Fuel 220 (2018) 817–825

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Full Length Article

To split or not to split: Feasibility of pre-storage splitting of large poplar (*Populus* spp. L.) fuelwood logs

Gernot Erber*, Christoph Huber, Karl Stampfer

University of Natural Resources and Life Sciences, Vienna, Department of Forest and Soil Sciences, Institute of Forest Engineering, Peter Jordan Strasse 82, 1190 Vienna, Austria

ARTICLE INFO

Keywords:
Splitting
Logwood
Fuelwood
Poplar
Natural drying
Transport

ABSTRACT

Contrary to firewood, and despite the availability of dedicated equipment splitting of logwood is not yet a common practice in fuelwood supply. This study investigated the impact of a pre-storage splitting treatment on moisture content alteration, dry matter loss and volumetric energy density. Further, economic and environmental implications of splitting were investigated. Splitting increased the drying rates of large poplar logs 2–3 times and enabled to reach a 15.3% lower final moisture content compared to intact logs at similar dry matter loss rates (9.2% vs. 7.8%). Final volumetric energy density of split logs was 27.2% higher than for intact logs. Splitting increased the profit from poplar fuelwood and decreased respective supply cost. Further, 26.3% less truck trips were required for woodchips produced from split logs. Pre-storage splitting is highly recommended for large logs of slowly drying species like poplar, to, firstly, reach low moisture content levels at all, and secondly, reach them in less time. This treatment has the potential to become an integral part of sustainable and responsible utilization of our fuelwood resources, as less material is required to supply the same amount of energy. At the same time, less truck trips are required to transport it, which is clearly beneficial from an environmental viewpoint.

1. Introduction

Wood is a major source of renewable energy in the European Union. About 744 million m^3 per year could be harvested economically, which is about 58% of the total potential. To realize more of the potential, efficiency in fuelwood supply has to increase [21]. Moisture content is the key parameter in fuelwood supply, with strong influence on the net calorific value, pricing and transportation economics and CO_2 emissions [22]. While a decrease of moisture content increases the calorific value of the material, it decreases the share of water transported per truckload. This is beneficial in terms of payload and vehicle loading volume utilization [36,35,3,20,24,37,11].

Natural drying has been studied intensively in the recent years and is considered to be an efficient and low cost method to decrease the raw material moisture content [8,10,12,13,11,9,28,30–33]. Traditionally small diameter wood has been the most important source of commercial forest energy. However, large and low quality logs have become a significant source of wood energy as well. Small diameter logs dry easier and faster than large logs [34,1,8,30,5,38]. Due to the fact that in wood in bark moisture is transported primarily in longitudinal direction, it expels moisture mostly at the cutting surfaces. Radial movement of moisture is somewhat slower and additionally hampered by the presence of bark. By splitting a larger drying surface to mass ratio is achieved. Slower moisture transport in radial direction is thus balanced by a significant reduction of the average distance to the drying surface [39,8]. Visser et al. [38] concluded that, the longer and larger the log, the more significant is the effect of this treatment. In their study, the moisture content of 1.8 m long, split and covered radiate pine (*Pinus radiata* L.) logs decreased by 26.2% in summer and 12.8% in winter. However, the authors were not able to generally conclude if splitting is feasible from an economic point of view, as this strongly depends on the splitting method and material characteristics.

Poplar (*Populus* spp. L.) is a genus that represents about 0.62% of the total stocking volume in Austrian forests [4]. Though at the first glance of minor relevance, poplar is of major importance as the bread-and-butter tree in floodplain forests, which are mainly located in the Danube river region. Domestic poplar species include aspen (*Populus tremula* L.), white poplar (*Populus alba* L.) and black poplar (*Populus nigra* L.). Additionally, a large variety of poplar hybrids cultivated in plantation-fashion have been introduced [19]. A large share of poplar wood is consumed for the production of packaging material [16], while lower quality assortments are primarily utilized for the production of

* Corresponding author.
E-mail addresses: gernot.erber@boku.ac.at (G. Erber), c.huber@boku.ac.at (C. Huber), karl.stampfer@boku.ac.at (K. Stampfer).

https://doi.org/10.1016/j.fuel.2018.02.029
Received 15 December 2017; Received in revised form 5 February 2018; Accepted 6 February 2018
Available online 22 February 2018

chipboard and paper. Tree crowns and trees from thinnings are used for energy production in form of woodchips [18]. Poplar is usually harvested in late autumn and in winter and semi-mechanized and fully mechanized harvesting systems are available. Material intended for energy production, which is about 20%–30% of the total biomass at a site, is piled at the roadside and remains there until chipping, which usually takes place in autumn [14].

Despite the technology for splitting large logs (wood tongs, cone splitters, etc.) is already established on the market, only a small number of studies have dealt with this subject. As already known from firewood production, splitting dramatically increases the moisture evaporation capability of the raw material. Accordingly, it can be expected that this effect is present at the up-scaled level of split logs too. If this is the case with large white poplar (*Populus alba* L.) logs, was investigated in this study. Foresters report that they have frequently observed that, poplar logs stored in floodplain forests are still capable of sprouting new shots even after one year of storage. This indicates that they maintained a high moisture content level if stored intact. Thus, poplar logwood can be expected to be a raw material that could benefit the most from pre-storage splitting. Accordingly, the aims of the present study were to 1) compare the drying performance of large split and intact poplar logs over a prolonged period, to 2) investigate economic and to 3) determine environmental effects of including a splitting treatment in the fuelwood supply chain.

2. Materials and methods

2.1. Site and climate

The logwood storage site was located near Traismauer (48.375897° latitude and 15.718628° longitude, 194 m above the Adriatic) in the province of Lower Austria. Situated in a lowland floodplain forest near the Danube river, the flat, grassy storage site was skirted by a tree line in the south (about 15 m from the piles), while open for at least 50 m in all other directions. In this region, the mean annual sum of precipitation is 551 mm, while the mean annual temperature is 9.6 °C [7].

2.2. Continuous weighing approach for drying monitoring

Detailed monitoring of the drying performance of fuelwood was carried out by the “continuous weighing approach” [12], as it “offers the best opportunity to acquire data on a continuous scale” and “is highly recommended for its accuracy” [23]. This approach has been chosen by numerous studies in the recent years [10,12,13,9,17,26,28,31–33]. Dedicated equipment consists of load cell-supported metal frames and a meteorological station, equipped with a data logger. As employed by [12,13,11,9], two metal frames of about 600 kg weight each, 2.5 m width and height and 2.6 to 2.7 m length, shaped similarly to those used on timber trucks, were placed on four load cells each. Load pressure was distributed evenly by squared metal plates (30 cm × 30 cm) under the load cells and atop of square edged wooden beams. Frames were placed in succession, with their shorter sides facing in north and south direction and about five meters apart. Five meters to the west of the gap between the frames, a mobile, solar powered meteorological station was set up, which recorded relative air humidity air temperature, wind speed, wind direction, solar radiation and precipitation. Both meteorological and load data were measured at a 10-s interval and were recorded by a data logger at a ten-minute interval. During daylight hours, data was transferred to a server via GSM network. In the present study, the drying progress of two piles was monitored via the pile weight alteration for 513 days between March 9th 2016, 17:00 h and August 07th 2017, 08:00 h.

Table 1
Parameters of the stored material.

Parameter	Variate intact	Variate split
Number of logs [n]	39	43
Average diameter [cm]	4.69 ± 0.53 m	4.55 ± 0.34 m
Average length [m]	27.8 ± 4.5 cm	30.7 ± 5.1 cm
Total pile volume [m^3]	12.18 m^3	11.06 m^3
Total pile mass [kg]	11,299	10,067
Initial sampled moisture content [%]	49.3 ± 3.6	47.7 ± 2.9
Initial sampled bone dry density [$kg\ m^{-3}$]	470.0 ± 30.3	475.4 ± 23.4

2.3. Material preparation and sampling

White poplar (*Populus alba* L.) was harvested in February 2016 and stored intermediately at the harvesting site. On the 9th of March, the material was forwarded to the storage site. Logs were separated into two different treatment variates (Table 1), each representing roughly half of the total logwood volume. Logs from the first variate were split into half by a do-it-yourself splitting device mounted on the side of a farm tractor-pulled forwarding trailer. This device consisted of a “u”-shaped metal profile, into which the log was placed by forwarding trailers crane. A hydraulically powered splitting wedge was driven horizontally through the log, thereby splitting it. The operator lifted one log at a time into the profile, split it and put the split parts into the metal frame. Some of the logs had to be split a second time from the other side or splitting had to be supported by pulling the crane’s grapple. The average productivity was about 10 m^3 per productive hour of work. Logs constituting the second variate remained intact.

Ten randomly selected logs per variate were sampled for laboratory analysis of moisture content and bone dry density. Due to the forest owner’s requirement to maintain the log’s original length, samples could not be taken in sample slice fashion. Alternatively, samples were taken in form of four cm thick semicircles, thereby ensuring log integrity. Samples were cut at 50 cm from the upper and lower end of the logs and at opposite sides. A two-colour-combination code was used to mark the sample logs for later re-identification. Sample segments were weighed immediately at the storage site, provided with identification and sealed into paper bags for transport. After one year of storage, random samples were cut from ten logs per variate on March 29th 2017. Selection of logs was limited to logs physically accessible to chainsaw operation. Samples were again cut at about 50 cm from both ends. At the end of the experiment, samples were cut form the same logs as in the beginning. This time, four samples, located 25 cm and 150 cm from the lower and upper end and on the opposite sides of the samples cut the start, were extracted. Analysis of and final moisture content was carried out in accordance with the European standard CEN/TS 14774-2. Moisture content values are reported on wet weight basis.

2.4. Dry matter loss correction

Poplar is a species particularly vulnerable to dry matter loss of considerable size (up to 9% per year; eg. [2]). Thus, a deviance of the final moisture content obtained from load data from the actual moisture content was to be expected (e.g. [31]). To obtain the “real” drying curve, the load data based curve has to be corrected for dry matter losses, which is usually done by attributing the final deviation in moisture content to dry matter losses. In this study, dry matter loss could be directly obtained from bone dry density samples. For a realistic distribution of dry matter losses, a temperature and (estimated) moisture content related approach was chosen. Wood-decay fungi’s optimum temperature for growth is 20 °C to 35 °C (optimum conditions), while almost no growth happens below −3 °C and above 60 °C. Between −3 °C and 20 °C and 35 °C and 60 °C (semi-optimal conditions), growth of wood-decay fungi declines substantially. Further, fungi can grow between 20% and 65% wood moisture content, but their