Review: Biochar From Co-Pyrolysis of Biomass and Plastic

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ABSTRACT

Plastic and biomass waste disposal will increase if it is not accompanied by appropriate, efficient, and effective waste treatment. Recent research on the yield of charcoal produced by co-pyrolysis has shown that the product of co-pyrolysis of plastic and biomass raw materials is a beneficial additive with a variety of applications, ranging from soil and water improvement, increasing agricultural yields, fuel cells, supercapacitors, as a support/ catalysts, sustainable chemistry, and carbon sequestration. Therefore researchers need to ensure the quality of the results of co-pyrolysis in the form of biochar obtained from any raw material and process to provide maximum benefits, mainly from biomass and plastic raw materials. This study aims to review the formation of biochar from the co-pyrolysis of plastic and biomass raw materials by examining the raw materials, pyrolysis techniques, and the type of reactor used to identify the appropriate parameters. This review discusses biochar production techniques, pyrolysis technology mechanisms, types of pyrolysis, the type of reactor used, the properties of both biomass and plastic raw materials and the properties of biochar produced from various raw materials for comparison. Biochar will be obtained with maximum yield quality from the results of mixing the raw materials for biomass and plastic and optimal operating conditions. It can be an alternative in the bio-oil and syngas energy sector and reduce carbon emissions.

1. Introduction

The increasing demand for energy amid the depletion of fossil fuel reserves and concerns about greenhouse gas emissions has been marked by the pace of climate change. The use of renewable and efficient waste resources in producing electricity can be an alternative to reduce harmful emissions from fossil fuels [1]. A potential solution to this problem is converting biomass and organic and inorganic waste into fuel to increase the economy and add value to society. The most cost-effective and scalable simple technology can be obtained from pyrolysis, which can convert biomass and other raw materials into energy and other usable products [2]. Pyrolysis is the thermal decomposition of organic matter without oxygen entering it. Currently, many researchers are starting to focus on the results of pyrolysis in the form of biochar for processing and improving soil, leaching of heavy metals from the soil, and reducing carbon emissions [3].

The potential of biochar has increased because it can provide many applications, such as agricultural fertilizers, adsorbents, supercapacitors, fuel cells, charcoal in steel and power, and catalysts in various processes [4]. According to Mahdi et al. [5], biochar can increase agricultural yields by improving soil fertility, nutrient retention, water retention, cation exchange, microbial activity, and pH. While mixing biochar in the soil, the effect on soil quality and the impact on crop yields has been reviewed by Lehmann et al. 2011 [6], that the type and composition of raw materials and pyrolysis temperature can significantly affect carbon absorption [7]. So according to [8] Hassan M. et al., 2020 the possibility of applying biochar to the soil can provide potential benefits such as reducing CO_2 emissions from soil and global warming. according to S. Jamilatun (2022), biochar produced in pyrolysis with a temperature of 300-600°C was analyzed for surface area, total pore volume and average pore size [9]. In Brazil 2016, the application of biochar in sugarcane fields can cause carbon sequestration of 31% of all carbon produced [10]. Water and soil retention can increase up to 46% and 37% biochar utilization [11]. Several studies have been conducted on pyrolysis and co-pyrolysis regarding the production of energy, bio-oil, and syngas from biomass, plastics [12], and other raw materials that can improve the output quality of bio-oil [13]. Plastic that is not utilized properly and its management system that is less than optimal will cause problems for the environment [14]. Moreover, if the production of plastic waste in 1950 reached 1.5 million tons, in 2017 plastic waste was produced as much as 348 million tons, [15], [16] then in 2050 it is estimated that plastic waste will be produced as much as 12 billion metric tons [17]. Various plastic wastes, such as LDPE, HDPE, ABS, PC, PS, PTFE, etc., which in many cases have a good synergistic effect in pyrolysis processing [18].

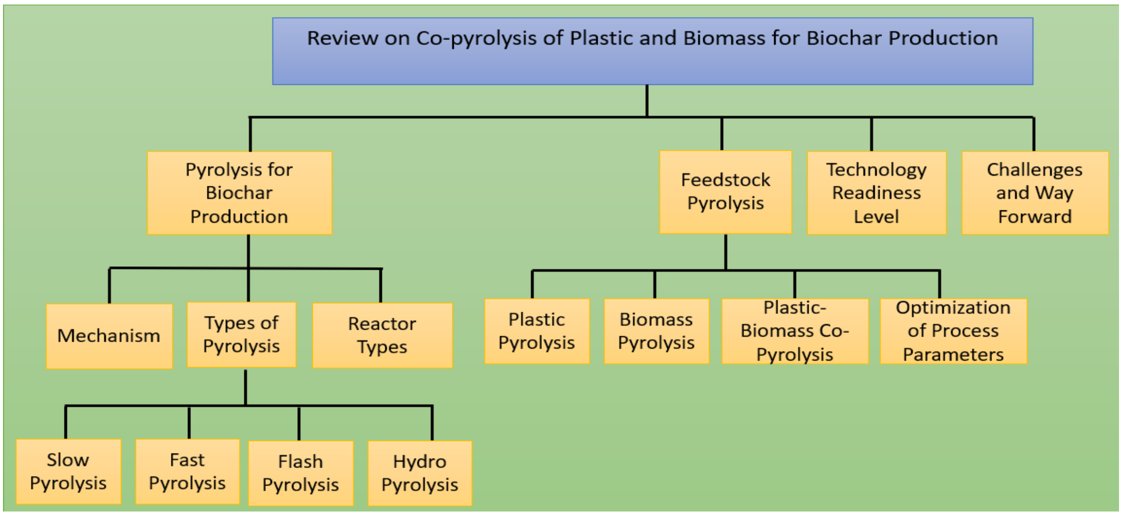

Fig.1. Review article structure

Biochar production is a target to get optimal results. Various biochar production processes and their effects on biochar yields have been reviewed by many researchers [19]. Various types of processes used to produce biochar, various raw materials, and yield attributes have been studied by Panwar et al. [20]. While the application of pyrolysis techniques for the co-production of biochar and bio-oil and the effect of temperature and raw materials on biochar yields was studied by Tomczyk et al. [21], and production of biochar for its proper implementation in direct carbon fuel cells was studied by Jafri N. et al. [22]. Pyrolysis at temperatures less than 400°C produces more biochar, while pyrolysis at high temperatures produces less biochar [23], [24]. Biochar will face the challenge of ensuring the quality and efficacy of biochar produced from various raw materials combined to obtain maximum benefits from biochar production for the environment, agriculture and the economy. Pyrolysis can convert waste into energy and by-products used as biochar. Factors such as temperature, pressure, heating rate, residence time, particle size, catalyst, carrier gas flow rate, raw material composition, moisture content, and reactor configuration can affect the quantity and product yield [25]. Biochar is a technology whose economic cost and scalability can be estimated [26]. However, for the complete separation of plastic and biomass waste which is a process that is expensive, time-consuming, laborious and of equal technical difficulty, co-pyrolysis of plastics and biomass can be an alternative with high yield quality [27].

From the discussion above, biochar production can improve the quality of agriculture, the environment, and the economy. Research from various researchers can ensure the quality of biochar produced from a combination of raw materials and different types of processes. Production of quality biochar can be used for soil improvement, water treatment, carbon sequestration, and emission reduction. This study aims to analyze biochar production from the co-pyrolysis of biomass and plastics with maximum yield and technological feasibility. This study aimed to study the pyrolysis technique and the type of reactor to produce optimum co-pyrolysis biochar from biomass and plastic. Figure 1 illustrates the review structure concerning the research objectives.

2. Biochar Production Techniques and Pyrolysis

Biochar can be obtained by burning, torrefaction, gasification, and pyrolysis and will produce charcoal with different levels of carbon. These processes can be distinguished by temperature ranges, heating rates, residence times for raw materials and steam, charcoal yields, carbon content, and carbon yields, as shown in Table 1 [28].

Table 1. Biochar Production Process

Process type	Process temperature (°C)	Residence time	Char yield (%feedstock by weight)(A)	Carbon content (% mass of the char) (B)	Carbon yield (A(/(B)
Torrefaction	~290	10–60 min	61%–84%	51%–55%	0.67 to 0.85
Slow pyrolysis	~400	Minutes to days	~30%	95%	~0.58
Flash Carbonisation	~300 – 600	Less than 30 min	37%	~85%	~0.65
Gasification	~800	~10–20 sec	~10%	-	-
Fast pyrolysis	~500 – 1000	~1 sec	12%–26%	74%	0.2 to 0.26

One method used in the early days of this process was burning with woody biomass. However, the yields obtained were very low, and pollution levels were intense, so this process began to be abandoned. Combustion can produce heat, while gasification produces gas in the presence of oxygen and decomposes organic matter thermally. Both are exothermic processes [29]. To meet energy needs as well as reduce emissions and manage waste, several studies have shown pyrolysis to be an effective methodology [30].

2.1. Pyrolysis Mechanism

The definition of pyrolysis is a complex multi-step process in which organic matter is thermally disintegrated under a controlled application of heat over a wide range of temperatures providing the energy required to decompose the chemical structure of the raw material [31]. Various proportions of oil, charcoal, and gas are products of the pyrolysis process, which can mainly emit carbon, hydrogen, and methane [32]. Pyrolysis consists of two mechanisms, namely, the primary mechanism and the secondary mechanism. The process in which the chemical bonds of the raw materials are broken, and the volatile compounds are released in the reactor under heat, which undergoes further reactions as part of the secondary mechanism, is called the primary mechanism. Decomposition results in depolymerization to break down organic materials into monomers; these organic materials consist of long polymer chains then release water, non-condensable gases, condensable vapors (oil and tar), and other volatile compounds in the primary mechanism. Then it is released at a higher rate during the initial phase of pyrolysis, which is around 250 – 300°C [29]. Small-chain organic compounds and gases which cannot be condensed due to the association of covalent bonds in the monomer are the final stages of the primary mechanism [33]. Unstable compounds either crack or recombine to be restructured, called secondary mechanisms. These compounds decompose to form low molecular weight molecules during cracking, whereas volatile compounds combine to form inert or high molecular weight volatile compounds during recombination.

In some cases, the secondary mechanism also forms charcoal [34]. Pyrolysis at a high heating rate and a temperature greater than 800°C will produce more gas and ash. The rate will produce a higher amount of biochar at a temperature of 450 °C and slow heating. Thus, the yield and composition of the byproducts depend on the raw material, moisture content, reactor type, temperature, heating rate, residence time, pressure, catalyst, and fluidizing gas type and flow rate [29].

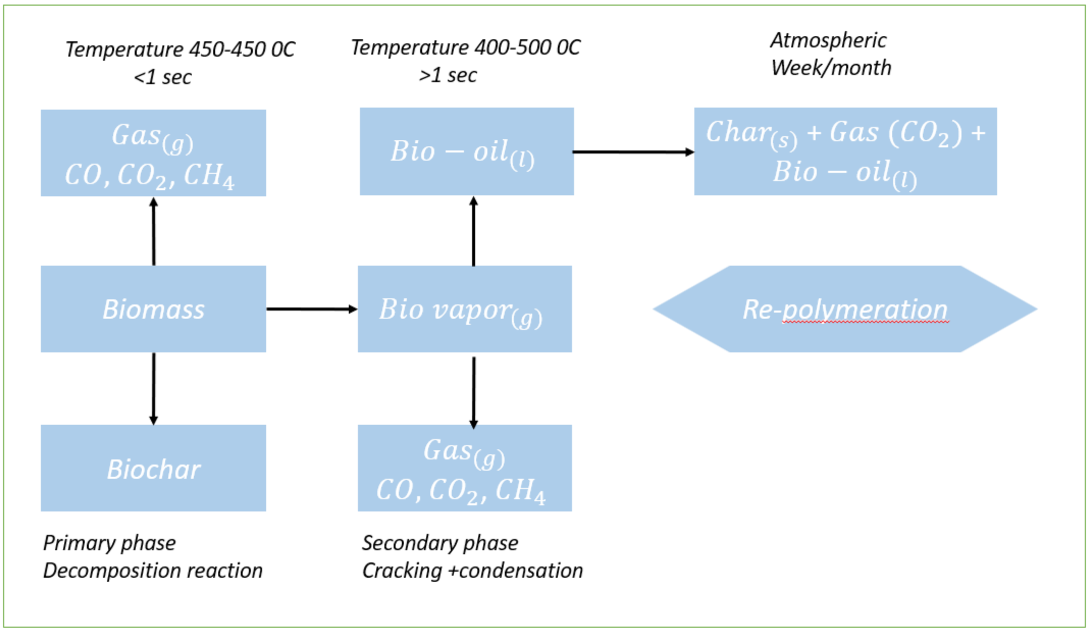

Fig.2. Primary and secondary mechanisms of the pyrolysis process

2.2. Reactor Type

During pyrolysis, the type of reactor is essential to determine the result of converting organic matter into energy (gas, liquid, solid fuel). So the reactor was designed considering pressure specifications, heating temperature, steam residence time, and others [35]. From Aisha et al., (2022) [27] the separation of the types of reactors according to the movement of raw materials and the mechanism of heat transfer is shown in Figure 3. Meanwhile, Table 2 summarizes the various types of reactors used in pyrolysis, their working tools, advantages and challenges.

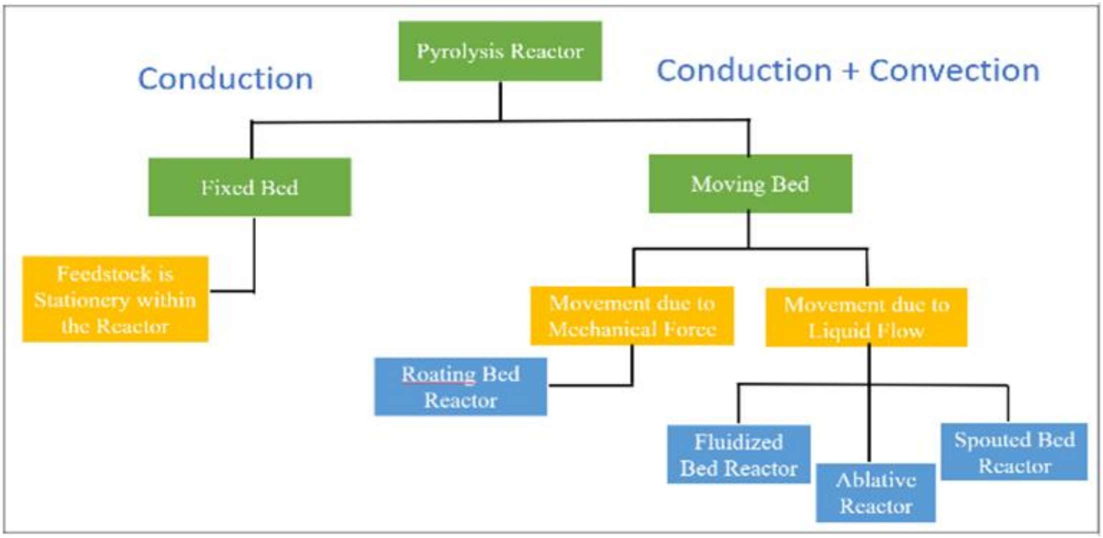

Fig.3. Types of reactors according to the movement of raw materials and heat transfer

Table 2. Summary of Reactor Types

Reactor	Working mechanism	Advantages	Challenges	Ref

type				
Reactor Batch	• Sealed system, there is no outflow or inflow of products or reactants. • Reactants are placed in a reactor for the desired duration.	• Very simple build-up and operation. • Suitable for lab-scale biochar production. • Preferable for char production. • Only raw material is present in the reactor.	• Product variability from one batch to another. • Difficulties related to using batch reactors in large-scale pyrolysis production.	[36]
Semi-Batch Reactor	• The reactant addition and product extraction are possible simultaneously.	• Advantage of reaction selectivity and product variability. • Semi-batch reactors are suited to the production of high yields of oil.	• Sintering of catalyst through coke deposition. • Low production rate due to un-uniform heat and mass transfer.	[37]
Fixed Bed Reactors	• The catalyst is packed in a static bed in pelletized form.	• Low cost, simple build-up, and operation. • Lengthy residence time for a higher carbon conversion rate • High yield of char and low ash carryover.	• Upscaling and heat, and mass transfer issues. • Tar removal and cleaning problem • Low yield of liquid and gas products.	[35]
Fluidized Bed Reactors	• Feed and bed material are mixed through the fluidization. • The velocity of the fluidized medium is used to combine them. • Continues operation.	• Flexible reaction processes and work at the higher temperature. • Uniform heat and mass transfer. • Controlling the vapor holding time. • Accessible in scaling up for biochar production.	• Emission of pollutants. • High capital cost and pre-treatment cost. • Pipes corrosion and blockage of feeding system.	[35]
Bubbling Fluidized Bed Reactor	• Air distribution grid at the bottom to fluidize the feed particles and inert material. • Fluidization velocity used.	• Very efficient at heat transfer • Ease of construction and operation. • Excellent storage capacity • Pilot plant operation up to 60 kg/h.	• Oxidation spots form due to oxygen diffusion. • High capital cost.	[38]
Circulating Fluidized Bed Reactors	• Similar operations like bubbling fluidized with the recycling of fluidized agent/gas.	• To handle large quantities of feed. • Energy efficient for circulating fluidizing agent and material.	• Costly for low-scale operation.	[38]
Ablative Reactors	• Heat is transferred to feed particles through direct. • contact of dis, cone, or liquid. • Fast decomposition of organic matter makes flash pyrolysis.	• Good heat transfer and low energy are needed. • Does not require fluidizing gases. • Lenient to the size of the organic particles, thereby saving additional costs.	• Sophisticated and compelled setup - Scaling takes work.	[35]
Vacuum Pyrolysis Reactors	• Feed is fed through a conveyor belt and stirred mechanically.	• Does not require any carrier gas.	• Unable to handle larger particles. • Complicated design and maintenance. • Need special input apparatus.	[39]
Conical Spouted Bed reactors	• An alternative of fluidized bed reactor and useful flash pyrolysis and continuous feed.	• Able to handle various particle sizes, shapes, and densities. • Lower attrition rate and bed segregation.	• Challenges such as the feeding of catalysts and entrainment. • Product collection like liquid and solid.	[40]
Rotating Cone	• Centrifugal forces use to mix the sand, and the	• High yields of pyrolysis oil. • Economical at large-scale.	• Complex design.	[41]

Reactors	feed moves upward. Feed enters from the bottom.			
PyRos Reactor	• The combination of cyclonic reactor and spouted. • reactor the mixture in a downward direction.	• Short residence time and low tar. • Compact and low-cost setup maintenance.	• Difficult to separate the products.	[29]
Plasma reactor	• Feedstock is placed in the cylindrical tube fitted with two copper electrodes.	• Fats reaction and fast reactions and low tar formation.	• Energy-intensive and High operating cost.	[42]
Microwave reactor	• Facilitate energy transfer via atomic or molecular • interaction using a microwave.	• Lowe by-product formation effective heat transfer and chemical recovery. • Suitable for co-pyrolysis for oil and gas production.	• Scaling up and continuing operational issues. • Waste particle size control and poor mixing. • High dependence on waste dielectric properties.	[41]
Solar Reactors	• Solar reactors are composed of opaque quartz tubes. • and the outer walls are used to highly four concentrates solar radiation.	• Low-cost heating process. • Fast start-up and shutdown time for the pyrolysis process.	• The need for a proper solar design to generate solar energy is still needed to be investigated.	[43]

2.3. Pyrolysis Technology

The thermal decomposition of organic matter in the absence of oxygen can result in the creation of three main products, such as charcoal, oil, and gas, in varying proportions in a process called pyrolysis. To increase the production of one of the three by changing the conditions in the reactor, it can be adjusted from the choice of operation [44]. Three types of pyrolysis are commonly used: slow, fast, and flash. Apart from these three types of pyrolysis, there are other technologies: microwave pyrolysis, catalytic pyrolysis, catalytic hydro-pyrolysis, hydrate pyrolysis, and hydro pyrolysis [29].

2.3.1. Slow Pyrolysis

Pyrolysis techniques started in the early 1900 s when wood was industrially pyrolyzed for 24 hours to produce methanol, ethanol, acetic acid, and coal is called slow pyrolysis or conventional pyrolysis [45]. This slow pyrolysis uses a continuous system, namely heating organic matter slowly in an anaerobic environment at temperatures of more than 400°C, with a minimum heating rate ranging from 5-7°C/minute and a maximum rate ranging from 20-100°C/minute [46]. In this case, slow pyrolysis is a technology developed to produce biochar, while bio-oil production is currently on a pilot scale of slow pyrolysis [45].

2.3.2. Fast Pyrolysis

The pyrolysis technique that maximizes the production of high-quality liquid oil is fast. Hydrocarbons in gasoline and diesel can be increased from medium solid energy fuels to liquid oil [47]. In fast pyrolysis, organic materials will be treated thermally without oxygen at 600-650°C, and high heating rates will reach 1000°C/second. This causes organic matter to produce vapor and aerosols in large quantities and small amounts of gas and coal, and even organic matter can decompose quickly. This research has shown that fast pyrolysis provides good benefits because this technology produces an extensive product from high-quality fuel oil and can be used as an energy source for industrial applications such as engines, turbines, and boilers [48], [49].

2.3.3. Flash Pyrolysis

Flash pyrolysis produces dark brown pyrolysis oil after raw material decomposition, cooling, and condensation, like fast pyrolysis. Pyrolysis produces small amounts of charcoal as well as vapors and aerosols. Flash pyrolysis is carried out at a temperature of almost 1000°C, low retention time (<0.5 sec), and heating rate greater than 700°C/sec. To produce high-quality oil, the product produced by flash pyrolysis reaches 75% of the total product weight [50]. However, the pyrolysis results are not economically feasible because the pyrolysis shows a catalytic effect which results in more viscous oil until some contain solid residues that require a sizable cost to upgrade to improve quality [29].

Table 3. Below shows some of the operating parameters of the three types of pyrolysis processes [51]

Process	Time (s)	Rate (K/s)	Size (mm)	Temp (K)	Oil Yield	Char Yield	Gas Yield
Slow	450–550	0.1-1	5–50	550–950	30	35	35
Fast	0.5–10	10–200	<1	850-1250	50	20	30
Flash	<0.5	>1000	<0.2	1050-1300	75	12	13

2.4. Pyrolysis of Raw Materials

In Figure 4. Presenting products from pyrolysis based on raw materials and the pyrolysis process.

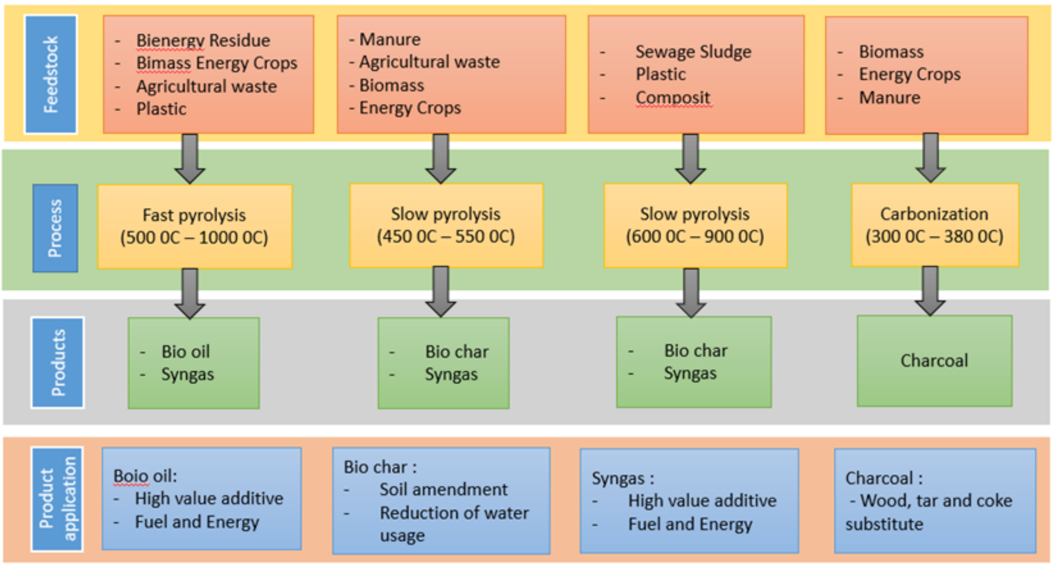

Fig. 4. Pyrolysis products are based on raw materials and the pyrolysis process

2.4.1. Plastic Pyrolysis

Plastic is one of the inorganic wastes that can be recycled to produce valuable products. Research on the pyrolysis of plastics to make oil and gas can be seen in Figure 4. Several researchers have investigated the potential of PET in pyrolysis. Still, its corrosive properties can worsen the resulting fuel quality due to the pyrolysis oil's acidic nature. On the other hand, costs used during industrial applications will increase due to the sublimation of benzoic acid, which will clog heat exchangers and piping [52]. According to Diaz-Silvarrey et al. [53], in the process with materials from PET, up to 27% by weight of gas yield and 10% by weight are obtained. One of the most basic types of plastic produced is High-density polyethylene (HDPE). With various operating parameters and product yields, HDPE has been used for the pyrolysis process of plastic waste [52].

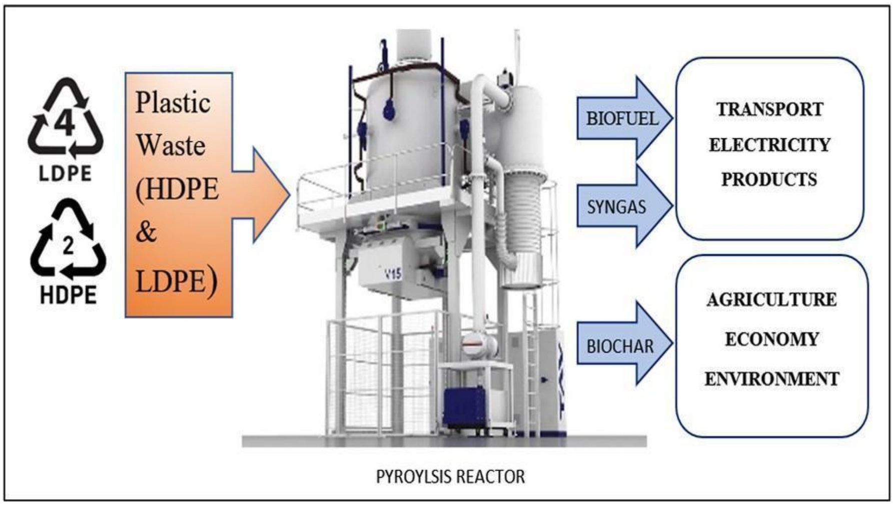

Fig.5. Pyrolysis of plastic waste with outputs and possible applications

The highest yield in the HDPE pyrolysis process occurred at 350 ºC, and the liquid was the primary yield at 80.88% by weight of the material recovered. PET-type plastic is important for pyrolysis due to the finding that the yield of bio-oil from PET pyrolysis ranges from 24-40% by weight, and the yield of gas ranges from 52-77% by weight. For aromatic and aliphatic constituents, the fuel produced meets existing market standards. HDPE pyrolysis in a batch reactor produces gasoline with a high-value range [54]. At moderate temperatures ranging from 500-550ºC, you can use a batch reactor, where the pyrolysis process is suitable for recovering LDPE waste into valuable oil, which is rich in aliphatic hydrocarbons and simple aromatic hydrocarbons or gas, which is very useful as fuel and petrochemical raw materials [55] so that a very potential plastic waste that is used as a raw material for pyrolysis in the energy recovery of used packaging materials is LDPE.

Table 3. Summary of plastic pyrolysis results.

Ref	Plastic Type:	Temp (ºC)	Char (%wt)	Liquid (% wt)	Gas (% berat)
[56]	PET	500	8.98	52.13	39.89
[57]	HDPE	300–400	33.05–0.54	80.88	-
[58]	HDPE	600	34.7	18.1	28.9
[59]	PP	300–700	78.8	21.8	7.2
[60]	PVC	500–700	-	29.65–0.38	–
[61]	LDPE	350–600	12.7	74.4	36.8
[62]	PP	380	13.3	80.1	6.6
[63]	PP	740	1.6	48.8	49.6
[64]	PP	400	16	76	8

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2.4.2. Pyrolysis of Biomass

One of the products from pyrolysis is biochar, which can be obtained from biomass and other wastes. The yield of biochar is determined by the composition, properties, and pyrolysis conditions

[64]. Materials for biochar production are usually obtained from abundant materials, which are generally considered waste due to their low cost [65]. The waste commonly used is from agriculture, such as wood, peanut shells, hazelnut, straw, and others which can be used to produce biochar at temperatures of 300-900ºC without oxygen through slow pyrolysis [3]. Heat and electricity are made from energy sources originating from gas and other by-products [66]. The raw materials and reaction process can show the biochar results obtained. A relatively high biochar value is produced from biomass with high lignin content. Meanwhile, more complex and coarser biochar with a carbon content of up to 80% by weight is made from pyrolysis using wood-based raw materials such as olive husks and date seeds. Raw materials for producing biochar include seaweed, animal manure, wood chips, seaweed, and plant residues [67]. Raw materials that can be processed by anhydrous reaction (fast pyrolysis), carbonization (brown at 300°C and black biochar at 380°C), or slow pyrolysis at low temperatures of 450-550°C to produce biochar anaerobically are biomass energy crops such as rapeseed oilseeds, palm oil, wood pellets, cereals, and corn. Biochar which is helpful for agriculture in terms of growth, can be applied at lower temperatures, but biochar produced at high temperatures is better used as coke [68]. The properties of the resulting biochar can be seen in Table 4.

Table 4. Properties of commonly used biochar produced from agricultural and forest residues

Ref	Biochar Feedstock	Pyrolysis Tem (ºC)	C	N	H	O	Char Yield (%)	Ash (%)	Gas (%)
[69]	Algae matter	300–700	50.4	10.6	7.54	30.7	40-90	4.8	-
[6]	Bamboo	500–900	54.49	0.19	6.15	37.1	-	-	-
[70]	Corn Stover	600	70.5	-	-	-	-	16.6	23.6
[71]	Animal dung	800	27.78	1.67	3.98	20.3	53.1	34	13
[67]	Pinewood	400	74.1	0.06	4.95	20.9	35.3	1.5	36.4
[72]	Wheat straw	500	62.9	-	-	-	29.8	18.0	17.6
[73]	Walnut shell	900	55.3	0.47	0.89	1.6	-	40.4	-
[73]	Turkey litter	700–800	15.6	0.78	0.83	4.4	-	64	-
[74]	Timothy grass	450	67.5	1.9	2.3	28.2	43	3.5	7.5
[75]	Sugarcane bagasse	600	76.5	3.03	2.93	19.8	-	-	-
[76]	Rice husk	400	37.2	1.3	1.2	12.4	-	47.9	38.2

3. Co-pyrolysis of Plastics and Biomass

Syngas, biochar, and liquid fuels are produced from technologies currently developing and commonly used today, namely gasification and pyrolysis of biomass. To produce effective biochar, some researchers focus on mixing biomass and plastic materials using co-pyrolysis [77]. The advantages of co-pyrolysis of plastic and biomass raw materials include reducing economic production costs, increasing process convenience, increasing effectiveness and efficiency in producing valuable products, and, most effectively, reducing waste [78]. A very effective method of waste management can be found with the co-pyrolysis process because the problem of little waste can be overcome, thus leaving residual waste that cannot be copied, and later efforts will be made to find efficient processing alternatives [30].

The average temperature used for co-pyrolysis is around 500ºC with a short residence time which can produce good quality bio-oil, which is about 75% higher than the weight of the raw material, as well as adjustments to operating parameters [79]. According to Kositkanawuth et al. [80], co-pyrolysis of mixed raw materials can improve bio-oil quality. The relevance and potential for commercial development have been demonstrated by the co-pyrolysis technique being more advantageous than conventional pyrolysis. Stable and homogeneous pyrolysis oil does not undergo phase separation in the co-pyrolysis process of a mixture of plastic and biomass raw materials.

Slow pyrolysis reactors such as drum, rotary and screw-fed reactors can optimize co-pyrolysis to produce biochar. In contrast, fast reactors such as fixed and fluidized bed reactors, vacuum, rotating cones, auger reactors, and ablative reactors can optimize co-pyrolysis in producing oil. And gas [81]. While for the final yield composition and physicochemical properties of charcoal can be determined by parameters such as heating rate, residence time, temperature, type of raw material, and mixing ratio. Reactors seen from the scalability and cost-effectiveness are in the fluidized bed reactor and rotating cone rector. However, if the configuration is more prioritized in terms of feed rate, then you can use an auger reactor or a fluidized bed reactor [82]. The results of plastic and biomass co-pyrolysis, comparing yields and differences in calorific value with pyrolysis mixtures consisting only of biomass, can be seen in Table 5. Thus, a combination of wood biomass can be mixed with several types of plastics.

Table 5. Summary of results of Co-Pyrolysis of plastics and biomass

Ref	Plastic Type	Biomass Type	Temp (°C)	Product Yield (wt%) (Plastic-biomass)	Product Yield (wt%) biomass pyrolysis	Calorific Value (MJ/kg) (Plastic-biomass)	Calorific Value (MJ/kg) Biomass pyrolysis
[83]	PS	Palm shell	500	61.63	15.5	38.01	22.51
[84]	Plastic waste	Pine residue	400	53	21	45	25
[85]	PS	Karanja seeds, NigerSeeds	550	60.11 61.3115.8	27.21- 27.92	42.18 41.42	4.53
[86]	PP	Cotton straw	380-480	35.80	15.84	46.9	9.27
[87]	LDPE PP PS	Pinecone	500	63.90 64.10 69.70	16.4 16.6 22.2	46.33	31.4
[88]	PP (block)	Woodchip	500	63.10	23.8	45,58,46,43,45	25.1
[89]	LDPE	Sunflower stalk CedarWood Fallopia Japonica Stem	600	57.17 64.08 58.96	27.23 25.25 28.53	-	-
[90]	PE	Cellulose	500	58.8	13.3		-
[23]	HDPE	Potato skin	500	39	16	45,61	13.61

4. Advantages of Co-pyrolysis of Plastics and Biomass for Biochar Production

Biochar production has many economic and social benefits, including overcoming climate change, an energy source, soil improvement, water treatment, and waste management [20]. Factors that affect pyrolysis results include catalyst, carrier gas flow rate, temperature, pressure, heating rate, particle size, residence time, raw material composition and moisture content, and configuration. Where Pyrolysis can convert waste into energy and by-products that can be used [3]. Biochar production is the technology chosen because of its stability and low economic cost. However, the complete separation of plastic and biomass waste is a process that is expensive, time-consuming and has the same technical difficulties. The solution to produce high-quality biochar from industrial and agricultural waste products is co-pyrolysis [25]. Rodriguez et al. [26] have researched the pyrolysis of biochar made from a mixture of pig manure and poultry manure with tires, wood construction, and PVC plastic by analyzing the effect of co-pyrolysis on the properties of biochar. The research was pyrolyzed at 300-700°C with the addition of 100°C and found that the mixture of biomass and plastic increased the ash content of biochar, water holding capacity (WHC), cation exchange capacity (CEC), and alkalinity so that biochar is suitable for increasing nutrient supply. And CEC in soil [26].

5. Conclusion

This review article provides insights into the co-pyrolysis of biomass and plastics for biochar production. This discusses reactor types and pyrolysis techniques to identify optimal processes that can increase biochar production from the co-pyrolysis of plastic and biomass raw materials. In addition, producing quality biochar by co-pyrolysis of biomass and plastics can be used for soil amendment, water treatment, carbon sequestration, and emission reduction. From the above discussion, it can be concluded that (i) Biochar production is more suitable using slow or conventional pyrolysis because of the longer residence time, which can produce the primary mechanism and result in the conversion of raw materials into solid product charcoal. (ii) Production of biochar from biomass and plastics on a small scale can use a batch reactor, while on a large scale, it can use a continuous reactor. (iii) co-pyrolysis of biomass and plastic can produce up to 60% biochar. (iv) The combination of pyrolysis of biomass and plastic can optimally handle biochar yields. Further research is needed to test the parameters for producing maximum biochar production.

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