Material Science. Textile and Clothing Technology
doi: 10.7250/mstct.2013.011
2013 / 8

# Performance of Fibreboards Made from Wet-preserved Hemp

Edgars Kirilovs[1], Hans-Jörg Gusovius[2], Silvija Kukle[3], Juris Emsins[4], *[1;3;4] Riga Technical University, Institute of Textile Materials Technologies and Design*, *[2]Leibniz-Institute for Agricultural Engineering Potsdam-Bornim (ATB)*,

***Abstract.*** **Article describes a new type of fiber boards for the furniture production, developed in cooperation with ATB (Leibniz-Institute for Agricultural Engineering) by using a new method to prepare raw materials and specific production technologies of ATB. The main raw materials are aerobically aged hemp stalks. The samples are made of materials with different curing time and varying the binder. Specimens are 8 mm thick and correspond to a medium-density fiberboard, fitting standard EN622. On the experimental processing line 1.200x800x8mm and 1.200x800x16mm size board samples are developed and the tests are performed to determine such parameters as bending strength, perpendicular tensile strength, thickness swelling and thermal conductivity according to EU standard methods. The proposed material the main component of which is the annual renewable resource, hemp stalks, could be used for furniture, interior design and heat isolation.**

***Keywords*: Hemp, Fibreboard, Urea-formaldehyde, Phenol-formaldehyde, wet-preservation.**

## I. Introduction

Natural plants are completely recyclable, widely available, and regularly renewable, comparatively cheap, with a sufficiently good level of physical and mechanical properties with a low density and friendly to environment (1). Their natural ability of decomposition solves ecological problems, comparably low costs and good qualities induce economic interests (2). Research and practice has showed that alongside with natural fibres used in textiles, they can also be used successfully as reinforcements of composites, compounds of building materials, as heat and sound insulation materials, and in many other applications (3). Fibreboards as well as three-dimensional pressed parts can be produced for the application in construction and furniture industry (4). Hemp fibreboard can be seen as an alternative to such boards that are made from processed wood fibres and resins. MDF (Medium Density Fibreboard) is cellulose composite that is processed comparable to the strength found in trees (5). Therefore, it is not necessary to use over 60 year's old trees to make houses and furniture that lasts less. Instead of wood, hemp that takes only about 100 to 150 days to grow, can ensure the same house and furniture that lasts as long (5). At the usual harvest date in September, European weather conditions are often harmful to harvest good quality hemp straw. The harvest of hemp by chopping method followed by anaerobic storage is favourable for the farmer, because the typical weather risk can be avoided. The following actions are the same as for ensiling of fodder (6). Fiber hemp as a raw material for production of composites and boards deals with practically all ecological issues, that threaten the future of mankind, as well as it is also a highly productive, not very demanding, and good for cultivation agricultural plant. The aesthetical and mechanical properties of prototypes can be improved by laminating, covering with textiles, for example, flax/ hemp fabric of different textures. In order to obtain fully ecological material of boards, the synthetic adhesives should be substituted with the natural products, such as lignin available in the hemp fractions, starch, etc.

## II. Materials and Methods

According to ATB developed technology harvested and chopped whole hemp plants (seeds, leaves, fibres, shives) are wet preserved under anaerobic conditions (7). Raw material that is stored for 14 days to maximum 12 months is used to manufacture the boards; Phenolformaldehyde resins (PF) – Prefere 16J536 and Urea-formaldehyde copolymer in water (UF) - Hexion LL4547 in amount 10 g/kg of mixture dry mass are used as the binders. The plant raw material processing as well as the subsequent procedures were conducted on experimental production line with 330 kg/h capacity, that is developed and tested in Leibniz-Institute for Agricultural Engineering Potsdam-Born (ATB) (Figure 1). To ensure optimal moisture the preserved material is mixed with dry hemp straw and processed with an extruder and in a second step with a disc mill. Next the material is passed to the hot air dryer (150 $^0$C). Dry material is divided into 20 kg units that are placed in the mixer, where it is mixed with glue and passed to the three chamber dissipation machine where with airflow system on conveyer belt fleece is formed and passed to the double belt pre-press. The resulting fleece (6.5 kg/m$^2$) is pressed in the heated press to 180 degrees with holding time 283 seconds fewer than 100 bar pressure. Pressing resulted in the board with dimensions 1.200x800x8 mm and 1.200x800x16 mm which were cut according to testing standards.

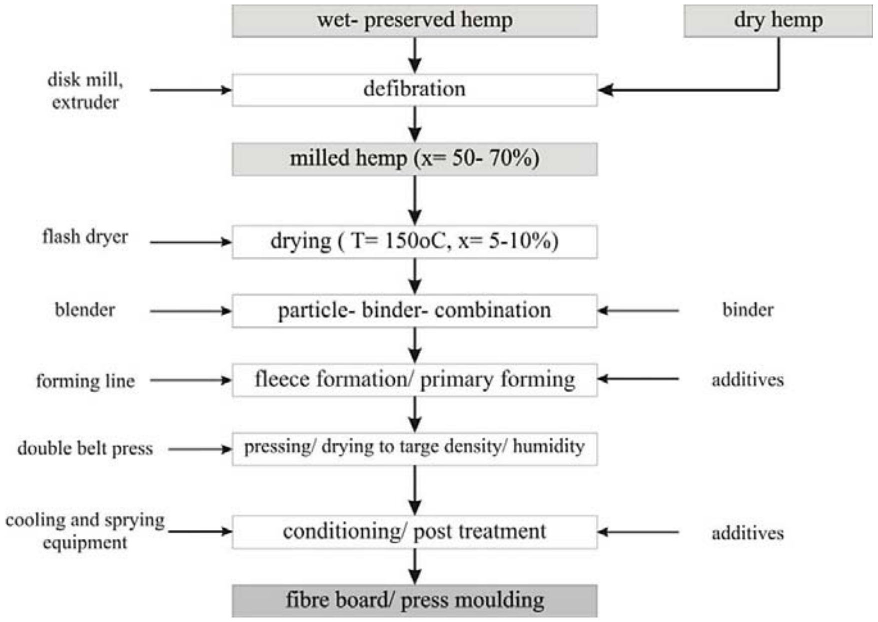


Fig. 1. ATB Technological line for wet-preserved hemp processing

All products from a comminution process are characterized by means of the average particle size as well as the variation of particles size. Sieving as the simplest and most widely used methods for particle size analysis determines the separation of fine material from coarse material.(8)Sieving is carried out by stacking sieves in ascending order of aperture size and placing the sample on the top sieve. The stack is vibrated for a fixed time (8 min) and the residual weight on each screen is determined for each sample. Results are usually reported in the form of a cumulative percentage of passing sizes. Modulus of rupture (bending strength) and modulus of elasticity test of bord material samples (25 from each board) were executed on universal testing device Zwick/Roel Z010 (maximum strength 100 KN) using EN310 (9) testing standard. Tensile strength perpendicular test to bord material samples (22 from each board) were executed on universal testing device Zwick/Roel Z010 (maximum strength 100 KN) using EN319 (10) testing standard. The thickness swelling and water absorption tests after immersion in water were carried out according to EN 317 (11). Pre-weighed-measured specimens (25 from each board) were immersed in water for 24 hours at 20 °C. After 15, 30, 45, 60 min and 2, 3, 4, 5, 24 hours each soaking, the specimens were wiped of excess of water, measured for thickness and weighed. The thickness swelling and water absorption was determined on the basis of initial dry measurements. The thermal conductivity of the board samples was determined using the thermal conductivity measuring instrument FOX600 of the company Laser Comp according to the standard ISO 8301(12).

## III. Results

### *A. Sieving and size distribution*

A sieve analysis of the fibre material was carried out to obtain a distribution of particle sizes according LVS EN 933-2:1995 (13) standard. As may be seen from Figure 2 the finest fibre material is got from mixing two weeks storage material with dry hemp material (FDH) as a result getting a higher amount of large particles than small particles. In contrast mixing the twelve months storage material with dry hemp material (PDH) there are 17% less large particles and 60% more small particles. Approximately 40-45% of the particles were of a size greater than 2000µm.

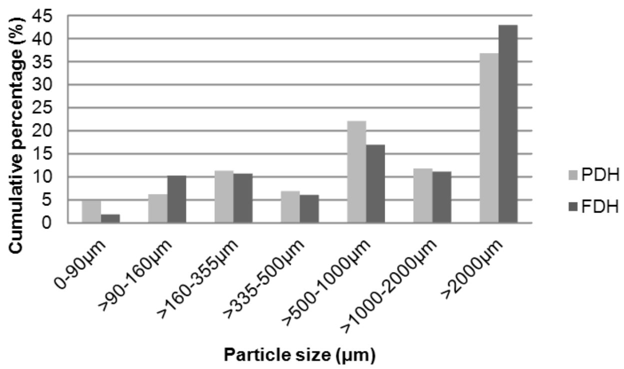


Fig. 2. Particle size distribution of hemp fibre

### *B. Board material swelling*

The results of swelling tests (Figure 3) reflect changes of material samples in thickness. The lowest water absorbtion values in all range show samples from preserved hemp with PF binder. That is on average 16% less than other samples sorbtion capacities. All other materials have quite similar results; FDH-UF has on average 3% less water absorption compared to PDH-UF. The fastest rate of thickness changes are noticed at the first 15 minutes (Figure 3).

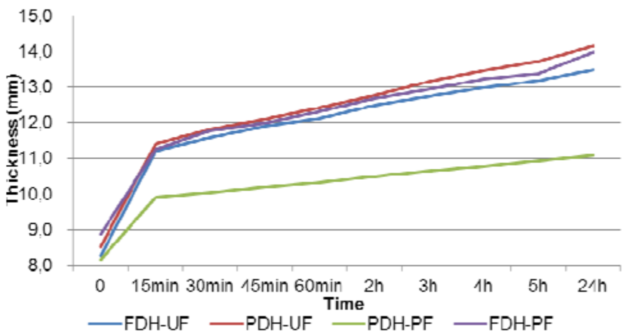


Fig. 3. Changes of material samples in thickness

The changes of samples mass (Figure 4) is less for material that is made from preserved hemp with PF glue. The mass difference of FDH-UF and PDH-UF are about 4%, but PDH-PF mass is on average 14% less compared to FDH-PF. Also it could be concluded that the sample mass with PF glue is for 14% less than of samples with UF glue.

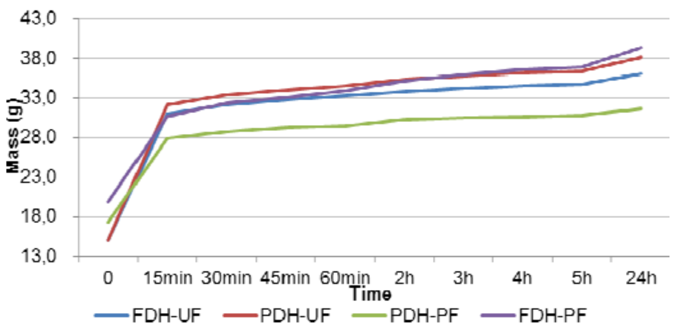


Fig. 4. Changes of material samples in mass

### *C. Bending Strength*

As seen from graph of Figure 5 the lowest value of bending strength is 7.95 N/mm$^2$ for FDH material where the UF adhesive is used. The highest bending strength 14.66 N/mm$^2$ show PDH material with the PF adhesive. The average bending strength of samples FDH-UF is for 7% less than for PDH-UF. But the bending strength for FDH-PF material (10.51N/mm$^2$ ) is for 39% less than that of PDH-PF sample (14.66 N/mm$^2$). Bending strength average of all experimental samples are higher than for hemp shive board, but only PDF+PF sample show average bending strength value higher (22 %) than wood chip board (Figure 5).

### *D. Tensile strength perpendicular to surface*

As seen from the graph of Figure 6, the lowest tensile strength perpendicular to surface is 0.04 N/mm$^2$ for FDH material with UF adhesive, but the highest tensile strength is 0.15 N/mm$^2$ for PDH with PF adhesive. The difference between the highest and lowest values is almost three times. Also quite high result 0.14 N/mm$^2$ show FDH-PF samples. In general better resistance to the tensile stresses is inherent for samples where PF adhesive is used.

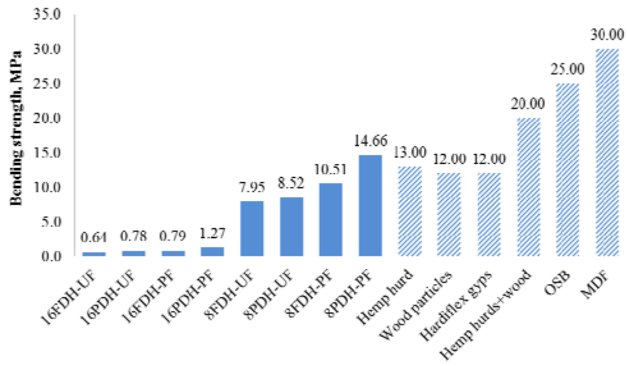


Fig. 5. Comparison of experimental hemp and other board bending strength

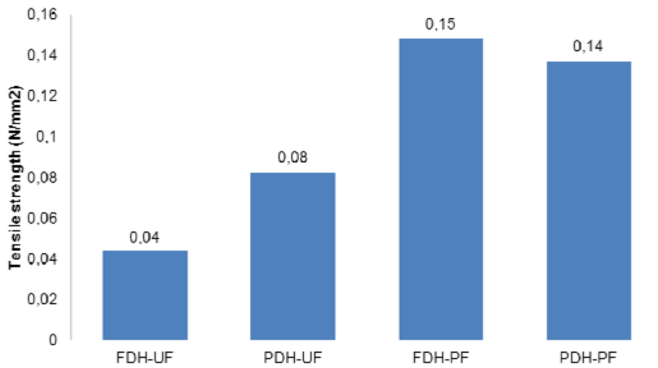


Fig. 6. Tensile strength perpendicular as function of fibre type, adhesive and bending elongation

As shown in Table 1 bending strength, modulus of elasticity, perpendicular tensile strength and swelling thickness with UF binder are much lower for the samples where hemp component is aged for 2 weeks to compare with the same aging time of samples with PF resin. The same trend is observed at the holding time 1 year. The results with the PF resin are higher.

TABLE I

| **Glue** | **UF** | | **PF** | |
|---|---|---|---|---|
| **Conservation time** | **2 weeks** | **1 year** | **2 week s** | **1 year** |
| Modulus of elasticity (N/mm$^2$) | 1003 | 1107 | 1033 | 1602 |
| Modulus of rupture (N/mm$^2$) | 8 | 9 | 11 | 15 |
| Tensile strength perpendicular (N/mm$^2$) | 0,04 | 0,08 | 0,15 | 0,14 |
| Fibre material moisture content (%) | 11,99 | 9,24 | 11,99 | 9,24 |

Physical and Mechanical properties of hemp board

### *E. Thermal conductivity*

As it is seen in Equation $Y_{L1}$ and response surface, Figure 7, thermal conductivity of the board samples changed within the range from λ= 0.074 to λ= 0.125 W/m.K. The smallest thermal conductivity is for 16 mm samples with the wet-preservation period of hemp components from 278 to 365 days. Thermal conductivity within the range between λ=0.08-0.09 W/m.K can be also provided by 14-16 mm thick samples with shorter wet-preservation period. When the wet-preservation period increases, the thermal conductivity coefficient of the 8 mm thick board increases within the range from λ=0.112 to λ=0.125 W/m.K, that is by 12 %. The thermal conductivity coefficient of a 16 mm board decreases within the range from λ=0.076 to λ=0.074 W/m.K, that is by 3 %. When the thickness decreases, the thermal conductivity coefficient increases from λ=0.076 to λ=0.112 W/m.K, if the hemp fibre – shive mix has been in the wet-preservation mode for 14 days, and from λ=0.074 to λ=0.125 W/m.K, if the hemp fibre – shive mix has been in the wet-preservation mode for 365 days.

$$Y_{L1}= 0.097-0.022*x_1- 0.003*x_2 + 0.004*x1*x_2 \quad (1)$$

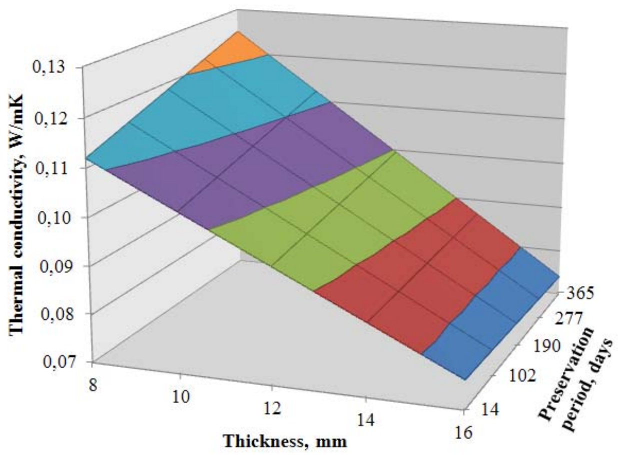


Fig. 7. Response surface of thermal conductivity of 8 mm and 16mm board

Compared to the wood-fibre board, both the 16 mm experimental board with the hemp fibre – shive mix preserved for 14 days, and the board with the hemp fibre – shive mix preserved for 365 days, the thermal conductivity and density are much lower (Figure 8), whereas their thermal conductivity can be compared with the respective indicators of rape, flax and reed boards; at the same time the density of boards with rape and reed hemp fibre – shive mix is lower, but for the board filled with flax it is higher than the densities of the previously mentioned experimental boards of 16 mm thickness. The thermal conductivity coefficients of the 8 mm thick boards are lower than those of the wood-fibre board; however their densities do not exceed the density of the wood-fibre boards to be taken into account.

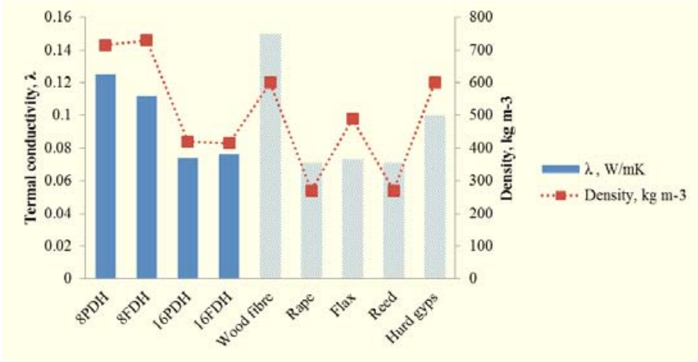


Fig. 8. Response surface of thermal conductivity of 8 mm and 16mm board

## III. CONCLUSIONS

- The use of chopped and wet preserved hemp for the production of boards permits the usage of the whole stem, including its leaves and seeds. It makes obtaining of the raw material independent of the weather conditions, the material storable in a compact way, reduces changeability of its properties, shortens the processing cycles significantly, reduces their power-intensity and simplify the technological processes, at the same time create necessity to develop new types of products, test their properties, and determines their application areas. The investigations to combine hemp fibre – shive mix types with different binders show that higher quality of board could be reached by combination of PF glue with one year preserved hemp compared to UF glue and fresh material (two weeks preserved).
- The boards of 8 mm thickness with the PF binder made of the raw materials of hemp preserved for 365 days have a higher density and higher bending strength indicators, but also have a larger thermal conductivity, approaching the average showings of wood-pulp.
- The boards of 16 mm thickness with the PF and UF binders and smaller filling of the hemp mass are significantly lighter, with a rather low thermal conductivity and can be used as sound and heat insulation materials, as the middle layers in the multilayer packets, if necessary, increasing the sound and heat insulation properties.

## REFERENCES

1. Faruk, O., Bledzki, A. K., Fink, H., Sain, M. (2012) Biocomposites reinforced with natural fibres: 2000–2010, *Progress in Polymer Science*, Vol 37, pp. 1552-1596. http://dx.doi.org/10.1016/j.progpolymsci.2012.04.003
2. Kirilovs, E., Dolacis, J., Kukle, S. (2011) With hemp fibre filled fibre plastic composites. In: Rusu, C. (eds) *Proceedings of 7th International Conference on Management of Technological Changes*, Democritus University of Thrace, Greece, Alexandroupolis, pp. 521-524.
3. Pecenka, R., Fūrll, C., Idler, C., Grundmann ,P., Radosavljevic L., (2009) Fibre boards and composites from wet preserved hemp, *Materials and Product Technology, Vol 36, pp. 208-220.* http://dx.doi.org/10.1504/IJMPT.2009.027832

4. Radosavljevic, L., Hoffmann, T., Pecenka, R., Fūrll, C. (2009) Mathematical model of the binder application for the production of fibre boards, *Biobased materials and bioenergy*, **Vol.** 3, pp. 265-268.
5. Crowley, J.G. (2001) The performance of cannabis sativa (hemp) as a source for MDF, Carlow, pp 1-9.
6. Amaducci, S. Gusovius, H.-J. (2010) Hemp- Cultivation, Extraction and Processing. In: Mussig J., Stevens C. (eds) *Industrial applications of natural fibres,* Wiley, Great Britain, pp**.** 109-133.
7. Idler, C., Pecenka, R., Fūrll, C., GusoviusH-J. (2011) Wet Processing of Hemp: An Overview. *Natural Fibres*, Vol. 8, pp. 59-80. http://dx.doi.org/10.1080/15440478.2011.576089
8. Turner, T.A., Warrior, N.A., Pickering, S.J.; Re-used of carbon fibres in high value moulding compounds &pre-pregs, 17 International Conference on Composite Materials, Edinburgh, UK, 2009, Available from http://www.iccm-central.org Accessed: 2012-01-12
9. LVS EN 310:2001 Wood-based panels; determination of modulus of elasticity in bending and of bending strength. Available at: www.lvs.lv, 27 March 2012.
10. LVS EN 319:2000 Particleboards and fibreboards - Determination of tensile strength perpendicular to the plane of the board. Available at: www.lvs.lv, 27 March 2012.
11. LVS EN 317:2000 Particleboards and fibreboards - Determination of swelling in thickness after immersion in water. Available at: www.lvs.lv, 27 March 2012.
12. ISO 8301:1991 Thermal insulation; Determination of steady-state thermal resistance and related properties; Heat flow meter apparatus. Available at: www.iso.org, 27 March 2012.
13. LVS EN 933-2:1995 Tests for geometrical properties of aggregates - Part 2: Determination of particle size distribution - Test sieves, nominal size of apertures. Available at: www.lvs.lv, 27 March 2012.

**Edgars Kirilovs**, Dr.sc.ing., Lecturer
Riga Technical University, Institute of Textile Materials Technologies and Design,
Azenes Str. 18, Riga, LV-1048, Latvia,
Phone: + 371 67089816, e-mail: edgars.kirilovs@rtu.lv

**Hans-Jörg Gusovius**, Dr.rer.agr., Research Scientist
Leibniz-Institute for Agricultural Engineering Potsdam-Bornim (ATB),
Max-Eyth-Allee 100, 14469 Potsdam-Bornim, Germany
E-mail: hjgusovius@atb-potsdam.de

**Silvija Kukle**, Dr.habil.sc.ing., Professor
Riga Technical University, Institute of Textile Materials Technologies and Design,
Azenes Str. 18, Riga, LV-1048, Latvia,
Phone: + 371 67089816, e-mail: skukle@latnet.lv

**Juris Emsins**, Assistant Professor
Riga Technical University, Institute of Textile Materials Technologies and Design,
Azenes Str. 18, Riga, LV-1048, Latvia,
Phone: + 371 67089816, e-mail: juris.emsins@rtu.lv

**Edgars Kirilovs, Hans-Jörg Gusovius, Silvija Kukle, Juris Emsiņš. Šķiedru plātņu izgatavošana no mitri konservētām kaņepēm.**
Rakstā tiek aprakstīta mēbeļu ražošanā izmantojama jauna tipa šķiedru plātne, kas izveidota sadarbībā ar Leibnica Lauksaimniecības pētniecisko institūtu (ATB), izmantojot jaunu izejmateriāla sagatvošanas metodi un specifiskas ATB produkta tehnoloģijas. Materiāla galvenā izejviela ir kaņepju stiebrs, kas tiek izturēts aerobos apstākļos. Paraugi izgatavoti, izmantojot kaņepju šķiedras ar dažādu konservācijas ilgumu un dažādām saistvielām. Iegūtais plātņu materiāls ir ar vidēju blīvumu un 8mm biezs, kas pieskaitāms pie vidēja blīvuma šķiedru plātnēm, kas iekļaujas standartā EN622. Uz eksperimentālās ražošanas līnijas tiek iegūti 1200x800x8mm un 1200x800x16mm plātņu paraugi, un atbilstoši Eiropas Savienības standartiem tiek veikti testi, lai noteiktu tādus parametrus kā stiprība liecē, stiepes stiprība perpendikulāri plātnes plaknei, ūdens uzsūktspēja un siltumvadītspēja. Piedāvāto materiālu, kura galvenā komponente ir ikgadēji atjaunojama izejviela - kaņepju stiebrs, var izmantot mēbeļu ražošanā, interjera dizainā, siltumizolācijai.

**Эдгарс Крыловс, Ханс-Йорг Гусовиус, Силвия Кукле, Юрис Эмсиньш. Изготовление плит из влажноконсервированной конопли.**
В работе рассмотрена применяемая в производстве мебели волокнистая плита нового типа, которая создана в сотрудничестве с Лейбницским сельскохозяйственным исследовательским институтом (ATB), применяя новые методы подготовки исходного материала и специфические ATB технологии. Главное сырье продукта - конопля, которая выдерживается в аэробных условиях. Образцы изготавливались из волокон конопли с различной длительностью консервации и различными связующими. Полученный плиточный материал имеет среднюю плотность и соответствует требованиям стандарта EN622 для волокнистых плит средней плотности. На экспериментальной производственной линии получены образцы плит размером 1200x800x8 мм и 1200x800x16 мм, которые прошли тестирование в соответствии со стандартами ЕС для определения таких параметров как прочность при изгибе, прочность при растяжении перпендикулярно плоскости плиты, влогопоглощение и теплопроводность. Предложенный материал, главная составная часть которого ежегодно возобновляемое сырье - коноплянный стебель, может использоваться для изготовления мебели, для теплоизоляции или в дизайне интерьера.