Production of Fuel Pellet and Coke from Heavy Oil and Bio-char Mixture of Various Blending Ratios

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Abstract
Bio-chars for pellets are affected by pyrolysis temperatures and binder. Thus, controlling for these two variables can produce an ideal product with engineered properties - "designer bio-pellet." The potential for designer bio-char pellets stems from its ability to combine the properties of pyrolysis bio-char, which is rich in nutrients and alkalis, with heavy oil products another from pyrolysis which will also be rich in carbon and energy. In this study, raw material from rice straw was pyrolysis, its products are heavy oil HO and char. The HO and char are mixed at different ratios (100%, 75%, 50%, 25%, and 12.5%), pelletized (diameter 14.1 mm), and then undergo heat in mold at different temperatures (80 °C, 140 °C, and 200 °C) to create test chars. Blending pellets are tested for energy characteristics, pellet tensile strength (TS), and elemental composition. The results showed that the mixed HO/char had different tensile strength in each mixture, the maximum TS of rice straw 400 °C with a mixture ratio of 100%. The blending HO/char at 100% had a high in ash content and high energy content (HHV), and also lower in the moisture uptake. Structurally, blending HO/char pellets resemble bituminous coal. Although the bio-char/char pellet mixture degrades faster in combustion, mixing HO/char for pellets and coke production can alleviate some energy conversion application problems, and be obtained co-firing with bituminous coal.
Keywords: pellets, energy conversion, pyrolysis, heavy oil and char, blending

1. Introduction

Agricultural residues are abundant and widely distributed in the many countries. The traditional treatment methods such as open burning, pulverization, and return to the field, causing environmental pollutions and leave a considerable amount of energy unutilized. Researches regarding the efficient and environmentally friendly treatment of agricultural residues have gained increasing attention in the past decades. Many technologies turn agricultural biomass into thermal energy or bio-products.

Pyrolysis is the main step of biomass gasification, and the formulation of condensable organic products, which is generally called tar, while carbon-rich residues are called bio-char.[1] In this study briquettes were made from a mixture of biochar and its heavy oil/ tar.

2. Experimental Section

Rice straw (RS) was pyrolyzed in a horizontal auger reactor, which is popular in the biomass pyrolysis, with temperatures of 400 °C, 450°C and 500 °C. The details of the reactor are reported elsewhere.[2] The bio-oil was condensed at the reactor downstream with a silica fiber made aerosol filter (150 °C) and three condensers (0, −40, and −70 °C, respectively) in series. Heavy oil (HO) and bio-oil have been mixed by dissolving acetone. Prior to evaporation at a temperature of 60 °C, a mixture of HO/Char was stirred at stirring rate of 170 rpm for overnight.

The palletization process was

performed using hydraulic press consists of stainless steel cylindrical interior diameter and length are 14.10mm and 28mm, respectively. Approximately 1 g of powder was filled inside the hole, compacted to a pressure of 128 MPa for holding time 8 min at 200 °C. After the pressure release, the mold was cooled down naturally to ambient temperature. The briquette heat for the carbonization at atmospheric flow of N_2 at the rate of 3 °C /min to 1000 °C where the temperature held for 10 min.

3. Results and Discussion

The yields and distribution of pyrolytic products are presented in Fig 1. Incorporating HO into char results in considerable increase in the yield of solid fuel (i.e., HO/char mixture), from 34.4 - 40 wt% for char only to 41 - 50 wt% for mixture of HO and char. The two concepts,

(i) char as a sorber for HO capture and

(ii) HO as a binder for char briquetting, have been successfully demonstrated.

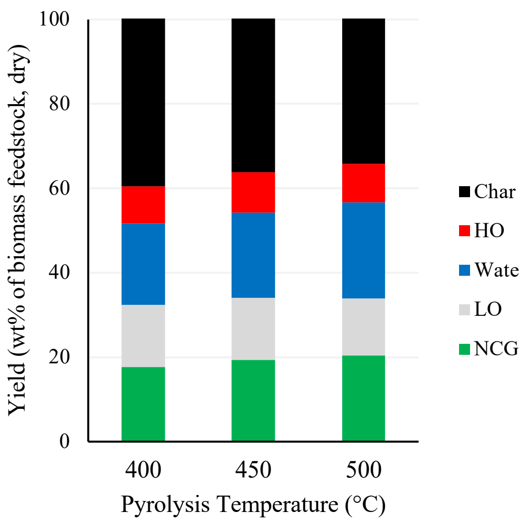

Fig 1. Yield of char, heavy oil (HO), water, light oil (LO) and non-condensable gases (NGC) from pyrolysis of rice straw (RS)

Fig. 2 presents the energy densification of blending of HO/char generated from RS at 400 °C, 450 °C and 500 °C. It was found that some synergetic effects on energy densification. In the under higher blending ratio conditions, the energy densification are great, and the small blending ratio or more char provided low energy densification, it was due to the heavy oil is rich in volatile and also high density, conversely the HO is contained greater of carbon content. Other impacts also occur on the ash content, the higher the blending ratio of HO/char gives a low ash content, while the small blending ratio generates high the ash content.

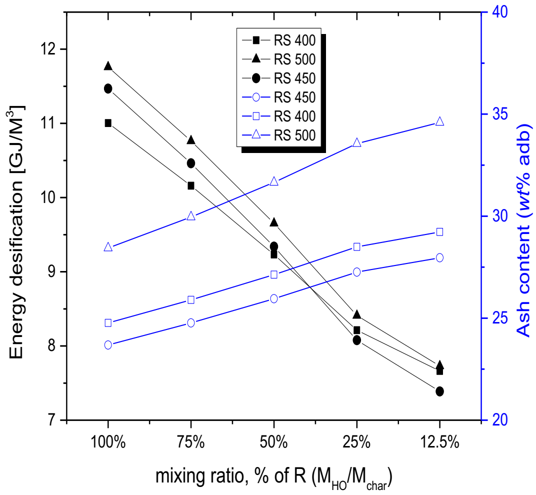

Fig 2. Energy densification and ash content of char

As discussed above, the noticeable synergies always occur under conditions of a higher mixing ratio condition. This due to the sufficient quantity of HO in the mixture is needed to offer plenty of carbon donors.

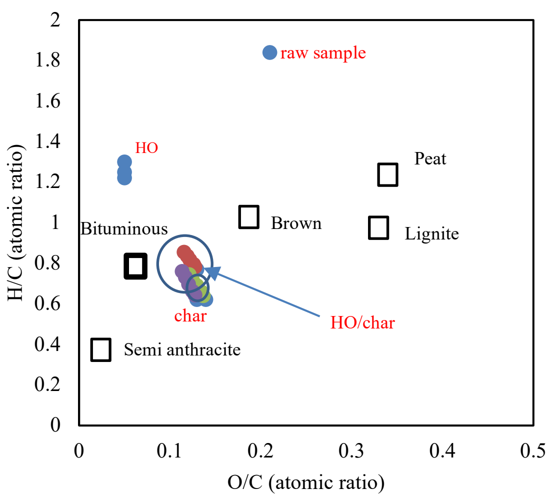

Fig. 3 Van Kreven diagram of blending ratio

Fig.3 It shows the Van Krevelen plot of pyrolyzed rice straw and shows the changes in H/C and O/C atoms used to determine the level of maturation of pyrolysis products. The van Krevelen diagram also provides information about differences in the composition of elements (C-H-O). The Van Krevelen diagram shows that the characters obtained from the pyrolysis of rice straw HO and char have a ratio of H/C and O/C which is much lower than raw rice straw. This shows the gradual loss of hydrogen and oxygen and char enrichment of carbon. In this figure the composition of blending HO/char shows that H/C and O/C are very close to Bituminous coal. It's clear that blending HO/char compared to bituminous coal contains more oxygen.

Fig.4 shows the measured moisture uptake of pellets RS-400 at 25 °C and 80% relative humidity. It was observed that the pellets reached saturation in about 10 h. The hydrophobicity improved when the HO/char high mixing ratio and long residence time were used, with RS-400 100% exhibiting the lowest moisture content, at around 3.8%.

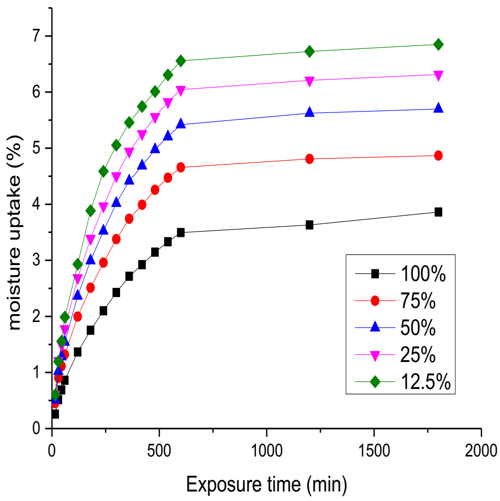

Fig. 4 Moisture uptake of pellets RS-400

Among the mixing ratio of HO and char, the high hydrophobicity of the pellets due to the HO intercalation, which is the hygroscopicity of bio-char played of preponderant in moisture uptake. In addition, suggest the pellets high of mixing ratio can be stored safely in humid environment for long time [3].

This section also explores the optimized pyrolysis temperature and HO/Char mixing ratio for production of fuel pellets and coke from rice straw pyrolysis. In practice, pyrolysis of rice straw at given temperature produces certain amounts of HO and char, with the mass ratio of HO/Char being *R* (0.22, 0.26 and 0.26 for 400, 450 and 500 °C, respectively). It has been previously demonstated that biomass feedstock itself is also an excellent sorber fo HO capture. Therefore, if fuel sorbers filled with char and rice straw are applied, it is practically feasible to produce HO/Char mixtures at any ratios lower than *R*. To determine the optimized HO/Char blending ratio, HO and char produced from pyrolysis of rice straw at 400, 450, and 500 °C were blended at different ratios (100%, 75%, 50%, 25%, and 12.5% of *R*.

$$R = M_{HO}/M_{char} \qquad .eq\ (1)$$

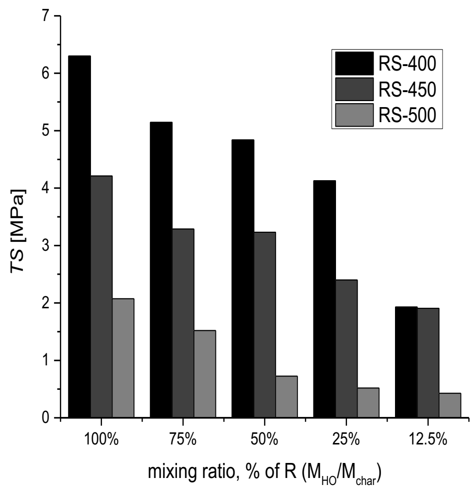

Fig 5. Tensile strength (TS) of briquetting fuel pellets from HO/Char with temperature of 200°C

Tensile strength (*Ts*) is critical for the briquettes because soft hardness might lead to breakage during transportation and handling processes. In the present study, the mechanical properties of the briquette pellets were evaluated in terms of their tensile strength, as illustrated in Fig. 5. As expected, all pellets showed relative low tensile strength, the strongest pellet with tensile strength 6.3 MPa is produced at pyrolysis temperature of 400 °C, hot briquetting temperature of 200 °C and the HO/Char blending ratio of 100% of *R* (0.22 g HO/g Char).

All mixing ratios are more strength than without heavy oil and the surface was much smoother, that indicating the interval between particles which are considered heavy oil recrystallizing after the drying process and solid forming to bind the particle. After briquetting at high temperature, consistency of polymerized serving as a glue. The surface was much smoother, indicating the interval between particles.

As illustrated in Fig 6, the highest TS of 19.9 MPa has been achieved for coke produced at the same process conditions as those for fuel pellets. There is a strong bond between HO/Char before the release of volatiles at the carbonization temperature.

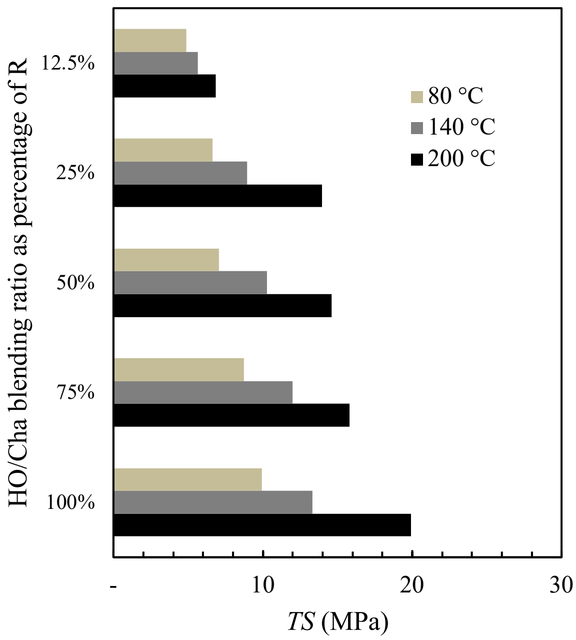

Fig 6. TS of coke from HO/Char mixture of pyrolysis 400 °C

4. Conclusions

In this work, typical agricultural biomass, rice straw was briquettes under different mixing ratio of HO and char to obtain fuel pellets and coke. The hydrophobicity of pyrolyzed char pellets increased with increasing the mixing ratio. High mixture HO/Char pellets exhibited increased tensile strength and density. The mixing ratio 100% has higher TS around 6.3, the increased TS due to strengthening from HO. The same blending and briquette conditions as pellets, coke has a tensile strength with an average of three times stronger than pellets. The coke is sufficient to become metallurgical coke.

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