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Short communication

Poplar wood chip storage: Effect of particle size and breathable covering on drying dynamics and biofuel quality

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A B S T R A C T

Used as alternative energy sources, solid biofuels have the advantage of simultaneously reduce fossil fuel dependence and mitigate climate changes by reducing greenhouse gas emissions. Biomass storage and handling play a key role for wood fuel quality assessment: in particular, the presence of covering systems influences biomass drying process and factors leading to bulk compaction (e.g. reduced particle size) negatively affect woody biomass preservation till final use. To study the effect that particle size and covering have on biofuel quality, Short Rotation Forestry (SRF) poplar trees were harvested and chipped by means of a Claas Jaguar 890 operating machine equipped with a "GBE-1" header for SRF. The chipping procedure was carried out in March 2009 using on the same header both the standard chipping drum and a special on purpose drum designed by CRA-ING to obtain coarser particles. The chipped biomass was subsequently stored in stacks on a paved surface for a 120 days period to evaluate: i) effect of particle size on uncovered stacks drying dynamic and fuel quality, ii) effect of the presence of non-woven tarp on drying and fuel quality of biomasses standardly chipped with the conventional drum. Coarser stack was found to have a less prompt dehydration and, at the end of the storage period, have less energy and dry matter loss. In case of biomass chipped with the conventional drum, at the end of the storage period the effect of covering ended up in wood fuel with significantly higher heating value.

1. Introduction

Rises in fossil fuel derived energy prices, as well as increased environmental concerns, encourage the use of alternative and renewable energy sources as woody biomasses [1]. These are a low carbon power sources which, thanks also to short rotation forestry (SRF) programs, have become widely available: their energy exploitation has the advantage that the emitted CO_2 amounts are the same that are absorbed during the growth phase. After cutting, storage and handling play an important role for the good quality of wood fuel: at varying of the storage span and of the seasonal changes, wood fuel quality changes as well [2–6]. On average lignocellulosic biomass has an average dry matter (DM) heating value between 16.7 and 18.4 MJ kg^{-1} DM which correspond to 4.65 ÷ 5.11 kWh kg^{-1} DM [7]: good storage conditions result in low moisture content and higher heating value [8] and the importance of this is enhanced by the fact that logging residues are a low value material therefore, any slight change in quality parameters can cause the feedstock to become uneconomical [9].

The freshly harvested wood is particularly vulnerable to microbial attack (both fungi and bacteria) which normally would not reach it because of the presence of the bark. In anaerobic conditions, microbial activity is temperature dependent: very low below 10 °C and when temperature exceeds 65 °C (but in this case, wood degradation goes on thanks to physical-chemical oxidative processes). Temperature has been proven to be a crucial factor during the storage of fresh forest residues [4]: high temperatures lead to high Volatile Organic Compounds (VOC) and gas emissions which, in turn, are positively related to dry matter losses [10,11]. As a matter of fact, during storage, temperatures and moisture gradients inside the stack cause a progressive partial dehydration of wood chips: this, being connected to microbial respiration, involves dry matter losses, the extent of which is related to both meteorological and operating factors like chip size and stack's degree of

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compaction [12]. A lot of space between wood chips enhances air movements inside the stack with subsequent reduction of moisture content and microbial activity; on the contrary, when chip particle size decreases, water absorption and fungal activities are enhanced due to the reduced passage of air between the interstices of the wood mass [3,13,14]. During storage, excessive temperature increase can also lead to spontaneous combustion whose interrelated triggering factors hardly ever can be foreseen and controlled [15,16]. Even the presence of barks and leaves increases stack deterioration [17,18] and increases the risk of fire in the stack [19] so that precautions to be adopted to reduce fire risk are reported [20].

Natural drying is a viable and effective method to enhance energy efficiency of wood based fuel products [21] reducing transportation costs [9]: forest biomass harvested at the end of winter and beginning of spring provide wood fuel with the best performance for energy production [22]. Climate and seasonality influence gain and losses of moisture in wood based materials according to storage duration [23]: spring and summer are the best drying seasons, nevertheless the positive effect of covering stacks to lower moisture content over the winter months has also been pointed out [23,24].

Poplar trees grown in Short Rotation Forestry (SRF) systems are a valuable source of wood fuel in areas with good water availability [25,26]. Plants are usually harvested in the cold season (from December to March) with a biomass moisture content of 55÷60%: is therefore necessary enhance SRF poplar wood dehydration till adequate moisture content is reached. The aim of this work is to investigate the effect of particle size and the use of breathable covering system on the dynamics of drying, as well as on biofuel quality of poplar woody biomass during a springtime 120 day storage period in open air.

2. Material and methods

SRF poplar trees were harvested and chipped with a *CLAAS* forager (Jaguar series, CLAAS KGaA mbH, Germany) powered by an engine rated at 372 kW. The unit was fitted with one "GBE-1" header for SRF crop harvesting equipped with one pair of large circular saws placed at the bottom of the same shafts carrying the crop collectors (Fig. 1). The header cuts the stems and moves them toward the horizontal in feed rollers built into the forager unit. Harvesting was carried out equipping the forager unit as follows: *i*) standard drum (on purpose adapted to wood chipping by reducing the number of knives from 24 to 12) with theoretical chip length of 16 mm; *ii*) special drum, designed by CRA-ING, equipped with 10 fixed knives 5° inclined to the rotation axis to increase biomass particle size [27] whose theoretical cut length was 20 mm. The obtained chipped biomass was subsequently organized into cone shaped stacks (with the 10 m wide base), equipped with six temperature probes to continuously record the inner temperature with the acquisition rate of 10 s. In every stack, temperature probes were placed at different heights from the pavement (Fig. 2):

- *1 m height (L1)*: one probe at the centre and two of them symmetrically placed two meters from the median line.
- *3 m height (L2)*: two probes symmetrically placed at 1 m from the median line
- *4 m height (L3)*: one probe placed along the median line

When setting up the stacks, we measured the woody biomass particle size distribution [28] to highlight the effect of the different used drums. One portion of chipped material representative of the whole stack was placed inside a resistant plastic bag in proximity of any probe to perform moisture content measurements [29], moisture and dry matter content (%), Lower and Higher Heating Values

Fig. 1. Particular of the GBE-1 header for SRF harvesting.

[30]. Micrometeorological data (air temperature and relative humidity) were recorded as well.

When stacks had been set up, they were left in open air on a paved surface in Northern Italy climatic conditions (45°57′ N; 10°38′ E) for a 120 days storage period (from 1st March to 29th June 2009), with the main aim of evaluating the effect of particle size distribution on biomass drying and on the quality of solid biofuel after storage in uncovered stacks having different particle size. For this purpose we used three stacks made of standardly chipped wood (labelled "STD-D") and three made of wood chipped with modified drum (labelled "MD-D").

Moreover, as sub aim of the experiment, we evaluated also the effect of the covering with gas-permeable non-woven geotextile fleece (TenCate Geosyntetics, The Netherlands) during the storage period in stacks made of standardly chipped wood.

Data processing was performed with MINITAB 17 statistical software [31] to check the statistical significance of differences between treatments by means of ANOVA (verifying whether the assumptions of normality and homogeneity of variance holds by means of Ryan-Joiner and Levene tests) and to analyse inner temperature trends during storage time. With reference to this, temperature time series data underwent non parametric analysis by means of Mann–Kendal test [32–34] to statistically assess if there is a significant ($\alpha = 0.05$) monotonic upward or downward trend of the variable of interest over time and Sen's slope estimator (SSe) [35] which is a nonparametric alternative, insensitive to outliers [36], to estimate the slope of univariate time series. In few words,

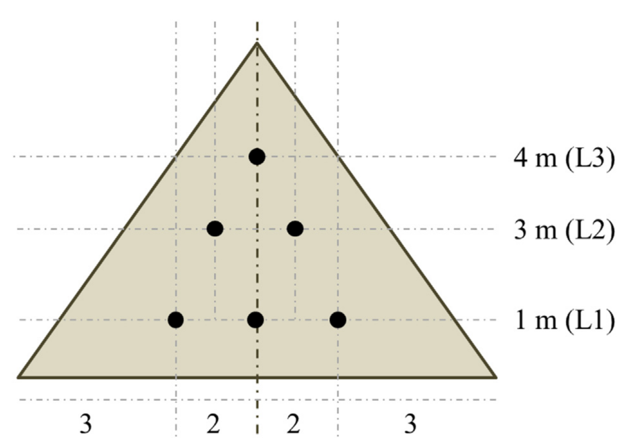

Fig. 2. Schematic drawing of the woodchip stack profile representing the position of the temperature probes and of the sampling points.