Research Activities related to Biomass Storage

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ABSTRACT

The power plants need to be continuously supplied throughout the year while SRF harvesting normally occurs from December to March. The natural drying seems to be the cheapest method to obtain a good quality chip characterized by low moisture value, necessary for the combustion. Although the moisture content reduction, there is a loss of a considerable quantity of dry matter, necessary for energy by combustion due to the microorganism actions during drying. During the winter 2008, CRA-ING conducted some experimental tests on the chip harvested, in order to learn about the natural dehydration in piles, to understand the physical-chemical dynamics inside the piles, to verify any losses. The first pile, (large size chip), was built close to Franco Alasia Vivai in Savigliano (in the province of Cuneo), whereas the second pile, (reduced size chip), was built close to the Biomass plant of Bando Argenta in the province of Ferrara. The results of this study show how high moisture and high temperatures represent the most favourable conditions for both dry matter losses and energy loss.

Keywords: SRF poplar; storage; natural drying; moisture content, Italy.

1. INTRODUCTION

The harvesting of poplar growth as Short Rotation Forestry (SRF) occurs during the rest vegetative period (from December to March). For energy conversion, the power plants need to be continuously supplied throughout the year. So the storage period is necessary to meet both the demand and to alleviate the difficulties of using a product recently harvested, which makes combustion difficult, due to a moisture content of 55-60%. The water evaporation, in fact, reduces the amount of heat that is useful in combustion (latent heat of vaporization).
Therefore, the dehydration of SRF poplar chips should be facilitate to reach moisture contents that adhere to combustion technology regulations: these values are on the order of 30-40%.
Wet wood, immediately after harvesting, is particularly suitable for xylophagous microorganism development (fungi and bacteria). Under normal conditions, fungi and bacteria are unable to penetrate the bark. These organisms reach the woody tissue only where it is interrupted, for example at cuts made during chipping. In other words, the specific surface subject to microorganism attack increases with consequent losses of dry matter. Bacterial activity, in

Luigi Pari, Vincenzo Civitarese, Angelo del Giudice. "Research Activities related to Biomass Storage". International Commission of Agricultural and Biological Engineers, Section V. Conference "Technology and Management to Increase the Efficiency in Sustainable Agricultural Systems", Rosario, Argentina, 1-4 September 2009. The authors are solely responsible for the content of this technical presentation. The technical presentation does not necessarily reflect the official position of the International Commission of Agricultural and Biosystems Engineering (CIGR), and its printing and distribution does not constitute an endorsement of views which may be expressed. Technical presentations are not subject to the formal peer review process by CIGR editorial committees; therefore, they are not to be presented as refereed publications.

anaerobic conditions, is mainly influenced by temperature: at temperatures less than 10° C, bacterial activity is reduced, whereas at temperatures above 65°C, bacteria die. Above this temperature, degradation is mainly controlled by chemical and physical oxidative processes.
For both energetic and economic aspects, the best solution for poplar chip dehydration is natural drying. The poplar chips, harvested with machines now available on the market, are piled and stored for a length of time which depends on the end use (power plant for electricity production or planting for heat production). During storage, the inside temperature together with the degree of moisture cause moisture loss. However, such a system, using the heat generated by microorganism respiration processes, always causes dry matter loss, due to the size as well as the compaction of the product, as well as other factors including weather conditions. During the winter of 2008, we performed an experimental comparison testing SRF on poplar chips of different sizes. The first pile, comprising the largest chips obtained by the Spapperi harvester, was carried out at Franco Alasia Vivai in Savigliano (CN). The second pile, with smaller chips obtained by a Class Jaguar 890 harvester, was carried out at the Biomass Power Plant of Bando d'Argenta (FE) of San Marco Bioenergie Spa. It should be noted that the final size of the product depends on both the harvester and on the age of the plant: the R2F2 chip (two-year-old roots and stalks) will have lower average size than a four-year plantation.

2. MATERIALS AND METHODS

Using the 2007 testing results (Informant Agrario n. 39/2008 page 52-55), CRA-ING, during 2008, and through collaboration with the Franco Alasia Vivai in Savigliano (CN) and with the Biomass Power Plant of Bando d'Argenta (FE) of San Marco Bioenergie Spa, carried out SRF poplar chip storage tests in order to: 1. Verify whether the thickness of the wet layer surface is consistent with increasing pile dimensions; 2. Compare how product size can affect the rate of drying in the uncovered pile; 3. Evaluate dry matter and energy content losses due to storage.
To this end, in Savigliano, we prepared a pile of poplar chips whose size was: 6% weight between 25 and 50 mm, 65% between 10 and 25 mm, 29% lower than 10 mm. The pile was 16 m in length, 12 m in width and 6 m in height, exposing its great sides to east and west. During pile building, the product was not removed and the chip was subjected to chemical-physical analysis. Each pile was divided in two sections, each of them divided in three levels:

- Low: 1 m in height, 5 sampling points, 5 temperature sensors;
- Medium: 2.5 m in height, 3 sampling points, 3 temperature sensors;
- High: 5 m in height, 1 sampling point, 1 temperature sensor.

Each temperature sensor is surrounded by transpiring bags containing chips for which the wet weight was known (Fig. 1), for the evaluation of dry matter loss as well as for the drawing of samples to be analyzed.

Figure 1. Bags in use for sampling

A weather unit contributes to survey data.
The pile in Bando d'Argenta was built with thin/smaller chips' size whose dimensions were: 3% between 25 and 50 mm; 49% between 10 and 25 mm; 48% lower than 10 mm. The pile dimensions were: 29 m in length; 19 m in width and 8 m in height, exposing the pile's great sides to North and South. During the storage building, the chip was, in part, kept off with a shovel. The chips were subjected to chemical and physical analysis.
Even this pile is divided in two sections, with two levels for each of them: low (2.5 m in height) and high (5.5 m in height). We did not place temperature sensors in this pile, but we identified the points of sampling. There were three points in the lower level and three points in the higher one. At each point, two transpiring bags containing chips, previously weighed, were positioned. In July, we cut piles at the first section, including the samples in sealed bags. A first bag was used to measure moisture and then to calculate the dry substance loss. A second bag was analyzed in the laboratory to determine the heating power (calorific value), ash content and chemical characterization. The data were then processed and reported in this work. After recovery of the samples, the removed material was put back into place. The second section was made in mid-December and the same operations previously described were carried out.

3. RESULTS

3.1 Large-size Piles

Table 1 shows the initial analytical values of the pile built in Savigliano in March 2008. The moisture values are 55-60% and the ash content does not exceed 1%. The ash value reflects the low bark/heartwood index of plants of a certain age.

Table 1. Initial values of Savigliano and Bando Argenta pile

Proof area		Savigliano pile		Bando Argenta pile	
		Lower level	Medium and high level	Lower level	Medium and high level
Ashes 660°C	% ar	0,7	1	2,4	2,4
Ashes 660°C	% dm	1,7	2,3	4,9	4,9
Moisture	%	59,2	56,6	50,9	50,9
Net heating Val.	Mj/kg ar	5,05	6,18	7,09	7,09
Gross Heating Val.	Mj/kg dm	15,90	17,42	16,97	16,97

In July of that year, the first section was made and bags of known weight were surveyed (Table 2).

Table 2. Parameter values of the pile in Savigliano

	% Weight loss dm		Moisture (%) t.q.		NCV MJ/kg dm		kJ lost/ g H_2O evaporated	
	07	12	07	12	07	12	07	12
Lower level								
Point 1	-13,7	-20,1	21,7	36,5	17,00	16,34	2,8	9,3
Point 2	-14,4	-14,2	23,0	30,7	16,01	16,79	5,3	4,5
Point 3	-15,2	-14,7	21,4	27,8	16,97	17,10	3,6	4,1
Point 4	-14,2	-18,3	22,8	25,6	16,53	16,94	4,1	5,5
Point 5	-15,9	-16,1	21,7	29,6	16,60	17,09	4,6	4,3
Average	***-14,7***	***-16,7***	***22,1***	***30,0***	***16,62***	***16,85***	***4,1***	***5,5***
Middle level								
Point 6	-14,4	-24,1	19,6	38,6	16,40	17,18	8,7	16,8
Point 7	-17,8	-20,6	20,0	32,9	16,73	17,24	9,2	12,6
Point 8	-13,5	-18,7	17,7	31,9	16,90	16,14	6,7	14,2
Average	***-15,2***	***-21,1***	***19,1***	***34,4***	***16,68***	***16,85***	***8,2***	***14,5***
High level								
Point 9	n.d.	-7,5	n.d.	37,1	16,99	17,14	n.d.	7,3
Average	n.d.	***-7,5***	n.d.	***37,1***	***17,0***	***17,14***	***n.d.***	***7,3***

As has happened in the past (see L'Informatore Agrario No. 39/2008, pp. 52-55), the presence of a moist/wet superficial layer with thickness of about 30 cm, was noted. This confirms the assumptions made in those times: the thickness of the superficial layer remains constant during changes in the pile size.
Dry matter losses in the lower level of the pile ranged between 16% and 14%, with an average of 14.7%. After 4 months, the moisture of the product averaged ~22%. As expected, the specific NCV increases.
At the average level of the pile, dry matter losses averaged 15.2%, whereas the moisture value reached 19.1%.

At the higher level, a slight increase in dry matter was noticed. This is to be interpreted not as a real increase but rather as uncertainty in the data survey due to methodology, thus no significant losses were reported.

The graph in Figure 2 shows the evolution of temperatures inside the pile. After the usual initial peak, there is a gradual decrease in the thermal level inside the pile, which appears not to suffer a significant effect of external disturbances (events such as rainfall).

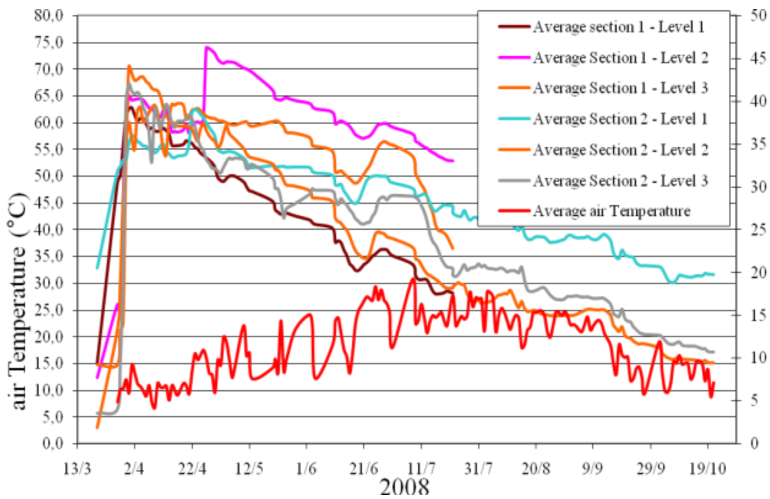

Figure 2. Internal temperatures into the Savigliano pile

The extent of the dry matter loss (with its energy content) per unit weight of evaporated water is the "cost" that is supported for drying. For the lower level, 4.1 kJ per gram of lost water were observed on average. At the middle level, the average value was equal to 8.2 kJ per gram of lost water.

In December, the second section (Fig. 3) with recovery of the sample bags (Table II), was created. The pile was covered with 25 cm of snow, which involved rehydration of the product, bringing the moisture of the low level to 30%, the moisture of the average level to over 34%, and the moisture of the high level to 37%. The dry matter losses, from the low level to the high one, were 16.7%, 21.1% and 7.5%.

Figure 3. December - Second section– recovery sample bags

Rehydration of the chips, together with the increase in dry matter losses, corresponds to energy expense per unit weight of evaporated water: 5.5 kJ per gram of water at the low level, 14.5 kJ per g at the average level, and 7.3 kJ per g at the high level. It is clear that what had been gained in the previous months, has been lost due to the snow. It is reasonable to think that in our latitudes, without near-permanent freezing weather conditions, the blanket of snow gradually dissolves and returns to hydrate the product. Microbiological activity in the pile continues (or is stimulated by water), with consequent increases in dry matter losses.

3.2 Small-size Piles

The material used has the initial characteristics reported in Table I (pile built in March 2008). The moisture value is 50%, and the ash content is almost 5%.
The first section was obtained from this pile in July (Table 3, Fig. 4). We observed a 12% loss in dry matter weight, at the lowest level, with a moisture value of 46%.
We observed that dry matter loss and moisture values for the high level were 11%, 7% and 34.3%, respectively.
The energy (cost) of evaporation is 36 kJ per gram of water lost at the lower level and 11 kJ per gram of water lost at the higher level.

Table 3. Parameters values of Bando Argenta pile

	% Weight loss dm		Moisture (%) t.q.		NCV MJ/kg dm		kJ lost/ g H_2O evaporated	
	07	12	07	12	07	12	07	12
Lower level								
Point 1	-9,1	-15,9	49,5	47,7	16,10	16,90	41,3	30,2
Point 2	-13,1	-19,6	53,4	25,7	17,26	16,63	41,3	30,2
Point 3	-14,2	-23,3	36,8	33,0	16,83	17,05	15,9	17,2
Average	***-12,1***	***-19,6***	***46,6***	***35,5***	***16,7***	***16,9***	***36,4***	***20,3***
High level								
Point 4	-13,1	n.d.	36,8	31,6	17,26	14,12	10,5	12,4
Point 5	-10,5	-14,8	39,0	19,9	17,29	14,56	11,6	13,5
Point 6	n.d.	-21,9	27,0	31,7	17,50	16,39	n.d.	16,8
Average	***-11,7***	***-18,3***	***34,3***	***27,7***	***17,3***	***15,0***	***11,1***	***14,2***

We also observed a lack of drying and dry matter loss which were not to be ignored.
In December 2008, the second section of the pile was made (Table III). The average losses of dry matter were over 19% at the low level, compared with a moisture level of 35.5%. At the higher level, an 18% loss in dry matter was associated with humidity of almost 28%.
The energy used to achieve such a degree of moisture is 20 kJ per gram of evaporated water for the low level, and 14 kJ per gram of evaporated water for the higher one.


Figure 4. First section of the small-sizes pile

3.3 Comparison of the two piles

Table 4 compares results for the two piles. In July, four months after building the pile of material in Savigliano, we observed 58% humidity, water content of 20%, and energy losses of 4-8 kJ per g water lost.

Table 4. Savigliano pile compared to Bando Argenta pile

	July		December	
Proof area	Savigliano	Bando Argenta	Savigliano	Bando Argenta
Moisture (%)				
-average of lower level	22,1	46,6	30,0	35,5
-average of middle level	19,1		34,4	
-average of high level	n.d.	34,3	37,1	27,7
Lost kJ/ lost g of H_2O				
-average of lower level	4,1	36,4	5,5	20,3
-average of middle level	8,2		14,5	
-average of high level	n.d.	11,1	7,3	14,2

In the same month, the attained moisture in Bando d'Argenta, did not fall below 34% (average value of the highest level), compared with an energy loss of 36 kJ per gram of water lost (lower level). However, due to rehydration of the material following a December snowfall (Fig. 3) in Savigliano, the difference between moisture levels of the two piles dropped from 52% (July) to 14% (December) (Table IV).
In contrast, the energy loss is always higher than in Bando d'Argenta.
The reasons, particularly considering the first four months of storage, could be in part due to the partial compaction of the material in Bando d'Argenta. In combination with the smaller size, this prevented moist air from rapidly flowing into the pile. We therefore deduce that the drying of large-size material which is not at all compacted is faster (apart from rehydration due to the snow in Savigliano), allowing us to place the product on the market in a short time. On the other hand, a product such as that in Bando d'Argenta can be part of a mix of fuels in a power plant of large size, so as to meet the specifications dictated by the designer regarding power planting for power boilers.
Another difference is the climate trend (Fig. 5-6). The average air temperatures surveyed in Bando d'Argenta were higher than those in Savigliano, and rainfall was more intense. It is

important to try to assess the balance between the outside temperature and inside temperature, as well as to evaluate the moisture or meteoric water that can penetrate into the pile, thus altering the flow of moist air.

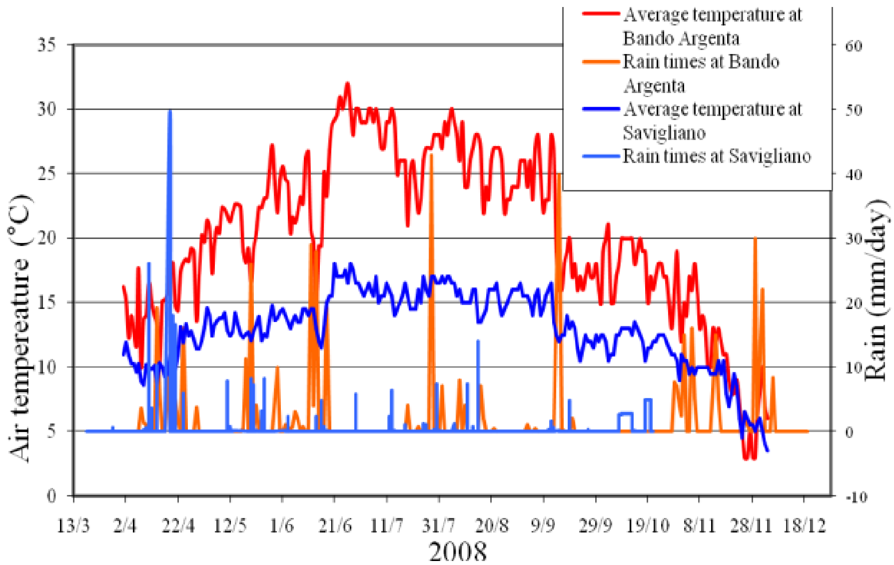

Figure 5. Comparison of climatic data between two sites

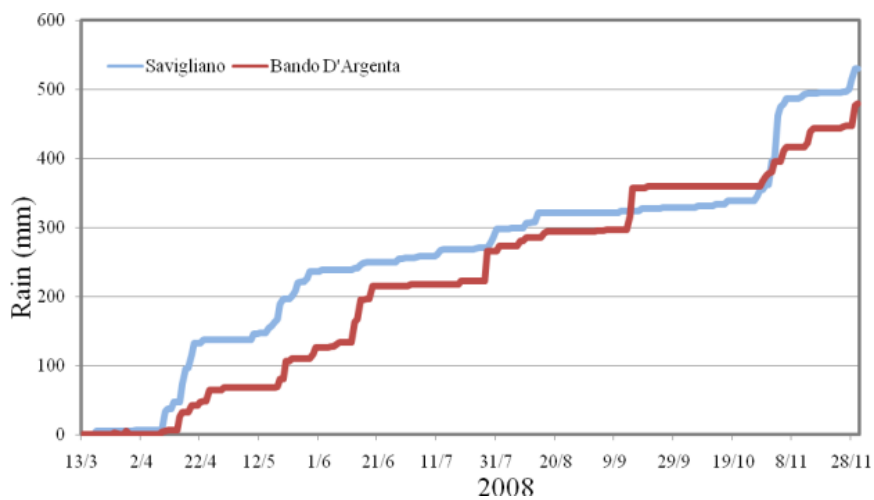

Figure 6. Curves of rainfall compared

The experiments showed how the dry matter losses, translating to a loss of potential chemical energy in fuel (observed for the whole period of storage), played a key role in this process. In other words, high moisture and high temperatures represent the most favourable conditions for both dry matter losses and energy loss.

In order to determine how the chip size and its preservation (storage) (covered or uncovered pile) affect dry matter losses, and therefore energy loss, further testing, in collaboration with the "Enervision" Company of Dosolo (MN), is currently underway. These efforts involve the

evaluation of a “large”-size uncovered pile, using a CLAAS Jaguar equipped with the CRA- ING modified rotor. There are also two smaller-size piles: one of them uncovered and the other covered with geotextile fabric (TopTex ®), for which we use a CLAAS Jaguar equipped with a current rotor.
The storage site was previously asphalted to prevent the contamination of inert material during chip loading, as well as to limit the intake of moisture from the soil due to meteoric water.
Tests are still ongoing and the results will be reported in a forthcoming publication.