

Small-scale utilization of torrefied woody biomass fuel in rural area

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Abstract. Torrefaction is a mild heat treatment that improves hydrophobicity, durability, and grindability of wood. In combination with pelletization, torrefaction maximizes energy density. Although the usage of torrefied fuel has been mainly aimed at large-scale power generation, small-scale decentralized heat utilization has benefit of easier supply with raw materials from local communities. In this study, for the small-scale use of torrefied pellets in the local communities, a combustion test using a small cooking stove was carried out. In comparison with normal wood pellets, both pellets burned with flame, and no significant difference was observed in their ignition. Given the longer non-flame combustion period of torrefied pellets than normal pellets, the combustion chamber was kept hot for a longer period. Although torrefied fuel has been assumed for large-scale power generation, it can be possibly utilized as a convenient fuel for cooking and heating in the local communities with advantage in storage and handling.

1. Introduction

Torrefaction, defined as a mild heat treatment in the absence of or under drastically reduced oxygen to a temperature of approx. 250°C–320°C [1], has recently emerged as a promising technology to upgrade conventional wood fuel. Torrefaction improves the hydrophobicity, durability, and grindability of wood due to thermal degradation, such as dehydration, and maximizes energy density by combining volume reduction with pelletization. Given the similar properties of torrefied fuel and coal, drastically increasing the ratio of woody biomass to coal can be possibly achieved without replacing the existing facilities of coal-fired power plants [1]. Thus, the usage of torrefied fuel has been mainly aimed at large-scale power generation. In the economic analysis, the lowest cost can be obtained when the torrefied fuel is produced overseas and then transported to the consumer countries. On the other hand, the total growing stock of forests has reached approximately 4.9 billion m³ in Japan [2]; however, heat resources strongly depend on fossil fuels. In accordance with such circumstances, small-scale decentralized heat utilization can be considered as one solution. This becomes easier to supply with raw materials, proceeds replacement from fossil fuel to local biomass, and revitalizes the regional economy. Recently, demonstration plants aimed at small-scale utilization were established to produce torrefied fuels and to conduct operation tests



[3]. The torrefied fuel was employed for small appliances, such as pellet stove, and showed good ignition performance [3]. Since the Great East Japan Earthquake, disaster prevention has become one of the important issues in Japan. By utilizing the characteristic of better storage, torrefaction fuel can be possibly used at small-scale activities such as outdoor cooking.

In this study, we performed a combustion test using a small-scale apparatus and investigated the combustion properties of torrefied pellets. Then, we discussed the possibility of using torrefied fuel in local communities.

2. Experimental section

2.1 Wood fuel preparation

Wood pellets (normal pellets and torrefied pellets) and commercial disposable chopstick were employed as wood fuels. To produce the wood pellet from Japanese cedar (Sugi, *Cryptomeria japonica*), wet wood chips (moisture content 50% on wet basis) were used as raw materials. Torrefied wood chips were prepared in a rotary kiln-type oven and then pelletized in a ring-die type pelletizer, as described in a previous study [3]. The chopstick, made from *Populus* spp., was split and then cut in half length (about 100 mm).

2.2 Combustion appliance

The combustion of wood fuel was conducted by using a portable camp stove (Biolite). The shape of the main body (combustion chamber) was cylindrical with a bottom and size of 75 mm diameter and 145 mm height. The air was supplied from the bottom of the chamber by a sirocco fan. The weight of wood fuel was 100 g for the chopsticks and 200 g for the wood pellets. After adding wood fuel into the chamber, a piece of fire starter (6.5 g; a composite of wood fiber with wax), which was commercially received, was placed on the wood fuel. Air flow was supplied 5 min after ignition of the fire starter.

2.3 Cone calorimeter test

A cone calorimeter (model C3 type, Toyoseiki, Japan) was used in the study. The instrument is conventionally used to evaluate the fireproof performance of architectural materials, such as wood and wood panels. Recently, the combustion behavior of wood fuels has been traced [4][5]. In this study, the stove was set inside the calorimeter 30 min after ignition. **Figure 1** shows the combustion setup in the cone calorimeter. During the test, the oxygen concentration of the exhaust gas and sample weight were recorded every 2 s on a PC. The heat release rate (HRR) was calculated from the oxygen consumption based on lower heating value. The weight loss of the fuel was monitored by an electronic balance.

2.4 Water heating test

Wood pellets (normal and torrefied) were used as fuel. **Figure 2** shows the setup of water heating test. After ignition, a glass beaker with 300 g water was set above the stove. To prevent sudden breaking of the beaker and monitor the weight loss of the fuel, the stove and beaker were separated via a wire mesh. The weight loss of fuel was monitored by an electronic balance, whereas water temperature was recorded by a K-type thermocouple.



Figure 1. Setup in the cone calorimeter test.



Figure 2. Setup of water heating test.

3. Results and Discussions

3.1. Cone calorimeter test

Figure 3 shows the combustion profiles for the chopsticks, normal pellets, and torrefied pellets. In the case of chopsticks, a large flame was observed 5 min after ignition. HRR reached 2.5–3.4 kW for 5–10 min. Then, no flame was observed around 10 min. Torrefied pellet initially burned with flame (flame combustion, 0–26 min) unlike the conventional charcoal, and then shifted to non-flame combustion like charcoal combustion. For normal and torrefied pellets, no significant difference was observed in the ignition of both pellets, and the flame covered the top of the chamber around 7 min after ignition. The HRR during flame combustion measured 1.5–2.2 kW, and no flame was observed at 26–28 min. The HRR of torrefied pellet in flame combustion was lower than that of normal pellet. Normal pellet showed a prolonged flame combustion period. On the other hand, the torrefied pellet showed a longer non-flame combustion period.

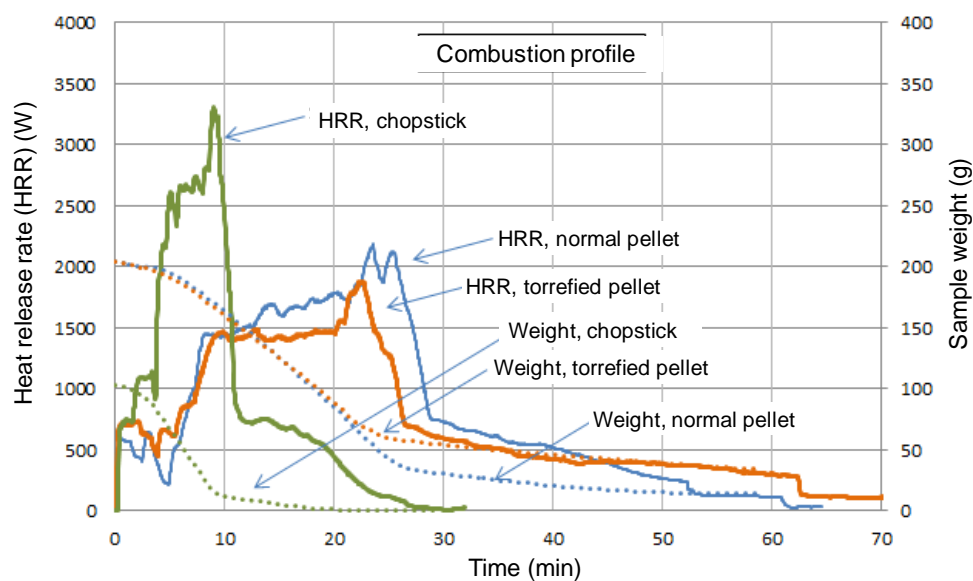


Figure 3. Combustion profiles for chopsticks, normal pellets, and torrefied pellets.

3.2. Water heating test

Figure 4 shows the temperature and weight profiles during water heating during burning of normal and torrefied pellets. The periods for water boiling reached 17 and 15 min for the normal and torrefied pellets, respectively. After fire extinguishment, the water temperature dropped for both pellets. However, the decrease rate was lower for the torrefied pellet. Thus, we suggest that torrefied fuel can keep the combustion chamber hot for longer periods than normal fuel. In this experiment, the stove and beaker were separated via a wire mesh. The cookware was directly placed at the top of the chamber during normal use. Thus, a longer period to maintain the hotness of the chamber was expected compared with the result in **Figure 3**.

3.3. Possibility of torrefied pellet use in local communities

Wood pellet is one of the homogenized fuels in terms of density (particle density and bulk density), as wood density differs in various wood species. However, wood pellets possess weak hydrophobic properties, and when saturated with water or vapor, they swell up and lose their shape. Torrefied pellets feature an advantage in hydrophobicity. Thus, torrefied pellets are considered as upgraded homogenized wood fuel. As torrefied wood also shows desirable durability against fungi and termite [6], torrefied pellets can be stored for long periods. In the local communities, torrefied pellets can be utilized as convenient fuel for cooking and heating etc. even in normal or emergency situations.

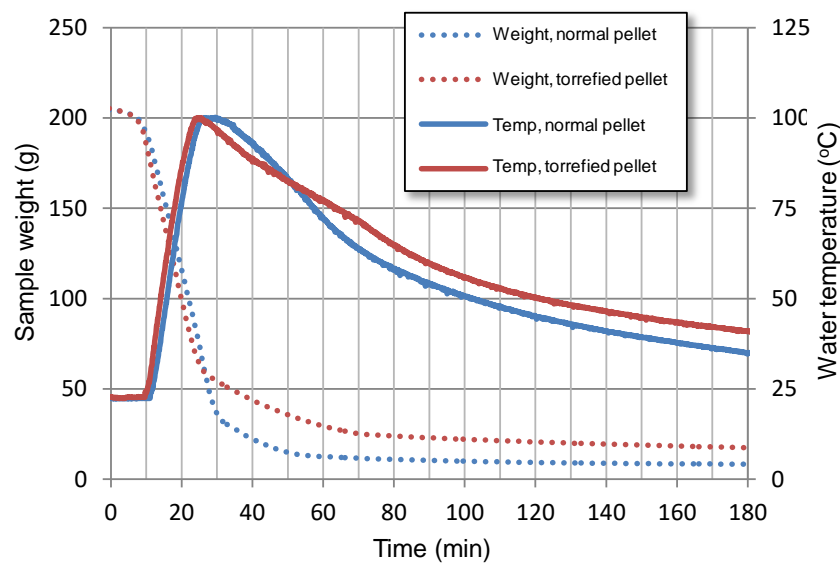


Figure 4. Temperature and weight profiles during water heating.

4. Conclusion

For the small-scale use of torrefied pellets in the local communities, combustion properties of torrefied pellets using a small cooking stove were evaluated by a cone calorimeter. In comparison with normal wood pellet, both pellets burned with flame, and no significant difference was observed in their ignition. Given the longer non-flame combustion period of torrefied pellets than normal pellets, the combustion chamber was kept hot for a longer period in water heating test. Although torrefied fuel has been assumed for large-scale power generation, it can be possibly utilized as a convenient fuel for cooking and heating in the local communities with feature of storage and handling, even in normal or emergency situations.

5. References

- [1] IEA Bioenergy Task 32 2015 *Status overview of torrefaction technologies - A review of the commercialization status of biomass torrefaction*
<http://www.ieabioenergy.com/publications/status-overview-of-torrefaction-technologies-a-review-of-the-commercialisation-status-of-biomass-torrefaction/>
- [2] Forest Agency in Japan 2016 *Annual Report on Forest and Forestry in Japan* 9
- [3] Yoshida Tet al. 2017 *J. Jpn. Inst. Energy* **96** 310
- [4] Kamikawa D, Kuroda K, Inoue M, Kubo S and Yoshida T 2010 *J Wood Sci* **55** 453
- [5] Lee C-g, Choi C, Yoo J-i, Kim H-j, Yang S-m and Kang S-g 2016 *Bioresources* **11** 9803
- [6] Itoh T and Masuda K. 2009 *Report Nara Forest Res. Inst.* **38** 45

Acknowledgments

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