CC: [alison.hamlin@jove.com](mailto:alison.hamlin@jove.com)  
  
Dear Mr. Tumuluru,  
  
Your manuscript JoVE54092R1 "Method of producing quality pellets at lower energy consumption using high moisture corn stover and a corn starch binder" has been peer-reviewed and the following comments need to be addressed.   
  
Please keep JoVE's formatting requirements and the editorial comments from previous revisions in mind as you revise the manuscript to address peer review comments. Please maintain these overall manuscript changes, *e.g.*, if formatting or other changes were made, commercial language was removed, *etc.*   
  
Please track the changes in your word processor (*e.g.*, Microsoft Word) or change the text color to identify all of the manuscript edits. When you have revised your submission, please also upload a separate document listing all of changes that address each of the editorial and peer review comments individually with the revised manuscript. Please provide either (1) a description of how the comment was addressed within the manuscript or (2) a rebuttal describing why the comment was not addressed if you feel it was incorrect or out of the scope of this work for publication in JoVE.  
  
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**Editorial comments:**  
***NOTE: Please download this version of the Microsoft word document (File name: 54092\_R1\_091715) for any subsequent changes.***   
  
  
•Please keep the editorial comments from your previous revisions in mind as you revise your manuscript to address peer review comments. For instance, if formatting or other changes were made, commercial language was removed, etc., please maintain these overall manuscript changes.   
  
•If your figures and tables are original and not published previously, please ignore this comment. For figures and tables that have been published before, please include phrases such as “Re-print with permission from (reference#)” or “Modified from..” etc. And please send a copy of the re-print permission for JoVE’s record keeping purposes.  
  
•Formatting (References): Please check that doi information has been added where applicable.   
  
•Additional detail is required  
-1.2-Approximately how long should the corn stover be ground using these different screens?

Reply: Typically in pellet production process the grinding is done sequentially (stage-1 & stage-2 grinder). The material what has gone through stage-1 fitted with a bigger screen (50.8 mm) is further passed immediately through stage-2 grinder fitted with a smaller screen (4.8 mm screen size). Information included in the revised manuscript (Page 5 lines 211-215).

-1.3-If this step is to be filmed, please provide additional details as to how to determine the moisture content.

Reply: Moisture content method is included in section 4 of protocol (page 7, lines 306; Page 8, line 307-310)

-2.2-Provide additional details as to where/how to attach the tapes/controllers to the hopper and screw feeder. In addition, what are the “desired temperatures”?

Reply: Additional information on tape heaters and controllers is included in the revised manuscript (page 6, lines 228-230).

-2.3/2.4-Please expand on how the frequency drive is “equipped”, and the power meter “provided.”

Reply: Included in the revised manuscript (page 6, lines 232-233).

-3.7-If this step is to be filmed, please provide additional details as to how to measure moisture content, etc.

Alternatively, include this step as a 3.6 Note.

Reply: Method for measuring the moisture content is included in the revised manuscript in section 4.

This has been included as step 3.7 in the revised manuscript (Page 8, line 307-311).

-4.1-Please provide details as to how to assess moisture content.

Reply: Included in the revised manuscript (page 8, line 311)

•Unnecessary branding should be removed from steps 3.8 and 4.5 (LabVIEW).

Reply: Removed in the revised manuscript.   
  
•Results: Please include error bars for all figures (Figure 5/6), and define whether they represent SEM or SD in the accompanying legends.

Reply: The error bars were included for graphs representing pelleting moisture content, pellet diameter, expansion ratio, bulk density and durability. In the case of percent fines and specific energy consumption, the error bars are not included as the data is from single pellet mill run from steady state pelleting condition. We have published this method in other high impact factor peer reviewed journals like Bioresource Technology, Biosystems Engineering and Energy Science and Engineering Journal.   
  
\* JoVE reference format requires that DOIs are included, when available, for all references listed in the article. This is helpful for readers to locate the included references and obtain more information. Please note that often DOIs are not listed with PubMed abstracts and as such, may not be properly included when citing directly from PubMed. In these cases, please manually include DOIs in reference information.

Reply: The manuscript has been carefully revised to JOVE requirements.   
  
***NOTE: Please copyedit the entire manuscript for any grammatical errors you may find. This editing should be performed by a native English speaker (or professional copyediting services) and is essential for clarity of the protocol. Please thoroughly review the language and grammar of your article text prior to resubmission. Your JoVE editor will not copy-edit your manuscript and any errors in your submitted revision may be present in the published version.***  
  
**Reviewers' comments:**  
  
**Reviewer #1:**   
*Manuscript Summary:*   
Both in the manuscript title and abstract, please include the pellet mill type used in the study (i.e., flat die pellet mill) because the conventional pelleting mill is a different model than the one used in the study.  
Reply: This has been included in the revised manuscript at all the appropriate places.

*Major Concerns:*  
-- One of the critical steps in pelleting is grinding of feedstock (P4, L153-154). The authors have ground the raw corn stover in two stages; however, it appears that the authors have not used the raw corn stover at 30% or higher moisture content. Instead, the authors ground a relatively dry corn stover and added water to obtain 30% or higher moisture samples for the study (P5, L179-180). In addition to the pelleting process, the grinding process has the ability to dry the biomass which was not discussed in the manuscript. Another important difference would be in the particle size distribution of the ground particles which would be different depending on the initial moisture content of raw feedstock. If the authors had ground the corn stover at 30% moisture or higher, the results presented in this manuscript would have been much different and would have affected all of the end results including the pelleting energy consumption and pellet properties. Let alone, the grinder energy consumption for grinding a high moisture corn stover (MC of 30% or more) would be huge. Thus, the usefulness of the study is highly questionable because the study was conducted using a dry raw corn stover than a high moisture corn stover at the grinding stage.

Reply: The emphasis of this manuscript to show that corn stover can make good quality pellets at high moistures. To prove this point we have tested the material by adjusting the moisture content to varying desired levels. This method has been accepted by the peer review community and many papers have been published using this method. References on this method have been included in the revised manuscript (page 4, lines 152-156). Many researchers have used this method to study the effect of moisture content on pellet quality properties. Our TEA study on conventional and high moisture pelleting has indicated that drying energy has a more significant impact on the cost of preprocessing compared to grinding (Lamers et al., 2015). Our recent tests of grinding corn stover using a commercial scale grinder associated with the Biomass National User Faciltiy at Idaho National Laboratory indicated that grinding corn stover at 30% moisture content (65 kWhr/ton) takes about 3 times more energy compared to corn stover at 10% (20 kWhr/ton) moisture content, whereas drying corn stover from 30 to 10% takes about 300-350 kWhr/ton using a rotary dryer. So reducing the drying energy is critical to reduce the preprocessing cost and in turn the pelleting costs. Our TEA analysis indicated high moisture pelleting reduces the pelleting cost by about 40 to 50% compared to conventional pelleting (Page 3, lines 125-131).

-- No statistical analyses were conducted. Especially, the significant effect of moisture or binder addition needs to be discerned using suitable statistical analysis.

Reply: Statistical analysis is included in the revised manuscript (page 8, lines 345; Page 9, lines 348-355), in the representative results section and new table 3 in the revised manuscript.

-- No replication was done for the pelleting process per se. Although the pelleting process is a continuous operation, pelleting at a given moisture and binder combination was not repeated at different times. Since this is a lab-scale study, this should be doable, but why the authors did not consider it. I noted that pellet properties were replicated, but not the energy consumption measurement.

Reply: As pelleting has resulted in steady state production condition, we have done our experiments a single time. The pellets which were produced at steady state conditions were further analyzed for physical properties. The pellet properties like pellet moisture content, bulk density, durability were measured in triplicates whereas pellet diameter measurement was an average of 10 measurements. We have published this procedure in other peer reviewed journals like Bioresource Technology, Biosystems Engineering and Energy Science and Engineering Journal.

-- No data on pellet temperature or pellet mill die temperature are reported. Since the authors have attributed the drying of corn stover due to frictional heating during pelleting, the temperature data need to be added to the manuscript.

Reply: As the die was rotating during pelleting it was difficult to attach a thermocouple. We measured the die temperature using a laser gun and reported this in our earlier work. This will be something we will definitely incorporate in our future studies.

-- No pellet dimensions (diameter and length) are provided. The L/D ratio of the die is given (P11, L445), but the die diameter or die length is not given. These critical data need to be added to the manuscript.

Reply: In the revised manuscript we have added information on die diameter and die channel length in the protocol section (page 8, lines 311-318). Also we have included data on pellet diameter and expansion ratio calculated using pellet diameter in the revised manuscript (page 9, lines 382-391; ; page 9, lines 392-413).   
  
*Minor Concerns:*  
P2, L80: Please check and correct - "biochemical chemical conversion".

Reply: Corrected in the revised manuscript.

P2, L83-84: Please remove "and its composition" which doesn't fit well in this sentence.

Reply: Removed in the revised manuscript.

P3, L104: Please corcted in Corect the word "table".

Reply: Corrected to tablet in the revised manuscript.

P3, L110: Please use the correct verb in "make helps to form".

Reply: Statement corrected in the revised manuscript.

P4, L147: Please use "evaluate specific energy consumption for pelleting" instead of "evaluate its specific energy consumption". Note the use of "its" is not clear here.

Reply: Changed in the revised manuscript.

P4, L166-167: Why was there a need for preheating of biomass in the hopper/feeder? You have not discussed the preheating temperature that you have used in your study.

Reply: Pellet mill is equipped to preheat the biomass to different temperatures, but in the present study we did not preheat the biomass before pelleting.

P4, L169-170: What were the die speed and feeding rate that you had used for the study? I did not find these data in your manuscript.

Reply: The feeding rates were adjusted based on the pelleting conditions to get a steady state pellet production.

P5, L185-187: It is not clear how the "uniform feeding of the biomass to the pellet mill" was achieved in this study. Is this manually done? Or, do you want to say "uniformly feed the biomass to the feed hopper".

Reply: Corrected in the revised manuscript.

P5, L194: Please use the correct article in "an laboratory oven".

Reply: Corrected the article in the revised manuscript.

P7, L265: Please add the word "respectively" at the end of this sentence.

Reply: Added in the revised manuscript.

P8, L347-348: Why do you think there is a need for "adjusting the feedstock moisture to the right levels" in a commercial pelleting process? In general, the lower the feed moisture, the better the pellet quality. Is it mandatory to have a moisture of 30% to make quality pellets? Or, are you suggesting to dry the high moisture corn stover if the moisture is higher than the values studied in this work (i.e., >30 to 40%)? Please elaborate this bullet point #1 to make it clear.

Reply: This has been corrected in the revised manuscript.

P9, L353: Please change "Our studies have indicated" to "Our study indicates".

Reply: Changed in the revised manuscript.

P9, L363: You have introduced a term "pelleting efficiency" here. Please define it.

Reply: I have changed this statement to match what we have measured in this study.

P9, L376: Please delete the repeating reference number "29" in "21,26,29-29".

Reply: Deleted in the revised manuscript.

P9, L371-383: The expansion of pellets is also affected by the "stress relaxation" behavior of the fibers in addition to moisture flash-off effect. The stress relaxation effect has to be mentioned here. You can easily find suitable references from the literature to cite for the stress relaxation effect.

Reply: Additional explanation included in the revised manuscript (page 14, lines 574-579).

P10, L421-429: Please provide the data on "L, D and L/D of the pellet mill die" in this paragraph.

Reply: Additional details of the die dimensions are included in the revised manuscript (page 6, Lines 240-241).

P10, L431: Please remove "50% of the".

Reply: Removed 50% in the revised manuscript.

Figure 1: Why is the preheating temperature given as "0 C". I hope you have not frozen the biomass. If no preheating is involved, please say "Preheat: None".

Reply: Changed to Preheat: None in the revised manuscript (figure 2 in the revised manuscript).

*Additional Comments to Authors:*  
What were some of the properties of the corn starch used as a binder in this study (e.g., moisture, particle size distribution, chemical makeup of the starch types in the corn starch, flowability, etc.)?

Reply: The corn starch that we used in the present study is commercial available product. The details of the commercial product are included in the material section (excel sheet). The details of moisture content and bulk density of the grdound corn stover and corn starch binder are included in Table 1 in the revised manuscript. Also as we feel that other details like chemical makeup of the starch, flowability may not be necessary as we are adding commercial corn starch binder at a very low percentage of 2 and 4 %

**Reviewer #2:**   
*Manuscript Summary:*   
N/A  
  
*Major Concerns:*  
My largest concern/question is that the results are somewhat counterintuitive - that a high moisture pellet can be made with high density and high durability. Even the samples with no binder had a reasonably high bulk density. As stated in the paper itself, it is generally accepted that pellets do not form, or do not form well, at high moisture ("Moisture in the biomass while in the densification process acts as a binder and increases the bonding via van der Waal's forces, thereby increasing the contact area of the particle, but when the moisture content exceeds the threshold levels it acts more like a lubricant and does not help with binding. In general, low moisture content in the biomass (5- 10%) will result in denser, stable, and more durable briquettes compared to those produced from biomass with a higher moisture content.").   
Given that, it remains unclear exactly why this approach works even though it is against the conventional wisdom. I believe it would be appropriate to mention specifically what aspects of the pelleting procedure used here are necessary for obtaining a solid pellet at high moisture, particularly if previous research has been performed to determine what variables are important. For example, a previous paper (Tumuluru 2014 - Biosystems Engineering) made the pellets using an 8 mm die. Is this larger die size required? Or is this simply the case where the "conventional wisdom" was never fully investigated and was incorrect, and therefore pellets can be easily made at the high moisture under many different process conditions?

Reply: I think the conventional wisdom on pelleting is based on meeting the specifications needed for transportation where higher density and durability are desirable for long distance transportation. But the literature has indicated that a lot of researchers have done pelleting research by varying moisture content in the range of 7-45% (w.b.) (page 4, lines 152-156), but increasing the feedstock moisture content results in lower density pellets. Pellets that are produced by the pellet industry have higher bulk density (>700 kg/m3) as they transport the pellets over longer distances. These densities are achievable at lower feedstock moisture content. The process we have developed helps to make pellets at higher moisture content with densities in the range of 350-550 kg/m3 based on the feedstock conditions selected and helps to reduce the pellet production cost (Lamers et al., 2015). According to the Pellet Fuel Institute (PFI), USA, and the European Committee for Standardization (CEN), durability and bulk density are a normative specification for grading of pellets (Tumuluru et al., 2010). Pellets with durability values >96.5% and bulk density >640 kg/m3 are designated as super premium pellets based on PFI standards; whereas, in the case of CEN, the durability and bulk density values should be >97.5% and >700 kg/m3 and are desirable for international transport. Both PFI and CEN have other density and durability standards for lower grade pellets (Tumuluru et al., 2010). In general, to transport pellets over shorter distances (e.g., interstate), very high density and durability pellets may not be required. This process gives an opportunity to customize the pellet production process to produce pellets with varying durability and density values to meet different transportation scenarios. The present study has indicated that pellets with different density and durability can be produced at different feedstock moistures and binder addition, which can have a significant cost impact on storage and transportation of biomass for different logistics scenarios (Page 4, Lines 158-174).

Tumuluru, J. S., Sokhansanj, S., Lim, C. J., Bi, X. T., Lau, A.,. Melin, S., Sowlati, T., Oveisi, E. Quality of wood pellets produced in British Columbia for export. Appl. Eng. Agric. 26, 1013–1020.

*Minor Concerns:*  
1) I did not see it mentioned what the die properties are in the article. What is the die size and thickness?

Die dimension are included in the revised manuscript (page 6, lines 240-241).

2) Figure 3: Is the bulk density shown here dry bulk density (ie, kg dry matter / m3) or wet bulk density? This is unclear in the paper.

Reported data is “as is bulk density” after cooling and after drying. We did not correct the bulk density to 0% moisture content.

3) I am assuming Fig 3 is dry bulk density, given that the difference between the bulk density before and after drying is less than the difference in weight from the drying. However, in general, the bulk density decreased slightly after drying. If so, then why does the dry bulk density decrease after drying; do the pellets expand?

The main reason for an increase in bulk density after drying could be due to lower inter-particle liquid bridges, which might have kept the particles closer and produced less open structure. Oginni (2014) in his studies observed the bulk density of ground Loblolly pine decreases with increases in moisture content. Explanation included in the revised manuscript.

4) Presumably, the reason that there is less drying occurring when binder is added is because there is less electricity consumption, which means less energy being turned to heat. Do you agree with this explanation?

Yes, it can be a good explanation for less moisture loss when binder is added.

5) Likewise, given the difference in electricity consumption, is this due to a decrease in the power consumption or due to an increase in the throughput of the pelletizer?

We have seen both lower energy consumption in the pelleting as well as increased throughput when binder is used.   
  
*Additional Comments to Authors:*  
N/A

**Reviewer #3:**   
*Manuscript Summary:*   
General Comments:  
\*The paper presents some interesting research. The procedures are carefully described for the most part and the work appears to be carefully carried out. One thing that is missing is an indication of the number of replications either for the experiments or for the property determinations (e. g. moisture content, bulk density, durability, etc.). Error bars are shown in figures 2 through 4 indicating some calculation of variability, but not in figures 5 and 6. This needs to be clarified.

Reply: The error bars were included for graphs representing pelleting moisture content, pellet diameter, expansion ratio, bulk density and durability. In case of percent fines and specific energy consumption, the error bars are not included as the data is from single pellet mill run from steady state pelleting condition. We have published this method in other high impact factor peer reviewed journals like Bioresource Technology, Biosystems Engineering and Energy Science and Engineering Journal.

\*The biggest concern I have is the rational for the research which is interestingly spelled out in the last paragraph of the discussion near the end of the paper in lines 431-433. "Most of the woody and 50% of the herbaceous biomass is available at feedstock moisture contents of >30% (w.b.) and biorefineries are not ready to use this material due to high preprocessing costs related to drying the material for conventional pelleting." First, this statement should be included in the introduction since it is not based on any data in the paper. And second, and more importantly, I don't think that 50% of herbaceous biomass, and particularly corn stover, is available at moisture contents >30% w.b. Most corn stover will likely be available at 20% or less moisture content. Since it is harvested in a narrow window in the fall and needs to be available throughout the year it needs to be less than 20% for storage. The primary rational for pelleting at moisture contents greater than 30% seems to be the advantages in drying after pelleting versus before pelleting. While drying may be necessary for woody biomass, I think it is much less so for herbaceous biomass.

Reply: This statement has been moved to introduction section and additional information has been included in the revised manuscript regarding the moisture content of the harvested biomass based on the harvesting methods (page 3, lines, 121-123).

\*On lines 130-132, the authors state that rotary dryers operating at 160 to 180oC are more energy intensive than grain dryers operating at 80oC. I don't think this is necessarily true. It may be true that there are less problems drying pelleted material in a grain-type dryer at 80oC than undensified, bulky biomass in a rotary dryer at 160 to 180oC, but I don't believe the rotary dryer is inherently less efficient (more energy intensive).

Reply: Belt or grain dryers operate at lower temperature, and they have greater efficiency compared to rotary drum dryers (additional information included in the revised manuscript). Additional explanation included in the revised manuscript (page 4, lines 140-145)

\*While binders appear to have some advantages, at least at these moisture contents, what do they cost and how does this impact the cost of pelleted material?

Reply: We have added binder at very low percentages. Our TEA analysis team is working on understanding how the binder addition will influence the cost. We feel cost information is not within the scope of the manuscript.

Specific Comments:  
Line 208 - include the dimensions of the plexi glass cylinder.

Reply: Plexi glass cylinder information included in the revised manuscript.   
  
*Major Concerns:*  
N/A

*Minor Concerns:*

N/A  
  
*Additional Comments to Authors:*  
N/A  
  
**Reviewer #4:**   
*Manuscript Summary:*   
The crop residue is one of important renewable biomass. The pelletization of crop residue has more challenges than woody biomass due to the physical properties and compositions. This manuscript investigated the effects of moisture content and binder on the corn stover pellet production. The information reported in this manuscript will be helpful for the agricultural biomass based pellet production. There are several questions needed to be addressed before published.  
1. The details of the material used in this studied was not clearly described? What was the moisture content in the biomass before adjust the moisture content? What is the composition of biomass?

Reply: We have included the moisture content of the biomass in the revised manuscript. We do not have the chemical composition data as we do not feel it is within the scope of this paper; however, we have added information regarding typical lignin content in corn stover (page 14, lines 603-605).

2. How did the authors adjust the moisture content to 33, 36 and 39%? Equipment and methods?

Reply: Included in the revised manuscript (page 6, lines 257-262; page 7, lines 263-267).

3. Page 7 line 270 and line 286, they should be "Figure 4".

Reply: Change to the correct number in the revised manuscript.

4. Why did the bulk density increased greatly after drying the pellet for FMC-33% without binder?

There was a slight increase in the bulk density values by about 50 kg/m3 after drying.

The probable reason for the increase in bulk density after drying could be due to lower inter-particle liquid bridges, which might have kept the particles closer with less-open structure. Oginni (2014) observed that the bulk density of ground Loblolly pine decreases with increases in moisture content. This information is included on page 10, lines 424-427.

5. In addition to the cost for binder, the cost of drying for the pellet might also increase due to the increase of moisture according to the results of this manuscript. This manuscript only investigated the specific energy consumption. The energy consumption and economic evaluation for whole process including pretreatment, pelletization, cooling and drying should be also investigated.

Reply: The emphasis of this manuscript is only on the method of producing good quality pellets using binder. Our analysis team is working on analyzing the cost of adding a binder into the pellet production process. This cost analysis of the whole high moisture pelleting process is presented in our TEA paper published in Bioresource Technology Journal.

*Major Concerns:*  
N/A  
  
*Minor Concerns:*  
N/A  
*Additional Comments to Authors:*  
N/A