PLANT CHICAGO

Exploring the Feasibility of Biomass Briquettes from Spent Brewery Grain

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Introduction

At *The Plant*, each batch of beer brewed by Whiner Beer produces roughly one ton of spent grain as a byproduct, and most weeks several batches are brewed. This results in a need to dispose of the grain or to somehow use it. Traditionally, if spent grain isn't hauled to a landfill, it is used on farms for compost or animal feed. An efficient process for producing a combustible fuel from the spent grain would reduce waste removal costs as well as provide supplemental fuel for the building, specifically the wood-fired oven used by Pleasant House Bakery.

Goals

The goal of our ongoing research is to explore the feasibility and scalability of creating a fuel made from waste materials produced either locally or onsite. The specific focus of this phase was to determine an efficient method for producing biomass briquettes and a recipe of materials . The goal was to make them mechanically strong enough to transport, as well as to characterize their combustion, looking for qualities such as burn duration and color of flames.

Background

There is precedent for taking widely available biomass and using it to formulate biomass briquettes. Although many have explored the process, significantly fewer have scientifically tested and documented their results at every step of the process. Creating biomass briquettes from rice straw and bran was thoroughly documented in a study documented by the National Pingtung University of Science and Technology[1]. Using a stainless steel mold and a manual operation hot press, the group investigated the importance of factors such as ratio of rice straw to bran, size of smashed straw, and hot pressing temperature in fabricating briquettes. The research group found the hot pressing temperature to be extremely important in both the mechanical strength as well as the heating value of the briquette. Another briquette feasibility study[2] was conducted by an Engineers Without Borders group in Cincinnati, this time regarding banana plant waste. This group tested a wide variety of methods with varying success. Ultimately the group recommended against using the banana plant waste for briquettes, as they were unable to find a process efficient enough.

Materials

Biomass

Three materials were tested for their potential in becoming a biomass briquette. Spent brewery grain was considered to be the 'main' ingredient for briquettes, as it was the main focus. Previous experiments determined that briquettes made entirely with spent grain were too 'spongy' to remain intact, and did not hold their size or shape while drying. Two additional materials were investigated as amendments to the spent grain: paper pulp and sawdust.

Paper pulp was created by soaking paper overnight in water. The paper was sourced from the recycling stream at *The Plant*, and mainly consisted of junk mail. Sawdust, while not a material produced at *The Plant*, it is a waste product of a few local businesses and is brought in as a growing medium for mushrooms.Multiple recipes were tested using various combinations of these materials, with the goal of finding a ratio that produced a stable, well compressed briquette.

Molds

The briquettes for this project were made using 2 different molds, one producing a solid cylinder and the other a hollow cylinder.

The solid cylinder mold was a piece of 3 inch PVC with multiple holes drilled in it, sitting on top of a solid piece of wood. The holes allowed the water to escape under pressure. A solid wooden cylinder flush with the inside diameter of the PVC pipe served as the plunger.

The hollow cylinder mold (see Image 2 below) was a piece of 3 inch PVC placed on top of a solid plywood block with a drainage hole in the center. A ½ inch piece of PVC with several holes drilled in it rested on top of the drainage hole. This assembly allowed water to be pressed through the holes in the ½ inch piece of PVC, down the drainage hole in the base, and out of the mold. A plywood ring was fitted within the 3 inch pipe and around the ½ inch pipe, and served as the plunger.

Press

Pressing of the biomass briquettes was done using a shop press with 6-ton hydraulic bottle jack. Hand pumping the jack creates linear motion, lowering a platform within the press. This platform then pushes the plunger down into the mold, compressing the biomass inside.

Food Dehydrator & Spice Grinder

A food dehydrator was used to dry a batch of spent grain in order to mill it into flour with a spice grinder.

5 Gallon Bucket

A plastic 5 gallon bucket was used to mix materials prior to being placed in the mold.

Propane torch

A propane torch was used as the source of ignition for evaluating the combustibility of the biomass briquettes.

Methods

To make each briquette, the desired ratio of materials (See Table 1 below) were mixed with water in a 5 gallon bucket. This mixture was poured into the mold and the mold was then placed in the shop press. The mixture was then pressed until significant resistance was felt from the bottle jack. At this point the mold was removed from the shop press, and the briquette was carefully removed from the mold. The briquette was then left to dry for 2-3 weeks.

Most recipes used unaltered spent grain, but one batch of briquettes was created using dried, milled grain. In order to make the milled grain, spent grain was dehydrated in the food dehydrator on the highest setting. Once it was dry to the touch (usually after 7-8 hours) it was removed and ground in the electric spice grinder, creating a coarse flour.

Table 1 (ratios of biomass materials by volume)

Briquette	Mold	Processing of Grain	Percentage grain	Percentage paper pulp	Percentage sawdust	Strong enough to transport
1 (baseline)	Solid cylinder	None	100%	0%	0%	No
2	Solid cylinder	None	50%	0%	50%	No
3	Hollow Cylinder	None	50%	0%	50%	Yes
4	Hollow Cylinder	None	40%	20%	40%	Yes
5	Hollow Cylinder	None	50%	50%	0%	Yes
6	Hollow Cylinder	Milled	50%	0%	50%	Yes

After the various recipes of briquettes were created they were air dried in one of two locations: indoors in our aquaponic farm or outdoors on the roof of the building. Neither of these locations produced ideal results. Indoor drying in a humid environment resulted in long drying times and an increased likelihood of mold. Outdoor drying went faster, but frequent summer storms resulted in the briquettes becoming wet again, regardless of the shelter we tried to provide them. Both of these issues resulted in us not reaching a definitive result for average or ideal drying time.

Mechanical Strength Results

We found that two factors made the most difference to the mechanical strength of the briquettes: mold shape and particle size.

Image 1: Solid Cylinder Briquettes (briquette type 2 on right)

The mold shape proved to be very important. The solid cylinder mold produced a briquette that tended to fall apart soon after removal (see Image 1 above). We suspect this was due to the relatively large number of holes in the PVC pipe, possibly reducing the effective pressure applied to the biomass. The hollow cylinder mold resulted in a much stronger briquette (see Image 2). With a solid outside surface and smaller, less numerous holes, more pressure could be applied to the material. The resulting tube-like briquette had a much larger surface area, allowing it to dry faster and more evenly (see Image 3).

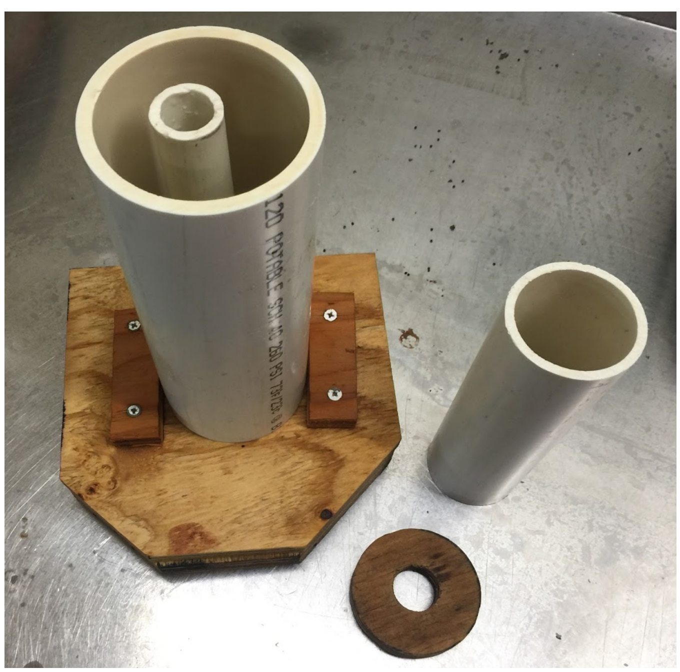

Image 2: Hollow Cylinder Mold with 3 inch solid outer pvc pipe, ½ inch perforated inner pipe for drainage, plywood ring and 2 inch pipe plunger.

Image 3: Hollow Cylinder Briquettes (Top row, from left to right: 50% grain and sawdust - briquette type 3, 100% sawdust - control sawdust briquette, 50% milled grain and sawdust - briquette type 6. Bottom row: 50% grain and paper pulp - briquette type 5)

Particle size was also a factor in mechanical strength. We found previously that briquettes made with 100% grain were simply not conducive to holding together. We knew that the addition of a smaller grained material would help to 'glue' the briquette together. Our two other materials (sawdust and paper pulp) were added in various ratios to help determine which would be more suitable and create a stronger briquette. Between the two, no significant difference in strength was noted.

To further address the issue of particle size, we explored the idea of making the size of the spent grain smaller (see Methods section above). Although both the unprocessed grain and the milled grain were strong enough to transport, the milled grain briquettes (briquette 6) were significantly stronger and harder, indicating that the particle size of the milled grain resulted in a stronger briquette. One possible downside to this stronger briquette is that the higher density increases drying time.

Characterization of Combustion

Initially we attempted to ignite the briquettes by firing them individually with a propane torch for 30-60 seconds. This resulted in a very slow, smoky smolder over the course of an hour (see Image 4 below). This was not the type of combustion we were looking for, as the briquettes' combustion is intended to replicate firewood. In order to better replicate the conditions within the wood-fired ovens we placed all of the briquettes made by our group onto an already burning kindling fire (see Image 5). This resulted in all of the bricks burning much quicker and hotter than our previous attempt. The flames were consistently orange throughout the burn. All of the bricks burned in one of two ways. The first being crumbling apart very gradually, similar to charcoal. Briquette formulations 3-5 burned in this manner. Briquette 6 only broke apart when pressure was applied, and retained its structure much longer than the other bricks.

More testing should be done to determine which of these two types of burns is preferable. This could be done by producing 10-20 of both briquette type 3 (this one uses sawdust, which is much more readily available than paper pulp) and briquette type 6. They would then be burned in separate fires started by equal amounts of kindling. Under these conditions a calorimetry test could be done on both the briquette 3 fire and the briquette 6 fire to determine which formula would better suit the needs of a wood-fired oven.

Image 4: Bio Briquette Burned Individually

Image 5: Bio Briquettes Burned as a Group

Conclusions

By moving from a solid cylinder mold to a hollow cylinder mold, we were able to produce consistently solid and stable briquettes across a range of biomass formulas. Using a steel shop press was much preferred over our previous tests using one of wooden construction. The steel press was larger, more stable and was equipped with a return spring that retracted the plunger when pressing was complete.

The pressing process is somewhat lengthy, involving the filling of the mold, the actual compressing of the briquette, and removal of the briquette from the mold. This last step can be somewhat tricky as the briquettes are the least stable immediately after being pressed and increase in stability as they dry. The compressing action itself can be multiple steps as well depending on any adjustments needed to the shop press (see *Moving Forward* below).

During the combustion tests, we determined that briquette types 3-6 were visually consistent with a traditional wood fire. All of these formulas additionally produced a strong structure that were able to dry thoroughly. Due to the inability to create sustained combustion from a single briquette, we were unable to empirically determine which of these types produced more heat.

Moving Forward

Using the information gathered during the test burns of the briquettes, we intend to produce a larger quantity of both briquettes 3 and 6 as mentioned above. We hope to then burn large amounts of each of these briquette types, and perform a basic calorimetric test to determine the heat output of each. With this information, we can hopefully determine which would make a better firewood substitute. Due to the extra energy and time required in the processing of the spent grain in briquette 6, we will necessarily have to weigh this against any heat output gains over briquette 3.

Additionally we intend to create two more sets of molds for the pressing of the briquettes. With 3 sets of molds and the help of volunteers, we can more quickly create briquettes since each stage of the pressing process can be accomplished by each person simultaneously.

The current press set-up centers around a 6-ton bottle jack with a roughly 4.5" stroke. Due to this short distance and the necessary length of the plunger, most briquettes require two pressings, with an adjustment of the press in between. A larger jack with a longer stroke would be ideal in order to produce a briquette with a single pressing.

In order to address the issues encountered with drying the briquettes, we also intend to experiment with other less passive, though still energy efficient, drying methods. These include solar kilns, cold frames, or even using the exhaust of the bakery oven as a heat source for active drying of the briquettes.

Check in with our blog for future updates on this ongoing project! If a final formula can be reached, we intend to start testing the briquettes in the Pleasant House Bakery oven!

Sources

[1]Chuen-Shii Chou, Sheau-Horng Lin, Wen-Chung Lu, Preparation and characterization of solid biomass fuel made from rice straw and rice bran, Fuel Processing Technology, Volume 90, Issues 7–8, July–August 2009, Pages 980-987, ISSN 0378-3820, http://dx.doi.org/10.1016/j.fuproc.2009.04.012.
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Keywords: Rice straw; Rice bran; Solid biomass fuel; Compressive strength; Heating value

[2]Nurhayati Abdullah, Fauziah Sulaiman, Muhamad Azman Miskam, Rahmad Mohd Taib, Characterization of Banana (Musa spp.) Pseudo-Stem and Fruit-Bunch-Stem as a Potential Renewable Energy Resource, International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering Vol:8 No: 8, 2014, Pages 815-819, scholar.waset.org/1999.1/9998963.
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