25 *Egypt. J. Agron.* **Vol. 47**, No. 2, pp: 293 - 302 (2025)

Egyptian Journal of Agronomy

http://agro.journals.ekb.eg/

Production of Dry Biofuel from rice straw and cotton stalk by Torrefaction Process

Mohamed H. Hemida[1*], AbdElhay Y. B[1], Heba M.Moustfa[1] and **Badr M. Ali[1]**

[1] *Agricultural Engineering Department, Faculty of Agriculture, Cairo University, Giza, Egypt*

THIS RESEARCH aims to estimate and calculate some thermal properties of torrefied product from torrefaction process of rice straw and cotton stalk under different torrefaction temperatures (200,250,300) °C, size (1.5, 3) cm and holding time (15,30,45) min. The calorific value for torrified product was estimated and the mass yield, energy yield and energy density were calculated for rice straw and cotton stalk. The results showed that the calorific value is affected by the torrefaction temperature, size and holding time. The highest calorific value for rice straw was 18.7 MJ / kg and for cotton stalk was 20.1 MJ/kg, at torrefaction temperature of 250 °C, size 1.5 cm, and holding time 30 min. Also, the mass yield and energy yield decrease with increasing torrefaction temperature, size and holding time, the highest value of mass yield and energy yield for rice straw were 70.1% and 72.84%, respectively, at torrefaction temperature 200 °C and size 1.5 cm and holding time 15 minutes. The highest value of mass yield and energy yield for cotton stalk was 74.5% and 76.44%, respectively, at torrefaction temperature 200 °C, size1.5 cm, and a holding time of 15 minutes. Also, the result indicated that the energy density for rice straw and cotton stalk was affected by the torrefaction temperature, size and holding time. The highest value of energy density for rice straw and cotton stalk were 1.24 and 1.17 respectively at torrefaction temperature of 250 °C, size 1.5 cm, and holding time 30 min.

Keywords: Torrefaction; Dry Biofuel; Rice straw; cotton stalk; Energy yield; Mass yield.

Introduction

Agricultural production is an essential element of the national income. It is necessary to work on solving any problems it faces in order to improve and increase productivity. the agricultural sector employs more than half of the workforce in Egyptian society (Hagras et al., 2025; Sadowski et al., 2024). Most of these problems among farmers is how to get rid of agricultural waste, which amounts to about 35 million tons annually (Hassan et al., 2014). A deficient percentage of agricultural waste is used for recycling approximately 15%, and the rest is often burned in the fields (Sadowski et al., 2024), which leads to environmental pollution (Riseh et al., 2024). Agricultural waste is considered one of the most important types of traditional fuel in the Egyptian countryside as a source of energy used in industrial furnaces, especially in the governorates of Upper Egypt and the Delta. Large quantities of agricultural waste are generated in these governorates, but it is a source of environmental pollution when used as fuel as a result of burning (Jain et al., 2024; Moustafa, Ahmed, et al., 2022). These agricultural wastes have specific characteristics such as low apparent density, relatively high humidity, hydrophilic components, low calorific value, difficulty in use on a large scale, and low energy density (Abd-Allah et al., 2025; Danewalia et al., 2016). There is also difficulty in transporting, handling, and storing these wastes. Agricultural wastes are by-products within the agricultural production system. Utilization must be maximized from them by converting them into organic fertilizers, fodder, human food, or clean energy, or manufacturing them (Eyssa et al., 2023; Odejobi et al., 2024). This contributes to achieving clean agriculture, protecting the environment from pollution (Abd El Lateef et al., 2025; Moustafa et al., 2025). Improving agricultural products, and providing employment opportunities in the countryside (Kaewtrakulchai et al., 2024; Mohamed Hussein &

* Corresponding author: mohamed.h.hemidal@agr.cu.edu.eg - Orcid ID: 0000-0003-1081-7084
Received: 02/03/2025; Accepted: 28/06/2025

DOI: 10.21608/agro.2025.364926.1636

Hussein, 2025). Thus, improving the economic, environmental situation, raising the level of health and social status among farmers in the Egyptian countryside (Hemida et al., 2023; Yang & Solangi, 2024). Biomass from agricultural waste is a unique fuel and has the potential to play a significant role in the future energy mix with the other renewables (Hemida et al., 2024; Yusriadi et al., 2024). Biomass can provide continuous electricity generation (Makepa & Chihobo, 2024; Moustafa, Nasr, et al., 2022), and is the only widespread source of renewable heat. Increased use of biomass as a source of energy (electricity and heat) will contribute to the reduction of CO2 emissions (Kalak, 2023; Youssef et al., 2025), increase energy security, and support sustainable development and regeneration of rural areas, both through increased agricultural and forestry activity and the provision of small scale localized energy and heat generation schemes. (Isawi et al., 2025; Ishii et al., 2016) were stated that converting waste into pelletizers facilitates handling, transportation and storage. Torrefied biomass could provide a way for countries and regions where interest in biomass co-firing has only recently begun to leapfrog technology without requiring significant modifications to existing plants (Daba & Hailegiorgis, 2023; Eling et al., 2024). Today, successful coffering of torrefied biomass in the cement industries has the potential to lower the cost of coal used in energy generation (Li, 2024). Rice straw and cotton stalk are among the most important field wastes due to their quantities. Cotton stalk leaves from an acre about 1.6 tons of stalk with a moisture content of 9.5%. Part of it is used in the production of direct energy by burning in ovens or molding it and then burning it, or it is used in a small percentage in the production of fodder and fertilizers (Li, 2024; Srivastava et al., 2024). As for rice straw its annual quantity reaches 3 million tons. An acre leaves 2 tons of straw annually with a moisture content of 11.8%. Part of it is used in many fields as an alternative raw material for the manufacture of paper and wood (Güleç et al., 2024; Moustafa et al., 2018; Moustafa, Hemida, et al., 2024), the production of biochar and active carbon, the production of fodder and fertilizers, as a cradle for agriculture, the production of mushrooms, and many other fields (Akshaya et al., 2023; Moustafa, Shemis, et al., 2024). It is still most of it is burned causing high environmental pollution. Torrefaction process is a heating process that carbonizes the biomass and leads to the improvement of the biomass as a fuel as it reduces its moisture content, which makes the biomass energy dense and thus increases the calorific value of the biomass (Aziz et al., 2024). Torrefaction, also known as roasting or high-temperature drying) is a mild pyrolysis process based on the thermal degradation of biomass at temperatures ranging from 200°C to 300 °C, mainly in inert atmosphere (Mpungu et al., 2024). This research aims to study the effect of torrefaction temperature, holding time, and waste size of rice straw and cotton stalk on calorific value, mass yield, energy yield, and energy density to be used as high-grade fuel

Materials and Methods

Materials

Rice straw and cotton stalks residues were collected from the fields in Sharkia Governorate, Egypt, and cut into various sizes and weighed in preparation for the torrefaction process. The wastes of rice straw and cotton stalk were cut into different sizes (1.5, 3 cm). They were weighed and then placed in laboratory torrefaction system, this system includes a furnace tube has two holes connected to the nitrogen gas hose, which is connected to the nitrogen tube, and the other is connected to a wire with a sensor connected at one end to the temperature controller to estimate the temperature in the tube and the regularity of temperature stabilization. The other end of the furnace tube is connected to a glass tube for the exit of gases from it to a condenser. These component of laboratory torrefaction system as illustrated in (Fig.1) (Chen, C., et al., 2021).

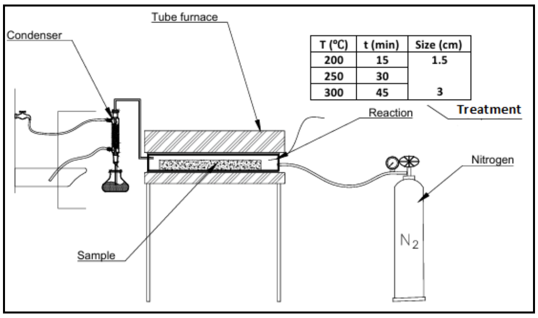

Fig. 1: Basic components of the laboratory torrefaction system

200 gm of rice straw and 400 gm of cotton stalk residue were placed separately from the size of 1.5 and 3 cm each residue, and three temperatures were applied for the laboratory torrefaction unit. Torrefaction temperature (200, 250 and 300 °C), at a heating rate 15 °C/min, and the holding time where (15, 30 and 45 minutes) for each specimen. All specimens were performed in a nitrogen atmosphere at a flow rate of 60 mL/min. The specimens were taken after the torrefaction process, and they were milling and then adding an adhesive to each combination, which is (hexamine), then the specimen was compressed into pellets. The calorific

value for torrefied product was estimated and the mass yield, energy yield and energy density for rice straw and cotton stalk were calculated.

Energy yield and Mass yield

According to (Hill et al., 2013), the primary benefit of torrefaction lies in its enhanced energy density and improved material quality. Temperature and processing time both affect the amount of energy produced during torrefaction. Mass and energy yield are two metrics that are used to gauge how effective torrefaction is (Al Afif et al., 2024; W.-H. Chen et al., 2021). Energy content is decreased by components of biomass, such as water and ash content. Reducing or getting rid of these elements makes the biomass more energy-rich. According to (Hill et al., 2013; Massaro Sousa et al., 2024).the ratio of dry torrefied biomass to dry, untreated biomass (Eq. 1) is the mass yield during torrefaction. The ratio of char's lower heating value to untreated biomass's lower heating value represents the energy yield during torrefaction (Eq. 2) (Khairy et al., 2024)

$$\text{Mass yield} = M1/M0 \times 100 \qquad [1]$$

$$\text{Energy yield} = V1/V0 \times 100 \qquad [2]$$

Where, M0 denotes the mass of the specimen before torrefaction process (g), M1 denotes the mass of the specimen after torrefaction process (g), $V0$ denotes the calorific value of the specimen before torrefaction process (MJ/kg), as well as $V1$ denotes the calorific value of the specimen after torrefaction process (MJ/kg).

Energy Density

The torrefaction product's energy density is still another crucial component(Javanmard et al., 2023).Terms like specific energy, calorific value, and heating value are also linked to energy density. Energy density was calculated as follows(Zhou et al., 2024; Zhu et al., 2024):

$$\text{Energy density ratio} = \frac{\text{Energy yield}}{\text{Mass yield}} \qquad [3]$$

Results and Discussion

Torrefaction product can be observed from the physical appearance, such as a color change from the original color (Fig. 2a) to a dark brown color, as shown in (Fig. 2b).

Fig. 2: Effect of torrefaction process on the color of cotton stalk (a) before torrefaction and (b) After torrefaction process

Figures (3) through (5) show the effect of holding time and the size of specimen at different of torrefaction temperature, on calorific value for torriefied rice straw. The results indicated that the calorific value decreases with the increase in the size and the decrease in the holding time. Where at torrefaction temperature 200 ℃, holding time 15 min the calorific value was 15.7 MJ/ kg at size 1.5 cm. While its value was 15.3 MJ/ kg, at size 3cm. On the other hand, at holding time 30 min the calorific value was 16.9 MJ/ kg at size 1.5 cm, while its value was 16.6 MJ/ kg, at size 3cm. Also, at holding time 45 min the calorific value was 16.5 MJ/ kg at size 1.5 cm, while its value was 16.4 MJ/ kg, at size 3cm, as shown in (Fig. 3). Fig. 4. indicated that when a torrefaction temperature 250 ℃ of the rice straw, the calorific value was 17.9 MJ/ kg at holding time 15 min and size 1.5 cm. On the other hand, its value is greater at holding time 30 min and size 1.5 cm where the calorific value was 18.7 MJ/ kg than at holding time 45 min with size 3 cm, where the calorific value was 17.6 MJ/ kg.

Fig. 5. indicated that at torrefaction temperature of 300 ℃ for the rice straw, the calorific value was 17.75 MJ/ kg at holding time 45 min and size 3cm.On the other hand the calorific value increases with the decrease in the size and the decrease in the holding time, where the calorific value was 18MJ/ kg at holding time 15 min and size 1.5 cm. The highest calorific value of rice straw at torrefaction temperature 250 ℃ with size of 1.5 cm and holding time of 30 min was 18.7 MJ/kg. While the lowest value was for the calorific value at the torrefaction temperature of 200 ℃, size 3 cm and the holding time was 15 min, as the value was 15.3 MJ/kg.

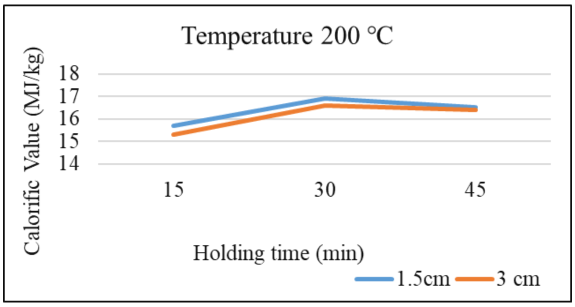

Fig. 3: Effect of holding time and the size of specimen at torrefaction temperature 200°C on calorific value for torriefied rice straw.

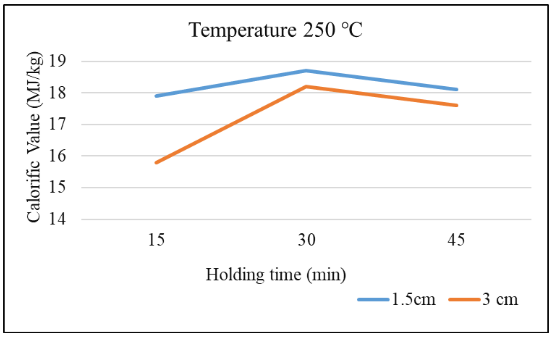

Fig. 4: Effect of holding time and the size of specimen at torrefaction temperature 250°C on calorific value for torriefied rice straw.

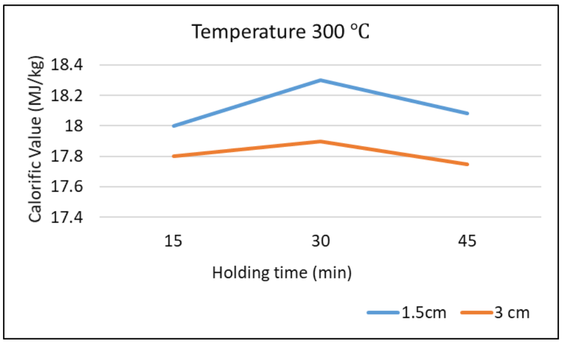

Fig.5: Effect of holding time and the size of specimen at torrefaction temperature 300°C on calorific value for torriefied rice straw.

Fig. 6. and Fig. 7. Show the effect of torrefaction temperature, holding time and the size of specimen on energy yield for torriefied rice straw. it is noted that they are mainly affected by the size and torrefaction temperature, where the lower temperature and the small size, the value of the energy yield increases. The highest value was 75.61% at size 1.5 cm, torrefaction temperature 200°C and holding time 30 min. On the other hand, the lowest value was 44.64% at torrefaction temperature 300 °C and size 3 cm and holding time 45 min.

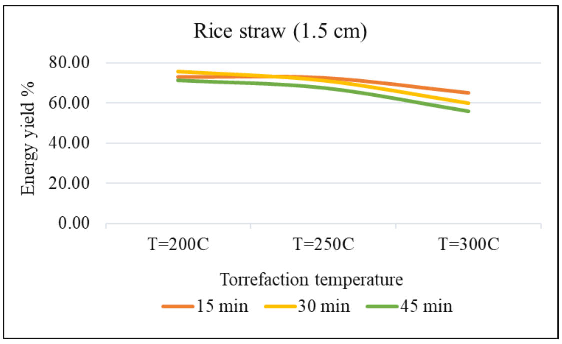

Fig. 6: Effect of torrefaction temperature for rice straw at size 1.5 cm on energy yield at different holding time.

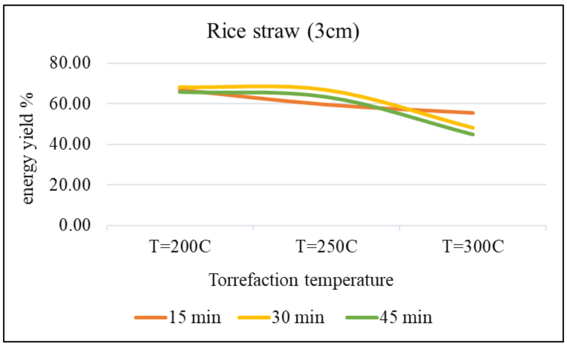

Fig. 7: Effect of torrefaction temperature for rice straw at size 3 cm on energy yield at different holding time.

Fig.8. and Fig. 9. Show the effect of torrefaction temperature, holding time and the size of specimen on mass yield for torriefied rice straw. The results indicated that the mass yield mainly affected by the size, holding time and torrefaction temperature. The mass yield decreases with the increase in the size, holding time and torrefaction temperature. Where the highest mass yield was 70.1% at holding time 15 min, size 1.5 cm and torrefaction temperature 200 °C. On the other hand, the lowest value was 38% at holding time 45 min, size 3cm and torrefaction temperature 300 °C.

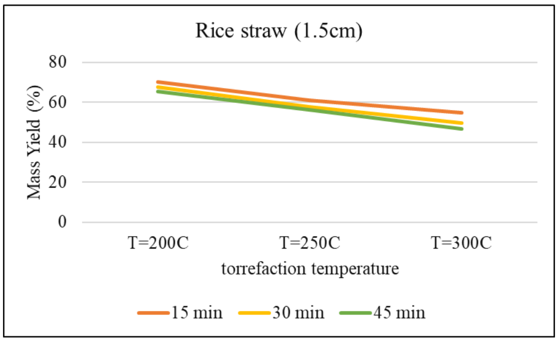

Fig. 8: Effect of torrefaction temperature for rice straw at size 1.5 cm on mass yield at different holding time.

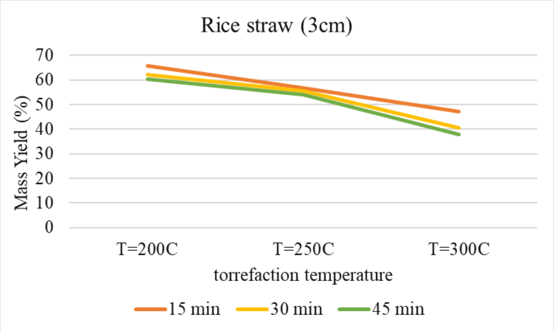

Fig. 9: Effect of torrefaction temperature for rice straw at size 3 cm on mass yield at different holding time

Table 1 shows the effect of torrefaction temperature, holding time and the size of specimen on energy density for torriefied rice straw. The results indicated that the highest value of energy density was 1.24 at torrefaction temperature 250 °C and holding time 30 min. The lowest value of energy density was 1.01 at temperature 200°C and holding time 15 min for the size of 3 cm.

Table 1: Effect of torrefaction temperature, holding time and the size of specimen on energy density for torriefied rice straw.

Operation Condition		Holding time (min)	Energy density ratio
Temperature (°C)	Size (cm)		
200	1.5	15	1.04
		30	1.12
		45	1.09
	3	15	1.01
		30	1.10
		45	1.09
250	1.5	15	1.18
		30	1.24
		45	1.20
	3	15	1.05
		30	1.20
		45	1.16
300	1.5	15	1.19
		30	1.21
		45	1.20
	3	15	1.18
		30	1.18
		45	1.17

Fig. 10, Fig. 11. and Fig. 12. Show the effect of holding time and the size of specimen at different of torrefaction temperature, on calorific value for torriefied cotton stalk. The results indicated that the calorific value decreases with the increase in the size and the decrease in the holding time. Where at holding time 15 min the calorific value was 17.7 MJ/ kg at size 1.5 cm. while its value was 17.5 MJ/ kg, at size 3cm. On the other hand, at holding time 30 min the calorific value was 18.8 MJ/ kg at size 1.5 cm, while its value was 18.4 MJ/ kg, at size 3cm. Also, at holding time 45 min the calorific value was 18.5 MJ/ kg at size 1.5 cm, while its value was 18.1 MJ/ kg, at size 3cm, as shown in Fig. 10., Fig. 11. Indicated that when a torrefaction temperature 250 °C of the cotton stalk, the calorific value was 19.5 MJ/ kg at holding time 15 min and size 1.5 cm. On the other hand, its value is greater at holding time 30 min and size 1.5 cm where the calorific value was 20.1 MJ/ kg than at holding time 45 min with size 3 cm, where the calorific value was 19.2 MJ/ kg. Fig.12. indicated that when a torrefaction temperature 300 °C of the cotton stalk, the calorific value was 19.5 MJ/ kg at holding time 45 min and size 3cm.On the other hand the calorific value increases with the decrease in the size and the decrease in the holding time, where the calorific value was 19.3 MJ/ kg at holding time 15 min and size 1.5 cm. The highest calorific value of cotton stalk at torrefaction temperature 250 °C with size of 1.5 cm and holding time of 30 min was 20.1 MJ/kg. While the lowest value was for the calorific value at the torrefaction temperature of 200 °C, size 3 cm and the holding time was 15 min, as the value was 17.5 MJ/kg.

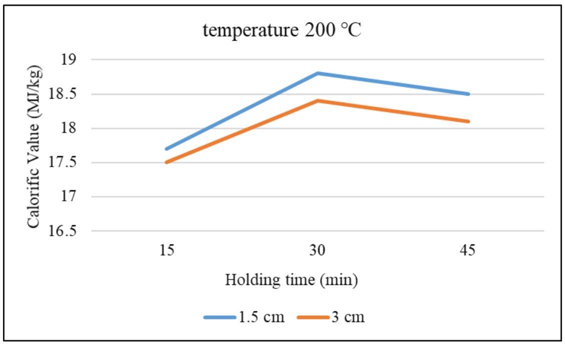

Fig. 10: The effect of holding time and the size of specimen at torrefaction temperature 200°C, on calorific value for torriefied cotton stalk.

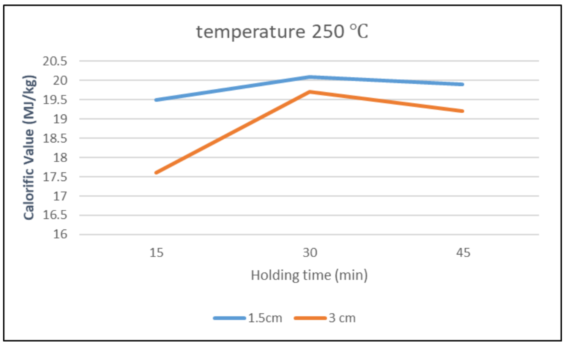

Fig.11: The effect of holding time and the size of specimen at torrefaction temperature 250°C, on calorific value for torriefied cotton stalk.

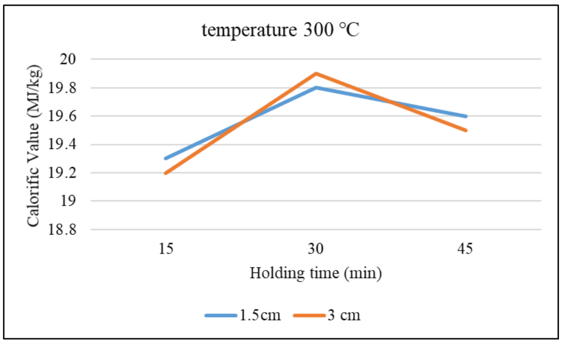

Fig. 12: Effect of holding time and the size of specimen at torrefaction temperature 300°C, on calorific value for torriefied cotton stalk.

Fig. 13 and Fig. 14. Show the effect of torrefaction temperature, holding time and the size of specimen on energy yield for torriefied cotton stalk. The results indicated that they are mainly affected by the size and torrefaction temperature, where the lower temperature and the small size, the value of the energy yield increases. The highest value was 78.91% at size 1.5 cm, torrefaction temperature 200°C and holding time 30 min. On the other hand, the lowest value was 45.5% at torrefaction temperature 300 °C and size 3 cm and holding time 45 min.

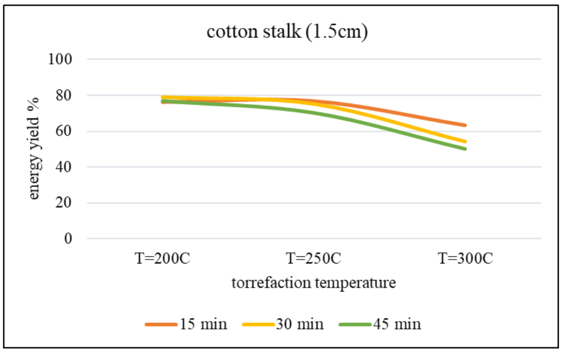

Fig. 13: Effect of torrefaction temperature for cotton stalk at size 1.5 cm on energy yield at different holding time.

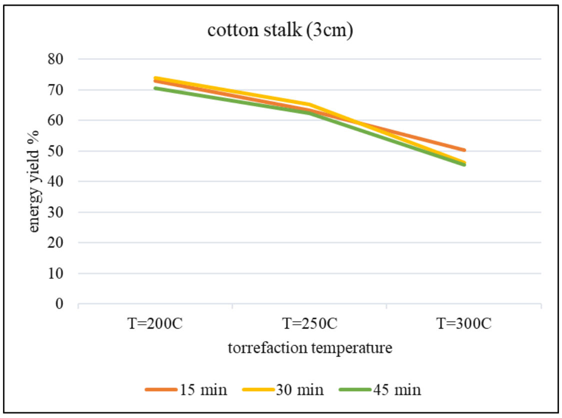

Fig. 14: Effect of torrefaction temperature for cotton stalk at size 3 cm on energy yield at different holding time.

Fig.15. and Fig. 16. Show the effect of torrefaction temperature, holding time and the size of specimen on mass yield for torriefied cotton stalk. The results indicated that the mass yield mainly affected by the size, holding time and torrefaction temperature. The mass yield decreases with the increase in the size, holding time and torrefaction temperature. Where the highest mass yield was 74.5% at holding time 15 min, size 1.5 cm and torrefaction temperature 200 °C. On the other hand, the lowest value was 40% at holding time 30 min, size 3cm and torrefaction temperature 300 °C.

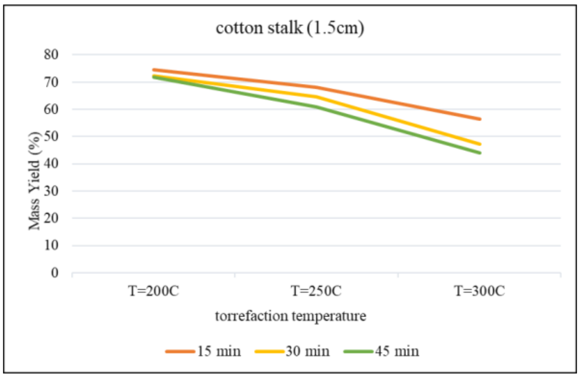

Fig.15: Effect of torrefaction temperature for cotton stalk at size 1.5 cm on mass yield at different holding time.

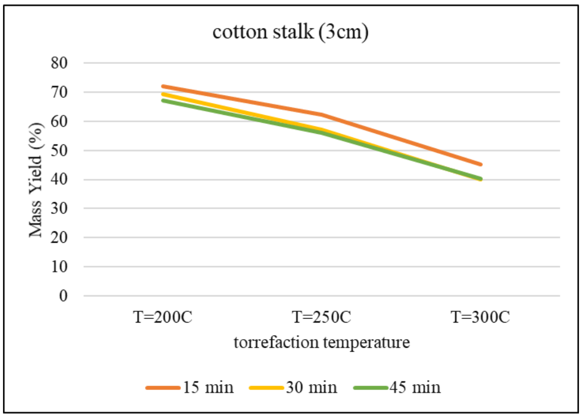

Fig. 16: Effect of torrefaction temperature for cotton stalk at size 3cm on mass yield at different holding time.

Table 2 shows the effect of torrefaction temperature, holding time and the size of specimen on energy density for torriefied cotton stalk. The results indicated that the highest value of energy density was 1.17at torrefaction temperature 250 °C and holding time 30 min. The lowest value of energy density was 1.01 at temperature of 200°C and holding time 15 min for the size of 3 cm. Table 3 Summarizes the mass yield and energy yield of rice straw and cotton stalk and other agricultural residues explained in previous literature.

Table 2: Effect of torrefaction temperature, holding time and the size of specimen on energy density for torriefied cotton stalk.

Operation Condition		Holding time (min)	Energy density ratio
Temperature(°C)	Size (cm)		
200	1.5	15	1.03
		30	1.09
		45	1.07
	3	15	1.01
		30	1.07
		45	1.05
250	1.5	15	1.13
		30	1.17
		45	1.15
	3	15	1.02
		30	1.14
		45	1.11
300	1.5	15	1.12
		30	1.15
		45	1.14
	3	15	1.11
		30	1.15
		45	1.13

Table 3: Mass yield and energy yield of rice straw and cotton stalk compared to other researches.

Agricultural Residues	Temperature (°C)	Duration time (min)	Mass Yield (%)	Energy Yield (%)	Reference number
Rice straw	250	30	55	71	**This study**
Cotton stalk	250	30	65	75	**This study**
Corn Stalk	250	30	75	70	(Poudel & Oh, 2014)
Reed canary grass	250	30	84	86.6	(Bridgeman et al., 2008)
Wheat straw	250	30	82.6	86.2	(Bridgeman et al., 2008)
Fountaingrass	250	25	28.3	42.3	(Huang et al., 2012)
Logging residue	250	30	81	92	(Phanphanich & Mani, 2011)
Coconut fiber	250	30	87	97	(Lopes et al., 2022)

Conclusion

Torrefaction process of cotton stalk and rice straw can produce high calorific value and more uniform cotton stalk and rice straw especially for small size of cotton stalk and rice straw. High temperature of torrefaction can release more mass of cotton stalk and rice straw although the calorific value was high. The holding time of torrefaction can change the composition of volatile matter. The shorter the holding time of torrefaction the lower the calorific value and the longer the holding time of torrefaction the higher the calorific value with high mass loss. The energy yield decreases with the increase in the torrefaction temperature. The mass yield decreases with the increase in the size, the holding time and torrefaction temperature, when using torrefaction process with cotton stalk and rice straw. The Energy density values for torrefied cotton stalk ranges from 1.01: 1.17 and for torrefied rice straw ranges from 1.01: 1.24.

Consent for publication:

All authors declare their consent for publication.

Author contribution:
The manuscript was edited and revised by all authors.

Conflicts of Interest:
The author declares no conflict of interest.

References

Abd-Allah, A., Mohamed, M., Hegab, R. H., & Elmehy, A. A. (2025). Effect of some soil amendments on nutrients uptake and productivity of cowpea/maize intercropping system under water stress in sandy soil. Egyptian Journal of Agronomy, 47(1), 95–106 .

Abd El Lateef, E., Abd El-Salam, M., Selim, M., Abdelaal, H., & Nowar, M. (2025). Biological Stress Impacts on Broad Bean Morpho-Physiological Traits, Yield and Water Productivity Under Drip Irrigation System. Egyptian Journal of Agronomy, 47(1), 39–53 .

Akshaya, V., Akila, I., Murali, R., Raajasubramanian, D., Kuppan, N., & Srinivasan, S. (2023). Rice Straw Biomass and Agricultural Residues as Strategic Bioenergy: Effects on the Environment and Economy Path with New Directions. In Bioenergy: Impacts on Environment and Economy (pp. 139–164). Springer .

Al Afif, R., Kapidžić, M., & Pfeifer, C. (2024). Evaluation of biochar and hydrocar energy potential derived from olive mills waste: The case of Montenegro. Energy, 290, 130234 .

Aziz, N. A. M., Mohamed, H., Kania, D., Ong, H. C., Zainal, B. S., Junoh, H., Ker, P. J., & Silitonga, A. (2024). Bioenergy production by integrated microwave-assisted torrefaction and pyrolysis. Renewable and Sustainable Energy Reviews, 191, 114097 .

Bridgeman, T., Jones, J., Shield, I., & Williams, P. (2008). Torrefaction of reed canary grass, wheat straw and willow to enhance solid fuel qualities and combustion properties. Fuel, 87(6), 844–856 .

Chen, C., Qu, B., Wang, W., Wang, W., Ji, G., & Li, A. (2021). Rice husk and rice straw torrefaction: Properties and pyrolysis kinetics of raw and torrefied biomass. Environmental Technology & Innovation, 24, 101872. https://doi.org/https://doi.org/10.1016/j.eti.2021.101872

Chen, W.-H., Lin, B.-J., Lin, Y.-Y., Chu, Y.-S., Ubando, A. T., Show, P. L., Ong, H. C., Chang, J.-S., Ho, S.-H., & Culaba, A. B. (2021). Progress in biomass torrefaction: Principles, applications and challenges. Progress in Energy and Combustion Science, 82, 100887 .

Daba, B. J., & Hailegiorgis, S. M. (2023). Torrefaction of corncob and khat stem biomass to enhance the energy content of the solid biomass and parametric optimization. Bioresource Technology Reports, 21, 101381 .

Danewalia, S. S., Sharma, G., Thakur, S., & Singh, K. (2016). Agricultural wastes as a resource of raw materials for developing low-dielectric glass-ceramics. Scientific Reports, 6(1), 24617 .

Eling, J., Okot, D. K., Menya, E., & Atim, M. R. (2024). Densification of raw and torrefied biomass: A review. Biomass and Bioenergy, 184, 107210 .

Eyssa, H. M., Afifi, M., & Moustafa, H. (2023). Improvement of the acoustic and mechanical properties of sponge ethylene propylene diene rubber/carbon nanotube composites crosslinked by subsequent sulfur and electron beam irradiation. Polymer International, 72(1), 87–98 .

Güleç, F., Parthiban, A., Umenweke, G. C., Musa, U., Williams, O., Mortezaei, Y., Suk-Oh, H., Lester, E., Ogbaga, C. C., & Gunes, B. (2024). Progress in lignocellulosic biomass valorization for biofuels and value-added chemical production in the EU: A focus on thermochemical conversion processes. Biofuels, Bioproducts and Biorefining, 18(3), 755–781 .

Hagras, A., Ragab, K., Abdelkhalik, S., Shahin, A. A. M., Youssef, W. A., Sehsah, M., Esmail, S. M., Fouad, N., Yosuf, A., & Tawkaz, S. (2025). Pyramiding Stripe Rust Resistant Genes Yr5, Yr10 and Yr15 in Sids 12 and Gemmeiza 11 Wheat Derived Lines. Egyptian Journal of Agronomy, 47(1), 15–37 .

Hassan, H. B. A., el Gebaly, M. R., Ghani, S. A., & Hussein, Y. M. M. (2014). An economic study of recycling agricultural wastes in Egypt. Middle East J Agric Res, 3(3), 592–608 .

Hemida, M. H., Moustafa, H., Mehanny, S., Morsy, M., Abd EL Rahman, E. N., & Ibrahim, M. M. (2024). Valorization of Eichhornia crassipes for the production of cellulose nanocrystals further investigation of plethoric biobased resource. Scientific Reports, 14(1), 12387 .

Hemida, M. H., Moustafa, H., Mehanny, S., Morsy, M., Dufresne, A., Rahman, E. N. A. E., & Ibrahim, M. (2023). Cellulose nanocrystals from agricultural residues (Eichhornia crassipes): Extraction and characterization. Heliyon, 9 .(6)

Hill, S. J., Grigsby, W. J., & Hall, P. W. (2013). Chemical and cellulose crystallite changes in Pinus radiata during torrefaction. Biomass and Bioenergy, 56, 92–98 .

Huang, Y., Chen, W., Chiueh, P., Kuan, W., & Lo, S. (2012). Microwave torrefaction of rice straw and pennisetum. Bioresource technology, 123, 1–7 .

Isawi, H., Ahmed, E. M., Rabee, M., & Moustafa, H. (2025). Using natural antioxidant Rhubarb extracts in PVA/chitosan bio-adsorbent films for efficient removal of cationic and anionic dyes from polluted water. Journal of Industrial and Engineering Chemistry, 141, 626–644 .

Ishii, K., Furuichi, T., Fujiyama, A., & Watanabe, S. (2016). Logistics cost analysis of rice straw pellets for feasible production capacity and spatial scale in heat utilization systems: A case study in Nanporo town, Hokkaido, Japan. Biomass and Bioenergy, 94, 155–166 .

Jain, S., Chandrappa, A. K., & Neelancherry, R. (2024). Utilization of Agricultural Wastes and By-Products in Asphalt: A Critical Review. Agricultural Waste to Value-Added Products: Bioproducts and its Applications, 207–227 .

Javanmard, A., Patah, M. F. A., Zulhelmi, A., & Daud, W. M. A. W. (2023). A comprehensive overview of the continuous torrefaction method: Operational characteristics, applications, and challenges. Journal of the Energy Institute, 108, 101199 .

Kaewtrakulchai, N., Wongrerkdee, S., Chalermsinsuwan, B., Samsalee, N., Huang, C.-W., & Manatura, K. (2024). Hydrophobicity and performance analysis of beverage and agricultural waste torrefaction for high-grade bio-circular solid fuel. Carbon Resources Conversion, 100243 .

Kalak, T. (2023). Potential use of industrial biomass waste as a sustainable energy source in the future. Energies, 16(4), 1783 .

Khairy, M., Amer, M., Ibrahim, M., Ookawara, S., Sekiguchi, H., & Elwardany, A. (2024). The influence of torrefaction on the biochar characteristics produced from sesame stalks and bean husk. Biomass Conversion and Biorefinery, 14(15), 17127–17148 .

Li, S. (2024). Reviewing Air Pollutants Generated during the Pyrolysis of Solid Waste for Biofuel and Biochar Production: Toward Cleaner Production Practices. Sustainability, 16(3), 1169 .

Lopes, F. C. R., Tannous, K., & de Barros Carmazini, E. (2022). Thermal behavior and kinetic analysis of torrefied coconut fiber pyrolysis. Thermochimica Acta, 715, 179275 .

Makepa, D. C., & Chihobo, C. H. (2024). Sustainable pathways for biomass production and utilization in carbon capture and storage—A review. Biomass Conversion and Biorefinery, 1–23 .

Massaro Sousa, L., Ogura, A. P., Anchieta, C. G. a., Morin, M., & Canabarro, N. I. (2024). Biomass Torrefaction for Renewable Energy: From Physicochemical, Bulk Properties, and Flowability to Future Perspectives and Applications. Energy & Fuels .

Mohamed Hussein, M. M., & Hussein, M. M. (2025). Growth and mineral status of panicum plants responses to foliar fertilizers and salt stress. Egyptian Journal of Agronomy, 47(1), 85–93 .

Moustafa, H., Ahmed, E. M., Hemida, M., Rabee, M., & Isawi, H. (2025). Surface grafting GO nanoplatelets with antimicrobial rosin acids for strengthening photocatalytic of chitosan/gelatin nanocomposites. Diamond and Related Materials, 112552 .

Moustafa, H., Ahmed, E. M., & Morsy, M. (2022). Bio-based antibacterial packaging from decorated bagasse papers with natural rosin and synthesised GO-Ag nanoparticles. Materials Technology, 37(13), 2766–2776 .

Moustafa, H., Darwish, D., Youssef, A., Reda, S., & El-Wakil, A. (2018). High-performance of nanoparticles and their effects on the mechanical, thermal stability and UV-shielding properties of PMMA nanocomposites. Egyptian Journal of Chemistry, 61(1), 23–32 .

Moustafa, H., Hemida, M. H., Nour, M. A., & Abou-Kandil, A. I. (2024). Intelligent packaging films based on two-dimensional nanomaterials for food safety and quality monitoring: Future insights and roadblocks. Journal of Thermoplastic Composite Materials, 08927057241264802 .

Moustafa, H., Nasr, H. E., & Youssef, A. M. (2022). Development of antibacterial carboxymethyl cellulose/quaternized starch bionanocomposites based on cinnamon essential oil nanoemulsion for wound healing applications. Biomass Conversion and Biorefinery, 1–13 .

Moustafa, H., Shemis, M. A., Ahmed, E. M., & Isawi, H. (2024). Improvement of hybrid polyvinyl chloride/dapsone membrane using synthesized silver nanoparticles for the efficient removal of heavy metals, microorganisms, and phosphate and nitrate compounds from polluted water. RSC advances, 14(28), 19680–19700 .

Mpungu, I. L., Maube, O., Nziu, P., Mwasiagi, J. I., Dulo, B., & Bongomin, O. (2024). Optimizing Waste for Energy: Exploring Municipal Solid Waste Variations on Torrefaction and Biochar Production. International Journal of Energy Research, 2024(1), 4311062 .

Odejobi, O. J., Ajala, O. O., & Osuolale, F. N. (2024). Review on potential of using agricultural, municipal solid and industrial wastes as substrates for biogas production in Nigeria. Biomass Conversion and Biorefinery, 14(2), 1567–1579 .

Phanphanich, M., & Mani, S. (2011). Impact of torrefaction on the grindability and fuel characteristics of forest biomass. Bioresource technology, 102(2), 1246–1253 .

Poudel, J., & Oh, S. C. (2014). Effect of torrefaction on the properties of corn stalk to enhance solid fuel qualities. Energies, 7(9), 5586–5600 .

Riseh, R. S., Vazvani, M. G., Hassanisaadi, M., & Thakur, V. K. (2024). Agricultural wastes: a practical and potential source for the isolation and preparation of cellulose and application in agriculture and different industries. Industrial Crops and Products, 208, 117904 .

Sadowski, A., Wojcieszak-Zbierska, M. M., & Zmyślona, J. (2024). Agricultural production in the least developed countries and its impact on emission of greenhouse gases – An energy approach. Land Use Policy, 136, 106968. https://doi.org/https://doi.org/10.1016/j.landusepol.2023.106968

Srivastava, N., Verma, B., & Mishra, P. (2024). Paddy Straw Waste for Biorefinery Applications. Springer .

Yang, Z., & Solangi, Y. A. (2024). Analyzing the relationship between natural resource management, environmental protection, and agricultural economics for sustainable development in China. Journal of Cleaner Production, 450, 141862 .

Youssef, E. A.-E., Abdelbaset, M. M., & El-Shafie, A. F. (2025). Citric Acid Foliar Application Impact on Growth and Yield Parameters of Maize (Zea Mays) Under Drought Stress Conditions. Egyptian Journal of Agronomy, 47(1), 145–155 .

Yusriadi, Y., Cahaya, A., & Hamzah, F. (2024). Farmer adaptation strategies through local farming systems in Enrekang, Indonesia. Scientific Reports, 14(1), 21652 .

Zhou, Q., Shen, Y., & Gu, X. (2024). Progress in torrefaction pretreatment for biomass gasification. Green Chemistry, 26(18), 9652–9670 .

Zhu, Y., Peng, Q., Wang, H., Lin, W., Yang, R., Qi, Z., Zhang, D., & Ouyang, L. (2024). Predicting the Higher Heating Value of Products through Solid Yield in Torrefaction Process. Renewable Energy, 121446.