**Steam and Hydro-Thermal Gasification of Canola Hull and Canola Meal Fuel Pellets.**

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**Highlights**

* Canola hull and meal were pelletized using bio-additives with optimized concentrations.
* Steam gasification showed suitable range (1.2-1.6) of H2/CO ratio for untreated syngas.
* Hydro-thermal gasification of pellets is suitable technique for hydrogen production.
* Steam-gasified biochars showed compact aromatic structure and high surface area.

**1. Introduction**

Conversion of agricultural wastes to value-added products such as fuel pellets has economic and environmental advantages. Use of abundant agricultural residues such as canola hull and canola meal can benefit both agriculture and industry sections. In this research work, bio-additives including lignin, glycerol, and L-proline were used for production of hydrophobic fuel pellets with high mechanical strength. The concentration of bio-additives in the pellet formulation was optimized based on the relaxed density and mechanical strength of pellets. Then, gasification was used for production of synthesis gas (syngas) and hydrogen from these fuel pellets. For steam gasification, effects of gasification temperature and equivalence ratio (ER) were investigated on the gasification products. For hydro-thermal gasification, the effects of gasification temperature, feed concentration (biomass/water mass ratio), and residence time were studied.

**2. Methods**

Canola hull and canola meal were provided by the Milligan Biofuels Inc. (SK, Canada). For pelletization, biomass particle size in the range of 100-1,750 µm was preferred. Alkali lignin (as binder), pure and crude glycerol (as lubricant), and L-proline (as plasticizer) were used as bio-additives. Samples were densified in a lab scale single-pelleting unit. Two-stage fixed-bed gasifier and batch reactor were used for steam and hydro-thermal gasification, respectively. A wide range of characterization techniques were used to probe properties of feedstocks, pellets, gas product, and biochars. Central composite design (CCD) was used to design the experiments.

**3. Results and discussion**

Optimization study for canola hull showed that durability (measured by drop test) and relaxed density of pellets, respectively, were in the ranges of 51-99% and 647-1,110 kg/m3. This study showed that pellet made of 6, 4, 6, 17 wt/wt % of lignin, glycerol, L-proline, and water, respectively, had the largest relaxed density (1,110 kg/m3) and durability (99%). An increase in water content up to 17 wt% resulted in better performance for alkali lignin as a binder in densification process. The pellets’ relaxed density and mechanical durability increased with an increase in the moisture content, for the entire range of lignin concentration. Glycerol showed lubricating effects in the form of 10-20 % decrease in pelletization’s compression energy. L-proline worked as a plasticizer to increase the mechanical strength of pellet. For canola meal, the optimum formulation identified included 8 wt% alkali lignin, 8 wt% glycerol, 2 wt% L-proline, and 4 wt% water. It had relaxed density of 1,050 kg/m3 and durability of 99%. As shown in Fig. 1, synchrotron 3-D imaging technique was used to visualize the internal void structure (blue color area) of pellets which is an influential parameter on the relaxed density and mechanical strength of pellets. Fig. 1 shows effects of alkali lignin, glycerol, and water on the internal porosity of canola meal pellets.

For steam gasification with an increase in temperature, concentration of hydrogen (H2) and carbon monoxide (CO), in the gas product, increased for all ERs. Effect of ER on the gas component concentrations was more intense at the highest temperature (850 oC), especially in case of increase in hydrogen concentration. In hydro-thermal gasification, with the rise in temperature from 350 to 650°C, H2 and CO2 yields increased , due to the enhancement of water-gas shift reaction at higher temperatures in hydro-thermal conditions. The same effect was observed with an increase in residence time (from 15 min to 60 min). However, these yields decreased with an increase in feed concentration. Hydro-thermally produced biochars showed characteristics of amorphous char at high gasification temperatures (≥550 °C). For steam-gasified biochars, higher BET surface area indicated the development of composite char at all gasification temperatures.

**4. Conclusions**

Use of bio-additives resulted in the production of mechanically durable and hydrophobic fuel pellets. Due to the increasing amount of lignin, glycerol and amino acids obtained, respectively from the pulp and paper industries, biodiesel refineries, and corn wet milling industries, they are promising bio-additives for production of fuel pellets. Steam gasification produced syngas with the suitable range of H2/CO molar ratio. In addition, it produced biochars with developed porous characteristics which can be used as adsorbent or catalyst. Hydro-thermal gasification produced larger H2/CO ratio and is more useful for hydrogen production.



**Figure 1.** Effects of lignin, glycerol, and water on pellet porosity in the cross section and longitudinal section for the canola meal pellets produced using the optimum formulation as follows: (a) without water, (b) without lignin, (c) without glycerol, and (d) including all ingredients.