1-1-2018

Processing Different Mixtures of Regionally Available Resources to Create Pellets That Meet a Minimum Standard

Jacob Hixson
Eastern Illinois University

The Graduate School
EASTERN ILLINOIS UNIVERSITY

Thesis Maintenance and Reproduction Certificate

FOR: Graduate Candidates Completing Theses in Partial Fulfillment of the Degree
Graduate Faculty Advisors Directing the Theses

RE: Preservation, Reproduction, and Distribution of Thesis Research

Preserving, reproducing, and distributing thesis research is an important part of Booth Library's responsibility to provide access to scholarship. In order to further this goal, Booth Library makes all graduate theses completed as part of a degree program at Eastern Illinois University available for personal study, research, and other not-for-profit educational purposes. Under 17 U.S.C. § 108, the library may reproduce and distribute a copy without infringing on copyright; however, professional courtesy dictates that permission be requested from the author before doing so.

Your signatures affirm the following:

- The graduate candidate is the author of this thesis.

- The graduate candidate retains the copyright and intellectual property rights associated with the original research, creative activity, and intellectual or artistic content of the thesis.

- The graduate candidate certifies her/his compliance with federal copyright law (Title 17 of the U. S. Code) and her/his right to authorize reproduction and distribution of all copyrighted materials included in this thesis.

- The graduate candidate in consultation with the faculty advisor grants Booth Library the nonexclusive, perpetual right to make copies of the thesis freely and publicly available without restriction, by means of any current or successive technology, including but not limited to photocopying, microfilm, digitization, or internet.

- The graduate candidate acknowledges that by depositing her/his thesis with Booth Library, her/his work is available for viewing by the public and may be borrowed through the library's circulation and interlibrary loan departments, or accessed electronically. The graduate candidate acknowledges this policy by indicating in the following manner:

__X__ Yes, I wish to make accessible this thesis for viewing by the public

_____ No, I wish to quarantine the thesis temporarily and have included the ***Thesis Withholding Request Form***

- The graduate candidate waives the confidentiality provisions of the Family Educational Rights and Privacy Act (FERPA) (20 U. S. C. § 1232g; 34 CFR Part 99) with respect to the contents of the thesis and with respect to information concerning authorship of the thesis, including name and status as a student at Eastern Illinois University. I have conferred with my graduate faculty advisor. My signature below indicates that I have read and agree with the above statements, and hereby give my permission to allow Booth Library to reproduce and distribute my thesis. My adviser's signature indicates concurrence to reproduce and distribute the thesis.

Please submit in duplicate.

PROCESSING DIFFERENT MIXTURES OF REGIONALLY AVAILABLE RESOURCES TO CREATE PELLETS THAT MEET A MINUMUM STANDARD

BY

Jacob Hixson

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Science in Technology

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

2018
YEAR

I HEREBY RECOMMEND THAT THIS THESIS BE ACCEPTED AS FULFILLING
THIS PART OF THE GRADUATE DEGREE CITED ABOVE

ABSTRACT

There are several ways to produce energy today, one of the oldest is the gasification of biomass. This process uses a fire to heat the material until it starts to produce gasses that are used as fuel. There are several types of biomass that can be used, many of which have large pieces with low bulk densities. By pelletizing the biomass bulk density increases and allows the opportunity to add in other biomass materials.

There are standards for condensing large pieces of biomass to smaller pelletized materials. Pellet Fuels Institute has set minimum standards for pellets used in the different industries. These standards outline the chemical and physical characteristics of the pellets.

The purpose of this study is to determine what mixture of resources, wood products and corn stover, does the durability of the pellet start to degrade and not meet the minimum standard. Samples mixtures were used to test the durability at predefined intervals to test the durability.

ACKNOWLEDGMENT

This study would have not been possible without the support and motivation from faculty at the School of Technology and family.

I would like to thank my parents first and foremost for instilling a drive in me from a young age to want to learn and grow as a person, in education and career.

I would also like to thank my educators that have supported me during my time at Eastern Illinois University. I would like to give thanks to Dr. David Melton for providing me with a post-baccalaureate opportunity and the continuous support to complete the degree.

Finally, to my friends for the support and push needed to achieve this goal.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Everyone uses energy. There are many different types of ways to produce energy these days. Some use coal, wind, solar, or natural gas. Eastern Illinois University has switched from coal to biomass energy. The transition has led to the development of a gasification learning process for students with opportunities to develop diverse material that may be used in this process.

Through research, mixtures of pellets produced with regionally available resources will be examined to determine which ones can meet the minimum standards for pellets according to the Pellet Fuel Institute (PFI Standards Committee, 2011). The research will provide results that will help develop pellets for further research in the biomass future at Eastern Illinois University.

To develop and expand the utilization of biomass for gasification, the School of Technology has purchased a hammer mill and pellet mill. These pieces of equipment have the potential to be used in undergraduate studies as training aids. The equipment has not been confirmed to be able to produce suitable pellets that meet the PDI set by Pellet Fuels Institute.

This research intends to determine which mixtures, of regionally available resources and wood products, can be produced to meet the PDI standard. By using the Pellet Pros equipment this study will derive a baseline pellet to compare the mixtures of stover and wood. Data will be collected from a durability box that has been construct from the standards according to Pellet Fuels.

Purpose and Objectives

The purpose of this study is to determine what mixture of resources, wood products and corn stover, does the durability of the pellet start to degrade and not meet the minimum standards

set forth by the Pellet Fuels Institute. By creating samples of 100 percent wood product and using it as a baseline, the mixtures of 5%, 10%, 15%, 25%, and 50% of stover can be used to determine when the degradation starts to be in effect. From these results a statement can be developed to analyze the purpose of the research.

Problem Statement

Eastern Illinois University has built a new biomass energy center that uses gasification of virgin wood chips to produce energy for the campus. The biomass is allocated from regional area wood mills transported in from central Missouri. Though wood chips are a good source of fuel for gasification, there are other fuels available that can be used to optimize the efficiency of transportation, storage, and gasifying.

Principle Research Question

Can a baseline pellet be made, from 100% wood, with equipment available that meets the Pellet Fuels Institute standard? This question will guide the research by establishing the capabilities of the equipment.

Based on the hypothesis of question 1, if we base the mixtures of the stover pellets at 75 PDI, then at what percentage are the pellets durability affected with stover?

Delimitations

This study was limited to factors that impact the results including:

1. The capabilities of the equipment available.
2. The materials available: hardwood chip, shavings, and tropical corn stover.
3. The variables capable of controlling during production: material particle size, material infeed amount, and cooling method after pelleting.
4. The baseline pellet and the five other mixture types of biomass.

Definition of Terms

To reassure the readers of this manuscript will clearly understand what is being described a few definitions will be included.

Bulk density: the fuel mass per cubic foot of the fuel sample (PFI Standards Committee, 2011).

Binder: something…that produces or promotes cohesion in loosely assembled substances ("Binder", 2018)

Fines: the percentage of fuel material in the fuel sample passing through a 1/8-inch screen (PFI Standards Committee, 2011).

Pellet durability index: a standardized parameter for specifying the ability of the fuel pellets to resist degradation caused by shipping and handling (PFI Standards Committee, 2011).

Pellet: a usually small rounded or spherical body; *specifically*: a small cylindrical or ovoid compressed mass ("Pellet", 2018).

Summary

This research intends to discover which mixture of regionally available resources, corn stover, and wood when pelleted can meet the standards set by PFI. The purpose is set a baseline that the Renewable Energy Center can utilize at the facility to produce pellets. Developing a pellet production process would reduce the cost and improve the environmental impact that the university has.

CHAPTER II

REVIEW OF LITERATURE

Due to the overwhelming search for sustainable energies there has been a need for research in many different areas. The area of biomass has been around for many years and has been applying new technologies to process and produce new products for use in the marketplace today. One type of technology is to pelletize the biomass and then use it as a fuel.

Biomass covers a vast array of products. To limit the research, the biomass studied will be wood with the addition of corn stover. An analysis of the biomass pellet mixtures to determine durability and compare to the standards set forth by the Pellet Fuel Institute will be conducted. This chapter will be divided into sections to help better discuss the topics and present relevance for the research.

Purpose and Objective

The purpose of this study is to determine what mixture of resources, wood products and corn stover, does the durability of the pellet start to degrade and not meet the minimum standards set forth by the Pellet Fuels Institute. By creating samples of 100 percent wood product and using it as a baseline, the mixtures of 5%, 10%, 15%, 25%, and 50% of stover can be used to determine when the degradation starts to be in effect. From these results a statement can be developed to analyze the purpose of the research.

General Biomass

To narrow the field of biomass for the purposes of this research these two forms will be discussed; wood products and corn stover. This section will provide information such as availability, annual production, and other factors outlining the biomass for use in renewable fuels.

Wood products are one of the main contributors as fuel in the renewable energy sector. Availability of wood products as biomass throughout the nation has been conservatively calculated at an average of 39.6 tonnes per hectare resulting in an annual yield of 0.79 tonnes per hectare per year (MacFarlane, 2009). Though wood products are available for use in biomass much of the yield is used in other processes such as manufacturing.

As the need for biomass products grow, a search for alternatives to consume does as well. This leads to corn stover as supplement to wood products for use in biofuels. Corn stover looks to be a prosperous route with an availability of "238 million tons" produced in the crop year 2001 (Sokhansanj, Turhollow, Cushman, & Cundiff, 2002).

Not all the corn stover produced throughout the year is available for use as a renewable energy crop. This is because of conservation programs for erosion and soil quality. "Currently only 6% of the stover is collected" leaving behind an enourmous amount left undefined as to whether it is beneficial to leave or not (Sokhansanj et. al. 2002, p.347).

According to Sokhansanj et al, it is unclear as to "how much the stover can be removed" and not cause adverse effects on the existing land (2002). For the stover that is removed from the field it has been found to process it rather than to leave it loose. In the research by Sokhansanj et al, the bulk density of loose stover ranged from 20-40 kg m^{-3} as to baled or pelleted stover that is 110-200 kg m^{-3} and 560-720 kg m^{-3} respectively (2002). From the annual production of the stover to its ability to be reduced too much greater densities shows why it would be beneficial to incorporate into biofuels.

Biomass and EIU

At Eastern Illinois University the coal steam plant was "rapidly failing" creating the need for a new plant (EIU Renewable, n.d.). Studies and surveys were conducted to determine if it would

be feasible to replace the current system based on the costs and environmental impacts of coal. After consideration "it became clear an alternative fuel source was the best option" (EIU Renewable, n.d.). A new facility that generated steam from biomass instead of coal was selected. This solution answered the environmental and the sustainability challenge that persisted with the old coal plant. The new facility houses four boilers, "Two boilers burn biomass — any biological material from wood chips to switchgrass —while the others bum natural gas with a fuel oil backup" (EIU Renewable, n.d.).

> "The plant is also designed for fuel flexibility through its gasifiers. Because it isn't a direct combustion facility, it is a lot more fuel flexible. With a traditional combustion boiler, the fuel sources must generally be the same in moisture, size, density, and so on. With these gasifiers, boilers are able to accept a lot more variation in their fuel sources" (EIU Renewable, n.d.).

This flexibility of the new plant gave way for research on other types of biomass that could be processed through the gasifiers. One form of biomass to analyze for use in the new plant would be pellets. This type of fuel at the new facility would provide a denser product than the current wood chips used and allow better utilization of the storage area.

Pellet Fuel Institute and Their Standards

"The Pellet Fuels Institute is a North American trade association promoting energy independence through the efficient use of clean, renewable, densified biomass fuel" (Pellet Fuels Institute, 2017). They are made up of a diverse network of companies ranging from industry leaders in fuel and suppliers to universities and sectors within governments (Pellet Fuels Institute, 2017). They strive to "represent the ultimate expertise in the residential and commercial

densified biomass fuel industry" by creating and maintaining standards that allow members to manufacture products for the marketplace (Pellet Fuels Institute, 2017).

Pellet Fuels Institute has gained accreditation for the standards and other publications through the American Lumber Standard Committee. The standards are published in "Pellet Fuels Institute Standard Specification for Residential/Commercial Densified Fuel" and will be the main source of information for the production and testing of the biomass pellets at Eastern Illinois University. This publication consists of several ASTM standards that define how to test for each property specified. The standards for pellet production in residential and commercial fuels are shown in TABLE 1.

Table 1. *Pellet Fuels Institute Fuel Standards.*

Residential/Commercial Densified Fuel Standards

Fuel Property	PFI Premium	PFI Standard	PFI Utility
Normative information- Mandatory			
Bulk density, lb/cubic ft	40-46	38-46	38-46
Diameter, inches	0.23-0.285	0.23-0.285	0.23-0.285
Pellet durability index	≥ 96.5	≥ 95	≥ 95
Fines, % (at the mill gate)	≤ 0.5	≤ 1	≤ 1
Inorganic as, %	≤ 1	≤ 2	≤ 6
Length, % greater than 1.5 inches	≤ 1	≤ 1	≤ 1
Moisture, %	≤ 8	≤ 10	≤ 10
Chloide, ppm	≤ 300	≤ 300	≤ 300
Heating value	NA	NA	NA
Informative only - Not Mandatory			
Ash fusion	NA	NA	NA

* Information sourced form Pellet Fuels Institute

Pellet Generation

Pelleting biomass is a simple but detailed process. In a publication by Tenorio, Moya, Filho, & Valaert (2015) the process incorporated a chipper, mill, dryer and pellet mill. When beginning the process biomass was reduced to uniform size in the chipper and mill before

preparing the material for the pellet mill in the dryer. Once all steps were completed pellets could be generated with the feedstocks available.

Typical pellets for use in energy production are made primarily of wood due to the maturity of the research that has been done (Sultana & Kumar, 2012). Though the primary use of wood in manufacturing is not for pelleting but for manufacturing and consumers, the waste generated is used for pellet production. With growing research in other areas of biomass such as Miscanthus, corn stover and switchgrass these can be combined with wood waste to produce higher volumes of pellets that still meet industry standard.

The pellets for this research will be comprised of wood product, hardwood chips and shavings, and corn stover. Starting with a baseline pellet out of hardwood material it will be determined if pellets are able to be made. Then samples will be made adding corn stover in increments of 5% until five samples are created to determine at which mixture the pellet begins to degrade, this will be determined by a durability test.

Relationship between Prior Investigation and Current Research

There have been numerous small-scale studies on pelleting different biomass fuels. These studies have included corn cobs, grasses, and other various feedstocks. A common characteristic within the studies is the durability of the pellet after production. By producing a pellet that can meet the durability standards, in this research the standard is in accordance with the Pellet Fuels institute, the other characteristics of the pellets can be determined easier due to the pellet staying intact during transportation. Some issues with lower durability of the pellets result in "pellet feeding systems, handling and transport difficulties, and inhomogeneous combustion" (Sultana & Kumar, 2012).

Summary

This chapter showed the need for biomass research at Eastern Illinois University and relevant information pertaining to pellet production. By reviewing biomass, the standards for pellets, and pellet generation the research can start with a foundation for investigation of wood product and corn stover pelleting.

CHAPTER III

METHODOLOGY

The purpose of this study is to determine what mixture of resources, wood products and corn stover, does the durability of the pellet start to degrade and not meet the minimum standards set forth by the Pellet Fuels Institute.

This section will include the following topics: (a) research method; (b) materials tested; (c) data collection instruments; (d) data collection; (e) summary.

Problem Statement

Eastern Illinois University has built a new biomass energy center that uses gasification of virgin wood chips to produce energy for the campus. The biomass is allocated from regional area wood mills transported in from central Missouri. Though wood chips are a good source of fuel for gasification, there are other fuels available that can be used to optimize the efficiency of transportation, storage, and gasifying.

Principle Research Questions

Q1: Can a baseline pellet be made, from 100% wood, with equipment available that meets the Pellet Fuels Institute standard? This question will guide the research by establishing the capabilities of the equipment.

Q2: Based on the hypothesis of question 1, if we base the mixtures of the wood pellets at 75 PDI, then at what percentage are the pellets durability affected with stover?

Research Method

The research method involved material preparation, pellet production, and pellet testing. The focus is intended to create a pellet that meets the PDI according to Pellet Fuels Institute Standard Specification.

To prepare the material a hammermill was used on the hardwood chips and corn stover. This machine has a ½-inch screen that allows the processed material to be uniform in size. The hardwood shavings did not need any processing before pelleting. Once the base materials were ready the sample mixtures had to be prepared for use in the pellet mill. The composition was determined by weight, a sample size of 10 pounds was used. The seven samples are shown in Table 2.

Table 2. *Sample mixtures and composition.*

Mixtures	Weight of Hardwood (lbs.)	Weight of Stover (lbs.	Total Mixture (lbs.)
Hardwood Chips	10.0	0.0	10.0
Hardwood Shavings	10.0	0.0	10.0
95% Shavings, 5% Stover	9.5	0.5	10.0
90% Shavings, 10% Stover	9	1.0	10.0
85% Shavings, 15% Stover	8.5	1.5	10.0
75% Shavings, 25% Stover	7.5	2.5	10.0
50% Shavings, 50% Stover	5.0	5.0	10.0

Pellet production used the following process. To start, the pellet mill needed to be clear of foreign material, rollers adjusted and turned on to warm up. On the discharge end a screen needs to be setup to catch the pellets to allow them to cool and the fines to drop out. Once the machine is setup and ready the samples can be added. Material needs to be added slowly and consistently into the machine. As pellets start to emerge, gently shake the screen. After running the mixture through the pellet mill let the pellets cool on the screen then collect to test.

Pellets were tested by tumbling each sample in the durability box. According to the test methods in "Pellet Fuels" the durability box had to rotate "at 50 ± 2 rotations per minute for a total of 500 revolutions." (pg. 7, 2015) A lathe was used to keep a consistent speed for tumbling.

Materials Tested

Material was gathered from two sources. The hardwood chips were from the Renewable Energy Center. These were received in bulk amounts by truck load and within the size ranges of approximately 2-inches by 4-inches. The hardwood shavings were from a local cabinet shop and were brought in loose by the bag. These did not need any extra processing before pelleting.

Data Collection Instruments

The instrument used to collect data of the pellet samples were a durability box. The durability box was made in accordance to the specifications in the Pellet Fuels "Standard Test Samples."

Data Collection

The data collected was the PDI, Pellet Durability Index, of the final pellets. PDI is calculated "by dividing the whole pellet sample weight (WPW) by the initial weight (IW) of the sample and multiply by 100." (Pellet, pg8., 2015)

Summary

This chapter reviewed the problem statement and present the research questions that are to be evaluated. The process has been reviewed and outlined the research method, materials and data collection used in the research. Analysis of the data recovered in this chapter will be reviewed in Chapter 4.

CHAPTER IV

RESULTS

The purpose of this study was to examine the effect of combing corn stover with wood products in a pelleting process to determine at what mixture does the PDI, pellet durability index, fail to meet the industry standard. Data collected for this study was from pellets produced with a pellet mill model PP600A. This section will provide the research questions, data collected from the pellet mixtures, an analysis of the data, and a summary of the results.

Principle Research Questions

Can a baseline pellet be made, from 100% wood, with equipment available that meets the Pellet Fuels Institute standard? This question will guide the research by establishing the capabilities of the equipment.

Based on the hypothesis of question 1, if we base the mixtures of the stover pellets at 75 PDI, then at what percentage are the pellets durability affected with stover?

Analysis of Data

The PDI is the determining factor of the research. To calculate PDI the final weight is divided by the initial weight and multiplied by 100. The final weight is after tumbling and separating out the fines. The purchased pellets were the first sample tested to validate the process and the durability box that was used. These pellets met the Pellet Fuels Institute "Premium Grade" for fuel standards, PDI $\geq$ 96.5. The next mixtures were the milled hardwood and hardwood shavings to determine which one to use as our baseline pellet. Neither sample pellets could meet the Pellet Fuels Institute standards, the results will allow the data to adjust the baseline for what is achievable out of pelleting process with the available equipment. As the

stover mixtures were processed and tested, it was found that the equipment was not possible of producing consistent pellets to test.

Table 3 provides the data of each mixture that was tested before determining that the equipment was deemed inadequate.

Table 3. Pellet Sample weights and calculated PDI

Type of Pellet	Sample ID	Initial Weight (kg)	Final Weight (kg)	Calculated PDI	Average PDI
Purchased Pellets					97.418
	D1	0.506	0.493	97.431	
	D2	0.501	0.488	97.405	
100% Milled Hardwood					46.024
	D3	0.503	0.230	45.726	
	D4	0.503	0.233	46.322	
100% Hardwood Shavings					75.751
	D5	0.505	0.390	77.228	
	D6	0.505	0.358	70.891	
	D7	0.575	0.478	83.130	
	D8	0.596	0.470	78.859	
	D9	0.508	0.365	71.850	
	D10	0.510	0.370	72.549	
5% Stover					80.539

	D11	0.461	0.398	86.334	
	D12	0.460	0.388	84.348	
	D13	0.289	0.205	70.934	
10% Stover					N/A
	D14	Undetermined			
	D15	Undetermined			
	D16	Undetermined			
15% Stover					N/A
	D17	Undetermined			
	D18	Undetermined			
	D19	Undetermined			
25% Stover					N/A
	D20	Undetermined			
	D21	Undetermined			
	D22	Undetermined			
50% Stover					N/A
	D23	Undetermined			
	D24	Undetermined			
	D25	Undetermined			

Summary

Although a pellet sample was not produced to meet the PFI standard, it was determined that hardwood pellets could be produced to meet a baseline durability of 75 PDI. Other factors

such as machine capabilities and limitations were the determining factor when producing other pellet samples. Without being able to keep pressure and temperature constant during production the data recorded was sporadic and inconsistent. The results and recommendations will be discussed in the next chapter.

CHAPTER V

CONCLUSION

As the Renewable Energy Center at Eastern Illinois University continues to grow the need for further research in renewable resources does too. From this, equipment has been made available by The School of Technology for use in developing the pelleting process. By utilizing regionally available resources and the new equipment, pellets can be made and tested using the Pellet Fuel Institute standards. This research will provide results to develop biomass further at Eastern Illinois University.

Problem Statement

Eastern Illinois University has built a new biomass energy center that uses gasification of virgin wood chips to produce energy for the campus. The biomass is allocated from regional area wood mills transported in from central Missouri. Though wood chips are a good source of fuel for gasification, there are other fuels available that can be used to optimize the efficiency of transportation, storage, and gasifying.

Principle Research Questions

Q1: Can a baseline pellet be made, from 100% wood, with equipment available that meets the Pellet Fuels Institute standard? This question will guide the research by establishing the capabilities of the equipment.

Q2: Based on the hypothesis of question 1, if we base the mixtures of the wood pellets at 75 PDI, then at what percentage are the pellets durability affected with stover?

Significance of the Study

The significance of the study is derived from the potential to make pellets from the mixtures of wood products and corn stover. By using hardwood shavings to create a baseline

mixture, stover was added to determine at what point the pellets start to degrade and fail the durability test set by PFI.

Recommendations

This study has shown that pellets made with hardwood shavings and corn stover have potential on the equipment provided, but more research needs conducted on the machine variables before progressing. Without controls on the variable inputs of the pellet mill, a uniform and consistent sample cannot be created. By researching what pellet mill inputs are needed, future testing could be conducted with hopes on successful samples produced.

REFERENCES

"Binder." Merriam-Webster.com. Merriam-Webster, n.d. Web. 8 Mar. 2018.

Carroll, J. P., & Finnan, J. (2012). Physical and chemical properties of pellets from energy crops and cereal straws. Biosystems Engineering, 112, 151-159.

EIU Renewable. (n.d.). Retrieved from http://www.eiu.edu/sustainability/eiu_renewable.php

Kuokkanen, M., Vilppo, T., Kuokkanen, T., Stoor, T., & Niinimaki, J. (2011). Additives in wood pellet production. BioResources, 6(4), 4331-4355.

MacFarlane, D. W. (2009). Potential availability of urban wood biomass in Michigan: Implications for energy production, carbon sequestration and sustainable forest management in the U.S.A. Biomass and Bioenergy, 33(4), 628-634. Retrieved November 10, 2017, from http://www.sciencedirect.com/science/article/pii/S0961953408002377

"Pellet." Merriam-Webster.com. Merriam-Webster, n.d. Web. 8 Mar. 2018.

PFI Standards Committee. (2011, June). Pellet Fuels Institute. Retrieved from PFI Standards Program: http://www.pelletheat.org/joining-the-pfi-standards-program

Sokhansanj, S., Turhollow, A., Cushman, J., & Cundiff, J. (2002). Engineering aspects of collecting corn stover for bioenergy. Biomass and Bioenergy, 347-355.

Sultana, A., & Kumar, A. (2012). Ranking of biomass pellets by integration of economic, environmental and technical factors. Biomass and Bioenergy, 344-355.

Temmerman, M., Mignon, C., & Pieret, N. (2012). Influence of Increasing Shares of Miscanthus. Journal of Agricultural Science and Technology B, 2, 768-779.

Tenorio, C., Moya, R., Filho, M. T., & Valaert, J. (2015). Quality of Pellets Made from Agricultural and Forestry Crops in Costa Rican Tropical Climates. BioResources, 10(1), 482-498.