MnVAP Xcel RDF Grant

Milestone 2

Prepared for:
MnVAP
Raymond, MN
Project No. 2008-026

June 24, 2011
EXECUTIVE SUMMARY: The purpose of this project is to evaluate the energy differences between MnVAP's present densification system and a system using Kinetic Energy called the KDS (Kinetic Disintegration System).

Testing will establish baseline performance between MnVAP’s present system and the KDS system. AURI (Agricultural Utilization and Research Institute) will conduct material testing at specific intervals throughout the two proposed processing lines to determine the energy utilization and process performance. Final testing will involve AURI Co-Product Utilization Pilot Lab conducting densification trials of test fiber from the two processing lines. Pelleting research will be conducted and pellet quality analyzed.

AURI set up a testing protocol to establish a baseline performance of the KDS that will be used to compare the performance of the KDS after improvements have been made to the KDS. AURI will then analyze material for quality and performance for producing a pellet. AURI will run preliminary tests on the KDS and evaluate the results.

Credit: “Project funding provided by customers of Xcel Energy through a grant from the Renewable Development Fund.”

TECHNICAL PROGRESS: The protocols and results for the testing of the KDS are in the following AURI report:
**Purpose**

The purpose of this research is to evaluate the energy efficiency differences between Minnesota Valley Alfalfa Producer (MnVAP) current alfalfa processing systems to the new KDS processing technology.

**Goal**

**Milestone 2: Initial KDS testing to determine baseline KDS performance. Finalize flow diagram for complete system analysis by AURI. Conduct AURI preliminary test runs and analysis of KDS.**

The focus of Milestone 2 is for AURI to conduct baseline testing of the current feedstock MnVAP is processing through two separate grinding and drying systems. AURI will assist to establish a baseline to compare the Kinetic Disintegration System (KDS) processing technology to MnVAP’s current process. AURI will be conducting material testing at specific intervals throughout the two proposed fiber processing lines to determine energy utilization and process performance. Final testing for Milestone 2 will involve AURI Co-Product Utilization Pilot Lab conducting densification trials of test fiber from the two processing lines. Pelleting research will be conducted and pellet quality analyzed.

**Work plan**

1) Establish baseline physical and chemical characteristics of alfalfa hay (control test fiber) including moisture, particle size distribution and density.

2) Process alfalfa hay through the shredder; collect process energy (amperage), throughput, moisture content, particle size (average distribution), and density.

3) Alfalfa will then be processed through the first hammer mill referred to as the “William’s”; collect process energy (amperage), throughput, moisture content, particle size (average distribution), and density. This test will confirm consistency or discrepancy of the product prior to entering the two test process lines.

4) Ground alfalfa will then enter their current line; upon exiting the dryer, process energy (amperage), throughput, moisture content, particle size (average distribution), and density of the ground alfalfa will be collected.

5) Dried ground alfalfa from the current line will then enter their “500” hammer mill; process energy (amperage), throughput, moisture content, particle size (average distribution), and density information will be collected.
6) Ground alfalfa in the new line will enter the KDS process from step 3; process energy (amperage), throughput, moisture content, particle size (average distribution), and density will be collected.

7) Steps 2, 3, and 6 will be repeated utilizing the new line and alfalfa containing three different moisture contents to identify the effect moisture has on KDS performance.

8) Step 6 will be repeated utilizing the new line and alfalfa containing three different particle sizes to identify the effect particle size has on KDS performance. Ground alfalfa will be introduced to the KDS system from a) the shredder in step 2; b) the William’s hammer mill from step 3, and c) the 500 hammer mill from step 5. Process energy (amperage), throughput, moisture content, particle size (average distribution), and density will be collected.

9) AURI will conduct an applied analysis of energy utilization to process alfalfa hay through the current process to the new KDS process.

10) AURI will conduct an applied analysis of energy utilization to process alfalfa hay with three different moisture contents through the new KDS process.

11) AURI will conduct an applied analysis of energy utilization to process alfalfa hay with varying particle size entering the new KDS process.

12) AURI will conduct pelleting trials on ground alfalfa from MnVAP’s current process and new process obtained from utilizing the KDS system. A control pellet die will be utilized. Pelleting throughput and energy utilization from the two processing systems for alfalfa will be evaluated during pelleting. Alfalfa pellets produced will be evaluated for pellet durability using the Kansas State test, pellet hardness, and density.

13) AURI will conduct material particle distribution analysis, product moisture, and density testing confirm uniformity or potential changes in the ground alfalfa as they were processed between the current and KDS systems.

14) A comparison of the current and new KDS line focusing on energy utilization, particle size distribution of the alfalfa hay, and moisture removal from the materials will be documented in a summary report. AURI will also identify potential densification differences between the two processed materials in the summary report.
Data collection flowchart

Alfalfa
(Base test product)

Sampe: Process Energy, Moisture, Ash, Density

Shredder

Sample: Process Energy, Moisture, Particle Size/ Density, Throughput

William’s Hammer Mil

Sample: Process Energy, Moisture, Particle Size/ Density, Throughput

Current line

Sample: Process Energy, Moisture, Particle Size/ Density, Throughput

Dryer

New line

Sample: Process Energy, Moisture, Particle Size/ Density, Throughput

KDS System

Sample: Process Energy, Product Energy, Moisture, Particle Size/ Density, Throughput

“A500” Hammer Mil

Sample: Process Energy, Product Energy, Moisture, Particle Size/ Density, Throughput

AURI
Action R&D: Pelleting evaluation of fibers from two systems

Agricultural Utilization Research Institute
Testing and Data Collection

AURI conducted data collection at MnVAP’s processing plant in Raymond, MN on Monday, June 20, 2011.

MnVAP had processed same moisture alfalfa through their current system. Material samples were collected according to the flowchart from the shredder, Williams hammer mill, and Roskamp 500 hammer mill to evaluate particle distribution, moisture, and density of the processes.

During MnVAP’s current processing of alfalfa, AURI gathered energy use information based on utilizing a voltage and amp meter on all operating motors and drag lines. Processed material was also collected to identify material through-put on a ton per hour basis. A picture of lowering an alfalfa filled tote from their current processing line to be weighed and then calculate the throughput data is pictured below (Picture 1).

Picture 1- Collecting test material from MnVAP tower

Data was then collected from the KDS process according to work plan steps 6, 7, and 8 to evaluate efficiency and performance data. The data collected from the KDS began with evaluating alfalfa from the Williams hammer mill. The data obtained serves as an indication to the ability the KDS has to replace a dryer and additional Roskamp “500” hammer mill in their current system. KDS data collection at MnVAP is shown in Pictures 2 and 3.

Picture 2 – Feeding test alfalfa into the KDS
Alfalfa that was ground through the shredder, Williams hammer mill, and Roskamp “500” hammer mill were evaluated on the KDS to identify efficiency performance differences between various starting particle sizes. The last information obtained was conducted on testing two additional samples of alfalfa with increased moisture. Originally processed on the Williams for fiber uniformity, this research evaluated efficiency changes within the KDS based on moisture variability. All data collected included energy consumption, product through-put, particle size evaluation, and product density.

Particle size distributions of all samples were determined utilizing a vibrating sieve Picture 4. AURI observed difficulty in sieving material from the KDS process due to the lack of uniformity in particle size and “stringy” fibers that would catch on the screens rather than pass through. The smallest sieve size utilized was 1,000 micron, more than adequate for producing a ¼” pellet.
**AURI Pilot Lab Testing of Alfalfa**

AURI conducted pelleting trials on ground alfalfa from MnVAP’s current process and new process obtained from utilizing the KDS system at the Co-Product Pilot Lab facility in Waseca, MN. A tote of approximately 400 pounds of material from each process was obtained.

All pellet blends were produced on a 60 hp California Pellet Mill, Model 1112-4 (Picture 5), using a 1/4 inch diameter hole die with a 7:1 compression ratio (1.75 inches effective). Compression ratio is the effective length of the die divided by width of pellet. Pelleting throughput and energy utilization from the two processing systems for alfalfa were evaluated during pelleting.

![Picture 5 -1112-4 Model California Pellet Mill in AURI’s Pilot Lab](image)

No additional moisture was added through water or steam during the pelleting process due to adequate moisture levels in the current alfalfa processed material which contained 12.65% moisture and the KDS process material containing 11.24% moisture.

During the pelleting trials, pellet mill operational amperage was operated at constant amperage to eliminate variability in determining throughput between products. Pelleting was initially conducted on product produced from MnVAP’s current process (Williams’s shredder, 500 hammer mill to pellet machine) which pelleted very easily without complications. However, during the pelleting trials with material produced on the KDS system, the process had to be stopped several time due to “plugging” of ground material in the pellet mill conditioner outlet and the chute to the feeder cone. Although the pre-pellet bulk densities were similar between the two processes, with their current processing having a 13.5 pound per cubic foot bulk density compared to the 13.0 pound per cubic foot bulk density of the KDS produced material, this material produces a small percentage of string textured material which cause plugging and difficulty in handling.
Pellet durability testing was conducted on a Kansas State Pellet Durability Tester. This test involves cutting off a 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 for AAE involved a Tyler #3.5 screen for sieving ⅛ inch diameter pellets.

Pictures of the final pelleted product are shown in Picture 6 and Picture 7.

Results of all pellet development and pellet durability are displayed in Table E.

Picture 6 – Raw and pelleted alfalfa from MnVAP’s current system

Picture 7 – Raw and pelleted alfalfa from MnVAP’s KDS system
There is a small advantage to the durability and density of the pellets through the KDS process vs. the current process. It should be noted that the KDS process was terminated at 32 amps because of plugging at the pellet mill.

<table>
<thead>
<tr>
<th>Product</th>
<th>Start Temp (pre-pellet)</th>
<th>Finish Temp (out of mill)</th>
<th>Amp Load (16 amp idle speed/65 amp full load)</th>
<th>Pelleting Throughput (Pounds/hr.)</th>
<th>Dry Pellet Moisture</th>
<th>Pellet Durability</th>
<th>Pellet Density (lbs. Ft3)</th>
<th>Pellet Die Utilized Hole diameter x compression ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test A – Control Alfalfa From Current Process</td>
<td>75 F</td>
<td>166 F</td>
<td>34 Amps</td>
<td>727</td>
<td>9.8%</td>
<td>97.2%</td>
<td>41.0</td>
<td>¼” X 7:1</td>
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<td></td>
<td></td>
<td></td>
<td>12% feeder speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test B – Control Alfalfa From Current Process</td>
<td>75 F</td>
<td>166 F</td>
<td>40 Amps</td>
<td>1,200</td>
<td>9.8%</td>
<td>97.2%</td>
<td>41.0</td>
<td>¼” X 7:1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20% feeder speed</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Test C – Control Alfalfa From KDS Process</td>
<td>70 F</td>
<td>164 F</td>
<td>32 Amps</td>
<td>708</td>
<td>9.3%</td>
<td>98.8%</td>
<td>41.5</td>
<td>¼” X 7:1</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>17% feeder speed (max without plugging)</td>
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</table>
Conclusion

AURI assisted MnVAP in conducting due diligence collecting data to determine baseline KDS performance and conduct preliminary pelleting trials to analyze material processed on their current system to the KDS system.

In order to compare the KDS system to MnVAP’s current system, data was collected during the processing and drying of alfalfa prior to pelleting. Energy data was collected along with through-put. During our evaluation, data collected indicated a total processing cost of $6.26 per ton; this included only the processing segment along with natural gas utilization for the drying process. The KDS system would only have the potential to replace a segment of their current process which would occur after alfalfa is ground through the shredder and Williams hammer mill. **Energy utilization post Williams hammer mill process is $5.10 per ton prior to pelleting.** AURI used the data collected to also determine an energy value per moisture removed from their process following the Williams hammer mill, electrical energy was converted to British Thermal Unit energy, this value was **3,414 Btu per pound of moisture removed using their current process.**

The core focus of Milestone 2 is to evaluate the KDS performance. The KDS was first evaluated utilizing pre-ground product from the shredder and Williams hammer mill; this would be the logical processing flow. During the KDS testing, the classifier remained stationary to eliminate variability between tests. The classifier has a direct effect on particle size; although the classifier remained stationary, the motor capacity of the classifier was at peak operating load indicating it was producing a ‘fine’ ground material at the levels tested.

KDS moisture removal performance was tested with three different moisture levels in alfalfa hay. **The KDS was capable of producing a dryer material at 11.2% moisture compared to the rotary drum dried and hammer milled product from their current process, producing moisture levels at 12.7%; both processes started with alfalfa moisture of 15.4%.** However there was a significant reduction in product through-put due to the limited capacity of the KDS system as compared to the current system. The KDS system operated at 1.6 tons per hour with 15.4% moisture alfalfa compared to MnVAP’s current process at 7.2 tons per hour of pre-pellet material. Total energy cost during the control trial was **$6.58 per ton for the KDS system compared to $5.10 per ton on their current system.** Energy efficiency for the KDS process was **3,526 Btu per pound of moisture removed** compared to the current system at 3,414 Btu per pound of moisture removed. A wide range in moisture removal was seen with the mid moisture alfalfa and the high moisture alfalfa observed in Table D. The KDS performed very well on moisture removal; a discrepancy in data was observed with the high-moisture alfalfa having a greater moisture removal along with improved through-put over the mid-moisture alfalfa; this could be due to a blend of grass hay with the high-moisture alfalfa and variation in drying characteristics between the plant materials.
KDS particle size was evaluated along with density. The smaller particle size entering the KDS for process resulted in improved through-put and improved energy efficiency. The KDS did not perform well with long stem fiber (+/- 6 inches) as observed in Table D with the processing performance on alfalfa from the shredder having a low through-put, low moisture removal, and poor energy efficiency value.

MnVAP’s current process produces a ground alfalfa product that has an average particle size of 0.92 millimeters prior to pelleting. The KDS system produced a final average particle size after processing material from the Williams hammer mill of 0.89 millimeters. In this test, we were only evaluating the material from the Roskamp 500 hammer mill currently used to material size from the KDS being fed with material out of the Williams hammer mill.

Pelleting trials between the end alfalfa product from the current system and the KDS system produced pellets of similar final moisture content, densities, and slightly improved pellet durability with material from the KDS system. The improved durability could be a result for a 1.4% reduction in moisture on the raw alfalfa. Steam was not utilized in the pelleting trial. Pelleting data on through-put potential could not be conducted at greater levels due to multiple plugging issues with the alfalfa ground through the KDS unit. This is a great concern when evaluating the KDS. Although sieve analysis do not directly indicate the differences in fiber structure, the KDS system produced a small percentage of fibers that were long and ‘stringy’ causing the pellet mill to plug at the exit of the conditioner and in the feed chute to the cone. This limits pelleting capacity and capability.

Data shared in this report is dependent on multiple factors including accuracy of through-put determination, variation in raw product composition (alfalfa vs. grass hay), product density, and variable moisture content. Data provided in this report should serve only as a tool to guide process decisions.

The KDS process at MnVAP has not been refined to optimum performance thus potentially resulting in poor performance data. During the testing that AURI conducted, the KDS process was utilizing two rotating bars rather than potentially up to eight, potentially affecting performance.
Baseline Performance of the KDS has been established with the following results:

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<tbody>
<tr>
<td>Throughput</td>
<td>1.6 tons/hour @ 37% load</td>
</tr>
<tr>
<td>Drying Efficiency</td>
<td>3,526 btu/lb of moisture</td>
</tr>
<tr>
<td>Energy Cost</td>
<td>$6.58/ton</td>
</tr>
</tbody>
</table>

The throughput of a commercial machine is very important to the profitability of a processing line. If the throughput of the machine is increased from 1.6 tons/hour to 2.0 tons/hour it is a 20% increase. Design changes to improve the throughput of the KDS are listed below:

- Classifier
- Cyclone
- Hub
- Bars and Chains
- Fan

The least amount of btu’s used to dry material will improve the profit margin of the process. Design changes to the KDS to improve the drying efficiency from using 3526 btu/lb of water to 2997 btu/lb of water is a 15% improvement include:

- Return Air
- Bars and Chains

The changes to Throughput and Drying Efficiency will result in a reduction of Energy Cost. If MnVAP can take the $6.58/ton baseline performance energy cost and change the KDS as listed above, it could change the energy cost to $5.26/ton, which would be a 20% improvement.

Evaluating the baseline performance through the KDS will be discussed from the parameters of moisture, particle size, density and durability. The particle size from the KDS was .89 millimeters which is comparable to the current process with a particle size of .92 millimeters. Moisture and density were also comparable, with the KDS process producing a slightly improved durability.

The material coming from the KDS included a small amount of long fibrous material that plugged the feed chute at the end of the conditioner. A redesign of the classifier is being looked at to alleviate this problem.

The above components of the KDS will be studied and changed where appropriate to improve the throughput and efficiency of the KDS. When completed the performance of the KDS will be evaluated with a variety of feedstocks. The chart below summarizes the goals of the project.
• Throughput: Improve
• Particle Size: Eliminate fibrous material
• Moisture Removal: Improve
• Energy Cost: Improve
• Pellet Moisture: Good
• Pellet Density: Good
• Pellet Durability: Good

MILESTONES: Milestone 2 has been completed. The baseline performance of the KDS has been established and the goals for the improvements to the KDS have been listed.

ADDITIONAL MILESTONES: Milestone 3 deals with the grinding and conveying equipment, which is delayed by a mid December delivery date. MnVAP is moving forward on the dryer equipment in Milestone 4. The upgrades to the dryer have been engineered and MnVAP has placed them out on bids.

PROJECT STATUS: MnVAP has been informed by the manufacturer of the grinding and conveying equipment that delivery will be mid December. This could affect MnVAP's cash flow in relation to the grant funding. MnVAP is well within the schedule for the completion of the project on time.

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APPENDIX: