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Research paper

Performance evaluation of different techniques for firewood storage in Southern Europe

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ABSTRACT

At present, many farmers prefer to use firewood instead of comminuted wood because it has a lower production cost and limited microbial activity during storage. The goal of this work was to assess the drying storage dynamics of different techniques for firewood storage adopted in Southern Europe (uncovered piles, piles covered with plastic sheets, and piles situated under roofs). In particular, the storage dynamics of firewood were analysed for three different tree species (poplar, beech, and black locust) for a period of 180 days (March–September). Storage dynamics were evaluated for the following key drying physical parameters: moisture content, temperature, heating value, dry matter, and ash content. Initial values of key parameters were different for all forestry species tested. Uncovered piles showed the same drying performance as piles under roofs. After the 180-day drying period, all three species showed a moisture content of about 18% and a lower heating value of 14.52 MJ kg^{-1}. In contrast, storing firewood in piles covered with plastic sheets did not show benefits in terms of moisture content losses and lower heating value increments. No variations were observed between initial and final values of the storage period for temperature, ash content, and dry matter losses.

1. Introduction

Firewood is the oldest and most common source of energy in many countries [1]. It is used as a primary energy source in developing countries [2], while in industrialised countries, it is only used integrated with fossil fuel [3]. In Europe firewood use is preferred [4], especially in Northern Europe where it is burned in domestic stoves for heat production [5,6]. In contrast, in southern European countries (e.g., France), firewood has limited use compared to the European average [7].

In general, firewood use has spread to the global level because its production process is easy, and it requires a limited investment [8]. Firewood preparation consists of cross-cutting and splitting the logs using manual tools or specific equipment [9,10]. That operation, independent of the geographic area considered (Northern [11] or Southern Europe [12]), is carried out not only by forestry companies, but also by private farmers who produce firewood mainly for personal use [13]. For this reason, the use of firewood can become an important activity for economic development in areas where coppice forests cover a large surface [14].

The main problem with firewood use is its moisture content because the value can affect the composition of the chemical compounds realised during combustion [15]. In addition, when the moisture content is higher, the firewood has a lower market value because it cannot be used directly in small boilers or stoves [16] due to its lower calorific value [17]. A solution to this problem can be the storage of firewood in piles for a period of time that is variable with respect to the geographic area considered [18]. In fact, in the Mediterranean zone a period of 3–6 months can be sufficient [19], whereas in Northern Europe the wood cannot be considered dry in less than 2 years [20].

At present, many farmers prefer to use firewood instead of comminuted wood thanks to limited microbial activity [21] and low dry matter losses (2% per year) [22] recorded during the storage period. Furthermore, stored woodchip can be dangerous because the internal temperatures of piles can reach values up to 70 °C (possible spontaneous combustion) [23].

In the literature, it was possible to find many studies focused on wood biomass used for energy production. Some works regarded woodchip characteristics with respect to the different tree species used for production: poplar [24], willow [25] or pine [26] or its storage dynamics, taking into consideration different drying methods [27], pile sizes [25], and coverage techniques [23,28]. Others were focused on logwood storage [18,19,29] or the environmental impact of the energy of wood production [30]. In contrast, few studies were carried out on firewood production [31] and no studies were focused on firewood storage, especially on the performance of storage techniques used

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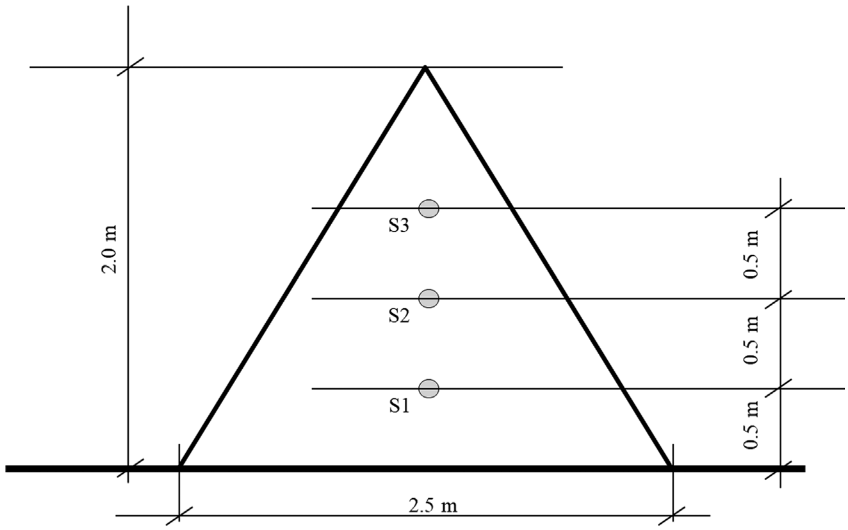

Fig. 1. Sample points inside of the piles.

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Based on this, the experimentation carried out was to be a first contribution to this topic. In fact, the goal of this work was to assess the drying storage dynamics of different firewood storage techniques adopted in Southern Europe (uncovered piles, piles covered with plastic sheets, and piles situated under roofs). The storage dynamics were analysed in detail and took three different tree species (poplar, beech, and black locust) commonly used for firewood production into consideration.

2. Materials and methods

This study was conducted in Moncalieri near Turin, Italy (45° 00′ 31″ N, 7° 42′ 53″ E; 356 m above sea level). The experiments were carried out during the spring and summer of 2014 (March–September) because this is the usual period to store firewood in Italy; logs are harvested until March, and firewood starts being used in October.

In this study, the main storage system used for firewood (under a roof) was compared to the other two storage techniques adopted: piles covered with plastic sheets and uncovered piles. The plastic sheet cover system is used by forestry operators due to its low economic cost and higher adaptability to pile sizes and forms, while uncovered piles are a storage technique that is sometimes adopted when the space under the roof is already fully occupied.

Tests were performed using two high-density tree species (beech—*Fagus sylvatica*—and black locust—*Robinia pseudoacacia*) and a low-density tree species (poplar—*Populus × euroamericana*). In northern Italy, these tree species are most common in forests and agricultural areas, and consequently they are usually used for firewood production [8,19].

The firewood used to make the piles was 0.33 m in length and had a diameter of approximately 200 mm; before being piled, the logs were split into two equal parts along the longitudinal axis. Firewood was obtained by subdividing stems of 2 m in length into six equal parts (in Italy, unprocessed firewood is commercialised at this length [32]). Stems were cut using a circular saw (Balfor® SC 750 C) powered by a 45 kW tractor. Logs were split successively using a log splitter (Comac® T16) with a force of 16,000 daN, powered by a 34 kW tractor. Each pile was made using a 5 m conveyor belt with a working height of about 3 m (SI·CO®). At the end of its preparation, each pile had a conical form of approximately 2 m in height and 2.5 m in diameter (an approximate firewood volume of 2.20 ± 0.10 m^3). A height of 2 m was chosen for the piles because this is the common piling height achievable by all small-scale firewood processing equipment used for cross-cutting and splitting logs into stove wood [8]. All piles were built on a concrete floor and were exposed to the sun. The experimental design included the realisation of 27 piles: three storage techniques and three tree species replicated three times.

Considering that moisture content, temperature, calorific value, dry matter losses, and the ash content of the material are the common key parameters considered in the evaluation of storage technique performance of firewood [33], in this study, all these parameters were analysed for each pile.

2.1. Moisture content

The moisture content of the wood was monitored using a hygrometer (GANN® Hydrometer HT85T) usually used in sawmills to determine the external moisture content of logs. The use of this instrument was possible because it was coupled with specific probes set up ad hoc by the University of Turin [19]. These probes were made with two steel electrodes (30 mm length) linked to a central unit by an electrical wire and appropriate connectors. Probes were fixed at the mid-length of a single log (approximately 0.16 m from the head). By using this probe type, it was possible to monitor the moisture content of the firewood without disassembling the piles. The accuracy of the measurement performed by this probe was tested by Manzone and Balsari [34] and was found to be 1% of the moisture content. Nevertheless, at the beginning and at the end of storage, the moisture content of the woodchips was determined using a gravimetric method [35]. In all piles, three sample heights from the soil were individuated (0.5, 1.0, and 1.5 m) and at each sample point, three probes were placed (three repetitions). To reduce data effect of meteorological events, probes were placed only in the middle of the piles and not on the external surface. This procedure was adopted also in other studies focused on woodchip storage in which different storage techniques were compared or in which storage dynamics were analysed (Fig. 1) [23,34]. Data were recorded every day for the first 30 days, and every 15 days thereafter. The reason for a different sampling frequency was the wish to capture the initial moisture loss peak and its effect. Later, moisture variations were much smoother, justifying longer sampling delays.

2.2. Temperature

Thermocouples with a readability of 0.1 °C were used to determine the temperature inside the piles. A single thermocouple was placed on each point of moisture content measurement. This parameter was also monitored every day for the first 30 days, and every 15 days thereafter.