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Research paper

Utilization of vineyard prunings: A new mechanization system from residues harvest to CHIPS production

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ABSTRACT

Italian wine-making covers 18.4% of global production and represents the world's largest production. Cultivation of the vineyards foresees the winter pruning necessary for preparation of the next year's production. The annual pruned biomass (1–3 t ha^{-1}) is considered waste and is managed by shredding or burning. The possibility of taking advantage of the pruned material in order to obtain biomass for heating purposes represents an alternative that can turn waste into a further product of the vineyard. The easiest form in which to manage the pruned biomass for energy purposes is that of wood chips. Chipping, however, requires specific equipment and has to deal with the problem of residual humidity. Moreover, transport to a processing center represents a critical extra cost. Aim of this study was to evaluate the feasibility of a new mechanization system based on the harvest of the pruned biomass in small diameter (450 mm) round-bales, their natural drying in stacks and then in chip the whole round-bales with a purpose-designed mill, powered by the tractor power take-off (PTO) itself. The trials, carried out in a typical North-West Italian wine-producing area, show that the bottleneck represented by the high water content of prunings directly chipped in field, doesn't represent a limit with the proposed system that foresees a period (4 months) of natural drying of round baled prunings before their energy (thermal) use. Further transformation processes for bulk density increase (i.e. pellet formation) have been considered as upgrade of the system.

1. Introduction

The continuous increase in fossil fuel costs and the major problems related to pollution, have generated long debates and lines of research to find energy alternatives that respect the ecosystem.

Several studies have been carried out on the energy use of pruning residues [1–7] but, at present, activities using residues of forestry origin predominate. Branches left on the ground as a result of pruning in vineyards are a residual biomass often conceived by the farmer as only a burden to be disposed of.

However, the amount of residues obtained from winter pruning is not negligible and it could be considered interesting for energy purposes. Nevertheless such residues have been used, to date, essentially as soil conditioner as they allow to recover about 25% of the yearly soil organic matter demand [8]. Residues of pruning are estimated to amount on average 2.3 to 2.4 t ha^{-1} and can provide up to 0.4–0.8 t ha^{-1} of humus together with non-negligible quantities of minerals (10–30% of annual requirements in macronutrients and 30–50% in micronutrients) [9]. In some cases, the branches are chopped in the vineyard for their return as organic matter and minerals to the soil with the problems however, related to the time of decomposition and mineralization and the risk of grapevine diseases. In other cases, the farmer opts for burning the residues in the field, which is without an economic return and in conflict with some regional regulations on air pollution. The possibility of recovery for energy purposes depends on economic conditions, the slope and size of the plots, the distance between the rows and the canopy management system. Moreover, there are logistical issues related to the mechanization of harvesting and location of the site of use. The recovery of pruning residues can be achieved with different methods [10] and equipment, whose development has derived from the modification of agricultural machinery already used for other operations. This machinery collects prunings arranged in swathes, treats (chopping or baling) and handles them in an appropriate manner [11,12]. Baling in the field, carried out either by a square or round baler, allows packing of the agricultural prunings into homogeneous units and their adaptation to farm needs. This system is not prone to fermentation risks because it is now possible to chop the baled prunings after a period of natural drying. Moreover,

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the proposed system does not need any supplementary operation of – and device for – mixing and handling the drying material. Currently being studied is rationalization of the work chains based on using balers powered by narrow-track tractors, reduced mass and low-power consumption that can reduce the apparent mass of wood cut and create regular packages easy to handle and also to use as an energy source in commercial heaters. However, one of the critical aspects related to the use of balers is now the need to collect the bales produced and deposited along the interrows, which increases the total working time. A purpose designed baler-accumulator was introduced to clean from prunings the interrow space up to 240 m in length in a single pass. The bales of pruned material are deposited first along the headlands and then stocked in a covered building at the farm, for natural drying. No other device or operation is needed for mixing and handling. Finally, the dried bales are shredded by a simplified mill in order to obtain wood chips ready for use in heaters.

With this goal in mind, CAEB International (Petosino di Sorisole, Bergamo, Italy) designed and manufactured a novel micro-plant for pruning harvesting, shredding bales and producing wood chips for use in vineyards and orchards in order to reduce the overall economy of pruning management and energy production. Setup trials were performed in a typical Italian wine production area during the winter pruning season, followed by a period of natural drying before the chipping and storage of the material for subsequent energy use as wood-chips. The purpose of the research reported in this study was to test the working capacity of the system composed of a round baler – provided with an innovative system of accumulation and displacement of formed bales – and a simplified shredder to obtain dried wooden chips.

2. Material and methods

2.1. Prototype plan design and built up

The prototype plant was composed of a harvest machine and a shredder. The harvest machine (Quickpower, CAEB International, Petosino di Sorisole, Italy) is a round baler connectable to an accumulator (Fig. 1). The latter is suitable for containing 7 bales. Consequently, this machine combination has a range of 120–240 m considering 8 bales stored (7 in the accumulator and 1 in the baler) and 20–30 m of theoretical average distance for each single bale before being discharged into the head. The bale chamber - 450 mm in diameter, 600 mm width - was fitted with special lateral disks to reduce friction and power demand. The measured minimum power required by the baler was 15.0 kW enabling it to be combined with a 4 WD narrow-track tractor of 36.7 kW nominal power. The speed of the rear power take-off (PTO) of the tractor used to provide rotational power to the baler was set to operate at values ranging between 6.7 and 7.5 Hz (400–450 rpm).

The baler was provided, alternatively, with two tie systems (Fig. 2). For these alternatives, it was considered that the net system is generally faster when tying but the net has to be disposed-of as waste after use, while the twine knotter is slower when tying but the natural sisal can be reused (or directly burned if the bales are introduced as-they-are into boilers which door diameter is suitable).

Fig. 1. The harvest machinery combination composed of a narrow-track tractor, a small diameter round baler and a baler accumulator.

Fig. 2. The baler was used, alternatively, with a plastic net tying system (left) or a twine knotter based on natural twine (sisal; right), in order to obtain bales secured with materials eventually compatible with direct burn-up.

Fig. 3. The bales' accumulator is able to unload automatically the 7 bales stored into the tunnel, while the bale contained into the baler chamber is discharged at the end of this operation, independently.

The bales were automatically discharged on the headlands (Fig. 3) and then manually loaded on a trailer to be transported to the farm for drying. The drying of the prunings occurred indoors - for these trials in a barn - and naturally. To facilitate this latter operation, the bales were stacked horizontally, in layers up to 5 and on a grid made of simple wood pallets used for multi-way transport (Fig. 4); no other operation was needed for the material to dry out. Considering that the bales weighed 27.7 ± 1.9 kg (average, standard deviation), these operations (trailer load/unload and stacking in layers) were performed manually.

Taking into account the favorable season for drying the baled prunings (late winter – spring – early summer) before their use, a maximum period of 4 months of natural aeration was considered for this operation.

Fig. 4. The harvested bales are stored over a grid of wood pallet in up to 5 layers for a natural drying period. Note, on the left, the twine-secured bales and, on the right, the net-tied ones.