BIOMASS AND BIOENERGY 42 (2012) 43–50

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Fuel quality changes in full tree logging residue during storage in roadside slash piles in Northwestern Ontario

Shuva Gautam, Reino Pulkki, Chander Shahi, Mathew Leitch*

Faculty of Natural Resources Management, Lakehead University, 955 Oliver Road, Thunder Bay, Ontario, Canada P7B 5E1

ARTICLE INFO

Article history:
Received 29 June 2010
Received in revised form
24 January 2012
Accepted 20 March 2012
Available online 18 April 2012

Keywords:
Ash content
Bioenergy
Fuel quality
Gross calorific value
Moisture content
Northwestern Ontario

ABSTRACT

The procurement of logging residue for energy production can be uneconomical due to high moisture content and low gross calorific value. High moisture content in biomass lowers the energy density and transportation becomes less efficient. Logging residue, from full tree logging operations stored in roadside beehive and windrow piles, were examined to determine the effect of storage method and duration on fuel quality in northwestern Ontario, Canada. The fuel attributes assessed were moisture content, gross calorific value and ash content. Windrows displayed lower moisture content than beehives. Softwoods generally displayed lower moisture content and higher gross calorific values than hardwoods. Smaller diameter stems displayed higher gross calorific value and ash content than larger diameter stems. The moisture content (green basis) reduced from a green state to 15.1% after two years of storage in roadside slash piles, whereas gross calorific value and ash content did not change significantly with storage time. The gross calorific values ranged from 19.5 to 23.1 MJ kg^{-1} and the ash content ranged from 0.4% to 8.4% for all species, components and storage years. The study demonstrates that the storage regime plays a significant role on the fuel quality of logging residue. Proper storage and drying techniques improve the fuel quality and net energy yield from logging residue biomass, thereby leading to an overall cost reduction of the biomass feedstock.

1. Introduction

In northwestern Ontario, approximately 13%–14% of volume harvested using the full tree to roadside, roundwood to mill system is left on the harvest site as logging residue in the form of slash piles [1,2]. The present options for slash piles are either: i) to leave these on site to decay where they pose a potential fire hazard and occupy valuable space where seedlings could be established [3], or ii) to dispose these slash piles through burning [2,3]. A third option is to use the slash piles for energy production in the light of global warming issues [4,5] and the current forest industry crisis that is partly a result of high energy costs. However, the economic viability of procuring such low bulk density logging residue, already low in energy density, depends on its moisture content (MC) [7,8].

The fuel quality in bioenergy production is assessed based on the properties that affect the energy yield and costs. MC, gross calorific value and ash content of the logging residue are three properties used to assess the fuel quality in slash piles, as each of these properties determine the viability of biomass procurement for bioenergy production [9]. The gross calorific value of a fuel is a measure of the maximum amount of energy that is released during burning of a given quantity of the fuel [10]. However the net energy released will depend on its MC [6,11,12] and ash content [9]. Furthermore, the overall cost can

* *Corresponding author.*
E-mail address: shgautam@lakeheadu.ca (S. Gautam).
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doi:10.1016/j.biombioe.2012.03.015

rise due to extra transport, dumping and handling costs to deal with ash [9,13]. Therefore, information on gross calorific value alone is not sufficient.

Studies in Europe have shown that logging residue can be stored in-field to reduce MC and improve the fuel quality [8,15–17]. In the study conducted by Nurmi [15], Norway spruce (*Picea abies* (L.) Karst.) logging residue in Finland was piled 4.5 m high. It was found that the average MC reduced from 55% (green basis) to approximately 40% after being piled from September 1994 to September 1995. Another treatment of the same study that involved leaving the residue on the cutover from September 1994 to June 1995, then forwarding to the landing until September 1995 resulted in a lower MC of 28%. The form, duration of storage, and the weather conditions affect fuel quality [8]. However, no comparable published research could be found for Canadian continental climate and boreal forest conditions. Knowledge gained from European studies could be applied to northwestern Ontario to a certain extent, but due to differences in logging systems, stored material and weather conditions, this may not be completely valid. This is especially true in areas of continental climate conditions, where there is relatively low summer rainfall and high daily temperatures.

The purpose of this study was to determine a storage regime for boreal forest conditions, with a dry continental climate, that enhances the fuel quality of full tree logging residue stored at roadside. The specific objectives were to determine the differences in fuel quality attributes (MC, gross calorific value and ash content) for: (i) storage years (three drying seasons), (ii) pile shapes (beehive and windrow), (iii) pile heights (more than and less than 2 m), (iv) species (softwood and hardwoods), and (v) logging residue' branch sizes (small with diameter less than or equal to 4 cm and large with diameter greater than 4 cm).

2. Materials and methods

2.1. Study area and logging description

The study materials were located in harvest compartments in the eastern part of the Crossroute Forest, to the west of Atikokan, Ontario, Canada. A harvest compartment is a unit of land allocated for harvest under the same logging method and system during an annual work schedule (AWS) and is also prescribed a regeneration method in its totality. The AWS outlines all forest management activities, including harvesting that are scheduled for a one-year period extending from 1st April to 31st March of the following year. The mean monthly temperature and precipitation recorded at the Atikokan weather station (Lat. 48° 45.667′ N, Long. 91° 37.683′ W) during the storage period are displayed in Fig. 1. Average daily maximum temperatures for June, July and August are 21.7 °C, 24.7 °C and 22.8 °C [18]. Average monthly precipitation for June, July and August are 103.3 mm, 97.9 mm and 97.8 mm, and the average annual precipitation is 739.6 mm [18].

The compartments were harvested using a conventional mechanized full tree system [19], utilizing feller bunchers, grapple skidders, stroke delimbers and slashers. As a result the logging residue (branches and tops) were left in roadside piles. A total of 36 piles were excavated for the purpose of the study. The shape of the slash piles studied fall either under the general category "half-section of sphere" or "half-ellipsoid" referred to as beehive and windrow, respectively. General shapes of piled woody debris have been outlined in reference [20]. Tree species were divided into the categories of softwoods and hardwoods. The softwoods included balsam fir (*Abies balsamea* (L.) Miller), white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea marianana* (Miller) B.S.P.) and jack pine (*Pinus banksiana* Lamb.); and the hardwoods included red maple (*Acer rubrum* L.), white birch (*Betula papyrifera* Marshall) and trembling aspen (*Populus tremuloides* Michx.). The heights of the piles were recorded as being either greater or less than 2 m; the width ranged from 8 m to 16 m. Storage years included logging residue stored for 1, 2 and 3 drying (summer) seasons.

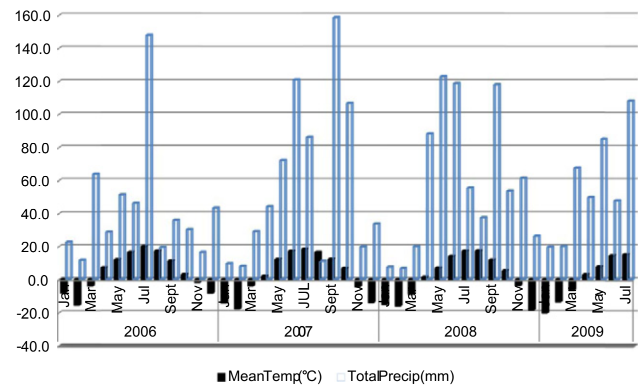

Fig. 1 – Mean monthly temperature and total monthly precipitation at the Atikokan weather station. Source: Environment Canada [18].

2.2. Experimental design and statistical methods

Analysis of variance tests were carried out using the General Linear Model in SPSS to test the null hypotheses of no significant difference in MC, gross calorific value, and ash content for different storage years, pile shapes, pile heights, species, and logging residue diameters. The experimental designs for all the models are full factorial design, with MC, gross calorific value, and ash content as the dependent variables, respectively for each model and storage years, pile shapes, pile heights, species, and logging residue diameters as the independent variables. For gross calorific value and ash content analysis of variance, only two storage years were tested due to financial constraint. Storage years 1 and 2 were tested for ash content but for gross calorific value years 2 and 3 were tested because shorter term studies already exist [8,13,17] with longer term studies lacking. The data for each model was tested for normality and homogeneity of variance before conducting the analysis of variance. Any significant differences in the analysis were analyzed using post-hoc tests.

2.3. Field sampling

A list of all harvest compartments in the area west of Atikokan for the annual work schedule years of 2006–07, 2007–08, and