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Evaluation of Hemp (*Cannabis Sativa* L.) Quality Parameters for Building Material from Foam Gypsum Products

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Hemp (*Cannabis sativa* L.) is an agricultural crop that can be used as a building material in combination with foam gypsum. The hemp varieties were sown in the sod calcareous soils of Latvia. Complex fertilizer was added before sowing N – nitrogen fertilizer rates – N-0 control, N-60, and N-150 kg·ha^{-1}.
Average dry matter (DM) yield for the hemp variety was from 9.1 to 11.5 t·ha^{-1}, shive total was from 7.4 to 11.6 t·ha^{-1} which is a good result and is dependent on the amount of N supplementary fertilizer applied.
The nitrogen fertilizer rate increase from N0 to N150 kg ha^{-1} provided a significant ($p<0.05$) increase in DM for both varieties of hemp.
Nitrogen fertilizer rates had a positive significant effect on the shives content of the hemp varieties.
A composite building material, that consists of foam gypsum as a binder for hemp shives or woody core of hemp stalk with a volume density 400 – 450 kg m^{-3} has a successful application as sound and heat insulation materials.
The aim of this study was to evaluate hemp (*Cannabis sativa* L.) as a building material resource.

1. Introduction

In agricultural production, increasing the crop yield has always been an important way to raise the income of the farmers. Nowadays hemp (*Cannabis sativa* L.) has become very important as a crop for lignocellulosic biomass production. Hemp as building material is used in a lot of building structures in European countries (Allin, 2005). One way for EU agriculture to compete in the world market of lignocellulosic fibres is to supply high quality raw materials with an added value for the user. This can only be achieved when the qualitative aspects have been defined in detail for each specific end-use.
Another potential market for lignocellulosic materials is an increased interest in renewable materials in building and construction applications. Complex building regulations and standardization in the different EU member states, combined with different legislation on the use of building materials on national levels, make the introduction of novel products on this scattered and conservative market difficult.
Lightweight lignocellulosic composites are potentially contributing to sustainable development. However, lignocellulosic fillers are not always fully compatible with an inorganic matrix, which causes a variety of adverse outcomes such as the coherence and mechanical properties of composites (Stevulova et al., 2012).
Hemp as shives has been used (Madsen et al., 2007) in a lot of composite materials, for example, in composition with lime and mortar (Elfordy et al., 2008). Hemp fibres increase the bending strength of foam gypsum (Brencis, 2011). The foam gypsum pore structure has influence on the material volume density and its physical and mechanical properties (Skujans et al., 2010). The purpose of the research is to develop the technology for producing composite, energy saving building material foam gypsum with hemp shives reinforcement which, in turn, leads to the economizing of the use of foam gypsum. The research is

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focused also on the mechanical qualities of this material. The research coincides with the EU objectives of environmental protection and is directed to construction of ecological dwelling houses in the future.

2. Materials and methods

The hemp varieties ‘Bialobrzeskie’, ‘Futura75’ and ‘Tygra’ were sown in the sod calcareous soils (pH_{KCl} 6.7), containing available P 52 mg kg $^{-1}$, K 128 mg kg $^{-1}$, organic matter content 21 to 25 g kg $^{-1}$ in the soil of Latvia. The total seeding rate was 50 kg ha^{-1}. The plots were fertilised as follows: P 40, K 150 kg ha^{-1}. Complex fertilizer was added before sowing N – nitrogen fertilizer rates – N-0 control, N-60, N-120 and N-150 kg·ha^{-1}. Hemp was sown by the sowing-machine SLN-1.6 in the middle of May in the plots of 10 m^2, triplicate. The crop was harvested in the middle of September by trimmer in both years. The biometrical indices of the hemp plants, crop density, weediness, height and stalk diameter in the middle of the stalk at harvesting time, the amount of green and dry over ground mass, and fibre content were evaluated.

The chemical composition of the plants was determined by the following methods: dry matter (DM - dried); ash content for the dry matter (DM) according to Standard ISO 5984:2002/Cor1:2005; potassium(K)- according to Standard LVS EN ISO689:202, carbon(C) content – CS-500 analyzers method, lignin content (three replications) in samples was determined using the Classon method . The experimental data were processed using regression and factors variance analyses (ANOVA) and descriptive statistics. The means are presented with their LSD test.

Samples of crushed hemp separated into fibres and shives and were analyzed. The basic materials that were used for preparation of the specimens: water (drinking quality), gypsum (powder), surface active substance (SAS, liquid), unretted hemp shives of ‘Tygra’ (T), ‘Futura 75’ (F) and ‘Bialobrzeskie’ (B). The specimens of foam gypsum were produced using the dry mineralization method (Skujans et al., 2007). The concentration of hemp shives is the amount of shives in grams per 1 kg dry gypsum raw material (c, g kg^{-1}). The hemp shives concentration was varied within the limits of 25÷75 g kg^{-1}. Two different hemp shives fractions of each variety were used in the sample production, and they were added to the foam gypsum during its production process (residue on stainless steel wire sieve mesh 2 mm and 3.15 mm, volume density – $T_{2\text{-}3mm}$=104 kg m^{-3}, $T_{3\text{-}5mm}$=100 kg m^{-3}, $F_{2\text{-}3mm}$=104 kg m^{-3}, $F_{3\text{-}5mm}$=85.5 kg m^{-3}, $B_{2\text{-}3mm}$=92.5 kg m^{-3}, $B_{3.15mm}$=83.0 kg m^{-3}). Beams of size 40x40x160 mm were produced from the foam gypsum, which were further used for testing the bending and compressive strength. The measurements were carried out using commercially available instruments. All specimens were dried as written in (LVS 150:1998). Weight invariability was used as control of the specimen dryness. To gather the data presented in this paper, the following methods and instruments were used. “Retsch AS 300” vibratory sieve shaker was used for hemp shives separation.

The flexural and compressive strength measurements were carried out using the company's “INSTRON 5985” testing machine. The measurements were made in an ambient air temperature of~20°C. For the specimens tested, the following information will be presented in detail: the graph showing the foam gypsum’s volume density depending on the concentration of hemp shives; the volume density expressed in kg $m^{-3;}$ the graph showing the dependence of flexural and compressive strength on the volume density.

3. Results and discussion

Field trials have established that the yield of hemp dry matter in Latvia's agro-climatic conditions depending on the variety and fertilizer rates accounted for an average of 5.03 - 14.67 t ha^{-1}. Dependence on the version being subject to inspection, the yield of dry matter for variety 'Futura75' was 5.90 to 14.67 t ha^{-1}, 'Bialobrzeskie' – 5.56 to 12.09 t ha^{-1}, but for 'Tygra' – 5.03 to 11.56 t ha^{-1}, and the total fibre yield - respectively 3.15, 2.65 and 2.40 t ha^{-1} (Table 1).

The formation of sound insulating foam gypsum sheets, using hemp as reinforcement material can be significantly influenced by the structure of hemp stalks and chemical composition, therefore attention should be paid to the quality of reinforcement material. It has been stated in our research variants that the choice of hemp variety and fertilisation rates are the factors which affect the content of ash and carbon in the dry matter most of all. The content of lignin, phosphorus and potassium in the researched varieties was not significantly affected by nitrogen fertilizer rates.

Table 1: The hemp productivity and chemical composition (average from two years)

Hemp varieties	Fertilizer rates, kg ha^{-1}	Green biomass, t ha^{-1}	Dry matter (DM), t ha^{-1}	Content in DM, %			
				Ash	C	P	K
'Futura75'	N0	25.97	5.90	3.19	47.41	0.16	0.25
	N60	53.19	12.09	3.08	45.12	0.13	0.23
	N120	56.64	13.42	2.68	44.43	0.10	0.33
	N150	62.51	14.67	2.50	45.59	0.08	0.29
Average		49.57	11.52	2.86	45.63	0.11	0.27
'Bialobrzeskie'	N0	23.70	5.56	2.78	40.21	0.12	0.27
	N60	45.80	9.72	2.59	43.26	0.14	0.26
	N120	47.30	10.95	2.43	43.23	0.12	0.29
	N150	51.40	12.09	2.40	42.39	0.10	0.30
Average		42.05	9.58	2.55	42.27	0.12	0.28
'Tygra'	N0	22.78	5.03	2.57	39.22	0.10	0.32
	N60	41.68	9.72	2.39	41.68	0.08	0.29
	N120	46.33	10.13	2.52	41.14	0.10	0.35
	N150	49.70	11.56	2.50	38.36	0.10	0.34
Average		40.12	9.11	2.49	40.10	0.09	0.32
$LSD_{0.05}$			0.68				

As a basis, the foam gypsum manufacturing technology was used with a water gypsum proportion of 0.7 and surface active substance amount of 4 ml per 1 kg of gypsum, which resulted in the foam gypsum with the volume density of 400 kg m^{-3}, bending strength of 0.22 MPa and compression of 0.34 MPa. Taking into consideration the fact that the hemp shives volume density is from 85 to 105 kg m^{-3}, it was expected that adding them to foam gypsum the volume density of the newly obtained composite material will be lower than that of the foam gypsum without additives.

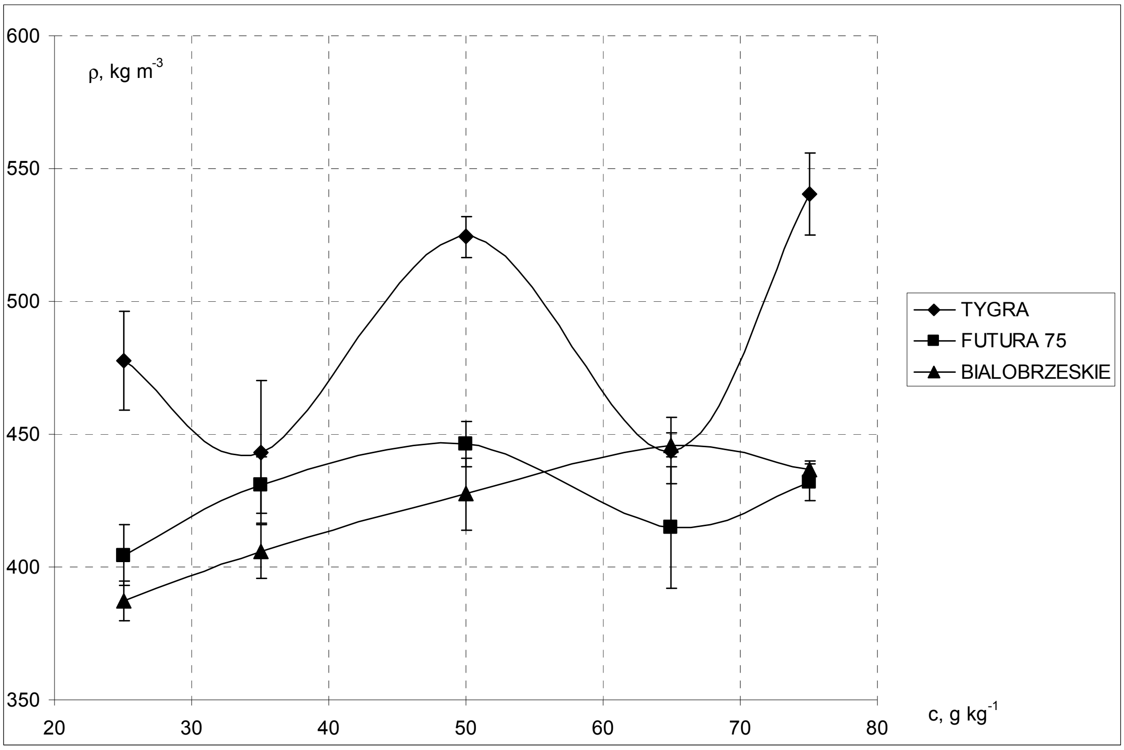

Figure 1: The foam gypsum volume density depending on concentration of hemp shives.

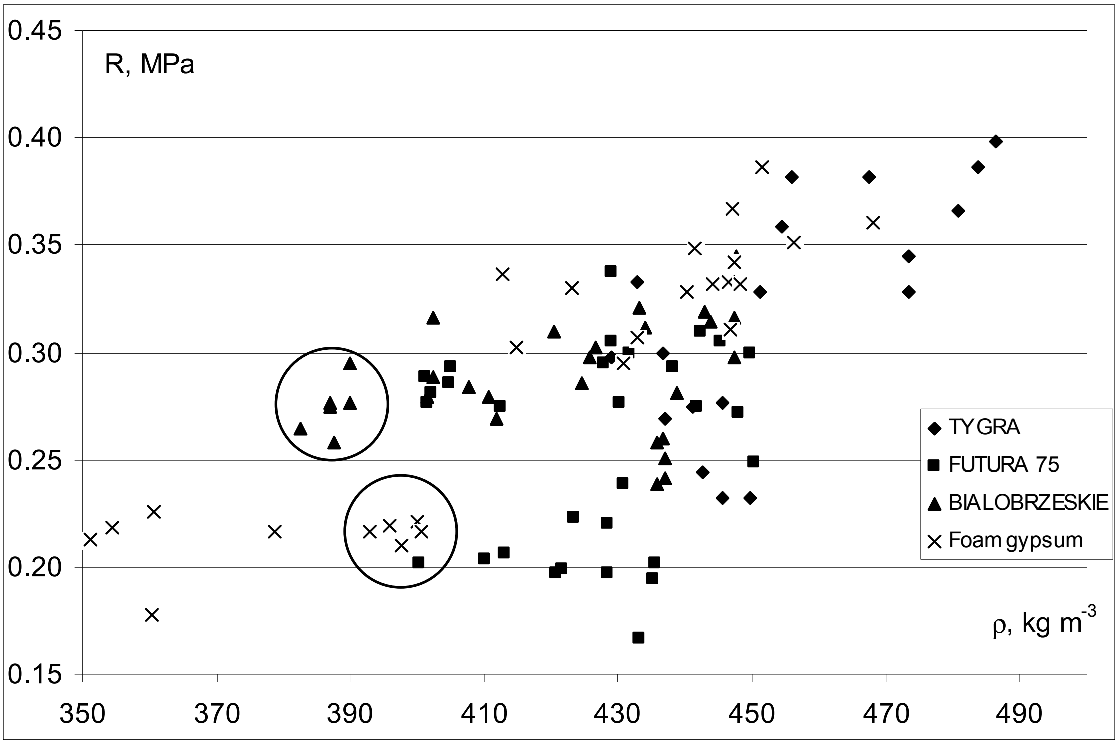

Figure 2: Value of bending strength in foam gypsum and foam gypsum with three hemp variety's shives with size 3 – 5 mm depending on its volume density.

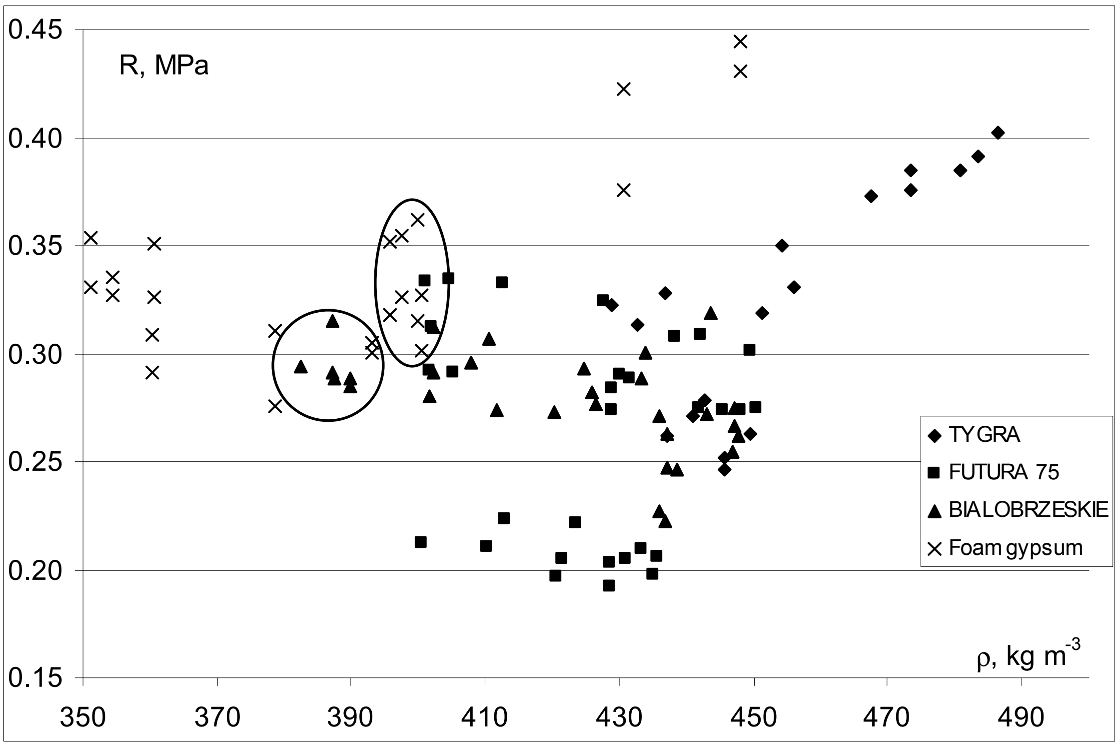

Figure 3: Value of compression strength in with foam gypsum three hemp variety's shives with size 3 – 5 mm depending on its volume density.

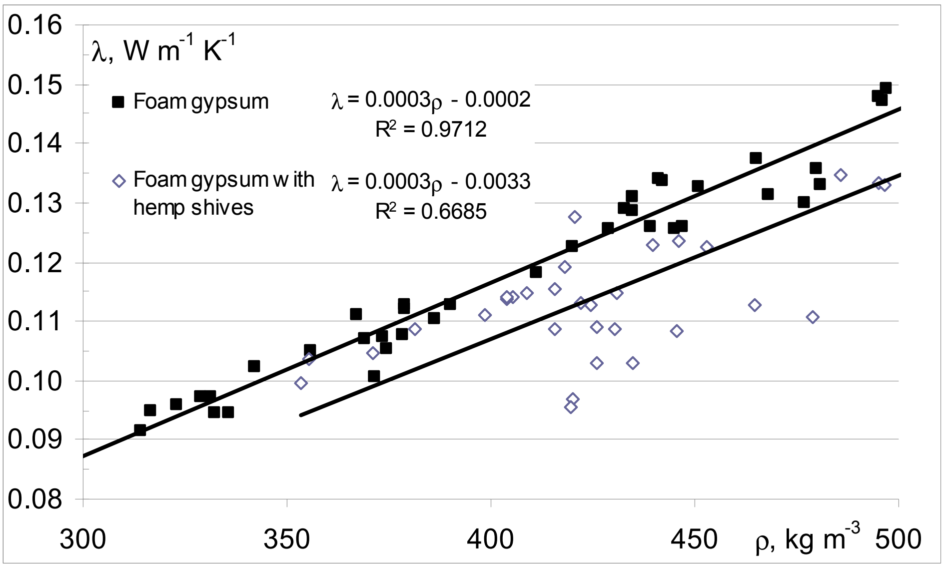

Figure 4: Value of heat conductivity coefficient in foam gypsum and foam gypsum with hemp shives depending on its volume density.

Adding hemp shives of different sizes and concentrations to the foam gypsum, a material with the volume density above 400 kg m^{-3}, was obtained, which was unexpected. Only with shives of the hemp variety 'Bialobrzeskie' 3 - 5 mm fraction 25 g kg^{-1} additives, a composite material with 387 kg m^{-3} volume density was obtained. For hemp varieties 'Futura75' and Bialobrezskie, using hemp fraction of 2 - 3 mm a composite material with the volume density of 420-470 kg m^{-3}, was obtained, but with using the shives fraction of 3 - 5 mm – from 380 to 450 kg m^{-3} correspondingly (Figure 1). The fluctuations in the results of the hemp variety 'Tygra' at a different concentration of shives were withinin a very wide range of volume density - from 440 to 540 kg m^{-3}, which significantly exceeded the limits of 400 – 450 kg m^{-3} volume density. The closest results for the chosen volume density of 400 kg m^{-3} are provided by the use of shives of the hemp variety 'Bialobrzeskie'. Foam gypsum with the shives of the hemp variety 'Bialobrzeskie' at the volume density 390 kg m^{-3} (fraction 3-5 mm) showed a bending strength of 0.28 MPa (Figure 2), which is higher than that in the foam gypsum without shive additives (0.22 MPa), but value of compression strength is 0.29 MPa of the foam gypsum with hemp shives and 0.33 MPa of the foam gypsum (Figure 3).
Heat conductivity coefficient of the foam gypsum is higher then that in the foam gypsum with hemp shive additive (Figure 4).

4. Conclusions

The growing year and the variety had a significant effect on hemp yield. Variety effect was significant ($p<0.05$).
The increase of nitrogen fertilizer rate from N0 to N150 kg ha^{-1} provided a significant ($p<0.05$) increase in green and dry matter biomass yield.
The shives of the hemp variety 'Bialobrzeskie' were found to be the best for the production of foam gypsum material with the volume density of 400 kg m^{-3}.
The use of hemp shives improved the bending strength of foam gypsum composite material.

5. Acknowlegements

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