Final report for SNS research projects

Submit the report to sns@slu.se by 24:00 CET, 1st of September, 2022, at the latest.
The report should not exceed 2500 words (including words in the template).

Please adjust the size of the box according to the length of your answer.

1. Project title:	Valorization of wood biorefinery products into novel functional hydrocolloids (WOOD-PRO)
2. Reporting year:	2016–2018

3. Project coordinator:	Assistant Professor Kirsi S. Mikkonen
Email:	kirsi.s.mikkonen@helsinki.fi
Address:	Department of Food and Nutrition, P.O. Box 66, 00014 University of Helsinki

Activity report

4. Provide a project summary, including:

a) The purpose of the project/main problems /hypothesis addressed

The aim of this project was to establish thorough understanding of the functioning conditions and parameters enhancing or limiting the applicability of nanocelluloses and hemicelluloses as hydrocolloids. The project activities included nanofibrillation of cellulose and extraction of hemicelluloses and their use as biobased polymers, composites, and emulsifiers.

b) A short description of the main activities of the project

To achieve the aim of the project, polymers, composites, and emulsions were prepared and their physical and physicochemical properties were characterized. The raw material sources for nanocellulose preparation were forest residues. Hemicelluloses isolated from softwood and hardwood by the most recent, advanced techniques were used. The natural gelling ability of nanocelluloses was exploited in gel formation to prepare packaging material prototypes. In addition, aqueous suspensions/solutions of nanocelluloses and hemicelluloses were prepared and emulsified with oil by homogenization. Model food and packaging matrices were prepared and evaluated with respect to their funtionality and stability.

c) Achieved targets and to what extent the research plan was fulfilled

We have improved the processing efficiency of the fibrillation and shown excellent properties which can be achieved by dispersion and orientation of the nanocellulose. We showed that hemicelluloses have excellent emulsion stabilization capacity and they are promising novel food hydrocolloids. Nanocelluloses and hemicelluloses can be combined to produce novel active packaging materials. All main targets of the research plan were fulfilled.

5. Published outputs achieved as a consequence of the project (peer-reviewed articles, other publications)

Peer-reviewed publications:

1. Berglund L, Anugwom I, Hedenström M, Aitomäki Y, Mikkola J-P and Oksman K, Switchable ionic liquids enable efficient nanofibrillation of wood pulp. Cellulose 24, 8(2017) 3265-3279.
2. Berglund L, Forsberg F, Jonoobi M, Oksman K. Hemicellulose based aerogels and hydrogels from barley residues: effect of crosslinking degree and nanofiber reinforcement, RSC Adv, 8 (2018) 38219 – 38228.
3. Geng S, Yao K, Zhou Q, Oksman K. High-Strength, High-Toughness Aligned Polymer-Based Nanocomposite Reinforced with Ultra-Low Weight Fraction of Functionalized Nanocellulose, Biomacromolecules (2018) DOI: 10.1021/acs.biomac.8b01086
4. Geng S, Wei J, Noël M, Aitomäki Y and Oksman K, Well-dispersed Nanocellulose Reinforced Composites Synthesized by a Generalizable Single-step Method. Nanoscale, 2018 DOI: 10.1039/C7NR09080C
5. Lehtonen, M., Merinen, M., Kilpeläinen, P.O., Xu, C., Willför, S.M. Mikkonen, K.S. 2018. Phenolic residues in spruce galactoglucomannans improve stabilization of oil-in-water emulsions. Journal of Colloid and Interface Science. 512, 536–547.
6. Bhattarai, M., Pitkänen, L. Kitunen, V., Korpinen, R., Ilvesniemi, H., Kilpeläinen, P.O., Lehtonen, M. and Mikkonen, K.S. 2019. Functionality of spruce galactoglucomannans in oil-in-water emulsions. Food Hydrocolloids, 86, 154–161.
7. Berglund L, Breedveld L, Oksman K. Toward eco-efficient production of natural nanofibers from industrial residue: Eco-design and quality assessment", submitted to Journal of Cleaner Production (July 2019).
8. Lehtonen, M., Kekäläinen, S., Nikkilä, I., Kilpeläinen, P., Tenkanen, M., Mikkonen, K.S. Active food packaging through controlled in situ production and release of hexanal, submitted to Food Chemistry X (May 2019).
9. Aaen, R. et al. Stabilization of emulsions by combining nanocellulose and galctoglucomannan. To be submitted.

6. Other practical outputs of the project (websites, policy recommendations, conferences, scientific meetings, large-scale project applications, research training etc.)

Research training: Ragnhild Aaen from NTNU / RISE PFI has been 4 months on a research stay at the University of Helsinki as a part of her PhD study. One scientific article will result from this work. Her PhD graduation is delayed because two periods of maternity leave, and she will defend her thesis in 2020.

The research activities were presented in numerous international scientific conferences. Several project meetings were organized both face-to-face and via Skype.

7. How and within which areas was the project beneficial for the Nordic countries?

The project advances the utilization of wood-based raw materials – nanocelluloses and hemicelluloses – in food, cosmetics, chemicals, and packaging. Wood nanocelluloses and hemicelluloses are bio-based and sustainable alternatives for many currently used synthetic polymers. The project is beneficial to forest, food, cosmetic, and chemical industries. The project also supports the sustainable use of natural raw materials.

8. Please provide a short popular science piece of the project (maximum 500 words) for publication by SNS in various channels

Nordic forests are rich in valuable raw materials, including cellulose and hemicelluloses. In the SNS-funded WOOD-PRO project, our Nordic consortium developed new methods to utilize cellulose and hemicelluloses in products, including food and packaging materials. Wood cellulose was refined to nanofibrils, which formed strong composite materials that could be used as bio-based packaging materials, for example. Hemicelluloses were extracted from wood by a sustainable method using pressurized hot water, and used to stabilize emulsions, i.e. oil droplets dispersed in water. Hemicellulose-stabilized emulsions could be an interesting Nordic alternative in food and beverages, or in cosmetic creams and lotions. We also combined nanocelluloses and hemicelluloses to form emulsions and composite aerogels with improved stability and strength. Active packaging materials produced from nanocelluloses and hemicelluloses can preserve fresh fruit and vegetables longer than conventional packaging, and reduce food waste.

Participation

9. Number of participants

Country	Young researchers / PhD students	Senior researchers	Stakeholders	Others (specify)	Gender			Total
					Women	Men	Other	
Denmark								
Finland	5	1	2		5	3		8
Iceland								
Norway	2	2	2		4	2		6
Sweden	2	3			4	1		5
...								
...								
...								
...								
...								
...								
Total	9	6	4		13	6		19

10. List the participating sectors
Academy, forest industry, food industry, cosmetic industry, chemical industry

Economic report

11. Received grant from SNS in total (SEK):
1 500 000

12. Transfer of SNS funds to project partners

Country	Partner organization	Sum (SEK)
Denmark		
Finland		
Sweden	Luleå University of Technology	450000
Norway	RISE PFI	450000
Iceland		
Other countries (specify)		
Total SUM		900000

13. Costs

	SNS funding	External funds*	Total*
Travel and hotel	190 704	586 298	777 002
Meeting costs	7 065	45 663	52 728
Consumables	306 151	132 885	439 036
Salary	920 305	8 827 892	9 748 197
Communication	0	0	0
Other costs (specify)	55 501	3 114 674	3 170 175
Total SUM (SEK)	1 479 726	12 707 412	14 187 138

* If possible, provide details otherwise summarize the total sum for external funds and total.

14. Economic result (deficit or surplus):

Luleå University of Technology has 61 746 SEK surplus. RISE PFI and University of Helsinki do not have deficit nor surplus. Currency fluctuations also affect the total sum of the used funding.

Optional: Comments to the economic reporting:

Use of external funds resulted in surplus at LTU. We request to use the remaining 61 746 SEK during year 2019.

I hereby declare that the above statements are true to the best of my knowledge

Signature of the project coordinator

Signature	Institution	Date
	Univ. of Helsinki	27.8.2019

Kirsi Mikkonen

Printed name

Signature of the department head at the department of the project coordinator

Signature	Institution	Date
Marina Hervia	Univ. of Helsinki	27 August, 2019

MARINA HERVIA

Printed name

Second applicant's signature, place and date

Signature	Institution	Date
	Luleå tekniska universitet	26.8.2019

KRISTINA OKSHAN

Printed name

Third applicant's signature, place and date

Signature	Institution	Date
Kristin Syverud	RISE PFI	27/8-2019

KRISTIN SYVERUD

Printed name