Biomass and Bioenergy 83 (2015) 269–277

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: http://www.elsevier.com/locate/biombioe

Research paper

Open-air storage of fine and coarse wood chips of poplar from short rotation coppice in covered piles

Hannes Lenz [a], Christine Idler [a], Eberhard Hartung [b], Ralf Pecenka [a, *]

[a] Leibniz Institute for Agricultural Engineering Potsdam-Bornim (ATB), Max-Eyth-Allee 100, 14469, Potsdam, Germany
[b] Institute for Agricultural Engineering, Christian-Albrechts-University Kiel, Max-Eyth-Strasse 6, 24118, Kiel, Germany

ARTICLE INFO

Article history:
Received 26 June 2015
Received in revised form
8 September 2015
Accepted 30 September 2015
Available online 22 October 2015

Keywords:
Short rotation coppice
Poplar
Wood chip
Storage
Drying
Dry matter loss

ABSTRACT

The cultivation of short rotation coppices (SRC) on agricultural land represents an economically and environmentally promising option for sustainable provision of bioenergy. Not only the further development of efficient harvesting machinery, but also the development of harvest-optimised storage systems are necessary to implement cost-efficient cultivation and use strategies for SRC in practice. The storage of fine wood chips from poplar harvest with a forage harvester results in high dry matter losses of up to 25%. Tractor-mounted mower-chippers can harvest coarse wood chips that might possess more favourable storage and drying properties. The main objective of the current research project was to develop and perform a storage experiment in which the storage behaviour of fine and coarse wood chips could be examined and compared in detail over a period of nine months. In this experiment two covered storage piles (height 3.5 m), with over 500 m^3 fine and coarse wood chips respectively, were examined under practice scale conditions in Germany. After nine months of storage the fine chips in the core of the storage pile had dried to a moisture content of 34% with dry matter losses of 22%. Coarse chips, on the other hand, achieved a moisture content of 29% and dry matter losses of 21% in the same period. The maximum moisture content of 40% required by heating plants in practice is achieved by fine chips after 6.5 months and by the coarse chips already after 3.5 months.

1. Introduction

Woody biomass from agriculture and forestry is one of the main sources for meeting global energy demand. On the basis of European objectives to increase energy supply from renewable sources to 20% of end energy consumption for the Member States of the EU by the year 2020, demand for wood will increase further in the coming years [1]. In order to ensure regional supply with wood for energy use, fast-growing trees such as poplar and willow are already being cultivated in short rotation coppices (SRC) on over 32,000 ha in Europe [2]. The prerequisite for increasing acceptance of energy wood cultivation in agriculture, however, is not only the cost-efficiency of wood chip production, but also the availability of suitable technologies and competitiveness vis-à-vis other energy-supplying plants and traditional field crops [3–5]. The key problems currently facing expansion of SRC cultivation include insufficient availability of efficient harvesting machinery [6–11] and high dry matter losses during the storage of wood chips [12–14]. As in winter wood chips are harvested with a moisture content of 50–60%, they generally have to be placed in intermediate storage until the next heating season (for six to nine months). The different storage systems used so far can either only be managed with high technical expense (e.g. hot air drying, whole tree storage), or lead to high storage losses of up to 30% dry matter (e.g. in uncovered fine chip piles in the case of natural drying) that are reflected completely in cost-relevant energy losses and quality losses [15–17].

Examinations of the storage and drying behaviour of chips, chunks and whole trees have shown that the particle size of the material has an essential influence on moisture content and losses during storage over a period of six to twelve months [17–21]. Barontini et al., 2014 [12] and Pecenka et al., 2014 [2] determined storage losses of 15–27% dry matter and moisture contents of 30–34% for the storage of fine chips (storage duration six to seven months). For the drying of willow chunks, Gigler et al., 2004 [18]

* Corresponding author.
E-mail addresses: hlenz@atb-potsdam.de (H. Lenz), cidler@atb-potsdam.de (C. Idler), ehartung@ilv.uni-kiel.de (E. Hartung), rpecenka@atb-potsdam.de (R. Pecenka).

http://dx.doi.org/10.1016/j.biombioe.2015.09.018
0961-9534/

determined storage losses of only 5% and moisture contents of 10% after storage in an open air pile for five months. Studies on the storage of whole trees (poplar) have shown that storage losses can be reduced distinctly in comparison with those of fine chips (to approx. 7%), but with a 41% moisture content after storage for 10 months [22]. Mass losses are caused by physical, chemical and microbiological conversion processes leading to a significant temperature rise in a storage pile. According to Pecenka et al., 2014 [2], Barontini et al., 2014 [12] and Manzone et al., 2013 [13], when the different temperature profiles in wood chip piles are considered, two typical phases lasting over a relatively long period become visible:

- >50 °C (high temperature phase)
- <30 °C (low temperature phase)

Due to the homogenous raw material and bulk properties and the associated ease of handling and use, wood chips are preferred as a matter of principle for supplying automated heating boilers [23–25]. Coarse chips produced with modern tractor-mounted mower-chippers [26,6] have distinctly larger dimensions. On the one hand they satisfy the requirements made of bulk product properties for wood chip fuels in accordance with the standard DIN EN ISO 17225-4 [27], and on the other hand – due to their coarse particle structure – they can show advantages regarding faster natural drying in storage piles coupled with reduced losses. Therefore the main objective of the current research project was to develop and perform a storage experiment in which the storage behaviour of fine and coarse chips could be examined and compared in detail over a period of nine months under practice scale conditions.

2. Material and methods

In the harvest season 2014, two storage piles with poplar chips of different chopping formats were established on a practical scale at the location Altentreptow, Germany (53°40′N; 13°13′E). In order to provide the necessary wood chips, two neighbouring poplar plantations (53°47′N; 13°14′E) were harvested with the clones Max 1, 3, 4 (Populus nigra × P. maximowiczii). Fine chips were produced from the four-year, double-row stand. The coarse chips originated from a five-year single-row stand. The harvest was carried out with two different continuously-working harvesting systems. In addition to a forage harvester with an SRC header (New Holland FR9060 with KUP 130), which produced the fine chips, the tractor-mounted mower-chipper (Fendt 820 Vario with ATB mower-chipper, Germany) produced coarse chips [6].

The harvesting and the storage intake of approx. 600 m^3 coarse chip material were carried out on 31.01.2014 at a temperature of −5 °C. The approx. 1000 m^3 fine chips were harvested and taken into storage at a temperature of +4 °C on 12.02.2014. Both storage piles were established next to each other on a concrete surface in a horizontal clamp silo (Fig. 1). In order to generate regularly measuring data over a nine-month storage period, ten stainless steel lattice columns (height 2.5 m, diameter 0.64 m, mesh aperture 20 mm) filled with the respective wood chips were placed in each pile at intervals of 2 m centrally and lengthways to the storage heap direction during storage intake. The size and positioning of the lattice columns in relation to the size of the storage pile has been investigated in several pretests. Due to the chosen layout an influence of the extraction of a sampling column on the neighbouring columns can be virtually ruled out. Various measurements were conducted regularly at three different heights (0.8 m; 1.6 m; 2.4 m) (Fig. 1). The measured values from these three levels have been combined to one measuring point to generate representative data for a statistical evaluation of the storage process.

The two storage piles were covered with a semi-permeable non-woven fabric of type Toptex (weight 200 g m^{-2}, Tencate, Austria) which allows water vapour to leave the pile structure, but reduces the infiltration of precipitation.

The integrated lattice columns in each pile served to support the measurements and make it possible to withdraw wood chip samples completely without damage every four weeks (Fig. 2). The wood chips samples have been attached inside and outside of the columns in balance bags (PP – plastic bags, mesh size 12 × 4.5 mm, sample weight 2 kg fresh material). After extracting a lattice column and removal of the balance bags the remaining wood chips from the column have been used to close the hole in the pile.

The chip formats were characterised with the help of an ultimate analysis (C, N, S, H, n = 5) on the ultimate analyser (Vario EL, Elementar, Germany) in accordance with VDLUFA, 1997 [28] and the ash contents in accordance to DIN EN 14775 (n = 30) [29]. Both chip formats were distinguished and classified in accordance with DIN EN ISO 17225-4 [27] (n = 7).

On each of the ten monthly sampling dates, one lattice column was removed from the storage pile and the following parameters were determined:

- Pile temperatures with the aid of temperature sensors (Gemini Type Tinytag TGP-4017, United Kingdom) at three heights with two sensors each
- Dry matter contents (n = 10 per level)
- Dry matter losses from balance bags (n = 10 per level)
- Higher and lower heating values (n = 3 per level)
- CO_2 and O_2 concentration (n = 1 per level)

These parameters were also measured for each type of wood chips on storage intake.

The dry matter content respectively moisture content were determined in accordance with the oven dry method [30]. The losses were determined from the material in the balance bags. The dry matter losses (L_{DM}) were calculated using the following Equation (1).

$$L_{DM} = \left(1 - \frac{m_{out}\,(100 - x_{out})}{m_{in}\,(100 - x_{in})}\right) \times 100\,\% \qquad (1)$$

L_{DM} dry matter losses [%]
m_{in} weight of material taken into storage [kg FM]
m_{out} weight of material retrieved from storage [kg FM]
x_{in} moisture content of the material taken into storage [%]
x_{out} moisture content of the material retrieved from storage [%]
DM dry matter
FM fresh matter

For the energy evaluation, the higher heating value in accordance with DIN EN 14918:2014-08 [31] was determined with the calorimeter C200 (IKA, Germany). The higher heating value of the water-free material (HHV) was calculated from the measured calorific value, the ash content and the elements carbon, hydrogen and sulphur from the ultimate analysis in accordance with Equation (2).

$$HHV = q_{v,gr,d} - [k \times H + 0.8 \times (100 - x - A - C - H - S)] \qquad (2)$$