Biomass Briquettes: Turning Waste Into Energy

A Boise State University study proves that low-energy feedstocks can be densified and when combusted produce heat output comparable to higher energy content fuels.

By Owen McDougal, Seth Eidemiller, Nick Weires,
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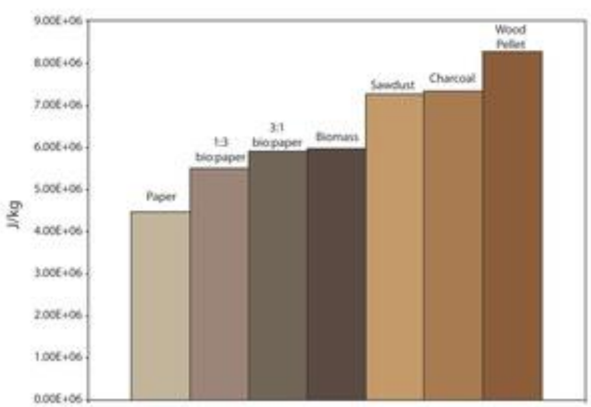
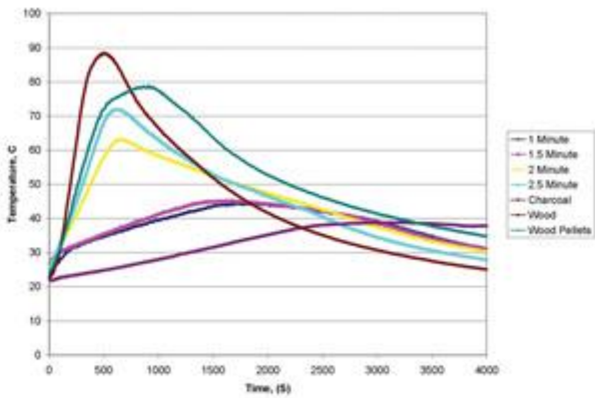
- 

- 

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Biomass Packed: Boise State University researchers tested biomass briquettes of four different compositions, left to right, 100 percent paper, 1:3 paper to biomass, 3:1 biomass to paper and 100 percent paper to demonstrate that the energy output of d
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Fuel briquettes generated by the low-pressure compaction of paper, sawdust, agricultural or yard waste, etc. currently serve as an alternative to firewood, wood pellets and charcoal in developing countries in Africa, Asia and South America. Research at Boise State University in Idaho, explored both the caloric content and shape to optimize burn efficiency of the biobriquettes. The energy content of briquettes ranged from 4.48 to 5.95 kilojoule per gram (kJ/g) depending on composition, whereas the energy content of sawdust, charcoal and wood pellets ranged from 7.24 to 8.25 kJ/g. Biobriquettes molded into a hollow-core cylindrical form exhibited energy output comparable to that of traditional fuels. The study demonstrates that low-energy content feedstocks can be composted, pressed and combusted to produce heat output commensurate with higher energy content fuels.

In 2006, the U.S. produced more than 227 billion kilograms (kg) of solid waste; this equates to approximately 2.1 kg per person per day, where approximately half of this amount is in the form of paper and horticultural rubbish[1]. Conversion of these wastes into combustible biomass briquettes would provide a means to satisfy individual energy needs while alleviating landfill use[2,3]. Further, lumber has become a scarce resource in many regions of the world, and there is a pressing need for sustainable fuels to augment or replace traditional wood fuels[4].

The energy produced when properly molded biobriquettes are combusted is comparable to traditional fuels. These biobriquettes can be burned in unmodified wood and wood pellet stoves, fireplaces, patio heaters and charcoal grills, and provide a low-cost method for converting organic wastes into energy [5]. Ideally, biofuels can be made from renewable and readily available materials, and their production should result in a reduced environmental impact when compared to traditional fuels being replaced[6]. The four types of biobriquettes produced and analyzed in this study consist of the following compositions: 100 percent biomass, 3:1 biomass to paper, 1:3 biomass to paper and 100 percent paper. This manuscript focuses on briquette composition and production, combustion, and energy content as determined by oxygen bomb calorimetry.

Biobriquette Composition and Production

The materials for biobriquettes including paper, leaves, pine needles, sawdust and shop waste were ground into particles of 6 to 8 millimeters (mm) in diameter to increase surface area for soaking and to enhance packing efficiency[7]. Briquettes made entirely of shredded paper were prepared by the addition of just enough water to cover the material and soaked for approximately one week. As the ratio of biomass to shredded paper increased, the amount of time required to soak the material for successful molding also increased. For instance, biobriquettes made entirely of shredded leaves required approximately five weeks soak time before pressing. The soaked material was tested for readiness by pressing a scoop of the mash by hand. Mash that held its form in the palm of the hand was considered ready to be pressed into briquettes.

Compaction occurred at moderate to low pressures (approximately 30 to 50 megapascal (MPa)) using adaptations of the original hand-operated lever press developed by Ben Bryant of the College of Forest Resources in Seattle, Wash.[8-10]. The mold for this press consists of a 100 mm diameter poly vinyl chloride (PVC) pipe with predrilled holes that was capped at the bottom with a thick piece of plastic drilled to accept a 38 mm diameter dowel used to create the central air channel in the briquette. Presoaked material was loaded into the mold around the dowel and the mold was capped with a plastic plug to create the air grooves at the briquette base. The concept of air grooves to increase surface area and facilitate air flow in the base of the briquette was introduced by Kobus Venter of Vuthisa Technologies, a briquette stove manufacturer in South Africa. Once loaded into the press, the biomass was compacted; the briquette manually pushed out of the PVC mold and placed onto a drying rack. After drying, the briquette dimensions were 97 mm outer diameter, and approximately 70 mm in height, with a 38 mm inner diameter hollow core. Figure

1 shows biobriquettes composed of 100 percent paper with increasing percent biomass to 100 percent biomass.

A Bunsen burner was used to simultaneously ignite the hollow core center, bottom and sides of the briquette. Upon ignition, flames formed a convection column in the center of the briquettes facilitated by the air grooves in the bottom of each briquette. The air grooves appeared to enhance the combustion, which lead to increased burn temperatures, combustion rates, more complete combustion and cleaner burns as evidenced by less smoke emission as compared to wood, wood pellets and charcoal[11].

Calorimetric Analysis

A Parr oxygen bomb calorimeter interfaced to a Vernier Logger Pro thermocouple was used to determine the caloric content of the biobriquette materials relative to traditional fuel sources. Bomb (or constant volume) calorimetry experiments were performed by traditional methods[12-17]. Briefly, the sample to be tested was grated, filtered with a 20-mesh sieve and then pressed into a 1 gram (g) pellet. Ignition of material under 2.533 megapascal oxygen (MPa $O2$) resulted in an observed temperature increase of the steel bomb vessel. The caloric content of the material was then calculated while taking into account corrections for unoxidized fuse wire. The heat capacity of the calorimeter was calibrated with benzoic acid and naphthalene standards[15].

Combustion Analysis

The combustion tests were carried out in a fume hood with a face velocity of 30.5 meters (m) per second, to provide a steady flow of air. Biobriquettes, weighing on the order of 100 g each, were placed on a wire mesh stand 21 centimeters from the floor of the hood and enclosed in a modified Weber chimney stove topped with wire mesh. A Bunsen burner placed under the briquette served as the ignition source. Once the biobriquette had begun to combust, the ignition source was removed and a 2-liter (L) aluminum saucepan containing 500 milliliters (mL) of deionized water was placed on top of the stove (Figure 2). This process was implemented in order to monitor the heat output from the biobriquette once the Bunsen burner was removed. The temperature of the water bath was recorded by the Vernier Logger Pro device interfaced to a computer, which measured the temperature change in the water every second over a span of 4,000 seconds (just over an hour). The four types of briquettes mentioned earlier were combusted in this study. In addition, traditional fuels including charcoal, wood and wood pellets were ignited and energy output was monitored under the same set of conditions (i.e. mass of 100 g, consistent ignition time by Bunsen burner, same method of recording heat output).

Briquettes of each composition were tested from two to four times whereas traditional fuel sources were tested thrice each.

Calorimetric Results

Figure 3 shows the results of the oxygen bomb calorimetry experiments. The caloric content of the briquettes increased with the percent of biomass in the briquette. The lowest value was found to be 4.48 kJ/g for 100 percent paper briquettes and the highest was 5.95 kJ/g for 100 percent biomass briquettes. The values for the 1:3 and 3:1 parts paper to biomass briquettes were determined to be 5.48 and 5.90 kJ/g, respectively. In all cases, the briquette materials were found to be lower in caloric content than wood pellets (8.25 kJ/g), wood (7.24 kJ/g), and charcoal (7.33 kJ/g). It should be noted that the caloric content of materials vary depending on the calorimetry method. In this study, bomb calorimetry was used on materials grated through a 20 mesh sieve to ensure consistent surface area of the sample. It is also important to note that combustion of unmodified materials will generally yield lower energy values than materials of increased surface area[18]. More effective thermal output is achieved by increasing the surface area, which allows biobriquettes to compete in terms of energy output with traditional fuel sources that may have greater caloric contents.

Combustion Analysis

When approximately 100 g masses of wood and wood pellets were rapidly ignited, the result was an average increase in temperature of 500 mL of deionized water of between 57 and 64 degrees Celsius, respectively. The charcoal sample was the slowest to ignite, resulting in the smallest water temperature increase, a change in temperature of 17 C, although it burned for the longest duration. In comparison, it was found that briquette combustion was optimized by airflow grooves and a 150 second ignition time in an air-rich environment. These conditions mimic the combustion of multiple briquettes at one time, which is their intended use.

To demonstrate the characteristic properties of biobriquette combustion under these ideal conditions, an experiment was conducted using the 1:3 part biomass to paper briquette. The results of this test demonstrate that biobriquettes can produce temperature changes for 500 mL of water that are consistent with those of wood and wood pellets (i.e. a change in temperature less than or equal to 47 C) (Figure 4). Ignition times of 60 and 90 seconds provided slower, smoldering burns with a change in temperature of less than or equal to 20 C, but as ignition times increased to 120 and 150 seconds, peak temperatures rose accordingly, which caused an increase in water temperature between a change in temperature of less than or equal to 40 C and a change in temperature of less than or equal to 47 C, respectively (i.e. commensurate with traditional fuels).

Discussion

Study results show that the energy output of biobriquettes compressed from biomass waste is nearly equivalent to that of common fuel sources when burned in an oxygen-rich environment comparable to unmodified wood and wood pellet stoves, fireplaces, patio heaters and charcoal grills. There are many clear advantages of biobriquettes, including the simplicity by which they can be produced and the availability and affordability of materials used in their production.

REFERENCES

1. U.S. EPA; Municipal Solid Waste: Basic Information, www.epa.gov/msw/facts.htm (Accessed 16 July 2010).

2. Mississippi Department of Environmental Quality, Jackson, MS; Junk Mail Reduction, http://deq.state.ms.us/MDEQ.nsf/page/Recycling_JunkMailReduction?OpenDocument (Accessed 16 July 2010).

3. Recycling Advocates, Portland, Ore.; Ten Ways to Stop Junk Mail Reduce, Reuse, Recycle, www.recyclingadvocates.org/pdf/pubs/junkmail.pdf (accessed 16 July 2010).

4. Chaney J O, Clifford M J, Wilson R, An Experimental Study of The Combustion Characteristics of Low-Density Biomass Briquettes.

5. Landfills: Environmental Problems, www.landfill-site.com/html/landfills__environmental_probl.php, Search Term: Landfill Problems, (Accessed 17 July 2010).

6. Demirbas A. Sustainable Charcoal Production and Charcoal Briquetting. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, Vol. 31, Is. 19, January 2009, pp. 1694-1699.

7. Grover P D, Mishra, S K, Biomass Briquetting: Technology and Practices. Food and Agriculture Organization of the United Nations, Bangkok, Thailand. The FAO Regional Wood Energy Development Program in Asia, April 1996.

8. Volunteers in Technical Assistance, Arlington, Va.; Understanding

Briquetting, www.cd3wd.com/cd3wd_40/vita/briquett/en/briquett.htm (accessed 17 July 2010).

9. Volunteers in Technical Assistance, Arlington, Va.; Understanding Wood Wastes as Fuel, Technical Paper #46, www.bioenergylists.org/vitawood (accessed 17 July 2010).

10. Volunteers in Technical Assistance, Arlington, Va.; Understanding Paper Recycling, www.cd3wd.com/cd3wd_40/vita/paprrcyc/en/paprrcyc.htm (accessed 17 July 2010).

11. Legacy Foundation, Ashland, Ore.; Fuel Briquettes, www.legacyfound.org/ (Accessed 16 July 2010).

12. Jessup R S. Precise Measurement of Heat of Combustion with a Bomb Calorimeter. Natl Bar Std US Monograph 1960; 7.

13. Coops J, Jessup R S, van Nes K, Hubbard W N, Scott D W, Prosen E J, et al. Chapters 3, 5 and 6. In: Rossini FD, editor. Experimental Thermochemistry, New York: Interscience Publishers, Inc; 1956.

14. Sturtevant J M. Technique of Organic Chemistry. In: Weissberger A, editor. Physical Methods of Organic Chemistry, New York: Interscience Publishers, Inc; 1959, vol. 1, pt. 1, p. 597-8.

15. Oxygen Bomb Calorimetry and Combustion Methods, Parr Instrument Co. (Moline, Ill.); 1960, Tech. Manual 130.

16. International Critical Tables. New York: McGraw-Hill Book Company; 1929, vol. V, p. 162.

17. Selected Values of Chemical Thermodynamic Properties, Natl. Bar. Std. U.S. Circl 500, 1952.

18. Holstein S, Stanley R, McDougal O M. Fuel Briquettes Out of Junk Mail and Yard Wastes. J Chem Innovation 2001;31:22-8.

Authors: Owen M. McDougal, Seth Eidemiller, Nick Weires, Mark Swartz and Mike McCormick
Professor of Chemistry and Biochemistry, Boise State University
(208) 426-3964
owenmcdougal@boisestate.edu