Biomass and Bioenergy 96 (2017) 119–129

Contents lists available at ScienceDirect

Biomass and Bioenergy

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

Research paper

Continuous weighing of a pile of poplar wood chips – A comparison of methods to determine the dry matter losses during storage

Hannes Lenz [a], Ralf Pecenka [a,*], Christine Idler [a], Sabrina Dumfort [b], Carly Whittaker [c], Christian Ammon [a], Eberhard Hartung [d]

[a] Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Max-Eyth-Allee 100, 14469 Potsdam, Germany
[b] Management Center Innsbruck (MCI), Maximilianstrasse 2, 6020 Innsbruck, Austria
[c] Rothamsted Research, Harpenden, Hertfordshire AL5 2JQ, United Kingdom
[d] Institute for Agricultural Engineering, Christian-Albrechts-University Kiel, Max-Eyth-Strasse 6, 24118 Kiel, Germany

ARTICLE INFO

Article history:
Received 8 September 2016
Received in revised form
18 November 2016
Accepted 22 November 2016
Available online 1 December 2016

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

ABSTRACT

The measurement of dry matter (DM) losses occurring during the storage of wood chips is of crucial importance for understanding the efficiency of bioenergy supply chains.

When obtaining representative measurements of a whole storage heap, it is necessary to distribute a large number of samples over cross sections of the pile. The recovery of these samples can be very labour-intensive, and can lead to major disturbances in the pile. Accordingly, this method is not suitable for periodic examinations of storage heaps.

In this study, two 100 m^3 piles (P1 and P2) of fine wood chips from poplar were investigated over a period of 228 days of storage. The P1 pile was used to compare the different methods in which to determine the moisture content (MC) changes and DM losses during storage. The results generated by the balance bag method (M1) were compared with three alternative methods. These alternative methods (M2–M4) involved the analysis of MC and mass changes in balance bags within measuring columns located within the heap (M2), MC and mass changes occurring in the entire pile (M3), and from changes in ash contents of samples in balance bags within the measuring columns (M4).

DM losses of 23.3% and 22.7% were determined using methods M1 and M2, respectively. The DM losses calculated using M3 and M4 were considerably lower at 13.9% and 16.6%, respectively. The M2 method proved to be the most suitable for periodic determination of storage losses in a similar experimental design.

1. Introduction

Poplar and willow, grown as short rotation coppice (SRC), have been identified as important bioenergy crops in Europe. As they are fast-growing crops that tend to perform well at poorer quality sites, they offer a potential biomass resource that does not compete for fertile arable land. Such crops also offer a mechanism for decentralising energy supplies and promoting the local use of bioenergy [1]. There are also observed benefits to local biodiversity with the uptake of SRC [2] meaning they can play an important role in the sustainable intensification of agriculture. Even with these benefits, however, the SRC cropping areas in the EU have stagnated. Despite the introduction of policies that provide financial incentives to farmers, uptake has been limited, with 7000 ha established in Germany [3,4], 1000 ha in Austria [5] and 5500 ha in the United Kingdom [6]. One of the reasons for this unsatisfactory uptake is the insufficient integration of the ecological benefits of SRC in agricultural support policies (EU Regulation 639/2014) and a prevailing lack of acceptance among farmers [7].

Uncertainties regarding the technical methods of harvesting and machinery availability have raised additional barriers to farmer confidence in SRC [1]. Although harvesting machinery manufacturers have successfully tackled many of the problems encountered through technological developments and innovations [8–11], there still remains a clear demand for research into efficient post-harvesting storage [12–19]. Current research focuses on developing low-cost methods of storage that reduce the dry matter (DM) losses and preserve the quality of the biomass fuel [3,20–25].

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

http://dx.doi.org/10.1016/j.biombioe.2016.11.011
0961-9534/

When harvested in winter or early spring, wood chips from SRC have a moisture content (MC) of between 50 and 60% (defined as water mass fraction or moisture content on the wet basis). The biomass must then be stored until the following winter when it is required for heating. In bioelectricity supply chains it is also beneficial to simultaneously store and dry the material until required, and in all supply chains, a storage phase provides a means to buffer between periods of supply and demand [26]. Currently adopted storage methods either involve higher technical efforts and costs (e.g. technical ventilation, whole tree storage) or lead to high DM losses (e.g. uncovered storage with natural drying). Due to cost limitations, it is common practice to allow wood chips to dry naturally in piles stored in the open. This leads to DM losses of between 6.6 and 26.6%, as reported in relevant literature (Table 1).

Not only does the tree species, particle size, weather conditions, and experimental set-up influence the DM losses during storage, but the method used to determine the DM losses is also important. It is essential to use reliable and accurate methods wherever possible in order to reduce errors and/or uncertainties when comparing losses between different storage conditions. Additionally, the adopted method must be feasible with respect to labour input and costs. In the literature studied, the most widespread method is to use balance bags, where the mass of a filled sample bag (generally made of netting material) is determined at the beginning and end of the storage experiment. The differences in DM content in the bags then determine the losses incurred between the two sampling times. Various studies adopting this method find different results (see Table 1). For example, monthly DM losses during the storage of poplar chips are reported to range from 1.4 to 4.2% (Ø = 2.6%). In willow chips, mean monthly DM losses of 4.6% have been reported. In comparison with SRC, the DM losses during storage of forest residue chips are 1.3% per month [20]. The different tree species could explain these differences, however the different weather conditions could also play a role: in Southern Europe wood chip storage gave monthly DM losses of 2.2% [21,22,24], and in Northern Europe they were 3.4% [3,23,25]. Also, the balance bag method can be employed in different ways, and the use of different bag materials, mesh widths, ‘trickling’ losses from the bags, sample sizes, the number of samples, sampling areas and the disturbances of the pile structure during sampling events can all influence the final results [14,21–23,25]. There is also the risk that the bags can be damaged during storage, or as they are withdrawn at the end of the experiment. Therefore, the uncertainties in this method warrant the exploration of alternative methods.

The DM content is determined by the mass and MC of a sample, hence measuring the latter effectively is vital to determine changes in DM. The rate of drying within a wood chip pile can vary widely, and can depend on physical aspects such as the particle size, type of wood, pile volume, and prevailing winds and solar exposure. Major deviations in the MC can arise, therefore the accuracy of the determined MC will depend on the positioning and number of

Table 1
Magnitude of dry matter losses during storage of short rotation coppice and forestry-derived wood chips reported in relevant literature.

Wood type (particle size category)	Dry matter loss[a]	Pile volume	Storage duration		Dry matter loss[a]	Land/Region	Moisture content[b] X_{in}	X_{out}	Sample weight[b]	Loss determining method	Reference
	%/month	m^3	days	Period	%/storage duration		%	%	kg		
Poplar crowns (P31)	1.4	117	189	Mar.–Sep.	6.6	Central Italy (Monterotondo)	54	31	ND	Sample bags	[22]
Poplar (P63)	1.6	20	170	Mar.–Sep.	9.3	North-West Italy	39	25–35	6000[d]	Whole pile	[21]
Poplar crowns (P31)	1.6	117	189	Mar.–Sep.	10.0	Central Italy (Monterotondo)	54	31	35,000[d]	Whole pile	[22]
Poplar (fine[c])	1.8	ND	120	Mar.–Jun.	7.2	North Italy	62	26	ND	Sample bags	[24]
Poplar (P31)	2.3	1000	271	Feb.–Nov.	22	North-East Germany	60	34	2	Sample bags	[23]
Poplar (P45)	2.3	600	284	Jan.–Nov.	21	North-East Germany	59	29	2	Sample bags	[23]
Poplar (fine[c])	3.2	ND	120	Mar.–Jun.	12.9	North-Italy	62	34	ND	Sample bags	[24]
Poplar (P31)	3.2	500	223	Jan.–Aug.	24	North-East Germany	62	33	2	Sample bags	[3]
Poplar trunk (P31)	3.4	117	189	Mar.–Sep.	21.6	Central Italy (Monterotondo)	48	34	ND	Sample bags	[22]
Poplar (P45)	3.6	500	223	Jan.–Aug.	27	North-East Germany	60	34	2	Sample bags	[3]
Poplar trunk (P31)	4.2	117	189	Mar.–Sep.	26.6	Central Italy (Monterotondo)	48	34	35,000[d]	Whole pile	[22]
Willow (fine[c])	2.6	540	210	Mar.–Oct.	18	England (East Midlands)	54	39	3–4	Sample bags	[25]
Willow (fine[c])	6.5	320	97	Apr.–Jul.	21	England (South-East)	50	43	84,000	Whole Pile	[25]
Spruce (fine[c])	1.0	960	232	Apr.–Dec.	8.0	Italy (South Tyrol)	42	43	1.5–2	Sample bags	[20]
Spruce (fine[c])	1.6	700	258	Apr.–Jan.	13.6	Italy (South Tyrol)	55	43	1.5–2	Sample bags	[20]

ND … no data, X_{in} … moisture content of the wood chips on storage intake, and X_{out} … on storage outtake.
[a] Defined as mass fraction on dry basis.
[b] Defined as moisture mass fraction on wet basis.
[c] According to Standard EN ISO 17225-1 no allocation to a particle size category is possible.
[d] Assumed mean bulk density 334 kg m^{-3}.