Feasibility of Biomass Fuel Briquettes from Banana Plant Waste

By: Lee Hite, Dr. Zan Smith and the fuel briquetting team.

Fibers from the banana plant could be a new binder for sawdust other than paper pulp. Biomass from banana plant waste is usable in a fuel briquette under limited conditions and this paper reviews those limitations.

Summary:

We examined the issues with making fuel briquettes from banana plant waste to determine how likely it was they could be solved. It is our opinion that with special processing for the fibers from the banana stalks they could be used as a binder for sawdust, but the process may not be practical or economically solved at this time. We therefore believe it would be more practical to harvest fibers from the banana stalk for commercial purposes.

Background:

In support of the Chapter's work in Rwanda (Muhororo, Ntobwe & Rubona) we wanted to explore the possibility of using the banana plant waste products as a biomass fuel. We set out to learn as much as we could about the banana plant and its properties that would support fuel briquettes. With that in mind, we have conducted limited testing. Research in this paper was limited to banana leaves, stalks, leaf ribs, blackened banana skins, banana fruit (the part you eat), sawdust, wood chips, paper pulp from newspaper and yard leaves from the maple tree, and may not apply to other biomass materials.

The Banana Plant, Simply Amazing

In addition to being a ubiquitous fruit many enjoy, the banana plant has a long list of amazing qualities for which many wonderful products result.[1] The sap is used to dye cloth, produce indelible inks and assist with the production of antibacterial soap and gel. The superior strength of the fibers have a long list of applications in the textile fabrics and the paper pulp industries[2]. Unfortunately, the very qualities that contribute to making this a unique plant also work against its successful use as a biomass fuel briquette.

For example, the plant has a natural antimicrobial and antibacterial substance that allows the leaf to be used as a hygienic dining plate.[3] Efforts to compost plant waste are seriously impeded by this antimicrobial and antibacterial quality. Over seven months we composted a batch of banana plant waste (mostly chopped stalk, leaf and leaf ribs) with little signs of decay or a bad odor. See picture at right.

In contrast, we added 10% fresh chopped stalk to a 90% well composted batch of ward waste and after four months, the bacteria in the yard compost decayed most of the banana stalk. From this experience, we were convinced that composting was not a practical option to breakdown banana plant waste.

In addition, the banana fiber contains numerous capillary tubes which allow it to absorb and release liquid better than cotton fiber.[4 and 5] Also see Figures 20 and 21 on page 9.

This absorption quality of the fiber is used in the production of fabrics for shirts, bedding, household textiles, socks and feminine hygiene products. Banana fibers can quickly absorb moisture yet remains dry to the touch[6]. The fibers are used for natural water purification, for bioremediation and for recycling[2]. Unfortunately, when the fibers are packed tightly into a fuel briquette, the water release is very slow and it is nearly impossible to completely air dry the briquette. When other biomass is added to the fiber mixture, water release from the fibers is further impeded.

Superior strength is another positive quality for this fiber allowing it to be used for printing money, and for making rope cordage, yarns, abrasive backing paper, tea bags and shoes[6]. High-strength plastics made using the banana fibers are thirty percent lighter and three to four times stronger than conventional high strength plastics.[12] The fiber has a beautiful sheen and is not easily crumpled, making it ideal for wedding gowns, dress materials, handbags, wall hangings and table mats[6]. Unfortunately, this strength inhibits the fiber from easily breaking and requires cutting into small sections for the biomass preparation.

Banana peels are used for polishing silverware, leather shoes, and the leaves of house plants. Researchers found that minced banana peel could quickly remove lead and copper from river water as well as, or better than, many other materials. A purification apparatus made of banana peels can be used up to eleven times without losing its metal-binding properties.[11] The banana peels are very attractive as water purifiers because of their low cost and because they don't have to be chemically modified.[11]

Available Plant Waste

An important part of the word "biomass" is the word mass and there isn't much mass in the banana stalk. Ninety-seven percent of the stalk by weight is liquid in its harvested condition[9] and this percentage is not much lower in the remainder of the plant[10]. The mass is mostly fibers. See Figures 1, 2 & 3

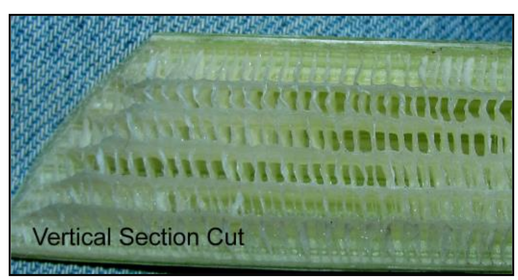


Figure 1

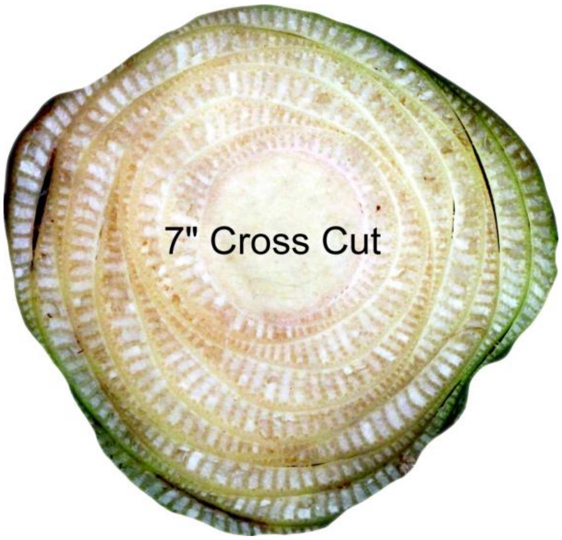


Figure 2

Figure 3

We investigated the biomass from both the green banana plant available immediately after the hand of bananas had been harvested and the dried fronds left from past harvests. To include all the waste products form the banana plant in our research we included some blackened banana peels and the fruit (the part you eat) as a binder for the fiber mixture. We included some formulations using non-banana biomass as a means to judge the effectiveness of the banana plant waste as a fuel briquette compared to non banana plant waste,. Twenty eight formulations were tested.

Biomass Preparation:

Cutting the material to length was done using an automated machete chopper that we developed for this application called the "Easy BioChop". See Figure 4. Three lengths of fibers were used, 3 inch, 1 ½ inch and ½ inch. Figures 5 & 6.

Figure 4 (Easy BioChop)

The first batch of feed stock using the green stalk, green leaf and green leaf rib were cut into sections about three inches long and two inches wide (Figure 6). These were composted four weeks in a rotatable drum composter (Figure 7 & 8) and in a black plastic bag (Figure 9) with an ambient daytime air temperature of 80°F. The use of a black plastic bag is a more typical method of composting used by many biomass producers, rather than the drum.

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

The results from that procedure were not the normal decayed biomass one would obtain from a composting process (Figure 10), but rather a softened and dark colored material with no visible decay and no bad odor. Removing the green color from the mixture was an important indication that the chlorophyll (a known carcinogenic in the smoke from the burning of green material[7]) had been released. The natural antimicrobial and antibacterial[2] properties worked against the composting process used to help expose the fibers.

The dark brown material from the composting effort was divided into two groups. The first group was placed on tarp and dried in the sun for four weeks. The dry fronds were then run through a special grinder, the Easy BioGrind (Figure 11) developed for this purpose to expose about eighty percent of the available fibers. (Figure 12)

Figure 11 (Easy BioGrind)

Figure 12

Group two (Figure 13) remained as a wet biomass and was mashed in a Mortar & Pestle operation sufficient to expose about ninety percent of the fibers and pass the ‘Ooze’, ‘Spring back’ and ‘Shake’ test.[8]
The ‘Ooze’, ‘Spring back’ and ‘Shake’ test is used as a quick measure to determine the likelihood the finished briquette would be well formed and structurally sound.

Figure 13

The leaf and leaf rib from the waste remained their original size and were placed on a black driveway, and exposed to the sun to dry. (Figure 14) The stalk was cut into sections about three feet long. Because the stalk was very slow to dry, even in the hot sun, the bark of the stalk was pealed back (like removing a single sheet of paper from a roll of paper towels) to expose thinners sections of the stalk.

Figure 14

Figure 15

The leaves dried quickly in about three days but maintained their green color (not desirable because it indicates trapped chlorophyll). The rib of the leaf dried in about three weeks and turned brown in the process (chlorophyll removed). (Figure 15)

Conversely, the bark dried slowly and was not completely dry after eight weeks in the sun. We drove over the bark with car tires to squeeze the sludge from the stalk bark. The material subsequently dried and turned brown in about three weeks.

The dry leaves and stalk bark were run thru the Easy BioChop and cut into sections about three inches long. That material was then run through the Easy BioGrind to expose the fibers. Some of the fibers were exposed from the grinding process but not all. About twenty percent of fibers from the leaves and about forty percent of the fibers from the stalk bark were exposed. Once the material was dry, exposing the fibers became more difficult compared to the wet process.

Paper pulp was B&W newspaper dissolved in warm water. Sawdust was from soft woods cut using a twenty four teeth/inch saw blade. Peanut Shells were gleaned from shelling raw peanuts that were run through the Easy BioGrind to break up and flatten them. Leaves were dried maple leaves put through the same grinder to create cornflake size pieces.

Binding Formulations

We found three formulations acceptable for binding the fibrous banana waste. The first formulation used the darkened brown output from the composting efforts, mashed using a Mortar and Pestle to expose most of the fibers, (Figures 13) and formed directly in the briquette mold. This resulted in a fairly well formed briquette but required tedious hand packing. (See test 14)

The second successful formulation had paper pulp added to the fibrous material. An excellent structural briquette was formed from this mixture. (See test10.)

The third formulation utilized fibers produced by a short burst in a food blender after a Mortar and Pestle operation on fresh green stalk. A formulation using ten percent fibers in a sawdust mixture then was used to produce a solid briquette. Some sawdust required twenty percent fibers for a well formed briquette.

Figure 16

Unsuccessful formulations resulted when biomass other than paper pulp was added to the mixture. Sawdust, leaves or peanut shells served to loosened the mixture and for the most part, were quite unacceptable. See test pictures 8, 13, 17 & 19. The exception was the use of fibers from the high-tip-speed food blender, Figure 17. Dried fronds were ground to expose some of their fibers using the Easy BioGrind, (see test 20.) They were less likely to bind well compared to the fibrous mixture used in test 14.

Figure 17

Mixture/Blend Formulations:

Table 1

Test 1, 2, and 8 thru 28: 3" Diameter Briquette with 1" center hole approximately 1 1/4" tall.
Test 1 thru 7: 96g of feedstock.

Test 1: 80% sawdust 20% paper pulp, donut shaped briquettes
Test 2: 80% leaves/ 20 paper pulp, donut shaped briquettes
Test 3: 80% leaves/20 paper, handmade ball briquettes
Test 4: 2/3 sawdust, 1/3 banana peel, caulking gun briquettes
Test 5: 2/3 dry banana leaves, 1/3 banana peel,, caulking gun briquettes
Test 6: 1/3 dry banana leaves, 1/3 banana peel, 1/3 sawdust, caulking gun briquettes
Test 7: 96g of softwood blocks
Test 8: 50% Banana Fronds, 50% Sawdust (Dried 2 hrs @ 300° F)
Test 9: 1/3 Banana Fronds, 1/3 Paper Pulp, 1/3 Sawdust (Dried 2 hrs @ 300° F)
Test 10: 70% Banana Fronds, 30% Paper Pulp (Dried 2 hrs @ 300° F)
Test 11: 40% Banana Fronds, 40% Sawdust, 20% Paper Pulp (Moisture) (Dried 2 hrs @ 300° F)
Test 11A: 40% Banana Fronds, 40% Sawdust, 20% Paper Pulp (Oven Dry) (Dried 2 hrs @ 300° F)
Test 12: 1/3 Banana Fronds 1/3, Paper Pulp, 1/3 Small Wood Chips (Dried 2 hrs @ 300° F)
Test 13: 50% Banana Fronds, 50% Small Wood Chips (Dried 2 hrs @ 300° F)
Test 14: 100% Banana Fronds (Fibers Exposed) (Dried 2 hrs @ 300° F)
Test 15: 40% Banana Fronds, 40% Maple Leaves, 20% Paper Pulp (Dried 5 hrs @ 300° F)
Test 16: 90% Banana Fronds, 10% Banana Skins (Dried 5 hrs @ 300° F)
Test 17: 40% Banana Fronds, 40% Saw Dust, 20% Banana Skins (Dried 5 hrs @ 300° F)
Test 18: 40% Peanut Shells, 40% Saw Dust, 20% Paper Pulp (Dried 5 hrs @ 300° F)
Test 19 80% Banana Fronds, 20% Peanut Shells (Dried 5 hrs @ 300° F)
Test 20: 100% Banana Fronds (Minimal fibers exposed) (Dried 5 hrs @ 300° F)
Test 21: 1/3 Banana Fronds, 1/3 Paper Pulp, 1/3 Sawdust (Dried 5 hrs @ 300° F)
Test 22: 50% Composted Hostas Plant, 50% Wood Chips (Dried 5 hrs @ 300° F)
Test 23: 100% Banana Plant Bark, Fresh cut into 1/2" long chunks, Mashed to a fiber consistency. Dried @ 220° F for 6 hrs and 330° F for 5 hrs
Test 24: 80% Banana Plant Bark, Fresh cut into 1/2" long chunks, Mashed to a fiber consistency; 20% Paper Pulp. Dried @ 220° F for 6 hrs
Test 25: 80% Banana Plant Bark , Fresh cut into 1/2" long chunks, Mashed to a fiber consistency; 20% Paper Pulp, Dried @ 220° F for 6 hrs
Test 26: 80% Banana Plant Bark, Fresh cut into 1/2" long chunks, One freeze/thaw cycle, Composted for 1 week, Mashed to a fiber consistency, 20% Paper Pulp, Dried @ 220° For 6 hrs and 330° F for 5 hrs
Test 27: 80% Banana Plant Bark, Fresh cut into 1 1/2" long chunks, One freeze/thaw cycle, Composted for 3 weeks, Mashed to a fiber consistency, Dried @ 220° F for 6 hrs and 330° F for 5 hrs
Test 28: 80% Banana Plant Bark, Fresh cut into 1 1/2" long chunks, One freeze/thaw cycle, Composted for 3 weeks, Mashed to a fiber consistency, 20% Paper Pulp, Dried @ 220° For 6 hrs and 330° F for 5 hrs

Briquette Production:

Unless noted otherwise, briquettes were made using the micro compound lever press with a mold diameter of three inches and a center hole of one inch. (Figure 18) The alternate briquettes were made using a caulking gun press (Figure 19) or hand made ball briquettes.

Test 1 thru 7 was 96g of feedstock and test 8 thru 22 was between 66g and 126g of feedstock. Test 1, 2 and 8 thru 22: used a 3” diameter mold, 3 ½” high with a one inch center hole. The mold was filled to the top with wet biomass. Some mixtures produced a good form factor when ejected from the mold and other mixtures had excessive spring back[8]. The mold was difficult to fill with the fiber mixture using a pouring cup. Instead, we hand packed the mold, which was a tedious and time consuming operation. Test two used hand made ball briquettes and briquettes for test 3- 5 were from the caulking gun press.

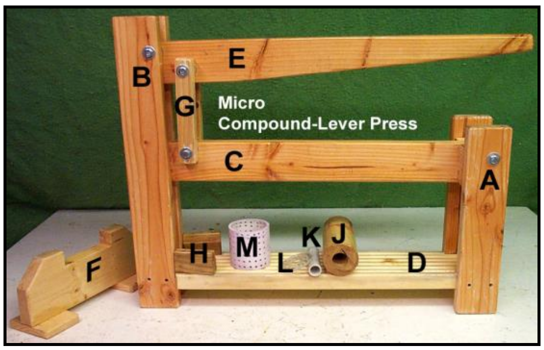


Figure 18

Figure 19

Drying the wet briquette:
This was a difficult task to accomplish successfully. The banana fiber is quick to absorb moisture (Figure 20) making it a desirable material for a number of other applications. The structure of the fiber contains numerous capillary type tubes[7] (Figures 22 & 23) that easily absorb moisture. While the release of that moisture is normally good (Figure 21) when the fiber is dried in an unrestricted surrounding, we found that when the fibrous biomass was packed tightly into a briquette, the moisture was difficult to release by air drying. Some formulations added non banana material to enhance binding or burning, and this addition further impeded air drying.

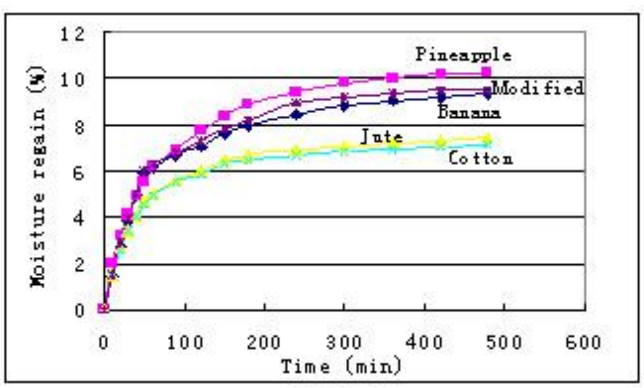


Figure 20

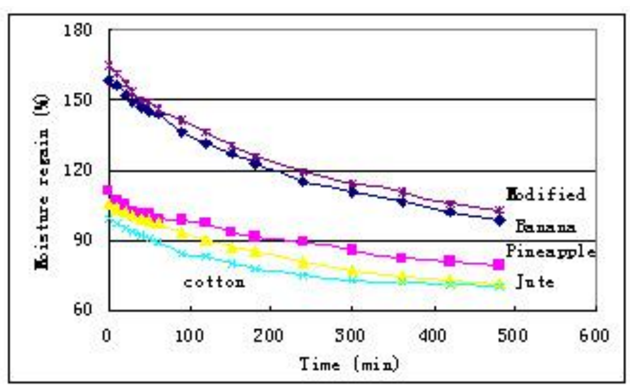


Figure 21

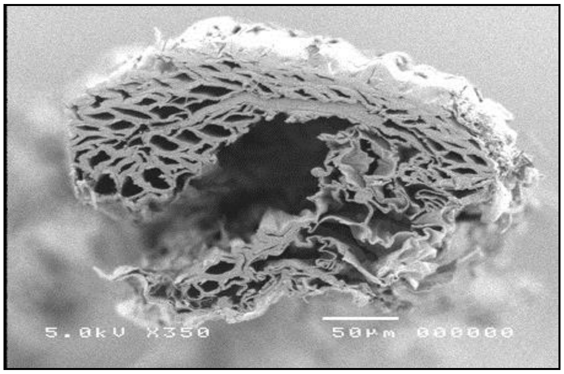


Figure 22

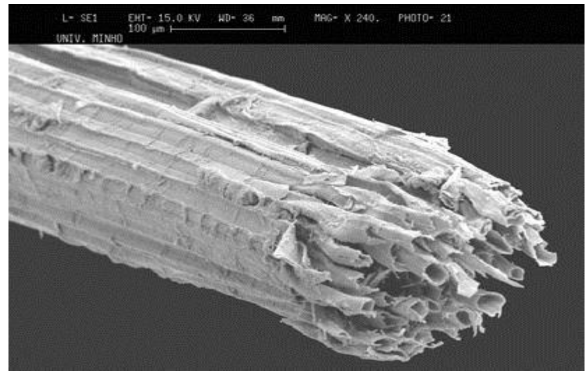


Figure 23

In fact, if non banana biomass was added to the banana fiber mixture we found it impossible to adequately air dry the briquette. Excessive smoke lasted through most of the burn until final flash point was achieved for the moisture laden air-dried briquettes. This was considered an unacceptable performance.

We used extreme measures in an attempt to dry briquettes containing banana fibers. The first attempt was to oven dry the briquette for two hours at 300°F. If the moisture test (described below) failed we again baked the briquette for an additional three hours at 300°F. Most briquettes containing banana fibers passed the moisture test after five hours at 300°F, but not all.

Moisture Test:

The test for residual briquette moisture was to place the briquette into a small sealed plastic bag, squeeze out the air, and heat the briquette in a 1,000 W microwave oven for a period of not more than one minute. Observe the bag for expansion and moisture condensation on the inside surface of the bag. If none was observed, we placed the bag in the refrigerator to accelerate the condensation of possible water vapor on the inside of the bag. If no condensation was observed we considered the briquette to be dry. See Figures 24 & 25.

Figure 24

Figure 25

Caution with this test: over-heating the briquette in the microwave oven can cause the briquette to catch fire and burn from the inside out. Immediately immerse in water should this occur.

Drying Time vs. Formulation:
We were curious about the drying time for other briquettes mixtures. We tested four mixtures (Figures 26 & 27). They were placed on an outdoor elevated wire mesh screen twenty four hrs/day and received about eight hours of sun/day. Ambient daytime air was 75°F with a wind of 0-5 mph and a dewpoint of 44°.

We found that any formulation made from the trunk of a wood tree (paper pulp, wood chips or sawdust) can dry to about six percent moisture in thirty six hours in Ohio sun. However adding leaves to the mixture doubles the drying time to seventy two hours. (Figure 27)

Adding banana fibers to a formulation significantly lengthened the drying time (Figure 28)

Figure 26

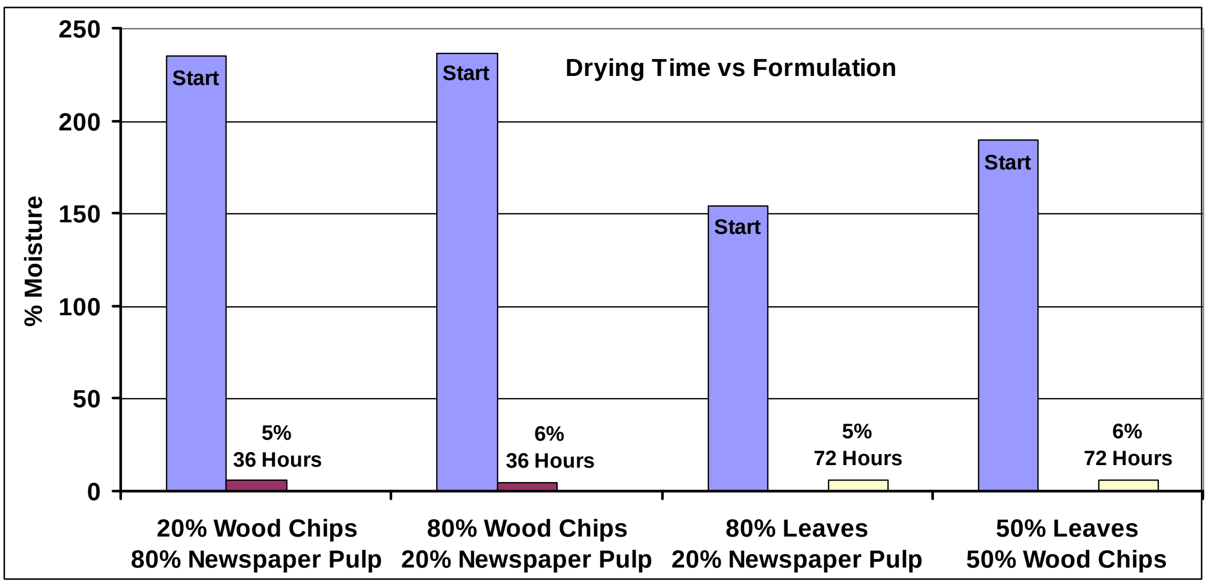


Figure 27

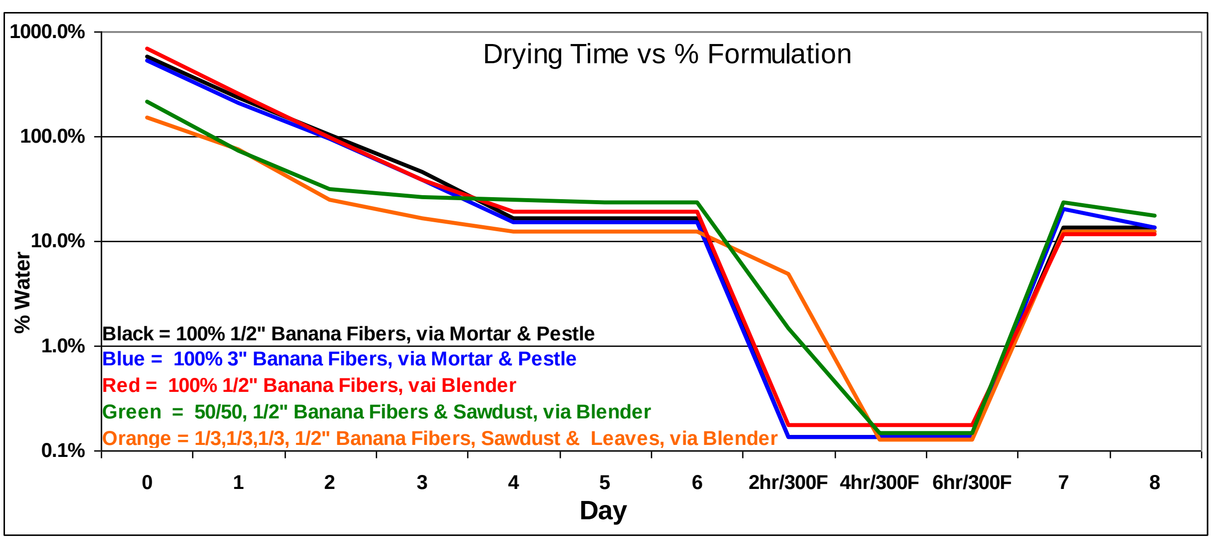


Figure 28

Moisture Re-absorption vs. Formulation:
Briquettes were oven-dried to less than one percent moisture by weight and left outdoors under a rain shelter. Day one and two had intermittent rain with daytime temperatures around 85°F and seventy percent relative humidity. Day 3, 4 & 5 were sunny with temperatures around 85°F and forty percent relative humidity.

At the end of the first 24 hrs, (Day one) the briquettes rapidly absorbed moisture to above ten percent by weight. Most briquettes released some moisture when it stopped raining at the end of day two and by day three had returned to the moisture levels present at the end of day one. (See figure 29)

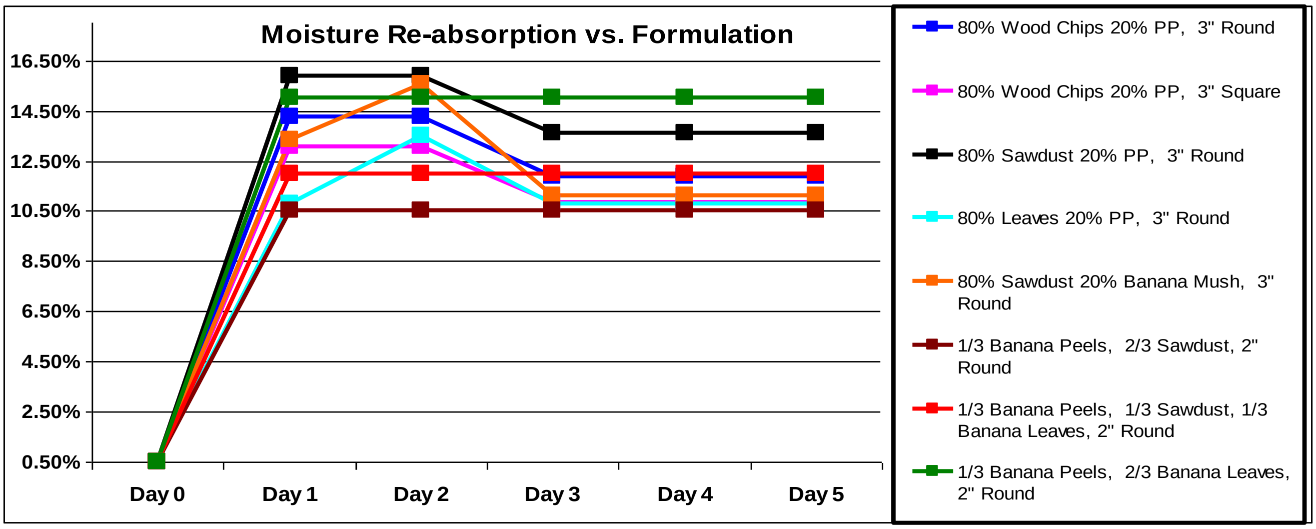


Figure 29

Burn Formulations:
Formulations listed in table one include mixtures for both banana plant waste and other mixtures not using banana biomass.

Early testing revealed that using a mixture that included long banana fibers (say four inches or longer) made it impossible to adequately stir a mixture without creating a large ball of fibers that was impossible to unravel. In addition, the longer the fibers the more difficult it was to pack the mold. This limitation required all green and dry material be cut to a length of two to three inches or shorter to minimize clogging during the wet process.

Several mixtures did not pass the 'Ooze', 'Spring back' and 'Shake' tests as suggested by the Legacy Foundation as a measure for the potential integrity of the briquette. However, we continued to include them in the burn for determination of the available BTU generated.

Burn Test:
All burns were done using the same stove which was a paint can with air holes around the bottom circumference and around the top circumference. A grate raised the burn floor up about one inch from the bottom of the can. (Figure 30 & 31)

Figure 30

Figure 31

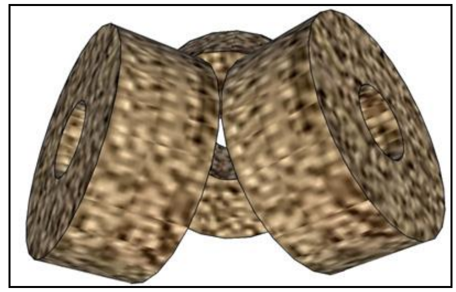


Figure 32

The water was in a coffee can that just fit on top of the paint can. The weight of the water was measured before and after the burn. Water temperature was logged every one minute until no increase in temperature was observed. (Figure 33)

Three briquettes from each mixture were selected for each burn and weighed prior to burning. See briquette pictures for test 8 thru 22.. Not all three - briquette combinations were exactly the same weight. Ignition was a single sheet of 8 ½' x 11" paper crumpled, ignited and placed in the center of the three briquette stack. (Figure 32) No gasses or particulates were measured. BTU for each burn was calculated from test results and plotted for each mixture.

(Figure 33)

We found BTU/gram of dry briquette mixture a useful measure of burn performance and helped to normalize the uneven weight from the various three-briquette mixtures. See Figure 34.

We recommend the appropriate use of safety goggles and rubber gloves for these tests, and suggest you have a pail of water and a fire extinguisher available.

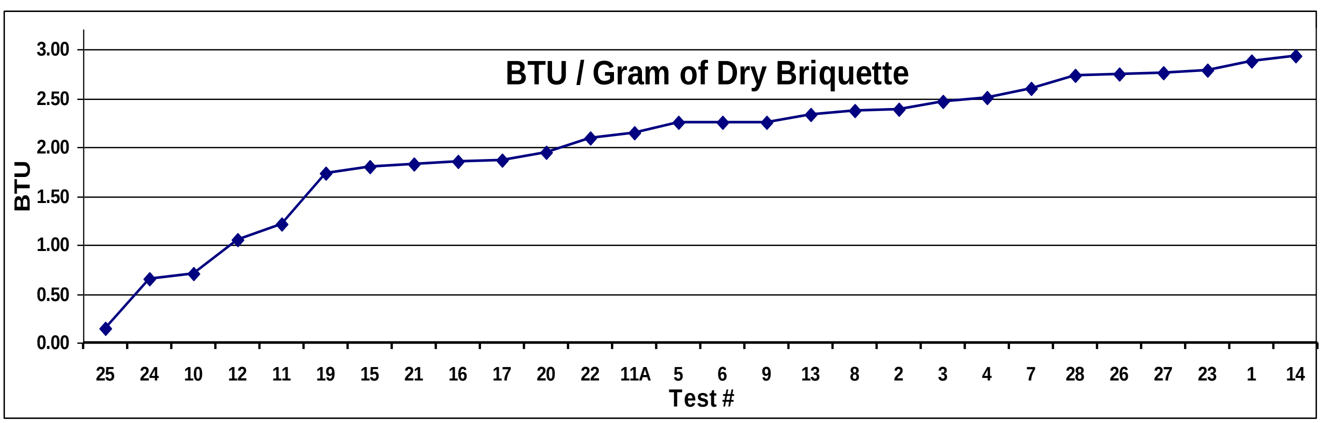
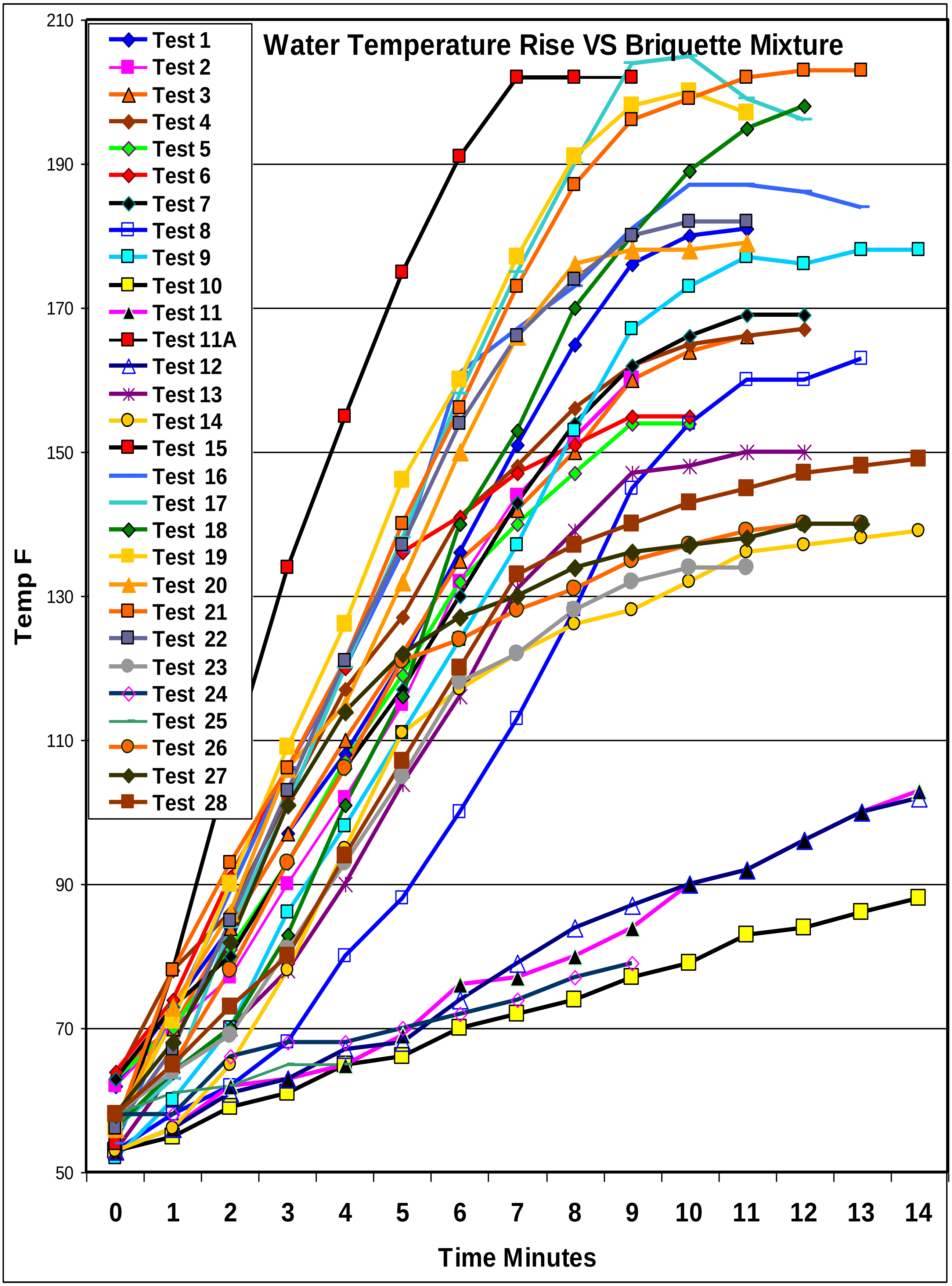


Figure 34

Water Temperature Rise VS Briquette Mixture

The rate at which the water temperature increased was dependent on the available BTU from the briquettes, the mass of the three selected test briquettes, briquette moisture content and air supply to briquette material. This was not intended to be a definitive test but rather a general means of evaluation.

For example, test fourteen was 100% banana waste with fibers exposed. The openness of the briquette was high as a result of the exposed fibers. Excessive spring-back[8] existed when ejected from the mold and was not considered to be a structurally sound briquette. However, it did burn rapidly at the start of the burn test because of the good air supply to the inside of the briquette caused by the openness. However, as burning progressed it was slowed because it took time to force the moisture from the fibers. You can see in Figure 35 that test number fourteen heated quickly but stalled as the moisture laden fibers used up the heat to expel the moisture.



Water Temperature Rise VS Briquette Mixture
Temp F
Time Minutes
210
190
170
150
130
110
90
70
50
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Test 1
Test 2
Test 3
Test 4
Test 5
Test 6
Test 7
Test 8
Test 9
Test 10
Test 11
Test 11A
Test 12
Test 13
Test 14
Test 15
Test 16
Test 17
Test 18
Test 19
Test 20
Test 21
Test 22
Test 23
Test 24
Test 25
Test 26
Test 27
Test 28

Figure 35

Conclusions:

1. To prevent clogging the wet process with long fibers, both the green and the dry material need cutting into small lengths (under three inches).

2. No natural biomass binding properties exist within the chopped green or dry material. Self binding was possible after the green material had been softened via a composting like process and then mashed into a sludge using a mortar and pestle. This process exposed fibers sufficient for binding. The structure of the finished briquette was acceptable for testing but not considered to be commercially acceptable. Paper pulp increased binding and made a good structural briquette but the use of other biomass weakened the structure unless paper pulp was present.

3. Fibers from fresh green bark that were mashed using a Mortar and Pestle were further processed using a short burst in a high speed food blender. The Legacy Foundation determined that a formulation using 10% of these fibers and 90% sawdust produced a structurally sound briquette. The sawdust used in our test required twenty percent fibers for good binding when using the fibers from a high-tip-speed food blender. The challenge remains to find a wet grinding process that will emulate the same results produced by the food blender. As The Legacy Foundation points out, perhaps a sharp abrasive combustible residue like charcoal fines, rice husks or rough sawdust could act as a shearing medium, and then proceed to pound the mixture in the a Mortar and Pestle operation.

4. The natural antimicrobial and antibacterial properties of the banana plant worked against the composting process used to help expose the fibers. The chunks of banana waste turned brown and softened but never decayed after months in the composting process.

5. The binding of dry fronds was only possible after cutting to lengths of less than three inches and grinding to expose the available fibers, then mixing with a large amount of mashed dead banana skins and mashed banana fruit. This process was difficult to press because of the sticky mixture. In addition, it required an excessive amount of dead banana skins and fruit to bind a small amount of fronds.

6. Air-drying a banana biomass briquette was nearly impossible. Unobstructed by other surrounding material the banana fiber normally releases its moisture quickly. When pressed into a briquette the release of the moisture was very slow, even when oven dried. When surrounded with other biomass to enhance binding or burning, release of the fiber moisture was difficult to achieve even in an oven at 300°F.

7. We were not able to complete a successful burn using an air-dried briquette containing banana fibers because of excessive smoke from the burn. Perhaps the briquette would burn better in a forced air stove like a gasifier, but we did no testing for that condition.

8. Packing the briquette mold with the fibrous material was difficult, tedious and time consuming. The fibers were interwoven with other fibers and did not pour well. Hand packing worked better.

9. Softening by freezing was tested but not included in this report. We did expose a batch of fresh green chopped stalks to a single freeze/thaw cycle as a softening methodology. While that process did significantly hasten and enhance the softening process, it was not considered a practical solution for a tropical climate.

10. In our opinion producing a biomass fuel briquette from the waste of the banana plant is not worth the effort. It may be more practical to harvest and use the fibers from the stalk for commercial purposes. If one could find an adequate process to emulate the wet grinding

accomplished by using a food blender, then a small amount of those fibers (around 10% to 15%) could be effective as a binder for sawdust.

Credits:
Thank you to the EWGCP briquetting team that donated numerous hours to the project over the past 14 months.

Thank you to the efforts of the Krohn Conservatory for an endless supply of banana plant waste products.

Thank you to the Legacy Foundation for their excellent documentation on briquetting and for experiments using a food processor for fiber extraction and associated formulations.

Thank you to my wife for tolerating the use of her conventional oven and the microwave oven for briquette testing. Drying wet briquettes did not exactly have the same odor as baking cookies.

Thank you to the contributing editors.

Sources:

1. http://www.chiangmai-chiangrai.com/fruit-banana.html

2. Antibacterial and Antioxidant Activities of Banana
   (Musa, AAA cv. Cavendish) Fruits Peel
   Matook Saif Mokbel and Fumio Hashinaga
   Department of Biochemical Science and Technology, Faculty of Agriculture
   Kagoshima University, 1-21-24, Korimoto, Kagoshima 890-0065, Japan
   American Journal of Biochemistry and Biotechnology 1 (3): 125-131, 2005
   ISSN 1553-3468 © 2005 Science Publications
   http://www.scipub.org/fulltext/ajbb/ajbb13125-131.pdf

3. SWICOFIL AG Textile Services
   Postfach 1926
   Gerliswilstr. 23
   CH - 6021 Emmenbruecke
   Switzerland http://www.swicofil.com/products/010banana.html

4. Figures 22 & 23
   Banana Fibers – Variability and Fracture Behavior
   Samrat Mukhopadhyay, Ph.D.1, Raul Fangueiro, Ph.D.1, Yusuf Arpaç2, Ülkü Şentürk2
   1University of Minho, PORTUGAL, 2Ege University, TURKEY
   Journal of Engineered Fibers and Fabrics Volume 3, Issue 2—2008
   http://www.jeffjournal.org/papers/Volume3/Mukhopadhyay3.2.pdf, Page 43.

5. Figures 20 & 21.
   Suzhou Lifei Textile Co.,Ltd.
   221# Sudai road xiangcheng District Suzhou city China
   Zip Code: 215132 http://www.li-fei.com/banana.htm http://www.shenboo.com.cn
   http://www.li-fei.com/products/4/e10.htm rts

6. Nisshinbo Textile Inc.
2-31-11, Ningyo-cho, Nihonbashi,
Chuo-ku, Tokyo 103-8650, Japan http://www.nisshinbo-textile.co.jp/english/goodidea/banana.html

7. The Legacy Foundation, 4886 Highway 66, Ashland, OR 97520 http://www.legacyfound.org/
2003 —Fuel Briquettes: Theory and Applications from Around the World. Page 4

8. The Legacy Foundation, 4886 Highway 66, Ashland, OR 97520 http://www.legacyfound.org/
User- Producers Manual, Page 10

9. http://www.pulverdryerusa.com/applications.html

10. INVESTIGATIONS ON PREPARATION AND PRESSING OF BANANA PLANTS
H Prigge, R Kohlheb & K Becke, Universitat Gottingen, West Germany. March, 1980

11. Banana Peel Applied to the Solid Phase Extraction of Copper and Lead from River Water: Preconcentration of Metal Ions with a Fruit Waste. Industrial & Engineering Chemistry Research
Renata S. D. Castro,† La□ercio Caetano,‡ Guilherme Ferreira,§ Pedro M. Padilha,§,||
Margarida J. Saeki,§
Luiz F. Zara,^ Marco Antonio U. Martines,# and Gustavo R. Castro*,§
†FEIS-UNESP, Dept. de Fitotecnia, Tecnologia de Alimentos e S ocio Economia, C.P. 31, 15385-000 Ilha Solteira, SP, Brazil
‡FEIS-UNESP, Dept. de Física e Química, C.P. 31, 15385-000 Ilha Solteira, SP, Brazil
§IB-UNESP, Dept. Química e Bioquímica, C.P. 510, 18618-000 Botucatu, SP, Brazil)
INCT de Bioanalítica - UNICAMP, C.P. 6154, 13084-971 Campinas, SP, Brazil
^UNB - Dept. Química, 73300-000 Planaltina, GO, Brazil
#UFMS - Dept. Química, 79074-460 Campo Grande, MS, Brazil
http://pubs.acs.org/doi/pdf/10.1021/ie101499e

12. "Green" cars could be made from pineapples and bananas.
The research was presented at a meeting of the American Chemical Society on March 27, 2011

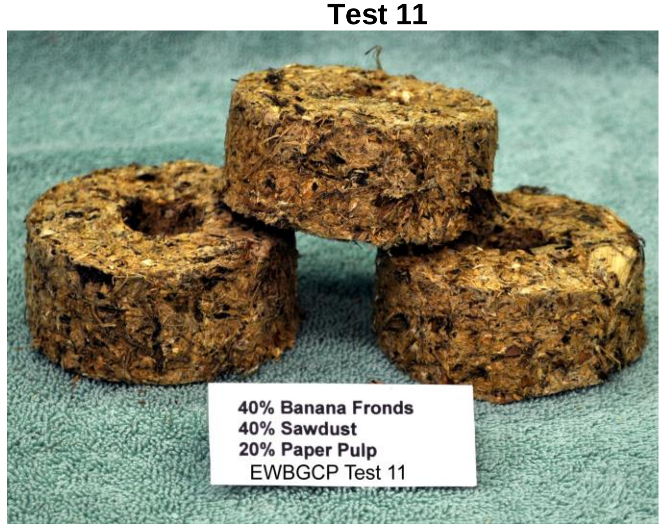
Briquette Pictures for Tests 8 - 28

Test 8

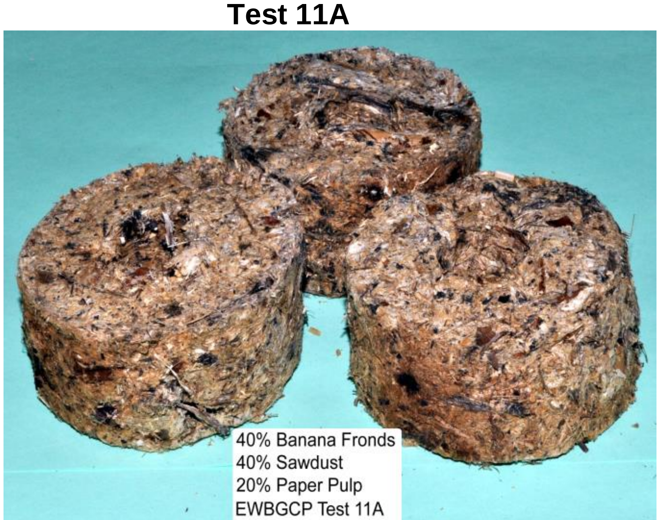
Test 9

Test 10

Test 11



Test 11A



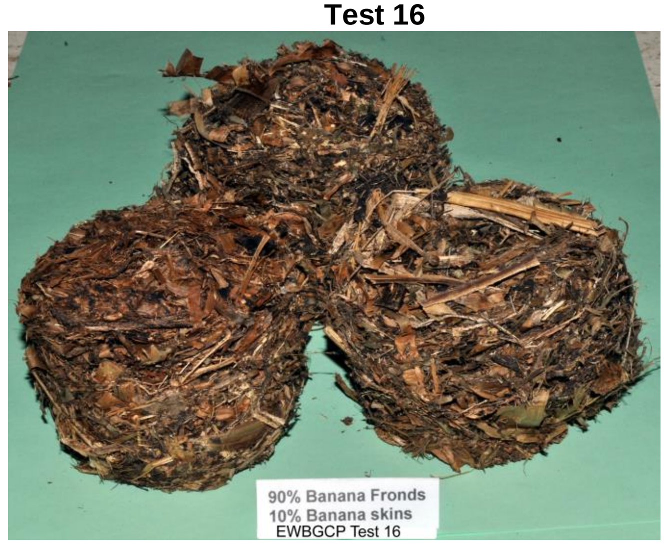
Test 12

Test 13

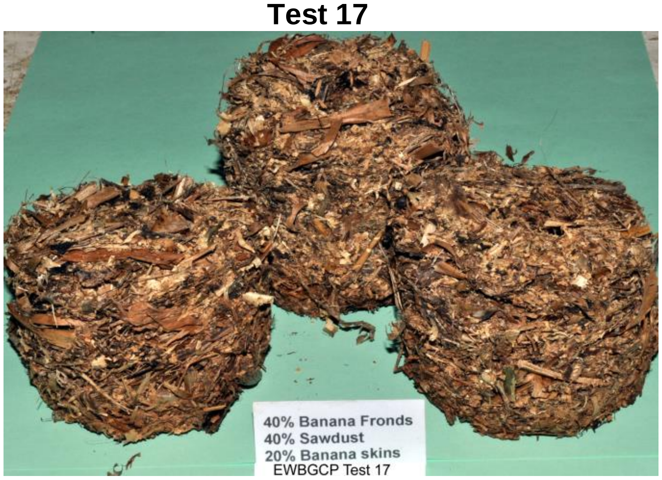
Test 14

Test 15

Test 16



Test 17



Test 18

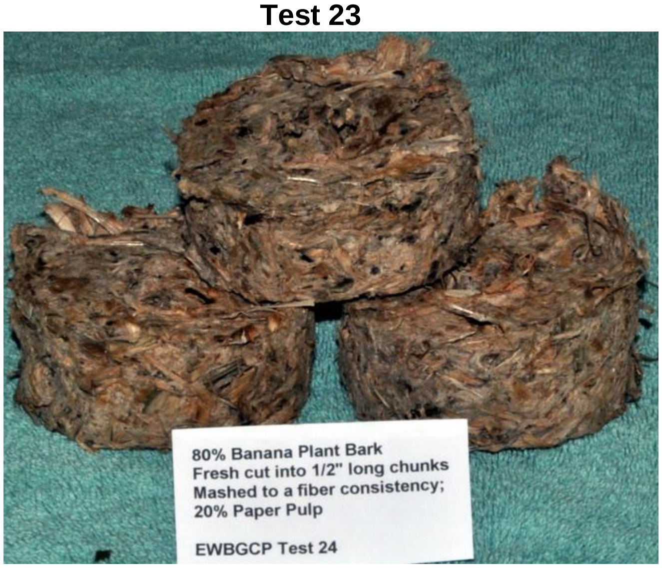
Test 19

Test 20

Test 21

Test 22

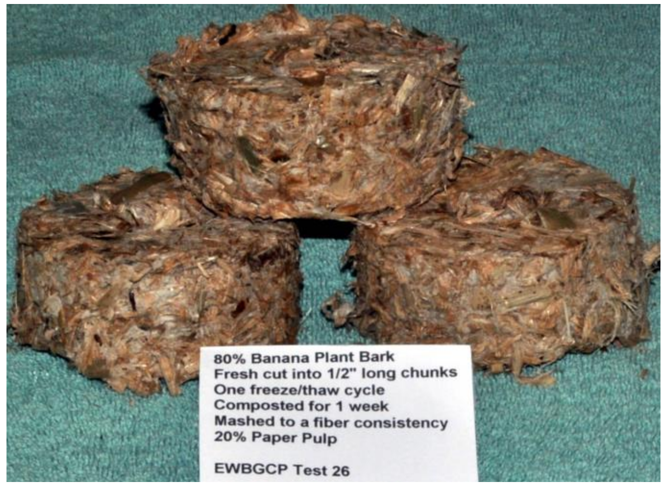
Test 23



Test 24

Test 25

Test 26



Test 27

Test 28