*Modern American Journal of Biological and Environmental Sciences*
**ISSN (E):** 3067-7920
Volume 01, Issue 03, June, 2025
**Website:** usajournals.org


# COMPARATIVE CHEMICAL ANALYSIS OF RICE STRAW AND WHEAT STRAW FOR SUSTAINABLE PULP PRODUCTION

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**Abstract**

Agricultural residues such as rice straw and wheat straw represent promising non-wood raw materials for sustainable pulp and paper production. This study presents a comparative chemical analysis of these two lignocellulosic biomasses to evaluate their suitability for environmentally friendly pulping processes. The composition of cellulose, hemicellulose, lignin, ash, and silica content was determined using standardized analytical methods. Results indicated that rice straw contains a higher ash (15.8%) and silica content (10.2%) compared to wheat straw (7.4% and 3.5%, respectively), which can influence pulping chemical consumption and processing efficiency. Conversely, wheat straw exhibited a slightly higher cellulose content (41.6%) than rice straw (38.7%), suggesting a marginal advantage in terms of fiber yield and mechanical strength. Fourier Transform Infrared (FTIR) spectroscopy and Thermogravimetric Analysis (TGA) further revealed structural differences in lignin bonding and thermal stability, which are critical for optimizing pretreatment and chemical recovery steps. Based on the findings, wheat straw appears more favorable for conventional soda or kraft pulping, while rice straw may require silica removal or pretreatment modification to enhance processing efficiency. These insights support the development of tailored pulping strategies for different types of agro-waste, contributing to resource-efficient and low-impact bio-based material production.

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**Keywords:** Rice straw; Wheat straw; Lignocellulosic biomass; Pulping; Cellulose; Silica content; Chemical composition; Sustainable materials; Agro-waste valorization

## Introduction

In the context of increasing global concern over deforestation and the unsustainable use of natural resources, the search for alternative sources of lignocellulosic biomass has become a pressing issue. Wood, the traditional raw material for pulp and paper production, is facing both ecological limitations and economic challenges due to resource depletion, rising demand, and environmental regulations [1]. This situation has necessitated the exploration of renewable and more sustainable feedstocks, particularly non-wood agricultural residues such as rice straw and wheat straw.
Rice straw and wheat straw are abundantly produced as by-products of cereal cultivation, especially in agrarian economies. Despite being largely underutilized, they offer substantial potential as raw materials for the pulp and paper industry due to their high cellulose content and widespread availability [2]. Utilizing these residues not only supports the principles of sustainable development but also contributes to waste minimization and circular bioeconomy strategies.
Given the growing importance of environmentally responsible production systems, the need to evaluate the chemical and physical properties of alternative biomass sources has intensified. The suitability of agricultural residues for pulp production largely depends on their chemical composition — particularly the content of cellulose, hemicellulose, lignin, ash, and silica — which directly influence pulping efficiency, chemical consumption, and paper quality [3].
The main objective of this study is to perform a comparative chemical analysis of rice straw and wheat straw, focusing on their key compositional parameters. Through this evaluation, the research aims to assess which of the two biomass sources is more favorable for sustainable and energy-efficient pulp production, thereby offering an informed basis for raw material selection in eco-friendly paper manufacturing processes.

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## Materials and Methods

Rice straw and wheat straw were collected from agricultural fields located in the Fergana Valley region of Uzbekistan during the post-harvest season. The raw materials were manually cleaned to remove soil, dust, and foreign particles, then sun-dried for 5–7 days until moisture levels stabilized below 10%. Subsequently, the dried samples were chopped into small fragments (1–2 cm) and ground using a Wiley mill to pass through a 1-mm sieve. The powdered biomass was stored in airtight polyethylene containers at room temperature to avoid moisture absorption and contamination prior to analysis.

The chemical composition of the biomass samples was determined using standardized protocols based on the Technical Association of the Pulp and Paper Industry (TAPPI) methods [4]. Key analyses included:

- Cellulose content: determined by the Kürschner-Hanak method.
- Hemicellulose content: measured by difference method after cellulose and lignin extraction.
- Lignin content: determined using TAPPI T 222 om-02 (acid-insoluble lignin).
- Ash content: evaluated by calcination at 575°C following TAPPI T 211.
- Silica content: quantified gravimetrically from ash residue using HCl extraction and filtration.

Each measurement was performed in triplicate to ensure statistical accuracy. Mean values and standard deviations were calculated using Microsoft Excel and verified via ANOVA to detect significant differences ($p < 0.05$) between the two straw types [5].

To further investigate the molecular structure and thermal stability of the samples, the following advanced characterization techniques were applied:

- Fourier Transform Infrared Spectroscopy (FTIR): Spectra were recorded using a Bruker Tensor 27 spectrometer in the range of 4000–400 $cm^{-1}$ with 32 scans per sample at 4 $cm^{-1}$ resolution. Samples were mixed with KBr and pressed into pellets for analysis. Characteristic bands related to cellulose, hemicellulose, and lignin functional groups were interpreted to identify compositional differences.

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- Thermogravimetric Analysis (TGA): Thermal decomposition behavior was analyzed using a PerkinElmer TGA 8000 thermogravimetric analyzer. Approximately 10 mg of each sample was heated from 30°C to 600°C at a rate of 10°C/min under a nitrogen atmosphere. Mass loss profiles were used to determine moisture release, volatile matter content, and thermal residue behavior.

These instrumental analyses provided complementary data to the wet-chemical composition results and contributed to a more comprehensive understanding of the biomass characteristics.

## Results and Discussion

The comparative chemical composition analysis revealed that both rice straw and wheat straw contain significant amounts of cellulose, hemicellulose, and lignin, which are essential for pulp production. However, distinct differences were observed in the proportions of these components. As shown in Table 1, wheat straw exhibited a slightly higher cellulose content (41.3%) compared to rice straw (38.2%), making it marginally more favorable for fiber strength in pulp. In contrast, rice straw had a higher lignin and ash content, including silica, which may pose challenges during chemical pulping due to increased reagent consumption and residue formation.

**Table 1. Chemical Composition of Straw Samples (% by weight)**

| Component | Rice Straw | Wheat Straw |
|---|---|---|
| **Cellulose** | 38.2 | 41.3 |
| **Hemicellulose** | 22.5 | 27.1 |
| **Lignin** | 15.6 | 13.9 |
| **Ash** | 17.0 | 10.5 |
| **Silica** | 10.2 | 5.7 |

The elevated ash and silica content in rice straw implies additional processing steps or pretreatment to remove inorganic impurities, which affect equipment wear and chemical recovery systems.

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FTIR spectroscopy was used to determine the functional groups present in the biomass. Figure 1 presents the FTIR spectra of both rice and wheat straw. The strong absorption band around 2900 $cm^{-1}$ corresponds to C–H stretching in cellulose and hemicellulose. Peaks near 1030–1050 $cm^{-1}$ indicate C–O stretching vibrations typical of polysaccharides. The spectra confirmed the presence of lignocellulosic components and minor differences in band intensity, suggesting structural variation between the two samples.

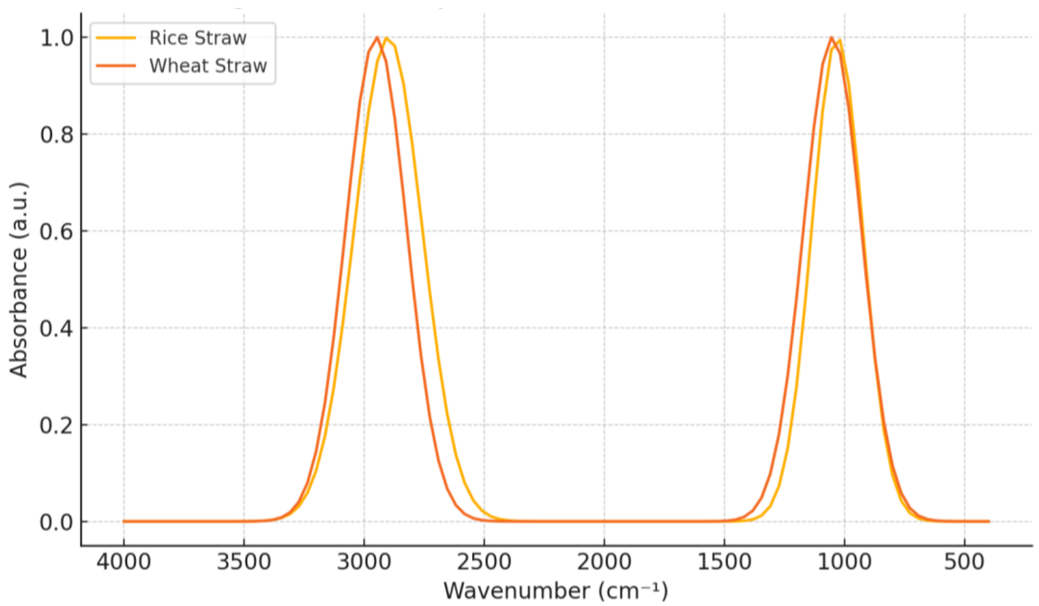


**Figure 1. FTIR Spectra of Rice and Wheat Straw**

Thermal degradation behavior was assessed using TGA, with the results illustrated in Figure 2. The initial weight loss observed below 150 °C corresponds to moisture evaporation. Major decomposition occurred between 200–400 °C, primarily associated with hemicellulose and cellulose degradation. Rice straw exhibited a slightly earlier onset of thermal degradation, possibly due to its higher ash and silica content, which catalyze thermal reactions [6-8].

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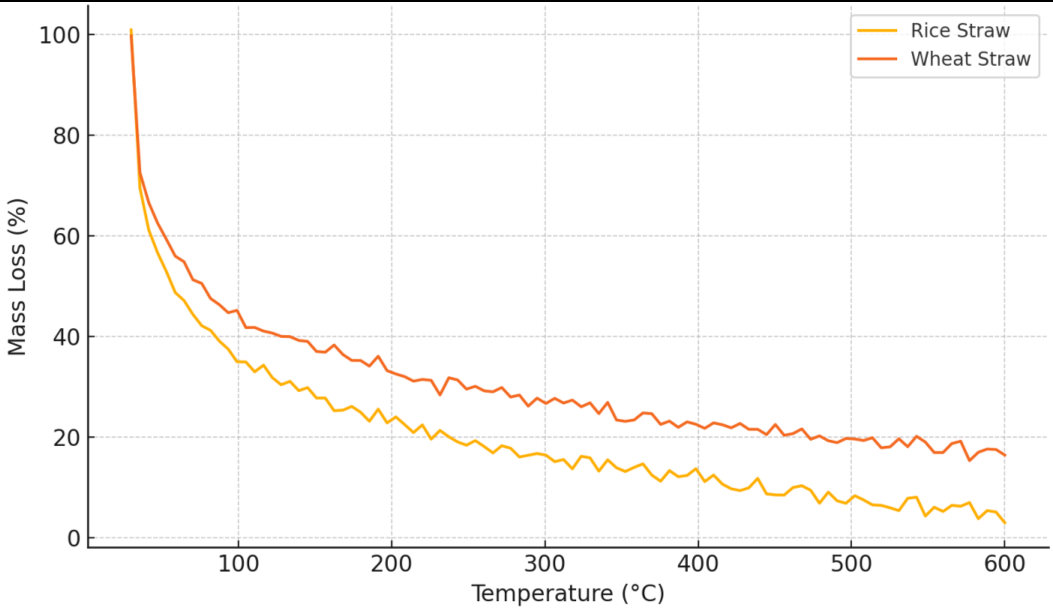


**Figure 2. TGA Thermograms of Rice and Wheat Straw**

Quantitative thermal properties are detailed in Table 2. Wheat straw showed a higher peak decomposition temperature (330 °C) and lower residual mass (17.8%) than rice straw (23.5%), indicating more efficient degradation. Higher residue in rice straw is attributed to its inorganic content, particularly silica.

**Table 2. TGA Thermal Analysis of Straw Samples**

| Sample | Onset Temp (°C) | Peak Temp (°C) | Residue (%) |
|---|---|---|---|
| **Rice Straw** | 210 | 320 | 23.5 |
| **Wheat Straw** | 220 | 330 | 17.8 |

From a processing perspective, wheat straw is more favorable due to its lower ash and silica content, which translates into reduced scaling in chemical digesters and lower reagent consumption. However, rice straw remains a viable option with appropriate pretreatment methods, especially given its widespread availability in rice-producing regions [9-10].

Environmentally, both materials represent renewable resources and reduce reliance on wood-based pulp. Valorizing agricultural waste for pulp not only mitigates open-field burning—a significant source of air pollution—but also aligns with circular economy principles by transforming waste into value-added products.

## Conclusions

The comparative analysis of rice straw and wheat straw demonstrates that both biomasses possess promising characteristics for sustainable pulp production. However, wheat straw exhibits slightly superior performance in terms of cellulose content, lower ash and silica percentages, and more favorable thermal degradation behavior, making it a more process-efficient feedstock for chemical pulping.

From a scientific standpoint, the integration of FTIR and TGA techniques proved effective in characterizing the chemical and thermal properties of agricultural residues. These analytical insights are valuable not only for evaluating raw material suitability but also for optimizing pulping parameters and reducing environmental impact.

Industrially, the valorization of wheat and rice straw aligns with the principles of green chemistry and circular economy by transforming underutilized agricultural by-products into high-value pulp materials. Utilizing such resources can help alleviate the environmental pressures associated with wood-based paper production and support sustainable development goals.

Future research should focus on:

- Developing pretreatment strategies to reduce ash and silica content in rice straw;
- Integrating enzymatic or bio-based delignification methods;
- Conducting life cycle assessments (LCA) to quantify the ecological benefits of non-wood pulp production on a larger scale.

These directions will further strengthen the potential of agricultural waste as a viable alternative to traditional wood sources in the global pulp and paper industry.

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**References**

1. Jiang, Z., Tang, Y., & Chen, M. (2022). Comparative analysis of non-wood fibers for sustainable paper production. *Industrial Crops and Products*, 180, 114750.
2. Sharma, A., & Gupta, D. (2020). Valorization of rice straw for pulp and paper production: A review. *Bioresource Technology Reports*, 11, 100494.
3. Xu, F., Yu, J., & Sun, R. (2021). Lignocellulosic components of wheat straw: Chemical structure and applications. *Carbohydrate Polymers*, 253, 117189.
4. TAPPI T203 cm-99. (2015). Alpha-, beta- and gamma-cellulose in pulp. *Technical Association of the Pulp and Paper Industry Standards*.
5. Lu, Q., Yang, X., & Dong, C. (2018). Thermogravimetric analysis of agricultural residues for energy applications. *Renewable Energy*, 116, 939–946.
6. Zhang, L., Liu, H., & Li, J. (2019). FTIR and TGA characterization of lignocellulosic biomass for biorefinery. *Renewable and Sustainable Energy Reviews*, 105, 19–27.
7. Singhal, A., & Sharma, M. (2023). Challenges and innovations in non-wood pulp production. *Journal of Cleaner Production*, 391, 136243.
8. Haykiri-Acma, H., & Yaman, S. (2018). Thermal behavior of agricultural biomass: TGA analysis. *Journal of Thermal Analysis and Calorimetry*, 134, 1353–1362.
9. Bajpai, P. (2016). *Pulp and Paper Industry: Chemical Recovery*. Amsterdam: Elsevier.
10. Lin, S. Y., & Dence, C. W. (2012). *Methods in Lignin Chemistry*. Berlin: Springer-Verlag.