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***FACTIBILIDAD TÉCNICA Y ECONÓMICA DE LA RECUPERACIÓN DE
RESIDUOS FORESTALES MEDIANTE PELLETIZACIÓN, EN LA SIERRA MADRE
OCCIDENTAL DE MÉXICO***

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TECHNICAL AND ECONOMIC FEASIBILITY OF FOREST RESIDUES RECOVERY BY PELLETIZATION, IN THE WESTERN “SIERRA MADRE” IN MÉXICO

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1. Introduction

Mexican forest resources are concentrated along two large ridges (eastern and western Sierra Madre) (fig 1) that supply most of the timber products consumed in the country. Mexican forest industries create significant quantities of waste in the form of sawdust, bark, cuts and foliage, which in most cases ends up as garbage in the vicinity of the sawmills (fig 2). This waste creates a serious environmental pollution and fire hazard problem. One possible solution to the described problem is to transform the forest waste into a biofuel, this work presents an estimation of the wood pellets generation potential, based on the forest wastes produced in the sawmills. Unlike other developed countries in the northern hemisphere, currently in Mexico there are not pellet industries established yet. The feasibility of implementing pellet manufacturing and consumption in Mexico will depend upon several factors ranging from the availability of raw materials to quality and logistics. To quantify the volume of generated waste, a field study was performed in Madera City, Chihuahua, where the major sawmills in the region where surveyed. To carry out the characterization of the wood-waste, a manual pelletizer prototype was built. The produced pellets were found to comply with the requirements of DIN Plus Standard for high quality pellets. Thus, an economic analysis is developed to evaluate the feasibility of commissioning a pelletizing plant in the Madera City region, which is representative of similar cities in the Sierra Madre. Five different commercially available pelletizing machines were analyzed. Included parameters were pellets selling price, existing waste availability, machine production capacities and costs, power requirements, operating expenses (salaries, maintenance and electricity costs), and machine recovery price.

2. Methodology

Quantification

The volume of sawdust-waste produced in Madera City was quantified by surveying the 10 major sawmills of the region.

Characterization

The average sawdust moisture content was determined. The percentage of C, H, O, N was determined using an elemental analyzer. The sulfur content was determined via an emission spectrometer (ICP-OES).

Pellet

Manufacturing

A manual pelletizer prototype was constructed. The heating value of the pellets was determined using a bomb calorimeter.

Financial Analysis

Annual capital cost (Cc) and capital recovery (CRF) were calculated:

$$Cc = CRF \cdot Ic \quad (1)$$

Ic is the acquisition cost of machinery. An interest rate of 5%, a lifetime (n) of 10 years, and maintenance cost of 2% were considered.

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (2)$$



Figure 1. Forest resources in México



Figure 2. Wood-waste

Table 1. Results of the characterization of the sample

| Feature | Unit | Measurement |
|-----------------|-------|-------------|
| Carbon | % | 53.3 |
| Hydrogen | % | 6.75 |
| Oxygen | % | 0.52 |
| Nitrogen | % | 0.04 |
| Sulfur | % | 0.002 |
| Power Calorific | MI/kg | 22.13 |

3. Results

The 10 sawmills surveyed produced 955 m³ of sawdust per week. Chemical characterization and calorific value are shown in table 1, the moisture content of the sample was 54.5%. Capacities and costs of the evaluated machines are given in table 2. Plant operating costs are shown in table 3, on which electricity consumption and 8 employees salaries (245 working days/year) were considered. Selling price of pellets is estimated on 110 \$/ton, F.O.B. Financial analysis results of the included options are shown in Table 4, as expected yearly profit.

Table 4. Financial viability (expected annual profit)

| Option | Cost of operation per year US\$ | Production per year (ton) | Selling price per year US\$ | Expected profit per year US\$ |
|--------|---------------------------------|---------------------------|-----------------------------|-------------------------------|
| 1 | 92668.80 | 1960 | 215600.00 | 122931.20 |
| 2 | 97137.60 | 1960 | 215600.00 | 118462.40 |
| 3 | 123009.60 | 3920 | 431200.00 | 308190.40 |
| 4 | 163699.20 | 4900 | 539000.00 | 375300.80 |
| 5 | 156525.60 | 4900 | 539000.00 | 382474.40 |

Table 6. Specific costs for each option

| Option | Production per year (ton) | Total production costs US\$/year | Specific costs US\$/ton pellets |
|--------|---------------------------|----------------------------------|---------------------------------|
| 1 | 1960 | 107464.80 | 54.83 |
| 2 | 1960 | 106760.60 | 54.47 |
| 3 | 3920 | 136009.60 | 34.70 |
| 4 | 4900 | 207289.20 | 42.30 |
| 5 | 4900 | 227957.60 | 46.52 |

Table 2. Pelletizing machines considered

| Options | Production capacity ton/h | Power required kW | Machinery cost \$ |
|---------|---------------------------|-------------------|-------------------|
| 1 | 1 | 97 | 112,020.00 |
| 2 | 1 | 106.5 | 72,850.00 |
| 3 | 2 | 161.5 | 98,420.00 |
| 4 | 2.5 | 248 | 330,000.00 |
| 5 | 2.5 | 232.75 | 540,782.00 |

Table 3. Cost of operation (wages and electric energy)

| Option | Total wages per year US\$ | Cost of electric energy per year US\$ | Cost of operation total per year US\$ |
|--------|---------------------------|---------------------------------------|---------------------------------------|
| 1 | 47040.00 | 45628.80 | 92668.80 |
| 2 | 47040.00 | 50097.60 | 97137.60 |
| 3 | 47040.00 | 75969.60 | 123009.60 |
| 4 | 47040.00 | 116659.20 | 163699.20 |
| 5 | 47040.00 | 109485.60 | 156525.60 |

Total annual costs are shown in Table 5. Pellets production specific costs (US\$/ton) are shown in Table 6. From the results it is show that the option number 3 results in the best economic alternative for the existing waste production capacity of the sawmills analyzed in this study.

Table 5. Total annual costs

| Costs US \$/year | Option 1 | Option 2 | Option 3 | Option 4 | Option 5 |
|------------------------|-----------|-----------|-----------|-----------|-----------|
| Annual capital costs | 14506.00 | 9434.00 | 12745.00 | 42735.00 | 70031.00 |
| Maintenance costs | 290.00 | 189.00 | 255.00 | 855.00 | 1401.00 |
| Cost of operation | 92668.80 | 97137.60 | 123009.60 | 163699.20 | 156525.60 |
| Total production costs | 107464.80 | 106760.60 | 136009.60 | 207289.20 | 227957.60 |

4. Conclusions

- Considering that 20% to 30% of each wood log ends up as waste, it is possible to estimate that México generates about 2.9 million m³/year of waste. This large amount of wood wastes could be transformed into a sellable biofuel, but until now is just an environmental problem. Pelletizing is a positive economic option.
- Forestry waste generated in México have the required characteristics to produce high quality pellets.
- Financial viability looks favorable, therefore great chances of economic success exists for installing pelletizing industries in México.
- It is recommended to develop a financial analysis of pellets export opportunities.