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PHYSICOCHEMICAL AND THERMAL CHARACTERIZATION OF PRODUCTS FORMED DURING THE SLOW PYROLYSIS OF WOOD WASTE

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Abstract
In this study, the yield and physicochemical properties of condensable products (wood vinegar and bio-oil), charcoal (biochar), and gas fractions formed during the slow pyrolysis of willow and poplar wood chips and board waste were investigated. In addition, the thermal stability of charcoal samples was evaluated. The results confirmed that the type of waste and particle size significantly affect product quality and energy characteristics.

Introduction

Pyrolysis of biomass is one of the promising methods for producing alternative fuels and high value-added products. During the slow pyrolysis process, biomass decomposes under high temperature in an oxygen-free environment and produces three main products:

- **Solid product** — charcoal (biochar)
- **Liquid condensable products** — wood vinegar and bio-oil
- **Non-condensable gases**

In this study, the behavior of wood chips and board waste during the pyrolysis process and the quality of the resulting products were comparatively analyzed.

2. Physicochemical Characteristics of Condensable Products

The following parameters were determined for wood vinegar and bio-oil samples:
Color and appearance
Amount of insoluble particles (%)
Density (g/mL)
Electrical conductivity (mS/cm)
pH value

2.1. Color and Appearance

Wood vinegar obtained from both types of waste had a reddish-yellow color, while bio-oil appeared smoky black.

2.2. Insoluble Particles

The amount of insoluble particles in wood vinegar was very low (0.15–0.16%). In bio-oil, however, this value was significantly higher (11.5–13.5%), indicating its higher viscosity and complex organic composition.

2.3. Density and Electrical Conductivity

- Density of wood vinegar: 1.02 g/mL
- Density of bio-oil: 1.02–1.10 g/mL

The higher density of bio-oil indicates that it contains heavier fractions. Electrical conductivity was also higher in bio-oil (3.0–3.1 mS/cm) compared to wood vinegar (2.2–2.3 mS/cm), indicating a higher concentration of ionic compounds.

2.4. pH Value

Wood vinegar has a strongly acidic environment (pH ≈ 2.9), which determines its antibacterial and pesticide properties. Bio-oil has a slightly higher pH value (3.0–3.1).

3. Yield of Pyrolysis Products

During the slow pyrolysis process, the distribution of products was as follows:
Charcoal: 26–28%
Wood vinegar: 28–30%
Non-condensable gases: ≈37%
Bio-oil: 7.7% (higher in board waste)
No significant differences were observed in the yield of charcoal and wood vinegar. However, the yield of bio-oil was higher in board waste. This can be explained by differences in moisture content, density, and heat transfer conditions.

4. Physical, Chemical, and Energy Properties of Charcoal

4.1. Physical Characteristics

- Bulk density: 0.23 g/cm³ (for both types)
- Moisture content: 4.13–4.44%
- Mechanical stability: high

4.2. Chemical Composition

The elemental composition of the obtained charcoal samples is presented in the table below.

Parameter	Board (%)	Chips (%)
Carbon	79.6	82.4
Hydrogen	2.97	2.48
Oxygen	14.11	7.78
Ash	3.26	3.21

The results show that the carbon content in charcoal obtained from wood chips (82.4%) is higher than that obtained from board waste (79.6%). A higher carbon content generally indicates better fuel properties and higher calorific value.

The oxygen content is noticeably higher in board-derived charcoal, which may reduce its energy density compared with charcoal obtained from wood chips.

The ash content in both samples is relatively low (about 3%), indicating that the resulting biochar has good quality and suitability for fuel and soil improvement applications.

Charcoal obtained from wood chips contains a higher carbon content and lower oxygen content, indicating a more complete pyrolysis process.

4.3. Energy Characteristics

- Board waste: 28.33 MJ/kg
- Wood chips: 31.16 MJ/kg

Charcoal obtained from wood chips has a higher calorific value, indicating greater energy efficiency.

5. Temperature Stages

- 25–100 °C: evaporation of moisture
- 100–200 °C: release of volatile compounds
- 200–800 °C: decomposition of hemicellulose, cellulose, and lignin

A maximum decomposition peak was observed on the DTG curve in the temperature range of 450–550 °C.

Charcoal obtained from board waste retained more residual mass at higher temperatures, indicating the presence of partially unpyrolyzed components.

6. Discussion

The results indicate that:

- Wood chips, due to their smaller particle size, allow faster heat transfer, resulting in a more complete pyrolysis process.
- Board waste produces a higher bio-oil yield, but the resulting charcoal may still contain partially decomposed lignin fractions.
- The physicochemical properties of condensable products are similar for both raw material types, which allows flexible industrial application.

7. Conclusion

- Willow and poplar wood waste produce stable and high-quality products during the slow pyrolysis process.
- Wood chips generate charcoal with higher carbon content and a higher calorific value (31.16 MJ/kg).
- Board waste increases the bio-oil yield (7.7%).

REFERENCES

1.Kholikov, Komil. "Determination of the fraction composition of bio-oil products in a laboratory device." *BIO Web of Conferences*. Vol. 71. EDP Sciences, 2023.

2.Nurmahmatovich, Kholikov Kamil. "The influence of the main technological parameters on the pyrolysis process." *European Scholar Journal* 3.11 (2022): 35-38.

3.Nurmahmatovich, Xoliqov Komil. "Trubkasirnon piroliz pechidan olingan mahsulotlar va ularning tarkibi. Лучшие интеллектуальные исследования, 20 (4), 108–113." 2024,

4.Узаков, Г. Н., Давлонов, Х. А., Хужакулов, С. М., & Холиков, К. Н. (2019, May). Оценка энергетической эффективности пиролизной установки для систем топливоснабжения теплиц. In *Proceedings of the XIII internationalScientific and Practical Conference «International Trends in Science snd Technology* (Vol. 1, pp. 33-35).

5.Uzakov, G. N., H. A. Davlonov, and K. N. Xoliqov. "Applied Solar Energy, 2020, Vol. 54, No. 6." (2019): 481-484.

6.Uzakov, G. N., H. A. Davlonov, and K. N. Holikov. "Study of the influence of the source biomass moisture content on pyrolysis parameters." *Applied Solar Energy* 54.6 (2018): 481-484.

7.Холиқов, Комил Нурмаҳматович. "Бионефт маҳсулотларининг фракцион таркибини лаборатория қурилмасида аниқлаш." *Лучшие интеллектуальные исследования* 7.1 (2023): 16-24.

8.Холиқов, Комил Нурмаҳматович. "Пиролиз қурилмасининг иссиқлик алмашинуви ва иссиқлик ўтказиш жараёнини аниқлаш." *Ta'lim Innovatsiyasi va Integratsiyasi* 7.1 (2023): 137-146.

9.Uzakov, G. N., X. A. Davlonov, and K. N. Holikov. "Study of the Influence of the Source Biomass Moisture Content on Pyrolysis Parameters. Applied Solar Energy, 54 (6), 481–484." 2018,

10.Nurmahmatovich, Kholikov Komil. "General information about bioneft products." *British Journal of Global Ecology and Sustainable Development* 10 (2022): 121-124.

11.Nurmahmatovich, Kholikov Komil. "General information about bioneft products." *British Journal of Global Ecology and Sustainable Development* 10 (2022): 121-124.

12.Nurmahmatovich, Kholikov Komil. "Renewable Energy is A Traditional Energy Production technology." *Galaxy International Interdisciplinary Research Journal* 10.2 (2022): 407-409.

13.Салайдинов, Ачил Мейлиевич, and Комил Нурмахматович Холиков. "Алгоритмические приёмы в процессе решения физических задач." *World scientific research journal* 22.1 (2023): 53-60.

14.Нурмахматович, Холиков Комил. "Возобновляемая энергетика–традиционная технология производства энергии." *Международный журнал междисциплинарных исследований Galaxy* 10.2 (2022): 407-409.

15.Nurmahmatovich, Xoliqov Komil. "Biomassani qayta ishlash orqali energetik jihatdan qimmatli mahsulotlarga aylantirish texnologiyalari." *Sanoatda raqamli texnologiyalar/ Цифровые технологии в промышленности* 3.1 (2025): 182-185.

16.Nurmahmatovich, Xoliqov Komil. "Xomashyoni piroliz qilish va uning energiyasini texnologik jarayonlarida qo ‘llanishi yo‘llari." *International Journal Of Integrated Sciences* 1.1 (2025)

17.Салайдинов, Ачил Мейлиевич, Комил Нурмахматович Холиков. "Последовательности и пределы при решение физических задач." *ACTIVIST SCIENCE* 1.1 (2025).

18.Турсунов, М., Сабиров, Х., Холов, У., Холиков, К. и Эшматов, М. (ноябрь 2025 г.). Моделирование эффективности фотоэлектрических и фототермических аккумуляторов с использованием программного обеспечения Python. В *материалах конференции AIP* (том 3331, № 1, стр. 030062). AIP Publishing LLC.

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