Biomass and Bioenergy 94 (2016) 258–267

Contents lists available at ScienceDirect

Biomass and Bioenergy

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

Research paper

Development and test of a simplified method to calculate dry matter loss during open-air storage of poplar wood chips by analysing ash contents

Hannes Lenz [a], Ralf Pecenka [a, *], Eberhard Hartung [b], Christine Idler [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 21 December 2015
Received in revised form
6 September 2016
Accepted 9 September 2016
Available online 17 September 2016

Keywords:
Short rotation coppice
Wood chips
Storage
Ash content
Dry matter loss calculation

ABSTRACT

Short rotation coppice (SRC) in agriculture can be established successfully, only if the entire process chain is economically competitive. Despite the substantial dry matter loss (up to 25%) occurring during open-air storage of wood chips, it is the most applied storage technique. Since the particle size of wood chips plays an important role in storage and drying processes, two storage piles (>500 m^3) with fine and coarse wood chips were investigated comprehensively under the weather conditions of North-East-Germany over a period of 9 months.

The objective of this experiment was to develop a simplified method to calculate dry matter loss by determining the ash content and to compare the results with the conventional sample bag method. The new method delivered statistically sound results, particularly when ash contents were calculated from separated bark and wood samples instead of from wood chip samples. Furthermore, the significant and consistent increase in ash content of the bark samples during storage suggests, that the development of a model solely based on ash content of separated bark could be advantageous in terms of simplified yet reliable determination of dry matter losses. Since the ash content of wood chips is largely governed by the bark content, exact data for the proportion of bark is required, which varies between 18 and 35% depending on tree size represented by the stem diameter at cutting height (SDCH). Moreover, it was found that the fuel quality depends more on the SDCH of the SRC-harvest than on the produced wood chip format.

1. Introduction

Cultivating short rotation coppice on arable land offers the opportunity to produce biomass sustainably, while improving the agricultural earnings. Under European conditions, fast growing trees like poplar *(Populus sp.)*, willow *(Salix viminalis)* and robinia (*Robinia pseudoacacia L.*) cultivated in short rotation coppice or agroforestry systems have the potential of producing more than 10 t ha^{-1}yr^{-1} of plant biomass (dry matter) [1–3]. The wood produced on such land is either preferably utilized for the heat generation in farm-owned facilities or sold as fuel to regional heating (power) plants. However, in order to increase the acceptance of cultivating fuel wood in agriculture, ensuring the quality of the produced wood chips is a prerequisite alongside the economic efficiency of wood production and the availability of suitable technologies for cultivation, harvest, and storage. Since wood chips are harvested in winter with moisture contents of up to 60% (defined as moisture mass fraction or moisture content on the wet basis), they must initially be dried and stored until the next heating season. Storage in the form of open-air piles facilitates a cost-efficient natural drying process, albeit leading to high dry matter losses up to 30% (defined as mass fraction on the dry basis) [4–7]. These losses cause cost-relevant drawbacks not only in terms of energy, but also quality [8–11]. Previous investigations have shown that particle size has a significant impact on storage and ventilation characteristics [7,12,13]. Fine poplar wood chips with dry matter losses ranging from 13 to 27% and moisture contents ranging from 30 to 34% demonstrated clearly inferior storage characteristics after a storage time of 6–7 months than coarse willow wood chips [4,7,14]. Gigler et al. [15] have determined dry matter losses of only 5% and 10% moisture contents after 5-months storage of willow wood

* Corresponding author.
E-mail address: rpecenka@atb-potsdam.de (R. Pecenka).

http://dx.doi.org/10.1016/j.biombioe.2016.09.011

chips in open-air piles. Depending on mass loss during drying, energy losses of up to 14% may occur. At the same time, the ash content increases during storage due to the reduction of organic components by approximately 1% point [14]. High bark contents in the crop mass resulting in high ash content may hence lead to exceeding the limit of 3% ash for wood chips, as stipulated in the EN ISO 17225-4 [16] fuel standard.

The efficient and trouble-free operation of biomass fired heating (power) plants requires exact knowledge about storage characteristics of wood chip piles as well as the fuel parameters such as particle size, moisture content, heating value, and ash content. Lenz et al. [13] presented a comprehensive storage test comparing the storage behaviour of fine (P31) and coarse (P45) wood chips from poplar. The experiment was designed to monitor the continuously changing mass losses, moisture contents, heating values, and ash contents during 9-months storage under the weather conditions of North-East-Germany. The investigation was conducted on practice scale storage piles (>500 m^3). The continuous determination of mass losses by means of the commonly used sample bag method was fairly troublesome, particularly when measurements had to be performed over a long period of time. Furthermore, the inversely proportional relationship between the ash contents and the content of organic components might be utilized as a basis for the indirect determination of mass losses during storage [4,17]. Therefore, the main focus of the research work lies on analysing the relationship between ash content and the progression of mass losses, with the objective of developing a simple and reliable method to calculate the dry matter losses. The developed model is then validated by comparing the results with the conventional sample bag method, which serves as a reference.

2. Material and methods

2.1. Experimental set-up

In January 2014, two neighbouring poplar plantations (clones Max 1, 3, 4) located in west Mecklenburg Pommerania (North-East-Germany, 53°40′N; 13°13′E) were harvested by two different systems and the produced wood chips were stored on a concrete surface (53°47′N; 13°14′E) for 9 months (Table 1). Fine wood chips (P31) were produced by employing a modified standard forage harvester with coppice header, while for the coarse wood chips (P45) the ATB mower-chipper [7,18] was used.

In a bunker silo, 2 adjacent piles, one 1000 m^3 pile of fine wood chips (pile dimensions: 40 m × 9 m × 3.5 m) and a 600 m^3 pile of coarse wood chips (pile dimensions: 25 m × 9 m × 3.5 m), were stored in farm typical fashion. Further details of the experimental set-up and the results regarding the differences in the storage behaviour between fine and coarse chips in terms of moisture content, dry matter losses, gas concentrations, and changes in calorific value during this storage experiment were reported by Lenz et al. [13].

2.2. Sampling

For continuous sampling over 9 months, ten stainless steel built grit columns (t_1–t_{10}) filled with wood chips were positioned along the central axis every 2 m (see Fig. 1). The height, diameter and mesh size of the grit columns were 2.5 m, 0.64 m and 20 mm respectively.

Every month, one grit column from each pile including the sample bags previously positioned on three different levels (0.8 m, 1.6 m, 2.4 m) was retrieved with a pulley and examined. The extraction spaces of the samples were refilled subsequently with the respective materials.

The grit columns contained sample bags with three different types of material:

1. Chips with the natural proportions of wood and bark;
2. Bark;
3. Wood without bark.

On each level, 6 sample bags filled with chips were positioned inside the column, while four additional sample bags were mounted outside the column (Fig. 1). Moreover, one sample bag filled with bark, and wood without bark was positioned inside the column on the middle level. Manually decorticated trees served as the source of these separated bag contents. The lower and upper level contained exclusively sample bags filled with chips.

The stored sample bags allowed the measurement of investigated parameters, which were recorded and analysed at regular intervals of 4 weeks over the entire storage period of 9 months (Table 2).

2.3. Reference method for determination of dry matter loss

The calculation of dry matter loss by means of sample bag method was used as reference. According to this method dry matter loss at any storage time, i can be calculated using Equation (1). In general, moisture contents in this study are defined as moisture mass fraction on the wet basis. All other percentage values such as dry matter losses or ash contents are defined as mass fractions on the dry basis.

$$L_{(sb)i} = \left(1 - \frac{m_i(100 - x_i)}{m_{in}(100 - x_{in})}\right) \times 100\% \quad (1)$$

$L_{(sb)\,i}$	dry matter loss via sample bags at time, i	[%]
m_{in}	wet mass of in-column materials at storage start	[kg]
m_i	wet mass of ex-column materials at time, i	[kg]
x_{in}	moisture content of in-column materials at storage start	[%]
x_i	moisture content of ex-column materials at time, i	[%]

Table 1
Origin and harvest of wood chips for storage.

Plantation (layout)	Age	Harvest	Harvesting system	Chip format	Stem diameter at cutting height of 10 cm (SDCH)
m	Years	Date			cm
Double row (2.2 × 0.5 × 0.6)[a]	4	12-02-2014	New Holland forage harvester, FR 9060 with 130 FB coppice header	Fine wood chips (P31)	4.3 (σ ± 1.3)
Single row (2 × 0.6)[b]	5	31-01-2014	Fendt 820 Vario with tractor mounted ATB mower-chipper	Coarse wood chips (P45)	7.1 (σ ± 1.4)

[a] (row distance × inner row distance x planting distance).
[b] (row distance × planting distance).