VINE PRUNINGS AGRO – ENERGETIC CHAIN: EXPERIMENTAL AND ECONOMICAL ASSESSMENT OF VINE PELLETS USE IN GASIFICATION POWER PLANTS

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ABSTRACT: Vine prunings are a very abundant by product of the wine industry and their production can be estimated to be between 1 to 5 ton/year for every hectare. In the view of a decarbonisation and the development of the circular economy this biomass should become an opportunity even if in most of the cases it ends up being a problem. This is due to their common burning in situ that has a huge environmental impact, and to their shredding when left on the field that can be an infection source in presence of grape diseases. This work follows the one presented the 26th EUBCE "Gasification and wine industry: report on the use vine pruning as fuel in small – scale gasifiers" where it was evaluated the possibility of producing electrical energy using this biomass as fuel in APL PP20 gasifier – engine system. The results of the previous work showed quite promising results about the gasification efficiency and the quality of the gas produced using this biomass, however the difficulties encountered during the reactor feeding and the bridging problems have made this process quite challenging. In order to overcome these issues, it was considered the possibility of pelletizing this biomass. More than 2.5 ton of pelletizing vine prunings were successfully gasified with a quite high efficiency, 1.1 kg consumed for every electric kWh produced. The 150 kg of biochar produced through the process were tested on a vineyard as soil improver. The entire supply chain, from the harvesting of the vine prunings on the field, to the pelletization and gasification, was economically evaluated considering different possible scenarios and some of them were quite profitable and therefore practically feasible.
Keywords: agricultural residues, agropellet, biobased economy, cost analysis, gasification, winery

1 INTRODUCTION

Wine industry is very important in Italy, where about 800 thousands hectares are cultivated with vineyard (around 20 % of the European production) [1][2][3]. For every hectare of vineyard there is a production from 1 to 5 tons every year of vine prunings [1]. In this work a possible way to give value to this huge amount of byproduct was studied.

It follows the work presented at the 26th EUBCE "Gasification and wine industry: report on the use vine pruning as fuel in small – scale gasifiers" where vine prunings where successfully used as fuel in a small scale gasification system for power production [2].

Gasification is a promising technology to use biomass as energy source in an efficient way [4]. However, the process control complexity and the high construction and maintenance costs make the this research field quite challenging [5] and therefore often not enough explored.

In the next table, the average results of the previous experimental campaign were summarized to show the good quality of vine prunings as fuel for gasification.

Table I: Specific biomass consumption ($S_{bio,tot}$) [2], gasification efficiency (η_{gas}) [2], electrical efficiency (η_{tot}) [2] and particulate (P) and tar (T) sampling before the filtration system.

$S_{bio,tot}$ kg/kWh	η_{gas} %	η_{tot} %	P g/Nm^3	T g/Nm^3
1.17	67.1	16.1	0.54	0.95

As shown in Table I, vine prunings are quite good as fuel for gasification systems, nevertheless during that experimental campaign a lot of trouble were encountered in the feeding of the reactor. They were due to the shape of the fuel obtained chipping the prunigs with a rotary valve [2].

Furthermore, this kind of pre-processing of the biomass took long time with a lot of manpower. To overcome these issues, possible alternatives to vine prunings chipping were investigated.

The identified one was the pelletization of the biomass. In this work, the process was studied both from the technical and from the economical point of view, starting from the harvesting in the field to the energy production. "CAEB International" company systems were used for the field and pelletization operations while the ALL Power Labs PP30 downdraft gasifier was used for the thermochemical conversion of the biomass [6].

Once established that the previous operations were technically feasible, all the agro-energetic chain was evaluated from a financial point of view, to understand if it can realistically be applied not only for research purposes but that it can become a common practice in the vine industry [6].

2 MATERIALS AND METHODS

2.1 Pellets production

The selected method to produce vine prunings pellets was the one proposed by the "CAEB intenational SRL" company, this because they are able to provide all the equipment needed to collect and transform the vine prunings into pellet.

The first operation was the collecting and baling of the prunings with the Quickpower 1230 baler. This tool needs a power of 15 kW at PTO and 350 r.p.m of rotating speed [7].

Figure 1: Quickpower 1230 baler during field operation

The dimensions of the produced bales were, on the average, 60 cm high, with a diameter of 40 cm and with a mass of 27 kg (average moisture 40 % wet basis) [6].
To transform the bales into pellets the CAEB EPS line was used. It is a modular system made up including a shredder, conveyors and the pellet machine (**Figure 2**) [8].

Figure 2: CAEB EPS Line [8]

This system needs an electrical installed power of 43 kW, it operates with an average input power of 27 kW and it has a pellet productivity of about 100 kg/h [8].

2.2 Pellets gasification

The ALL Power Labs PP30 system was used for the gasification and electrical power production tests.

It is a 22kWel @ 50Hz gasifier-engine pilot plant composed by a 0.33m^3 hopper, auger biomass moving system, a single throat downdraft fixed bed, a filtration stage and an internal combustion engine (Ashok Leyland 4.0 l) linked to an electrical generator (Marathon 284CSL1542) [9].

Figure 3: PP30 Power Pallet [10]

In the first experimental campaign the previous model was used. This new one has an improved filtration, that is always a crucial part of gasification systems [11][12][13][14] and bigger engine with a higher compression ratio in order to improve the efficiency of the system [15].

More than 2500 kg of vine prunings pellets where successfully gasified in the system and about 150 kg of biochar were produced. Knowing the elemental composition the Higher Heating Value can be estimated with the equations suggested by Channiwala and Parikh [16][17][18] (kJ/kg):

$$HHV = 349.1C + 1178.3H + 100.5S - 103.4O - 15.1N - 21.1Ash \quad (1)$$

Ultimate analysis was performed on both pellets and biochar. The syngas composition was measured with a micro GC GCX gas analyser and its higher heating value was calculated with the formula [19]:

$$HHV_{syngas} = x_{CH_4} HHV_{CH_4} + x_{H_2} HHV_{H_2} + x_{CO} HHV_{CO} \quad (2)$$

The efficiency of the system was calculated weighing the fuel and measuring the electrical energy produced with the PP30 Deep Sea control module. Then, it was compared with the efficiency measured with other fuels tested in the system.

2.3 Economical analysis

To understand if vine prunings pellets gasification can be profitable, different scenarios were studied. The best one is presented in this work.

An hypothetical winery farm or a consortium is the ideal subject for this kind of project because it usually features the planted area, the room for all the equipment and tractors [6].

The initial investment includes the Quickpower 1230 baler, the Bale Transporter 8CM that is to transport up to eight bales and reduce the processing time [7], the pelletization system EPS line and the PP30 biomass genset [6].

An amount of 1800 working hours was considered both for the EPS line and for the PP30 [6]. To produce 100 kg of pellets every hour, and therefore 180 tons per year, it was calculated that 186.2 hectares of vineyard are necessary, considering a vine prunings availability of 2900 kg/ha [6] and that it is possible to produce about 1 kg of pellets every 3 kg of prunings collected in the field [6].

The annual costs assumed for the agricultural diesel consumed for the baling process was calculated measuring the consumption during the experimental test, and it was about 5.6 liters/ha [6], and the considered cost per liter was 0.9515 €/l [6].

A maintenance cost of the PP30 was estimated for every MWh of electrical energy produced [6].

All the electrical power produced by the PP30 was considered used to support the electrical consumption of the EPS line, however its consumption is, on the average, 7 kW higher than the PP30 production, assumed conservatively to 20 kW. For this reason, this extra electrical power needed should be purchased from the grid, and the considered price was 0.186 €/kWh [6].

A cost item that was considered only in the first year is the biochar certification as soil improvers, fixed at 1250 € [6]. Biochar can have various utilization, i.e. soil amendment, raw material for activated carbon production, filter media and carbon source for nutraceutical and pharmaceutical [20]. Tests on the benefits of biochar as amendment for vineyards are in progress, therefore for this economical evaluation it was chosen to sell all the 2070 kg of biochar produced annually with a price of 300 €/ton [6].

The other source of income of this scenario was the pellets selling, with a price of 210 €/ton [6].

The amount of pellets available for sale was calculated as the difference between the produced and the consumed by the gasifier.

Together with these direct incomings, the possibility of exploting the thermal power produced by the PP30 was taken into account as a substitute of natural gas [6].

Considering a cold season of six month and a utilization factor of 0.5 a savings of 1690 m^3 of natural gas was obtained, that correspond to 930 € saved every year [6].

Lastly, a 65 % tax deduction for the first ten years on the PP30 price was assumed [6].

3 RESULTS

3.1 Pellet gasification

In Table II the results from the ultimate analysis performed on vine pruning pellets and on biochar are shown:

Table II: Pellets and biochar ultimate analysis

	C %	H %	S %	N %	ASH %	HHV MJ/kg
Pellets	46.4	6.5	/	0.9	3.6	19.3
Biochar	67.8	0.8	/	0.6	22.1	23.3

The average syngas composition measured during the tests is shown in Table III:

Table III: Average syngas composition

H_2 %	N_2 %	CO %	CO_2 %	CH_4 %	HHV MJ/m^3
16.3	48.3	20	13.7	1.7	5.3

The measured heating value is in line with the one measured with woodchips in a previous model of the APL Power Pallet [21].

Most of the tests were carried out with an average electrical load of 13.75 kW, with a consumption of 1.09 kg/kWh [3] resulting in an overall electrical efficiency of 16.7 %. This value is quite good compared to the efficiency obtained with the chipped vine prunings (16.1%) [2] or with another waste biomass like cotton stalks chips (14.1%) [4].

3.2 Economic analysis

The results of the economical analysis performed on the identified scenario are summarized in Table IV:

Table IV: Economical analysis results [6]

INITIAL INVESTMENT	
Quickpower 1230 baler	*
Bale Transporter 8CM	*
EPS line	*
PP30 gasifier	*
TOTAL	151472 €
COSTS	
Biochar certification (only 1° year)	1250 €
Annual agricultural diesel consumption	992 €
Annual electrical energy for EPS Line	2344 €
Annual PP30 maintenance	*
EARNINGS	
Annual pellet sales	29106 €
Annual biochar sales	621 €
Annual natural gas saving	933 €
Annual tax deduction (first 10 years)	4256 €

*The separated cost of single items is confidential

Considering a 5% discount rate [9] the calculated payback time was 7 years [6].

4 CONSLUSIONS

In this work a possible energy use of vine prunings was presented. The entire energetic chain was studied, from the field to the energy production, proving that the solution of pelletizing the prunings is not only technically feasible but also economically viable.

Several hundreds of running hours demonstrated the improvements in the gasification process with this biomass. The proposed solution provides pellets for sales, electrical energy for its production, thermal energy for the company and biochar.

The estimated payback time of 7 years could be further reduced in case of subsidies for the electrical energy production through waste biomass.

The biggest uncertainty of the model was the PP30 maintenance cost that were only assumed, and not evaluated after years of tests.

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