Final Report Summary - BIOPURFIL (Bio-based polyurethane composites with natural fillers)

The overall aim of the project titled “Bio-based polyurethane composites with natural fillers” (Acronym: BIOPURFIL) was to create multinational partnership between European and South American research teams in order to exchange and develop knowledge and experience concerning different bio-based polyurethane materials. Finally 4 participants have been involved in this project, which allowed strengthening research cooperation and transfer of knowledge between participants from Poland, Latvia, Spain and Argentina. Short and longer-term periods (from 1 to 4 months) of staff exchange between participants allowed participants having different expertise areas to share the experience of preparing bio-based composites. This also allowed developing modern bio-composites, for which there is a growing demand in the world. The project consisted of four stages: synthesis of bio-based polyols, preparing natural fillers, producing solid and porous bio-polyurethanes and their composites reinforced with natural fillers, as well as tests and evaluation of final product.

In the frame of project different type of bio-polyols were successfully synthesized. Rapeseed, palm, linseed and tall oils were used to synthesize natural oil-based polyols with high content of natural components. In the synthesis of the bio-polyols, the following methods were used: epoxidation and oxirane ring opening, hydroxylation, transesterification and transamidization reactions, which allowed obtaining a large number of hydroxyl derivatives that are capable to react with isocyanate components in order to create polyurethane materials. The obtained bio-polyols with the broad range of hydroxyl values from 100 to 520 mg KOH/g as well as commercial bio-polyols from soybean and castor oils were used as replacements for petrochemical polyols to obtain various polyurethane materials from flexible to rigid. The characteristic of the most beneficial bio-polyols for the synthesis of different type of polyurethane materials is one of the effects of common collaboration of BIOPURFIL project. The second group of bio-components were nano- and microfillers isolated from cellulose and sisal fibers by different chemical treatments like extraction, alkalization, acetylation and acid hydrolysis. The obtained fillers were applied to obtain various polyurethane (nano)composites as foams and elastomers.

The reference (petrochemical based) systems of solid and porous polyurethane materials were elaborated and modified with bio-polyols replacing petrochemical polyols up to 70 wt.%. Moreover, selected systems were also modified with (nano)fillers in the amount up to 10 wt.%. Such modification allowed obtaining good quality elastomeric and foamed materials with different thermal-mechanical properties. The elaborated materials have a potential to be applied on an industrial scale. One of the successes of the project is elaborating porous polyurethanes containing up to 70% of bio-polyols. Such foams can be implemented as an innovative thermal insulation materials characterized by good mechanical performance, excellent sustainability and large impact on the reduction of energy consumption, environmental pollutions and CO₂ emissions. The influence of different type bio-components (bio-polyols, natural fillers) on selected properties of obtained polyurethane materials was estimated and reported by publishing common papers and presenting oral and poster communications during the workshops and international conferences. Such basic knowledge is important to elaborate the materials with properties tailored to potential applications.

The observed trends, legislative requirements and limited crude oil resources, force the producers of polyurethane materials to use raw materials derived from renewable sources. The results of works carried out in the frame of BIOPURFIL project confirmed that the use of bio-polyols may have beneficial effect on selected properties of polyurethane materials. Among porous materials two different types of foams were elaborated using renewable raw materials. The application of
rapeseed and palm oil based polyols in polyurethane formulations allowed elaborating rigid foams of low apparent density with a high content of closed or open cells, respectively. Moreover, good quality rigid polyurethane foams were obtained also using linseed oil. Such foams are interesting for industry and may be applied as good quality heat insulating materials. In the case of the foams modified with the palm oil-based polyols such products, with high content of open cells, are also permeable for moisture. However, lower thermal conductivity in the case of the foams modified with the rapeseed oil-based bio-polyol was noticed. Both types of foamed products are interesting for different applications in building industry (in Latin America and Europe) as heat insulating materials.

The comparison between unfilled polyurethane elastomers denoted that the system modified with bio-polyol based on rapeseed oil reduces the overall rate of thermal degradation attributed to a more cross-linked structure. Modification of polyurethane system based on petrochemical polyols with castor oil caused increase modulus up to 100% and elongation at break ca. 650%. Polyurethane elastomers based on palm and rapeseed oil were characterized by good useful properties. It was noticed that the increase content of bio-fillers such as sisal fibers have no impact on tensile strength of obtained elastomeric materials. The obtained results showed a possibility to decrease polyurethane price through modification with cheap natural fibers as well as bio-wastes.

The collaboration in the frame of BIOPURFIL project resulted in a significant deepening of the current state of knowledge of bio-based polyurethanes and their composites with natural fibers and nanofillers isolated from them. Project results have been presented at conferences held in Europe and Latin America as well as in the papers published in journals included in the list of Journal of Citation Report. Industrial participants of workshops with technical conferences, (specialists in polymer chemistry and material science) confirmed a significant impact of the BIOPURFIL project results on the industry development.

The results of BIOPURFIL project allowed dissemination new technologies associated with modern materials and new bio-components based on renewable raw materials. In the frame of BIOPURFIL project porous and solid bio-based composites have been elaborated what is within the scope of sustainable development of such materials, especially for automotive and building industry. The use of vegetable oil derivatives and natural fillers in the synthesis of polyurethane materials is an important part of the circular bio-economy. Moreover, the processes of bio-composites preparation mostly were conducted without solvent and with reduced amount of catalysts. Such solutions allow decreasing greenhouse gas emission and reducing of the need of fossil resources, which are the next intermediate environmental benefits.

Porous polyurethanes with low apparent density are needed for commercial and industrial applications due to possibility to reduce their cost. The material structures meet the criteria for knowledge-based economic development and innovation in Europe and Latin America. Rigid polyurethane foams are one of the most important materials used in construction industry and the global appliances (freezers, refrigerator, etc.) industry with excellent characteristics as, heat-insulation, sound-absorption, as well as being light-weight and shock-proof.

Solid polyurethanes such as elastomers are used in the manufacturing of structure elements. Owing to high abrasion resistance they replace, in many applications, rubber, other plastics and metallic plastics. Each year more and more polyurethane elastomer applications appear and so their production is steadily growing. Replacing petrochemical raw materials with renewable raw ones will allow to reduce carbon dioxide emission, which is their main advantage.

Environmental aspect of sustainable development of chemical branches has a significant influence on the increase of the interest in the production of materials with renewable compounds. Many companies have shown interest in the production of polyurethane materials with plant polyols. The obtaining of such products and their subsequent processing cause increases the competitiveness of industrial plants and can reduce dependence of them on the limited resources of petroleum and natural gas. Application of the polyols based on natural oils in many commercial products, in the industries such as automotive, furniture, bedding, construction, footwear allow to increase the attractiveness of the company's offer. Among the population increased environmental awareness is connected with interest in organic products. Demand for environmentally friendly products will increase their synthesis and the development of companies.

BIOPURFIL project allowed researchers from European universities and research centers to establish contacts with the partners in Latin America. The BIOPURFIL project allowed to build a strong international cooperation confirmed by a new project proposal prepared and submitted to European Commission in the frame of program ERANet-LAC.

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