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Emissions of heating appliances fuelled with agropellet produced from vine pruning residues and environmental aspects

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ABSTRACT

Vine is one of the most widespread crop cultivated in Italy. The management of these residues is linked to an additional cost for the operator and determines environmental issues mainly due to open field combustion. A better exploitation of these residues could be the use for thermal energy production in residential heating devices fuelled with pellet. In the present work vineyard pruning residues were collected, pelletised, then characterised according to the standard for solid biofuels. Combustion tests were performed in a 150 kW_{th} boiler fuelled with pruning pellet and the related TSP, CO, NO_x emissions were measured. In order to make a comparison with the open field combustion emissions of the vineyard pruning residues, simulation tests were conducted at lab scale. Open field emissions are up to 120 times for CO emission and 30 times for TSP more than the boiler emission. Results highlighted that by avoiding open field combustion and using this residual biomass for energy production, a significant reduction of environmental pollution together with an increase in renewable energy production can be obtained. The results can be useful as support for policy makers engaged in developing the strategy for the promotion of renewable energy and air quality improvement.

1. Introduction

The use of residual biomass is increasingly incentivized due to the high sustainability of this practice. Several authors studied the possibility to produce bioenergy from different crop residues [1–4] highlighting advantages and issues regarding technical, social and environmental aspects. At European level a lot of residues are produced from the cultivation of vineyards, olive groves and orchards [5–7]. Vine is one of the most widespread crop cultivated in Europe with a share of 20% in Italy [8]. According to a specific research carried out in Italy and funded by Italian MiPAAF ministry [9], in 2013 it has been estimated a production of about 2.67 Mt $year^{-1}$ of residues from vine cultivation.

Currently vineyard pruning residues are not valorised and are generally managed by mulching it into the ground or by combustion in open field as stacked piles. This represents an additional cost for the operator and determines environmental issues. Mulching pruning residues in the vineyard contributes to maintain the organic matter content, but may contribute to inoculate vine diseases [10].

Open field combustion is a simple and widespread way to manage pruning residues due to the low cost but this management system is questionable because affecting air quality due to the combustion performed in uncontrolled conditions. Nevertheless this solution is legally permitted in Italy following specific requirements [11], with the consequent drawback of air pollution. This practice can also have consequences in the increase of Cu and Zn contents of vineyard soil [12]. Open field burning emissions have been studied by many authors for different crop residues such as rice straw [13], wheat straw, corn stover [14] and other residues [15,16] reporting huge differences in emission factors.

Other possible management systems of these residues, in addition to landfilling or composting [17], are the combustion in controlled conditions for energy applications [12,18–20] and the use as feedstock for extraction of interesting substances. This latter use is still a potential application but many studies have been yet carried out so far [21–25]. The combustion of pruning residues for energy application can be a practical and interesting solution for the Italian situation to avoid the drawbacks of combustion in open field and at the same time to mitigate the carbon footprint of vine

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Abbreviations

VPpel	vineyard pruning residues pellet
Wpel	wood pellet
VPraw	vineyard pruning residues raw
TSP	total suspended particles
CO	carbon monoxide
NO_x	nitrogen oxides expressed as NO_2
λ	air excess ratio
db	dry basis
ar	as received
EF_{B_O2}	emission factor of the pollutant (i.e. TSP, CO, NO_x) for boiler combustion test standardized to reference oxygen level (11%)
EF_{B_fuel}	emission factor of the pollutant (i.e. TSP, CO, NO_x) for boiler combustion test reported on burnt mass basis
EF_{OF_fuel}	emission factor of the pollutant (i.e. TSP, CO, NO_x) for open field combustion test reported on burnt mass basis
M	moisture content
A	ash content
C	carbon content
H	hydrogen content
N	nitrogen
O	oxygen
NCV	net calorific value
Cl	chlorine content
S	sulphur content
BD	bulk density
D	Durability
SST	shrinkage starting temperature
DT	deformation temperature
HT	hemisphere temperature
FT	flow temperature

[26]. Some specific studies addressed the problem of correctly harvesting these residues [6,20]. The heterogeneity and average quality of these residues, highlighted by different authors [8,27–29], make difficult the direct combustion in small and medium combustion systems [27]. This problem can be overcome by producing agropellet [30] to standardize the biofuel making it more easily managed by stoves and boilers. These devices should be chosen carefully because not all the systems can correctly manage agro-pellets. On the other hand these problems are not relevant in power plants with high energy productions since are equipped with specific systems for emission control and reduction.

The present study aims to evaluate the emissions of heating devices fuelled with agropellets produced by vineyard pruning residues and to compare the results with the emissions released in open field combustion to have an estimation of the advantage of a controlled combustion of these materials. To this aim specific tests simulating an open field combustion of pruning residues have been performed as well. Although many authors argue that the open field combustion increases pollution and decreases air quality there are no specific estimations in scientific literature of the differences between the impact of controlled combustion and open field combustion of vine pruning residues.

2. Materials and methods

2.1. Biomass sampling

Vineyard pruning residues, employed both for open fire combustion tests and pellet production, were collected from different commonly managed vineyards in Verona province area. Raw vineyard pruning residues (VPraw) were manually sampled after the pruning activity and afterwards characterised and employed for the tests simulating open field combustion.

For pellet production instead, raw material was recovered by the vineyard ground after one month storage time by means of an automatic pruning collector and chopper (mod. Alba 150, MAREV). The device picks up pruning from the ground, reducing soil contamination, and cuts it while is moving along rows of vines.

Afterwards the cutted biomass was stored on the field for about two months before the grinding at 2–3 mm particle size (mod. K1000, COSTRUZIONI NAZZARENO) and the pelletizing (mod. 3000 series, CPM, 6 mm of pellet diameter). Vineyard pruning pellet (VPpel) was characterised and employed for boiler combustion tests. The wood pellet normally used by boiler owners (Wpel) was also characterised and employed as standard reference to make a comparison with the VPpel.

2.2. Biomass analysis

For evaluating the quality of both the agropellet and raw pruning residues a series of chemical and physical analysis have been carried out following the international standards. Physical and chemical parameters for all the biomasses evaluated in this study are listed in Table 1 with methods and equipment employed for the determinations. Short descriptions of these methods can be found in previously published papers [31–33].

To check the representativeness of raw and pelletised aforementioned materials, some statistics related to other samples collected and analysed by the Biomass lab of Università Politecnica delle Marche have been compiled. In fact during the last years Biomass Lab has analysed different samples of vineyard pruning and vineyard pruning pellet coming from several part of Italy. A general descriptive statistics was reported to supply useful data about this residual biomass and to make a comparison with the samples evaluated in this study.

2.3. Pellet combustion tests

Pellet combustion tests were performed on a boiler (mod. Powerfire TDS 150, KWB) with a thermal power equal to 150 kW_{th}.

Wood pellet is automatically supplied into the boiler from an adjacent storage room by means of rotary auger screws. Fuel energy conversion is managed by the combustion system, i.e. a rotary grate, a cyclone combustion chamber, a flue gas re-circulation system and a lambda probe, which allows to obtain high efficiency and low emissions. Fuel mass flow and air excess are automatically tuned during the whole combustion thanks to an electronic control system.

The boiler is installed in a rural building complex and supplies heat for a farm holiday centre, a greenhouse and some offices.

Combustion tests were performed feeding the boiler with vineyard pruning agropellet (VPpel) and commercial wood pellet (Wpel) to make a comparison between new and traditional solid biofuel respectively. In order to evaluate different heat powers,