

EVALUATION OF DIFFERENT WOOD CHIPS STORAGE TECHNIQUES

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Abstract:

One of the main problem of the power station for thermal and electric energy produced by biomass wood is the bio-fuel storage. Power station, in fact, needs a suitable chips-wood storage for the energy production because the biomass harvesting is discontinuous. In this study, with the aim to identify a reliable technique for chipped wood storage in the field, different solutions have been tested. In detail, several chopped wood heaps have been realized and covered with different material: transpiring sheet, water proof sheet for silage coverage (both black and white inner part was utilized) and a simplified roof. An uncovered heap was used as blank. With the coverage systems, except for water proof sheets because they not allowed the transpiration of the chip wood, has been obtained a final value of the LHV of about 3600 kcal/kg. The locust species is characterized by a smaller initial water content value (about 20%) and the poplar chips wood is characterized by more gradual drying up on the all the storage period considered.

The roof coverage system, being characterized by good performances and lower assembling heap cost (about 50%), seems to be the best storage technique.

1. Introduction

In the last years, due to the requirement of thermal and electric energy produced by alternative sources several biomass power stations have been realized in Italy. At present, about 130 stations for a power energy of 120 MW (thermal + electric) are working only in Piedmont Region (Bosser_Peverelli, 2003). One of the main problem of the power studies is the bio-fuel storage.

Power station, in fact, needs a suitable chips-wood storage for the energy production because the biomass harvesting is discontinuous (Ciolo, 1997; Francescato *et al*, 2004). An 1MW power house needs about 0,8 t/h chips-wood, about 5000 m² of Short Rotation Coppice (SRC) cultivated area (Nord-Larsen and Talbot, 2004).

It's also necessary to point out that after one year of storage, the wet biomass lost about 20% of its energetic value (Riva and Balsari, 1988; Thoernquisit and Lundstroem, 1982). Considering that the market demand is intermittent and the chips wood with low moisture increase the market price (a higher of 40% moisture value has a lower price), the bio-fuel storage at present in Italy is mostly made on the farm (Riva *et al*, 1997). Therefore, also the chips-wood storage on farm requires a large surface (Mattsson, 1996). The direct solution for these problems could be the direct storage on field close to the biomass production area.

With the aim to identify a reliable technique for chipped wood storage, different solutions have been tested. Furthermore, an energetic and economic evaluations of the different storage option has been made.

2. Trials realized

The research has been realized in piedmont region (North West Italy) during 2008 season. For chipping operation, drum clipper with 2 tangential new cut was used. Several chopped wood heaps of about 20 m³ volume have been realized and covered with different material: transpiring sheet, water proof sheet for silage coverage (both black and white inner part was utilized) and a simplified roof. An uncovered heap was used as blank. All coverage system has been assessed with poplar chopped-wood; transpiring sheet only has been tested with poplar, willow and locust chips-wood (Table 1)

Table 1. Different type of chopped wood heaps considered

| Coverage systems | Chopped wood | Heaps number | Heaps volume (m ³) |
|---------------------------|--------------|--------------|--------------------------------|
| Without coverage | Poplar | 2 | 20 |
| Transpiring sheet | Poplar | 3 | 22 |
| | Willow | 3 | 19 |
| | Locust | 3 | 18 |
| Water proof sheet (white) | Poplar | 1 | 19 |
| Water proof sheet (black) | Poplar | 1 | 19 |
| Roof | Poplar | 1 | 20 |

2.1. Monitored parameter

Several parameters have been monitored during the test period, considering both environmental conditions and physical-chemical chopped wood characteristics.

Weather condition, heaps moisture content and temperature have been monitored for whole experimentation (march-september). The chips-wood quality has been determined at the beginning and the end (after six month) of the storage period. The material classification was carried out according to UNI CEN/TS 14961 (UNI CEN/TS 14961, 2005). The screening on the six dimensional class (<3 mm; 3-15 mm; 16-45 mm; 46-63 mm; 64-100 mm; >100 mm) has been determined on 1 kg sample weight at the beginning and the end of the storage period. The temperature of the heaps has been registered by thermocouples, while the moisture content was recorded with TDR (*Time Domain Reflectometry*) technique using two probe TDR prototype realized by DEIAFA - University of Turin. In detail, one probe typology (P) has been used for the point measurement and one probe typology (R) has been used for the average measurement. Value was recorded every day during one month, after with a frequency of tree days.

The thermocouples and the probes (P) have been positioned at 3 different height above ground (0,5 – 1 – 1,5 meters). The probes R have been positioned in the centre of the heap (Figure 1). At the same time, the wood humidity has been observed also with gravimetric methodology.

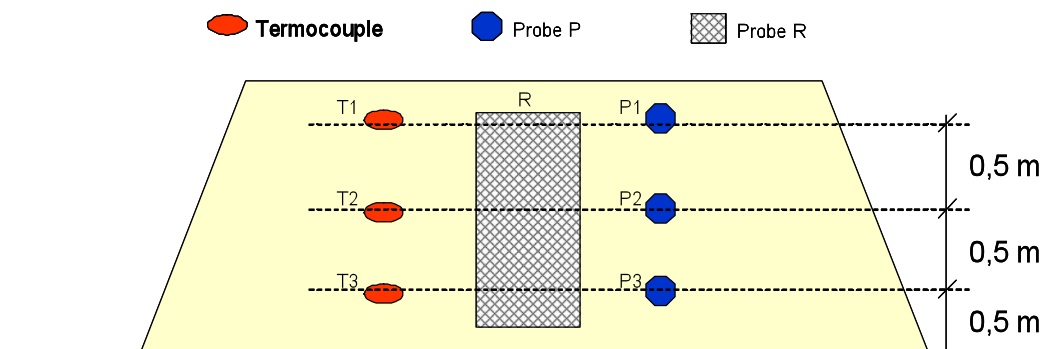


Figure 1. Inner position of the termocouples and probes

2.2. Energy analysis

A global energy analysis has been made. The weight and the volume of each heaps and the LHV (Lower Heating Value) of the chips wood have been determined at trial start and end.

The energetic costs of the machines were determined considering both direct costs – fuel and oil lubricant consumption - and indirect costs – machine, equipment and mineral fertilizer energetic contents Bridges and Smith, 1979; Cavazza, 1983; Jarach, 1985; Piergiovanni, 2002) (Table 2). The amount of fuel consumption for whole operations necessary to produce chopped wood has been estimated filling the tank at the end of each operation. This measure has been made by a gradual 2 litres cylinder (range of 20 ml). The machine oil lubricant consumption has been estimated by means of a algorithm realized by University of Turin (Piccarolo, 1989).

Table 2. Primary energy of the different material considering

| Material | Energy value (MJ/kg) |
|------------|----------------------|
| Fuel | 51,5 |
| Lubricant | 83,7 |
| Tractor | 92,0 |
| Implements | 69,0 |
| Coverage | 68,0 |
| Chip wood | 18,7* |

* Refer to Dry Matter

2.3. Economic evaluation

The economic evaluation of the different storage technique has been performed. The total cost for heap assembling (machine and manpower cost) was determined according to methodology suggested by the Mechanic Section of – DEIAFA - Turin University (Ribaudo, 1977), with prices updated to 2008. A cost for manpower of 12,5 € h⁻¹ was considered (AA. VV., 2008). As working time have been considered: 2 minutes for to tip over chips-wood wagon, 15 sec/m³ for the chips-wood handling and 10 minutes as additional times. In this last times, wait time between the travels, manoeuvre of the trailers and necessary time for the heap coverage are included (Berti *et al*, 1989). For the covering material, the market price and 2 years lifetime were considered. The roof has been realized with a modular steel frame and covered with a water proof sheet; for this structure a 15 years lifetime has been considered (Table 3).

Table 3. Unit price of different coverage materials considering

| Coverage | Unit price (€/m ²) |
|----------------------------|--------------------------------|
| Transpiring sheet | 1,95 |
| Water proof sheet | 0,50 |
| Roof (modular steel frame) | 0,70 |

3. Result

3.1 Meteorology data

Environmental temperature ranged between 8 and 27 °C (average 17 °C). Relative humidity between 72 and 78%. The higher value has been registered in correspondence to rain events: about 260 mm rain were recorded during the test (Figure 2).

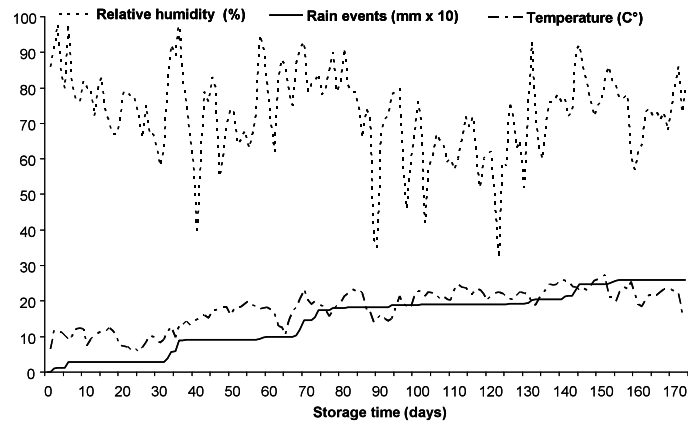


Figure 2. Meteorology data registered during of storage period

3.2. Heaps inner temperature

The higher temperature (max 65 °C) was recorded after 5 days of storage. After 100 days all heaps' temperature were close to 32°C. A lower average temperature (25 °C) was detected for the roof coverage (Figure 3). Any difference at the 3 sampling levels were recorded.

The use of transpiring sheets has ensured a constant drop of the temperature, while the “blank” and roof system of chips wood storage has determined a considerable drop in temperature in the first 30 days.

Similar temperature trend with transpiring sheet and black water proof sheets has been registered, but this last covering system has been characterized by a value of the temperature lower of 30%.

The water proof white sheet inhibits the fermentation process up to the forty five day. At the end of the sixth months, independent by environmental condition, all heaps have reached a thermal equilibrium of 20 °C except for white water proof covering system (Figure 3).

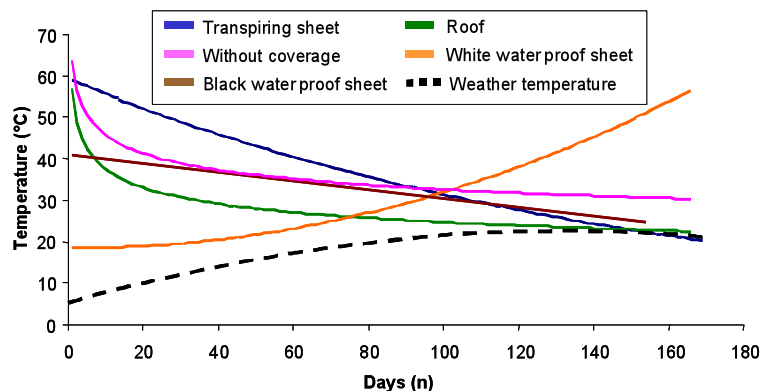


Figure 3. Average temperature recorded in the different heap

With the transpiring sheet covering system, no variation was pointed out between willow and locust: both heaps have been characterized by considerable drop of temperature during the firsts 30 days, while the poplar chips wood highlights a constant decrease of the temperature long all the testing period (Figure 4).

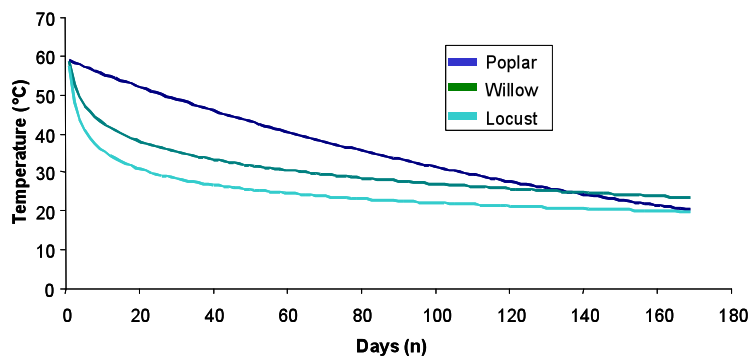


Figure 4. Average temperature in the transpiring sheet storage system with different forest species

3.3. Chips wood particle size

A high quality and homogeneity of the material stored was pointed out by chips wood particle size analysis. About 50% of the material resulted to be part of the second dimensional class for all the forestall species tested. This chips wood characteristic were constant during all period considered (Figure 5).

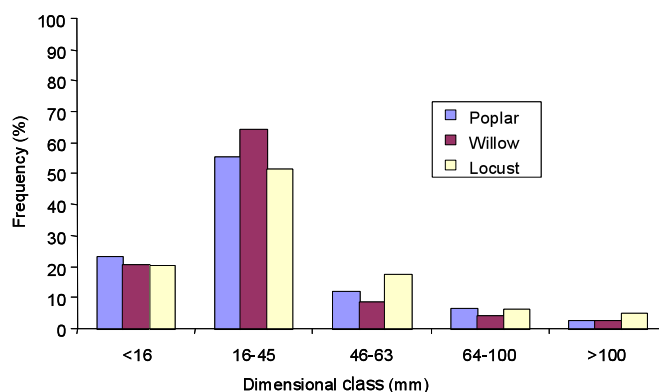


Figure 5. Chips wood dimension of the different forest species tested

3.4. Moisture content of chips wood

All coverage systems considered, except for water proof sheets, has ensured a decreasing in water content during the storage. At the end of the considered storage period, in all heaps has been recorded a water content decreasing of about 22%. In detail, the highest value (about 50% of the initial moisture content) has been registered with transpiring sheet with about 80% of D.M. Similar performances have been observed with the roof coverage system (Figure 6).

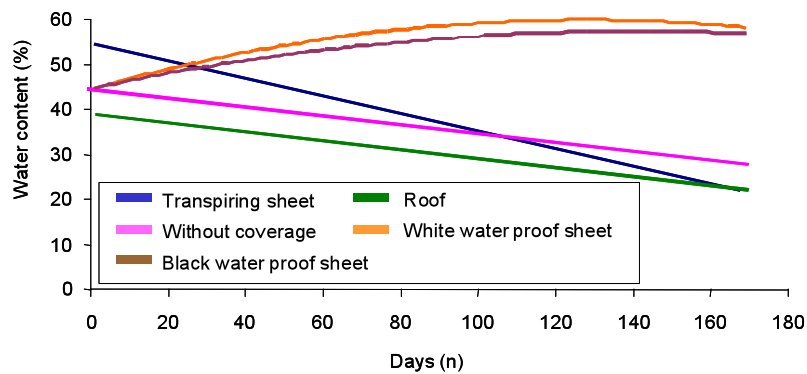


Figure 6. Average water contents of different poplar heap

Moreover, it must be pointed out that in the water proof sheets heaps, the value recorded by the superficial probe was 15% higher than that recorded by the inner probe. This was probably due to the no transpiring material used that may have caused moisture accumulation on the heaps surface.

The transpiring sheet coverage system has pointed out similar performances both with poplar and willow species, while the locust chopped wood has shown lower water losses (Figure 7).

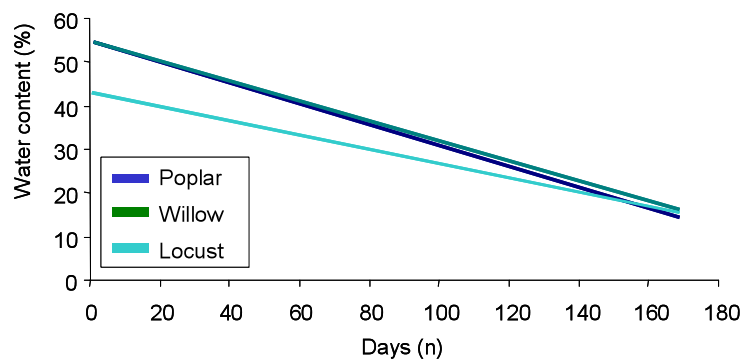


Figure 7. Average water contents of the heap assembled with different forest species.

3.5. Energy evaluation

The reduction of weight obtained during all storage period is due both to the moisture decreasing of the chips wood and the Dry Matter losses generated by fermentation process of the same material. The amount of this reduction was of about 50% for the transpiring sheet coverage system, of 30% for the roof coverage system and only of 17% for the water proof sheet. The heap “blank” has pointed out a weight reduction of about of 36%.

The Dry Matter losses results different for the coverage system tested.

The use of transpiring sheet and the without coverage storage system have pointed out, following up of higher fermentation, about 10% D.M. losses, while the used of the roof has registered about 7% D.M. losses only. Lower Dry Matter losses (about 5%) resulted with the use of the water proof sheets.

This energetic losses, in function of the coverage system used has been able to reduce of about 12 - 6% the heap’s volume. Lower volume reduction has been registered with the water proof sheet, higher with the transpiring sheet. (Figure 8).

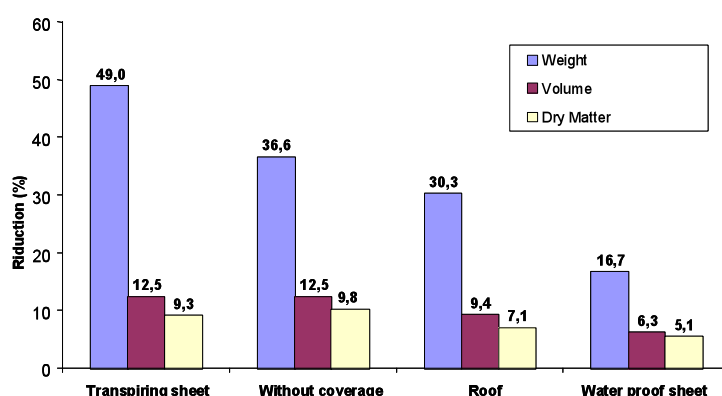


Figure 8. Weight, DM and Volume reduction registered in function of the heaps coverage system tested

The transpiring sheet has been able to ensure about 100% LHV of the biomass increase during the storage period and similar value with the roof coverage system has been registered, while the “heap no cover” has lost about 40% of its initial LHV. Similar performances between the forest species tested has been obtained for what concern this parameter (Table 4).

Table 4. Biomass lower heating value registered at the beginning and the end of the storage period in the different trials

| Coverage system | Forestall species | LHV (kcal/kg t.q.) | | Increase LHV (%) |
|---------------------------|-------------------|--------------------|-------|------------------|
| | | Initial | final | |
| Without coverage | Poplar | 2100 | 2900 | 38 |
| Transpiring sheet | Poplar | 1720 | 3400 | 98 |
| | Willow | 1780 | 3300 | 85 |
| | Locust | 1900 | 3350 | 76 |
| Water proof sheet (black) | Poplar | 2100 | 2150 | 2 |
| Water proof sheet (white) | Poplar | 2100 | 2350 | 12 |
| Roof | Poplar | 2300 | 3600 | 57 |

3.6. Economic evaluation

The assembling heap cost has been resulted of 0,35 €/m³ of which about 40% only for manpower. The total storage cost is closely related to the type of coverage system used. The cost of the covering material result between 0,54 €/m³ (water proof sheet) and 2,11 €/m³ (transpiring sheet) and it influence the total storage cost for 61% and 86% respectively (Table 5). Total storage cost of 1,10 €/m³ has been resulted for the roof built with a modular steel frame.

Table 5. Heap’s assembling cost for the different coverage system tested

| Costs | Trans. sheet | Without coverage | Roof | Water proof sheet |
|---------------------------------------|--------------|------------------|------|-------------------|
| Assembling heap (€/m ³) | 0,35 | 0,35 | 0,35 | 0,35 |
| Coverage material (€/m ³) | 2,11 | 0 | 0,76 | 0,54 |
| Total cost (€/m ³) | 2,46 | 0,35 | 1,11 | 0,89 |

If the total storage cost is referred to the biomass produced for hectare (3,5 t of DM/ha for years), it result between 35 €/ha (without coverage) and 240 €/ha (transpiring sheet) (Figure 9).

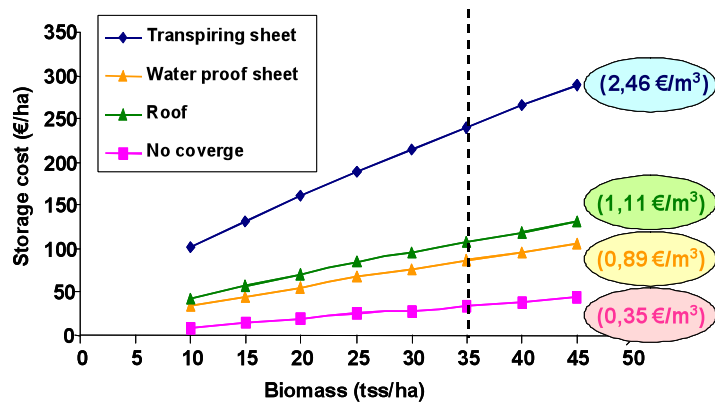


Figure 9. Heap assembling cost for the different coverage system tested in faction of the biomass production

The economic evaluation pointed out a market value at the end of the storage period, higher with the roof coverage system (14,34 €/m³) and lower (12,78 €/m³) for the water proof sheets, considering an initial volume of the heap of 20 m³ and 0,025 €/Mcal market price.

The market value of the biomass stored in heap without coverage resulted similar to stored one with roof because the higher total solid losses and humidity of the first are offset by its a lower storage cost.

Good economic value has been obtained also with the transpiring sheet storage system. (Figure 10).

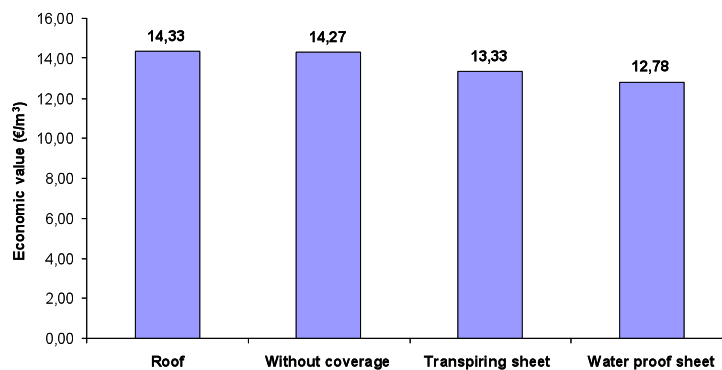


Figure 10. Economic value of the biomass after then storage with the different techniques tested

3.7. Energetic cost of the chips wood storage

The energetic cost of the chips wood storage operation corresponded to about 6,4 MJ/m³ FM of which 42% is represented by the coverage system used. The energetic cost of wood storage for ha of SRF cultivated are related to the biomass production (DM/ha) with value between 360 MJ/ha (with coverage) and 620 MJ/ha (without coverage) if considering 35 DM/ha biomass production (Figure 11).

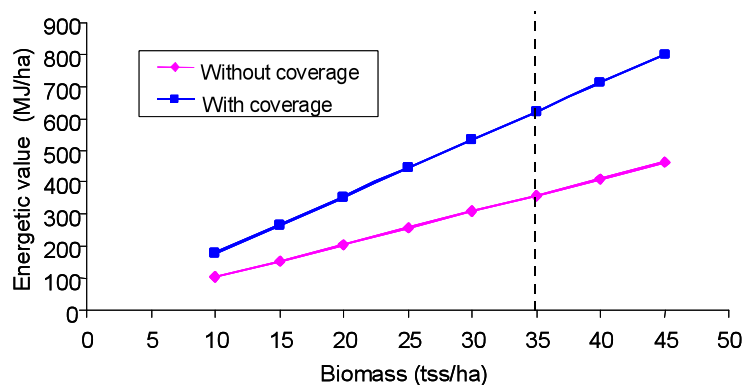


Figure 11. Energetic cost of the chip wood storage in function of the biomass production for surface unity

4. Conclusion

With the coverage systems, except for water proof sheets because they not allowed the transpiration of the chip wood, has been obtained a final value of the LHV of about 3600 kcal/kg. The locust species is characterized by a smaller initial water content value (about 20%) and the poplar chips wood is characterized by more gradual drying up on the all the storage period considered.

The trails have pointed out that, the more simple storage system (heap without coverage) has lower storage cost but higher Dry Matter losses, while the water proof sheets, although is able to guarantee smaller Dry Matter losses, not allowed the necessary drying up of the biomass. The market price of the biomass at the end of the storage period is similar (about 14,30 €/m³) for the simple storage system (no cover) and for the roof coverage system.

The roof coverage system, being characterized by good performances and lower assembling heap cost (about 50%), seems to be the best storage technique.

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