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LEATHER WASTE VALORISATION THROUGH MATERIAL INNOVATION: SOME PROPERTIES OF LEATHER WOOD FIBREBOARD

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Abstract
Due to the ever-increasing scarcity of resources and raw materials in the wood panels industry, it is imperative to look for suitable alternatives to the established resources. Therefore a combination of the traditionally used and newly explored sources may reveal highly innovative ways. The objective of this study is to provide an insight into the behavior of the material and possible new applications of those fiber/particle wood and waste leather composites.

For this reason exclusively fibers of spruce were used for the trials. Wet white (WW) leather particles and wet blue (WB) leather particles were mixed with the wooden materials for the production of high density fibreboards. Besides the mechanical properties such as the internal bond (IB) the bending strength (MOR) and modulus of elasticity (MOE) was analyzed. Further physical property as thickness swelling after 24h watering was investigated. To analyze how the density influences the behavior under thermal conditions, fiberboards with the densities 500, 700 and 900 kg/m³ were tested.

The results of the material properties were influenced by the leather content of the panels. The results for the UF-bonded HDF boards show enhancement of the transverse IB with increasing wet blue leather content, whereas the other mechanical properties decline meanwhile. The thickness swelling showed higher values compared to the wood fibreboard. The results of this study underline the usefulness of integrating leather shavings to HDF and give an overview of their influence in wood fiber materials.

The combination of the natural resource wood fiber and the leather waste products (Wet Blue and Wet White) gives a very interesting new material, its mechanical properties allow a variety of possible application in future applications.

Key words*: *wet white leather; wet blue leather; wood-leather based panels.

INTRODUCTION

According to the current market situation in Europe and an increasing trend of using energy that is won by burning any kind of biomass (Barbu et al. 2014a,b), a wealth of investigations according to possible new material resources had been conducted. Most of these investigations were dealing with an up- or recycling of by-products. A variety of different board types and panel systems with specific properties and different features are established to the market so far (Deppe and Ernst 1996, Barbu et al. 2014a,b, Paulitsch and Barbu, 2015). To gain a new and innovative range of products for the future, unusual ways need to be considered (Barbu et al. 2014a, Paulitsch and Barbu, 2015), to achieve this goal with sustainable methods. One of the possible options is to develop a new source of raw material and combine its positive properties with those of wood.

A way of up-cycling, that seems quite seminal, is the use of by-products that occur as waste in the meat production (Windandy et al. 2007, Wieland et al. 2010). Most of these by-products are currently recovered thermally or getting landfilled in depositories in Central Europe (Cabeza et al. 1998, Joseph and Nithya 2008). Investigations by Ostrowski (2012), Grünewald (2012), Rindler (2014), Solt (2014) describe the mechanical and physical influence of leather shavings in medium density fibreboards (MDF) and in insulation mats. Furthermore, Grünewald (2012), and Wieland et al. (2013) presented results according to the distribution of wood fibres and leather particles in panels. Wieland et al. (2012) determined an increasing fire resistance with increasing leather-amount in MDF panles. Rindler (2014), Solt (2014) and Solt et al. (2014) described the mechanical properties of particleboards and fiberboards made from waste leather and wood, which is issued by Lackinger (2009) in a patent.

This work deals with the comparison between the mechanical properties of hard-density fibreboards made from wood fibres. Investigations concerning the mechanical and physical properties of both board types have been made to determine the behaviour of leather.

MATERIALS AND METHODS

Materials

Leather. When leather gets produced, hides have to run through different production steps. After the withdrawal of skin a preservation has to be done to protect the freshly peeled skins against the influence of microorganisms. The next step, the tanning process, is used to protect the skin against enzymatic degradation and increase their resilience. Only after this production step the skins are called leather. For this investigation two different leather types, which are defined as wet white (WW) and wet blue (WB), were used. The tanning process of wet white uses a synthetically non-chromatic tanning, whereas in wet blue chromium is connected with the proteins of the hides in a stable bond. These leather particles accrue during the shaving process of hides preparation, were they got sliced to a specific thickness. The leather particles were dried to a moisture content of 8 ± 1% in a dry kiln (Brunner-Hildebrand) at a temperature of 40°C.

Wood fibres. Norway spruce wood fibres (*Picea abies (L.) [Karst.]*) were used for this study. The fibres were produced in an industrial facility for medium density boards (MDF) and had a moisture content of 8 ± 1%.

Adhesive. For the production of the sample boards, urea formaldehyde (UF) was used. This adhesive has a solid content of 66%. As hardener a 33% ammonium sulphate solution was used.

Production of the panels

The objective of this study is to provide an insight into the mechanical behaviour of the material and possible new applications of those fibre wood and waste leather composites. Therefor fibreboards with dimensions 450 x 450 x 4.5mm were produced under laboratory conditions.

The fibres and WW leather particles were glued with 10% urea-formaldehyde resin (UF) with 1% ammonium sulphate solution in a ploughshare blender with a Schlick two-substance nozzle upright section. For the process a nozzle with a hole diameter of 2.3mm and a pneumatic pressure of 2 bar was used. Further the glued fibres were distributed manually in a frame and were finally pressed in a Hoefer HLPO 280 automated hot press at 80°C with a pressing factor of 1min/mm. After the pressing process the samples were stored in a standard climate (20°C / 65% r. H).

Mechanical testing methods

The testing samples for both board types, for the modulus of rupture (MOR) and elasticity (MOE), were prepared by the formula 50mm x (50mm + 20mm x thickness) which is in accordance to the EN 310 (2005) with a crosshead speed of 10 mm/min. To analyse the internal bond (IB) the test was conducted according to EN 319 (2005) and therefore the testing samples were prepared in dimensions of 50 x 50mm. To obtain meaningful results, each of the mechanical tests had an amount of 5 samples [n=5].

Burn-through test

To obtain meaningful comparisons, wood - leather fiberboards with 50% ratio, pure leather and pure wood fiberboards were produced. To analyze how the density influences the behavior under thermal conditions, densities from 500, 700 and 900kg/m³ were used. Further the samples were conditioned in a standard climate at 20 ± 1°C and 65 ± 1% relative humidity, until the equilibrium moisture was reached.

The independently prepared test helps to understand the behavior of the leather-fiberboards under high temperature. The samples were determined at a temperature of 530°C using a hot air blower (Bosch GHG 660 LCD Professional). By analyzing the time it needs to burn through, the graph gives a digestion how the leather behaves under temperature. The "burn-through" was defined as the moment at which a visible, mostly glowing hole was formed at the testing backside of the treated panel.

Therefore a wooden frame with a heat-protecting gypsum fiberboard at the edges was constructed. In this frame, the already described samples (100 x 100mm) were inserted from above and were treated with a constant temperature of 530°C and a constant airflow of 250l/min by the hot air blower. The blower itself was fixed at a distance of 25mm to the panel surface and the airstream was focused to the center of the sample.

RESULTS

Influence of leather type and amount to mechanical properties

Table 1 displays the estimated mean of mechanical properties of the HDF boards with WW and WB particles. An overview of the obtained values of the IB, MOE and MOR and the measured density is presented.

Table 1

Estimated mean and standard deviation (SD) of the density and mechanical properties of the composite material

Relation wood to leather content	Density [hg/m^3]	IB [N/mm^2]	MOE [N/mm^2]	MOR [N/mm^2]
	n=10	n=5	n=5	n=5
100/0	800 (40.0)	0.92 (.19)	2083.3 (110.1)	29.8 (3.8)
85/15 WW	920 (80.2))	1.23 (.46)	2697.8 (358.0)	37.1 (5.1)
75/25 WW	970 (76.4)	1.52 (.19)	3230.2 (806.1)	47.8 (9.9)
65/35 WW	970 (42.9)	1.39 (.14)	2599.5 (222.5)	35.2 (4.2)
50/50 WW	880 (98.5)	0.98 (.34)	1902.7 (414.4)	25.3 (6.9)
85/15 WB	950 (64.0)	0.74 (.20)	2988.5 (384.9)	38.0 (5.1)
75/25 WB	870 (40.3)	0.85 (.18)	2508.0 (163.5)	33.4 (3.4)
65/35 WB	920 (47.8)	1.04 (.11)	2361.2 (558.4)	31.8 (9.1)
50/50 WB	920 (67.3)	1.65 (.16)	1863.2 (260.3)	28.5 (4.4)

The variation of the measured density values can be explain to the manual small-scale scattering attributed. On the other hand springback effects after the pressing process in the high density fibreboard (only wood) and shrinkage effects in WW particles can not be neglected. Likewise, the density differences may be occur due the fact that leather can absorbs high moistrue (Pauligk and Hagen 1987).

As clearly visible in Table 1 all WW and WB blending ratios of HDF panels obtained similar density means. According to results of the mechanical properties it is to say, that the WW HDF panels reached overall higher means compared to the WB HDF panels with the same leather ratio. Only WB 50 achieved higher results in case of IB compared to WW 50%. In case of MOE and MOR the panels with 15% WB amount show better properties than the WW 15% panel.

In total it is to sum up, that the MOE mean decreases for the fibreboard with increasing leather content, although 25% leather content in the HDF showed better properties than pure wood. According to the analysis of variance (ρ=0.05) it is to say that the amount of leather is highly significant for fibreboard.

Fig. 1 shows the mean of the IB results, which indicate an interesting relation between strength and leather content in the panels. It can be seen that the means of the boards reached IB values between 0.7 and 1.7N/mm^2.

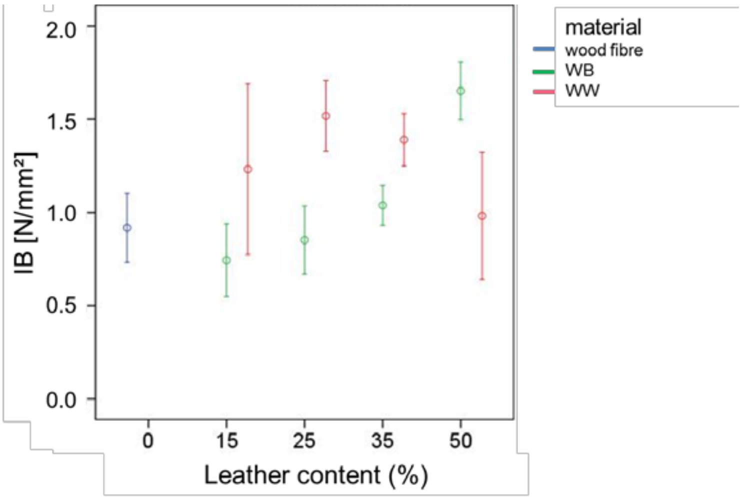

Fig. 1.
Internal bond of various high density fibreboard with WW and WB

Influence of leather type and amount to physical properties
Thickness swelling after 24h

Fig. 2 shows that there is a significant difference of thickness swelling after watering between fibreboards with leather content and pure wood panels.

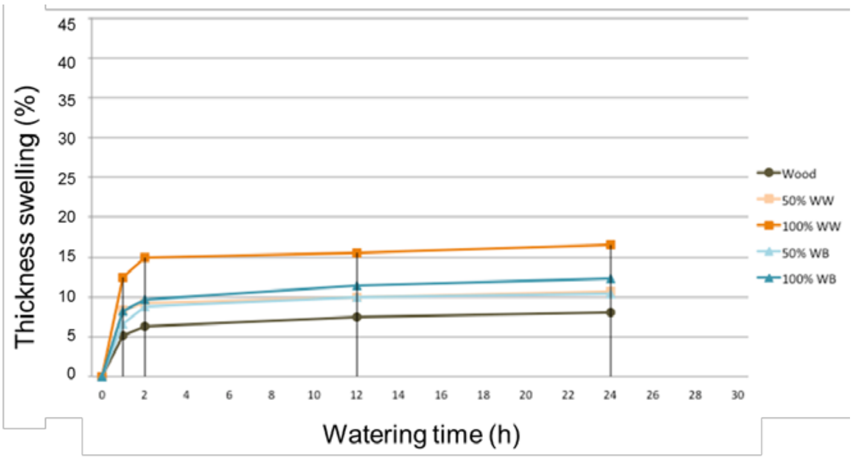

Fig. 2.
High density fibreboard thickness swelling after 14 h watering time

Here the panel WW 100% with around 17% and WB 100% with around 13% show the strongest performance in swelling. WW 50% and WB 50% nearly reached the same increase of thickness of around 11%. According to the analysis of variance (ρ=0.05) there no significant influence of the leather type but of the amount of leather on the swelling behaviour.

Influence of panel density to thermal behavior

Fig. 3 shows the results of the tested boards, were the WW 50/50 samples with 900kg/m^3 reached an average of 365 sec the best values. At this density the difference between WW 50/50 to WB and wood is, with a three times longer heat endurance, the most noticeable. The lower densities of the WW 50/50 boards reached 270 sec for 700kg/m^3 and 146 sec for 500kg/m^3.

50% WB-panels does not differ much in their burn-though-time than 100% WB and wood panels. Further it is clearly visible, that all tested samples have a linear increase based on its raising density.

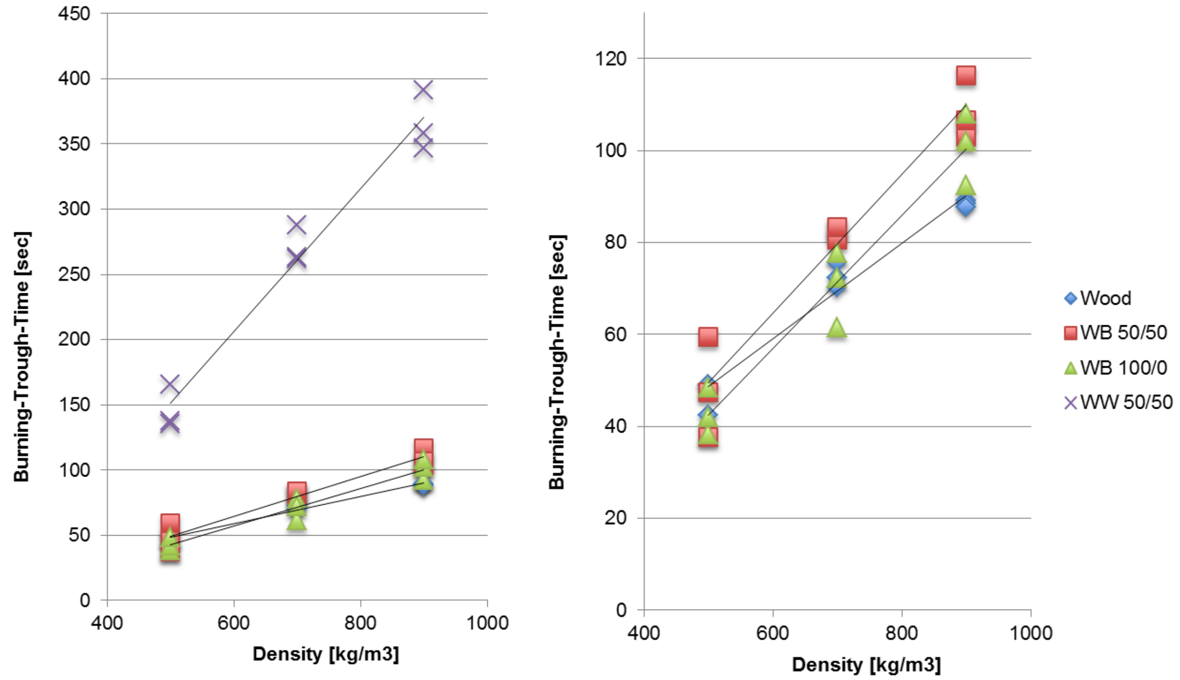

Fig. 3.
Burning-trough-time at different densities

As expected from prior investigation (Wieland et al. 2012), the high-density fibreboards that contain leather particles resisted longer against heat than pure wood fiberboards.

CONCLUSIONS

The results for the modulus of rupture (MOR) and of elasticity (MOE) showed a decrease for fibreboard with increasing leather content. Also Grünewald (2012) describe the same phenomenon with medium density fiberboards (MDF). In his opinion this behavior is attributed to the dominating material in the board. To the authors opinion also a different linking behavior between leather particles and UF resin and wood fibres and UF should be considered. To get certainty about this behavior the linkage and penetration of UF to leather could be discovered in further research.

Regarding to the findings of the internal bond (IB) the results showed astonishing insight into the importance of the mixing proportion between leather particles and wood. Probably the correlation of the density of the panel and the particle size of the leather particles is a significant factor, which needs more research to obtain a better understanding. The most interesting finding of the IB values is the increase of tensile strength with increasing leather content in the high-density fibreboards (HDF).

According to the results of the physical investigations the enormous hydrophilic behavior of boards with higher leather content is to mention. To really use leather as an alternative to wood fibres in particle or fibreboards any kind of additive needs to be involved to reduce its water adsorption.

The results of the burning-through-time compared to the board density show a significant increase with increasing density. The boards that contain WB (WB 100/0, WB 50/50) have a similar behavior than the pure wood panels. Interestingly the samples with 50% WW reached with 360 sec a three times longer endurance compared to the other samples. To the opinion of the author this behavior is related to the tanning substitutes of the WW leather.

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