Potential of wood fibers and nanoparticles in light-weight foams

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Abstract

To elucidate the potential of various wood derived biomaterials in replacement and improvement of synthetic foams, the effect of wood fibres, nanocellulose and nanoparticle lignin on solid polymer foams prepared from synthetic polymer dispersion was studied. The structure and properties of foams containing wood derived fibres and nanoparticles was determined by microscopy and mechanical testing. The type of wood fibres used as reinforcement was found to affect the mechanical properties as well as pore size distribution and porosity of the solid foam. Both nanocellulose and nanoparticle lignin modified by chemical and/or enzymatic means also contributed to the structure and properties of foam.

Introduction

Currently, there is a high interest in replacing synthetic materials by biomaterials in light-weight products. Porous and foamy products are light and can be applied in various end-uses, such as in foods and packaging, as construction and insulation materials and in printing and coating of paper products. Biopolymers, such as lignin, protein as well as nano- and microscale fibres origin from wood and agrobiomass could offer a potential means to stabilize and reinforce foamy structures when aiming at novel light-weight materials. In this work, the effect of wood fibres with different dimensions and nanoparticle size lignin and nanocellulose on the formation, structure and properties of solid foams was studied. .

Experimental

Materials and Methods

A polymer dispersion based on polyvinyl butyral polymer was used as a basic component in solid model foams. Nanosize lignin dispersion was prepared from spruce by VTT Lignofibre (LGF) cooking process (Mikkonen *et al.*, 2008) using acetic acid as organic solvent. *Trametes hirsuta* laccase (ThL) was prepared and partly purified at VTT according to Poppius-Levlin *et al.* (1999). Fibre materials used for reinforcement of foam structure were thermomechanical pulp (TMP), bleached birch kraft pulp, refined bleached birch kraft pulp, and nanocellulose, all delivered by UPM-Kymmene Oyj. Model polymer foam was prepared by mixing polymer dispersion, lignin and ThL together in pre-determined proportions. In foams purely based on fibrous and nanoscale materials chemically modified pulp and nanocellulose by different ratios were mixed together in order to achieve liquid foam. Foamy structure was produced by mixing materials mechanically together by Dispermat. Foamy mousse formed was kept in freezer for 24 hours, and then displaced into vacuum drier for approximately 72 hours. Compression strenght of the solid model foams was tested by applying ASTM D1621-7 and by using Textura Analyzer. Elasticity of the solid foams was also analyzed with Textura Analyzer. Density was determined from solid model foam samples by using objects of 10×10×10 mm. In stereomicroscopic analysis, colour and surface features of the samples were examined with Zeiss SteREO Discovery.V8 stereomicroscope and imaged using an Olympus DP-25 single chip colour CCD camera and the Cell^P imaging software.

Results and Discussion

The polymer dispersion as such formed a foamy structure, but the air bubbles produced were unstable. When nanosize lignin dispersion was mixed with the polymer dispersion, foaminess of the mixture increased. Polymerisation of lignin by *T. hirsuta* laccase (ThL) addition slightly decreased the foaminess of the structure. Nonetheless, solid foam structure maintained. Various fibers together with model foam produced a more foamy mousse than the model foam mixture as such. Particularly, both nanocellulose (NFC) and thermomechanical pulp (TMP) had an enormous positive effect on solid foam network. Stabilizing effect of nanocellulose can be seen in Figure 1.

a) b)

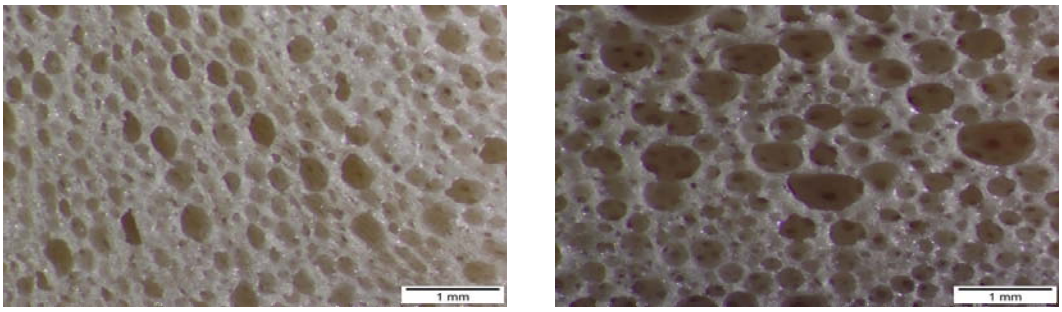

Figure 1. Stereomicroscopy image of foam structure. a) Polymer dispersion + 2 w-% lignin dispersion, b) Polymer dispersion + 2 w-% lignin dispersion + 0.5 w-% NFC + *ThL* (250 nkat/g of lignin) at pH 4.

Hydrophobised pulp and hydrophobised nanocellulose produced stable liquid foam. Foam was formed on top of the water phase, and some phase separation between foam and water phase could be observed. Increasing the amount of NFC, more foam was produced and less phase separation occurred. Addition of lignin dispersion resulted more stable liquid foam structures, and the foaminess increased by increasing the pH of lignin dispersion.

References

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Poppius-Levlin K, Whang W, Tamminen T, Hortling B, Viikari L, Niku-Paavola ML. Effects of laccase/HBT Treatment on pulp and Lignin Structures. J Pulp Pap Sci. 1999:3; 90-94

Acknowledgements

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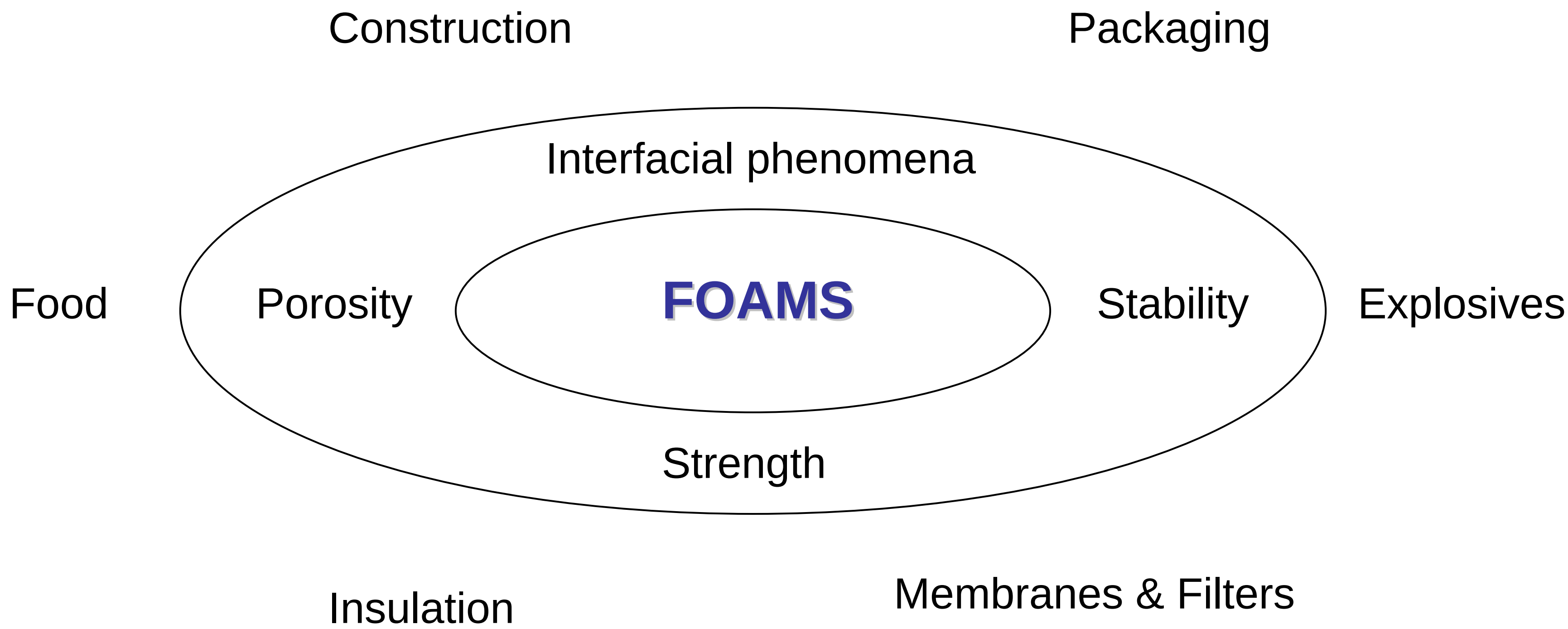
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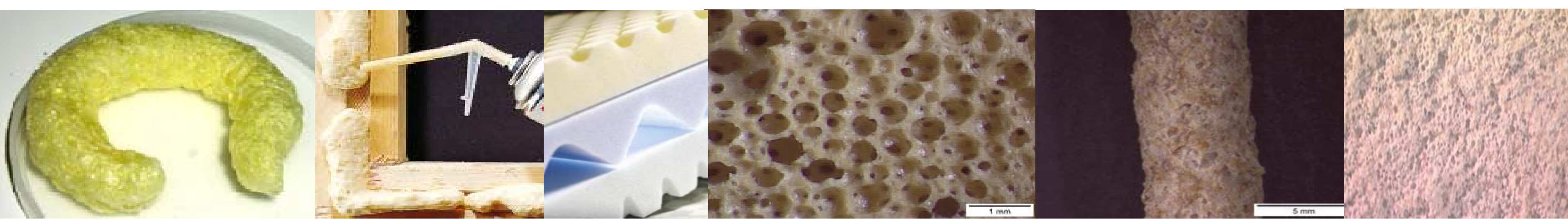
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Contents of the presentation

- Preparation and analysis of fibre-based foams
- Results
- Conclusions & acknowledgements

Aim

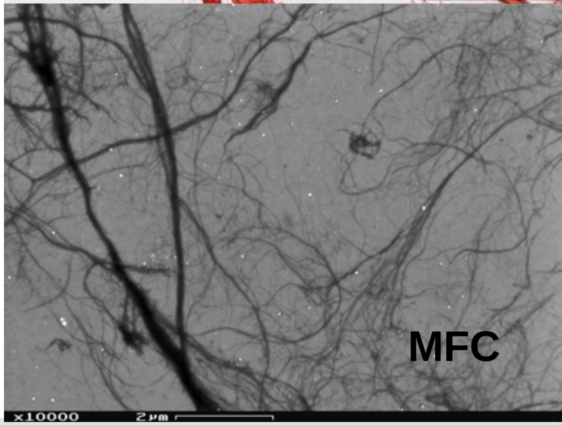
- To produce fibre-based solid model foams
- To study the influence of raw material chemistry and treatment conditions on foaming and material properties

Materials and methods

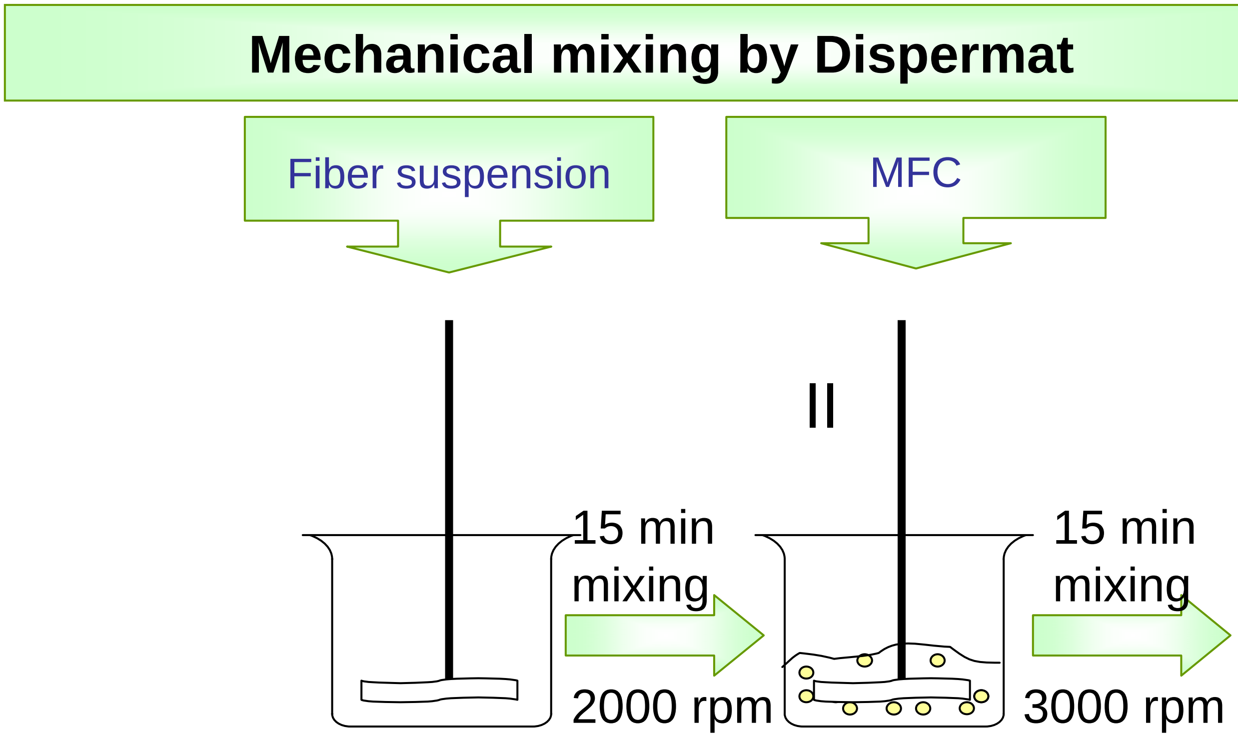
- Bleached birch kraft pulp
  - Native or butylated birch kraft pulp
- MFC
  - Native or butylated MFC

- Fiber:MFC were mixed by Dispermat in ratio 100:1, 10:1 and 2:1

- Mechanical material properties *i.e. density and compression strength* analysed

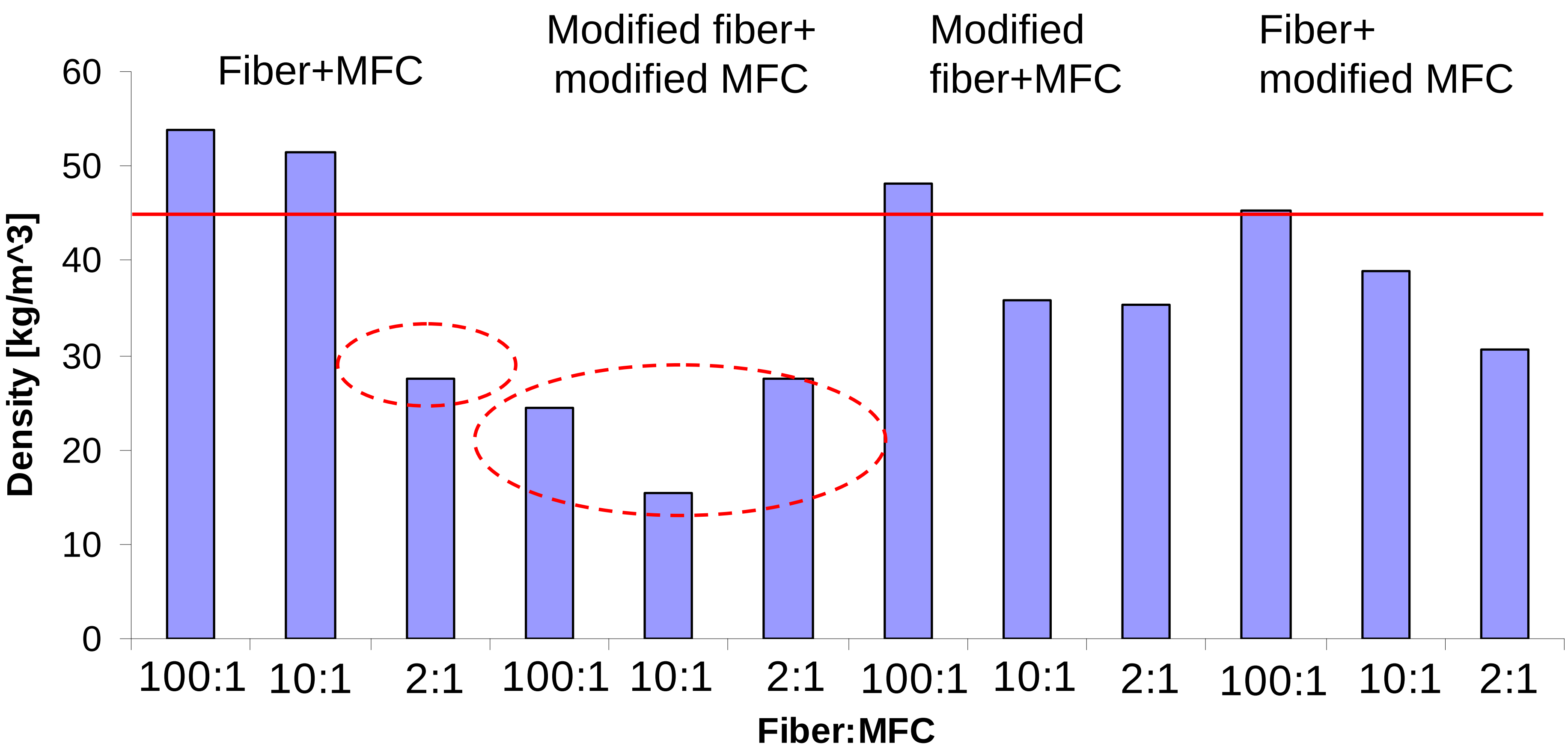


Foam processing method of the fiber based solid model foams

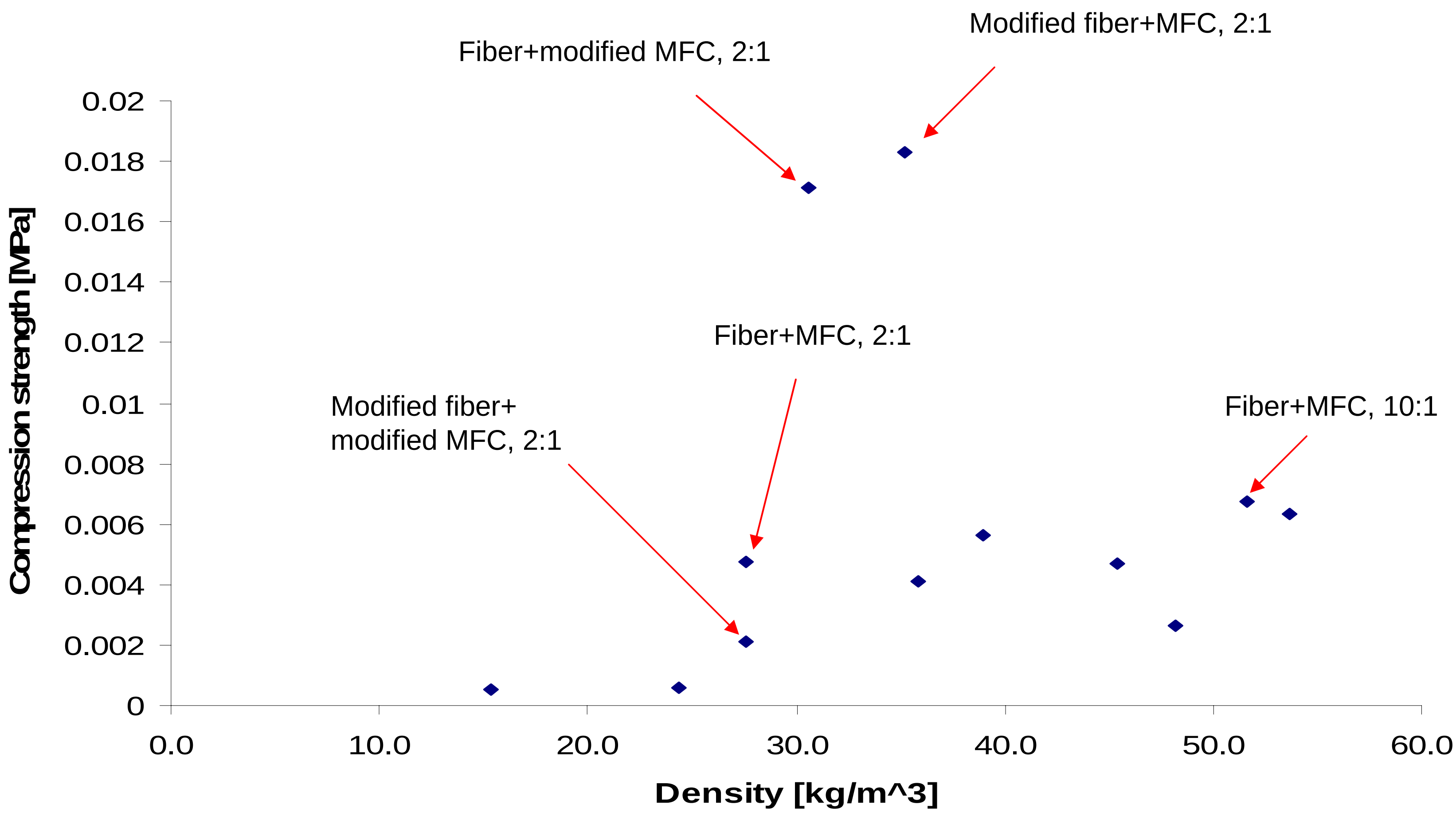


Freeze drying

Fiber based foams with MFC
Density



Fiber based foams with MFC
Compression strength as a function of density



Conclusions

- In fiber-based model foams increase in MFC resulted in more stable foam structure
- Most foamy structures were achieved with modified fiber + modified MFC –combination
- No clear correlation between foam density and compression strength was observed

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Thank you

PRESENTED BY

Anne Savolainen

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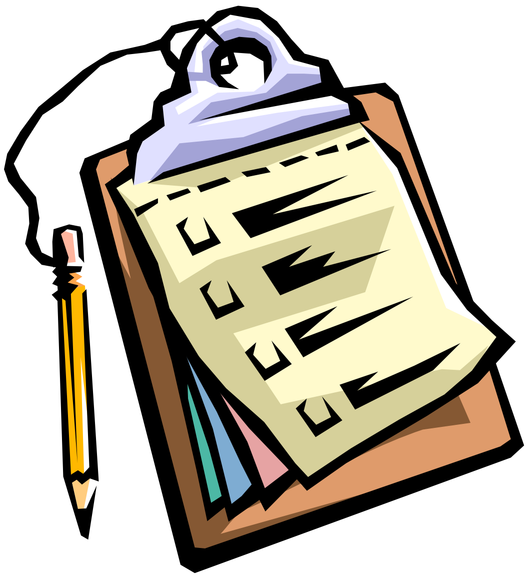

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