



AperTO - Archivio Istituzionale Open Access dell'Università di Torino

Poplar woodchip storage in small and medium piles with different forms, densities and volumes

This is the author's manuscript
Original Citation:
Availability:
This version is available http://hdl.handle.net/2318/1616525 since 2016-11-25T11:38:21Z
Published version:
DOI:10.1016/j.biombioe.2016.02.026
Terms of use:
Open Access
Anyone can freely access the full text of works made available as "Open Access". Works made available under a Creative Commons license can be used according to the terms and conditions of said license. Use of all other works requires consent of the right holder (author or publisher) if not exempted from copyright protection by the applicable law.

(Article begins on next page)

1 Poplar woodchip storage in small and medium piles with different forms,

2 densities and volumes

3

4

5 Abstract

6 Wood biomass is one of the main sources of biofuel for bioenergy production worldwide.

7 Generally, the exclusive use of comminuted biomass in automated boilers is preferred because these

8 woodchips consist of homogeneous particles with a specified size. Wood biomass is harvested

9 mainly in autumn and winter, whereas the demand for biomass-fired power stations is continuous

10 throughout the year. Nevertheless, large amounts of woodchips are also produced in the spring and

summer from residual materials obtained from the utilisation of conventional poplar plantations.

12 This study focused on uncovered small and medium woodchip piles. In particular, the influence of

13 form, density, and the size of piles on the biofuel quality during woodchip storage was analysed.

14 The woodchip moisture contents and dry matter losses were considered when evaluating the storage

15 dynamics.

The results suggest that a storage system can be selected to service only the needs of thermal stations because any difference between the form (trapezoidal and cone), volume (35 and 70 m³), and density of the piles was highlighted by the observed on woodchip quality <u>analysis</u>. In fact, a mean moisture content of 18% and average dry matter losses of 10% were recorded at the end of storage period for all treatments. Notably, the climate conditions and storage periods affected the results of this experiment.

22

23 Keywords: Poplar woodchips, storage, uncovered piles, form piles, natural drying, losses

- 24
- 25

26 Introduction

Wood biomass is one of the main sources of biofuel for bioenergy production worldwide [1].
Generally, the exclusive use of comminuted biomass in automated boilers is preferred because
woodchips consist of homogeneous particles with a specified size. Moreover, chipping offers
additional benefits in terms of an increased load density and improved handling quality [2].

31

Chipping may take place during timber harvesting or some months after tree cutting. At present, 32 two different groups of machines can be use in chipping operations: chippers, or machines that use 33 sharp tools (knives) to cut or slice the wood; and grinders, or machines that use blunt tools 34 (hammers) to smash or crush the wood [2]. In particular, grinders are used for contaminated wood, 35 as their blunt tools are less sensitive to the wearing effect of contaminants, but these machines 36 generate a rather coarse product that is unsuitable for use in some plants [3]. In contrast, chippers 37 38 are exclusively applied to clean wood and offer a finer and better product [1]. In addition, the chippers used to produce woodchips for energy uses can be divided by function based on their knife 39 40 support: disc and drum [4-5].

41

Generally, wood biomass is harvested in autumn and winter during tree felling and short rotation
coppice harvest. Nevertheless, woodchips can also be produced in spring and summer from residual
materials obtained from the utilisation of conventional poplar plantations.

Independent from the harvesting period, the demand of biomass-fired power stations is constant and may contrast the farm's activities [6]. Creating a fuel buffer in the farm to secure the availability of biofuel at all times may solve this problem [7]. Furthermore, biomass storage in the farm is an interesting option for power station because it generates woodchips with a high market value low moisture content.

51	The woodchip can be stored in different ways in terms of site condition functions [8], and logistical
52	strategies [9]. Nevertheless, many studies have shown that long-term woodchip storage (over three
53	months) can cause significant dry matter losses and a consequent net energy value reduction [10-
54	12]. In fact, these dry matter losses can reach 20% of the initial value for a storage period of one
55	year [13-15]. Woodchip storage methods and their associated problems have been well documented
56	in the literature [11-12, 16-19]. Wood chips stored in small-sized piles can be used in different
57	covering systems in order to guarantee good calorific values and limited energy losses [20]. By
58	contrast, the storage of wood biomass in large piles is only possible outdoors, where the piles are
59	uncovered due to logistical and economic reasons [21]. Nevertheless, previous studies in
60	northwestern Italy have shown that uncovered storage is better than covered storage for small piles
61	as well [20]. Until now no study was focused on pile characteristics (form, density, and volume)
62	used in woodchip storing.
63	
64	For this reason, the goal of this study was to analyse the influence of the form, density, and volume
65	of uncovered piles on the quality of the biofuel during woodchip storage. In particular, this study
66	focused on uncovered small and medium piles.
67	
68	Materials and methods
69	The experiments were conducted in north western Italy (Vinovo town near Turin) between June and
70	
71	September 2012. During this period, this geographic area produces relatively large amounts of
/1	woodchips from the logging residues of conventional poplar plantations. Unlike previous studies, a
71	September 2012. During this period, this geographic area produces relatively large amounts of woodchips from the logging residues of conventional poplar plantations. Unlike previous studies, a short period of four mouths was selected because the air temperature was high and the woodchips
72 73	September 2012. During this period, this geographic area produces relatively large amounts of woodchips from the logging residues of conventional poplar plantations. Unlike previous studies, a short period of four mouths was selected because the air temperature was high and the woodchips dried quickly.
72 73 74	September 2012. During this period, this geographic area produces relatively large amounts of woodchips from the logging residues of conventional poplar plantations. Unlike previous studies, a short period of four mouths was selected because the air temperature was high and the woodchips dried quickly. The tests compared different forms of piles for woodchips storage: small (35 m ³) and medium
71 72 73 74 75	September 2012. During this period, this geographic area produces relatively large amounts of woodchips from the logging residues of conventional poplar plantations. Unlike previous studies, a short period of four mouths was selected because the air temperature was high and the woodchips dried quickly. The tests compared different forms of piles for woodchips storage: small (35 m ³) and medium (70 m ³) piles; trapezoidal and conical forms; and low (340 kg m ⁻³ fresh matter) and high (470 kg m ⁻¹

used for the trial was limited (approximately 1200 m²). In this study, the tests were conducted using
only poplar woodchips produced from the logging residues of conventional poplar plantations
(*Populus x Euramericana* G., clone I-214).

Small piles were built with the load from one wagon trailer used for woodchip transportation (35 80 m^{3}), while the medium piles were built with the loads from two wagon trailers (70 m^{3}). Different 81 geometric forms (trapezoidal and conical) were compared only for piles with medium volumes. 82 Notably, the piles appeared to be of different sizes due to their geometrical forms and volumes (Fig. 83 1). The woodchip density was increased following the method used for maize ensilage, in which the 84 woodchips were pressed with vehicles. Therefore, the density was compared only for trapezoidal 85 86 piles. Wood chips were pressed with a telescopic handler, which was used to build the pile. The volumes of the compacted piles were estimated by measuring their size after wood chip 87 compaction. 88

Each test consisted of a single pile and was replicated three times for a total of 12 replicates (table
1). All piles were made on a concrete floor using a random method. None of the piles were covered.

92 Wood chips were produced from fresh logging residues (approximately 15 cm in diameter and 9.5 m in length) and, consequently, woodchip was mixed with leaves. A drum chipper (Pezzolato PTH 93 900) was used to comminute the wood. The moisture content and temperature of woodchips were 94 95 used to evaluate the storage dynamics. These two parameters are reliable indicators of the storage dynamics of wood used in energy production [21]. Therefore, they were monitored for all storage 96 period considered (June – September). The temperature inside each pile was monitored using a 97 98 thermocouple, and the moisture content of the woodchips was measured with an electrical hygrometer (GANN®Hydromette HT85T), which is normally used in sawmills and includes a 99 100 prototype probe developed by DISAFA (University of Turin). The probe of the hygrometer consist of two short steel electrodes (20 mm) and is designed for registering the external moisture content 101 of logs. In this experiment, the probe was substituted with a prototype made by inserting the 102

electrodes directly into a particle wood and wiring them to the hygrometric unit. The gravimetric 103 method [22] and woodchips with physical characteristics equivalent to those used in the tests were 104 used to set up the probe. The accuracy of this sensor was 1% in moisture content. During the first 105 30 days, the measurements were performed daily, then every three days. The high frequency of 106 reads during the first 30 days was performed to evaluate temperature peaks, which occur primarily 107 during this period [14, 16, 20]. The sampling points were located in the middle of the pile at three 108 different heights (0.5 m above the ground, centre of pile, 0.5 m under the pile surface) (Fig. 1). 109 In this study, energy losses were expressed in terms of weight (dry matter) and volume. Small piles 110 showed a volume of a single trailer, while medium piles were built using the loads of two trailers. 111 The trailers were weighed by a certified weighbridge before being offloaded. The volume of wood 112 chips was calculated by levelling the load to the tops of the caisson trailer sides. At the end of the 113 storage period, all single piles were reweighed and the dry weight was calculated as a function of 114 115 the moisture content of the wood chips.

The weather conditions, including the air temperature (C°), air humidity (%) and precipitation
(mm), were monitored by a dedicated weather station sited near the piles. The values were recorded
every hour.

119 The particle size distribution affects the air circulation into the chip piles and therefore can

120 influence the storage performances [12]. In this study, the air permeability was estimated using the

121 coefficient (A) defined by Nellist [23]:

122
$$A = 19125 * P^{-0.874}$$

123 where P is the mean of particle size expressed in mm.

124

125 This coefficient was calculated only for uncompacted piles.

127	The size of the woodchips used in the tests was determined following the European Standard EN
128	15149-1: 2011 using 1 kg samples. In particular, the wood chips were split into eight classes: <3.15
129	mm, 3.16-8 mm, 9-16 mm, 17-31.5 mm, 31.16–45 mm, 46–63 mm, 64–100 mm, and >100 mm.
130	
131	The wood energy content (Low Heating Value) was calculated according to the following formula
132	[24]:
133	LHV = Wdw * Es - Ww * Ew,
134	where:
135	LHV = wood energy content (Low Heating Value) (GJt^{-1}) ,
136	Wdw = dry wood weight (t),
137	Ww = water weight (t),
138	Es = the specific energy content of dry poplar wood (19 GJ t^{-1} [7]), and
139	Ew = the amount of energy needed to evaporate the water in wood (2.5GJt-1).
140	
141	The data were processed with Microsoft excel and SPSS (2013) statistical software. Eventual
142	differences between the trials were checked with the Ryan-Einot-Gabriel-Welsch (REGW) test
143	because it has a higher statistical power given this data distribution. This study adopted a
144	significance level of $a = 0.05$.
145	
146	Results
147	80%-Eighty percent of the comminuted wood used in the trials was in the form of chips, with sizes
148	between 8 and 45 mm (central particle size class) (Fig. 2). The average particle size of the
149	comminuted wood was 31 mm, and the permeability coefficient calculated was 951.
150	

151	During the test, the air temperature ranged from 17 to 28 °C. A mean value of 23 °C was recorded
152	over the entire storage period. The air humidity ranged from 56% to 62% (monthly average), with
153	peaks occurring during rain events (Fig. 3). The total precipitation was 50.6 mm of rain.
154	
155	Fig. 4 reports the temperature trends obtained from the different piles. The trends for all piles are
156	similar, and all piles showed gradual descending temperature trends. The higher temperature values
157	were obtained a few days after building the piles. Subsequently, the values exhibited a constant
158	decline until reaching equilibrium with the air temperature after approximately 50 days.
159	
160	The temperature values obtained over the entire storage period at the different measurement points
161	are shown in Table 2. The data processing showed no significant differences between the values
162	recorded in the same test and time period at three different heights.
163	
164	The moisture content of the woodchips decreased during the entire storage period, with similar
165	trends for all pile types tested (Fig. 5).
166	All chips originated from the same stem stack. Thus, the initial moisture content was the same for
167	all treatments. We therefore assumed that the general trends presented in this study are
168	representative of the differences in treatment.
169	The statistical analysis did not show any significant differences between the moisture content
170	readings obtained from the different heights (Table 3).
171	
172	Table 4 and Figure 6 show the initial and final mean volumes, the green weight and the dry matter
173	losses determined for the different types of piles. An average dry matter loss of 10% was recorded
174	for all treatments .
175	
176	Discussion

The results obtained in this work are similar to those obtained in other Italian [20, 25] and northern European [26] studies comparing different storage techniques. In these studies, chip piles covered with different materials (plastic sheets, semi-permeable fleece sheets, and roofs) and uncovered chip piles were analysed. In detail, the dry matter losses obtained in this study (10%) are similar to those recorded in other experiments using uncovered chip piles.

182

In contrast, our results for moisture content differ from those obtained in other studies conducted in 183 northern Europe [7, 17, 19, 26]. This is because the Italian climate is drier, which limits re-wetting. 184 In fact, rain events are rare in northwestern Italy, especially in the summer reason (the storage 185 186 period chosen in this study). These favourable weather conditions contributed to drier wood chips (20%) after only 30 days of storage. In northern Europe or in the same locality but with different 187 weather conditions, storage periods of up to 180 days may be necessary to obtain drier wood chips 188 189 [19-20]. Notably, drier woodchips offer a high reward, especially in the residential heating market sector [27]. 190

191

All treatments showed an early temperature trend that can be taken as an indication of biological 192 activities inside the piles, which is the main cause of dry matter losses [7, 21]. As in other studies, 193 194 early temperature peaks were recorded during the first ten days of storage [28]. Differently the temperature inside the pile were lower than 15% compared to values the same authors found in 195 other work carried out in the same geographical area [20]. That difference could be attributable to 196 different storage period considered: summer in this study, and spring/summer in the previous 197 experiment [20]. The compaction of the woodchips, which drove out air, did not limit the biological 198 activity. The temperature recorded in high density piles was similar to that observed in low density 199 piles. One reason for this could be the leaves presence in the woodchip and the high environmental 200 temperature during the experiment period. 201

Moreover, no differences were observed between the forms (trapezoidal and conical) and volumes ($35 \text{ and } 70 \text{ m}^3$) of the tested piles. These results suggest that a storage system can be selected to service only the needs of thermal stations.

206

Care should be taken when interpreting these results because only poplar chips wood were tested.
This forestry species is less durable than other forestry species used to produce woodchips. The
relative permeability offered by a rather large chip size facilitated water movements. In this study,
the permeability coefficient of wood chips was estimated to be approximately 900 (31 mm chip
side), which is a relatively low value compared to those obtainable from fine woodchips (1500)
[29].

213

The different dry matter losses obtained in other studies conducted in Britain [17] using willow, a species very similar to poplar, are probably due to the different climate conditions and storage period (winter). In fact, the high dry matter losses (20%) recorded in northern Europe could be linked to a wetter Atlantic climate and season, which cause high proliferation rates in fungi and pathogens.

219

The present study also showed that all tested treatments resulted in sufficient moisture loss after 30 days of storage (approximately 18%). This moisture loss can guarantee the use of woodchips in any processing type, including industrial boilers [30], co-firing [31], pulping [32] or green chemistry [33].

224

The results obtained in this experiment strongly depended on the period during which the storage occurred and particularly on the very low levels of precipitation that characterise Italian summers. Under Italian climate conditions, the rainfall normally exceeds 50 mm during the other seasons. In fact, another Italian study documented very high dry matter losses and limited drying for the same type of chips stored in trapezoidal and uncompacted piles for six months across the winter andspring seasons [25].

231

Finally, the logging of conventional poplar plantations often results in a summer availability of logging residues for use in wood chips production. This reduces the drying time of the wood chips and, consequently, the dry matter losses independently of chip pile form, size and density relative to wood chips produced from dedicated plantations, which are normally harvested in winter.

236

237

238 Conclusions

239 Under the conditions of the northern Italian summer, the forms and sizes of the uncovered wood

chip piles considered in this experiment do not influence the final poplar woodchip quality.

Furthermore, the woodchip density during the storage period did not affect the biofuel quality in

this study. These results are relevant to the wood biomass storage sector because a power station or

farm can build biofuel piles only as a function of its logistic requirements.

Notably, the climate conditions affected both the storage dynamics and the results obtained in this

study. In the future, it could be interesting to carry out experiments using wood chips produced

from other tree species, thereby allowing the evaluation of the differences between those results and

the results obtained in this study.

248

249 **References**

- [1] Spinelli R, Nati C, Sozzi L, Magagnotti N, Picchi G. Physical characterization of commercial
 woodchips on the Italian energy market. Fuel 2010;90:2198–202.
- [2] Pottie M, Guimier D. Preparation of forest biomass for optimal conversion. FERIC Special
 Report SR-32, 1985, Pointe Claire, Canada. 112 p.
- [3] Strelher A. Technologies of wood combustion. Ecological Engineering 2000;16: 25-40.

- [4] Spinelli R, Magagnotti N. Comparison of two harvesting systems for the production of forest
 biomass from the thinning of Picea Abies plantations. Scandinavian Journal of Forest Research
 2010;25:69-77.
- [5] Spinelli R, Cavallo E, Eliasson L, Facello A. Comparing the efficiency of drum and disc
 chippers. Silva Fennica 2010;47(2):http://dx.doi.org/10.14214/sf.930.
- [6] Nord-Larsen T, Talbot B. Assessment of forest-fuel resources in Denmark: technical and
 economic availability. Biomass Bioenerg 2004;27:97-109.
- [7] Jirjis R. Storage and drying of wood fuel. Biomass Bioenerg 1995;9:181–90.
- [8] Jirijs R. Effects of particle size and pile and pile height on storage and fuel quality of
 comminuted Salix viminalis. Biomass Bioenerg 2005;28:193–201.
- [9] Kanzian C, Holzleitner F, Stampfer K, Ashton S. Regional energy wood logistics optimizing
 local fuel supply. Silva Fennica 2009;43:113–28.
- [10] Nurmi J. The storage of jogging residue for fuel. Biomass Bioenerg 1999;17:41–7.
- [11] Jirijs R. Enumeration and Distribution of fungi in stored fuel chip piles. Material and
 Organismen 1989;24(1):27-38.
- [12] Casal MD, Gil MV, Pevida C, Rubiera F, Pis JJ. Influence of storage time on the quality and
 combustion behavior of pine woodchips. Energy 2010;35:3066-71.
- [13] Thoernquist T, Lundstroem H. Health hazards caused by fungi on stored wood chips. F prod J
 1982;32:11-2.
- [14] Riva G, Balsari P. Essiccazione del legno sminuzzato da utilizzare a fini energetici. Cellulosa e
 carta1988;39(6):31-6.
- [15] Riva G, Fabbri C, Calzoni J, Massari A. Prove di essiccazione e stoccaggio della biomassa.
 Roma: ENEL Direzione Studi e Ricerche; 1997.
- [16] Kubler H. Air convection in self-heating piles of wood chips. Tappi Journal 1987;65:63-79.
- [17] Mitchell CP, Hudson JB, Garder D, Storry P. A comparative study of storage and drying of
- chips and chunks in the UK. In: Proc of JEA/BE Workshop production, storage and utilization

- of wood fuels. Uppsala, Sweden. SLU, Department of Operational Efficiency, Garpenberg,
 Research notes1988;134:72–89.
- [18] Nilsson T. Lagring av smaved I mandre stackar. Summary: storage of chunk wood in smaller
 piles. Report, SLU, Department of Forest Products 1987;196:4-6.
- [19] Jirjis R, Thelander O. The effect of seasonal storage on the chemical composition of forest
 residue chips. Scand J For Res 1990;5:437–48.
- [20] Manzone M, Balsari P, Spinelli R. Small-scale storage techniques for fuel chips from short
 rotation forestry. Fuel 2013;109:687-92.
- [21] Fuller W. Chip pile storage a review of practices to avoid deterioration and economic losses.
 TAPPI J 1985;68:48–52.
- [22] UNI EN 14774-2. Solid biofuels, determination of moisture content oven dry method, Part 2:
 total moisture simplified method; 2010.
- [23] Nellist M. The effect of particle size on the storage and drying of wood fuels. In: Hudson B,
- 294 Kofman P, editors. Harvesting storage and road transportation of logging residues. Proceedings
- of a workshop of IEA-BA-Task XII activity 1.2 held in October 1995 Glasgow, Scotland. FSL,
- 296 Vejle (Denmark); 1995, p. 59-70.
- [24] Magagnotti N, Spinelli R. COST Action FP0902 good practice guideline for biomass
 production studies. CNR IVALSA. Florence, Italy; 2012. p. 41 [ISBN 978-88-901660-4-4].
- [25] Barontini M, Scarfone A, Spinelli R, Gallucci F, Santangelo E, Acampora A, et al. Storage
 dynamics and fuel quality of poplar chips. Biomass Bioenerg 2014;62:17-25.
- 301 [26] Gjölsjö S. Storage of comminuted birch in piles in Norway. In: Proc IEA/BA Task VI Activity
- 302 5. Garpenberg, Sweden, 13–16 June, Swedish University of Agricultural Sciences, Department
 303 of Operational Efficiency. Uppsala; 1994.
- 304 [27] Spinelli R, Magagnotti N. Comparison of two harvesting systems for the production of forest
- biomass from the thinning of Picea Abies plantations. Scand J For Res 2010;25:69–77.

- 306 [28] Eriksson A. Energy efficient storage of biomass at Vattenfall heat and power plants.
 307 Examensarbete (Institutionen för energi och teknik, SLU, Swedish University of Agricultural
 308 Sciences, Upssala, Sweden; 2011. p. 102 [ISSN 1654- 9392].
- 309 [29] Spinelli R, Hartsough B, Magagnotti N. Testing mobile chippers for chip size distribution. Int J
 310 For Eng 2005;16:29–35.
- [30] Khan A, De Jong W, Jansens P, Spliethoff H. Biomass combustion in fluidized bed boilers:
 potential problems and remedies. Fuel Process Technol 2009;90:21–50.
- 313 [31] Molcan P, Lu G, Le Bris T, Yan Y, Taupin B, Caillat S. Characterisation of biomass and coal
- 314 co-firing on a 3 MWth combustion test facility using flame imaging and gas/ash sampling
 315 techniques. Fuel 2009;88:2328–34.
- [32] Phelps J, Isebrands J, Einspahr D, Christ J, Sturos J. Wood and paper properties of vacuum
 airlift segregated juvenile poplar whole-tree chips. Wood Fiber Sci 1985;17:529–39.
- [33] Faaij A. Bio-energy in Europe: changing technology choices. En Pol 2006;34:322–42.