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CO-FIRING FEEDLOT AND LITTER BIOMASS:COAL BLENDS IN A LABRATORY SCALE BOILER BURNER

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ABSTRACT

The co-firing of animal biomass fuels with coal has the potential to solve both biomass disposal problems, and reduce net CO₂ emissions. The high flame temperatures produced by coal will allow the low heating value, high ash biomass to be completely burnt. Unfortunately, the animal biomass fuels are high in nitrogen and sulfur, which could lead to greater air pollution levels in the form of NO and SO₂. To determine the effect of switching to 90:10 Coal:biomass blend on combustion efficiency and emissions, the blends were fired in a 30 kW (100,000 BTU/hr) laboratory scale boiler burner. The results are presented along with the their relation to the fuel properties.

INTRODUCTION

The use of cattle manure as a fuel source has the potential to simplify feedlot cattle manure disposal, provide an environmentally friendly source of electrical power, and provide an additional revenues stream to feedlot lot operators. The Southern High Plains area, which includes Amarillo and parts of West Texas, has a one time feeding capacity of 3.6 million cattle. Each animal produces about 11.8 kg (62 lbs) of wet manure per day [1] that must be safely disposed of. Some excess manure can be used as fertilizer but the amount of manure that can be beneficially spread on farmland is limited, and complying with manure storage regulation can be difficult. Since feedlot cattle manure has the potential to be both a fertilizer and a fuel source, it should be referred to as feedlot biomass (FB) to emphasize its economic potential. Previous attempts to use FB as a fuel source have met with only limited success due to FB's high ash, high moisture, and low heating value which make it difficult to use in conventional combustion apparatus due to ignition and flame stability problems. To overcome the poor fuel properties

of FB, it is proposed that the FB be mixed with coal and co-fired in existing coal power plants. The high temperatures produced by the coal will enable the FB to be completely burned.

Before existing power plants can be converted to cofiring coal and biomass blends, the fuel properties of the biomass fuel have to be analyzed and along with the combustion performance when firing blends. Of particular interest is the burnt mass fraction when firing blends, as the addition of the high ash, low heating value biomass may decrease the overall degree of combustion. Additionally the biomass fuels are high in sulfur and nitrogen which could lead to higher NO and SO_x emissions when switching to a blended fuel. To determine the fuel properties the fuels were subjected to an ultimate analysis, and proximate analysis, and a kinetic analysis using Thermogravimetric (TGA) techniques. Then a laboratory scale boiler burner was built, and the combustion performance of coal and coal biomass blends was evaluated.

RESULTS

To determine the basic fuel properties, the fuels were subject to an ultimate and a proximate analyses as shown in table 1. The analysis was performed by a commercial testing company, and the results are given on an as received basis. The fuel listed are: coal, partially composted FB, and chicken boiler litter, another biomass fuel similar to FB and properly referred to as Litter Biomass (LB). Some results are included for LB, but the main focus of the project is the FB. The results of the ultimate and proximate analyses show that both of the biomass fuels are high in ash, lower in heating value, and contain 2-3 times the nitrogen that coal does. It is also seen that the biomass fuels have a much higher percentage of their combustible content in

the form of VM, as compared to coal. However the heating values (HV) of the volatiles of FB are lower than those of coal [2]. FB and LB biomass are high in N (0.96 %, 0.379 kg/GJ for coal and 1.78%, 1.89 kg/GJ for FB) and S (.23%, 0.097 kg/GJ for coal and 0.5%, 0.531 kg/GJ for FB) which can create air pollution emissions. FB (46.9 kg/GJ) and LB (22.22 kg/GJ) have greater ash than coal (2.24 kg/GJ) on a heat basis. FB and LB biomass have a greater volatile content if calculated on a dry ash free basis (47% coal and 86% FB).

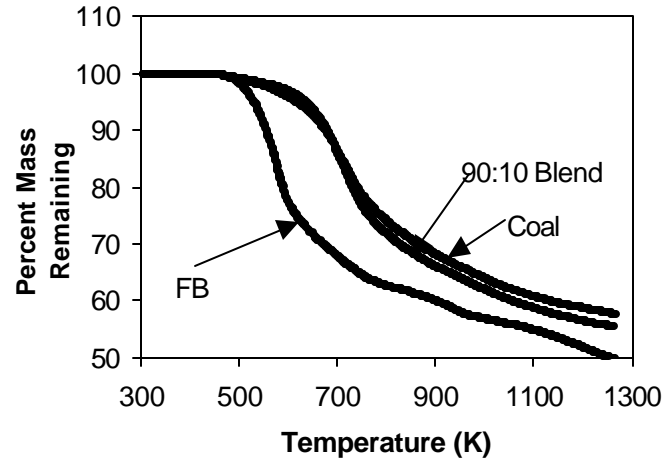


Figure 1: Comparison of TGA traces

Table1: Fuel Properties

	Coal B	Feedlot B	Litter
C	60.3	23.6	28.44
H	3.62	2.91	3.71
O	14.5	19.01	22.80
N	0.96	1.78	3.035
S	0.23	0.5	0.66
cl	<.1	1.85	0.93
P	NA	NA	1.965
Dry loss	15.12	7.735	11.62
Ash	5.33	44.165	26.82
VM	37.17	41.43	50.65
FC	42.38	6.535	10.92
HHV (kJ/kg)	23709.8	9423	12065
N kg/GJ	0.405	1.89	2.545
S kg/GJ	0.097	0.531	0.547
CO ₂ kg/GJ	93.2	91.83	86.43

To determine the kinetic behavior of the fuels, 25 mg samples of the fuel were subjected to a TGA analysis in a TGA analyzer. The resulting traces in nitrogen are shown in figure 1, for coal, FB, and a 90:10 blend by mass of coal and FB. The results show that the FB will lose volatiles at a lower temperature, and a faster rate than the coal. Feedlot biomass

(cattle manure) starts pyrolysis at about 273°C (523 °F) while coal pyrolyses at a higher temperature of 377 °C (711 °F). The fuels were also fit to the parallel reaction model, and an ignition analysis was performed with the results available elsewhere [3].

The fuels were tested in a 30 kW boiler burner constructed especially for the current project. The 0.1524 m (6 in) combustion section was formed by an inner ceramic shell, backed by ceramic fiber insulation and a steel shell (Figure 2). The fuel was injected into the top of the furnace through a swirl burner, and gas readings were taken at a sampling port right before a water spray used to quench the flow. The details of the boiler burner are given in Annamalai and Thien [4]. Gas analyses and ash analyses were used to determine the burnt fraction [5]. The burnt mass fraction for coal, and a 90:10 blend of coal and FB is shown in figure 3 with gas analyses and Figure 4 with ash analyses. The results show there will not be a decrease in the burnt mass fraction despite the lower heating value of FB, and its high ash content. The lack of a decrease when switching to a lower quality fuel is attributed to the high VM content of the FB on a daf basis, combined with the fast release of volatiles from the fuels. The more rapid release of volatiles enhances combustion, and is able to make up for the reduction in heating value and increase in ash. The S analyses of ash and fuel were used to determine the S capture by ash. Figure 5 shows the results. There seems to be negligible change for coal while there is decrease for FB with excess air %.

The effect of switching to a blended fuel on the NO emissions are shown in figure 6 on a kg/GJ basis. It is noted that even though the N content in kg/ GJ for the blend is about 15% higher than coal, coal:biomass blends fired in boiler burners, produce lower or similar levels of NO (0.15kg/GJ) compared to coal even though FB has a higher N, due to biomass N release in the form of NH₃ and biomass's high volatile content the NO_x in kg/GJ did not increase. The faster release of volatiles into the top of the furnace create local areas with a fuel rich chemistry which prevent the formation of NO. It is also believed that the release of fuel nitrogen from biomass occurs mostly in the form of NH₃ instead of the form of HCN in the case of coal. Different kinetics for the reaction involving NH₃ result in a lower level of NO formation. Larger scale tests at the DOE were performed on 90:10 Coal:FB blend, along with an evaluation of the fouling behavior of the different fuels. Results are reported elsewhere [6]. Promising work is also being performed to determine whether FB or LB can be used as a reburn fuel in order to reduce NO emissions.

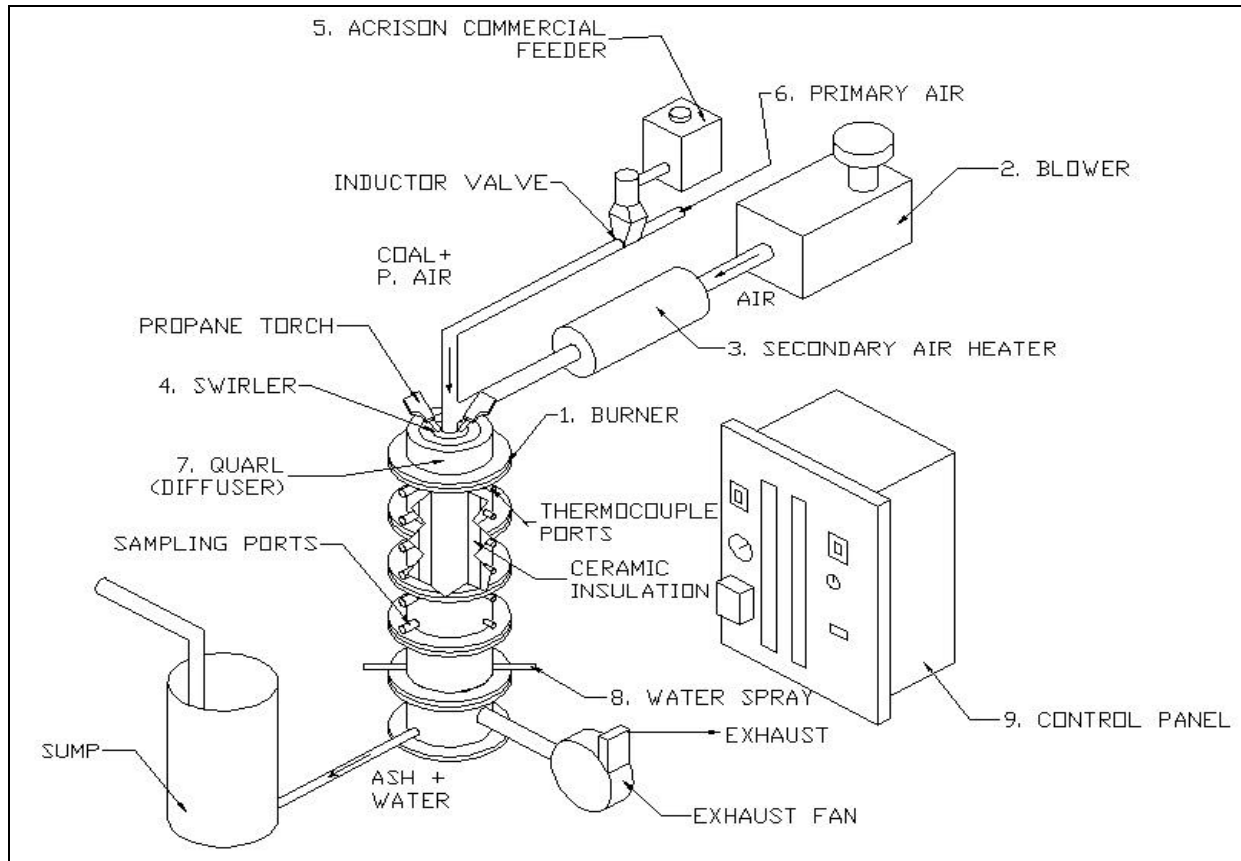


Figure 2: Boiler burner facility

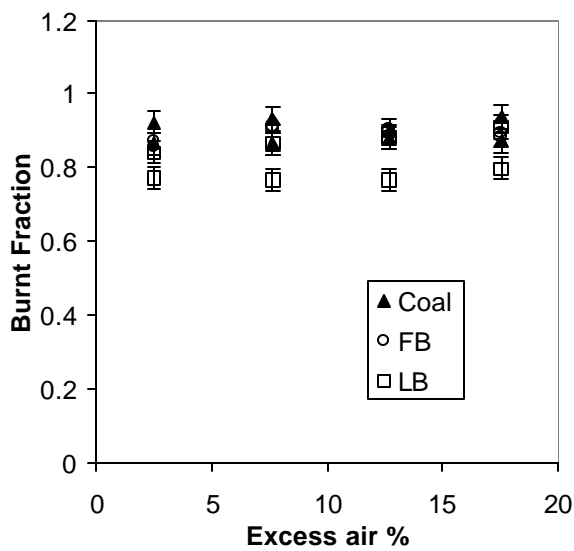


Figure 3: Burnt mass fraction based on gas analysis

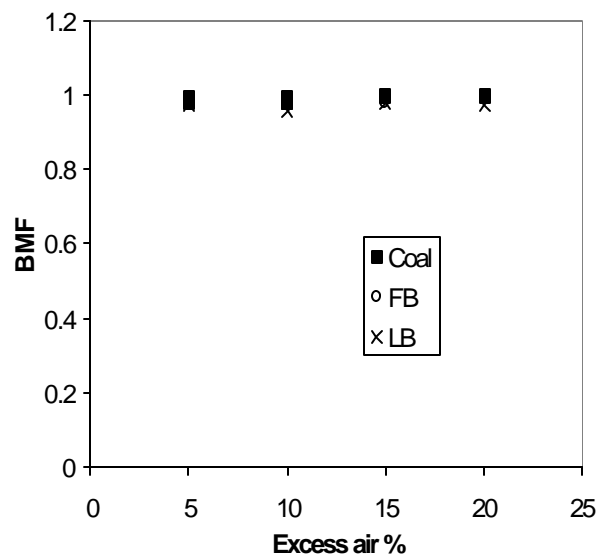


Figure 4: Burnt mass fraction based on ash analysis

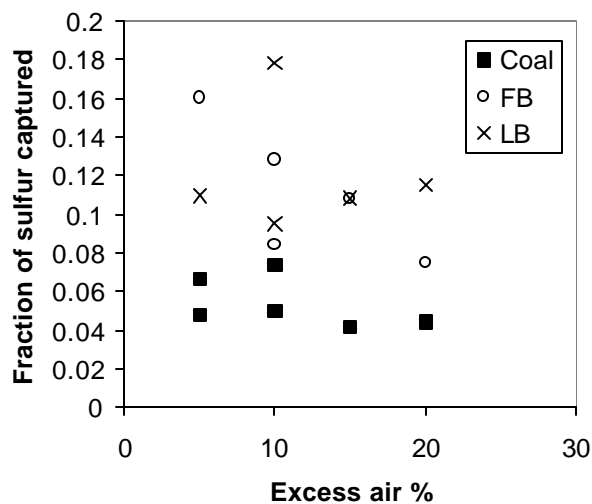


Figure 5: S capture by ash

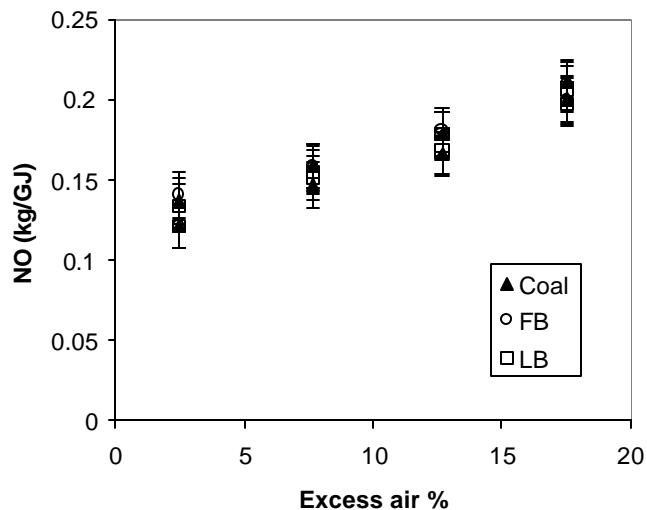


Figure 6: NO emissions on a heat basis

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