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Production and quality of biomass fuels from mechanized collection and processing of vineyard pruning residues

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ABSTRACT

Vineyards cover about eight millions of hectares worldwide and their annual pruning generates a large amount of ligno-cellulosic biomass, potentially available for industrial and energy use. Commercial pruning residue harvesters are now available, which may allow cost-effective recovery. The study aimed at determining the quantity and the quality of pruning residues potentially derived from vineyard management. Data were obtained from 17 fields in Northern and Central Italy. Fields were harvested with seven different machines. The experimental design adapted to the necessities of field trials, but was adequate for testing the main sources of variability. Net residue yield varies around 1 oven dry tonne per hectare, with minor differences between grape varietals and harvesting technologies. Losses are still high, and are generally related to ineffective management techniques. Moisture content at harvest varies between 40% and 45%, whereas the higher heating value is slightly lower than that of forest fuels. Comminuted vineyard residues are unsuitable for firing residential boilers, due to the frequent presence of oversize and/or undersize particles. The application of pesticides does not result in any significant contamination with noxious chemicals, because these products are almost completely weathered before residues are recovered. In wine-producing regions, the recovery of vineyard pruning residue may represent a substantial source of industrial bio-fuel.

1. Introduction

Originating thousands of years ago in the Mediterranean, the cultivation of grapes is now common all over the world and often represents a very profitable endeavor. In 2008, the surface covered with vineyards amounted to almost eight million hectares worldwide [1]. This crop requires much tending, including annual pruning. That generates a substantial amount of residues, which must be disposed of before implementing any other tending measures. Finding some use for vineyard pruning residues would allow converting a disposal problem into a collateral production, with a potential for revenues or reduced management cost. Pruning residue harvesters have been developed, which may effectively recover vineyard pruning residues and make them available to the markets [2]. Vineyard pruning residues could partly replace traditional wood assortments for energy and industrial use [3], and they may play an important subsidiary role in supplying bioenergy plants with renewable fuel [4], especially in rural areas and where the forest resource is scarce. On the other hand, vineyard pruning residues have peculiar quality characteristics compared to other ligno-cellulosic feedstock, which may affect the choice and the performance of the conversion technology [5], as well as the potential for co-firing [6]. In general, wood fuel characteristics have a significant impact on the yield, quality and stability of both syngas [7] and pyrolysis oil [8]. Although particularly efficient [9], the newest small scale gasification technologies are especially sensitive to wood fuel characteristics [10]. Nor can one think about targeting high-quality wood fuel only, because the growing demand for wood fuels must be matched by an expanding supply, in order to guarantee price stability [11]. This is crucial to the development of the biomass energy sector, where fuel represents a major cost item [12]. Hence the interest in determining the main quality characteristics of most wood fuels, including vineyard pruning residues. In particular one should determine: particle size distribution, calorific value, moisture content and the potential for chemical contamination.

Particle size distribution is crucial to fuel handling efficiency [13], to its drying and reaction rate [14], to the energy required for conversion into ethanol [15], and to the yield of bio-oil obtained from pyrolysis [16]. Calorific value is the essential quality of any fuel, and is

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relatively constant for wood fuels in their dry status [17]. In this respect, moisture content is the most important physical characteristic of wood fuels, and it depends on a number of factors, including the collection period, the handling system and the duration of the eventual storage [18]. As most agricultural crops, vineyards are sprayed with pesticides, which raises the question of chemical contamination. There is a growing concern about the permanence of these chemicals, which may not be completely removed through weathering. If so, chemicals could concentrate in the wood ash, preventing their use as a fertilizer.

Against this background, the Italian National Council for Research (CNR), the Foundation Edmund Mach (FEM) and the Council for Research in Agriculture (CRA) set out to determine the quantity and the quality of residues that can be obtained from the annual pruning of vineyards in Italy. Ten percent of the global area grown with vineyards is concentrated in Italy, which occupies the third place among the countries with the largest vineyard surface. Italian vineyards provide a good example of modern industrial plantations, and can be taken as a representative example. In particular, the study aimed at quantifying: (1) the available amount of pruning residues per hectare; (2) the harvesting losses; (3) the moisture content of the product before and after storage; (4) the particle size distribution obtained with different machines; (5) the higher heating value; (6) the eventual concentration of pesticides on vineyard pruning residues.

2. Materials and methods

Three different areas in northern and central Italy were sampled for determining the amount of pruning residues that can be harvested from one hectare of vineyard. To this purpose, seventeen fields were harvested with a range of machines currently available on the European market, during dedicated machine trials. Overall, seven different machines were tested. Tests took place within the scope of several machine trial projects, which explains the loose experimental design. This could not be accurately drawn at the beginning of the trials, because each test belonged to a separate project. However, all tests were conducted by the same principal investigators and with the same methods, which assured consistency. Hence the limited but clear variability in sample size and number, as well as the deviation of the overall design from the exact balanced ideal. Nevertheless, this study gathers a large number of samples and offers a comprehensive set of information, determined with scientific methods and so far unavailable to the international scholar. Statistical analysis demonstrated that this design was adequate for testing the main sources of variability, while too loose for detecting secondary effects.

2.1. Residue yield and harvesting losses

Residue yield was determined by measuring all the mass of residues extracted from fields of known surface area. Harvested area was determined with measure tapes and laser rangefinders. Residue yield was determined by weighing all loads with portable scales, which were calibrated by taking a subsample of the same loads to a certified weighbridge. This procedure offered information on the amount of residue technically available, net of harvesting losses.

Harvesting losses were determined on eight of the same seventeen fields. Five to six square sample plots were randomly placed on each field. The area of each plot was determined with a measure tape, and varied between 20 and 40 m^2, depending on field size and interrow spacing. All residues inside the plots were collected manually and weighed with a portable scale.

2.2. Moisture content

The moisture content of the product before and after storage was determined on 91 samples, obtained from the same fields mentioned above. Five additional samples were collected when chipping vineyard pruning residues stored four months in the form of bales. Each sample consisted of approximately 1 kg of chips, which were put in individual bags, duly tagged and dispatched to the laboratory. Moisture content was determined with the gravimetric method, according to European standard CEN/TS 14774-2.

2.3. Particle size distribution

The particle size distribution obtained with different machines was determined on 84 samples, representing eleven different machines. At least 5 samples were collected from each machine. Most of these samples came from the same seventeen fields mentioned above, although some of them were obtained from additional operations, where it was impossible to determine the surface and the amount harvested. Hence, these additional tests were excluded from the analysis of yields and harvesting losses, and were only used to obtain information on particle size distribution. This was done in order to expand the range of tested machines. In fact, particle-size distribution is especially affected by machine type [19], comminuting device [20], and tool conditions [21]. Particle size distribution was determined on 500 g subsamples with a certified screening device, according to the European Standard CEN/TS 15149-1:2006. Five sieves were used in order to separate the six following chip length classes: >100 mm, 100–63 mm, 63–45 mm, 45–16 mm, 16–3 mm, <3 mm. Each fraction was then weighed with a precision scale. For easier understanding, the different fractions were grouped into three functional classes: oversize particles (>63 mm), large chips (63–45 mm) accepts (45–3 mm) and undersize particles (<3 mm) [22]. This way one could easily check if the chips would qualify for the P45 class, fulfilling the particle size specifications set for residential users. According to European Standard CEN TS 14961, the P45 class identifies a biomass fuel with three conditional characteristics: (1) 80% of the total mass must consist of particles not longer than 45 mm; (2) particles longer than 63 mm must represent less than 1% of the total mass; (3) particles smaller than 1 mm must represent less than 5% of total mass.

2.4. Heating value

Higher heating value (HHV) was determined on 7 samples obtained from a subset of the original seventeen fields. HHV was determined according to the European Standard CEN/TS 14918. Samples were ground with a rotating-blade mill and compressed into one-gram sample pellets [23]. Pellets were burned into a IKA C 400 adiabatic bomb calorimeter. Before starting actual measurements, the calorimeter was checked with 16 individual calibration runs.

2.5. Concentration of pesticides

Chemical contamination by pesticide residues was determined on 21 samples collected from five fields, at two different times. The first batch was collected at the beginning of the pruning season and the second at its end, in order to test the effect of weathering on contamination levels. In northern Italy these two periods coincide with the months of December and March, respectively. These fields were not part of the original pool of seventeen fields mentioned above. However, all fields were similar in terms of size, grape varietal and plant layout, and were all managed with conventional techniques, which included regular spraying with pesticides. Organic vineyards were excluded from the sample, because