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Comparison of gaseous and particle emissions produced from leached and un-leached agricultural biomass briquettes

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ABSTRACT

This paper presents the results of an investigative study to determine the impact of leaching agricultural biomass on gaseous emissions and total suspended particles. Gaseous emission and total suspended particulates were measured in the stack of a domestic wood stove fired with leached and un-leached briquettes produced from commonly available agricultural biomass feedstock grown in Nova Scotia, Canada. The study primarily focuses on reducing gaseous and particulate emissions by leaching the biomass feedstock with water, prior to conversion and comparing against un-leached biomass feedstock. The result showed that the process of leaching significantly improved the fuel properties of the feedstock; however, a proportional reduction in gaseous and particulate matter emissions was not evident.

1. Introduction

Agricultural biomass is gaining popularity as a viable alternative to more traditional wood based biomass fuel [1–3]. Agricultural biomass is an abundantly available crop, however, burning biomass under poor combustion conditions can transform a significant portion of the fuel carbon into incomplete combustion products [4]. The presence of alkali metals and other inorganic elements result in additional emissions from particulates and oxides of nitrogen and sulfur, which have a higher environmental impact than CO_2 alone [5–7].

Particulate matter produced from biomass fuel combustion has been associated with various respiratory and cardiovascular issues [8,9]. The vapors from incomplete combustion and fly ash inorganic materials, such as potassium, sulfur and chlorine, condense to form particulate matter [10–12]. In addition to particulate matter, biomass combustion inherently results in the emission of toxic gases such as CO, NO, NO_2 and SO_2. NOx (NO, NO_2 and other oxides of nitrogen) and SOx (SO_2 and other oxides of sulfur) emissions primarily depend upon the nitrogen and sulfur content of the fuel [13].

Alkali metals inherently present in agricultural biomass tend to form deposits on heat exchanger tubes and slag the furnace when burnt at temperatures in excess of 800 °C. These deposits are rich in potassium and chlorine and will ultimately lead to corrosion of heat exchanger tubes [14,15].

One solution to these issues is to harvest, the biomass in winter or spring following the growing season. This delay in harvest reduces the amount of inorganic elements present in the biomass, however, can also reduce the yield, by an average 25% [16,17]. To avoid yield loss, the biomass could be harvested in fall and the inorganic elements leached by submerging biomass in water [15,18–21].

Though properties of the biomass fuels themselves are a vital source of emissions, the condition in which these fuels are combusted is equally important. A number of studies have been conducted and factors identified that influence the efficiency and emissions of agricultural biomass combustion. Dare et al. performed tests on a 50 kW combustor using bark residue and stem wood from purpose-grown eucalyptus and reported that the inorganic reactions highly impact the combustion behavior of biomass fuel. Further, these reactions are strongly influenced by combustion temperature, which in turn is affected by the moisture content of the fuel [22]. Paulrud et al. combusted reed canary grass with different ash contents (by blending in leaf and stem fractions) in a 180 kW burner. Results indicated that variation in ash content did not affect emissions from the burner. Furthermore, no severe clinkers or deposits were detected in the burner after combustion [23]. Gonzalez et al. tested an 11.6 kW mural boiler with a range of agricultural biomass residues and reported that both mass flow of fuel and draught greatly affect the combustion efficiency of such boilers [24,25]. Roy and Corscadden compared briquettes produced from wood and un-leached agricultural feedstock in a domestic wood stove and determined that although efficiencies were similar, agricultural based fuels exhibited higher NOx emissions, with these emissions proportional to fuel N_2 content [26].

This study presents the combustion and emission results obtained using a Drolet XV Stove using leached (with well water for 24 h at room temperature) and un-leached briquettes made from four agricultural feedstock, switch grass and reed canary grass and wheat and barley straw. The residence time and water temperature have been

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shown by Ravichandran et al. to provide sufficient reduction in problematic minerals [21]. This research has predominantly been undertaken to investigate the impact of combustion characteristics of leached materials and expand on the potential benefits of this process if in fact it results in a reduction in gaseous and particulate emissions during direct combustion.

2. Materials and methods

2.1. Feedstock

Reed canary grass, switch grass, wheat straw and barley straw represent some of the potential energy crops and abundantly available agricultural residue in Nova Scotia, Canada. These feedstocks were produced in round bale and small square bales and processed at the Bioenvironmental Engineering Centre, Dalhousie University, Faculty of Agriculture in, Truro, NS.

2.2. Feedstock pre-processing

The feedstocks collected as bales were first pre-ground in a Supreme Enviro pull type TMR (Total Mixed Ration) mixer to reduce the whole bale to stalk of about 3–6 in. in lengths. Chopped straw was fed into New Holland hammer mill with an 8 inch screen to reduce the feedstock to a fine fiber (1–2 mm in width and 1–1.5 cm in length). Half of each feedstock was bagged for producing

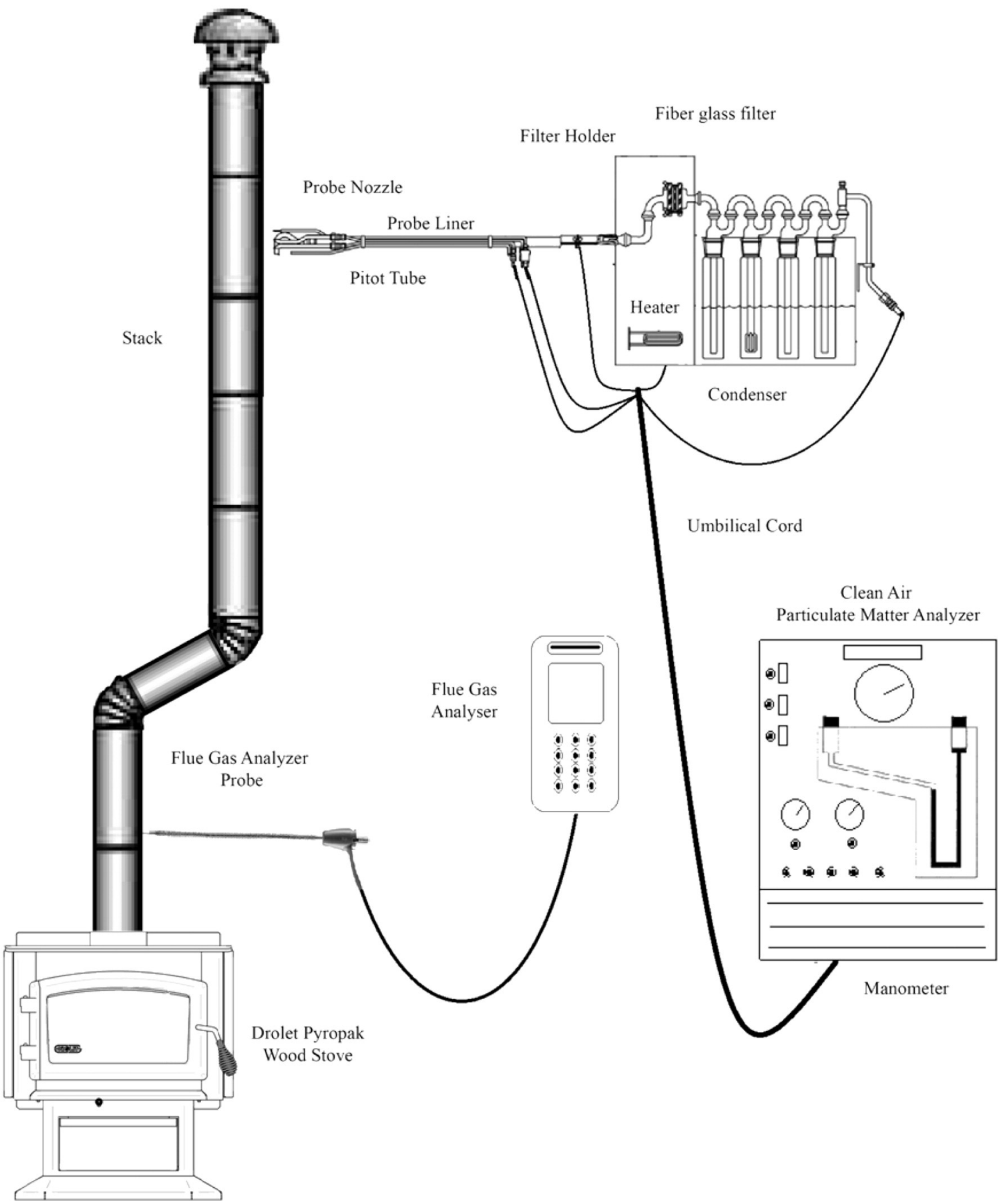

Fig. 1. Schematic diagram of the experimental setup.