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New composite material based on winter rapeseed and his elasticity properties as a function of selected factors

Štepán Hýsek, Milan Gaff*, Adam Sikora, Marián Babiak

Department of Wood Processing, Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Kamýcká 1176, Praha 6 - Suchdol, 16521, Czech Republic

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ABSTRACT

Using crop residues for the production of composite materials is increasingly substantiated due to the increasing lack of quality wood pulp in the wood processing industry. Crop residues of winter rapeseed, the stems of which are produced in the amount of 42 million tons each year in the European Union and have not yet been exploited for products with high added value, are a potentially interesting raw material for the manufacture of composite materials. If materials based on annual plants are to fully replace the use of materials based on wood, glass, metal or plastic, it is necessary to know their characteristics. In the wood processing industry most of the attention is focused on physical properties, which have an immediate effect on the mechanical properties. Knowledge of the effect of the interaction of several factors (feedstock, technological parameters) on characteristics describing the elastic properties of the material is this article's contribution. Knowledge of the interaction of these factors gives the manufacturer instructions for modifying the input parameters with the aim of producing a material with specific mechanical properties appropriate for the intended use.The article deals with the mechanical properties of composite materials manufactured from winter rapeseed crop residues subjected to bending. The results of the research describe the effect of surface modification (chemical or hydrothermal) of particles on the bending characteristics measured within the elastic region: bending modulus of elasticity „**MOE**", elastic potential „$\mathbf{E_P}$", stress at the limit of proportionality „**LOP**". Thanks to the acquired knowledge, we can specifically modify the properties of composite material for the intended use in the future.

1. Introduction

The production of biomass-based composite materials, which is a secondary product of agriculture, is becoming increasing important today. There are several reasons for the increasing interest in this production [1,2]. Some of the main reasons include the ever-increasing requirements for the volume of timber supply from various wood-processing as well as energy industries [1,2]. One possible solution is partial or complete substitution of wood in wood-based composite materials with biomass produced in agriculture [2]. This biomass is an inexhaustible source of both food and feed, as well as material for various industrial processes [3]. In recent years, there has been much research focusing on the use of biomass from annual plants in wood-based composites. Research has been conducted concerning the use of grain straw [4–6], rice straw [7], sunflower stalks [8], sugar cane [9], bamboo [10], reed [11], peanut and [12] hazelnut husks [13], chili pepper stalks [14], bast fiber-producing plants such as flax, hemp and kenaf [3,15,16], and many others.

Post-harvest remnants of rapeseed can also be classified as a potentially interesting raw material for the production of composite materials. Rapeseed (*Brassica napus*), an annual or biennial plant, is one of the most important oil plants worldwide. Rapeseed is grown for the food and feed industry, and in recent years especially for biofuel production. According to the Czech Statistical Office, the rapeseed production in the Czech Republic has more than tripled from 1990 to 2015. In 2015, a total of 366,180 ha of land were covered with rapeseed, which is 14.9% of the total sowing area in the Czech Republic [17]. The global rapeseed production is also growing fast; according to the FAO, the world's largest rapeseed producers are Canada, China, India, Germany and France [18]. The average global yield of rapeseed is around 1.9 t/ha, and the average yield in Europe is 3–4 t/ha [19]. The yield of stalks per hectare in Europe is 3–10 t/ha, which means that approximately 42 million tons of stalks were produced in the European Union in 2014 [20]. The rapeseed plant can reach a height of up to 2 m, and the stem is often branched. The stalk density at 10% moisture content is about 270 kg/m^3, and the substance density is 1550 kg/m^3 [21]. Unlike

* Corresponding author.
E-mail address: gaffmilan@gmail.com (M. Gaff).

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Table 1
Representation in fractions of chopped rape straw.

Fraction (mm)	0–0.25	0.25–0.5	0.5–0.8	0.8–1.6	1.6–2	2–3.15	3.15–8
Representation (%)	1.2	2.8	4.8	39.4	20.1	23.1	8.6

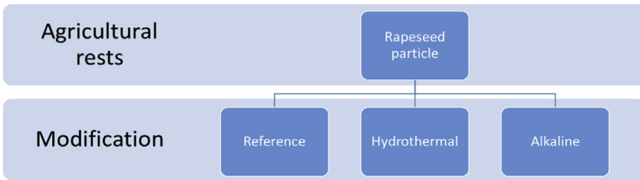

Fig. 1. Categorization of monitored group samples.

wood, rapeseed fibers are more heterogeneous because the plant contains multiple kinds of cells. According to Tofanica, the fiber length ranges from 0.7 – 2 mm, the width ranges from 9 – 20 µm and the cell wall thickness ranges from 1.8 – 3 µm. The rapeseed stalk contains 41% cellulose (Kürschner–Hoffer method), 23.4% hemicelluloses, 21.5% lignin, 6.8% extractives and 5.8% ash. If we were to analyze the stalk after the removal of the pith, the percentage of cellulose would be greater and the percentage of ash would be smaller. The chemical composition of individual fibers after the removal of the pith is 61.3% cellulose, 13.9% hemicelluloses, 5.2% lignin, 1.9% extractives and 4.8% ash [19]. The chemical composition of the stalks and dimensions of the rapeseed fibers are similar to the chemical composition of deciduous wood species, making the substitution of wood with rapeseed stalks in wood-based composites obvious. Still, rapeseed stalks are rarely harvested; they are usually plowed under after the harvest and used to enrich the soil with minerals. Some farmers produce rapeseed straw or straw pellets for energy purposes, but rapeseed straw has yet to be used industrially in products with higher added value. Post-harvest rapeseed remnants have the potential to be used for the production of composite materials and materials for construction purposes, as well as in the paper and chemical industries.

In the past, there has been some research on the use of particles from rapeseed stalks for the production of particleboard. Authors who examined the possibility of particleboard [22], they have proven that rapeseed particles are a suitable alternative to wood particles, and the produced boards allegedly met the standard requirements for particleboard for use in dry environments (P2). They also developed sandwich boards with a middle layer of rapeseed particles and double-sided beech veneer with a thickness of 1.7 mm. The rapeseed particle sandwich panels had better mechanical properties than the same (with the same density) sandwich panels made of wood particles [22]. The improvement in the mechanical properties was due to the fact that it is possible to press a larger amount of particles into the board thanks to the lower density of rapeseed. In another study [1], the particleboards were lightened by replacing wood particles in the middle layer with rapeseed particles and by adding polystyrene. Again, the produced boards allegedly met the standard requirements for boards for indoor use [1]. Research on the possibility of using rapeseed stalks for the production of particleboard for construction purposes was also conducted, where the boards were bonded with hybrid isocyanate and phenol-formaldehyde glue (pMDI/PF). The best results were achieved by boards with a density of 650 kg/m^3, but they exhibited high thickness swelling [23]. Further research, in which particleboard was produced with the addition of rapeseed particles in various weight ratios, showed that the internal bonding, bending strength and screw withdrawal resistance decreased as the rapeseed particle content increased. On the other hand, the produced boards met the standard requirements, and the dimensional stability improved with the increasing content of rapeseed particles [24]. The aim of the research conducted in Iran was to improve the properties of particleboard bonded with urea-formaldehyde

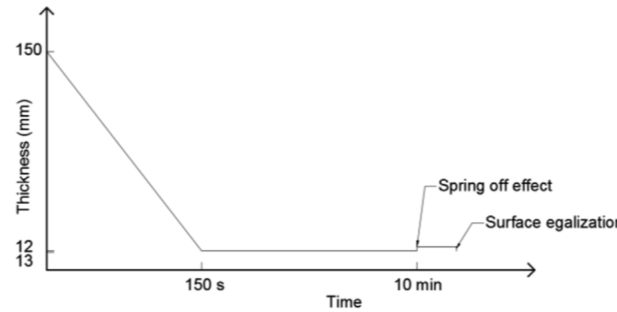

Fig. 2. Pressing regime.

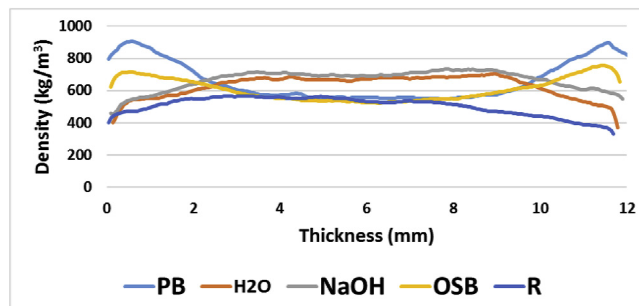

Fig. 3. The density profile measured in the monitored sets of test samples.

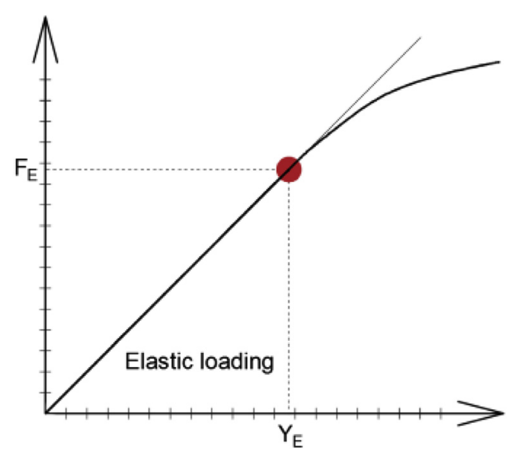

Fig. 4. Force – deflection diagram for bending.

adhesives with the addition of rapeseed particles and recycled polyethylene. The results showed that the increasing proportion of rapeseed particles has a negative effect on internal bonding, water uptake and swelling, and a positive effect on the tensile and flexural modulus. It has also been proven that with the increasing content of recycled polyethylene, the content of urea-formaldehyde (UF) adhesive can be reduced [25]. In Germany, three-layer particleboard was produced under laboratory conditions; the top layers were made of wood particles and bonded with a mixture of UF adhesive and wheat protein adhesive (50/50 ratio). A mixture of wood particles and particles from annual plants (sugar cane, rapeseed and hemp) was used in the middle layer. The particles in the middle layer were only glued with UF adhesive. A reduction in formaldehyde emissions was achieved and the boards met