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Research paper

Effect of storage methods on willow chips quality

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ABSTRACT

Lignocellulose biomass is a key source of bioenergy in the EU and in Poland. Therefore, this study analysed the effect of the method of storing chips obtained from short rotation willow on their thermophysical and chemical properties and on the biomass loss, depending on the method of storage and the type of cover, in the climatic conditions of Central-Eastern Europe. The experiment involved examination of five methods of storage of willow chips: with no cover (control), under permeable covers Toptex 200 and Toptex 300, under vapour-permeable foil and in a wooden shed. The chips were stored from March 2011 to March 2012. Use of cover made of permeable materials was found to improve the biomass quality: its moisture content decreased more than twice and its heating value increased more than twice. The energy content of the stored piles was also found to increase by 10% after a year of storage. The energy content was also found to increase in a roofed pile and to decrease in biomass covered with foil (−9%) and uncovered (−50%). Biomass loss for chips stored under permeable covers ranged from 3.8% to 5.1%. Similar findings were recorded for chips stored in a shed, while the effects were worse for the piles stored under vapour-permeable foil. The worst biomass parameters were recorded for an uncovered pile. Storage of willow chips in an open space under cover could be a cheaper alternative, which could improve the quality of willow chips compared to roofed warehouses.

1. Introduction

Lignocellulosic biomass is an abundant and renewable feedstock. It can includes cereal straw, wheat chaff, rice husks, corn cobs, corn stover, sugarcane bagasse, nut shells, forest harvest, residue, wood process residues, energy crops on marginal and degraded lands [1–5]. This type of biomass is used in many advanced and conventional power generation technologies, i.e. in heat energy production carried out in boilers and furnaces, power plants as well as in combined heat and power plants [6–11]. Biomass is also used in electricity generation in hybrid systems, in fuel cells, through gasification or used in the production of 2nd generation biofuels [12–16].

Lignocellulose biomass is a key source of bioenergy in the EU. It is noteworthy that it is obtained mainly in the community area, as a local energy source. The import of wood biomass accounted for only 1.92% of gross bioenergy consumption in 2014 in the territory of the Community, with wooden chips being among the major biomass fuels used in nearly 4 thousand installations of more than 1 MW [8].

The importance of wooden biomass used as energy feedstock in the EU is set to increase until 2020. However, as more and more forest areas come under legal protection, the potential of forest biomass will decrease by 10% in 2030 compared to 2010 [17]. A similar situation in Poland was taken into account in the National Action Plan for energy from renewable sources, which states that including new forest areas in the Natura 2000 programme will limit the possibility of using forest biomass and will increase the area of cultivation of energy crops on agricultural land [18]. Moreover, Polish national regulations as well as those drafted on the EU level will force energy producers to use agricultural biomass, such as straw and biomass obtained from permanent energy crop plantations [19,20]. For this reason, SRC biomass, including that from willow, has become popular in Poland among large electrical power plants and heat and power cogeneration plants as combustion or co-combustion feedstock, while willow cultivation has expanded from 6160 ha in 2009 to 7728 ha in 2013 [21–23].

The high cost of biomass harvest and considerable loss of dry

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weight during the storage of wood chips remains a considerable issue [24]. The biomass quality (thermophysical properties) depends on the species and the time of biomass harvest, but also on another two main factors: technology of biomass harvest and the method of its further storage [25,26]. In practice, two methods of harvesting wood biomass cultivated in short rotations are used. The cut-and-storage method involves harvesting whole shoots or whole trees in forests which - due to their large diameter - cannot be harvested with agricultural machines. On the other hand, cut-and-chip involves simultaneous harvesting and cutting up shoots to obtain chips of various sizes [24,25]. The former method is used on a smaller scale since it generates higher costs in large-scale supply chains than the one-stage-harvest method [27]. For this reason, the cut-and-chip method with the fastest possible delivery of biomass for conversion is a more economically justified method.

Wood biomass of the most popular species cultivated in short rotations in Europe: willow, poplar or black locust, harvested in winter, has a moisture content of 40–60%, which makes it necessary to store it to reduce the parameter (usually to below 40%). This aims to increase the calorific value of biomass and, consequently, the price of the feedstock [28–31]. Since freshly harvested wood contains high levels of moisture, whole shoots are stored outdoors in uncovered or covered piles. Chips can be stored outdoors, but also in warehouses with or without systems of ventilation, refrigerating or drying. Biomass drying before it is used further is caused by economic (higher price) and technological reasons (better conditions of burning, higher calorific value). SRC chips are harvested in winter and then, in most cases, are stored until the next heating season. Their prolonged storage (usually from several months to a year) results in infestation by microorganisms, such as fungi and bacteria, which further results in an increase in temperature in wood piles, wood decomposition and loss of dry weight. This negative process can be controlled by ventilated storage, increasing chip size or covering chips piles [32–34]. It has been shown in a number of studies that covering piles of SCR chips reduces their moisture content from 50 to 60% to as little as 22%. Moreover, this reduced loss of dry weight to even 5.1% [34–37].

Due to the high cost of construction of roofed warehouses in Poland, chips are often stored in open spaces, in concrete silos or often on unhardened ground. Some chips are covered by impermeable tarpaulin to protect them from atmospheric precipitation. Minor biomass users in rural areas store them in their farmstead buildings, under plastic covers, or uncovered. Moreover, it should be pointed out that the majority of the quoted scientific literature on the SRC biomass storage refers to poplar biomass. A study on the effect of storage methods on willow chip quality is therefore of high significance particularly because willow is one of the most important SRC species in north-eastern Europe. Therefore, a decision was taken to determine the effect of the method of chips storage on their thermophysical and chemical properties and on biomass loss, depending on the method of storage and the type of cover, in the climatic conditions of Central-Eastern Europe.

2. Materials and methods

2.1. Description of the experiment

The chip storage experiment was conducted at the Didactic and Research Station in Łężany (53°58′N, 21°8′E) owned by the University of Warmia and Mazury in Olsztyn (UWM).

Chips from willow cultivated in a 3-year harvest rotation were harvested for the experiment in mid-March 2011. The material was obtained from Tur and Ekotur cultivars (both of *Salix viminalis* species), grown at the Łężany station. The willow biomass was harvested in two stages. Plants were cut down with a DCS520 (Makita) chain saw 5–10 cm above the ground level. At the same time, the whole shoots with branches were cut up on the spot into chips with a Junkkari HJ 10 G chipper, working together with a tractor (New Holland) with the power of 130 kW.

Piles were made immediately after the chipping. Chips were transported for 2 km to a concrete-covered site on which 2000 kg piles were made. Each pile was formed into a cone approximately 1.5 m high and approximately 4 m in circumference, to facilitate rainwater to flow down.

Five representative samples of about 1 kg each (pooled sample of about 5 kg) for laboratory analyses were collected from each pile while the piles were prepared. The samples were packed in foil bags and sent to the laboratory at the Department of Plant Breeding and Seed Production for determination of the thermo-physical and chemical properties of fresh chip biomass (moisture content, higher heating value (HHV), lower heating value (LHV), ash content and C, H, S and N).

Five methods of chips storage were compared:

1. Vapour-permeable and waterproof roof foil with a weight of 110 g m^{-2}. The membrane is used as cover to protect against dampening and leaking of roofs. The material is easily available and relatively cheap.
2. Toptex 130 membrane with a weight of 130 g m^{-2}. This membrane is a gas-permeable fleece composed of 100% endless polypropylene filaments. Its properties and forms of supply are adjusted to the requirements of each individual application in the field of agriculture (e.g. beetroot, potato, straw, wood chips covering).
3. Toptex 200 membrane with a weight of 200 g m^{-2}, with extended stability and higher strength than Toptex 130.
4. Wooden shed with a roof.
5. No cover, in an open space, on concrete slabs, as a control.

The storage lasted 12 months, from mid-March 2011 to mid-March 2012.

2.2. Measurement of biomass temperature and meteorological conditions

The temperature of biomass was measured with ethanol-filled thermometers placed inside the willow chip piles in order to analyse the temperature variability. The thermometers were situated at half of the pile height and at a depth of approximately 80 cm under the surface. The temperature measurement was taken manually, always at the same site, at weekly intervals from March to June 2011, and then every 2 weeks until March 2012. Meteorological data on the total precipitation and air temperatures during the study period and data from the multi-year period of 1998–2014 were obtained from the Meteorological Station in Łężany, administered by the Institute of Meteorology and Water Management.

2.3. Laboratory analyses

Samples of biomass for laboratory analyses to determine the moisture content in chips were collected once, at the end of each month. The samples were packed in air-tight plastic bags and sent to the laboratory. Subsequently, samples of biomass were taken every three months to analyse the changes in the thermophysical and chemical properties of the willow chips. The following features were determined: moisture content, higher heating value (HHV), lower heating value (LHV), ash content and concentrations of C, H, S and N. Each analysis was performed in triplicate. The moisture was determined with the oven-dry method. To this end, a sample of biomass was dried at 105 °C in a Premed KBC G-65/250 dryer until a