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The impact of torrefaction on coniferous forest residue fuel

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Abstract

As bioeconomy principles and sustainable use of biomass resources (including the use of forest resources) are becoming increasingly important issues, it is necessary to find the right use of forest biomass with the highest added value. During the harvest of timber, forest residues are created. Currently, this residue is used in relatively small quantities, mainly for the production of forest woodchips. Coniferous woodchips are considered to be a lower quality fuel, however, using certain methods, the physical properties can be improved, and a better quality fuel can be obtained. The method for the wood fuel property improvement selected in this paper is torrefaction. This study is conducted in order to evaluate the changes in fuel properties of coniferous forest residue, in particular, spruce and pine needles and twigs, influenced by torrefaction. In this study eight different samples are prepared according to a three-factor experimental design. The moisture content, gross and net calorific value and ash content is determined in laboratory conditions. The results are analysed, and a comparison with other biomass types is carried out.

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Keywords: needles; coniferous; torrefaction; forest fuel; logging waste; ash content; combustion heat; ash melting

1. Introduction

As bioeconomy principles and sustainable use of biomass resources (including the use of forest resources) are becoming increasingly important issues, it is necessary to find the right use of forest biomass with the highest added value. The greatest natural resource in Latvia is its forests (52 % from the total country area [1]). More than half (41 %) [1] of Latvia's forests are coniferous (pine and spruce) forests. During the harvest of timber, forest residues are created and currently itis used in relatively small quantities, mainly for the production of forest

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woodchips [2]. Coniferous woodchips are considered to be a lower quality fuel, however, using certain methods, the physical properties can be improved, and a better quality fuel can be obtained. The method for the wood fuel property improvement selected in this paper is torrefaction.

Torrefaction is a thermal biomass conversion method in the temperature range from 200 to 300 °C (in some cases exceeding 300 °C). In most cases it is performed in atmospheric conditions in the absence of oxygen [3, 4]. The key benefits from torrefaction is the increase of fuel calorific value through energy densification, increasing the biomass hydrophobicity (lowering the equilibrium moisture content), and decreasing both the moisture content and fuel mass [5].

The amount of published studies on torrefaction is comparatively small, however, in recent years the number of studies concerning torrefaction as a method for improving fuel quality has increased. These studies include some non-woody biomass waste torrefaction, for example, olive mill waste [6], food waste [7], tomato processing industry residues [8], reed canary grass, and wheat straw [9]. Though the main focus has been on wood biomass torrefaction research [5, 10–12]. The fuel quality improvements by torrefaction of forest logging residues also has been studied in several studies, for example, different species of softwood residues [13], impact of torrefaction on the grindability and fuel characteristics of pine biomass [14] and properties of forest residues torrefaction [15, 16]. The impact of torrefaction on the coniferous forest biomass residue fuel properties has been previously studied incompletely. The studies so far have analyzed only the woody part of the logging residues omitting the torrefaction impact on pine and spruce needles. Therefore this study is conducted in order to evaluate the changes in fuel properties of coniferous forest residue, in particular, spruce and pine needles and twigs, influenced by torrefaction.

2. Materials and methods

In order to evaluate the coniferous logging residue (pine and spruce needle and twig) fuel properties an experiment was performed. In the experiments the tree species (pine and spruce), needle torrefaction, and needle drying temperature (natural drying at 25 °C, and convective drying at 105 °C) was taken into account. According to a three-factor experimental design, eight needle samples (sample No. 1–8) were prepared (see Table 1).

Table 1. Experiment plan for needles examples.

Factors	Sample No.											
	1	2	3	4	5	6	7	8	9	10	11	12
Tree specie	pine	spruce	pine	pine	pine	spruce	spruce	spruce	spruce	pine	spruce	pine
Torrefaction	no	yes	no	yes	yes	yes	no	no	no	no	yes	yes
Drying temperature, °C	25	105	105	105	25	25	25	105	-	-	-	-

For all the samples Net and Gross calorific values are determined according to LVS EN 14918 Standard using IKA C200 calorimeter, moisture content according to LVS EN 14774-2, and ash content according to LVS EN 14775. The calorific value is one of the most significant characteristics of any fuel, as it is the energy released when burning [17].

The same parameters are also determined for torrefacted and non-torrefacted fine (diameter below 5 mm) pine and spruce twigs. The samples (sample No. 9–12) were prepared according to a two-factor experimental design (see Table 1). The two factors taken into account in the analysis of the twigs are the tree species, and torrefaction. The influence of the twig drying temperature on the torrefaction results was not studied because such studies have already been carried out [15].

The sample material was harvested in the autumn of 2014 in forest clearings from logging residues. The torrefaction was performed using a metal torrefaction mould, ensuring the exhaust of the gases discharged from biomass while heating, and at the same time limiting the entrance of oxygen. In this experiment series, the optimal temperatures and duration of torrefaction were not studied in detail; only if torrefaction has a positive effect on the needles fuel properties. The torrefaction of the samples is performed at 300 °C for two hours, with the initial temperature of 22 °C, reaching the maximum temperature in an hour, and the cooling time of one hour.