Design of biocomposites based on nano-cellulose and hemicelluloses for future packaging materials (BioPack)

FINAL REPORT

Title of the research project	**Design of biocomposites based on nanocellulose and hemicelluloses for future packaging materials**
Coordinator of the project	Lennart Salmén

BASIC PROJECT DATA

Project period	01.01.2008-31.12.2010
Contact information of the coordinator (institute/unit, address, telephone, fax, e-mail)	Innventia AB Dr. Kristinas v. 61, Box 5604 SE-11486 Stockholm Tel. +468-6767340 Fax. +468-4115518 E-mail lennart.salmen@innventia.com
URL of the project	http://-

FUNDING

Total budget in EUR	204.537
Public funding from WoodWisdom-Net Research Programme:	Total funding granted in EUR by source:
Finland	
Tekes - Finnish Funding Agency for Technology and Innovation	-
Ministry of Agriculture and Forestry (MMM)	-
Academy of Finland (AKA)	153.730 EUR
Denmark	
Danish Forest and Nature Agency (DFNA)	-
Danish Research Council for Production and Technology Sciences (FTP)	-

Germany	
Federal Ministry of Education and Research (BMBF)/	-
Project Management Agency Jülich (PtJ)	
Norway	
The Research Council of Norway (RCN)	-
Innovation Norway (INVANOR)	-
Sweden	
The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas)	199.000 EUR
Swedish Governmental Agency for Innovation Systems (VINNOVA)	-
France	
Ministry of Agriculture, General Direction for Forest and Rural Affairs (DGPAAT)	-
Technical Centre for Wood and Furniture (CTBA)	-
National Institute of Agronomical Research (INRA)	50.608 EUR
United Kingdom	
Forestry Commission (FC)	-
Nordic Forest Research Co-operation Committee (SNS)	-

Other public funding:

Region Champagne Ardenne, France	96.638 EUR
Innventia, Sweden	44.150 EUR
University of Helsinki, Finland	30.000 EUR

Other funding:

COST-STSM-928-05174	1.980 EUR	(see section 1.6)
COST-STSM-FP0602-05360	2.500 EUR	
COST-STSM-ECOST—FP0901-210610-000000	2.000 EUR	

PROJECT TEAM (main participants)

Name, degree, job title	Sex (M/F)	Organization, graduate school	For a visitor: organization & country of origin	Funder
Lennart Salmén, Ph.D., Docent, Research Manger	M	Innventia	-	Formas + Innventia

Jasna Stevanic, Licentiate, PhD student	F	Innventia, Chalmers University	-	Formas
Paul Gatenholm, Ph. D., Professor	M	Chalmers University	-	Formas
Maija Tenkanen, Ph.D., Professor	F	University of Helsinki	-	University of Helsinki
Kirsi Mikkonen, Ph.D., PhD student, Post Doctoral Researcher	F	University of Helsinki	-	AKA
Catherine Joly,Dr Associate professor	F	LRGIA / University Lyon	-	University Lyon
Caroline Rémond, Dr Associate professor	[F]	UMR INRA URCA	-	University Reims
Ying Zhang, Ph D student	[F]	UMR INRA URCA	-	INRA + regional funding

DEGREES
Degrees earned or to be earned within this project.

Year	Degree	Sex (M/F)	Name, year of birth and year of earning M.Sc., D.Sc., etc. Degree	University	Supervisor of thesis, supervisor's organization
2009	Ph.D.	F	Kirsi Mikkonen, 1977, M.Sc. 2004	Univ. of Helsinki	Maija Tenkanen, University of Helsinki
Ph.D. funding was received also from other sources before this project					
2011	D.Sc.	F	Jasna Stevanic, 1971, M.Sc. 1999, Lic. 2008,	Chalmers Univ.	Lennart Salmén, Innventia Paul Gatenholm, Charlmers
2012	D.Sc	F	Ying Zhang, 1983 M.Sc.2008	University of Reims	Caroline Rémond, INRA

ABSTRACT

A summary of the project.

In order to explore the possible use of hemicelluloses as barrier films in packaging materials different xylans and glucomannans were characterised with regard to their film forming properties. The possibilities to improve the mechanical performance of such hemicelluloses by reinforcement with small to moderate amounts of celluloses nanofibrils were also investigated. With decreased molecular weight as well as with decreased degree of substitution (arabinose groups) the mechanical properties of xylans films deteriorated. Addition of nanocellulose generally improved strength properties but had only marginal effects on the moisture sorption capacity. Oxygen permeability was not affected to a large extent.
For spruce galactoglucomannans addition of a polyol is a necessity for obtaining cohesive self-supporting films. The addition of nanocellulose made it possible to decrease the content of polyol substantially, thus largely improving mechanical properties of such films.
In general the addition of nanocellulose to the hemicelluloses here studied improved film properties. However the use of wood hemicelluloses as barrier films still faces some challenges.

1.1 Introduction

1.1.1 Background

Describe the background of the project and the basic problem that it sought to address.

There is an increasing demand for environmentally friendly packaging materials providing superior barrier properties as well as showing good mechanical properties. Biopolymers from renewable resources (or renewable carbon) are thus much studied as a potential alternative for "green" packaging materials. Polar biopolymers such as polysaccharides lead to good barriers against oils/fats. However, due to their hydrophilicity they are generally not very efficient moisture barriers. Brittleness is another challenge related to biopolymers.
As all polar polymers, hemicelluloses create a dense network made of macromolecules presenting low mobility or more exactly a mobility dependant on the water content, and/or plasticizers content. It is well known that mobility and polarity are directly related to the gas permeation properties. For example, dense and polar biopolymer networks lead to very attractive gas barrier properties which are essential in the field of food packaging to preserve food from oxidation. Hemicelluloses (xylans, glucomannans), pectins, chitosan, starch or proteins are “potential candidates”, for these applications. Compared with starch, which is until now the mostly studied biopolymer for films and barriers, hemicelluloses have i) the advantage to be amorphous (transparent films), ii) properties much more variable as a function of the botanic origin, the isolation method, and the degree of branching. Xylans have rather recently been identified as a promising natural polymer as oxygen barrier in packaging (http://www.xylophane.com/).

1.1.2 Objectives

Describe the project objectives.

The objective of the project was to develop a new biobased packaging materials based on nanocellulose and hemicelluloses providing both good mechanical properties such as strength and flexibility without decreasing the intrinsic good oxygen barrier properties.
The project has tackled the specific drawbacks of hemicelluloses (water sensitivity and low strength) with the introduction of nanocellulose and/or plasticizers. From such nanocomposites and blends balanced gas permeation properties may be achieved. Such a biopolymer could be an alternative coating for EVOH (copolymers of ethylene and vinyl alcohol), the synthetic O_2 barrier copolymer used to prevent food from oxidation in packaging applications. This will increase the use of biobased materials in the production of advanced packing materials, thus contributing to the global efforts to increase the use of renewable resources instead of oil and petrochemicals in industrial production.

1.2 Results and discussion

Main achievements of the project, quality, innovativeness, industrial relevance and contribution to competitiveness, environmental and societal impact.

The structure of hemicelluloses found in nature varies substantially and also so for wood hemicelluloses. In this project the focus has been on more softwood type hemicelluloses, arabinoxylan and glucomannan. For this reason xylans with different substitution degrees of arabinose units were examined as model substances together with investigations of spruce glucomannan. Film forming properties as well as strength properties related to usability of the material was evaluated.

1.2.1 Pure ArabinoXylan films

1.2.1.1. Wheat ArabinoXylan (wAX) films

Wheat arabinoxylan (wAX) film properties were investigated as a function of the side group content (i.e. the A/X ratio). Three fractions were isolated depending on their solubility in water /ethanol, covering a large range of native A/X ratio (from 0.2 to 1.34), Table 1.

Table 1. Characteristics of wheat ArabinoXylan

Samples	Extraction yield (weight%)	Degree of substitution (A/X)	Molecular weight ($g.mol^{-1}$)	Oxygen permeability, $cm^3.\mu m/j.m^2.kPa$	T_g (^oC) (54% relative humidity, 1 Hz)
wAX1	71	0.2	166 000	8	5
wAX2	19	0.8	152 000	15	34
wAX3	11	1.3	218 000	24	38

From DEA measurements (dielectrical analysis), two transitions were observed, attributed to alpha and beta transitions. The glass transitions, T_g (alfa transition), in the dry state occurred around 130°C. Water plasticized the fractions with different degrees of substitution differently (Table 1), the wAX1, low substituted fraction being more plasticized than the wAX3 high

substituted one. A systematic increase in subT_g (and T_g to a minor extend) with A/X ratio was evident. Figure 1 (also displaying T_{beta} data collected for other plant species). The higher the degree of substitution the lower was the macromolecular mobility in the amorphous phase (higher T_{beta}), probably due to the larger amount of disubstituted xylose regions which act as bulky groups, and are able to establish a hydrogen bond network.
Permeability coefficients, Table 1 increases with degree of substitution (A/X ratio). These values are higher than for EVOH at 50% relative humidity, RH (0.08 to 0.3).
In Xylan films, permeability seems to be governed by the molecular packing (linked to crystallinity) rather than by the local chain mobility.

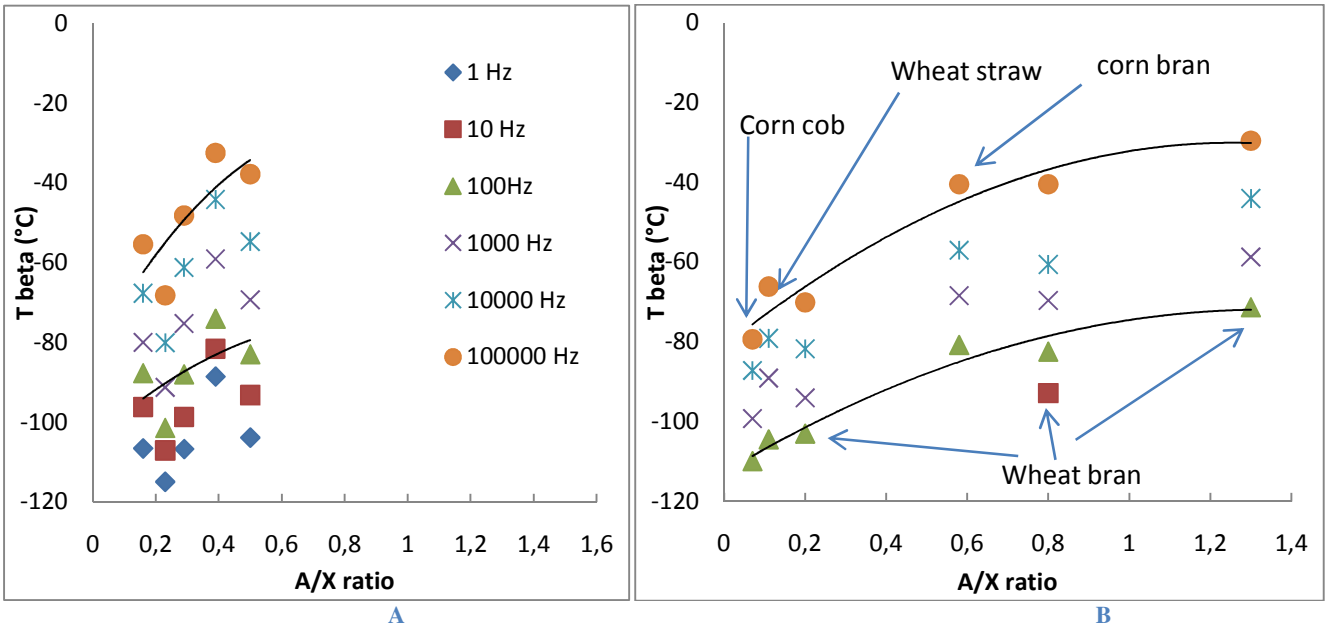

Figure 1. Beta transition temperature for some xylans as a function of the arabinose side group content (A/X) (dielectrical analysis). A) enzymatically modified rye xylans at different frequencies, B) native xylans isolated into different fractions

1.2.1.2. Rye ArabinoXylan (rAX) films

For the reason of clarifying the importance of the structural differences model xylans were produced. The arabinose side group is considered as of high importance for the solubility of the xylans. Thus the amount of arabinose units as well as of molecular weight were investigated by enzymatic debranching or chain cutting.

Debranching of rAX was carried out by a treatment with α-arabinofuranosidase, rAX with substitution degrees (A/X) of 0.5, 0.39, 0.29, 0.23, 0.16 was thus obtained. With increased debranching the some crystallization of the xylan occurred, reaching about 20% at a DS of 0.16.

Also for these rye arabinoxylans the local mobility (T_{beta}) decreased with increasing degree of substitution, DS, increased sub T_g , Figure 1A.

Water uptake was somewhat lower at the highest relative humidities for the debranched AX (lower DS) as the swelling behaviour is limited by crystallites present.

1.2.2. Cellulose reinforced films

Reinforcement of the hemicelluloses films were explored by the addition of cellulose nanocellulose in the form of either micro-fibrillated cellulose (MFC) or as bacterial cellulose (BC).

1.2.2.1. BC-reinforced ryeArabinoXylan (rAX) films

The addition of 5 and 15 wt-% of bacterial cellulsoe, BC, to the xylans of DS 0.5 and 0.16 (A/X) increased the strength and stiffness of the films. The addition of BC had though only marginal effects on the T_g of the xylans as well as of its moisture sorption ability. However, the reinforcement brought about quite noticeable reductions of the moisture sensitivity of the mechanical properties; a lower modulus decrease and a lower mechanical damping.

1.2.2.2. MFC-reinforced rAX films.

The reinforcing effect of microfibrillated cellulose, MFC, (15 wt.-% MFC) was investigated for different types of enzymatically modified arabinoxylans, see Table 3. The addition of MFC increased the RH of softening of the rAX films. In general, the relative storage modulus of MFC-reinforced films was higher than that of the pure films at RH values higher than 40%. The decrease in DS of rAX increased the softening of films at high RH.

Table 3. Characteristics of enzymatically modified ryeArabinoXylans

Sample	**rAX-H**	**rDAX-H**	**rAX-L**	**rDAX-L**
Characteristics	native,high molecular weight, MW	high molecular weight, debranched	low molecular weight	low molecular weight, debranched
MW, g/mol	184 000	152 000	49 000	59 000
DS (A/X)	0.5	0.29	0.5	0.23

The tensile testing confirmed the reinforcing effect of MFC on rAX. The tensile strength of the rAX-H film was 64 ± 6 MPa and that of the rAX-H:MFC film was 95 ± 19 MPa. The reinforcement by MFC was high also for rDAX-H, but for low DP rAXs, the effect was much smaller and not statistically significant. The addition of MFC also increased the Young's modulus of films from high DS rAXs, but not that of films from low DS rAXs. The addition of MFC did not affect the elongation at break of films. The reinforcing effect of MFC on rAX-H and rDAX-H was clearly higher than that of BC on rAX films.

Decreasing DS of rAX decreased the tensile strength and Young's modulus of films, but did not affect the elongation at break. A decrease in the DP of rAX clearly decreased the tensile strength and elongation at break of films, while Young's modulus was not affected.

When viewed with polarizing optical microscopy, there were no visible structures in the pure rAX films, but the composite films with MFC showed bright polarizing fibers and textures indicating crystalline structures.

All rAX films had high light transmittance in the visible region of the spectrum, indicating that the films were transparent.
Haze is the scattering of light by a specimen responsible for the reduction in contrast of objects viewed through it. The rAX films differed greatly in haze. The addition of MFC clearly increased the haze of films, especially that of films from high DP rAXs. The highest haze was measured for the rDAX-H:MFC film. The haze of films from low DP rAXs was lower than that of films from high DP rAXs.

1.2.2.3. CNW reinforced wheat ArabinoXylan (CNW-wAX) films
Cotton cellulose nanowhiskers (CNW) were added to wAX fractions, wAX1 and wAX3 (5 and 10%wt) in order to study fibre/xylan interactions as a function of the xylan degree of substitution. For the low substituted xylan (wAX1) both T_g and sub T_g increased when fibres were added. The interactions with the matrix was very side groups dependent, the higher the DS, the lower the interactions.

1.2.2.4.BC-reinforced GalactoGlucoMannan (GGM) films.
The addition of bacterial cellulose, BC, 5 wt.-% and 15% (plasticized with 40 wt.-% glycerol of the weight of GGM) increased the stiffness of the films measured with DMA. The tensile strength and Young's modulus of GGM:5BC/40gly films were lower and those of GGM:15BC/40gly at the same level as the tensile strength and Young's modulus of GGM/40gly film. The elongation at break was the highest for the GGM:15BC/40gly film. The GGM:5BC/40gly film did not significantly differ from GGM/40gly film with regard to the elongation at break. Addition of BC did not significantly change the moisture uptake of the films.

1.2.2.5. MFC-reinforced GGM films.
Microfibrillated cellulose, MFC, was used at 5% on GGM films containing 40% glycerol and at 15% on GGM films with 10, 20, 30, and 40% glycerol as plasticizer. Moisture clearly acted as a plasticizer for GGM, which was evident from the decrease in storage modulus. The GGM/40gly film showed the lowest stiffness of all the films studied. A successive lowering of the amount of added plasticizer (i.e., 30% and 20 wt.-% of GGM) caused an increase in the stiffness of the corresponding films. The reinforcing of the GGM with MFC resulted in an even higher increase in stiffness. For the composite films of GGM and MFC with lower amounts of the plasticizer added (i.e., 30%, 20%, and 10% w/w of GGM), the stiffness was successively increased as the amount of glycerol was decreased. Both glycerol and moisture lowered the softening temperature by affecting intermolecular forces (hydrogen bonding) between the polymer chains, providing a higher mobility of the polymer chains and a higher free volume. On the other hand, the reinforcement with MFC showed an opposite effect by providing less mobility of the polymer chains, probably due to the interactions between cellulose and GGM chains.
The tensile strength of GGM/40gly film was 6.5 MPa. Decreasing the glycerol content to 30% did not affect the tensile strength, but the GGM/20gly film was slightly stronger than the GGM/40gly and GGM/30gly films. The addition of 15% MFC clearly increased the tensile strength and Young's modulus of films, especially at low glycerol contents, and even a GGM:15MFC/10gly film was successfully measured. In contrast, MFC decreased the elongation at break of films at high glycerol contents. The GGM:MFC composite films became stronger, stiffer, and more brittle when decreasing amounts of plasticizer were added (i.e., 30%, 20%, and 10% wt.-% of GGM). The accumulation of glycerol on the GGM-MFC interface could have been

the reason for the small reinforcement effect at high glycerol content (40%). At lower glycerol content (30–10%), a clear reinforcement was detected.

The addition of MFC did not affect the degree of crystallinity of GGM in the films, which was between 20 and 25%. The addition of MFC somewhat decreased the moisture uptake of films at high RH, indicating that some of the water sorption sites available on GGM/glycerol mixtures became unavailable when fibres were added. MFC also increased the T_g of films at all glycerol contents. The decrease in the macromolecular mobility in the presence of fibres confirmed the fibre/matrix-specific interaction in the amorphous phase.

1.2.3. Permeability measurement

Permeability was unfortunately difficult to measure due to the difficulty to handle films without heterogeneity, defaults and ageing in a sufficient amount. For example, when A/X is low solutions to cast have insoluble parts or aggregates. When fibres were added, sample heterogeneity was higher as fibres may also form some aggregates. As an indication values in Table 4 may be representative. Thus there is an indication that the addition of cellulose reinforcements may to some extent increase O_2 permeability.

Table 4. Oxygen permeability of some selected films

Sample, rAX, DS 0.5	O_2 permeability $cm^3.\mu m/d.m^2.kPa$
rAX, no1	2,7
rAX, no2	5,3
rAX MFC 15%, no1	9,9
rAX MFC 15%, no2	8,8

1.3 Conclusions

The most important contributions to the state-of-the-art, derived from the results and discussion.

These studies of nanocellulose reinforced hemicellulose films have shown that small amounts of cellulose reinforcements (up to 15%) may substantially improve the mechanical prosperities of such films. For low molecular mass hemicelluloses, where softeners as glycerol are a necessary component, their amount may be reduced, still producing good films. The moisture sensitivity of mechanical properties were considerably improved with the addition of nanocellulose while moisture sorption was only marginally affected. With debranching of xylans (lower degrees of arabinose units) the mechanical properties of films were decreasing. Thus the prospect for the use of wood hemicelluloses in film applications faces still high challenges.

1.4a Capabilities generated by the project

Knowledge generated in the project / outcomes of the project, such as unpublished doctoral theses, patents and patent applications, computer programs, prototypes, new processes and practices; established new businesses; potential to create new business opportunities in the sector.

The knowledge generated in this project has broadened the basic knowledge among researchers in the countries involved in the project (1 PhD thesis produced) and has also lead to a valuable collaboration in this area, a collaboration which will continue after the end of the project. As an example, a collaboration will be in effect from 2011 within the Wallenberg Wood Science Centre in Stockholm between KTH, Innventia and University of Helsinki. The project will also lead to two doctoral thesis that will be published in the coming year/s.

1.4b Utilisation of results

Give a brief description of how the results of the research and development have been used and/or what is the exploitation plan or plans for transferring the results into practice.

The research here performed has rendered a substantial increase of knowledge with regard to structure–property relations of hemicelluloses as well as to the potential benefits of reinforcements with low amounts of nanocellulose fibrils. This knowledge has been put together in one doctoral thesis and two in the process, as well as in numerous publications to come. The research has given the basis for further research in this area, a necessity to be able in the future to explore the use of wood hemicelluloses in higher value added products.

1.5 Publications and communication

a) Scientific publications

For publications indicate a complete literature reference with all authors and for articles a complete name. Indicate the current stage of the publishing process when mentioning texts accepted for publication or in print. Abstracts are not reported. Indicate the five most important publications with an asterisk.

1.5.1. Articles in international scientific journals with peer review

Mikkonen KS, Mathew AP, Pirkkalainen K, Serimaa R, Xu C, Willför S, Oksman K, Tenkanen M (2010). Glucomannan composite films with cellulose nanowhiskers. Cellulose 17:69-81.

Mikkonen KS, Heikkilä MI, Helén H, Hyvönen L, Tenkanen M (2010). Spruce galactoglucomannan films show promising barrier properties. Carbohydr. Polym. 79:1107-1112.

Stevanic JS, Joly C, Mikkonen KS, Pirkkalainen K, Serimaa R, Rémond C, Toriz G, Gatenholm P, Tenkanen M, Salmén L. Bacterial nanocellulose reinforced arabinoxylan films. J. Appl. Pol. Sci. Submitted.

Zhang Y, Pitkänen L, Douglade J, Tenkanen M, Remond C, Joly C. Wheat bran arabinoxylans: chemical structures and film properties of three different fractions. Carbohydr. Polym. Submitted

Mikkonen KS, Stevanic JS, Joly C, Dole P, Pirkkalainen K, Serimaa R, Salmén L, Tenkanen M. Composite films from spruce galactoglucomannans with microfibrillated spruce wood cellulose. Cellulose Submitted.

Mikkonen KS, Pirkkalainen K, Pitkänen L, Mabasa Bergström E, Serimaa R, Salmén L, Tenkanen M. Composite films from enzymatically modified arabinoxylans reinforced with microfibrillated cellulose. Manuscript in preparation.

1.5.2. Articles in international scientific compilation works and international scientific conference proceedings with peer review

Mikkonen KS. Recent studies on hemicellulose-based blends, composites and nanocomposites. In: Recent Advances in Natural polymers: Their blends, composites and nanocomposites, S. Thomas, A.P. Mathew, P.M. Visakh, Eds. Submitted.

1.5.3. Articles in national scientific journals with peer review

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1.5.4. Articles in national scientific compilation works and national scientific conference proceedings with peer review

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1.5.5. Scientific monographs

Mikkonen KS (2009). Mannans as film formers and emulsion stabilizers. Doctoral thesis, University of Helsinki, EKT series 1454.

1.5.6. Other scientific publications, such as articles in scientific non-refereed journals and publications in university and institute series

Mikkonen KS, Yadav MP, Mathew A, Oksman K, Willför S, Tenkanen M (2008). Blend films and composites from spruce galactoglucomannan. 10th European workshop on lignocellulosics and pulp (EWLP), August 25-28 2008, Stockholm, Sweden, proceedings, 64-67.

Mikkonen KS, Laine P, Parikka K, Yadav MP, Jouppila K, Xu C, Willför S, Tenkanen M (2009). Spruce galactoglucomannans are potential new biopolymers for films, microcapsules and emulsions. 2nd Nordic Wood Biorefinery Conference (NWBC), September 2–4, 2009, Helsinki, Finland, proceedings, posters, vol 2, 219-224.

Mikkonen, K.S., Stevanic, J.S., Joly, C., Pirkkalainen, K., Dole, P., Serimaa, R., Ankefors, M., Salmén, L., and Tenkanen, M. Microfibrillated cellulose reinforced spruce galactoglucomannan films, 11th European workshop on lignocellulosics and pulp (EWLP), August 16-19 2010, Hamburg, Germany, proceedings, 397-400.

b) Other dissemination

Such as text books, manuals, user guidelines, newspaper articles, TV and radio programmes, meetings and contacts for users and results.
Dissemination of results to industrial partners and industrial partners dissemination within the company.

Oral presentations

Mikkonen KS, Stevanic JS, Dole P, Mathew AP, Pirkkalainen K, Joly C, Serimaa R, Willför S, Oksman K, Salmén L, Tenkanen M. Spruce galactoglucomannan films reinforced with cellulose. Nordic Polymer Days, May 24-26 2010 Helsinki, Finland

Mikkonen KS, Heikkilä MI, Yadav MP, Mathew AP, Oksman K, Willför S, Tenkanen M. Biodegradable films and composites from spruce galactoglucomannan. Polysaccharides as a source of advanced materials, September 21-24 2009, Turku, Finland

Mikkonen KS, Heikkilä MI, Laine P, Parikka K, Xu C, Willför S, Tenkanen M. Spruce galactoglucomannans are potential novel biopolymers for films, microcapsules and emulsions. ACS National Meeting, March 22-26 2009, Salt Lake City, United States.

Mikkonen K, Yadav M, Mathew A, Oksman K, Willför S, Tenkanen M. Blend films and composites from spruce galactoglucomannan, 10th European workshop on lignocellulosic and pulp (EWLP), August 25-28 2008, Stockholm, Sweden

Mikkonen K, Mathew A, Xu C, Willför S, Tenkanen M, Oksman K. Mannan-cellulose nanocomposites. ACS National Meeting, April 6-10 2008, New Orleans, United States

Zhang Y, Pitkänen L, Douglade J, Tenkanen M, Remond C, Joly C. Wheat bran arabinoxylans: fractionation, chemical structure and films properties. Int. Conf. Biomass derived pentoses: from biotechnology to fine chemistry, November 14-16 2010, Reims, France

Posters

Mikkonen KS, Stevanic JS, Joly C, Pirkkalainen K, Dole P, Serimaa R, Ankerfors M, Salmén L, Tenkanen M. Microfibrillated cellulose reinforced spruce galactoglucomannan films, 11th European workshop on lignocellulosics and pulp (EWLP), August 16-19 2010, Hamburg, Germany

Mikkonen KS, Laine P, Parikka K, Yadav MP, Jouppila K, Xu C, Willför S, Tenkanen M. Spruce galactoglucomannans are potential new biopolymers for films, microcapsules, and emulsions. 2nd Nordic Wood Biorefinery Conference (NWBC), September 2-4 2009, Helsinki, Finland

Zhang Y, Pitkänen L, Tenkanen M, Remond C, Joly C. Arabinoxylanes films structures/Sub Tg relationships. MATBIM 2010, First International Meeting on Material/Bioproduct Interactions March 3-5 2010, Paris, France

Zhang Y, Pitkänen L, Douglade J, Tenkanen M, Remond C, Joly C. Structure/property behavior of isolated arabinoxylans from cereals. Lignobiotech One Symposium - Premier Symposium sur les biotechnologies appliquées aux lignocelluloses, March 28 mars- April 1 2010, Reims, France

1.6 National and international cooperation

Give a brief description of the cooperation/ networking (partnership between the project participants and how this has developed; industrial involvement; synergies of industrial and research expertise; Has the project collaborated with similar projects in the WW-Net countries or other regions, or established new links with/ between local or international organisations involved in the respective research field? Describe how these partnerships have supported the project.
National vs. transnational aspects in the project; added value for the project and its impacts which result from transnational cooperation.

Collaboration with the WW-Net project DesignCell in using nanocellulose produced for the mixing for the xylan/cellulose glucomannan/cellulose films has been made. Also the technique used in this project for homogenising the material has been used in the mixing of bacterial cellulose with xylan and glucomannan.

Cooperation was established with Kari Pirkkalainen, MSc, and Prof. Ritva Serimaa from the Department of Physics, University of Helsinki, for analyzing the crystallinity of the films using X-ray diffraction.

COST-STSM-928-05174:
Beneficiary's Name and Institution: Ms Ying ZHANG, UMR INRA URCA France
Host's Name and Institution: Maija Tenkanen, Department of Applied Chemistry and Microbiology, University of Helsinki, Finland
Period: from 06/10/2009 to 14/11/2009
The aim of this STSM was to characterize the structures of some cereal arabinoxylans. Patterns of arabinosyl substitutions were investigates with high-performance anion-exchange chromatography after Shearyme (GH10 endo-1,4-β-D-xylanase) hydrolysis. Furthermore, high performance size exclusion chromatography (HPSEC) with multiple detections (refractive index, light scattering, viscometric and ultra-violet detectors) was used to investigate the relationships between structures and hydrodynamic properties of polymeric arabinoxylans.

COST-STSM-FP0602-05360:
Beneficiary's Name and Institution: Ms Kirsi Mikkonen, University of Helsinki, Finland
Host's Name and Institution: Patrice Dole, UMR INRA URCA FARE, France
Period: from 19/10/2009 to 27/11/2009

The aim of this STSM was to prepare composite films from spruce galactoglucomannan with microfibrillated spruce cellulose and bacterial cellulose and examine the effects of added celluloses on water sorption and glass transition temperature of the films.

COST-STSM-ECOST—FP0901-210610-000000:
Beneficiary's Name and Institution: Dr Kirsi Mikkonen, University of Helsinki, Finland
Host's Name and Institution: Lennart Salmén, Innventia, Sweden
Period: from 04/10/2010 to 29/10/2010
The aim of this STSM was to study composite films from enzymatically modified rye arabinoxylans with microfibrillated spruce cellulose using moisture-scanning dynamic mechanical analysis.