



## EXERGOENVIRONMENTAL ASSESSMENT OF LIGNOCELLULOSIC BIOMASS PYROLYSIS FOR ENERGY VALORIZATION AND ENVIRONMENTAL SUSTAINABILITY

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### ABSTRACT

This study evaluated five biomass feedstocks—cotton gin trash, rice husk, coconut shell, flax straw, and corn cob—for thermochemical conversion via pyrolysis. The analysis focused on gas fraction, fixed carbon, volatile matter, and ash content. Results indicated that flax straw achieved the highest gas yield (74%), rendering it optimal for energy generation applications, despite exhibiting the highest ash content (9.22%). Conversely, coconut shell demonstrated superior biochar production (17.61%). Rice husk and corn cob yielded the lowest ash content (5.44% and 5.7%, respectively), facilitating cleaner processes with minimal solid residue. Cotton gin trash presented a balanced profile between gas yield (73.4%), biochar (16.8%), and volatile content (69%), with moderate ash generation (8.33%). These findings demonstrate that each biomass offers specific strategic advantages depending on the process objective: gas maximization, biochar synthesis, or waste minimization. Consequently, feedstock selection can be precision-tailored to align with the operational priorities of the exerگوenvironmental system.



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### I. INTRODUCTION

Pyrolysis involves the thermochemical decomposition of organic matter in the absence of oxygen to produce fuels, biochar, and liquid fractions (bio-oil). This process has emerged as a promising technological alternative for the sustainable utilization of agro-industrial residues, enabling energy recovery and the valorization of by-products with energy, environmental, and industrial applications. Recent studies report that, depending on biomass type and operating conditions, bio-oil yields can reach values between 60% and 75% in fast pyrolysis processes, whereas slow pyrolysis favors biochar production [1]. In the present study, five types of biomass were evaluated: cotton gin trash, rice husk, coconut shell, flax straw, and corn cob, considering their energy potential and environmental impact.

These lignocellulosic residues exhibit variable compositions of cellulose, hemicellulose, and lignin, which directly influence product distribution during pyrolysis. It has been demonstrated that the thermal decomposition of cellulose and hemicellulose occurs primarily between 220 and 380 °C, favoring the formation of volatile compounds and non-condensable gases. In contrast, lignin degrades over a broader temperature range (250–500 °C), contributing significantly to the generation of biochar and aromatic compounds in the bio-oil [2]. Global reliance on fossil fuels, which account for approximately 85% of global energy consumption, and their direct impact on the increase of greenhouse gas (GHG) emissions have raised serious concerns regarding the sustainability of the energy system and environmental protection, intensifying the need to develop and implement sustainable energy technologies [3].

This dependence has resulted in a sustained increase in global CO<sub>2</sub> emissions, exceeding 37 Gt annually in recent years [4]. In this context, alternative renewable energy sources, such as biomass, have gained relevance due to their potential to reduce carbon footprints and promote sustainable energy systems. Thermochemical conversion of biomass enables the partial substitution of fossil fuels in thermal and industrial applications, contributing to climate change mitigation [5]. biomass-based renewable energy sources have emerged as a strategic alternative, particularly through thermochemical processes such as pyrolysis and gasification, which present lower net CO<sub>2</sub> emissions and enable the utilization of agricultural residues that would otherwise be underutilized or inefficiently incinerated. Several studies have evaluated complementary thermochemical processes, such as gasification, to analyze the effects of key operational variables including temperature and equivalence ratio (ER). It has been reported that increases in ER promote exothermic partial oxidation reactions, raising reactor temperature but reducing the lower heating value (LHV) of the produced gas due to dilution by non-combustible gases. Furthermore, increasing ER leads to a progressive decrease in CO and H<sub>2</sub> concentrations due to their oxidation into CO<sub>2</sub> and H<sub>2</sub>O [6],[7]. These results highlight the importance of meticulously controlling operating conditions to maximize the process's energy efficiency.

Additionally, recent research on fast and slow pyrolysis has shown that biomass type directly impacts product distribution. Current research provides insights into pyrolytic bio-oil obtained from different feedstocks regarding upgrading techniques and applications such as energy, fuels, chemicals, and carbon materials. Analysis indicates that the primary bottlenecks for the commercial application of upgraded bio-oil are the initial processing stages, high production costs, and pilot-scale production challenges [8]. Specifically, regarding flax straw, investigations have been conducted using conventional and advanced exergetic techniques across different operating temperatures. Using Aspen Plus software, the pyrolysis process was accurately simulated, identifying system inefficiencies and potential areas for improvement. The pyrolysis reactor, cyclone, and flash reactor were the primary sources of exergy destruction, accounting for 32.2%, 31.8%, and 18.7% of total exergy destruction, respectively [9]. Flax straw biomass possesses a high heating value (18.2 MJ/kg) and significant cellulose (27.4%) and hemicellulose (24.8%) content, favoring its thermochemical conversion into valuable products like bio-oil and biochar. Moreover, its low lignin and ash content, combined with significant reductions in moisture and fixed carbon, enhances pyrolysis efficiency. These factors position flax straw as a promising feedstock for bioenergy production, contributing to sustainability and resource optimization [10].

An exergoenvironmental analysis consists of three steps: an exergetic analysis of the conversion process, a life cycle assessment (LCA), and an evaluation of environmental impacts associated with the process's exergy flows [11]. The exergoenvironmental and thermodynamic evaluation of biomass pyrolysis is essential because it enables the optimization of energy efficiency by identifying and minimizing energy and exergy losses throughout the process, thereby contributing to more efficient and sustainable system design. Additionally, it integrates environmental indicators to assess and reduce the impacts of emissions and by-products, promoting cleaner energy conversion. In this context, [12] characterization of crop residue biomass blends, including corn cobs, rice husks, sesame stalks, and cotton gin trash, evaluated gasification temperature, syngas LHV, and cold gas efficiency (CGE). It was found that temperature, syngas composition, LHV, and CGE were negatively affected as the proportion of rice husk in the blend increased. CGE values up to 57.91% and LHV up to 4460 kJ/kg were achieved under specific blending conditions. A higher percentage of rice husk caused a considerable increase in the variability of the equivalence ratio, resulting in suboptimal gasification conditions.

Studies by [13] utilized Aspen Plus® and detailed CO<sub>2</sub> emissions and other environmental impacts through integrated LCA, identifying the possibility of achieving a net-negative carbon footprint in scenarios involving carbon capture. Finally, [14], quantified environmental emissions from biochar production using traditional Kon-Tiki kilns. Multiple impact categories were evaluated, including Global Warming Potential (GWP), fossil fuel depletion, and eutrophication, finding that biochar application as a soil amendment generated significant net reductions in CO<sub>2</sub>-eq emissions, particularly in agricultural scenarios. Based on the considerations, the main objective of this work is to identify cleaner and more efficient methods for renewable energy production to reduce fossil fuel dependency and mitigate GHG emissions. Key variables such as temperature and equivalence ratio were studied, demonstrating their significant influence on the generation of critical energy-related gases such as carbon monoxide and hydrogen. Furthermore, the potential of flax straw and other agricultural residues as promising feedstocks was highlighted, contributing to energy generation, the circular economy, and the optimization of natural resources.

## II. MATERIALS AND METHODS

### II.1 CHARACTERIZATION OF BIOMASS

The comparative analysis of the thermophysical properties of corn cob, cotton gin trash, rice husk, flax straw, and coconut shell is summarized in Table 1. This characterization encompasses proximal analysis (moisture content, ash yield, volatile matter, and fixed carbon), ultimate analysis (carbon, hydrogen, nitrogen, sulfur, and oxygen), and the determination of the higher heating value (HHV).

Table 1: Composition of biomass used.

| Component                  | Corn Cob | Cotton gin trash | Rice husk | Flax straw | Coconut shell |
|----------------------------|----------|------------------|-----------|------------|---------------|
| <b>Elemental analysis.</b> |          |                  |           |            |               |
| S (v/v)                    | 0.09     | 0.2              | 0.1       | 0.012      | 0.005         |
| HHV (kJ/kg)                | 16,230   | 18,263           | 16,166    | 18,200     | 20,150        |
| C (v/v)                    | 39.95    | 39.3             | 39.27     | 0.444      | 0.6423        |
| H (v/v)                    | 4.97     | 4.7              | 4.91      | 0.067      | 0.0689        |
| O (v/v)                    | 46.77    | 49.35            | 55.23     | 0.456      | 0.2761        |
| N (v/v)                    | 0.6      | 1.21             | 0.59      | 0.014      | 0.0077        |
|                            |          |                  |           |            |               |
| <b>Proximate analysis.</b> |          |                  |           |            |               |

|           |       |       |       |       |       |
|-----------|-------|-------|-------|-------|-------|
| MC (v/v)  | 10.52 | 10.51 | 10.18 | 0.044 | 0.101 |
| ASH (v/v) | 7.71  | 5.44  | 8.33  | 0.029 | 0.032 |
| VM (v/v)  | 65.23 | 68.42 | 64.67 | 0.813 | 0.755 |
| FC (v/v)  | 16.54 | 15.63 | 16.82 | 0.813 | 0.112 |

Source: Authors, (2026).

The data for the analysis of corn cob, rice husk, and cotton gin trash were obtained from a previous study detailing their proximate and ultimate analyses [12]. Likewise, data corresponding to the different analyses for flax straw were obtained from [10]. Similarly, data for coconut shell were taken from [15]. The pyrolysis process for each biomass feedstock was executed through computational simulations using Engineering Equation Solver (EES) software. This platform facilitated the robust modeling of the thermodynamic equations governing the process for each specific biomass type. The governing equations for the parameters on a dry basis are formulated as follows:

$$VM_w = \frac{VM}{1 - MC} \quad (1)$$

$$FC_w = \frac{FC}{1 - MC} \quad (2)$$

$$ASH_w = \frac{ASH}{1 - MC} \quad (3)$$

Donde:  $MC$  is the initial moisture content,  $VM$  is the volatile matter,  $ASH$  is the ash generation.

To simulate pyrolysis in EES, stoichiometric balances and temperature-dependent empirical correlations are used, in a range from 650 to 990 K [16].

$$\alpha_1 = 1.94 \cdot 10^{-6} \cdot T^{1.87} \quad (4)$$

$$\alpha_2 = 1.305 \cdot 10^{-11} \cdot T^{3.39} \quad (5)$$

The mass balance equation could be written as follows:

$$Mass_{total} = Mass_{tar} + Mass_{char} + Mass_{gas} + Mass_{steam} \quad (6)$$

The fraction equations for the products are given by:

$$f_{gas} = \frac{Mass_{gas}}{Mass_{total}} \cdot 100 \quad (7)$$

$$f_{tar} = \frac{Mass_{tar}}{Mass_{total}} \cdot 100 \quad (8)$$

$$f_{char} = \frac{Mass_{char}}{Mass_{total}} \cdot 100 \quad (9)$$

$$f_{vapor} = \frac{Mass_{steam}}{Mass_{total}} \cdot 100 \quad (10)$$

### III. RESULTS AND DISCUSSIONS

#### III.1 PYROLYSIS OF CORN COB

The results obtained for corn cob demonstrate a characteristic behavior of lignocellulosic biomass with a balanced structural composition of cellulose, hemicellulose, and lignin. As shown in Figure 1, gas production is predominant, followed by an intermediate bio-oil fraction and a lower biochar yield. This behavior can be directly attributed to the high volatile matter content (65.23%) and moderate fixed carbon content (16.54%), which facilitate the thermal cleavage of weak chemical bonds during the initial and intermediate stages of the pyrolysis process.

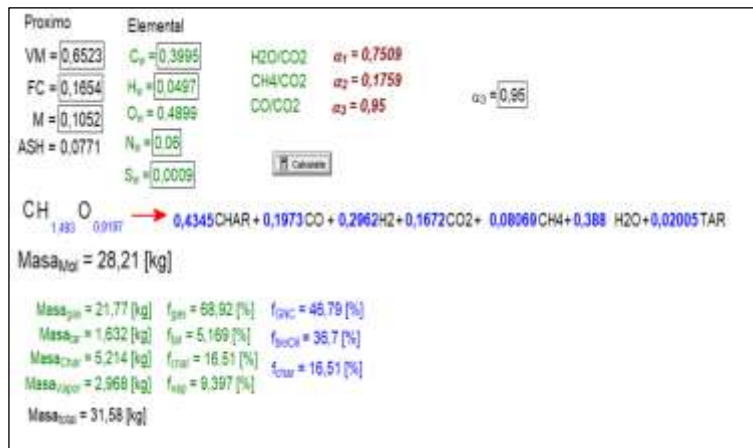


Figure 1: Pyrolysis of Corn Cob.  
Source: Authors, (2026).

Figure 2, corresponding to the composition of the gaseous products, a predominance of CO and CO<sub>2</sub> is observed, with lower fractions of H<sub>2</sub> and CH<sub>4</sub>. The increase in CO is mainly associated with the thermal decomposition of cellulose and hemicellulose, whose degradation mechanisms include decarboxylation and decarbonylation reactions. Conversely, CO<sub>2</sub> is significantly generated during the initial stages of the process due to the cleavage of oxygenated functional groups within the hemicellulose matrix. The lower hydrogen fraction can be explained by the absence of secondary reforming reactions, which are typical of gasification processes, and by the limited recombination of free radicals at high temperatures under pyrolysis conditions.

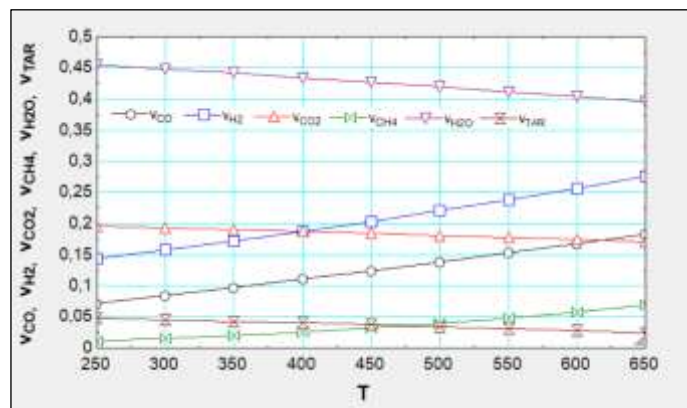


Figure 2: Composition of gaseous products during pyrolysis.  
Source: Authors, (2026).

The mass distribution shown in Figure 3, confirms that the gaseous phase dominates the overall process balance. This behavior is closely linked to the fibrous and porous structure of the corn cob, which facilitates the diffusion of volatiles toward the particle exterior, thereby mitigating secondary reactions that would otherwise promote biochar formation. Consequently, the residual solid fraction remains relatively low. Finally, the product fraction analysis in Figure 4 positions corn cob as a suitable feedstock for applications focused on syngas production. However, its moderate yield of bio-oil and biochar also grants the substrate a degree of energetic versatility.

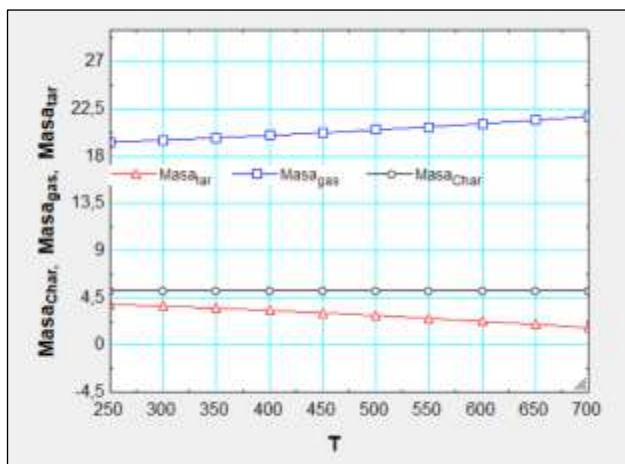


Figure 3: Mass distribution of corn cob products.  
Source: Authors, (2026)

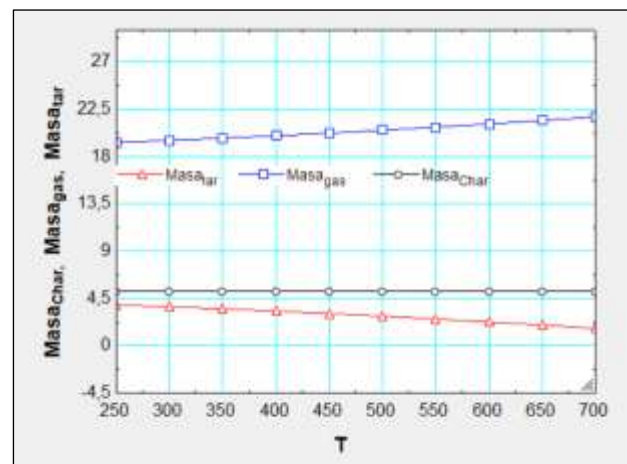


Figure 4: Products fraction.  
Source: Authors, (2026).

### III.2 PYROLYSIS OF COTTON GIN TRASH

Regarding cotton gin trash, the results presented in Figure 5 exhibit particularly favorable behavior, characterized by a high gas yield and a significant biochar fraction. This superior performance is attributable to its HHV of 18.26 MJ/kg and its elevated volatile matter content (68.42%), which intensify the thermal degradation kinetics and promote the formation of light gaseous species.



Figure 5: Pyrolysis of cotton gin trash.

Source: Authors, (2026).

Figure 6 reveals a gaseous composition with a noticeable increase in CO and H<sub>2</sub> compared to other biomasses. This increase in hydrogen is directly related to the presence of organic compounds rich in C–H bonds and to the enhanced release of free radicals during pyrolysis, which promote dehydrogenation reactions. The lower proportion of CO<sub>2</sub> indicates a more efficient degradation of the organic matrix, with reduced formation of undesirable oxygenated products.

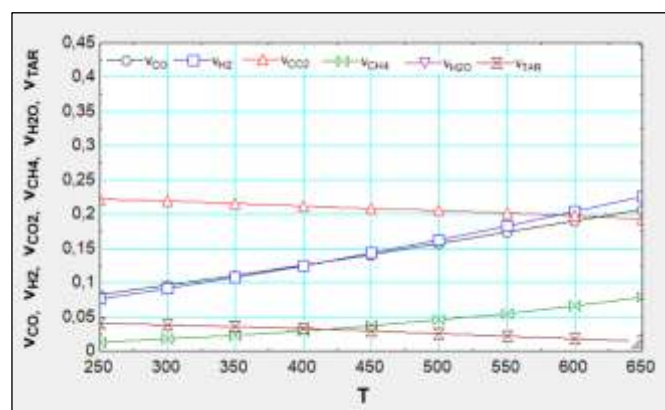


Figure 6: Composition of gaseous products during pyrolysis.

Source: Authors, (2026).

Figure 7 illustrates a clear dominance of the gaseous phase, accompanied by a significant biochar fraction. This behavior is a result of the moderate fixed carbon content, which facilitates the formation of stable carbonaceous structures without compromising gas yields. The liquid fraction remains regulated, suggesting an efficient pyrolysis process with limited tar formation. Figure 8 confirms that cotton gin trash achieves the highest biogas fraction in this study ( $\approx 49.17\%$ ), positioning it as one of the most attractive feedstocks for direct energy conversion systems, particularly in cogeneration and thermal energy production applications.

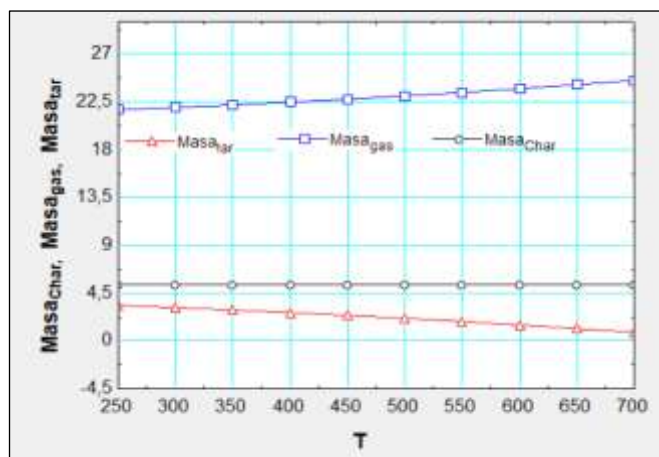


Figure 7: Mass distribution of corn cob products.

Source: Authors, (2026).

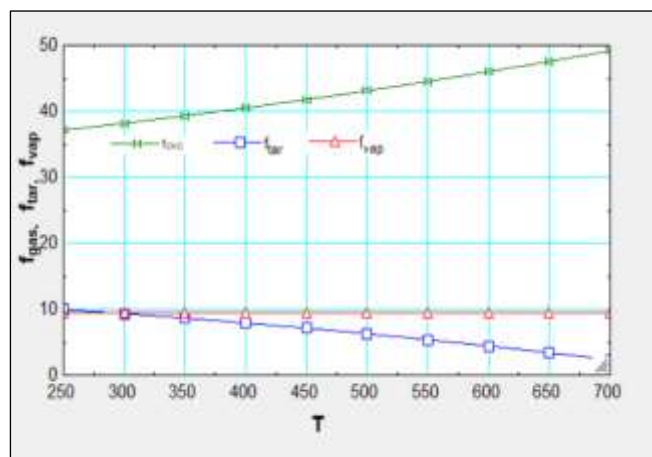


Figure 8: Products fraction.

Source: Authors, (2026).

### III.3 PYROLYSIS OF RICE HUSKS

The results corresponding to rice husk, shown in Figure 9, reflect a markedly different behavior compared to the other biomasses, mainly due to its high ash content rich in silica. These structural characteristic limits heat transfer within the particle and alters the kinetics of thermal decomposition.



Figure 9: Pyrolysis of rice husks.

Source: Authors, (2026).

Figure 10, a higher proportion of CO<sub>2</sub> relative to CO is observed, indicating a less efficient decomposition of the organic fraction. The presence of silica acts as a thermal inhibitor, reducing the intensity of cracking reactions and favoring internal partial oxidation processes. As a result, the generation of combustible gases such as H<sub>2</sub> and CH<sub>4</sub> remains relatively low.

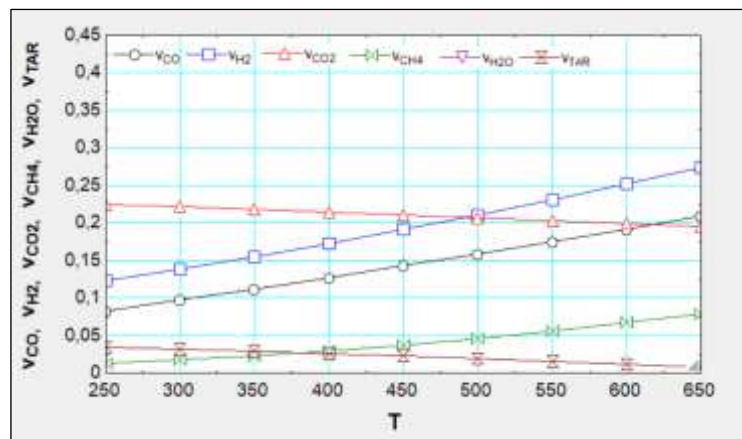


Figure 10: Composition of gaseous products during pyrolysis.

Source: Authors, 2026

Figure 11 illustrates a mass distribution with a significantly higher solid fraction compared to the other feedstocks evaluated. This behavior is attributed to the fact that a substantial portion of the inorganic mineral matter remains as solid residue post-pyrolysis, thereby artificially inflating the biochar fraction. In Figure 12, rice husk exhibits the highest biochar yield ( $\approx 17.29\%$ ), positioning it as a particularly suitable biomass for carbon sequestration applications, activated carbon production, or as a soil amendment, rather than for primary syngas or bio-oil generation.

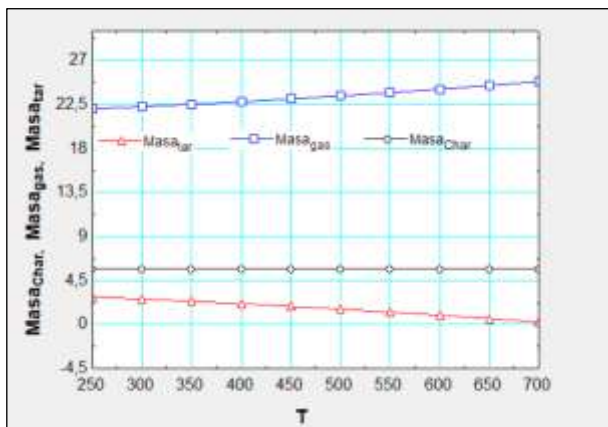


Figure 11: Mass distribution of corn cob products.

Source: Authors, (2026).

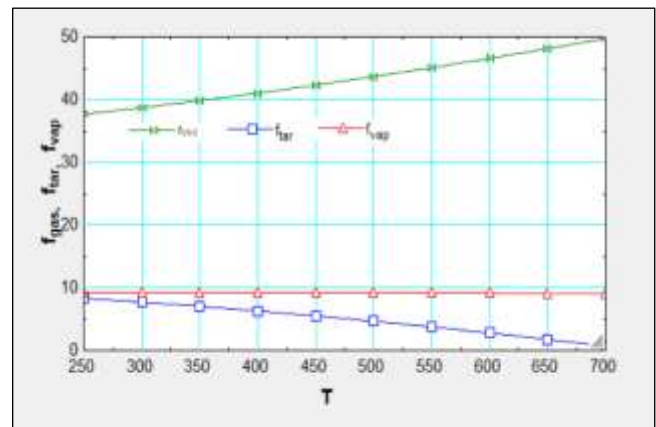


Figure 12: Products fraction.

Source: Authors, (2026).

### III.4 PYROLYSIS OF FLAX STRAW

Flax straw shows the most outstanding results in terms of gas production, as shown in Figure 13. This behavior is directly related to its high cellulose and hemicellulose content, together with a low lignin and fixed carbon content, which favors rapid and efficient thermal decomposition.

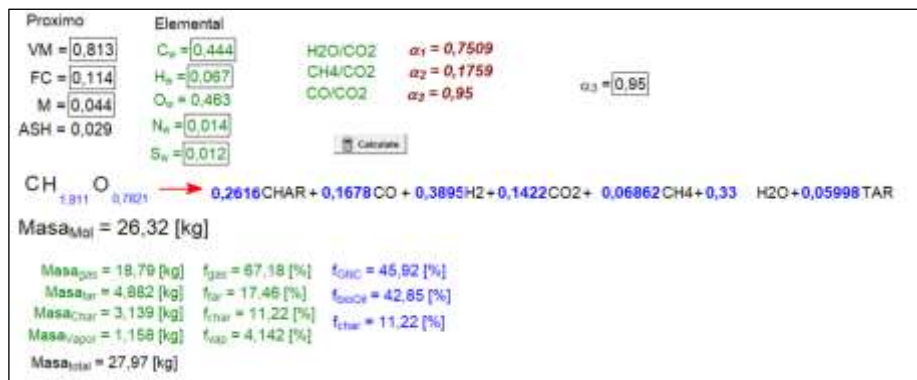


Figure 13: Pyrolysis of flax straw.

Source: Authors, (2026).

Figure 14, the gaseous composition is dominated by CO and H<sub>2</sub>, indicating an efficient conversion of the organic fraction into high-energy-value gases. The increase in hydrogen is associated with a greater availability of C–H bonds and a lower formation of stable aromatic structures, which are typical of lignin-rich biomasses.

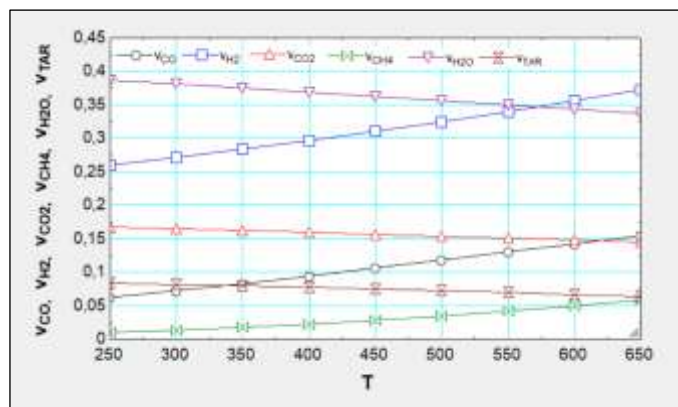


Figure 14: Composition of gaseous products during pyrolysis.

Source: Authors, (2026).

Figure 15 displays a mass distribution clearly dominated by the gas phase, whereas the biochar fraction is minimal. This behavior confirms that flax straw is highly suitable for processes aimed at maximizing gaseous energy yields, although it exhibits a reduced capacity for biochar production. Finally, Figure 16 reveals that, despite its excellent energetic performance, flax straw generates a higher ash fraction. This characteristic necessitates the integration of robust solid waste management strategies when considering large-scale industrial applications.

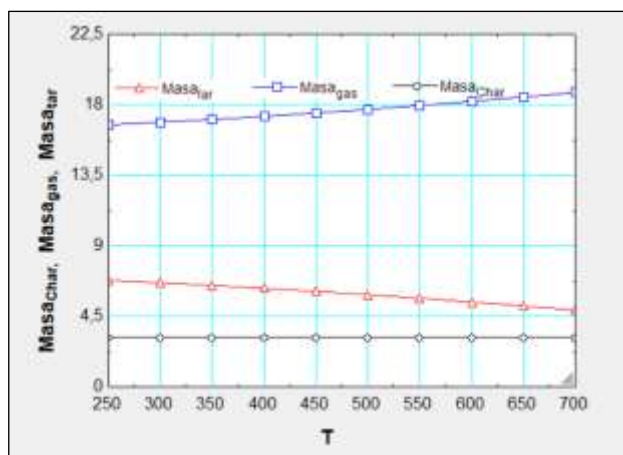


Figure 15: Mass distribution of corn cob products.

Source: Authors, (2026).

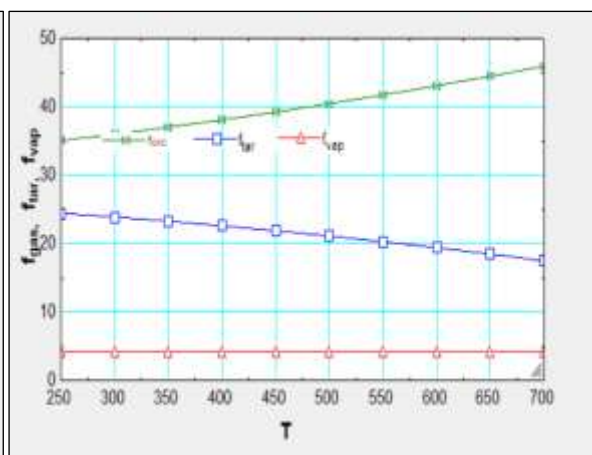


Figure 16: Products fraction.

Source: Authors, (2026).

### III.5 PYROLYSIS OF COCONUT HUSKS

The results for coconut husks, shown in Figure 17, reveal behavior dominated by bio-oil production, which is closely linked to their high lignin content. Lignin has a highly stable aromatic structure, which during pyrolysis tends to form condensable phenolic compounds rather than light gases.



Figure 17: Pyrolysis of coconut husks.  
Source: Authors, (2026).

Figure 18, the gaseous composition exhibits lower fractions of CO and H<sub>2</sub>, confirming that a significant portion of the chemical energy is directed toward liquid products. This trend is further accentuated by the thermal stability of lignin, which limits the complete breakdown of the carbonaceous matrix.

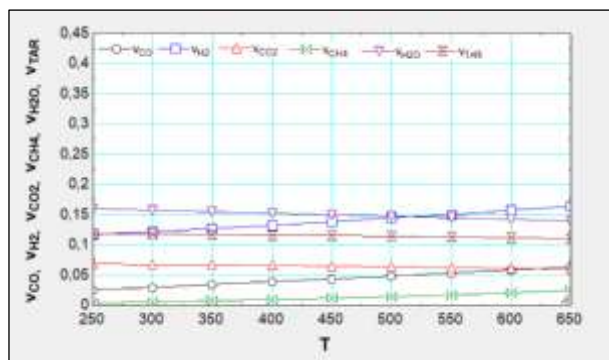


Figure 18: Composition of gaseous products during pyrolysis  
Source: Authors, (2026).

Figure 19 demonstrates a mass distribution clearly dominated by the liquid fraction, whereas the gaseous and solid phases remain secondary. This result is consistent with prior literature reporting high bio-oil yields from lignin-rich biomass sources. Finally, Figure 20 confirms that coconut shell achieves the highest bio-oil yield in this study ( $\approx 63.36\%$ ), positioning it as the most suitable feedstock to produce liquid biofuels and high-value-added chemical specialties.

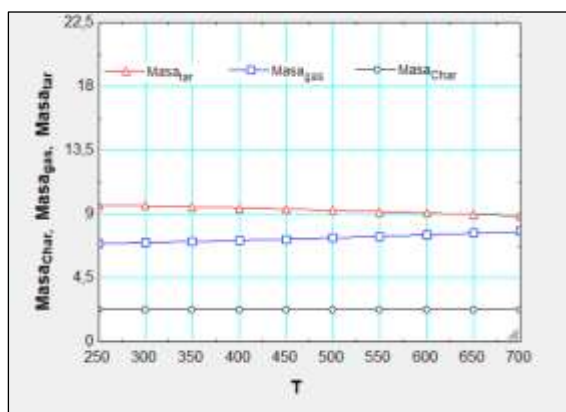


Figure 19: Mass distribution of corn cob products.  
Source: Authors, (2026).

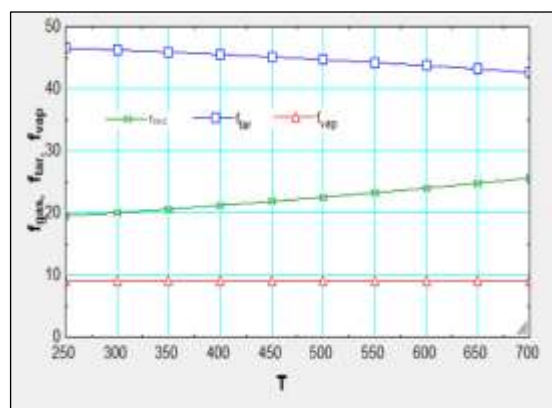


Figure 20: Products fraction.  
Source: Authors, (2026).

Figure 21 presents a direct comparison of the biogas, bio-oil, and biochar fractions obtained during the pyrolysis of the evaluated biomasses, highlighting the strong influence of the physicochemical composition of each residue on product distribution. It is observed that cotton gin trash and corn cob achieve the highest biogas fractions, which is attributed to their high volatile matter content and the predominance of cellulose and hemicellulose.

These components readily decompose within the typical temperature ranges of pyrolysis, promoting the release of light gases such as CO and H<sub>2</sub>. This behavior positions these biomasses as suitable feedstocks for applications focused on direct energy generation.

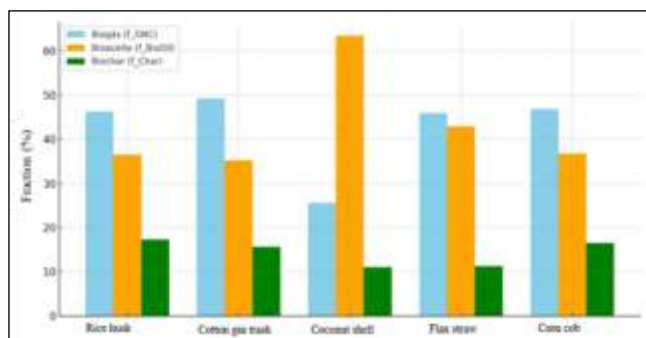


Figure 21: Composition of gaseous products during pyrolysis.  
Source: Authors, (2026).

In contrast, coconut shell exhibits the highest bio-oil fraction, exceeding 60%, a result directly correlated with its elevated lignin content. The aromatic structure of this macromolecule promotes the formation of phenolic compounds and condensable fractions during thermal degradation, thereby limiting gas conversion and shifting the process equilibrium toward liquid yields. This finding suggests a superior potential for coconut shell in the production of liquid biofuels or high-value chemical precursors. Conversely, rice husk displays a relatively higher biochar fraction, primarily attributed to its high silica-rich ash content, which remains as a solid residue post-pyrolysis. While this behavior constrains gas and bio-oil yields, it favors biochar applications in carbon sequestration, soil amendment, and adsorbent material synthesis. Collectively, the results illustrated in Figure 21 confirm that feedstock selection must be strategically aligned with the target end-product whether maximizing gaseous energy, bio-oil production, or biochar generation. This reinforces the necessity of integrating energetic and environmental criteria into the design and optimization of pyrolysis systems.

### III.6 EXERGOENVIRONMENTAL ANALYSIS OF BIOMASS FEEDSTOCKS

The environmental impact assessment of agro-industrial waste pyrolysis shows that this process provides clear net benefits in terms of sustainability and mitigation of GHG emissions, particularly when analyzed under an exergoenvironmental framework integrated with life cycle assessment. Replacing fossil fuels with biogas derived from pyrolysis enables a significant reduction in CO<sub>2</sub> and other GHG emissions by valorizing a renewable resource that, under conventional scenarios, is often disposed of through practices such as open burning, which are characterized by uncontrolled emissions and low energy recovery [2]. In this sense, the energetic use of biogas directly contributes to reducing the carbon footprint associated with thermal and electrical energy generation. From an exergoenvironmental perspective, a particularly relevant aspect is the production of biochar as a solid co-product of the process. Biochar is characterized by high structural stability and a high fixed carbon content, which confer a remarkable potential as a long-term carbon sink. Several studies have demonstrated that a significant fraction of the carbon retained in biochar is resistant to biological degradation, which can result in net negative GHG emissions when this material is applied to agricultural soils [17].

Life cycle assessments reported in the literature show substantial reductions in CO<sub>2</sub>-equivalent emissions when biochar is integrated as a soil amendment compared to conventional agricultural systems [18]. Additionally, the application of biochar exhibits positive effects on the dynamics of other GHGs beyond CO<sub>2</sub>. Recent meta-analyses have reported average reductions in N<sub>2</sub>O and CH<sub>4</sub> emissions on the order of 10–15% and 5–10%, respectively, associated with changes in soil microbial activity, improved nutrient retention, and alterations in nitrification and methanogenesis processes [19]. These effects complement the climate benefit of carbon sequestration and reinforce the environmental value of biochar within a circular economy framework. From a life cycle assessment perspective, recent studies indicate that pyrolysis systems with energy integration and efficient utilization of co-products tend to exhibit superior environmental performance compared to fossil fuel-based technologies or traditional waste disposal schemes. Overall, despite differences in assumptions, LCA results demonstrate that biochar represents a highly promising pathway to contribute to efficient carbon resource circulation, climate change mitigation, and economic sustainability [20]. Under optimized scenarios, including heat recovery, efficient biogas utilization, and productive application of biochar near-neutral or even negative GHG balances have been reported, highlighting the potential of pyrolysis to support decarbonization strategies.

## IV. CONCLUSIONS

This research conducted a comprehensive assessment of the pyrolysis process applied to five agro-industrial residues to analyze their energetic and exergoenvironmental performance, focusing on product distribution, gaseous composition, and the valorization potential of the resulting by-products. The findings confirm that the pyrolysis process is strictly governed by the physicochemical composition of the biomass, particularly the volatile matter, lignin, fixed carbon, and inorganic fractions. From an energetic standpoint, feedstocks such as flax straw, cotton gin trash, and corn cob exhibit superior potential for biogas generation due to their high cellulose and hemicellulose content, which promotes the formation of combustible gases during thermal degradation. In contrast, coconut shell demonstrated a distinct propensity for bio-oil production, attributable to its high lignin content and the thermal stability of its aromatic structure, while rice husk yielded a higher biochar fraction, influenced by its significant silica-rich ash content. The product distribution analysis established that no single biomass is universally optimal; rather, feedstock selection must be strategically aligned with the specific objectives of the conversion system, whether maximizing gaseous energy, producing liquid biofuels, or generating biochar for environmental or industrial purposes.

This finding underscores the importance of integrating design and operational criteria based on the differentiated valorization of each biomass type. From an exergoenvironmental standpoint, the results indicate that the pyrolysis of agro-industrial residues represents a favorable alternative for reducing environmental impacts, as it enables the partial substitution of fossil fuels with renewable energy and the valorization of by-products with high environmental value. In particular, the produced biochar exhibits significant potential as a long-term carbon sink, contributing to CO<sub>2</sub> sequestration and climate change mitigation when applied as a soil amendment or used in the production of adsorbent materials. Furthermore, the energetic utilization of biogas enhances the overall system efficiency and reduces exergy destruction associated with conventional waste disposal processes.

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