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Changes in volumetric energy densities during storage of whole-tree feed stocks from silvicultural thinnings

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ABSTRACT

The quality issues of woody feed stocks usually report changes in the moisture content, heating value or dry matter, but these factors are rarely summed and reported as changes in energy densities for a given feed stock. This paper reports the results of ten whole-tree and two stem wood storage field trials on energy densities. The material consisted of eight Scots pine (*P. sylvestris*), and four downy birch (*B. pubescence*) trials, all after the first thinnings. Other factors studied were the length of storage, pile cover and seasoning in the stand. The two variables under scrutiny were the basic density and moisture content. It was shown that even a good degree of drying could not counterbalance the reduction in the basic density. The Scots pine feed stocks dried well, and the basic density losses were less than those of downy birch. As a result, the pine feed stocks increased in energy density from 0.7 to 17.6% over the trial period, whereas all of the birch feed stocks suffered losses from −3.4 to −9.6%. Although covering the feed stocks had a beneficial effect on moisture content, it proved to have a positive effect only on pine when the storage was extended beyond one year. There was some gain on energy density if the feed stocks were seasoned in the stand, but this advantage was lost at the roadside landing. Furthermore, transpiration drying in the stand requires a two-phase harvesting technique, and this expense may be difficult to justify.

1. Introduction

Fuelwood harvesting is characterized by long-term planning in which storage is of vital importance to the fuel supply during the winter months when the heat load is the greatest. From the end-user point of view, unfortunate disadvantages accompany storage, such as increased handling costs and tied up capital. In addition to the logistical and financial challenges, issues of feed stock quality are also a concern, with the most prevailing issues being changes in the moisture content, heating value and basic density. Together, these factors will determine the volumetric energy density [1].

A living tree acquires its moisture through water intake from the soil. Moisture is found as bound water in the cell walls and free water in the cell lumens of both wood and bark [2], and the moisture content [3] varies from one tree part to another [4], often being the lowest in the stem and increasing toward the roots and the crown. Furthermore, the moisture content of live trees varies with the season. With such genera as *Betula*, *Alnus* and *Populus*, the moisture level is highest in the spring, just before the breaking of the buds, and lowest in the

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summer [5]; the moisture content in Norway spruce and Scots pine is highest during the winter and lowest during the summer [6].

Once a tree is felled, the connection to the roots is severed, and no more moisture can be obtained from the soil; thus, after felling, the moisture content is dependent on the post-harvest handling and storage conditions. When the conditions are favorable, any non-comminuted fuelwood, e.g., whole trees, whole stems, split fire wood or logging residue, which is stored fresh on a roadside landing or a terminal is likely to loose moisture over time [7–10].

Moisture may be lost through transpiration drying, which is based on the ability of a tree to evaporate free water via its foliage. This is an old, well-recognized form of drying in Nordic countries but is dependent on the ambient temperature, relative humidity, season, tree species, tree volume and wind speed [6,9]. In northern temperate regions, the best season for drying is May through August, a period when the vapor pressure deficit of the ambient air is at its lowest level.

It has been shown that the covering of piled whole trees on a landing will result in a reduced moisture content when compared with uncovered trees [11,12]. In addition, the moisture variation is smaller within covered piles. The same observations have been made with regard to covered and uncovered stacks of split birch firewood [13]. There are indications that the piles should be made as high as possible to utilize the maximum effect of such cover [7].

Improvements in fuelwood quality by drying may be offset by reductions in the basic and bulk densities caused by dry matter losses through microbial activity. As a result, the net energy change, a function of the dry matter, moisture content and heating value, over a given storage period is most often negative. This is particularly true for all freshly comminuted forest-based woody feed stocks [14–17].

The objective of this study was to determine the effect of the length of storage, feed stock type, tree species, storage site and feed stock cover on the energy densities of non-comminuted whole-tree and stem wood biomass. Based on earlier studies, it is hypothesized that storage will have an adverse effect on the feed stock energy density and that covering the feed stock will have an ameliorating effect.

2. Material and methods

The material was composed of 12 storage trials with different treatments initiated in March and May 2002. The chosen variables for the Scots pine (*P. sylvestris* L.) trials were pile cover, storage duration, feedstock type and storage site; and for the downy birch (*B. pubescence* Ehrh.) trials pile cover and storage duration. The duration of each trial was dictated by the "harvest-season-use"-cycle enforced by the industry. As a result the storage duration varied from 8 to 17 months (Table 1).

All of the material originated from first thinnings. Of these, Trials 1–4, 6 and 8 consisted of whole trees and Trials 5 and 7 of multi-tree harvested (MTH) stem wood of Scots pine. Trials 9–12 consisted of whole trees of downy birch. In 10 of the trials, the material was transported fresh to the roadside storage site, i.e., immediately after felling. In remaining two Scots trials, Trials 7 and 8, the wood was allowed to season for two months along the strip roads within the stand prior to being transported to the roadside landing (Table 1).

The trials were conducted at four sites:

- Kannus 63° 58′N, 23° 33′E (Trials 1 and 2)
- Kaustinen 63° 36′N, 23° 27′E (Trials 3 and 4)
- Ruokolahti 61° 20′N, 28° 22′E (Trials 5, 6, 7 and 8)
- Alaveteli 63° 40′N, 23° 17′E (Trials 9, 10, 11 and 12)

To test the importance of pile cover, the wood for Trials 1, 3, 5, 6, 7, 8, 9 and 11 was covered with a fiberglass-reinforced, 230 g m-2 timber wrapping paper provided by Walki Wisa in Pietarsaari, Finland. Trials 2, 4, 10, and 12 were left uncovered (Table 1). The aim was the compliance of all of the piles with the minimum size requirements of 12 × 3 × 4 m (length × height × depth).

Samples acted as replications and were collected at the beginning and at the end of the storage period; intermediate samples were collected from Trials 1–8 (Table 1). The freshly felled feed stock at each site came from a single stand i.e. tree population. The initial moisture content of the feed stocks coming from the same stand could be considered to be uniform. Such being the case, the number of samples was limited

Table 1 – Sampling itinerary of Scots pine (*P. sylvestris*) (P) (Trials 1–8) and downy birch (*B. pubescence*) (B) (Trials 9–12) at the star and at various sampling dates. P=Scots pine, B = downy birch, WT = whole-tree, SW = stem wood, LA = landing, IS = in-stand, ·· = not applicable, *n* = number of samples, mo = storage months till sampling.

Trial													
Study initiated, month/yr		1	2	3	4	5	6	7	8	9	10	11	12
		3/2002	3/2002	5/2002	5/2002	5/2002	5/2002	5/2002	5/2002	5/2002	5/2002	5/2002	5/2002
Species		P	P	P	P	P	P	P	P	B	B	B	B
Feedstock		WT	WT	WT	WT	SW	WT	SW	WT	WT	WT	WT	WT
Site		LA	LA	LA	LA	LA	LA	IS	IS	LA	LA	LA	LA
Cover		Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Sampling At start	*n*	5	5	5	5	5	5	5	5	5	5	5	5
Sampling	*n*	15	15	15	15	··	··	··	··	15	15	15	15
1/-03	mo	10	10	9	9	··	··	··	··	8	8	8	8
Sampling	*n*	··	··	··	··	15	15	15	15	··	··	··	··
4/-03	mo	··	··	··	··	11	11	11	11	··	··	··	··
Sampling	*n*	15	15	15	15	15	15	15	15	··	··	··	··
8/-03	mo	17	17	15	15	15	15	15	15	··	··	··	··