FEASIBILITY OF USING FOREST RESIDUES FOR PELLETIZATION IN CHIHUAHUA MEXICO

Mónica Moreno-López, Ignacio R. Martín-Domínguez* and M. Teresa Alarcón-Herrera
Advanced Materials Research Center, S. C (CIMAV)
Department of Renewable Energy and Environmental Protection
Miguel de Cervantes 120. Complejo Industrial Chihuahua. 31109 Chihuahua, Chih. México.

* (614) 439-1148 ignacio.martin@cimav.edu.mx

Abstract

Due to its latitude and climate, Mexico does not have dense forests comparable to those in countries further north. However, there are two large mountain ranges running nearly parallel to the Pacific Ocean and the Gulf of Mexico. These mountains contain significant woodland which provides forest resources for the rest of the country. This industry also produces significant waste, in the form of sawdust, bark, scrap wood, and foliage, which in most cases can't be used. This residue is usually merely discarded near the sawmills that produce it, generating a pollution problem and a fire hazard. Mexico is considered an oil-producing country, and only lately has production diminished and existing oil supplies become scarce. Thus, only lately has there been an effort to characterize and quantify the country's other available energy resources, such as forest and agricultural waste. No local industry has yet tried to develop the technology to turn this waste into a more compact, homogenous, and manageable product, such as wood pellets. The wood pellet industry is highly developed in many countries, but does not yet exist in Mexico even though 72% of the total area of the country is dedicated to forestry. There are no local manufacturers of the devices and systems needed for the collection, storage, packaging, transport, and final use of the wood pellets as fuel for heating or industrial processes. As an initial step towards solving this national problem, we present an estimate of the potential for generating solid biofuels from forest waste in northern Mexico. We specifically analyze the waste generated by milling the most common tree species in this area, which include the Mexican weeping pine (Pinus patula) and the northern red oak (Quercus rubra). In order to characterize the product, we built a prototype manual pelletizer and used it to create three different pellet varieties (pine, oak, and a 50/50 mixture of both) that were subjected to calorimetric analyses. Our results show that Mexican wood pellets can easily replace fossil fuels in any kind of furnace. We performed a field study in order to quantify the available volume of forest waste, sampling the forest exploitation facilities in Ciudad Madera, Chihuahua. This city is located in northern Mexico, near one of the country's largest mountain ranges (the Sierra Madre Occidental), and is representative of other woodlands in the country. The results of our work show that it is technically feasible to turn Mexican forest waste to wood pellets, and it is thus justified to develop the industry necessary to do so.

1. Introduction

Due to its latitude and climate, Mexico does not have dense forests which can be compared to the ones that exist further north in countries situated in the Northern Hemisphere. However, Mexico has two large ridges, one that runs almost parallel to the Pacific Ocean and another one parallel to the Gulf of Mexico, which have considerable forest resources and supply the timber products required by the country. The by-products of Mexican forestry include significant quantities of waste in the form of sawdust, bark, pieces and foliage. In most cases, proper use is not given to the waste and it frequently ends up as garbage in the vicinity of sawmills. This waste creates an environmental pollution problem and, under certain conditions, a serious fire hazard.

Mexico was once regarded as an oil-producing country but, recently, there has been a steep decline in its production and the scarcity of oil reserves has begun. There haven't been almost any efforts in Mexico to characterize and quantify other available energy resources such as forestry and agricultural residues. Due to these reasons, Mexico needs a local industry able to develop the technology required to transform waste into a more compact, uniform and manageable product such as Pellets. The pellet industry is developed practically all over the world and, even though 72% of the total territorial extension of Mexico is destined for various forestry activities, there is currently a nonexistent pellet industry in Mexico. Consequently, there are no local manufacturers of devices and systems required for the collection, storage, packing, transport and usage of Pellets as fuel for heating or industrial processes.

As an initial step towards solving the described problem, this work presents an estimation of the potential generation of solid bio-fuels in the form of pellets from forestry wood-waste produced by sawmills.

To quantify the volume of the available wood-waste, a field study was performed where forestry facilities located in Ciudad Madera, Chihuahua, were taken as sample. The northern region of Mexico is located in the vicinity of the Sierra Madre Occidental and it is representative of other forest areas in the country. The forestry wood-waste generated in Chihuahua is comprised by some of the most common wood species in Northern Mexico, such as the patula pine (*Pinus patula)* and the oak (*Quercus rubra*).

To carry out the characterization of the product, a manual pelletizer prototype was built and three different types of pellets (patula pine, oak and a 50% combination) were produced. A calorimetric analysis was conducted in the three types of pellets in order to obtain their heating value. The results show that Mexican solid bio-fuel (pellets) can perfectly replace fossil fuel in any type of boiler designed for pellet use.

The results presented in this work show that it is technically possible to transform forestry residues into Pellets, which justifies the development of the necessary industry.

1.1. Development of the Pellet industry worldwide

The search of alternative sources to fossil energy is part of a worldwide research effort, and the production of pellets from wood-waste is one viable approach. Nowadays, the pellet industry is developed in some parts of South America and Europe, USA, and Canada.

Vinterback (2004) drew up an article summarizing the first Pellet World Conference which was held in Stockholm in 2002. The summary concluded that the pellet industry expansion is significant, with a European estimate of 4-5 million tons of pellets for the next 5 years. Despite the crisis, the demand and investment in pellet plants throughout Europe is still on the rise. Sweden is the world's main consumer of pellets with 20% of global production and, in order to satisfy its consumption, it produced 1.6 million tons and imported 300 million in 2008 (Buehlmann, 2009). The global demand for energy pellets has a steady increment of 8 to 10%. There are currently 450 pellet production plants and several other projects under construction in Europe. The countries with the greatest expected increments will be the United Kingdom, Denmark, Sweden and Germany. The price of pellets has increased during the last 7 years and, even with the global economic crisis, there are no signs of the contrary. (Reali, 2011).

1.2. Sources of raw material for the fabrication of pellets

In pellet manufacturing, one can use virtually any kind of waste-wood provided that it hasn't been previously impregnated or treated with any chemical that is harmful for the health or the environment (oils, fungicides, insecticides, water repellents, pigments etc.). Pellet sources so far come from:

- Waste from sawmills
- Industrial waste
- Urban waste

1.2.1. Waste from sawmills

The sawdust from conifers is the biomaterial most commonly used in the production of pellets. Experience indicates that the specific properties of different biomaterials influence the final quality of the pellets. A systematic study was conducted by Samuelsson *et al*. (2009), where 5 factors were mixed for 2 designated levels. The factors were: species of trees (Scots pine and Norway spruce); place of origin (latitudes 57 and 64 degrees North); storage of the sawdust (0 to 140 days); moisture content (9 and 12%); and treatment of steam (2 to 6 kg/h). The authors concluded that the moisture content was the factor that more significantly affected the density of the sawdust pellet from conifer bark and that the storage time was a factor that influenced the mechanical durability in a significant manner.

Granada *et al.* (2006) suggested through experimentation that the pine bark is the most sustainable product that can be used in the manufacturing of pellets; however, it needs a specific burner due to the different combustion behavior of the mixtures.

1.2.2. Industrial waste

In John Deere Company, the pallets of wood-waste are crushed and used in the manufacturing of pellets, which are then used as fuel for their boilers (López, 2010). It has been proven that wood-waste pallets (along with sawdust and all types of forest and agricultural residues with a certain heating value) can be used as raw materials for pellet manufacturing.

In Sweden, large quantities of wood-waste recovered from the construction industry and from industrial activities are annually generated and then imported as an energy source to be used in bio-fuels for boilers. (Krook, 2004).

1.2.3. Urban waste

In order to examine the potential of forestry residues, a regional study, which combined data and analysis from many other studies, was performed in an area of 13 counties of Michigan, USA. The study suggests that wood-waste and urban trees offer a modest amount of biomass which could contribute significantly to the current regional and national bio-economies. An efficient usage of biomass derived from wood-waste and urban trees could provide new sources for bio-fuels destined for heat generation; action which reduces fossil fuel consumption and waste disposal costs and thus relieves pressure from forests. (Mc Farlane, 2009).

Taylora *et al.* (2009) developed a survey in Australia to identify if there is a difference between the wood that is separated for recycling and the wood which is disposed of in landfills. The results suggest that the availability of recycling does not depend on the amount of wood in the landfill.

1.3. Environmental impact

Forest residues obtained in the production of wood can be classified in two types: by-products of forestry activities and residues from wood processing, the latter, due to its area-specific concentration, is more feasible. Wood processing includes sawing, unbarking and pulp extraction, which produce waste in the form of sawdust and small wood pieces (splinters and shavings). All these wood residues occupy significant space in sawmills, pose a fire hazard during the summer season, and also cause respiratory allergies and illnesses in the population. Additional environmental issues are caused by the residues of old pallets, old furniture, and residues from pruning urban trees, all of which end up in the landfill. This study offers an alternative destination for all the aforementioned residuals as raw materials in the manufacturing of wooden pellets for boiler fuel.

1.3.1. Environmental impact of wood

Wood pallets have a short life and consume vast amounts of resources. Wood pallets are also responsible for 2-3% of the total waste in landfills in the United States; this happens despite the existence of technologies destined to re-use, recycle, and convert the pallets into other products like boiler fuel. (Buehlmann *et al.*, 2009). In Australia, waste from wood flooring in the commercial and industrial sector represents 80% of the total of solids present in landfills (Taylora *et al*., 2009). In Sweden, the RWW (recovered wood waste) contains high concentrations of arsenic, chromium, zinc, nickel and copper, while the imported RWW contains high concentrations of mercury and cadmium, making them impossible to recycle. Consequently, the raw materials are used and the waste is dumped in landfills (Krook, 2004).

No specific data on the amount of wood-waste in Mexico was found.

1.3.2. Environmental impact of emissions

The daily impact that different emissions cause is a matter of worldwide research. Regarding the emissions generated by combustion of pellets, Fiedler (2008) developed five combinations of systems representing the range of typical solutions. Through modeling and simulation, a halving of the emissions was obtained if the pellet-fueled boiler is combined with solar heating systems.

Emissions (CO, NO_x, SO_x) and the efficiency of a pellet boiler (40 kW) was compared using six different types of biomass: Canary Reed, citrus shell residues, sunflower shells, peat, wheat straw, and wood pellets. Emissions vary according to the operating loads required for each type of pellet. The wood pellets reported lower emissions in all parameters; however, the specific optimization for each type of pellet is essential for the efficient use of agro-pellets in this type of boiler. (Verma, 2011).

1.3.3. Alternatives to mitigate the environmental impact

To mitigate the environmental impact generated by wood-waste, it can be recycled in several ways:

- Manufacturing of pressed sawdust sheets for the production of furniture.
- Usage of wood-waste in the production of compost.
- Usage of wood-waste to produce pellets.

Increasing the use of recycled wood biomass is a strategy used to reduce environmental impacts and the gas emissions from green wood, (Krook, 2004).

Many scientific papers explore the use of wood-waste, the production of compost for organic fertilization, and the improvement of soils in different countries. Compost is the product of mixing all vegetable and animal waste with the aim of wood suffering from microbial decomposition through fermentation, transforming the waste into what is known as mulch or humus (Alvarez, 2009). Furniture made with sheets of pressed sawdust will also become waste one day. In the production of compost, sawdust is only a part of a process. On the other hand, in the production of pellets, wood residues are the raw material; additionally, pellet combustion only generates a bit of ashes and, by attempting to have a complete combustion, the emissions are minimal.

1.4. Uses of pellets

Pellets can be used as boiler fuel, for electricity generation, and for water and air heating aimed towards domestic and industrial applications.

The usage feasibility of forest residues for electricity generation depends on the volume and types of wood available (Lesme, 2010).

Moran *et al*. (2003) developed a small domestic stove to produce heat and hot water which optimizes its efficiency when using lignocellulose pellets. Also, González (2004) developed an 11.6 kW boiler for domestic heating that used pellets as fuel.

The energy-need in residential buildings has led to the development of a complete model of micro-cogeneration where wood (as fuel pellets) is used for simultaneous heating and hot water generation. (Thiers, 2010).

2. Methodology

2.1. Quantification of the sawdust-waste volume in Ciudad Madera and determination of the potential raw material available for pellet manufacturing.

The quantification of residues was carried out during a visit to Ciudad Madera. The 10 major sawmills in the region were surveyed in order to know the constantly generated volumes of sawdust, as well as the characteristics of the waste and the expectations of mill owners.

2.2. Characterization of sawdust.

In Ciudad Madera, sawdust moisture content and its characterization was determined by taking small samples in each one of the sawmills. The wood is virtually the same for all the sawmills because they get their raw materials from the same forest. A mixture of the samples was made in order to obtain a single representative sample, which is what actually happens in the pelletization process when the sawdust is mixed in the hopper at the entrance of the pelletizer machine.

To determine the moisture content, a sample was weighed and then dried in the oven at 100°C. After 24 hours, the sample was taken out of the oven and weighed again. The sawdust was characterized in the elemental analyzer (EA 1110 CHNS-O) to know the percentage of carbon, hydrogen, oxygen and nitrogen in the sample. The sulfur content was determined via emission spectrometry by inductively coupled plasma (ICP-OES).

2.3. Construction of a manual pelletizer prototype and determination of the calorific power of the prepared pellets.

A manual pelletizer prototype was designed, based in the physical parameters required by European standards for high quality pellets, and it consists of the following three parts:

- A 10 mm diameter and 60 mm in length cylindrical mold with a hole in the center.
- A cylindrical mold covers that fits in the 9 mm diameter central hole.
- A solid bar of 8 mm in diameter and 34 mm in length.

The pelletizer is a steel prototype that was built using a lathe and, once it was finished, it was used to manufacture the pellets with the sawdust from Ciudad Madera (patula pine and oak, 50% each mixture). In order to obtain the heating value of the sawdust, a calorimetric analysis was performed in the University of Morelia, Michoacán, by means of a calorimetric bomb (model mark Parr 6772 calorimetric thermometer).

3. Results

3.1. Quantification of sawdust generated in Ciudad Madera

Ciudad Madera, Chihuahua, was visited to obtain information from the sawmills established in the region. The main interest was to obtain a frame of reference with respect to the handled volume of forest waste (chips, sawdust, shavings). It was found that 955 m^3 of sawdust per week are being produced in the 10 visited sawmills alone. According to the survey, all sawmills in the region obtained their raw material (red pine (*pinus patula*)) from the same timberland. Wood from oak trees also exists in the region, but its amount is negligible when compared to the red pine. In general, sawmills work throughout the entire year, except during extreme snowfall or when there is failure to reach economic agreements with the timberland owners who provide the raw material. The sawmill owners believe that the timber industry is part of a cycle that will never end, as long as care is taken with reforestation and forest fires. Table 1 presents the quantification of sawdust waste generated in the area.

Table1. Visited sites in Ciudad Madera

Name of the mill	**Production of sawdust (red pine) m^3 / week**
Los Pinos	200
Productos Forestales del Norte	150
Productos Forestales Cota B	150
El Durangueño	20
El Manantial	20
Ejido Madera	40
Transportes y Materiales del Norte	75
Productos Silvícolas Aztlán	100
Maderas J.R.	100
Ejido El Largo	100
Total	955

3.2. Characterization of sawdust of red pine generated in Ciudad Madera.

The sawdust moisture content is an important parameter because, if the moisture content is not around 10%, it's impossible to manufacture the pellets (Table2). The red pine sawdust presented a moisture content of 54.45%. For the sawdust characterization, the sample was analyzed using an elemental analyzer EA 1110 CHNS-O. The results were:

- Carbon 53.323 %
- Hydrogen 6.747 %
- Nitrogen 0.040 %
- Oxygen 0.515 %

The sulfur content in the sawdust sample was 0.002% and it was determined using emission spectrometry by inductively coupled plasma (ICP-OES).

3.3. Construction of a manual pelletizer prototype and determination of the calorific power of the prepared pellets.

Once the characterization of the sawdust was done, a manual pelletizer was designed and built in order to pelletize the sawdust sample. In the design, the physical parameters required by the German DIN Plus standard for high quality pellets were taken as a reference (Table 2).

Table 2. German DIN plus for high quality pellets

Feature	**Units**	**Requirement**
Diameter	mm	$4 \leq D \leq 10$
Length	mm	$\leq D$
Density	kg/cm^3	≥ 1.2
Water content	%	≤ 10
Ash	%	≤ 0.5
Calorific power	MJ/kg	≥ 18
Sulfur	%	≤ 0.04
Nitrogen content	%	≤ 0.3
Chlorine	%	≤ 0.02
Wear	%	≤ 2.3

A manual pelletizer prototype was constructed and it consisted of three parts: the pellet mold cylinder, the lid, and the compactor screw.

The sawdust sample was sundried, until its moisture content was around 10%. One cannot make pellets with wet sawdust because they fall apart once they exit the pelletizer. To produce the pellets, the mold was filled with approximately 2 g of sawdust and it was placed in a vice, pressure was applied until the sawdust was well compacted. Afterwards, the sample was immediately depressurized and the resulting pellet was taken out of the mold.

The manufactured pellets with sawdust from Ciudad Madera were sent to the University of Morelia in Michoacán Mexico for the determination of their heating value. The equipment used for the heat measurements was a calorimetric bomb (Parr model 6772 calorimetric thermometer). The results are shown in table 3.

Table3. Results of heating values

Pellets	**Heating Value MJ/kg**
Oak	18.98
Patula pine	22.13
Combined 50 %	19.19

According to literature, the expected heating value of pine wood varies between 11 and 16 MJ/kg. The obtained heating value of 22.13 MJ/kg is uncommonly high, but it coincides with results reported in the article "wood as a fuel" (Camacho, 2011), where it is explained how a carbon content of 50% can yield a calorific potential of 20.9 MJ/kg. The Ciudad Madera sawdust has a carbon content of 53.3%.

4. Conclusions

The amount of sawdust generated by the ten surveyed sawmills alone is enough to make the pelletization business affordable in Ciudad Madera. It may be concluded that it is feasible to produce at least 2.5 ton/h of sawdust pellets.

When the sawdust generated by sawmills in Ciudad Madera, Chihuahua, was analyzed, it was found that it had a heating value of 22.13 MJ/kg. This is not a common result because, according to scientific bibliography, the maximum heating value expected for pine wood is 16 MJ/kg. However, the characterization of the sawdust resulted in a 53.323% carbon content, which explains the high heating value found in the red pine sawdust of Ciudad Madera. The heating value is the most important parameter for pellets because combinations with other high heating valued wood-waste would be needed in order to meet the optimum pellet standards; this would represent more time and money costs. The percentages of hydrogen, oxygen, nitrogen and sulfur also meet the specified standards. It can be concluded that the sawdust generated in Ciudad Madera has the optimum characteristics in accordance to the DIN Plus norm for high quality pellets.

The use of pellets as boiler fuel is a common practice in Europe, USA, Canada and some parts of Asia. In countries like Sweden, Austria, and Germany, the use of wood pellets is so widespread that their production is not sufficient to meet their demand. The pellet demand is satisfied by countries like Argentina and Chile, which already have a well-established pellet industry. In Mexico, specifically in the state of Chihuahua, there exists the optimum raw material to manufacture high quality pellets. However, there is currently no developed pellet market in Mexico or even a culture that promotes the use of alternative fuels, which are currently more expensive than fossil fuels. Nevertheless, it is a well-documented opinion that the pellet market will grow exponentially in the future. It is therefore good business to produce pellets and obtain a position in the international market.

5. Acknowledgements

The authors wish to thank Mr. Leonardo Martín-Alarcón, of New Mexico State University, for the proofreading and translation of this document.

6. References

Alvarez, E. (2009). *ECO PORTAL*. Retrieved March 01, 2011, from http://www.ecoportal.net/Temas_Especiales/Educacion_Ambiental/Aprovechando_los_Residuos_Madereros.

Buehlmann, U. B. (2009). Ban on landfilling of wooden pallets in North Carolina: an assessment of recycling and industry capacity. *ELSEVIER Journal of Cleaner Production*, 17:271-275.

Camacho, A. (2011). *La Madera como Combustible (infomadera.net)*. Retrieved May 20, 2011, from http://www.infomadera.net/uploads/articulos/arch.

Fiedler, F. P. (2008). Carbon monoxide emissions of combined pellet and solar heating systems . *Applied energy*.

Gonzalez, J. (2004). Combustion optimization of biomass residue pellets for domestic heating with a mural boiler. *Biomass & Bioenergy*.

Granada, E. L. (2006). Feasibility study of forest residue use as fuel through CO-firing with pellet. *Biomass & Bioenergy*, 30:238-246.

Krook, J. M. (2004). Metal contamination in recovered waste wood used as energy source in Sweden. *ELSEVIER Resources, Conservation and Recycling*, 41: 1-14.

Lesme, R. O. (2010). *Factibilidad del empleo de los residuos de la industria de la madera para la obtencion de energia electrica*. Retrieved April 27, 2010, from http://www.cubasolar.cu/biblioteca/ecosolar/ecosolar11/HTML/articulo05.htm

López, G. (2010). Tarimas como materia prima en la producción de pellets. *John Deere Review*, 12-14.

Mc Farlane, D. (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 & Bioenergy*, 33:628-634.

Moran, J. G. (2003). Experimental modelling of a pilot lignocellulosic pellets stove plant. *Biomass & Bioenergy*, 27:577-583.

Reali, P. (2011). *Situación actual del mercado de pellets energeticos en la unión Europea. Forestweb.* Retrieved Abril 30, 2011, from http://wwwforestalweb.com/Pablo-Reali/situacion-actual-del-mercado-de-pellets-energeticos-en-la-union-europea/.

Taylora, J. (2009). The influence of distance from landfill and population density on degree of wood residue recycling in Australia. *Biomass & Bioenergy*, 33:1474-1480.

Thiers S., B. A. (2010). Experimental characterization, modeling and simulation of a wood pellet micro-combined heat and power unit used as a heat source for a residential building. *Energy and Buildings*, 42:896-903.

Verma V.K., S. B. (2011). Performance of a domestic pellet boiler as a function of operational loads: Part-2. *Biomass & Bioenergy*, 35:272-279.

Vinterback, J. (2004). Pellets 2002: The first world conference on pellets . *Biomass & Bioenergy*, 27:513-520.

ISES solar world congress | 2011

ISES
International
Solar Energy
Society

www.swc2011.org

Proceedings

August 28 - September 2, 2011
Kassel, Germany

Conference Themes

Solar Heating and Cooling | Solar Buildings | Renewable Electricity | Rural Energy Supply
Resource Assessment | Renewable Energies and Society

Resource Forecasting and Technical Potential

Analysis of the Use of Support Vector Regression and Neural Networks to Forecast Insolation for 25 Locations in Japan
Gari da Silva Fonseca Junior, J.

Assessment of the Benefits of Employing Thermal Energy Storage in Spain, Germany and Europe
Cabeza, L.

Feasibility of using forest residues for pelletization in Chihuahua, Mexico
Martin-Dominguez, I.

GHI and DNI Forecasting Using GFS, Neural Networks and Solar Radiation Estimated from Satellite Data Base
Martín Pomares, L.

PV and Wind Power – Complementary Technologies
Gerlach, A.

Running the USA from Wind and Solar
Mills, D.

Solar Thermal Power Plants in West Africa: Site Selection and Potential Assessment
Ramde, E.

Study and Development of a Pumping System Using a Small Wind Turbine Coupled to a Centrifugal Pump by Means of a Frequency Inverter
Nascimento, M.

A Study of CPV Potential in India
Sethu, G.

A System of Direct Radiation Forecasting Based on Numerical Weather Predictions, Satellite Image and Machine Learning
Gastón, M.