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The improvement of hog fuel by removing fines, using a trommel screen

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ABSTRACT

The study tested the use of a trommel screen originally designed for compost materials to reject oversize particles from hog fuel, processed from several sources and by two different comminution devices. The experiment consisted in screening material previously comminuted by a convertible crusher, designed to use both hammers and knives. Three different feedstock types were used, and namely: discarded pallets, logs and branches from park maintenance. Each feedstock type came in two different qualities, depending on the tool used for comminution, i.e. hammers or knives. Trommel screen productivity varied between 4.2 t h^{-1}, and 5.2 t h^{-1} of oven dry material. Screening hog fuel derived from pallets was 30% and 40% less productive than screening fuel derived from logs and branches, respectively. Screening cost varied from 16.2 € t^{-1} dry material in the case of branches, to 19.9 € t^{-1} oven dry material for pallets. Screening allowed an increase of fuel quality only when applied to pallet-derived hog fuel.

1. Introduction

The demand for wood biomass has consistently increased in the last years in Italy, as a response to the new and ambitious EU renewable energy strategy. Italy has received the EU Directive 2009/28 CE in her National Action Plan approved in 2010. In this new plan, biomass plays a major role, becoming the main renewable source and accounting for 44% of renewable energy production [1]. As a consequence, there is now a strong competition between energy and conventional industrial users for the available wood resources. Wood-based board producers currently complain about a shortage of raw material and hold the new energy users as the main culprits. However, not all the energy users demand for the same raw material. While small and medium size biomass plants require high-quality wood fuel, larger installations are less demanding and are currently targeting low quality sources, due to their substantially lower price. Low cost cellulosic material could also be targeted by the growing biorefinery sector, for conversion into a whole new generation of bio-based products [2].

Low-quality wood waste contaminated with nails and dirt is usually comminuted with crushers, fitted with blunt tools (hammers) and capable of producing hog fuel, a coarse feedstock within the particle-size specification of large-scale automated boilers. Bigger plants are less sensitive to the presence of oversize particles, rather abundant within hog fuel [3]. Among biomass manufacturers there is a constant effort to ameliorate low quality wood biomass and increasing its suitability for energy use, with the aim to achieve a higher market price.

Thus, several machine makers now offer a new line of horizontal crushers that can be temporarily converted into

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chippers by replacing the standard blunt hammers with sharp knives [4], therefore producing a more homogeneous end product. These machines offer improved particle size distribution, with both hog fuel and standard chips. If used as fuel, wood quality is defined by such parameters as moisture content, ash content, and particle-size distribution (EN 14961-1:2010).

Particle size distribution is one of the most important parameters for an efficient combustion at heating plants [5]. Particle size distribution is important also during storage, as it affects caloric value [6] and durability [7]. Conversion efficiency and emission rates are also influenced by particle size distribution [8]. In particular, gasifiers are most sensitive to this parameter [9], while circulating fluid bed boilers are most tolerant [10]. Particle size and shape play a crucial role with handling: long irregular particles tend to bridge over openings [11], especially when fuel moisture content is high [12]. In contrast, fine particles reduce the air flow within chips piles, accelerating microbial decay, raising internal temperature and increasing the risk of self-combustion [13]. Particle size distribution is the result of many factors, and especially chipper type [14], feedstock type [15], blade wear and screen size [16]. Unfavourable particle size distribution can be improved through screening, which is routinely implemented when using wood biomass in fast pyrolysis reactors [17]. In contrast, screening before direct combustion is not a generalised practice and is performed occasionally, often at a semi-experimental level [18]. Hence the difficulty in prospecting its full potential, once the market and the technology will be mature. Very little information is available on this topic in the scientific bibliography.

The goal of this study was to analyse the performance of a trommel screen specifically designed to ameliorate the characteristics of woody and herbaceous biomass from park and riverbeds maintenance before composting. The experiment aimed to determine: a) the productivity and the cost of the mechanical screening process and b) the quality improvement obtained when applying a composting screen to hog fuel. For the latter purpose only material of dimensions included between 3 and 63 mm ("accepts") was considered suitable for a medium size biomass plant. Material smaller than 3 mm ("fines") and bigger than 63 mm ("oversize") was considered unsuitable.

2. Materials and methods

The Authors tested a trommel screen, used in the composting sector to separate organic wastes into different size fractions. The machine was a Caravaggi V3000D mobile drum screen [19], produced in Italy by Caravaggi mfg. in three models: 2000, 3000 and 5000. Model numbers refer to drum length, in mm. In the test model, the rotating drum measured 1720 mm in diameter and 3550 mm in length. The rotating drum was fed by an auger conveyor, which had the additional task of refining coarse materials. The drum structure supported perforated screen plates: particles smaller than the screen mesh size would fall through it and onto a belt conveyor for moving to the small particle heap, to the side of the machine. Larger particles were moved to the end of the drum and dumped on a second conveyor belt for discharge onto a second heap, just at the back of the machine. Screen plates were interchangeable and came in different mesh sizes, to be selected according to job type. The machine on test was fitted with 20 mm-wide square mesh screen plates. It was powered by a built-in 44 kW diesel engine and installed on a two-axle trailer for transportation. Drum rotational speed was set to 0.25 Hz. All the screening functions were electronically controlled and visualized on a digital panel. The screen was served by a 70 kW farm tractor, equipped with a front-end loader. The tractor was used for relocating and feeding the screening machine, so that the trailer-mounted screening device, the tractor and its driver represented a fully independent small scale hog fuel screening operation.

Productivity was estimated with a time-motion study, conducted during commercial operation by one of Caravaggi's workers, at the firm location in Palazzolo sull'Oglio (BS), in Northern Italy.

The study consisted in screening material previously comminuted by a convertible horizontal crusher [4]. The crusher was equipped with a high-speed drum structure carrying 44 hammers, in four rows. As an alternative, the drum could be fitted with a series of fixed knife mounts, for conversion into a chipper. In the latter case, the total number of tools was halved to 22. Therefore, the convertible crusher was designed to use both hammers or knives, depending on raw material type and conditions. Conversion between the two configuration was simple, and would take ca. 4 h. Three different feedstock types were used for the experiment, and namely: discarded pallets, forest logs, residues from park maintenance. Pallets conformed to EU standards and were made of pine planks (*Pinus nigra* Arn.) discarded by a local construction company. Logs came from the cleaning of a country road and were an even mix of Austrian pine (*P. nigra* Arn.) and Black locust (*Robinia pseudoacacia* L.), in 2–3 m lengths. Park maintenance residues – originated from urban greenery in the town surroundings - consisted of branches from many ornamental tree and shrub species, and especially *Magnolia grandiflora* L. and *Cupressus* Sp., representing respectively 40% and 55% of the total bulk volume of the park residues. Minor amounts of palm branches were also included within the park maintenance residues. The average moisture content of the different feedstock types was 25%, 42% and 45% respectively for discarded pallets, logs and park maintenance residues. All feedstock types were processed with the convertible crusher in both configurations. Therefore, the screening experiment included 6 treatments, derived from the combination of 3 feedstock types and 2 comminution modes. Each treatment was replicated 3 to 4 times, depending on product availability. Each replicate consisted of a big bag of hog fuel, weighing between 170 kg and 410 kg (mean 270 kg). Big bags were weighed before screening, using a load cell connected with a hook to the bag handles, and hoisted with a forklift until the bag was fully suspended. The scale had a rated accuracy of 200 g. The weight of the big bag and the hook were subtracted from the reading. A second big bag was tied to exit of the large size particle evacuation conveyor, to collect all the product. This was weighed with the same method described before. The weight of the small size particles passed through the screen and into the small particle heap was