



HITECH Agro Flat Die Pellet Mill Evaluation
HITECH Agro Biomass Innovations
Bloomington, Minnesota 55431

Summary Report
Project 2008-063
December 22, 2008

Alan Doering
Sr. Associate Scientist – Co-Products
Agricultural Utilization Research Institute
P.O. Box 251
Waseca, MN

Purpose

The Agricultural Utilization Research Institute (AURI) has been approached by many Minnesota companies and individuals interested in the densification of agricultural biomass. Their intentions are to produce a renewable agricultural based pellet fuel that could be utilized for residential heating but more importantly serve as a solid renewable biomass fuel supply for industrial applications such as gasification, co-firing, and direct combustion.

AURI was contacted by Priya Jain, HITECH AGRO, Bloomington, Minnesota and A.K Khater, Director, Amrit NCES Ltd., Satya Niketan, New Delhi, India, to investigate the potential efficiency improvement that can be recognized utilizing their flat die pellet mill over a ring die pellet mill for densifying agricultural biomass. The United States and Europe conducts the majority of their starch and fiber pelleting on ring die pellet mills. AURI obtained a model PL500 one ton per hour HITECH Pellet Mill to conduct pelleting evaluation of biomass.

Goal

AURI developed an initiative, *Flat Die Pellet Mill Evaluation for Biomass*, to research the efficiency and product quality difference producing agricultural based pellets utilizing a traditional ring die pellet mill to the HITECH flat die pellet mill. Focus biomass materials and agricultural co-product materials utilized for the evaluation included Distillers Dried Grains with Solubles, wheat middlings, corn stover, wood and dried sugar beet pulp. Testing for pelleting these materials were conducted with the use of water if appropriate and steam.

This report focuses on the evaluation of the HITECH Agro PL500 flat die pellet mill only.

Preparation and Biomass Sources

Materials utilized for testing included Distillers Dried Grains with Solubles (DDGS), a co-product from corn ethanol production; wheat middlings, a co-product from the wheat milling industry, sugar beet pulp, corn stover, and pine wood. Materials were processed at the AURI Co-Product Pilot Lab in Waseca, Minnesota. Fibrous materials including corn stover, dried beet pulp, and wood were processed on a 25 Hp Jacobson hammer mill utilizing pneumatic air assist through a 3/8 inch hole screen the first pass followed by a second grind using a 5/32 inch hole screen (#10).

Testing- Pellet development and durability

All biomass pellets were produced on a HITECH Agro PL500 model flat die pellet mill, 40 Hp (1800 rpm) (Figure 1). The pellet mill operates on 60 amperage, 3 phase, and 480 voltage with a maximum operating load of 50 amps. The pellet die consist of a 8.5 MM diameter hole size for pellet production with a die thickness of 53 MM resulting in a 6.2:1 length (Figure 2) divided by hole diameter ration (L/D).

Figure 1 –HITECH Agro PL500 Pellet Mill in AURI’s Pilot Lab



Figure 2 – HITECH Agro Flat Die



Pellet evaluation was initially conducted utilizing only water for preliminary testing. Target pelleting moistures ranged from 18% to 13%. HITECH Agro recommends starting pellet production with material that is 18% moisture.

Distillers Dried Grain with Solubles was tested on multiple runs throughout this research. DDGS was chosen because of its high oil content (9-10%) which acts as a lubricant for initial pelleting. DDGS pelleted very easily with a low amp draw and excellent yield however pellet quality was poor due to the lack of heat generation.

Wheat middlings were the second material evaluated at three different moistures levels. Wheat middlings are typically easy to pellet, contain much less oil than DDGS and are higher in fiber. Wheat middling pellets produced good yields with low energy requirements.

Corn stover was tested at three different moisture contents, 19% moisture, 17% moisture, and 16% moisture respectively. The 19% moisture corn stover began to pellet with good temperatures although approaching the die holes filling, the amperage quickly increased and the result was slipping rollers and a plugged die. The second corn stover test with the 17% moisture corn stover also began to pellet and sustained pelleting for approximately two minutes followed by the die holes plugging once again. The final test was with 16% moisture content corn stover to confirm that the plugging was due to lack of fiber conditioning (heat treatment of the fiber) rather than strictly moisture. It was confirmed that corn stover required steam conditioning to sustain pelleting. Corn stover pellets were obtained with a high variability in pellet quality that can be seen visually prior to the die plugging.

Final pellet evaluation focused on a blend of DDGS and corn stover, the DDGS would serve as a pelleting aid for the corn stover. This resulted in sustained pelleting. Pelleting data utilizing water only can be viewed in *Table 1*.

Steam was utilized in eight pelleting test runs due to the greater glassing temperatures required to produce a quality pellet for most biomass materials. Steam was generated on a high pressure electric, 5 Hp Chromolox boiler at 65 p.s.i. Steam is then controlled and limited at the pellet mill from 18-20 p.s.i. Moisture additions of 3% to 6% from steam were typically included into the test blends to aid in pelleting and pellet durability.

Steam utilization while pelleting DDGS resulted in similar pellet yields to those using only water but with a 10% improvement in pellet quality and a reduction of energy utilized. The greatest impact of steam utilization was seen in the production of a corn stover pellet. Corn stover was pelleted at two different moisture levels. The pellet mill began to slip during the first test due to the excessive moisture content contained in the stover (22%). The second test was also run at greater moisture contents than what is typically desired (21%); however the temperatures obtained along with the moisture level resulted in sustained pelleting of the corn stover with excellent pellet durabilities and favorable energy requirements. Lowered moisture utilized in the second corn stover comparison did result in increased pellet yield and quality. The optimum moisture and temperature target was not identified.

Pellet evaluation also focused on two blended materials with steam. These blends included 50% DDGS and 50% corn stover along with 50% DDGS and 50% wood. Both tests were used primarily for comparison purposes identifying the effect steam has on pellet yield and energy requirements.

Final pellet research identified the ability of the HITECH Agro PL500 to pellet wood and dried sugar beet pulp. Ground pine wood was utilized with fair results. The PL500 easily pelleted with pine wood with poor pellet quality based on a high fraction incidence although pellet durability was excellent (96% and 97%). High fracture incidence can be resolved by utilizing a greater L/D ratio pellet die. Final pellet testing involved dried sugar beet pulp. Water and steam were utilized for pelleting beet pulp with excellent results. The PL500 generated an extremely durable pellet (97%) with an excellent yield of 900 pounds per hour at 92% of working load. In this situation the pellet die selection and conditioning of material were conducive of producing an excellent sugar beet pulp pellet. Pelleting data utilizing steam only can be viewed in *Table 2*.

Product temperatures across the die were recorded to serve as an indicator for proper die selection. An increase of 30 degrees Fahrenheit for grains and up to 100 degrees Fahrenheit for fibrous material is desired. Research conducted utilizing steam indicated proper steam condition and temperature rise across the die. However the steam generated during pelleting research had a low vapor to liquid water ratio that is less than desirable. This often resulted in excess moisture addition to obtain appropriate pelleting temperatures especially for corn stover.

Pellet durability testing was conducted on a Kansas State Pellet Durability Tester. This test involves cutting off a cooled 500 gram sample, tumbling it for 10 minutes at 50 r.p.m. and sieving the test sample on a screen specific for the pellet diameter. Sieving conducted involved a Tyler #3.5 screen for sieving 8.5 mm diameter pellets (+5/16”).

Results of all pellet development and pellet durability are displayed in Table 1 and Table 2. Pellet development runs highlighted in red indicate unsuccessful pellet development.

- Blank intentionally -

Table 1- Pellet Development Test with Water

Product	Start Temp (pre-pellet)	Finish Temp (pellet out of mill)	Amp Load (26 amp idle speed/ 50 amp full load - 480 V)	Added Moisture (pre- pellet) S=steam W= water	Dry Pellet Moisture	Pellet Durability	Pellet Yield (pounds per hour)
Distillers Dried Grain with Solubles	76 F	111 F	38 Amps 15.8 Kw	9% Water (18% mash)	16.8%	52.5%	1,584 (50% of load)
Distillers Dried Grain with Solubles (Figure 3)	78 F	119 F	37 Amps 15.4 Kw	6% Water (14% mash)	13.5%	46.5%	1,548 (46% of load)
Distillers Dried Grain with Solubles	78 F	128 F	37 Amps 15.4 Kw	4% Water (13% mash)	13.1%	44%	1,622 (46% of load)
Wheat Middlings	76 F	141 F	37 Amps 15.4 Kw	5% Water (18% mash)	Not tested	87.5%	Not tested
Wheat Middlings	76 F	146 F	37 Amps 15.4 Kw	3% Water (16% mash)	12.8%	89%	455 (46% of load)
Wheat Middlings	76 F	147 F	37 Amps 15.4 Kw	2% Water (15% mash)	12.2%	90.5%	373 (46% of load)
Corn Stover	77 F	114 F	50 Amps	9% Water (19% mash)	Fail	Fail	Plug (100% of yield)
Corn Stover (Figure 6)	62 F	175 F	42-50 Amps	8% Water (17% mash)	Fail	Fail	Pellet w/ low yield then plug
Corn Stover	62 F	265 F	50 Amps	7% Water (16% mash)	Fail	Fail	Plug (100% of yield)
Corn Stover – 50% DDGS – 50% (Figure 5)	58 F	133 F	32 Amps 13.3 Kw	6% Water (15% mash)	11.7%	Not tested	120 (25% of load)

Table 2 - Pellet Development Test with Steam

Product	Start Temp (pre-pellet)	Finish Temp (conditioned mash / pellet out of mill)	Amp Load (26 amp idle speed/ 50 amp full load - 480 V)	Added Moisture (pre- pellet) S=steam W= water	Dry Pellet Moisture	Pellet Durability	Pellet Yield (pounds per hour)
Distillers Dried Grain with Solubles (Figure 4)	44 F	106 F Mash / 114 F Pellet	34 Amps 14.1 Kw	5% Steam (13% mash)	9.3%	60%	1,122 (33% of load)
Corn Stover (Figure 9)	58 F	133 F Mash / 142 F Pellet	32 Amps 13.3 Kw	6% Steam (22% mash)	15%	94%	120 (25% of load)
Corn Stover (Figure 8)	58 F	145 F Mash / 152 F Pellet	40 Amps 16.6 Kw	4.5% Steam (21% mash)	13.3%	95.5%	342 (58% of load)
Corn Stover – 50% DDGS – 50% (Figure 7)	58 F	135 F Mash / 155 F Pellet	33 Amps 13.7 Kw	7% Steam (16% mash)	10.8%	96%	288 (29% of load)
Pine Wood – 50% DDGS – 50% (Figure 10)	48 F	125 F Mash / 127 F Pellet	40 Amps 16.6 Kw	7% Steam (17% mash)	7.8%	77%	360 (58% of load)
Pine Wood (Figure 11)	68 F	102 F Mash / 177 F Pellet	40 Amps 16.6 Kw	2.9% Steam (15%)	6.9%	97%	528 (58% of load)
Pine Wood	61 F	135 F Mash / 166 F Pellet	48 Amps 19.9 Kw	5.6% Steam (18%)	7.6%	96%	636 (92% of load)
Dried Sugar Beet Pulp (Figure 12)	61 F	123 F Mash/ 183 F Pellet	48 Amps 19.9 Kw	5% Water 6% Steam (19% mash)	11.2%	97%	900 (92% of load)

Pellet Exhibit

Figure 3 - DDGS with water



Figure 4 - DDGS with steam



Figure 5 - DDGS 50% / Corn stover 50% with water



Figure 6- Corn stover with water (16%) – variability noticed in color prior to die plug



Figure 7 - DDGS 50% / Corn stover 50% with steam



Figure 8 - Corn stover with steam



Figure 9 - Stover with high steam



Figure 10 - DDGS 50% / Pine Wood 50% with steam



Figure 11 - Pine wood with steam



Figure 12 – Dried sugar beet pulp with steam



Conclusion

AURI and HI-Tech Agro are conducting due diligence evaluating the potential of utilizing flat die pellet mill technology for biomass pelleting. This report focuses solely on the performance of HITECH Agro PL500 flat die pellet mill. **Pelleting performance, quality, and specifications were solely limited to one pellet die having an L/D ratio of 6.2:1.** Pellet die selection is often specific to grains or biomass types. The research provided was limited to identifying parameters associated with one specific die. Greater die selection would allow for increased pelleting ease in some situations and affect pellet quality; proper pelleting dies could be selected for specific biomass sources.

Steam conditioning has a dramatic effect on pellet quality. Initial product development utilizing water and friction heat generated from the pellet die was unproductive in most situations or resulted in poor pellet quality. The utilization of steam in the DDGS and corn stover pellet combination resulted in a 240% improvement in throughput or yield along with a 4% increase in pellet durability. Steam conditioning was a necessity to produce a corn stover pellet on the 6.2:1 L/D ration die after several attempts to produce a corn stover pellet with water only. Steam also allowed for the proper conditioning of fibrous materials resulting in lowered pelleting moistures, lower final pellet moistures, and increase pellet durability.

Pine wood pelleted easier than anticipated. An increase of 31 degrees Fahrenheit was observed across the pellet die while pelleting pine wood with high steam levels (5.6% moisture through steam, 18 p.s.i steam at the pellet mill) resulting in a pellet exit temp of 166 degrees Fahrenheit. Typical wood pellet production creates pellet exit temps of 175-205 degrees Fahrenheit. This data indicates the potential to use a thicker die (die length) for pellet production resulting in a pellet that has less fracture points producing a longer pellet (Figure 11). Pellet lengths were short yet had an excellent durability of 96% and 97%.

Dried beet pulp was the final co-product to be tested. Five percent water was added to the beet pulp to improve densification and pellet quality prior to pelleting. A 60 degree F temperature increase across the die was observed with a pellet exit temperature of 183 F. The PL500 maintained a steady pellet flow averaging a yield or throughput of 900 pounds per hour at 92% of working capacity resulting in a pellet durability of 97%.

Feasibility of producing a biomass pellet from agricultural sources is the most critical component to testing. Mechanical pelleting of most products can be achieved through proper product processing, moisture addition or exclusion, conditioning and die selection. The feasibility of developing a business producing biomass pellets needs to be based on economics of biomass collection, transportation, storage, densification, and retailing.