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Research paper

Long term storage of poplar chips in Mediterranean environment

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ABSTRACT

Industrial poplar plantations reach maturity in about 10–15 years, showing a wood productivity that is hardly achieved by other broadleaf species. Among the possible uses of this product, the energetic production is one of the most promising as it can offer additional revenues to plantation owners. However, the difficult handling and the large volumes occupied by crowns during storage decrease significantly the convenience of the recovery. Therefore, efficient and affordable storage methods need to be identified in order to make this product more manageable and profitable. The main goal of the research is to understand the dynamic of a long-term storage lasting 18 months and the effects of storage on fuel quality in both stem and crown of poplar chips. Storage performance were evaluated with respect to moisture content, dry matter losses, particle size distribution, bulk density, and fuel quality before and after storage. Contrary to the results obtained in Northern climates, this study revealed the poor storability of poplar chips, regardless the plant component (bole, branch, crown) considered, showing in the worse cases dry matter losses higher close to 50% and final moisture mass fraction increases to about 70%.

1. Introduction

Worldwide, *Poplar* trees are known for their rapid growth and their good ability to hybridize [1]. An industrial poplar plantation reaches its maturity in about 10–15 years, showing a wood productivity that is hardly achieved by other broadleaf species [2,3]. Among the possible uses of poplar, industrial wood production, paper and pulp production and biomass production for energy generation represent three of the most important fields of application [4–6]. Although these sectors are well distinct from each other, they can actually coexist, increasing both the environmental and the economic benefits of poplar cultivation. In fact, products deemed residuals by wood and paper industries such as branches and tree tops can be used to produce bioenergy, offering additional revenues to farmers [7]. The bio-economic outputs of the conversion are very significant, especially if the utilization of tops and brunches is associated with that of residual stumps and leaves. Studies have estimated that the proportion of aboveground biomass, defined as forest residue, range from 31 to 42% of the total [8]. On the other hand, in a literature review of Koopman & Kopejan [9], it is mentioned that the weight ratio between residues and processable woody material in forestry is generally 50:50.

Estimates show that the amount of biomass residues produced in the EU is approximately 80 Mt y^{-1} [8], a quantity which can provide sustainable energy on a large scale. However, the same study stresses that only 8% of this available resource is currently exploited. This is because the tree residues are difficult to collect, and expensive to transport and store.

Storage can be considered as the final step of the biomass-to-energy chain before conversion. It is a necessary step because forest operations are carried out in specific periods of the year, while in the Mediterranean the demand for energy is distributed all year round for producing respectively heat during winter and cold during summer.

During storage the wood is subjected to microbial degradation, which may cause losses in its energy value [10–12].

Energy wood is often stored as chips. Wood chips, unlike whole stems, are easier to handle and transport, but unfortunately they are much more vulnerable to microbial degradation during storage.

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This often leads to high dry matter losses, risk of self-ignition and potential human health risks [13,14].

Many studies have been carried out to analyze the storage dynamics in comminuted wood chip piles [15–20]. In the condition of Northern Europe, studies performed on SRF *Salix* wood chips demonstrated that storage performance are mostly influenced by factors such as chip particle size, pile dimension, air circulation and climatic conditions [21,22]. Other tests performed on willow chips in Poland showed that covering systems can also have significant impact on energy losses, indicating also that long-term storage in open-air can result in a considerable increase in biomass moisture mass fraction, with a consequent decrease in energy content and its large loss, associated with the microbiological decomposition of wood [23].

However, limited information is available concerning the storage of poplar chips, and more specifically about the storage of chipped poplar residues from industrial plantations in the Mediterranean environment.

This study is a continuation of an earlier reported experiment started in 2012, which focused on the storage of poplar chips obtained from the final harvest of an industrial poplar plantation [20]. This work deals with the storage performance of poplar chips, obtained from two tree parts: stem and crown, and stored under conditions typical of Southern Europe. The main goal of the research is to understand the dynamic of long-term storage and the effects of storage on fuel quality in both stem and crown poplar chips.

The previous part of the study [20] covered the monitoring of internal heat development in the wood chip piles, changes in moisture content, dry matter losses and fuel quality as occurring over a storage period of six months. Results from that study showed that crown chips stored better than stem chips. In this current study, the storage period was extended to eighteen months, to follow the storage results of the two chip types in a Mediterranean environment. In this study, temperature monitoring was not performed since the previous study revealed steady temperatures after three months of storage. The other analyses were undertaken and the results were correlated with changes in the particle size distribution of the chips.

2. Material and methods

The experiment took place between April 2012 and September 2013 in Central Italy at the CREA-IT Research Station in Monterotondo (42° 10′ 19″ N latitude, 12° 62′ 66″ E longitude). Chips were obtained from the final cut of a fifteen years-old monoclonal poplar plantation (*Populus* x *canadensis* M.), established at 6×5 m spacing. The tree felling was performed during the plant dormancy with the plants totally free of leaves. The plantation grew on a flat area, characterized by silty soils and included in the basin of the Tiber River.

2.1. Climatic data

The storage trial took place outdoors, with both treatments exposed to the same climatic conditions. Climatic parameters such as precipitation and air temperature were recorded during the entire test. Data were recorded using a weather cab "SIAP-MICROS DA9000" certified by SIAN (National Informative System for Agriculture). The instrument was placed approximately 800 m from the storage site (Lat. 42° 05′, Long. 12° 38′, Alt. 51 m AMSL).

2.2. Pile design and monitoring systems

After tree felling, the stems and crowns were separated and comminuted using a commercial drum chipper, model Pezzolato PH700/660. Six piles of loose chips (three of stem wood and three of crown wood) were built in a flat area near the plantation site. A plastic sheet was placed under each pile in order to isolate the chips from the ground and avoid soil contamination. Each pile was about 10 m long, 8 m wide and 4 m high, with a mean volume of 117 m^3. The size, shape and orientation of all piles were maintained as homogeneous as possible, to ensure the same surface area exposure to precipitation, wind and sun. A plastic net was used to split each pile into two equal halves, so that sampling could be performed at separate times. After 6 months of storage, the first half of all piles was dismantled and sampled before rebuilding it back to the pile. The results of the 6 months storage trials were published [20]. The current work is focused on the remaining half-piles. Within each half-pile, six sampling points were located at three different levels, corresponding to 1 m, 2,5 m and 3,5 m from the ground, designated hereafter as L1, L2 and L3 respectively (Fig. 1). Four net bags, filled with almost 1 kg of fresh chips, were weighed and placed near each sampling point in the pile.

2.3. Fuel quality parameters

Ash content, moisture content, heating value (lower and higher) and chemical composition were determined according to the respective European standards UNI EN 14774-2 [24], 14918 [25], 14775 [26], and 15104 [27].

During pile construction, 24 chip samples of 500 g each (12 from each treatment) were randomly collected and used to perform the initial fuel analyses. Changes in fuel quality parameters were determined after 6 months in the first part of the experiment using the chip samples collected from 36 net bags, one per each sampling point of the six half-piles investigated. The same operation was repeated in this study, (one year later) to analyze the fuel quality parameters after 18 months of storage in the remaining six half-piles.

Dry matter losses were calculated using two methods. In the first method, the chips contained in the 108 net bags (three per sampling point) were dried and weighed. The dry weight of each sample taken at a specific storage time was subtracted from the initial dry weight of the respective sample and dry matter loss was expressed in percentage. The second method consisted of direct weighing of all the chips in the 6 half-piles using a certified weighbridge available at CREA-IT. The half-piles were weighed individually before and after storage by loading and transporting the material to the weighing area using a truck-and-trailer rig. Their dry weight was calculated using the values of moisture content obtained from the initial 24 samples and from the net bags. The results of the two methods were compared for validation.

The bulk density of both stem and crown wood chips was determined according to UNI EN 15103 [28]. These measurements were repeated 24 times at the start of the trial and 36 times (6 replicates for each half-pile) at the end of the storage period.

The particle size distribution of the chips was determined before and after storage using 1 kg samples (10 per treatment) and employing a mechanical sieve according to UNI EN 15149-1 [29]. Finally, the overall changes in energy content were evaluated according the following equation [30]:

$$\Delta En.\% = \left\{ \left[\left(1 - \frac{\text{Dry matter losses}}{100} \right) * \text{final LHV} \right] - \text{inital LHV} \right\} \frac{100}{\text{initial LHV}} \quad (1)$$