

# Thermal Insulation from Hardwood Residues

I Sable<sup>1,4</sup>, U Grinfelds<sup>1</sup>, L Vikele<sup>1</sup>, L Rozenberga<sup>1</sup>, M Zeps<sup>2</sup> and S Luguza<sup>3</sup>

<sup>1</sup> Latvian State Institute of Wood Chemistry, 27 Dzerbenes Str., Riga, LV 1006, Latvia

<sup>2</sup> Latvian State Forest Research Institute “Silava”, 111 Rigas Str., Salaspils, LV 2121, Latvia

<sup>3</sup> Latvian University of Agriculture, Forest Faculty, 11 Akademijas Str., Jelgava, LV 3001, Latvia

E-mail: inese.sable@inbox.lv

**Abstract.** Adequate heat is one of the prerequisites for human wellbeing; therefore, building insulation is required in places where the outside temperature is not suitable for living. The climate change, with its rising temperatures and longer dry periods, promotes enlargement of the regions with conditions more convenient for hardwood species than for softwood species. Birch (*Betula pendula*) is the most common hardwood species in Latvia. The aim of this work was to obtain birch fibres from wood residues of plywood production and to form low-density thermal insulation boards. Board formation and production was done in the presence of water; natural binder, fire retardant and fungicide were added in different concentrations. Board properties such as density, transportability or resistance to particulate loss, thermal conductivity and reaction to fire were investigated. This study included thermal insulation boards with the density of 102-120 kg/m<sup>3</sup>; a strong correlation between density and the binder amount was found. Transportability also improved with the addition of a binder, and 0.1-0.5% of the binder was the most appropriate amount for this purpose. The measured thermal conductivity was in the range of 0.040-0.043 W/(m·K). Fire resistance increased with adding the fire retardant. We concluded that birch fibres are applicable for thermal insulation board production, and it is possible to diversify board properties, changing the amount of different additives.

## 1. Introduction

Adequate heat is one of the prerequisites for human survival; therefore, building insulation is required in places where the outside temperature is not suitable for living. For thousands of years, people have used natural materials for that purpose – moss, clay, straw, wool, herbs, etc. In the last century, however, a lot of synthetic materials have been developed in this application area, but considering the

<sup>4</sup> To whom any correspondence should be addressed.



global tendency to reduce CO<sub>2</sub> emissions, humanity comes again to green-thinking [1]. In addition, natural materials in construction create a pleasant microclimate for living. A modern thermal insulation material should have air permeability together with good thermal insulation properties and easy handling. Thermal insulation boards from soft wood fibres are part of the global market nowadays [2]. The climate change, with its rising temperatures and longer dry periods, promoted enlargement of the regions with conditions more convenient for hardwood species than for softwood species [3]. Manufacturers can change the focus on hardwood products. It is a known fact that bonding of internal and external hydroxyl (OH) groups of cellulose provides holding fibres together. Evaporation of water creates capillary force, which reduces the distance between the fibres, thereby hydrogen bonds and van der Waals attraction hold fibres together after drying [4]. Nevertheless, only 2% of all OH groups are involved in interfibre bonding [4]; so, additives are preferable. Insulation fibre boards and panels from softwood fibres are available on the market, but hardwoods with an average fibre length of 1-2 mm [5] are considered inappropriate for this product. Birch (*Betula pendula*) is the most common hardwood species in Latvia – its stock was 160 million m<sup>3</sup> in 2014, being 24% of the total wood stock of our country [6]; so, it can be a sufficient source of fibres.

The aim of this work was to obtain birch fibres from wood residues of plywood production and to form low-density thermal insulation boards. The impact of additives on density, transportability and thermal conductivity was also investigated.

## 2. Materials and methods

Residues of plywood production were the raw material for birch fibres, which were obtained in the thermo mechanical pulping (TMP) process at Institut für Holztechnologie (Dresden, Germany) using refiner 12-1 CPH (Andritz, Austria). The fibre material was studied and boards were made at the Latvian State Institute of Wood Chemistry, Laboratory of Cellulose.

Scanning electron microscopy was performed using SEM Vega Tescan 5136MM (Tescan Brno, Czech Republic). The fractional composition of the fibre material was determined, using mechanical sieving in a shaker Retsch A200 (Retsch GmbH, Germany) with several mesh sizes. The moisture content of all materials and substances was determined with Kern MLB 50-3N (Kern & Sohn GmbH, Germany).

A solution of binder was made, dissolving a specific amount of potato starch (Aloja-Starkelsen, Latvia) in cold water, obtaining 2 wt.% starch solution and then mixing with boiling water till gelatinization. Sodium tetraborate decahydrate Na<sub>2</sub>B<sub>4</sub>O<sub>7</sub>•10H<sub>2</sub>O (FR1) and boric acid H<sub>3</sub>BO<sub>3</sub> (FR2) (both granulated, Etimadan, Turkey) were used as a fire retardant (FR) and a fungicide, dissolved in cold water before adding to fibres. Amount of additives in boards was calculated regarding the weight of absolutely dry fibres; 0.1 – 2% in case of starch and 0 – 20% in case of FR.

Fibre board formation occurred as follows: fibres and water were mixed together with a weight ratio of 0.03:1, and starch gel, fire retardant and/or fungicide solutions were added to the mixture. Pulp was transferred to the board forming equipment, made of plywood with a hydro isolation layer inside, which let water drain by gravity, and then extruded to a 4-4.5 cm board thickness. A wet board was dried for 24 h at 60°C, then cooled, weighted and measured, and its density was calculated (see figure 1).



**Figure 1.** Thermal insulation board from birch fibres.

The test for imitation of transportation was conducted: 140 x 140 mm samples were cut from fibre boards. To provide the material for particulate loss only from the side faces, the upper and lower faces were coated. Weighted samples were put in a sieve (diameter 200 mm, height 25 mm, mesh size 1 mm) and placed in a shaker Retsch A200 (Retsch GmbH, Germany). The 3-D throwing motion mode was used with the amplitude 70 and vibration height 1.5 mm for 120 min. The weighting procedure and calculating of mass reduction were performed after shaking.

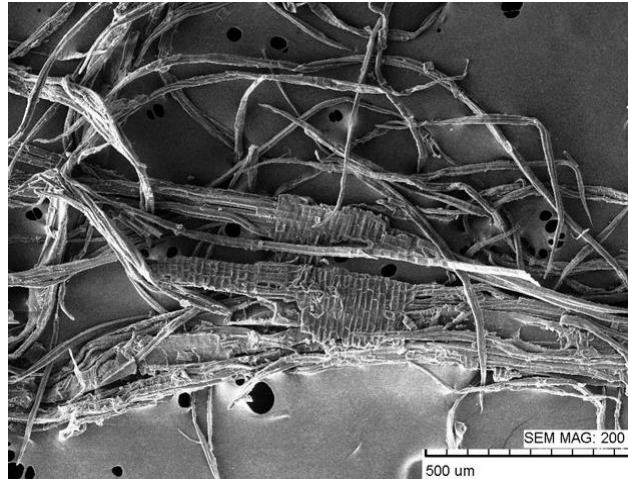
Thermal conductivity was determined according to ISO 8301 in a heat flow meter Linseis HFM 200/300/600 (Linseis GmbH, Germany).

For the reaction to the fire test ~40g of board sample was cut, fixed on non-combustible wire and placed in open fire (gas blow torch Rofire Piezo 1900, Rothenberger industrial, Germany) for 30 seconds simultaneously recording the weight loss dynamics and final weight loss was calculated.

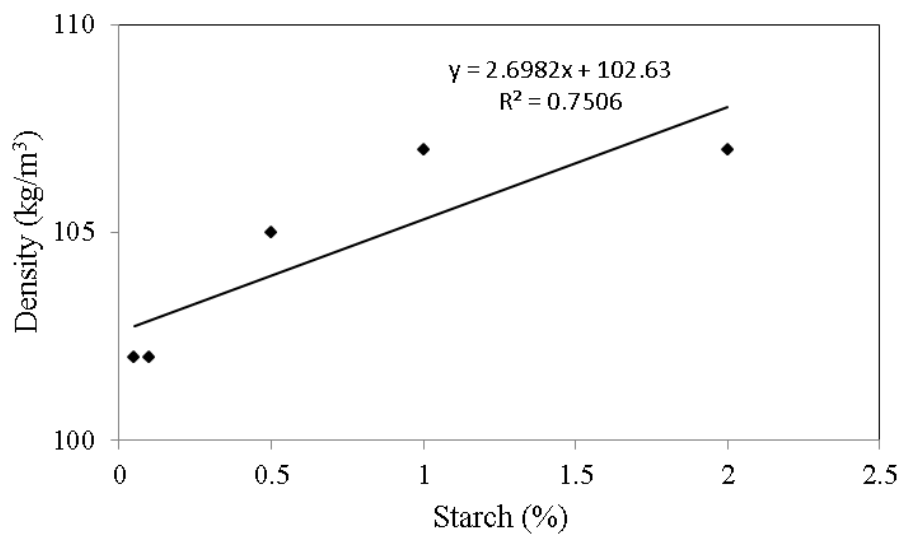
### 3. Results and discussion

The fibre mass after the TMP process consisted of fibres, particles and fines (small size particles from damaged fibres) of different size (figure 2). The fraction with the size of 0.5-2 mm was 44.5% of the obtained pulp; there were fibres and fibre fragments in this fraction. The fraction with the size of 2-3.25 mm constituted 16%, and fibres, fibre bundles and vessel fragments were found there. There were 0.5% of particles bigger than 3.25 mm and 29.5% of fines in the pulp.

Thermal insulation fibre-boards with the density of 102-120 kg/m<sup>3</sup> were made from TMP birch fibres. Starch was added in different amounts to improve the adhesion of fibres. There was a correlation between the amount of the added starch and the density of the board (figure 3). More added starch caused higher density; however, these changes were caused directly by the increase of the total weight of the substance. The role of starch in strengthening the inter-fibre bonds [4] also should be taken into account – this phenomenon can cause an increase of board density.

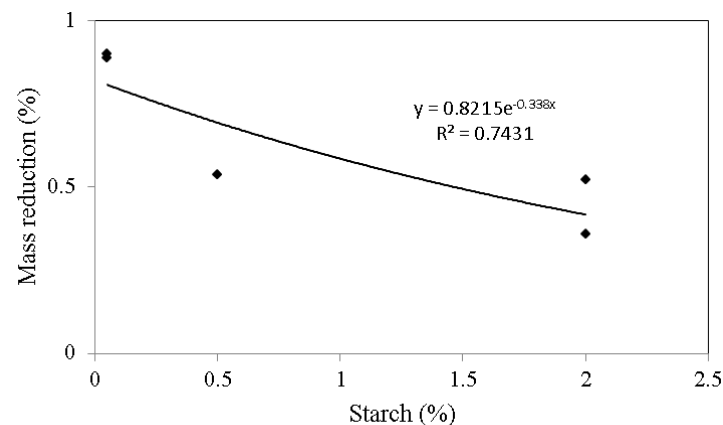


**Figure 2.** TMP fibres of birch (SEM).



**Figure 3.** Density of a thermal insulation fibre-board, made from birch TMP fibres, depending on the amount of the binder.

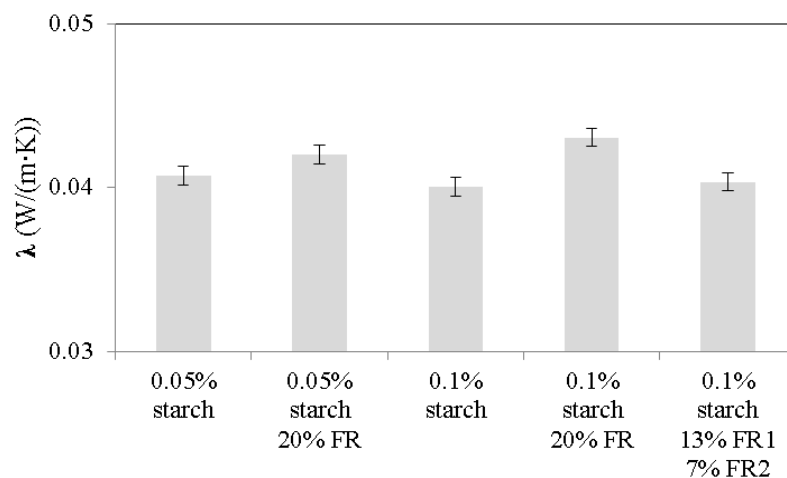
The effect of starch as a binder was shown in a transport imitation or shaking test, where a decrease of mass reduction was observed (figure 4). A rapid decrease in mass reduction was observed in the case, when the amount of starch was increased from 0.1 to 0.5 %, but continuing adding of starch did not change the result significantly. This proved the effect of starch as a binder on strengthening the inter-fibre bonds.



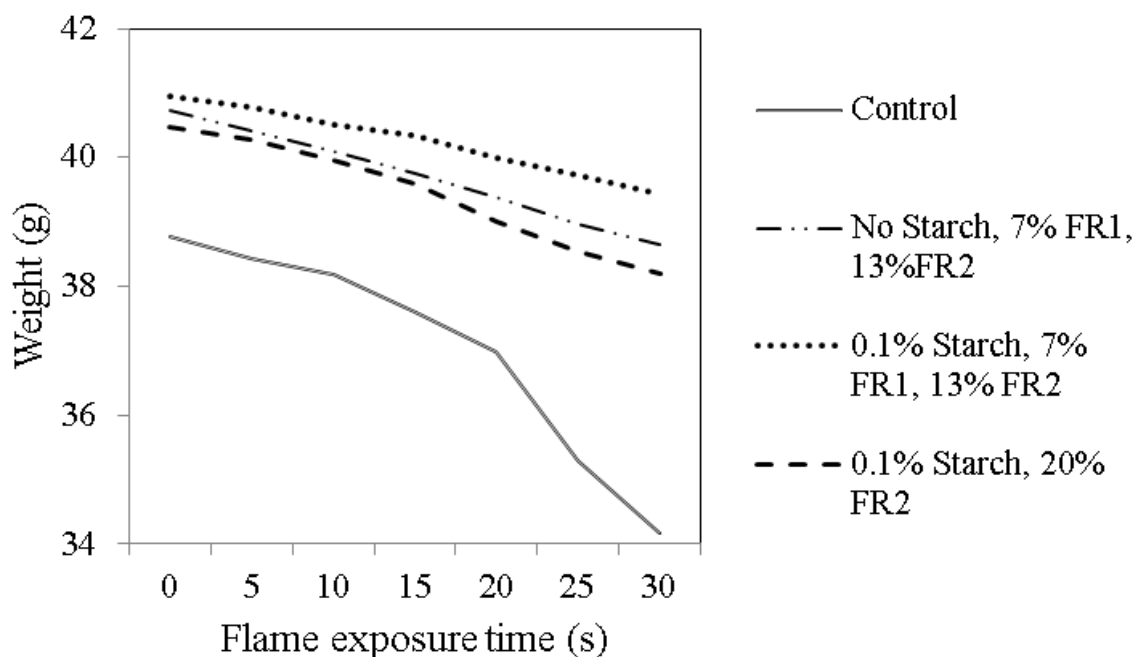
**Figure 4.** Decrease in mass reduction of a thermal insulation birch wood fibre-board during the “shaking” test (transport imitation). Influence of the concentration of the binder – starch.

The measured thermal conductivity of the obtained boards was within the interval 0.040-0.043 W/(m·K) and slightly varied depending on the additives (figure 5), but the differences were not significant. These results are in accordance with [7], where the thermal conductivity of 0.040 W/(m·K) for all natural fibre-boards was stated. As wood fibre-boards that are on the market nowadays have similar thermal conductivity, we can presume that our samples are appropriate for using in thermal insulation for residential houses [2].

The response of fibre-board samples to fire flame is shown in figure 6. A control sample was made only from birch fibres; no adhesives or fire retardants were added. Differences in the starting weight should not be taken into account; all samples were identically prepared and weight differences were caused by adding starch and a fire retardant.



**Figure 5.** Thermal conductivity of birch fibre-board, depending on additives (FR – fire retardant).



**Figure 6.** Response to fire of a birch thermal-insulation board with and without additives (FR – fire retardant).

The weight of the sample decreased with the time of flame exposure. Samples with a fire retardant lost their weight evenly, about 4-6% of the initial number after 30 s of flame exposure, whereas the control sample lost 12% of weight and had a sharp break point at 20 s. These results proved the efficiency of the tested fire retardants to reduce the combustibility of thermal insulation fibre-boards from birch TMP fibres. Preliminary comparing tests were done with thermal insulation materials, available on the market and results showed equal response to fire.

#### 4. Conclusions

It is possible to obtain fibre-board from birch TMP fibres for thermal insulation, using starch as a binder. Transportability improved with the addition of starch and 0.1-0.5% was the most appropriate amount for this purpose. Thermal conductivity of boards was in the range 0.040-0.043 W/(m·K). Fire resistance depended on the composition of the fire retardant. Birch fibres from the thermo-mechanical process are found to be applicable for thermal insulation board production. It is possible to diversify board properties, changing the amount of different additives. It is a good opportunity to obtain a product of high added value from wood residues instead of burning them to produce only energy.

#### 5. References

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