Moisture influence on the quality of pellets made of *Cistus ladanifer* shrubs

D. Almeida, T. Ferreira, E. Marques, J.M. Paiva*
Departamento de Engenharia Mecânica e Gestão Industrial
Instituto Politécnico de Viseu, Portugal
e–mail: diana.-almeida@hotmail.com; tania__vanessa@hotmail.com; edmundo@estv.ipv.pt; jmonney@demgi.estv.ipv.pt

C. Pinho
Departamento de Engenharia Mecânica
Faculdade de Engenharia da Universidade do Porto, Portugal
e–mail: ctp@fe.up.pt

ABSTRACT

Alternative biofuels have been the object of research, trying to find species that avoid competition with particular industry sectors, such as paper and furniture, not to mention the apparently (and most rightly) protected cereals sector. Samples of *Cistus ladanifer*, a local species, and known for its gluey content (which is probably why its common name is 'gum rockrose') were collected and dried in a solar kiln. Later on, pellets were produced, feeding batches of *Cistus ladanifer* sawdust with 10% humidity (wb), sequentially, up to seven times for each experiment. Samples were collected after each pelletization run to determine the evaporated water loss rate, and pellet quality tests were performed to evaluate the influence on pellets quality. An average 7% content was lost. A minimum final pellet moisture content of 3% (wb) was obtained. The durability tests revealed a 98.5% index, well above the international standards of 97.5%.

INTRODUCTION

Being a wild shrub, *Cistaceae* family represents an important element in Mediterranean flora. *Cistus ladanifer* L., commonly known as rockrose or labdanum, is one of the genera of the *Cistaceae* family; it germinates in poor soils in dry habitats. South of France, Iberian Peninsula, and North of Africa (Morocco and Algeria) Quercus woodland were colonized by *Cistus ladanifer*, mostly in highly degraded areas that had been burnt. This species has capsules witch open by 10 valves, and young stems and leaves. Rockrose has a resinous exudate that characterizes the plant with a distinct odor, particularly in summer [1-3]. Rockrose has applicability in areas such as perfumery industry [4], and in this work it was used as raw material to produce pellets.

Using biomass as a fuel is an attractive application because of its renewable nature and limited formation of pollutants and greenhouse-compounds [5]. However, using biomass to power production involves some issues due to poor handling properties and combustion related problems. In addition, biomass is variable in structure and composition and comparing to conventional fossil fuels presents low bulk and energy density. Different technologies can be used to improve the physical properties of solid biomass. Among them mechanical treatment can be applied, such as pelletization and briquetting [6].

* Corresponding author
Densification process, as known as pelletization, is a complex interaction between particles and has many factors involved to produce a good quality pellet, such as sawdust variables (moisture content and particle distribution), and manufacturing process variables (pressure applied and temperature reached during pelletization) [7,8].

Water represents an important factor in pellets production and quality. It works as a binding agent affecting mechanical durability and fines production. It acts too as a lubricant, during pelletization, that minor the friction between the die and the rolls causing low bulk density and energy consumption [9]. Another important factor is Lignin content, and depending of the raw material specie used there is a lignin content variation [8,9]. Therefore, pellettization has to be performed at temperatures between 80–200ºC to ensure lignin plastic deformation, because lignin in these conditions acts like glue and ensures particle bounding [10].

Reaching this range of temperatures, sawdust moisture content is going to be reduced, due to the water evaporation. In this work the main objective was to determine the amount of water that evaporates during pellettization, and how this fact interferes with pellets quality.

To begin with, samples of *Cistus ladanifer* were collected and dried in a solar kiln. Then, raw material was ground to be characterized later on in terms of particle dispersion and moisture content. Pelletization was then performed, temperatures, air relative humidity and forces involved being monitored. After a cooling time, pellets were then characterized. All over this paper, moistures are reported to the wet basis (wb).

**MATERIAL AND METHODS**

**Raw material capture and solar drying**

*Cistus ladanifer* shrub samples were collected and dried in a solar kiln. Solar dryer was instrumented to measure temperatures, air relative humidity and solar radiation. T type thermocouples were used to measure temperatures; Honeywell H1H 4000 sensors were used to acquire data from internal air relative humidity. These sensors were connected to Pico Technology TC-08 USB and ADC-20, respectively. Pico Technology Picolog Recorder was the software used for both dataloggers. Solar radiation data was collected using Apogee SP 110 pyranometers, connected to NI USB-6008 DAQ and using software Labview 8.6, both from National Instruments.

With the aim of verifying moisture content, each day a sample of *Cistus ladanifer* was collected from the solar kiln and dried in a lab Venticelli oven at 105ºC until losing all water content [11].

**Grinding and sawdust characterization**

Milling process took place in an Agico hammer mill, with (approximate) constant feed mass flow rate. The output product passed through an internal sieve of 6 mm diameter. Then, sawdust was characterized in terms of moisture content and average mean particle sizes were calculated according to ISO 3310-2 1999-01. Three sawdust samples were sieved in a Retsch AS 200 device. The particle mean diameter was calculated using Eq (1).

\[
\overline{dp} = \frac{1}{\sum \left( \frac{x}{dp} \right)}
\]  

(1)
where $\overline{dp}$ is the value of the average particle diameter (µm), $dp$ represents the sieve mean diameter at a specified interval (µm) and $x$ the retained mass fraction (g) in each sieve.

**Pelletization and pellets characterization**

J and K type thermocouples were used to measure temperatures outside and inside the pelletizer machine. A TC-08 USB board was used to connect thermocouples and Picolog record software to acquire data, both from Pico Technology. To verify the evaporated water during pelleting, a Rotronic air relative humidity sensor series F 3V was used connected to NI USB-6008 DAQ with software Labview 8.6, both from National Instruments. 6 mm diameter pellets were produced by stages, at (approximate) constant mass feed rate. From the first batch of pellets produced, a sample was collected and a cooling time was guaranteed [12], entering the remaining pellets again in the pelleting machine. This procedure was repeated seven times.

Pellets produced were then characterized by means of a set of procedures [12]. Water resistance and durability tests were performed to verify pellets quality. For the first property mentioned, sets of pellets were immersed in 25 mm of water at 27°C for 30 seconds - water resistance is the percentage of water absorbed by the pellet [9]. Durability index is obtained simulating mechanical handling of pellets with the objective of predicting the quantity of fines produced. For that, 500 g of pellets were placed into a metal can and tumbled at 50 rpm for 10 minutes; and then the pellets were sieved. Durability index was calculated as the ratio of weight after tumbling over the weight before tumbling [13].

**RESULTS AND DISCUSSION**

**Solar drying**

21 kg of *Cistus ladanifer* L. with an approximate 30% moisture content (in wet basis), $M_{wb}$, were placed inside the solar kiln. After approximately 2770 minutes the raw material was taken off the solar dryer and its $M_{wb}$ was 20%. Every day a sample was collected and its moisture content evaluated.

Figure 1 represents the air temperature and the relative humidity inside the solar kiln.

![Figure 1](image.png)

**Figure 1.** I. Temperature data (black – upper part; light gray – middle part; dark gray – lower part); II. Air relative humidity (dark gray – upper part; light gray – lower part).

Two pyranometers were placed in the solar kiln, one of them inside and the other outside, to verify the amount of radiation loss in the cover of the solar kiln.
In Fig. 1 I temperature reached high values in the upper part of the solar kiln due to the capture of a significant amount of direct radiation. As a result, high temperatures lead to lower air relative humidity, as shown in Fig 1. II, where sensor that was placed in the upper part collected lower values compared to the other sensor placed near to the ground. Figure 2 represents the irradiance evolution with time during the solar drying process.

![Figure 2. Irradiation data (light gray – external radiation; dark gray – internal radiation).](image)

Observing the data obtained, from both pyranometers, a reflected radiation ‘loss’ of 800 W/m² can be evaluated; this value is an indirect indication of the solar kiln efficiency.

**Sawdust characterization**

The sawdust obtained after the drying process was milled and presented a M_{wb} of approximately 10% with an average mean diameter calculated of 602 µm with a particle distribution presented in Fig. 3.

![Figure 3. Sieving results – mass versus mean diameter.](image)

**Pelletizing and pellets characterization**

Aiming at verifying the influence of water on pellets quality, as well as of the amount of water loosed on the pelletizing manufacture, successive pellets processing cycles were performed; at the end of each cycle a sample was collected. The pelletizing process was initiated with sawdust with an average 10% M_{wb} and the pelletizing machine was fed at an approximately constant rate of 32 kg/h, maintaining temperatures between 70 and 110 ºC, as seen in Fig. 4.
Figure 4. Pelletization data. I. Evolution of temperature during time (light gray - axis; black - cover upper part; dark gray - cover lower part); II. Air relative humidity data.

Each processing cycle in the pelletizing machine increases temperature and air relative humidity and, therefore, pellets produced suffered changes each cycle. It is possible to observe the pellets characteristics in Tab.1. With the succession of the production cycles, an expected loss of moisture was registered: sawdust entered at 10% M_{wb}, at the end of the first cycle the pellets presented 7.6% and after the seventh cycle 3.1. The average total loss was around 7%.

Table 1. *Cistus ladanifer* L. pellets characterization.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (mm)</td>
<td>6.3</td>
<td>6.2</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>19.8</td>
<td>22.9</td>
<td>21.5</td>
<td>24.9</td>
<td>26.2</td>
<td>26.0</td>
<td>26.2</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>0.6</td>
<td>0.7</td>
<td>0.7</td>
<td>0.8</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Fine content (%)</td>
<td>24.2</td>
<td>12.5</td>
<td>2.4</td>
<td>2.4</td>
<td>1.5</td>
<td>1.9</td>
<td>2.0</td>
</tr>
<tr>
<td>Moisture (% w.b.)</td>
<td>7.6</td>
<td>6.7</td>
<td>6.0</td>
<td>6.0</td>
<td>5.4</td>
<td>4.8</td>
<td>3.1</td>
</tr>
<tr>
<td>Particle density (m³/kg)</td>
<td>947</td>
<td>1026</td>
<td>1058</td>
<td>1120</td>
<td>1130</td>
<td>1169</td>
<td>1206</td>
</tr>
</tbody>
</table>

A decrease in pellets diameter and an increase in pellets length and weight was also verified over the succession of processing cycles, leading to an increase in pellets density. Fines content revealed a decrease, improving pellets quality (Fig. 5).

Figure 5. Quality tests results. I. Pellets durability variation (light gray - durability; dark gray – moisture content); II. Pellets water resistance variation (light gray – water resistance; dark gray – moisture content).
Quality tests revealed therefore an increase on durability indexes with the evolution of the production cycles, reaching 98.5% at the end of the fifth. Water resistance tests revealed low indexes, with practically no distinction between the different production cycles.

CONCLUSIONS
The drying process took around 2770 minutes; the raw Cistus ladanifer L. begun the drying process 30% Mwb and left the solar kiln with 20%.

Sawdust with approximately 10% Mwb and a calculated average mean diameter of 602 µm, was added to the pelleting machine in successive processing cycles. At the end of each cycle, pellets improved quality. In the end, an index of 98.5% was obtained, fulfilling international quality standards.

ACKNOWLEDGEMENTS
This work was partially supported by the PTDC/AGR-CFL/114826/2009 grant from the Portuguese Foundation for Science and Technology (FCT). The tests were carried out in the laboratory facilities of ESTV/IPV.

REFERENCES

