibits relatively high volatile matter, low ash content and a heating value of 16–22 MJ/kg. Bio-oil yields from corn cob pyrolysis range from 35.1% to 60%, depending on conditions. This highlights the challenges associated with feedstock variability, scalability of bio-oil production, and the environmental impacts of pyrolysis process. Addressing these challenges through innovative pretreatment and enhancement methods, process optimization, and stringent quality control measures is essential for achieving consistent and sustainable bio-oil production from corn cob.

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Corn cob; pyrolysis; bio-oil; pretreatment; biomass

Introduction

Heavy reliance on nonrenewable fossil fuels has led to a significant global energy challenge. Fossil fuels, particularly petroleum, have become the backbone of the world's energy supply, increasing from a mere 4% to a 40% share over the past century, with transportation fuels accounting for a staggering 96% [1]. This overreliance comes with substantial costs including environmental consequences, high prices, projected increase in consumption by 2050, and eventual depletion of finite reserves [2]. Global warming, primarily caused by fossil fuel combustion, is a pressing concern [3]. Predictions indicate that a 2 °C increase in global temperature could lead to catastrophic consequences, including loss of lives and species [4]. Greenhouse gases (GHGs), such as carbon dioxide, methane, and nitrous oxide are major contributors to rising global temperatures [5]. Carbon dioxide is a significant pollutant primarily due to its elevated atmospheric levels, which result from substantial human-induced emissions from fossil fuel combustion [6].

Consequently, global research efforts have increasingly focused on biomass utilization as an alternative to fossil fuels for energy generation [7]. The demand for renewable energy is on the rise, with the International Renewable Energy Agency (IREA) projecting that by 2050, all renewable energy sources combined will provide 86% of global primary energy [8]. In 2024, biofuel production is predicted to increase significantly, with the International Energy Agency (IEA) forecasting an expansion of about 38 billion liters from 2023 to 2028, marking a 30% increase from the previous five years [9]. To meet United Nations Sustainable Development Goal 7 of ensuring affordable and clean energy, a transition to renewable energy sources is

imperative [10,11]. This transition has sparked a global quest, marked by extensive research and development in the field of biofuels [7]. The global production of biofuels from renewable sources is widespread, measured in million tonnes of oil equivalent (Mtoe), with Asia leading at 452 Mtoe, followed by Africa with 371 Mtoe, and Europe with 133 Mtoe [2]. The transition to renewable energy sources is underscored by a diverse range, including biomass energy, hydroelectric power, wave energy, tidal energy, solar energy, geothermal energy, and wind energy [8].

Biomass plays a significant role in global energy supply, contributing about 70% of global energy sourced from renewables [12]. It is utilized in various sectors, including heat sources, electricity, and transportation fuels [13]. Among these alternatives, bio-oil, a liquid fuel derived from biomass, stands as a promising candidate [14]. The utilization of biomass for biofuel production not only offers a sustainable energy source but also addresses critical issues of waste management stemming from agricultural and animal byproducts [15]. The potential of bio-oil as a valuable substitute for fossil fuels is driven by renewability, reduced carbon emissions, and versatility which positions it at the forefront of sustainable energy solutions [16]. Biomass can be obtained from energy crops, forestry residues, algae, and food wastes [17]. Agricultural waste-derived biomass holds great potential as feedstock for generating substantial heat energy [18]. Compared to other fuels, it offers an energy value competitive with coal and diesel, making it a valuable resource [19]. Some of the widely used biomass for biofuel production are sugarcane and corn [20].

Corn cob, as both a widely available biomass and a byproduct of corn cultivation, presents a valuable opportunity for sustainable energy production [21]. Bio-oil from

corn cob has great potential to replace fossil fuels [10,22]. Despite the high potential of corn cob, detailed reviews are scarce on their utilization for bio-oil production. Therefore, this review discusses production of bio-oil from corn cob using pyrolysis and explores ways to enhance its quality and quantity.

Corn cob

Corn, one of the most abundant biomasses, is extensively cultivated worldwide [23]. Approximately 1.2 billion tonnes of corn are produced globally each year [24], including 11 million tonnes in Nigeria [25]. Every part of the corn plant, as illustrated in Figure 1, is useful for different purposes, including biofuel production [20,21]. Corn stover (leaves, stalks, and cobs left in a field after harvest) is one of the most abundant agricultural residues [26].

Corn cob is a substantial by-product of corn constituting 75–85% of the total weight of corn ears after grain removal [27]. Like other lignocellulose materials, the cell wall of corn cob mainly comprise lignin, hemicellulose, and cellulose, with hemicellulose being the predominant component [28]. Figure 2 illustrates the lignocellulose structure of corn cob and its composition varies with corn species [29]. Corn cob can be divided into three distinct tissue fractions: the central woody ring, the outer rigid and lightweight chaff, and the inner spongy and soft pith, accounting for approximately 77.5%, 21.1%, and 1.4%, respectively [30].

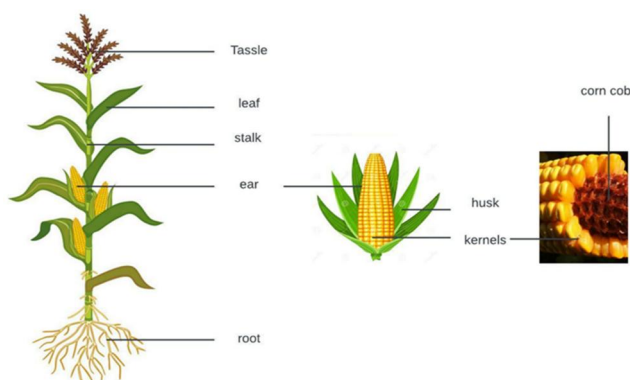


Figure 1. Parts of a corn plant.

These tissue fractions possess unique characteristics as depicted in Figure 3 and outlined in Table 1.

Corn cobs find diverse applications in agriculture, industries, and culinary world. Okoronkwo et al. [32] used corn cobs for silica extraction through sol-gel methods. Capetti et al. [33] demonstrated their use in the eco-friendly synthesis of xylooligosaccharides. Dhaneswara et al. [34] transformed corn cobs and rice husks into spherical mesoporous material SBA-16. Shao et al. [35] explored the potential of treated corn cobs, particularly corn cob aggregates, in crafting lightweight cement mortars. Beyond industrial applications, corn cobs have also found their way into the culinary realm. Lau et al. [36] incorporated sweet corn cobs into bakery processes, enhancing gluten-free muffins. Furthermore, corn cobs have gained significant attention for their potential in bio-oil and bio-char production [37, 38].

Processing of corn cob

Corn cobs are processed using various methods depending on intended purpose and available resource. Dawodu et al. [39] employed a rigorous process of drying fresh corn cobs at 105 °C and then pulverizing them to achieve desired particle sizes as feedstocks for better handling by different reactors. Castiblanco et al. [10] focused on a more uniform granularity by crushing dried corn cobs to a specific 125 μm size, which may be advantageous for applications requiring consistent particle size for better pyrolysis. In Contrast, Dai et al. [40,41] targeted a finer 60-mesh size for their corn cobs and included an extended 12-h drying process at 105 °C, suggesting a focus on achieving a finer, more

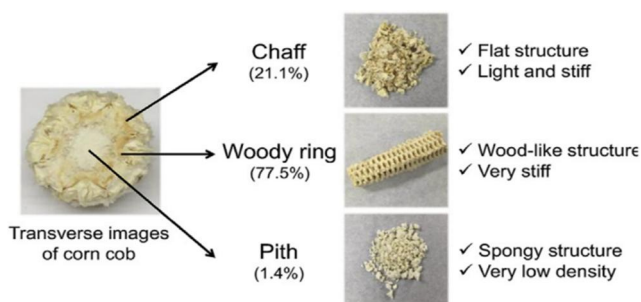


Figure 3. Tissue fractions of corn cob [30].

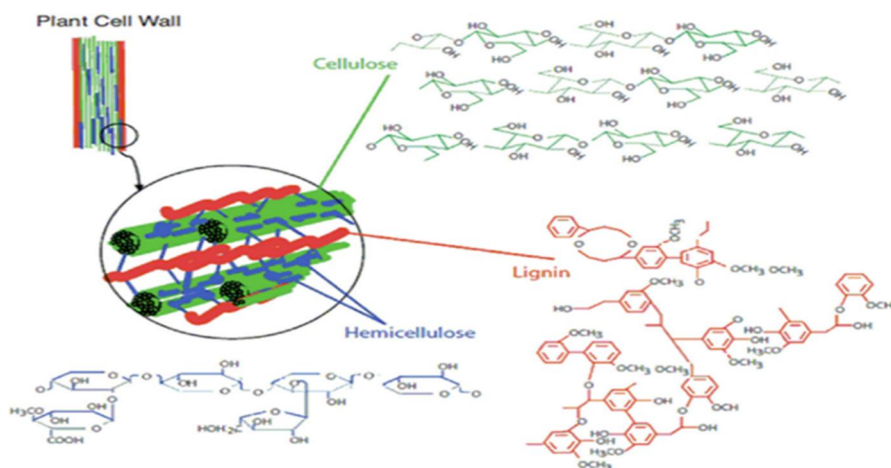


Figure 2. Chemical structure of lignocellulose biomass in corn cob [31].

Table 1. Chemical composition of corncob tissue fractions [30].

Tissue fraction	Tissue fraction(%)	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Protein (%)	Extractives (%)	Starch (%)	Ash (%)	Total (%)
Chaff	21.1	36.3	41.4	18.8	2.3	0.5	0.3	3.1	102.7
Woody ring	77.5	31.6	46.9	15.7	2.1	1.0	0.3	1.4	99.0
Pith	1.4	34.8	39.9	17.3	2.4	3.5	2.1	2.4	102.4

**Figure 4.** Processing of corncob.

homogeneous powder suitable for detailed chemical processes.

In other studies, Anukam et al. [42] adapted their methodology to the regional climate of Alice, South Africa, using air-drying at 30 °C, which might be less energy-intensive but could affect the uniformity of moisture removal compared to controlled oven drying. Wu et al. [43] also applied drying for 24 h at 105 °C, followed by crushing and sieving to a particle size below 120 µm. This method highlights the importance of drying for moisture removal, potentially improving the quality of the bio-oil produced. Singh et al. [44] adopted sun-drying for a week, which is cost-effective and environmentally friendly, but may introduce variability in moisture content due to environmental factors. The subsequent grinding and sieving to a precise 355 µm size indicated a focus on achieving a specific application requirement. Overall, these methods highlighted the importance of moisture control and particle size reduction in preparing corncobs for research. The systematic approach to processing corncob (Figure 4) underscores a common goal of achieving optimal material quality for research purposes.

Pretreatment of corncob for bio-oil production

Pretreatment is crucial for enhancing bio-oil quality from biomass by modifying physical and chemical properties. For example, pretreatment can reduce oxygen content from approximately 40–50% to 10–20%, enhancing stability. Viscosity typically decreases from around 0.05–0.1 Pa·s to 0.01–0.03 Pa·s, and density can be reduced from 1100 kg/m³ to around 900–1000 kg/m³. This process also improves the heating value, increasing it from 16 to 20 MJ/kg to 25 to 30 MJ/kg. Furthermore, pretreatment can boost bio-oil yield by 10–20% and decrease energy consumption by 15–30% [45]. Various techniques have been employed for corncob pretreatment with each method contributing uniquely toward enhancing the quality of corncobs for bio-oil production (Table 2). These methods include

mechanical, biological, hydrothermal, torrefaction and chemical pretreatment.

Mechanical pretreatment

Mechanical pretreatment, including milling and grinding, reduced particle size by 40%, which increased surface area, facilitating enzymatic hydrolysis and improving bio-oil yield by 25% [46]. It serves as a fundamental initial step which reduces biomass size and increases accessible surface area. Pretreatment enhances the physical properties of biomass like corncob by increasing its density from around 0.3–0.4 g/cm³ to 0.6–0.8 g/cm³ and reducing porosity from 60–70% to 20–30%, thus improving storage stability [47]. Mechanical pretreatment also reduces particle size from several millimeters to below 0.5 mm, which aids enzymatic hydrolysis, increasing conversion efficiency by up to 30–40% and leading to higher biofuel yields [47].

Biological pretreatment

Biological pretreatment employs microorganisms, such as fungi and bacteria, to enhance the accessibility of lignocellulosic biomass. This approach is both environmentally friendly and cost-effective compared to other methods. The process typically involves degradation of lignin and hemicellulose in corncobs making them more amenable to enzymatic action [48]. Fungi, particularly white-rot fungi, are highly effective in degrading lignin due to their enzymatic capabilities, leading to improved cellulose accessibility and higher bio-oil yields [49]. For example, Thangavelu et al. [50] investigated delignification of corncob using a combined approach of hydrodynamic cavitation and enzymatic pretreatment. Their study achieved a 47.4% reduction in lignin with an energy consumption of 1.35 MJ kg⁻¹. In another study, Ganesan et al. [51] combined hydrodynamic cavitation with enzymatic pretreatment using laccase from *Hexagonia hirta* (LcCH). This method effectively

Table 2. Summarized information on different types of pyrolysis.

Type of pyrolysis	Temperature range (°C)	Residence time	Heating rate (°C/min)	Advantage	Disadvantage
Slow	300–600	5 min–few hours	5–10	Good quality biochar Moderate oil and gas yield	Long reaction
Intermediate	400–500	2–5 min	1–70	Higher feedstock flexibility, produce to phase liquids	Requires several control mechanisms to maintain the operating parameters
Fast	400–700	2 min	–200	Short time High oil yield Moderate gas yield Low char yield	Expensive set up for heat insulation and rapid cooling of vapor, complex system, feedstock requires pretreatment
Flash	500–850	2s	1000–3000	Short time High oil yield Moderate gas yield	Expensive setup for heat insulation and rapid cooling of vapor, complex system, feedstock requires proper pretreatment

Source: Mong et al. [73].

delignified corncob, achieving 54.1% lignin removal and 42.25% increase in the cellulose fraction, thereby enhancing the suitability of biomass for bio-oil production.

Hydrothermal pretreatment

Hydrothermal pretreatment involves exposing biomass to high-pressure, high-temperature water, which disrupts biomass structure and enhances accessibility of hemicellulose and cellulose [52]. The method is effective in improving the production of hydrogen, methane, and bio-oil [53]. Hydrothermal pretreatment has been applied to produce xylose and furfural from corncob using a solid acid catalyst ($\text{TiO}_2\text{-ZrO}_2/\text{La}^{3+}$). The process efficiently removed hemicellulose and improved furfural production from corncob [54,55]. The studies demonstrated that hydrothermal pretreatment significantly enhanced the conversion of corncob into valuable platform chemicals. In another study, a novel catalyst ($\text{Fe}_2(\text{SO}_4)_3\text{-NaCl}$) was used in hydrothermal pretreatment of corncob to selectively convert hemicellulose to xylose [56,57]. $\text{Fe}_2(\text{SO}_4)_3$ was crucial for disrupting the interactions among hemicellulose, cellulose, and lignin, while NaCl inhibited cellulose conversion and $\text{Fe}_2(\text{SO}_4)_3$ limited lignin conversion. The compound facilitated dissolution of hemicellulose, leaving cellulose and lignin largely intact. Secondary hydrothermal treatment of the hemicellulose-free residue achieved a cellulose conversion of 42.2 wt% and a fructose yield of 79.7 wt% based on converted cellulose, presenting a viable approach for the comprehensive utilization of corncobs [56,57].

Torrefaction

Torrefaction as a pretreatment technique involves heating biomass in an inert, oxygen-free environment, typically using nitrogen, at temperatures between 200 °C and 300 °C. The duration of the process can range from a few seconds to several hours. This treatment effectively reduces the hydrogen-to-carbon (H/C) and oxygen-to-carbon (O/C) ratios of the biomass, decreases moisture content, and enhances properties such as energy density, hydrophobicity, reactivity, and grindability [58]. A lower H/C ratio indicates a more carbon-rich, energy-dense fuel, similar to high-grade fossil fuels, enhancing combustion efficiency. Pretreatment of corncob using torrefaction has been

studied by several researchers [59,60], with findings showing a significant reduction in water content and viscosity, improved grindability, and increased bio-oil yield. The optimal temperature was identified as 260 °C, which also enhanced the H/C ratio by 15%, improved mass yield to 75%, and energy yield to 90% [61,62]. Overall, these studies confirm that torrefaction is an effective method for enhancing the energy potential and yield of corncob, making it a valuable process for improving biomass quality.

Chemical pretreatment

Chemical pretreatment using alkalis is widely recognized as one of the most effective methods of processing corncob [21]. Alkali hydrolysis of corncob with NaOH achieved 82.03% lignin removal and increasing cellulose porosity [63,64]. In contrast, acid hydrolysis using H_2SO_4 , HCl, or oxalic acid primarily solubilizes hemicellulose with minimal lignin removal [65]. Zhou et al. [66] evaluated deep eutectic solvent (DES) pretreatment at various temperatures and durations to enhance hydrogen yield from corncob *via* photo-fermentation. The pretreatment effectively dissolved lignin while retaining cellulose, leading to improved enzymatic hydrolysis and hydrogen production. In another study, Sunkar & Bhukya [67] utilized NaOH to improve delignification of corncobs. The method resulted in approximately 83% delignification which significantly enhanced cellulose and hemicellulose accessibility. Compared to other chemicals such as KOH, NaClO_2 , Na_2SO_3 , and $\text{Na}_2\text{S}_2\text{O}_4$, NaOH proved to be the most effective pretreatment chemical for corncob biomass.

Pyrolysis of corncob

Following pretreatment, different methods have been explored for obtaining bio-products from corncob, each offering unique insights into its conversion potential [21]. Currently, pyrolysis remains the prevailing method due to its cost-effectiveness, high product yield, and ability to operate under atmospheric pressure [11,68,69]. Pyrolysis is a thermochemical conversion method that entails thermal decomposition of carbonaceous materials in an inert atmosphere within a reactor at 300 to 700 °C [70]. It involves depolymerization of organic matter in the absence of oxygen.

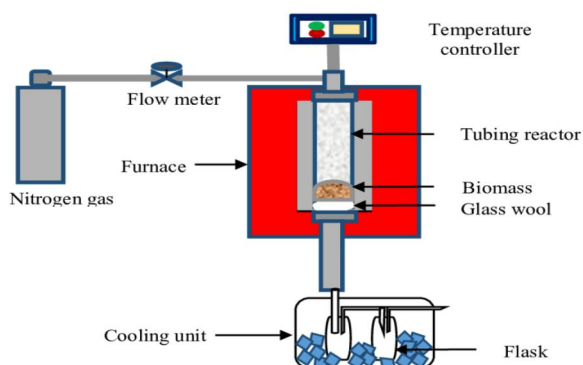


Figure 5. A lab scale fixed-bed reactor [75].

Pyrolysis is broadly categorized into three types based on heating methods and temperature profiles as slow pyrolysis, intermediate pyrolysis, and fast pyrolysis [71,72]. Each method has unique benefits and limitations characterized by distinct operational parameters and product profiles [73]. There is also flash pyrolysis which is variant of fast pyrolysis that uses shorter time and extremely high temperatures. Table 2 presents a summary of the major characteristics of these pyrolysis methods including their temperature ranges, residence times, heating rates, advantages, and disadvantages.

Pyrolysis reactors

Different types of pyrolysis reactors exist including fixed-bed, fluidized-bed, and microwave-assisted reactors and they play a crucial role in determining the efficiency and product yield. Fixed-bed reactors are known for their simplicity and cost-effectiveness (Figure 5) but may face limitations in handling large feedstocks or achieving uniform heating [73]. Fluidized-bed reactors are more complex and expensive but offer better temperature control and heat transfer which enhance overall efficiency of fast pyrolysis [74]. Microwave-assisted reactors provide rapid heating, which reduces processing times and improve yields [22]. The selection of a particular reactor is influenced by factors such as type of feedstock, desired pyrolysis distribution of products, and considerations of process scalability and accessibility [73].

Products of corncob pyrolysis and their applications

The pyrolysis of corncobs produces three primary products namely biochar, bio-oil, and biogas, each with distinct properties and applications (Figure 6).

Biochar

Biochar, often referred to simply as char, is a stable form of carbon that can be used as a low-grade fuel or as an additive to enhance soil fertility [76]. The yield of biochar from corncob pyrolysis varies with the pyrolysis conditions but is generally consistent, with slower pyrolysis methods producing higher quantities of biochar compared to faster methods [38]. The application of biochar in soil can improve soil structure, increase nutrient retention, and reduce soil

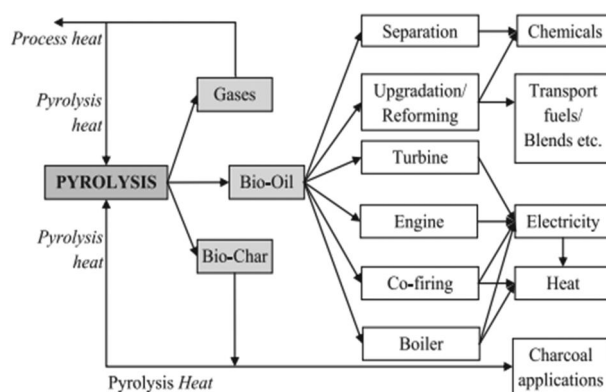


Figure 6. Applications of pyrolysis products [68].

acidity, making it valuable for agricultural and environmental management [21].

Bio-oil

Bio-oil is another major product of corncob pyrolysis, and it is highly sought after due to its potential as a renewable energy source [69]. It is a dark brown liquid composed of a complex mixture of organic compounds, including ketones and acids [77]. Typically, bio-oil constitutes about 30–75% of the total yield from corncob pyrolysis. However, this percentage varies based on factors such as reactor type, residence time, and heating rate [21]. The yield of bio-oil from corncobs ranges from 35.1% to 60%, depending on specific pyrolysis conditions employed. Beyond the use of bio-oils as a potential transportation fuel, it has applications in chemical processes, heat generation, and electricity production. The process of bio-oil production from corncobs encompasses different stages including feedstock acquisition, purification, feedstock characterization, pretreatment for enhanced characteristics, and subsequent pyrolysis process (Figure 7). The technique generates significant quantities of bio-oil and gaseous byproducts while minimizing the production of solid biochar [78].

Biogas (pygas)

Biogas (or pygas) comprises non-condensable gases such as CO, CO₂, CH₄, and various non-methane hydrocarbons [45]. These gases are produced during pyrolysis and contribute significantly to the overall energy profile of the process [79]. The composition and yield of biogas are influenced by pyrolysis conditions and reactor type. Biogas from corncob pyrolysis can be harnessed for energy production, further enhancing the efficiency and sustainability of the pyrolysis process.

Enhancement of bio-oil produced from corncob

The enhancement of bio-oil aims to address issues such as high moisture content, elevated ash content, and low heating value [80]. High moisture content adversely affects the quality of bio-oil, leading to lower energy density and diminished bio-oil yield [45,81]. Similarly, Elevated ash content in bio-oil is undesirable as it lowers the heating value, increases corrosion and fouling, and complicates processing [73].

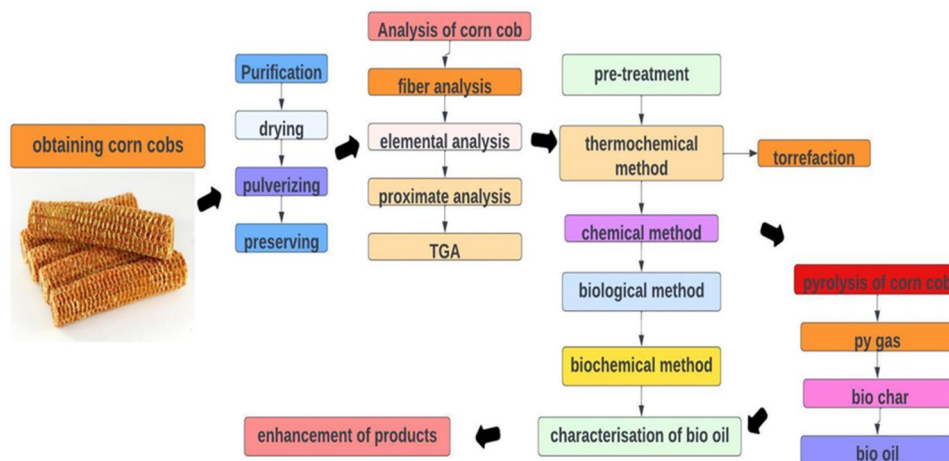


Figure 7. Pyrolysis of corncob for bio-oil production.

Table 3. Co-pyrolysis of corncob with other feedstocks.

Co-pyrolysis feedstock	Blend ratio	Temperature °C	Optimal yield of co-pyrolysis bio-oil (%)	Effect of co-pyrolysis	References
Polyethylene (PE)	1:3 (CC: PE)	550	52.1	The synergistic effect which reduced mass loss.	[44]
Waste cooking oil (WCO)	0.87:0.13 (WTO: CC)	550	70.62	Increased the bio-oil yield with improved properties.	[84]
Coal gangue	1:4 (CG: CC)	400	41.7	Increased aromatic compounds that enhanced oil properties.	[86]
Lignite	50:50	600	–	Increased yields of liquid, and gas products and reduced bio-char.	[85]
Cattle manure	1:1	360	22	Removal of oxygen and nitrogen that improved oil quality.	[52]

Note: CC: corncob; PE: polyethylene; CG: coal gauge.

Apart from pretreatment, researchers have explored other methods to enhance both the quality and quantity of bio-oil including co-pyrolysis [82], catalytic cracking [82], and urea infusion [43]. These methods, implemented at different stages, play crucial roles in mitigating the challenges posed by high moisture content, low heating value, and high ash content, ultimately improving its suitability for various applications in renewable energy and chemical synthesis.

Co-pyrolysis

Co-pyrolysis involves the pyrolysis of corncob with another feedstock to enhance the properties of bio-oil. This process aims to increase the carbon and hydrogen content in the corncob feedstock, which improves the volatile matter and heating value of both the feedstock and bio-oil produced [83]. Studies further indicate that co-pyrolysis reduces moisture content and improves the quality of bio-oil [21,82]. For instance, co-pyrolysis of corncob with polyethylene (PE) results in a synergetic effect that reduces mass loss and enhances bio-oil yield [44]. Similarly, co-pyrolysis with waste cooking oil (WCO) positively affected bio-oil yield achieving an optimal yield of 70.62% and properties, including higher heating value (MJ/kg), reduced viscosity, lower oxygen content (%), and increased carbon content (%), thereby improving the overall fuel quality [56,84]. Other feedstocks, such as coal gangue and lignite, also

improved bio-oil characteristics by increasing aromatic compounds and reducing biochar yield (Table 3).

Catalytic enhancement

Catalytic cracking, employing catalysts to break down heavy oil molecules into lighter and more valuable fractions is a useful technique in bio-oil refinement [40,41,87]. Zeolite-based catalysts, particularly hydrogen zeolite socony mobil (HZSM-5) are an effective tool for cracking bio-oil. Chaihad et al. [88] critically reviewed the utilization of HZSM-5, highlighting its efficiency in enhancing bio-oil. However, they emphasized the need for further studies to optimize the process efficiently. Qiu et al. [89] successfully demonstrated the application of solid industrial wastes as catalysts for bio-oil cracking during biomass pyrolysis. This method not only contributed to bio-oil enhancement but also addressed the utilization of industrial waste. Specific catalytic cracking methods employed for bio-oil production from corncob are detailed in Table 4.

Urea infusion

Urea infusion is a newer enhancement technique for pyrolysis which is particularly applicable to corncob. At high temperatures, urea reacts with feedstocks to release ammonia, which improves biofuel quality, combustion characteristics, and emissions [92]. It has been reported that urea

Table 4. Catalyst enhancement of bio-oil production from corncob.

Catalyst	Findings	References
CaCO ₃ , CaO	The addition of calcium compounds improved the structure of the solid and the behavior of the reaction order.	[10]
Zeolite- HZSM-5 and activated carbon (AC)	The synergistic effect between HZSM-5 and AC enhances the optimal conditions.	[37]
3,7-Dimethyloct-1-ene and butanol	Improved fuel properties such as acid content, viscosity, and moisture content.	[39]
Alumina	Reduction in reaction temperature and improved oil yield.	[90]
Zeolite HZSM-5	Improved bio-oil yield at lower temperatures.	[91]
HY zeolite	A slight reduction in bio-oil yield but improved heating value.	[84]
Activated carbon (AC) and HZSM-5	Improved bio-oil which is suitable for jet fuel.	[37]
HZSM-5, modified medical stone (MS)	Increased oil yield and improved oil properties.	[86]

increased the yield of nitrogen-containing compounds, which positively influenced bio-oil yield from 36.5% at 450 °C to 46.1% at 550 °C [80]. Wu et al. [43] further demonstrated that urea application improved bio-oil quality and yield up to 52%. Urea application in biomass pyrolysis demonstrates a significant potential for improving bio-oil production, marking a notable trend in current research which can be further explored.

Challenges of bio-oil production from corncob

While corncob pyrolysis offers significant potential for bio-oil production, several challenges must be addressed to improve the efficiency and quality of the resulting bio-oil [93]. One of the primary issues is the high ash content of corncobs, which can negatively impact the pyrolysis process [94]. Elevated ash content in biomass can significantly contribute to slagging during combustion processes, where molten ash particles adhere to furnace surfaces, impairing thermal efficiency and operational stability. Moreover, the presence of inorganic minerals within the ash catalyzes undesirable reactions during pyrolysis, leading to the production of bio-oil with inferior quality. This bio-oil is often characterized by increased acidity, reduced energy content, and a higher concentration of impurities, ultimately compromising its suitability as a high-performance fuel [95,96].

Another challenge is the relatively low heating value of the bio-oil produced from corncobs. Despite the high cellulose and hemicellulose content, bio-oil often exhibits a lower energy density compared to conventional fossil fuels [97]. This is partly due to the high oxygen content in bio-oil. Oxygenated compounds in bio-oil, such as acids, alcohols, and aldehydes, do not contribute to the calorific value as effectively as hydrocarbons. Additionally, the high oxygen content can lead to rapid combustion and formation of undesirable by-products, which hinders direct use of bio-oil as transportation fuels [98]. Catalytic processes and co-pyrolysis with low-oxygen feedstocks are some of the strategies employed to lower oxygen content and enhance the heating value of bio-oil [99].

The presence of high moisture content in corncobs also poses a significant challenge. Moisture in feedstock dilutes bio-oil thereby reducing its overall yield and quality [96]. Effective pretreatment methods, such as drying or torrefaction, are required to mitigate this challenge. However, these processes increase the overall cost and complexity of bio-oil production [100]. Additionally, managing the residual solid char from pyrolysis which accumulates due to the relatively high cellulose content, is crucial for optimizing the overall yield and efficiency of the process [96].

Finally, variability in the composition of corncobs, influenced by factors such as growing conditions and harvest time, often leads to inconsistent bio-oil quality [101]. Standardizing feedstock preparation and ensuring uniformity in biomass composition is essential for achieving reliable and high-quality bio-oil outputs. Addressing these challenges through advanced pyrolysis technologies, improved pretreatment methods, and better feedstock management is critical for realizing the full potential of corncobs as a sustainable bio-oil source. Moreover, the environmental footprint of bio-oil production must be carefully evaluated. Addressing issues such as greenhouse gas emissions, water usage, and waste management is vital for minimizing environmental impact and maximizing the benefits of renewable biomass feedstocks.

Conclusion

The pyrolysis of corncob emerges as a highly promising and sustainable approach for bio-oil production based on the abundant agricultural byproducts that are often underutilized. Corncob has been identified as a suitable feedstock for pyrolysis. However, several challenges must be addressed to optimize the commercial viability of corncob pyrolysis. Environmental considerations also play a vital role in the sustainability of bio-oil produced from corncobs. It is imperative to evaluate the entire lifecycle of bio-oil production, addressing issues such as greenhouse gas emissions, water usage, and waste management. Implementing stringent quality control measures and adopting sustainable practices are also crucial for minimizing the ecological footprint of this renewable energy source. Looking ahead, future research should focus on optimizing pyrolysis conditions, exploring co-pyrolysis strategies with other biomass feedstocks, and investigating the integration of advanced technologies to improve bio-oil yield and quality. Additionally, the development of innovative pretreatment methods can enhance the accessibility of cellulose and hemicellulose, further increasing bio-oil production efficiency.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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