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The influence of storage and drying methods for Scots pine raw material on mechanical pellet properties and production parameters

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ABSTRACT

Converting solid biomass into pellets through densification greatly improves logistical handling and combustion processes. Raw material properties can affect pellet quality. This study investigated how storage and drying methods for wood (*Pinus sylvestris* L.) used as a raw material for pellet production influenced pellet durability, bulk density and energy consumption. The pelletization experiments were performed using a Sprout Matador M30 press (nominal production capacity 3.5 tonnes/h). Results showed that pelletization of 11 months stored wood compared to fresh material and high drying temperature (450 °C) compared to 75 °C resulted in higher energy consumption, probably due to increased friction in the matrix caused by the loss of extractives. However, the pellets produced were of higher density than those made from fresh material dried at a low temperature. The latter had the highest durability. Increased energy consumption showed no correlation with pellet durability.

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1. Introduction

The densification of biomass into pellets makes standardization of wood fuel easier and improves its marketability. Pellets also have certain properties that make them easy to transport, handle and burn. This is especially important for smaller combustion systems (<1 MW). Pellets have several advantages compared to unrefined fuels such as wood chips, including a considerably higher density, lower moisture content, more homogeneity, higher transport efficiency and better handling properties. During thermo-chemical conversion to heat in stoves or boilers, fuels with more consistent properties make it easier to regulate the combustion process, and consequently reduce capital and maintenance costs. These types of fuels also routinely result in higher combustion efficiencies and lower emission levels than other non-densified biomasses.

Traditionally, pellets are mostly made from sawmill residues. However, this resource is limited. Therefore the industry is looking for alternative raw materials [1]. One potential feedstock that could be used to increase pellet production in Norway is Scots pine (*Pinus sylvestris* L.) pulpwood, due to its availability in certain areas of Norway and its lower price compared to Norway spruce (*Picea abies* L.) [1].

The Norwegian pellet market is mainly made up of smaller combustion plants that generally have higher quality demands than larger units. Standards have been developed to simplify biomass trade [2,3]. Pellet standards specify quality parameters such as durability and bulk density. However, an understanding of raw material characteristics and production process is essential to produce high quality pellets [4].

Durability is one of the most important pellet properties. Low durability results in more fines, which may create problems during transport, storage, feeding and combustion. Fines in pellets significantly increase the slide angle of the fuel, since the fines act as a binder between each pellet. Fines also reduce end user comfort due to dust exposure. During the combustion phase, dust often passes through the combustion chamber unburned, resulting in higher emissions and fuel residues in the boiler/stove [5,6].

Another important property is bulk density, since the fuel is fed by volume, not weight. Variations in bulk density can cause large variations in combustion efficiency. It is preferable that volume-to-weight ratios remain stable over time. Furthermore, feedstock that is relatively homogeneous, such as Scots pine pulpwood, might result in more stable bulk densities as compared to by-products from the lumber and woodworking industry.

Pellets are normally extruded without additives. Binding the wood particles into a pellet requires a temperature of about 110–130 °C [7]. At this temperature, the lignin softens, which binds the particles together [8,9]. This temperature occurs in the pellet matrix due to

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friction caused by extruding the material through the die. The pressures in pellet dies are estimated to 750 MPa [10]. The pellet industry reports a typical energy consumption of 75 kWh/tonne of pellets in extruding wood to pellets. The amount of energy consumed will vary with different raw materials, moisture levels and use of additives. This is mainly due to differences in friction between the die and material used [11].

During the production process, several variables influence how well the pellets bind, particularly the shape and pressure length of the matrix [7,12], the size of the raw material particles [13,14] and the moisture content of the raw material [7,14,15]. The moisture content is considered to be the most important parameter [15]. Lower moisture content will result in excessive temperatures in the matrix, causing rapid thermal decomposition of the pellet surface, which results in production problems [15]. If the moisture content is too high, the pellets fall apart [7,12]. This is likely due to excessive internal pressure from steam generated inside the pellet. Therefore, the raw material must have a moisture content that is optimal [15]. For wood raw materials, the optimal range is normally between 7 and 12%. The optimum varies for different wood types and production settings [12].

It is common to add steam during production. Steam heats the raw material and makes it more plastic, resulting in higher pellet durability [15,16]. Further, different tree species have different properties that affect the pelletizing process [17] and the pellet properties [7,18]. Holm et al. [17] found that higher pressure is needed to release pellets of beech (*Fagus sylvatica* L.) than for Scots pine. Samuelsson et al. [18] found higher bulk density and mechanical durability for Norway spruce than for pellets from fresh sawdust or Scots pine.

Logistics, transport issues and yearly harvesting conditions may require the manufacturers to store the raw material. Storage can alter the composition of the material [19], affect the pelletizing process and the properties of the pellets [18]. These relationships depend on storage time and methods as well as on the moisture content of the stored material. The most common storage method at pellet factories is to stockpile the wet raw material in large piles as chips or sawdust. Normally the piles are exposed to the weather due to the need to make the system as cost-effective as possible. This kind of storage method generally causes substantial changes in the material [19]. The extractive content will be reduced, and hemicelluloses, cellulose and lignin will degrade [20].

Nielsen et al. [11] found that a reduction in extractives resulted in increased friction between the wood material and the pellet matrix, suggesting that extractives have a lubricating effect in the die. They also found that pellet made of extractive-free materials tended to have higher strength. Finell et al. [21] found increased pellet strength and density with decreasing content of free fatty and resin acid. Samuelsson et al. [18] found a positive effect of storage on durability due to the loss of extractives. Some pellet producers separate and mix stored and fresh material to achieve optimal quality [4].

To produce high quality pellets, the feedstock has to be dried to a moisture content of about 10% (raw weight). Since it is not possible to reach such low moisture contents by natural drying, the material has to be artificially dried. However, a wide range of temperatures and retention times can be used in the drying process [22]. One of the most common drying methods used in the industry is drum drying, with use of flue gas with temperatures of around 450 °C as the drying medium in an inert atmosphere. Although the residence time in industrial drum dryers, with such temperatures, is only a few minutes, considerable losses of volatile components have been measured [22].

Drying can also be undertaken using temperatures below 100 °C. This minimizes the substance loss. Low-temperature dried materials might require less energy to pelletize since extractives are considered to have a lubricating effect.

Wood from Scots pine has relatively high extractives contents [18], compared to other softwood species such as Norway spruce. Substantial changes in the extractive content during storage and drying are expected [14], particularly when drying Scots pine at high temperatures.

The effect of raw material storage on pellet quality has been tested in several studies [4,11,18], but information about how the drying method influence the raw material characteristics and pellet quality, particularly in interaction with storage, is still limited. Extractive content is an important factor when it comes to these questions. Therefore a better understanding of how storage and drying influence the pellet production and the quality of the pellet produced, also with regards to extractive content, is pertinent in order to develop more optimal pellet production processes. Since Scots pine has relatively high amounts of extractives, it should be a suitable species to study.

The aim of this study was to investigate how storage, in interaction with drying temperatures, influences the mechanical properties of Scots pine pellets, as well as the energy consumption used in the process. The effect of extractive content on pellet properties was also investigated.

2. Materials and methods

2.1. Preparation of the materials

The raw material was chipped from unbarked stemwood from a pine stand located in Bygland in Setesdal in Southern Norway (EUREF N 6 533 862, E 82 480) at 220 m a.s.l. The stand was classified as F14 in the Norwegian site class system [23].

The first part of the material (Stored) was harvested in April and chipped in May 2008, and was stored in a 6 metre high pile for 11 months, until April 2009. The average chip moisture content at the start of the storage period was 41%. After storage (April 2009) the average moisture content had increased to 60%. The material in the chip pile was mixed before further use. The second part of the material (Fresh) was harvested and chipped in April 2009.

The low temperature drying was undertaken in a container with a perforated bottom. The chip layer was 0.6 m thick. The drying medium, which was blown through the chips, was ambient air heated to a temperature of 75 °C. This was done in batches during May 2009. The drying time was approximately 5 days, and samples were taken during the drying period to achieve the desired moisture content.

The high temperature drying was also undertaken in May 2009 in an industrial Saxlund drum dryer at Statoil's pellet factory in Säffle, Sweden. The dryer used flue gas from a wood dust burner and had a capacity of 8 tonnes evaporation per hour. The flue gas inlet temperature was 450 °C.

Table 1
Variables definition.

Abbreviation	Explanation	Unit	Variable type
R	Part of the residuals explained by replicate number	–	Random
S	Part of the residuals explained by the sample number	–	Random
St	Steam added or steam not added	–	Categorical
F/S	Fresh or stored material	–	Categorical
F	Fresh material	–	–
S	Stored material	–	–
DM	Drying method used for the raw material	–	Categorical
LT	Drying with low temperature	–	–
HT	Drying with high temperature	–	–
Moi	Moisture content of the raw material	% wet basis	Continuous
Ext	Extractive content in raw material	mg/g dry basis	Continuous
T	Raw material temperature at pellet press inlet	°C	Continuous

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