RECOVERY OF VINEYARDS PRUNING RESIDUES IN AN AGRO-ENERGETIC CHAIN

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ABSTRACT: The agri-energetic chain project, financed by the Ministry of Agriculture and Forestry, concerns the realization of a pilot plant for energy recovering of vineyards pruning residues near an important wine viticulture company in Umbria (Cantine G. Lungarotti). The chain is divided in the following phases: grapes pruning harvesting and storage by a round-baler; chipping cylindrical bales to obtain a biochips whose size is consistent with the biomass boiler; chemical-physical characterization of the biochips; biomass energy conversion in the diathermic oil boiler. Grapes pruning round-baling reached an average productivity of 0,70 tons/ha dry basis. Chipping of cylindrical bales, because of the huge dimensions of bales not compatible with mouth opening width of a common chipper, has been realised by means of a special mixer wagon. Energetic conversion phase will be executed by a diathermic oil boiler with useful thermal power 400 kW. The innovative aspect is burning residual vineyard pruning in a boiler to heat diathermic oil up to +300°C; diathermic oil allows the energy production in four different shapes: hot water for rooms heating; cool water up to -10°C for vinification processes; cool water up to +7°C for summer conditioning of company rooms; steam production for bottles sterilization processes.
Keywords: agricultural residues, harvesting, recovery of residues

1 INTRODUCTION

Energy collecting of biomass residues is a very current theme, both in consideration of Kyoto protocol objectives of gas emissions reduction, and of reducing fossil fuels dependence in Italy.

Agricultural sector can provide several types of biomass, from herbaceous to woody cultivation, from energy crops to residual biomass.

Residual biomass potential from agriculture in Italy consists of vine prunings, olive prunings and orchard prunings, that are generally cut up and then land-filled, or burned near the field, with additional costs for farmers and serious problems about parasites development or uncontrolled fires. The amount of agricultural residues can be determined multiplying cultivation surface with a coefficient, estabilished from CEESTAT [1] (Research Centre of Agriculture, Environment and Territory) and SESIRCA [2] (Centre for Agriculture Research), which describes residues productivity (t/ha). Table I shows the national average values of residues and the ratio between the residues and the product for principal cultivations. [3]

Table I: Values of residues (t/ha) and ratio of residue/product (wet basis) in Italy [3]

Plants	Residue (t/ha)	Residue/product
Vineyard	2.9	0.2-0.8
Olive trees	1.7	0.5-2.6
Apple trees	2.4	0.1
Pear trees	2.0	0.1
Peach trees	2.9	0.2
Citrus tress	1.8	0.1
Almond trees	1.7	1.9
Hazel trees	2.8	1.9

The agri-energetic chain project called ERAASPV – “Biomass project: renewable energy for farms deriving from vineyards pruning residues”, published and financed by the Italian Ministry of Agriculture and Forestry, is an innovative project developed by the Biomass Research Center (CRB) and realized near “Cantine Giorgio Lungarotti”, a famous wine and viticulture company in Umbria (Italy) which own about 250 hectars of vineyards.

Vineyard pruning residues collecting chain consists of these phases:

- grapes pruning harvesting (round-baling);
- bales transport, storage and exsiccation;
- bales chipping and chips storage;
- chemical-physical characterization of the biochip;
- biomass energy conversion in the boiler.

Currently the phases developed are round-baling, transport, storage and chipping; at the moment is under construction: the silo, the thermal power station and the plumbing system.

2 HARVESTING OF VINEYARD PRUNING RESIDUES

2.1 2006 and 2007 harvesting yard

Harvesting stage was executed using the roundbaler Lerda model T110, moved by a farm tractor New Holland model 82/86 and 80 hp power; table II shows the most important roundbaler technical specifications, while figure 1 shows a picture of the machine.

Table II: Technical specifications of the roundbaler “Lerda T110”

Specification	Value
Maximum length	320 cm
Maximum width	209 cm
Maximum height	187 cm
Maximum width picker	119 cm
Weight	1360 Kg
Maximum width harvesting	145 cm
Power required	35-45 hp
Bales length	110 cm
Bales diameter	100 cm

Figure 1: Picture of “Lerda T110”

The first grapes pruning harvesting campaign was executed between April and June 2006. Roundbaling was performed at the head of the rows, because of a delay in the machine delivery (April); Consequently, in that period, the residues were already taken out of the rows, by means of a tractor with a rake, in order to allow grapevine treatments. Moreover, during the harvesting, an excavator had to recover the residues and distribute them into a way practicable by the roundbaler.

The complexity of the harvesting operation determined the presence of two operators, one driving the tractor with the roundbaler and one driving the excavator, the extension of the harvesting time and the increase of biomass losses. Figure 2 shows harvesting phase during 2006.

Figure 2: Picture of 2006 harvesting yard

The second grapes pruning harvesting campaign was executed between January and April 2007. The yard was organized using only the roundbaler and the tractor which worked inside the rows, during the pruning. Pruning was performed by farm operators in order to make the residues of two rows fall in only one row, halving the harvesting time of the machine. Figure 3 reproduces an harvesting phase during 2007.

Finally, the experience matured during 2006 yard, determined the application of some modifications to the roundbaler, described in the next paragraph.

Figure 3: Picture of 2007 harvesting yard

2.2 Modifications to the roundbaler

The dimensions of the machine were chosen, at the beginning during the projection, as an arrangement between overall width machine, the shortest, and the bales dimensions, the biggest. The shortest width is important in order to permit the machine passage into the smallest raws. The largest bales dimensions is important in order to reduce the cost of bales collecting and transporting: in fact, the grater the number of the bales, grater time is spent for harvesting and transporting; besides, if the bales are too small, these may fall in the middle of the raw, with big problems to extract them.

The roundbaler, even though it didn’t show great lacks, it highlighted some small problems. The defects emerged during 2006 yard concern string fastening and cutting system: the longest residues, before entering in the rotary chamber, got stuck in the wagon or in the string, interfering with string movement and bale fastening. The modifications consist of the realization of a sheet metal to separate fastening system with residues harvesting zone.

In order to minimize costs-energy ratio of the chain, it’s necessary to reduce and speed up the operations, so the roundbaler need to move into the raws. Modern vineyards have raws 200 or 220 cm wide, more narrow than roundbaler. Therefore the tyres, mounted at the sides, have been replaced by two iron rollers, mounted under the machine; this modification allows a width reduction from 209 cm to 154 cm.

Figure 4 shows an image of the machine modified, while Figure 5 reproduce a particular of the roller.

Figure 4: Picture of “Lerda T110” modified

Figure 5: Particular of the roller

2.3 Results of 2006 and 2007 yards

The most important differences between 2006 and 2007 yards are:

- 2006 yard composed of roundbaler and excavator, 2007 yard composed only of roundbaler modified;
- Employment of two operators during 2006 yard, only one operator during 2007 yard;
- Pruning harvesting executed along the head of the rows in 2006 yard, across alternate rows in 2007 yard.

As regards 2006 yard, table III shows the characteristics of monitored vines and productivity obtained; figure 6 represents productivity of each vineyard; table IV describes principal results of 2006 pruning harvesting.

As regards 2007 yard, table V shows the characteristics of monitored vines and productivity obtained, different from 2006 vines because of agronomic requirements; figure 7 represents productivity of each vineyard; table VI describes principal results of 2007 pruning harvesting.

Table III: Monitored vineyards characteristics and productivity (2006)

Vine	age (y)	width (m)	area (ha)	Production (t/ha d.b.)
A	4	2.5	5.31	0.49
B	3	2.5	1.68	0.06
C	4	3.5	3.07	0.39
D	3	2.5	0.99	0.61
E	6	2.5	1.27	0.87
F	6	2.5-3.5	1.25	0.81

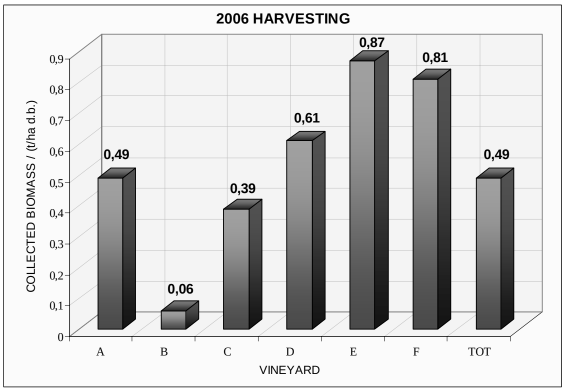

Figure 6: Vineyards productivity (2006)

Table IV: 2006 harvesting results

Specification	Value
Yard area	13.57 ha
Available residues *	0.99 t/ha d.b.
Collected residues *	0.49 t/ha d.b.
Losses	0.50 t/ha d.b.
Time spent **	3.18 h/t d.b.
Diesel used	24.25 l/t d.b.
Harvesting cost	86.97 €/t d.b.

* residues are expressed as dry basis (d.b.)
** working hours (2 operators employed)

Table V: Monitored vineyards characteristics and productivity (2007)

Vine	age (y)	width (m)	area (ha)	Prod.(t/ha d.b.)
1 Trebbiano	4	2	0.66	1.77
2 Pinot Grigio	8	3	1.77	0.88
3 Chardonnay	7	2.5	1.83	0.85
4 Merlot	18	3.5	1.22	0.11
5 Cabernet and Sangiovese	8	2.5	3.51	0.67
6 Sangiovese	8	2.5	2.37	0.27
7 Chardonnay	6	2.5	1.90	0.96

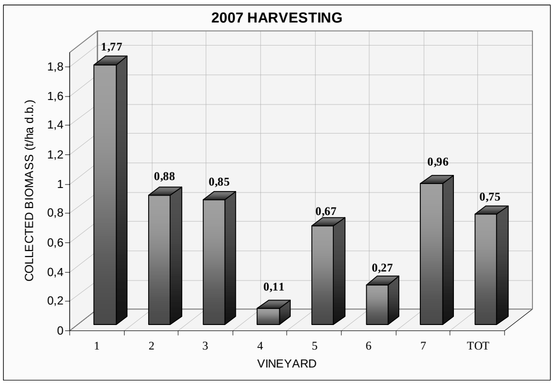

Figure 7: Vineyards productivity (2007)

Table VI: 2007 harvesting results

Specification	Value
Yard area	13.26 ha
Available residues *	1.02 t/ha d.b.
Collected residues *	0.70 t/ha d.b.
Losses	0.32 t/ha d.b.
Time spent **	2.32 h/t d.b.
Diesel used	5.74 l/t d.b.
Harvesting cost ***	19.15 €/t d.b.

* residues are expressed as dry basis (d.b.)
** working hours (1 operator employed)
*** deducted the avoided cost of tractor with rake (25€/ha)

Harvesting 2007 obtained better results than 2006 harvesting; the collected residues passed from 0.49 to 0.70 tons per hectar d.b. (43% better production); the harvesting cost passed from 87 €/t d.b. to 19 €/t d.b.

In table VII, the results of 2007 yard, dry bases, are compared with some literature studies.

Obtained result, in terms of the harvesting stage, are sensibly lower then the other studies.

Table VII: Comparison between results and other studies

Harvesting yard	machine Model	operators number	product. t/ha	Umidity %	cost €/t
Lungarotti	Lerda T110	1	0.70	0	19.15
Ancona [4]	Lerda 900L	2	1.99	44	45.00
Ancona [4]	Caeb Mp400	1	2.26	44	23.00
Cosenza [5]	Arbor Rs170	1	3.70	50	39.60*
Chieti [6]	Lerda 1000	2	4.20	32	34.00*

* not deducted the avoided cost of tractor with rake

The most important reasons that permitted these results are:

- pruning harvesting along alternating rows, which allowed the halving of the harvesting time and the reduction of losses, because the bigger biomass quantity made the harvesting easier;
- operators reduction from 2 to 1, which allowed the halving of manpower costs;
- modification to the roundbaler, which allowed both the reduction of dead times and the possibility to harvest trough rows of 2.0 and 2.2 metres.

3 TRANSPORT, STORAGE AND EXSICCATION OF THE BALES

The use of a roundbaler rather than a cutter-harvester was chosen, as confirmed by some studies, for the facility of bales storage and for the better preservation than chips, that tends to ferment; on the contrary, there are more problems during the next phases to employ the bales as biochip. [7]

The bales were collected at the head of the rows and transported in the storage; the storage was realized in an open place, 6 Kilometers far from the biomass thermal plant; the choice of this storage, quite far from the plant is due to the lack of space near the plant; the logistics causes an other transport stage, from storage to thermal plant, increasing production cost of the biochip. Figure 8 shows storage area.

Figure 8: Bales storage area

The choice of the open natural storage was very interesting for biomass exsiccation: the laboratory analysis shows that relative umidity changes from 38-40% after pruning, to 5-6% on summer, and goes up again until 10-12% on the next winter. Therefore natural exsiccation allows good results, even though, after more then a year from the harvesting, the biomass is degrading.

Figure 9 draws the trend of the moisture during the year.

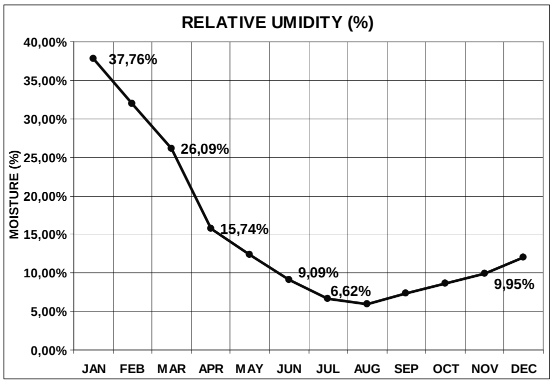

Figure 9: Moisture trend during the year

Transport stage has been realized using farm machines: a pitchfork for bales harvesting, a wagon and an hydraulic pliers for bales charge and discharge. The phase of transport from vineyards to storage was monitored, while the phase of transport from storage to thermal plant silos was estimated.

Table VIII shows time required and costs of this stage during 2006.

Table VIII: 2006 transport and storage costs

TRANSPORT	
TRANSPORT VINEYARD-STORAGE	
Time necessary	2.4 h/t
Cost	54.48 €/t d.b.
TRANSPORT STORAGE-THERMAL PLANT	
Time necessary	0.5 h/t
Cost	9.6 €/t d.b.
Transport total cost	*64.08 €/t*

As shown in the table above, transport stage is very expensive, also comparing it with literature dates, that, for distance shorter then 25 Kilometers, is about 20-25 €/t. [8]

Therefore this stage needs of a logistic optimization, that will be realized in 2007 yard, to make biomass cost more competitive.

4 CHIPPING AND STORAGE

Chipping stage of the bales is the agro-energetic chain link, because allows to obtain a biofuel (chips) with dimensions suitable to commercial biomass heaters.

High bales dimensions, 1.0 meters diameter and 1.1 meters length, allow an easy harvesting at the head of the rows, but on the other side aren't compatible with mouth opening width of a common small-medium chipper suitable for this plant; using a big woody-chipper, more suitable for big bales, will not be economically compatible with this chain project. Therefore it was experimented the use of a mixer wagon, commonly used for zootechnic feeding, which has a cost comparable to a small-medium chipper.

Chipping tests were executed on a mixer wagon Storti model Bulldog 15 m^3, whose technical characteristics are shown in table IX. Figure 10 shows the mixer wagon.

Table IX: Technical specifications of the mixer wagon "Storti Bulldog"

Specification	Value
Maximum length	603 cm
Maximum width	248 cm
Weight	6650 Kg
Power required	80 hp
Mixer wagon capacity	15 m^3

Figure 10: Picture of mixer wagon

Figure 11 shows the inside of the mixer wagon, where are inserted, by a forklift truck, the bales, that are chipped by rotative cutters of the machine. The chips have an average granulometry of about 5-7 cm, rather coarse but compatible with the choosen combustion system, moving grate boiler.

Figure 11: Internal of mixer wagon

Chipped material exiting trough the screws (figure 12) will be transported by a conveyer belt (electric power required 2 kW) from the mixer wagon to the silos near biomass heater.

Figure 12: Biomass chipped by mixer wagon

Time and costs of this stage are shown in table X.

Table X: Time and costs of chipping and storage stage

Characteristic	Value
Period of Chipping and storage cycle	2 h
Number of bales worked each cycle	15
Biomass worked each cycle	2.0 t d.b.
Tractor fuel consumption	5.25 l/t d.b.
Electricity consumption	6 kWh/t d.b.
Number of operators	1
Chipping and storage cost	*26.78 €/t d.b.*

Also this stage has low costs, optimizing with a better automation of the stage.

5 ENERGETIC CONVERSION

The most important characteristics of the energetic conversion system are:

- chips storage system with 60 m^3 capacity, which can give at least 8 days heater autonomy in the heaviest condition;
- chips transport system from silos to boiler which consists of moving rack at the bottom of the silos, conveyer belt and screws until the boiler;
- moving grate heater, which permits use of bigger or wet biomass, parameters variable during the seasons or the chipping cycle period;
- 400 kW useful thermal power heater; the size was chosen as arrangement between energy farm requirements and the energy obtainable from vineyard pruning;
- diathermic oil thermal fluid up to 300°C, in order to feed absorption chiller (Robur model GA ACF 60-00 LB Power Fluid – 13 kW) for production of cool water until -10°C;
- heat exchanger oil-water and oil-steam for farm requirements.

Biomass energy conversion will permit energy production in four different shapes:

- heat, by means of a heat exchanger oil-water, for rooms heating and for hot water;
- cool water up to -10°C, by means of an absorption chiller fed with diathermic oil, for vinification processes;
- cool water up to 7°C, by means of an absorption chiller fed with diathermic oil, for summer conditioning of company rooms;
- steam production, by means of heat exchanger oil-steam, for bottles sterilization processes.

2007 pruning harvesting will produce about 150 t/y biomass. Chemical-Physical biomass laboratory analysis furnished results described in table XI.

Table XI: Biomass analysis

Characteristic	Value
Moisture	9.09%
Volatile elements	83.6%
Ash (d.b.)	3.1%
Carbon (d.b.)	50.07%
Hydrogen (d.b.)	5.91%
Nitrogen (d.b.)	0.52%
Low heating value	17.730 KJ/Kg

Yearly available energy is about 740 MWh. The evaluation of energy farm requirements, 376 MWh thermal for heaters and 1010 MWh of electricity, came to reject heater connection too little used and too much far from biomass plant. The only absorption chiller will allow, at the beginning, a low electricity farm saving, but in the future it would be increased by the installation of other machines.

Table XII describes yearly fuel consumption and the savings obtainable with this configuration; table XIII describes economic analysis with six absorption chillers. The optimization of some chain stages could reduce biochip cost, reducing also the pay back period.

Table XII: fuel consumption and savings

Characteristic	Value
Diesel consumption	30.000 l/y
GPL consumption	11.000 l/y
Consumption of electricity	1010 MWh/y
Diesel saving	28.000 l/y
GPL saving	5.000 l/y
Saving of electricity	18 MWh/y
Yearly economical savings	35.000 €/y

Table XIII: economic analysis with six chillers

Characteristic	Value
Biomass plant cost	210.000 €
Yearly chips production cost	100 €/t
Yearly saving	45.000 €
Yearly revenue	30.000 €
Pay back period	8-9 years
Life of the plant	> 12 years

6 CONCLUSIONS

The production costs of the biochip, referred to the entire energetic chain, are about 110 €/t d.b., divided into the stages as shown in figure 13.

The stages that are currently optimized are harvesting, storage and bales chipping.

Transport is the stage that need to improve, both from the vineyards to the storage and from the storage to the silos near biomass thermal plant; in fact, this phase influences the biochip cost for about 60% of the total production cost, making biochip cost not completely competitive with chips from other sectors (S.R.F., woody wastes companies, woody maintenance).

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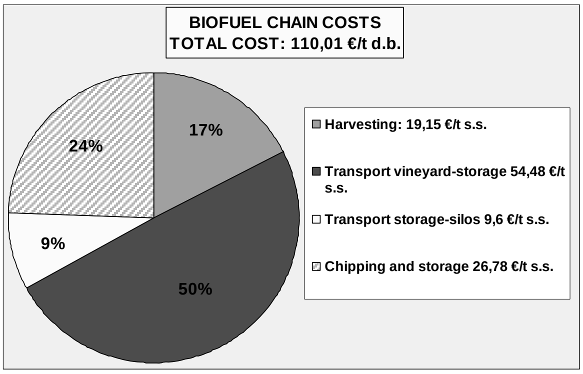

Figure 13: Costs of the stages of the energetic chain

Currently these results allow to obtain a 8-9 years pay back period, but this value could reduce improving and optimizing the energetic chain.

Nowadays we are realizing:

- thermal plant with safety and control systems;
- silos for chips storage with transport system (moving rack, conveyer belt, screws);
- hydraulic net for thermal fluids distribution;
- heat exchangers.

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