Poplar woodchip storage in small and medium piles with different forms, densities and volumes

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Abstract

Wood biomass is one of the main sources of biofuel for bioenergy production worldwide. Generally, the exclusive use of comminuted biomass in automated boilers is preferred because these woodchips consist of homogeneous particles with a specified size. Wood biomass is harvested mainly in autumn and winter, whereas the demand for biomass-fired power stations is continuous throughout the year. Nevertheless, large amounts of woodchips are also produced in the spring and summer from residual materials obtained from the utilisation of conventional poplar plantations. This study focused on uncovered small and medium woodchip piles. In particular, the influence of form, density, and the size of piles on the biofuel quality during woodchip storage was analysed. The woodchip moisture contents and dry matter losses were considered when evaluating the storage dynamics.

The results suggest that a storage system can be selected to service only the needs of thermal stations because any difference between the form (trapezoidal and cone), volume (35 and 70 m^3), and density of the piles was ~~highlighted by the~~ observed on woodchip quality analysis. In fact, a mean moisture content of 18% and average dry matter losses of 10% were recorded at the end of storage period for all treatments. Notably, the climate conditions and storage periods affected the results of this experiment.

Keywords: Poplar woodchips, storage, uncovered piles, ~~form piles,~~ natural drying, losses

Introduction

Wood biomass is one of the main sources of biofuel for bioenergy production worldwide [1]. Generally, the exclusive use of comminuted biomass in automated boilers is preferred because woodchips consist of homogeneous particles with a specified size. Moreover, chipping offers additional benefits in terms of an increased load density and improved handling quality [2].

Chipping may take place during timber harvesting or some months after tree cutting. At present, two different groups of machines can be use in chipping operations: chippers, or machines that use sharp tools (knives) to cut or slice the wood; and grinders, or machines that use blunt tools (hammers) to smash or crush the wood [2]. In particular, grinders are used for contaminated wood, as their blunt tools are less sensitive to the wearing effect of contaminants, but these machines generate a rather coarse product that is unsuitable for use in some plants [3]. In contrast, chippers are exclusively applied to clean wood and offer a finer and better product [1]. In addition, the chippers used to produce woodchips for energy uses can be divided by function based on their knife support: disc and drum [4-5].

Generally, wood biomass is harvested in autumn and winter during tree felling and short rotation coppice harvest. Nevertheless, woodchips can also be produced in spring and summer from residual materials obtained from the utilisation of conventional poplar plantations.
Independent from the harvesting period, the demand of biomass-fired power stations is constant and may contrast the farm’s activities [6]. Creating a fuel buffer in the farm to secure the availability of biofuel at all times may solve this problem [7]. Furthermore, biomass storage in the farm is an interesting option for power station because it generates woodchips with a ~~high market value~~ low moisture content.

The woodchip can be stored in different ways in terms of site condition functions [8], and logistical strategies [9]. Nevertheless, many studies have shown that long-term woodchip storage (over three months) can cause significant dry matter losses and a consequent net energy value reduction [10-12]. In fact, these dry matter losses can reach 20% of the initial value for a storage period of one year [13-15]. Woodchip storage methods and their associated problems have been well documented in the literature [11-12, 16-19]. Wood chips stored in small-sized piles can be used in different covering systems in order to guarantee good calorific values and limited energy losses [20]. By contrast, the storage of wood biomass in large piles is only possible outdoors, where the piles are uncovered due to logistical and economic reasons [21]. Nevertheless, previous studies in northwestern Italy have shown that uncovered storage is better than covered storage for small piles as well [20]. Until now no study was focused on pile characteristics (form, density, and volume) used in woodchip storing.

For this reason, the goal of this study was to analyse the influence of the form, density, and volume of uncovered piles on the quality of the biofuel during woodchip storage. In particular, this study focused on uncovered small and medium piles.

Materials and methods

The experiments were conducted in north western Italy (Vinovo town near Turin) between June and September 2012. During this period, this geographic area produces relatively large amounts of woodchips from the logging residues of conventional poplar plantations. Unlike previous studies, a short period of four mouths was selected because the air temperature was high and the woodchips dried quickly.

The tests compared different forms of piles for woodchips storage: small (35 m^3) and medium (70 m^3) piles; trapezoidal and conical forms; and low (340 kg m^{-3} fresh matter) and high (470 kg m^{-3} fresh matter) material density. The volumes of the piles were relatively small because the area used for the trial was limited (approximately 1200 m^2). In this study, the tests were conducted using only poplar woodchips produced from the logging residues of conventional poplar plantations (*Populus x Euramericana* G., clone I-214).

Small piles were built with the load from one wagon trailer used for woodchip transportation (35 m^3), while the medium piles were built with the loads from two wagon trailers (70 m^3). Different geometric forms (trapezoidal and conical) were compared only for piles with medium volumes. Notably, the piles appeared to be of different sizes due to their geometrical forms and volumes (Fig. 1). The woodchip density was increased following the method used for maize ensilage, in which the woodchips were pressed with vehicles. Therefore, the density was compared only for trapezoidal piles. Wood chips were pressed with a telescopic handler, which was used to build the pile. The volumes of the compacted piles were estimated by measuring their size after wood chip compaction.

Each test consisted of a single pile and was replicated three times for a total of 12 replicates (table 1). All piles were made on a concrete floor using a random method. None of the piles were covered.

Wood chips were produced from fresh logging residues (approximately 15 cm in diameter and 9.5 m in length) and, consequently, woodchip was mixed with leaves. A drum chipper (Pezzolato PTH 900) was used to comminute the wood. The moisture content and temperature of woodchips were used to evaluate the storage dynamics. These two parameters are reliable indicators of the storage dynamics of wood used in energy production [21]. Therefore, they were monitored for all storage period considered (June – September). The temperature inside each pile was monitored using a thermocouple, and the moisture content of the woodchips was measured with an electrical hygrometer (GANN®Hydromette HT85T), which is normally used in sawmills and includes a prototype probe developed by DISAFA (University of Turin). The probe of the hygrometer consist of two short steel electrodes (20 mm) and is designed for registering the external moisture content of logs. In this experiment, the probe was substituted with a prototype made by inserting the electrodes directly into a particle wood and wiring them to the hygrometric unit. The gravimetric method [22] and woodchips with physical characteristics equivalent to those used in the tests were used to set up the probe. The accuracy of this sensor was 1% in moisture content. During the first 30 days, the measurements were performed daily, then every three days. The high frequency of reads during the first 30 days was performed to evaluate temperature peaks, which occur primarily during this period [14, 16, 20]. The sampling points were located in the middle of the pile at three different heights (0.5 m above the ground, centre of pile, 0.5 m under the pile surface) (Fig. 1).

In this study, energy losses were expressed in terms of weight (dry matter) and volume. Small piles showed a volume of a single trailer, while medium piles were built using the loads of two trailers. The trailers were weighed by a certified weighbridge before being offloaded. The volume of wood chips was calculated by levelling the load to the tops of the caisson trailer sides. At the end of the storage period, all single piles were reweighed and the dry weight was calculated as a function of the moisture content of the wood chips.

The weather conditions, including the air temperature (C°), air humidity (%) and precipitation (mm), were monitored by a dedicated weather station sited near the piles. The values were recorded every hour.

The particle size distribution affects the air circulation into the chip piles and therefore can influence the storage performances [12]. In this study, the air permeability was estimated using the coefficient (A) defined by Nellist [23]:

$$A = 19125 * P^{-0.874},$$

where P is the mean of particle size expressed in mm.

This coefficient was calculated only for uncompacted piles.

The size of the woodchips used in the tests was determined following the European Standard EN 15149-1: 2011 using 1 kg samples. In particular, the wood chips were split into eight classes: <3.15 mm, 3.16-8 mm, 9-16 mm, 17-31.5 mm, 31.16–45 mm, 46–63 mm, 64–100 mm, and >100 mm.

The wood energy content (Low Heating Value) was calculated according to the following formula [24]:

$$LHV = Wdw * Es - Ww * Ew,$$

where:

LHV = wood energy content (Low Heating Value) (GJt^{-1}),

Wdw = dry wood weight (t),

Ww = water weight (t),

Es = the specific energy content of dry poplar wood (19 GJ t^{-1} [7]), and

Ew = the amount of energy needed to evaporate the water in wood (2.5GJt^{-1}).

The data were processed with Microsoft excel and SPSS (2013) statistical software. Eventual differences between the trials were checked with the Ryan–Einot–Gabriel–Welsch (REGW) test because it has a higher statistical power given this data distribution. This study adopted a significance level of a = 0.05.

Results

~~80%~~ Eighty percent of the comminuted wood used in the trials was in the form of chips, with sizes between 8 and 45 mm (central particle size class) (Fig. 2). The average particle size of the comminuted wood was 31 mm, and the permeability coefficient calculated was 951.

During the test, the air temperature ranged from 17 to 28 °C. A mean value of 23 °C was recorded over the entire storage period. The air humidity ranged from 56% to 62% (monthly average), with peaks occurring during rain events (Fig. 3). The total precipitation was 50.6 mm of rain.

Fig. 4 reports the temperature trends obtained from the different piles. The trends for all piles are similar, and all piles showed gradual descending temperature trends. The higher temperature values were obtained a few days after building the piles. Subsequently, the values exhibited a constant decline until reaching equilibrium with the air temperature after approximately 50 days.

The temperature values obtained over the entire storage period at the different measurement points are shown in Table 2. The data processing showed no significant differences between the values recorded in the same test and time period at three different heights.

The moisture content of the woodchips decreased during the entire storage period, with similar trends for all pile types tested (Fig. 5).

All chips originated from the same stem stack. Thus, the initial moisture content was the same for all treatments. We therefore assumed that the general trends presented in this study are representative of the differences in treatment.

The statistical analysis did not show any significant differences between the moisture content readings obtained from the different heights (Table 3).

Table 4 and Figure 6 show the initial and final mean volumes, the green weight and the dry matter losses determined for the different types of piles. An average dry matter loss of 10% was recorded for all treatments.

Discussion

The results obtained in this work are similar to those obtained in other Italian [20, 25] and northern European [26] studies comparing different storage techniques. In these studies, chip piles covered with different materials (plastic sheets, semi-permeable fleece sheets, and roofs) and uncovered chip piles were analysed. In detail, the dry matter losses obtained in this study (10%) are similar to those recorded in other experiments using uncovered chip piles.

In contrast, our results for moisture content differ from those obtained in other studies conducted in northern Europe [7, 17, 19, 26]. This is because the Italian climate is drier, which limits re-wetting. In fact, rain events are rare in northwestern Italy, especially in the summer reason (the storage period chosen in this study). These favourable weather conditions contributed to drier wood chips (20%) after only 30 days of storage. In northern Europe or in the same locality but with different weather conditions, storage periods of up to 180 days may be necessary to obtain drier wood chips [19-20]. Notably, drier woodchips offer a high reward, especially in the residential heating market sector [27].

All treatments showed an early temperature trend that can be taken as an indication of biological activities inside the piles, which is the main cause of dry matter losses [7, 21]. As in other studies, early temperature peaks were recorded during the first ten days of storage [28]. Differently the temperature inside the pile were lower than 15% compared to values the same authors found in other work carried out in the same geographical area [20]. That difference could be attributable to different storage period considered: summer in this study, and spring/summer in the previous experiment [20]. The compaction of the woodchips, which drove out air, did not limit the biological activity. The temperature recorded in high density piles was similar to that observed in low density piles. One reason for this could be the leaves presence in the woodchip and the high environmental temperature during the experiment period.

Moreover, no differences were observed between the forms (trapezoidal and conical) and volumes (35 and 70 m^3) of the tested piles. These results suggest that a storage system can be selected to service only the needs of thermal stations.

Care should be taken when interpreting these results because only poplar chips wood were tested. This forestry species is less durable than other forestry species used to produce woodchips. The relative permeability offered by a rather large chip size facilitated water movements. In this study, the permeability coefficient of wood chips was estimated to be approximately 900 (31 mm chip side), which is a relatively low value compared to those obtainable from fine woodchips (1500) [29].

The different dry matter losses obtained in other studies conducted in Britain [17] using willow, a species very similar to poplar, are probably due to the different climate conditions and storage period (winter). In fact, the high dry matter losses (20%) recorded in northern Europe could be linked to a wetter Atlantic climate and season, which cause high proliferation rates in fungi and pathogens.

The present study also showed that all tested treatments resulted in sufficient moisture loss after 30 days of storage (approximately 18%). This moisture loss can guarantee the use of woodchips in any processing type, including industrial boilers [30], co-firing [31], pulping [32] or green chemistry [33].

The results obtained in this experiment strongly depended on the period during which the storage occurred and particularly on the very low levels of precipitation that characterise Italian summers. Under Italian climate conditions, the rainfall normally exceeds 50 mm during the other seasons. In fact, another Italian study documented very high dry matter losses and limited drying for the same type of chips stored in trapezoidal and uncompacted piles for six months across the winter and spring seasons [25].

Finally, the logging of conventional poplar plantations often results in a summer availability of logging residues for use in wood chips production. This reduces the drying time of the wood chips and, consequently, the dry matter losses independently of chip pile form, size and density relative to wood chips produced from dedicated plantations, which are normally harvested in winter.

Conclusions

Under the conditions of the northern Italian summer, the forms and sizes of the uncovered wood chip piles considered in this experiment do not influence the final poplar woodchip quality. Furthermore, the woodchip density during the storage period did not affect the biofuel quality in this study. These results are relevant to the wood biomass storage sector because a power station or farm can build biofuel piles only as a function of its logistic requirements.

Notably, the climate conditions affected both the storage dynamics and the results obtained in this study. In the future, it could be interesting to carry out experiments using wood chips produced from other tree species, thereby allowing the evaluation of the differences between those results and the results obtained in this study.

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