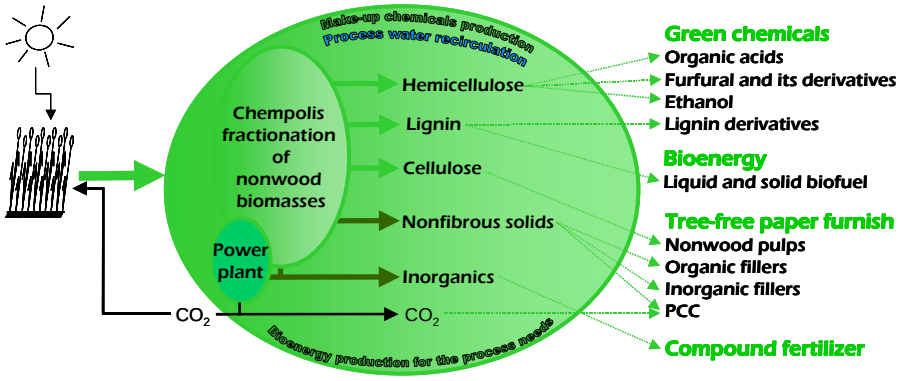
PEGRES:
Paper, bioenergy and green chemicals from nonwood residues by a novel biorefinery



1. Site of research and responsible persons

University of Oulu, Department of Process and Environmental Engineering, Chemical Process Engineering Laboratory, Prof. Juha Tanskanen, *responsible leader of the project*

University of Oulu, Department of Process and Environmental Engineering, Fibre and Particle Engineering Laboratory, Prof. Jouko Niinimäki

Lappeenranta University of Technology, Department of Chemical Technology, Laboratory of Paper Technology, Prof. Hannu Manner / Prof. Kaj Henricson

The research has been performed mainly in these three locations. However, in addition to these sites, national and international research parties, both from academia and industry, will contribute to the project. In the early spring 2007 UPM-Kymmene joined to the consortium and acts as financial party and provides visions and expertise of the paper products in interest. Prof. Hannu Manner is currently retiring and, in future, Prof. Kaj Henricson will be the responsible leader of the LUT research.

2. Objectives of the project

The goal of the PEGRES project is to develop a conceptual process model of a sustainable nonwood biorefinery. This pursued biorefinery concept is characterized by (1) total utilization of biomass into selected high value added products, (2) integrated production of paper and papermaking chemicals from the biomass and (3) self-sufficient overall production in terms of energy and process chemicals.

The third character, i.e. self-sufficient production of energy and process chemicals, is obtained by implementing the formic acid nonwood fractionation method of Chempolis Company. The Chempolis platform offers reliable and profitable fractionation of nonwood biomasses to cellulose, hemicellulose and lignin. The two other characters, i.e. production of value added products and paper and papermaking chemicals, would be the research challenges of this project. The target product groups of the biorefinery have been set to be (1) green chemicals from hemicellulose, (2) bioenergy form sulfur free nonwood lignin (3) tree-free paper furnish components from nonwood pulps and nonfibrous solids and (4) compound fertilizers from the inorganics.

3. Research results 2007

3.1. University of Oulu, Chemical Process Engineering laboratory (CPElab)

According to the original project plan, research tasks of CPElab for the year 2007 consists of the following areas (1) identification of the green chemical, (2) chemistry studies of hemicellulose conversion (3) conceptual modeling of the biorefinery and (4) organosolv cooking experiments. Implementing of different tasks from the areas 2, 3 and 4 will continue along the year 2008. Below, it is shortly described the CPElab progress in the PEGRES research during 2007. Research in general has progressed as planned and no big differences concerning the research plan have occurred. Following researchers have contributed to the results: Keijo Hytönen (CPElab), Kaisa Lamminpää (CPElab), Laura Kupiainen (CPElab), Jarkko Tenhunen (Chempolis Oy) and Jaakko Palola (Chempolis Oy). Of these Keijo Hytönen (2.5 months) and Kaisa Lamminpää (full time) have obtained financing from the PEGRES-budget.

Identification of the green chemicals

Kaisa Lamminpää has completed a literature study of furfural and its potential derivatives. Most of the furfural in the world is used in the production of its derivatives. One derivative, which has much potential for bulk production, is MTHF as a high value motor fuel additive. From organic acids, production of formic acid, acetic acid and multipurpose chemical, levulinic acid, are in focus of the project. Ethanol itself has not much potential as a green chemical in the PEGRES project, because biomass cellulose fraction is targeted to pulp, and hemicellulose conversion alone to ethanol is not an economically attractive option. Thus, it was decided that ethanol is not further studied as a green chemical in this project.

Chemistry studies of hemicellulose conversion

Furfural is obtained from biomass pentosans in acidic conditions. Optimal production of furfural from biomass was planned to be as one important subgoal of the project. Kaisa Lamminpää has concentrated on this task. In these studies, preliminary kinetic models for xylose conversion to furfural, and xylose selectivity, have been developed. Furthermore, production of formic acid from biomass has been under the study. Development of a suitable reactor system for the kinetic studies and necessary HPLC analyses took much of the planned research time and thus, more sophisticated models will be developed in 2008. However, current results are very encouraging and extensive conversion of hemicellulose to the selected green chemicals seems to be a feasible option.

Conceptual modeling of the biorefinery

Commercial ASPEN Plus Engineering software was selected for the conceptual model development environment. For optimizing the structure and state of the biorefinery, robust re-evaluation of the mass and energy balances of the whole process as well as subprocesses are needed. ASPEN Plus databanks do not have property values for the needed biopolymers and sugars, such as cellulose, xylan, lignin and xylose, but otherwise it offers superior features for process simulation. Thus, it was decided to build necessary databanks to include properties of the missing components, and properties of the polymers, which were modeled as repeating units having average properties of the polymers. Hemicellulose was modeled as xylan polymer. Values for the properties were obtained from the literature.

Cooking experiments

Formic acid based cooking experiments were directed to the development of organosolv fractionation of non-wood crops and residues. The main interest was wheat straw. The research indicates that it is possible to increase the hydrolysis rate of hemicelluloses in cooking without affecting the physical properties of the chemical pulp. The results also showed that there are many alternative ways to increase the hydrolysis rate. Although the effective time for this research was about two and half months, numerous experiments have been carried out. Chempolis company is acknowledged for their valuable help, knowhow and expertise for conducting these experiments. The research work created one conference article, which was presented in TAPPI conference, USA.

3.2 University of Oulu, Fibre and Particle Engineering Laboratory(FPElab)

The FPElab subproject was initiated by familiarizing with the area of the research. Literature search and postgraduate studies were planned to gain more information for the project. Raw material gathering for trials was found to be problematic due to their limited production capacity and distant location of production plants. Original research plan was modified, more weight was set down for the analysis of nonwood materials on first year. Mikko Karjalainen performed as a full time PEGRES researcher of FPElab.

Implementation of research plan

The tasks planned to be accomplished during the year 2007 were nonwood pulp fractionation and the analysis of acquired fractions. Laboratory equipment for pulp analysis was composed and built delaying the original time schedule.

Fractionation of nonwood pulps

Methods for nonwood pulp fractionation were clarified. Pressure screen and hydrocyclone are typical equipment used in pulp and papermaking industry. These fractionation methods are used for nonwood pulp fractionation as well. Preliminary fractionation tests using these methods were performed during the first year. Results from these tests are under processing.

Analysis of the nonwood pulp components

Methods for the analysis of the nonwood pulp components were clarified. Wide variety of analysis methods exist. The suitability of the field flow fractionation method for nonwood pulp analysis was examined. Test equipment was built and preliminary tests were performed, results from these tests are under processing.

3.3 Lappeenranta University of Technology, Laboratory of Paper Technology

During year 2007 research in LUT has concentrated answering two following objectives of the research: (1) “What is the potential of nonwood fibres and fines in modern papermaking?” and (2) “What are favorable paper furnishes for different nonwood pulps?” For the studies pulp samples were purchased from four different Chinese pulp mills and in addition several different types of laboratory scale samples were prepared in Finland. Pulp samples from mills and laboratory were purchased and prepared in co-operation with parties involved in the consortia. Päivi Rousu performed as full time PEGRES researcher and Heli Malinen as diploma thesis worker.

It has been observed that the characterization of raw material and pulps has been very important. For instance, based on the research on components of various nonwood pulps it has been found out that modern fibre dimension analyzers gives false results. However, according to own research it seems possible to modify the parameters of the analyzers so that more valuable results of nonwood pulps can be attained from these equipment. Based on this evaluation, it has been found out that the possible vessel picking problem of nonwood pulps seems to be overestimated. Instead, some other components of nonwood pulps could be more challenging components in the papermaking. Therefore the earlier tasks were deepened to find out: How each cell type of nonwood pulp affect (a) the production process and (b) the product quality. The fractionation results that will be carried out in co-operation with Fiber and Particle Engineering Laboratory (UO) are expected to give answers to both of these questions.

The diploma work carried out by Heli Malinen concerning wet pressing and water removal of nonwood containing paper furnish (to be completed on February 2008) is expected to give valuable new information and answering partly to the both (1) and (2) objectives mentioned. This diploma work has been carried out in co-operation with UPM-Kymmene and HUT. The results of the diploma work and work related to it seem to provide new and valuable information about the utilization potential of different nonwood pulps in modern paper making processes and the results are therefore aimed to be published in the scientific journal.

Research in general has progressed as planned and no big differences concerning the research plan have occurred.

During year 2007 three publications answering to objectives (1) and (2) have been presented and published in the TAPPI conference, USA and in PTS Symposium, Germany.

4. Publications

1. Rousu P & Tanskanen J. Wheat straw as a short fiber component – effect on linear / nonlinear behaviour of paper properties. PTS Pulp Technology Symposium 2007, K. Erhard, I. Demel (ed.) Munich: PTS 2007, PTS Symposium FS 703. Paper 11.
2. Rousu PP & Hytönen KJE. The role of nonwood fines constituents on pulp and paper properties. Proc. 2007 TAPPI Engineering, Pulping & Environmental Conference, October 21-24, 2007, Jacksonville, FL, USA, Paper 50-3.
3. Hytönen KJE, Rousu PP, Rousu PP & Tanskanen JP. Novel feedstocks – Future revolutions in papermaking? Proc. 2007 TAPPI Engineering, Pulping & Environmental Conference, October 21-24, 2007, Jacksonville, FL, USA, Paper 50-1.