

# Investigation of Densified Biomass Fuel for Partial Replacement of Coke Breeze in Sintering

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**Abstract:** *The primary solid fuel used in iron ore sintering operation is coke breeze. Iron ore sintering is known to be one of the most energy-consuming operations within the steelmaking industry. The use of coke breeze extensively results in increased emission of greenhouse gases, pollution of the environment, and exhaustion of fossil fuel resources. The current research work has investigated the utilization of densified biomass fuel as an environmentally friendly replacement for a portion of the coke breeze utilized in the sintering operation. The biomass waste was converted into briquettes or pellets to improve the bulk density and combustion characteristics. The biomass densification fuel was used instead of the coke breeze in the sinter pot experiments at different rates of substitution. The influence of the addition of biomass on the performance of sintering, flame front velocity, production efficiency, yield, as well as characteristics such as shatter strength, reducibility, and tumbler index was investigated. In order to assess the environmental advantages, emissions including CO<sub>2</sub>, SO<sub>2</sub>, and NO<sub>2</sub> were analyzed.*

*It has been observed that biomass densification fuel can be effectively used to reduce fossil fuel use and emissions without compromising on the quality of sinter. Biomass fuel, owing to its low sulfur and renewable characteristics, exhibited a decrease in sulfur emissions as well as increased combustion reactivity when used in small quantities. This was because biomass fuel contained lesser amounts of fixed carbon but higher amounts of volatile matter; thus, high amounts of replacement led to a weakening of the mechanical and thermal properties of the sinter. This research study indicates that biomass fuel is highly prospective as an environmental supplement fuel for iron ore sintering..*

**Keywords:** Densified biomass fuel, Coke breeze replacement, Iron ore sintering, Biomass briquettes, Emission reduction

## I. INTRODUCTION

The iron and steel industry is one of the most significant contributors to the industrial revolution as well as economic growth around the world due to the use of this versatile alloy in many aspects of modern life due to its superior mechanical properties, durability, and ability to be recycled. Sintering is considered to be an important pre-treatment step in integrated steel plants. Iron ore sintering refers to the process of agglomeration through heat of fine iron ore materials mixed with other materials including fluxes, return fines, and solid fuel to form sinter, which looks similar to clinker. Sintering helps improve reduction effectiveness, decreases fuel consumption in the production of iron, and also enhances the permeability within the blast furnace. Due to the fact that coke breeze, which is a byproduct in the production of coke, has high levels of fixed carbon, strong combustion performance, and adequate calorific value, it is normally used as the main fuel during the sintering process. The increasing dependency on coke breeze has led to grave concerns about carbon dioxide emissions, pollution, and the exhaustion of fossil fuels [1]. As a contributor of significant amounts of greenhouse gasses, the steel industry ranks among the largest manufacturers of carbon dioxide emissions globally. CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>2</sub>, and particulate matter emission due to coke breeze combustion in the process of sintering causes detrimental effects on human health and the environment. The consumption of fossil fuels in the metallurgical industry has been significantly enhanced owing to industrialization and an increasing



need for steel. In order to decrease the levels of carbon emissions and increase energy efficiency, steel manufacturers are required to employ environmentally-friendly technology. Scientists and industries are encouraged by environmental guidelines and carbon mitigation approaches to explore alternative energy sources to substitute traditional carbon-based fuel sources in metallurgy [2]. The availability, carbon neutrality, and sustainability of biofuels make them good substitutes. Biomass, derived from plant matter, forestry waste, agricultural waste, and other degradable materials, is known as biomass. Sawdust, rice husk, bamboo waste, coconut shell, bagasse, wood chips, straw, and biochar are some examples of biomass. Since the amount of carbon that enters into the body of plants during photosynthesis nearly equates to the amount of carbon that is produced during the combustion process, the consumption of biomass fuels is considered green. The emission of greenhouse gases is thus reduced. Moreover, biomass usually contains lower levels of sulfur and nitrogen than coke breeze, and so emits lower amounts of  $SO_x$  and  $NO_x$  in burning [3]. Besides helping reduce dependence on fossil fuels, biomass can be used for effective management of waste in the forestry and agricultural sectors. Every year, countries like India produce enormous amounts of biomass wastes, most of which remain underutilized or burnt in the open, leading to severe environmental pollution. It makes economic and environmental sense to convert such waste into biofuel that can be utilized in metallurgical activities. Raw biomass has some issues that make it unsuitable for use in iron ore sintering despite some strengths it holds. Such raw material is often characterized by low bulk density, high moisture levels, uneven particle size, poor grindability, low heating value, and poor combustion behavior. These qualities affect handling, transportation, and thermal efficiency when operated at high temperatures. Densification is done to overcome such issues with biomass. Through densification, the physical and combustion properties of the biomass are significantly improved through increased bulk density, reduced moisture content, energy density, and mechanical strength [4]. Densified biomass provides consistent combustion properties and better compatibility with existing industrial fuel facilities. Moreover, biomass becomes an alternative choice as a fuel source for industrial operations through ease of storage, transportation, and feeding into the sintering machinery. The application of biomass-derived fuels in iron ore sintering has been widely explored over the years. As per studies, substituting the conventional fuel sources such as coke breeze with biomass charcoal, biochar, or biomass briquettes reduces carbon emissions. High volatile matter content and reactivity characteristics during sintering help to ignite and burn quickly biomass. Since biomass has lesser sulfur content compared to coke breeze, the burning of biomass causes less emission of sulfur dioxide into the environment [5]. But since biomass has a lesser amount of ash and fixed carbon compared to coke breeze, the addition of more biomass may adversely affect the sintering process. Burning biomass rapidly decreases the availability of energy in the sinter bed that leads to poor melting characteristics in the produced sinter due to the absence of good bonding phases. Thus, reducibility and sintering qualities become poor, leading to reduced strength and production rates [6]. Hence, it is necessary to find a balance point for biomass substitution considering both environmental benefits and sintering qualities. Densified biomass fuel is increasingly being used for metallurgical sintering because it promotes the concept of sustainable production of steel and circular economy approach. Sustainable metallurgy aims at minimizing environmental impacts without compromising on the quality of production and efficiency. Sustainable biomass fuel can contribute to lowering the carbon footprint of the steel industry significantly. Use of biomass fuels can help support international initiatives geared towards reduction of carbon emissions and adoption of renewable energy. To reduce dependency on fossil fuels and support waste-to-energy conversion system, both the government of India and several foreign companies are encouraging biomass utilization techniques [7]. Thus, adoption of densified biomass fuel for iron ore sintering can bring about several advantages for strategic purposes. The high-temperature burning of densified biomass fuel is yet another essential factor in utilizing biomass in sintering. The combustion characteristics of ignition temperature, burnout rate, flame spread, heat evolution, and ash behavior greatly influence the quality of the sinter and the efficiency of the process. Due to their porosity and higher volatile content, biomass fuels generally possess a higher reactivity in combustion. Nevertheless, because of the variation in the mineral composition and lower ash content in biomass fuels, the process of melt formation and mineral bonding during sintering might be influenced. Thus, in order to evaluate the



suitability of biomass fuel as a supplementary source of fuel in place of coke breeze, it is necessary to conduct an extensive study on the sintering parameters [8]. Also, for the purposes of measuring environmental benefits and ensuring adherence to industrial emission standards, there is a need to monitor gaseous emissions resulting from the burning of biomass.

The study entails the analysis of densified biomass fuel as a partial substitute of coke breeze in the iron ore sintering process. Biomass fuels are prepared as briquettes or pellets in an effort to improve their properties for sintering processes. The preparation of the densified biomass fuels is analyzed using proximate analysis, ultimate analysis, density measurements, calorific values, and combustion analyses. Tests for assessing the influence on the sintering process performance, output, yield, flame front speed, and sinter quality parameters are conducted using the sinter pot test procedure. In addition to the environmental advantages of biomass use, it is necessary to study the features of emissions, including carbon dioxide, sulfur dioxide, and nitrogen oxides. The findings of this research are expected to assist in the effective application of renewable energy sources in metallurgical enterprises and contribute to developing low-carbon ironmaking technology.

## II. MATERIAL & METHOD

### 2.1 Material

The constituents that were used in this experiment included iron ore fines, coke breeze, limestone, return fines, and densified biomass fuel. Iron ore fines were the key raw material employed in sinter making because of their significant content of iron and suitability for agglomeration processes. The use of limestone as the flux was necessary to ensure that the proper ratio of basicity and help create the desired slag during the process of sintering. Return fines, derived from previous production of sinter, were used to improve the efficiency of the process by recycling materials. Coke breeze was used as the conventional solid fuel due to its high percentage of fixed carbon content and combustibility [6]. Examples of such agricultural and forest residues include sawdust, rice husks, bamboo residues, and bagasse. These residues were selected for this research due to their abundant nature, low sulfur levels, and renewability. The initial step involved air drying followed by oven drying of the feedstock in order to reduce the moisture level. Afterward, in order to achieve a uniform particle size suitable for densification, the biomass material was crushed and screened. This research focused on densification as it improves handling characteristics, storability, combustibility, and energy density since raw biomass material usually exhibits low bulk density, high volatility, and poor burning characteristics [7]. The powdered biomass material was compacted using a hydraulic briquetting machine after mixing it with a small quantity of organic binder. Cylindrical briquettes of uniform diameters were produced under precisely controlled pressure conditions. The prepared biomass briquettes were thoroughly dried and stored in sealed containers before conducting any tests. There are many advantages associated with densified biomass fuel compared to loose biomass, including improved bulk density, increased mechanical strength, higher thermal efficiency, and better combustion characteristics during metallurgical processing at elevated temperatures [8]. Both the nature of the combustion reaction and the final quality of the sintered material are greatly affected by the physicochemical properties of the biomass briquette and coke breeze fuels. Therefore, the standardized ASTM procedures were employed in order to characterize these fuels properly. Moisture percentage, ash percentage, volatile percentage, and fixed carbon percentage were evaluated through proximate analysis. This test was conducted for the purpose of determining the elemental composition of the fuel and measuring the amounts of carbon, hydrogen, nitrogen, sulfur, and oxygen in the biomass. Calorific value was determined using bomb calorimetry, whereas bulk density and compressive strength were determined using mechanical tests.

Table 1:- Chemical Composition of Iron Ore Fines

Component	Percentage (%)
Fe <sub>2</sub> O <sub>3</sub>	62–66
SiO <sub>2</sub>	4–6



Al <sub>2</sub> O <sub>3</sub>	2–4
CaO	1–2
MgO	0.5–1
Loss on Ignition	2–5

Table 2 :- Properties of Coke Breeze and Densified Biomass Fuel

Property	Coke Breeze	Biomass Briquette
Moisture (%)	3–5	6–10
Volatile Matter (%)	2–5	60–75
Ash Content (%)	10–15	3–8
Fixed Carbon (%)	75–85	15–25
Calorific Value (MJ/kg)	28–30	16–22
Sulfur Content (%)	0.5–1.2	0.05–0.2
Bulk Density (kg/m <sup>3</sup> )	700–800	850–1100

Table 3: Composition of Sinter Mix

Material	Percentage (%)
Iron Ore Fines	65–70
Return Fines	15–20
Limestone	8–10
Coke Breeze + Biomass Fuel	4–6
Moisture	6–8

## 2.2 Method:-

The following activities involved in this study included densified biomass fuel preparation, characterization of biomass feedstock, manufacturing of sinter mix, lab-scale testing of biomass briquettes sintering, and evaluation of sinter quality and emissions. Initially, the biomass waste was purified to eliminate impurities. Next, the biomass feedstock was dried out using sunlight and oven-drying techniques to lower the moisture content. For preparing small-sized particles required for biomass densification, the dried biomass was crushed and sieved. Water and a binder in controlled amounts were added to improve the compressibility of the biomass briquette. The biomass mix was compressed by a hydraulic briquetting press to form cylindrical briquettes with uniform sizes [10]. However, before using the biomass briquettes in the sintering experiments, it was ensured that all biomass briquettes were fully dried. To assess the effect of partially replacing the coke breeze by densified biomass, different biomass replacement ratios were selected. The ratio of biomass used as the fuel source was maintained at 0%, 5%, 10%, 15%, and 20% relative to the amount of coke breeze. For creating the sinter mix, iron ore fines, return fines, limestone, coke breeze, and biomass briquettes were carefully measured and mixed in specific proportions. Water was gradually added for granulation and proper bed permeability. An equipment called a sinter pot was designed to emulate industrial sintering processes in the lab. This consisted of a cylindrical steel vessel with igniting hood, suction fan, thermocouples, and gas analyzer set-up. For each trial, bed height was controlled, while the sinter mixture prepared was uniformly charged in the sinter pot. Sinter ignition was initiated by a gas burner and controlled air flow from the top surface of the sinter bed. To encourage flame front movement through the sinter bed, controlled suction pressure was maintained throughout the process [12].

During the entire course of burning, temperature profile, flame front velocity, and overall sintering time were determined. Once the sintering process was complete, the resultant sinter cake was allowed to cool naturally, crushed, and then sieved to eliminate return material from the useful sinter. In order to evaluate the effect of biomass



on the quality of the resultant sinter, the manufactured sinter was evaluated for productivity, yield, tumbler index, shatter strength, and reducibility characteristics. In addition, CO<sub>2</sub>, SO<sub>2</sub>, and NO<sub>2</sub> emissions generated in the process of sintering were determined using a flue gas analyzer [13].

The conventional process of using coke breeze and the substituted biomass were compared to identify an optimum biomass substitution ratio that provides satisfactory sinter quality and minimal environmental impact. The possibility of using densified biomass fuel as an alternative fuel source in iron ore sintering applications was analyzed by systematically evaluating experimental results [14].

Table 4: Biomass Fuel Replacement Levels

Parameter	Value
Sinter Bed Height	400–500 mm
Ignition Temperature	1000–1200°C
Suction Pressure	1200–1500 mmWC
Moisture Content	6–8%
Sintering Time	20–30 min
Basicity Ratio (CaO/SiO <sub>2</sub> )	1.5–2.0

Table 5: Experimental Parameters for Sintering

Parameter	Value
Sinter Bed Height	400–500 mm
Ignition Temperature	1000–1200°C
Suction Pressure	1200–1500 mmWC
Moisture Content	6–8%
Sintering Time	20–30 min
Basicity Ratio (CaO/SiO <sub>2</sub> )	1.5–2.0

Table 6: Evaluation Parameters of Produced Sinter

Parameter	Purpose
Tumbler Index	Mechanical strength
Shatter Strength	Impact resistance
Reducibility Index	Blast furnace suitability
Flame Front Speed	Combustion behavior
Productivity	Process efficiency
Yield	Usable sinter percentage
CO <sub>2</sub> Emission	Carbon emission analysis
SO <sub>2</sub> Emission	Sulfur pollution analysis
NO <sub>x</sub> Emission	Nitrogen oxide evaluation

### III. EXPERIMENTAL WORK

The aim of this experimental research is to find out if it will be possible to substitute some portion of coke breeze used in the iron ore sintering process with densified biomass fuel. Preparation of biomass, biomass densification, fuel analysis, preparation of sinter mixture, laboratory scale sintering tests, and analysis of gas emissions and quality of sinters formed were included in the method used in the experiment. In order to ensure reliability of results, all experiments were conducted in a laboratory environment. The selected biomass feedstock, for instance sawdust, rice husk, bamboo chips or bagasse was collected and purified to remove any contaminants from it. The moisture content was reduced by drying the biomass at room temperature and then by drying it for 24 hours at a temperature of 105°C. Following this, the dried biomass was pulverized and sieved to obtain particles which had an appropriate size of less than 2 mm. The biomass was then densified by a hydraulic briquetting machine under pressure ranging from



80-120 MPa. The addition of small amounts of water and organic binder was done to increase the compaction strength and the ability of the machine. Uniformly sized cylinders of biomass briquettes were produced, dried, and prepared to be used in sintering investigations [18].

The coke breeze and biomass briquettes were well characterized prior to the process of sintering to evaluate their fuel properties. Moisture content, volatile matter content, ash content, and fixed carbon content were determined through proximate analysis as per ASTM standards. The elemental analysis of the sample material was done using CHNS Analyzer to determine its elemental composition, i.e., carbon, hydrogen, nitrogen, sulfur, and oxygen content. Calorific value was determined by bomb calorimeter, and biomass briquettes were tested on bulk density and compressive strength to determine their handling characteristics [19]. Iron ore fines, limestone, return fines, coke breeze, and densified biomass fuel were used in predetermined proportions for producing the sinter mixture. Coke breeze was partially replaced with biomass briquettes up to 0%, 5%, 10%, 15%, and 20%. To ensure uniform distribution of fuel and flux in the sinter bed, the proportionate amount of each raw material was accurately weighed and blended. Moisture was ensured by adding water slowly. To maintain the moisture content within 6 to 8%, which is essential for proper granulation and bed permeability during the sintering process, water was added gradually [20]. For carrying out experimental studies on sintering under laboratory conditions, a sinter pot was designed to simulate conditions encountered in industrial sintering operations. The apparatus consisted of a steel cylinder along with a suction blower, igniter hood, thermocouples, gas analyzer, and temperature control system. The sinter mixture that had been prepared was uniformly fed into the sinter pot, ensuring that there was consistency in bed height during each experiment. Ignition began with the help of a gas burner at temperatures ranging from 1000°C to 1200°C. The application of constant downward suction was done to facilitate flame front movement through the sinter bed and ensure complete combustion of the fuel blend [21]. Some key parameters of sintering operations were continuously tracked and measured, such as temperatures, rate of flame front movement, ignition delay, and total sintering duration. The produced sinter product was allowed to cool naturally in the ambient environment after sintering operations concluded. The cooled sinter product was subsequently broken up and sorted to separate return fines from good quality sinter. The quantity of good quality sinter produced during sinter sorting was used to determine sinter yield and efficiency [22].

To evaluate the effect of biomass substitution on sinter quality, some physical and metallurgical properties of the produced sinter samples were evaluated. Tests for tumbler index and shatter strength were carried out to check the mechanical strength. Tests for reducibility were undertaken to investigate the applicability of the produced sinter for blast furnaces. X-ray diffraction method was employed to find out the presence of mineralogical phases formed through the sintering process, and scanning electron microscopy (SEM) was done to study the microstructure [23]. Emission testing was also conducted to determine the level of environmental impact on the sintering process. The gas analyzer was utilized to quantify the levels of emission such as CO<sub>2</sub>, SO<sub>2</sub>, and NO<sub>2</sub> that occur in the flue gases during burning in the sinter pot. The optimal replacement rate of biomass that could reduce emissions but still maintain good sintering quality was found through the comparison between coke breeze sintering and biomass substitution [24].

**Table 7: Experimental Conditions for Sintering Process**

Parameter	Value
Biomass Particle Size	< 2 mm
Briquetting Pressure	80–120 MPa
Moisture Content	6–8%
Ignition Temperature	1000–1200°C
Bed Height	400–500 mm
Suction Pressure	1200–1500 mmWC
Sintering Time	20–30 min



Biomass Replacement Ratio	0–20%
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Table 8: Testing Methods for Fuel and Sinter Characterization

Property/Test	Standard/Instrument
Proximate Analysis	ASTM Standards
Ultimate Analysis	CHNS Analyzer
Calorific Value	Bomb Calorimeter
Bulk Density	ASTM Method
Compressive Strength	Universal Testing Machine
Tumbler Index	ISO 3271
Reducibility Test	ISO 4695
SEM Analysis	Scanning Electron Microscope
XRD Analysis	X-Ray Diffractometer
Gas Emission Analysis	Flue Gas Analyzer

#### IV. RESULT & DISCUSSION

A difference was noted between the physical, chemical, and combustive properties of densified biomass and coke breeze. The volatile matter in biomass briquettes is 68.4% higher than in coke breeze (3.5%), while fixed carbon in the latter (79.5%) is substantially more than that of biomass (19.3%). Although low fixed carbon resulted in decreased heat generation time at the sinter bed of the biomass, high volatile matter made the biomass easier to ignite and burn during sintering. Densified biomass briquettes have great prospects of reducing impurities and toxic emissions of SO<sub>2</sub> during sintering due to lower ash and sulfur levels compared to coke breeze. Furthermore, densification greatly improved the bulk density of biomass fuel. The influence of biomass substitution on sintering behavior, productivity, mechanical properties, and gas emissions was determined by experimentation. Due to the enhanced reactivity of the fuel and better ignition characteristics, the flame front advance rate did not fluctuate significantly and sintering behavior continued as normal compared to conventional coke breeze firing for up to 5 to 10% biomass substitution. The productivity and yield were highest at 5% biomass substitution, where the productivity reached 1.55 t/m<sup>2</sup>/day and the yield was 79.3%, respectively. However, due to poor heat conservation and the reduced availability of fixed carbon, a further increase in biomass substitution above 15% caused productivity to decline, increased the time required for sintering, and reduced the temperature of the flame front. Moderate amounts of biomass replacement could retain an appropriate tumbler index and shatter strength because adequate melt formation and bonding phases were formed during the sintering process. However, the sinter strength would be reduced due to inadequate melt formation and high porosity when biomass addition exceeded 15%. Interestingly, the reducibility index had an increasing tendency with higher biomass content owing to enhanced gas permeability within the sinter matrix because of the generation of pores. Due to the fast combustion of volatiles, sinter with biomass exhibited relatively high porosity compared to ordinary sinter based on microscopic analysis through scanning electron microscopy (SEM). Hematite, magnetite, calcium ferrites, and silicates were observed for all sinter samples based on X-ray diffraction (XRD) examination; nonetheless, the amount of bonding phases slightly decreased with increasing biomass substitution owing to low bed temperatures. The results of emission analysis reveal that the use of biomass fuels has beneficial impacts on the environment. Biomass fuel has a lower amount of sulfur and nitrogen, and therefore, considered renewable carbon fuel. The level of CO<sub>2</sub>, SO<sub>2</sub>, and NO<sub>2</sub> emissions slowly decreased with an increase in biomass fuel substitution. The CO<sub>2</sub> emissions were 18.5% to 13.5%, and SO<sub>2</sub> was 420 ppm to 215 ppm with 20% biomass fuel substitution. In general, the densified biomass fuel is an efficient tool for decreasing the consumption of fossil fuels and environmental pollution without compromising the quality of sintering. Thus, the optimal level of substitution of biomass fuel for coke breeze should be in the range of 5-10%.



Table 9: Summary of Experimental Results

Parameter	0% Biomass	5% Biomass	10% Biomass	15% Biomass	20% Biomass
Flame Front Speed (mm/min)	24.8	25.6	25.1	23.4	21.2
Sintering Time (min)	22	21	22	24	27
Productivity (t/m <sup>2</sup> /day)	1.52	1.55	1.53	1.45	1.34
Yield (%)	78.5	79.3	78.8	75.6	71.4
Tumbler Index (%)	72.4	71.8	70.9	67.2	63.5
Reducibility Index (%)	65.5	66.8	67.5	69.3	71.6
CO <sub>2</sub> Emission (%)	18.5	17.3	16.1	14.8	13.5
SO <sub>2</sub> Emission (ppm)	420	365	318	260	215

## V. CONCLUSION

The current study effectively assessed the viability of partially substituting densified biomass fuel for coke breeze during the iron ore sintering process. The study showed that biomass briquettes are appropriate for metallurgical applications because they have good physical and chemical properties such high volatile matter, low sulfur content, minimal ash generation, and improved bulk density after densification. According to experimental findings, sintering performance, sinter quality, and emission characteristics were all greatly impacted by the partial replacement of coke breeze by biomass fuel. The best outcomes in terms of flame front propagation, productivity, sinter production, and mechanical strength were obtained at moderate biomass replacement levels of 5–10%. In these replacement proportions, the sinter obtained possessed an adequate tumbler index, shatter strength, and reducibility behavior similar to that of regular sinter. Due to inadequate heat generation and poor formation of the bonding phase due to the low fixed carbon content of the biomass fuel, high proportions of biomass above 15% caused decreased mechanical strength and sintering efficacy. But due to better pore formation and enhanced gas permeation throughout the sinter matrix, increasing the biomass proportion positively impacted sinter reducibility. Hematite, magnetite, calcium ferrites, and silicates were some of the important mineral phases found by microscopic examination. Among other things, the reduction in the amount of harmful gases produced was another key advantage of this study. Since biomass fuel contains low amounts of sulfur and nitrogen and is considered renewable carbon, levels of CO<sub>2</sub>, SO<sub>2</sub>, and NO<sub>2</sub> decreased as more biomass substitute was used. Biomass fuel has been shown to benefit the environment, which is illustrated by the decrease in the emission of SO<sub>2</sub> from using biomass in iron ore sintering operations.

In conclusion, this study showed that densified biomass fuel may serve as a substitute for coke breeze as a supplementary fuel in the sintering process. It can be seen that using 5-10% of biomass fuel produces optimal results concerning sinter properties, productivity, combustion efficiency, and environmental issues. The use of biomass will help achieve more eco-friendly steelmaking technologies, reduce dependency on fossil fuels, and minimize the emission of greenhouse gases. More studies should be conducted, particularly those focusing on industrial-scale experiments, optimal briquette formulation, and prolonged plant operations to implement the use of biomass for sintering commercially.

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