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Production of microfibrillated cellulose for fiber-based packaging applications using stirred media mills

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FiberLean
Strength by Design

FiberLean Introduction

Leading independent supplier of MFC production equipment

- Stirred Media Mills (SMMs) – **FiberLean MFC Grinders**.
- Experienced project implementation and engineering team.
- Expertise and experience in MFC production.
- Industrial scale demo plant and pilot plant, operating since 2014.
- Trials **worldwide**.
- Process development and application support to customers.

Contents

- Why use MFC in packaging?
- MFC production and optimization using Stirred Media Mills (SMMs).
- Coarse but highly fibrillated MFC networks from SMMs.
- Effective MFC from a wide range of pulps by changing conditions.
- Tensile and bonding performance.
- Comparative performance of SMM MFC v other MFC.
- Regulatory clearance, end-of-life and ESG for SMM MFC.
- Conclusions.

Why use MFC in packaging?

In-furnish application

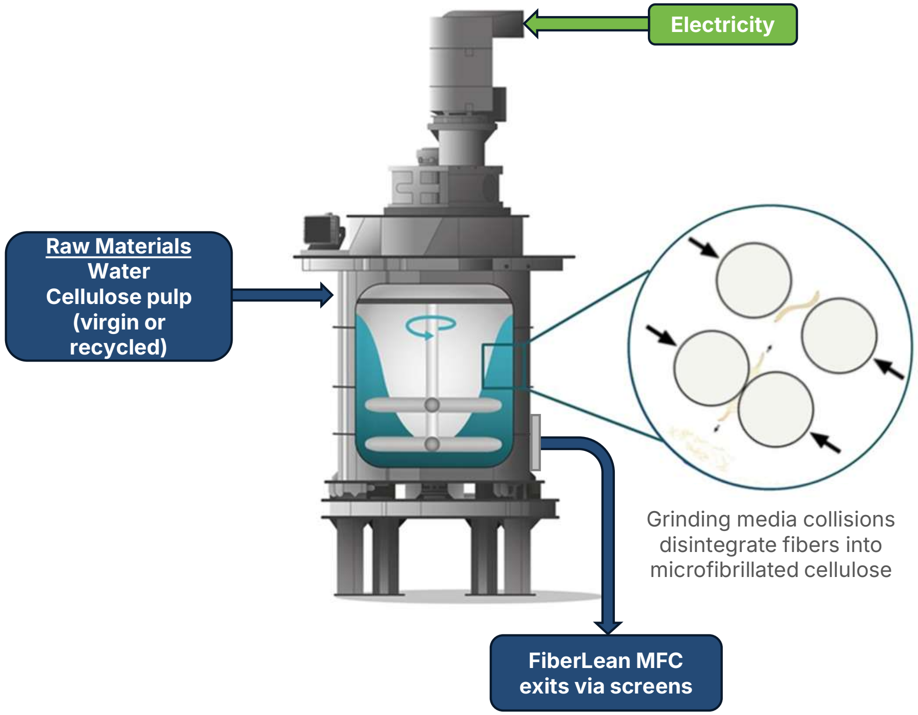
- **Folding box board** – chemical pulp reduction in outer layers. Potential savings $25-$35/ ton paper.
- **White top liner** – fiber reduction, improved optical properties from formation improvement and filler increase. Potential savings $26-$36/ ton paper.
- **3D Moulded Objects** – fiber reduction by light-weighting, improved formation, reduced porosity, much improved appearance. Potential ~30% weight reduction.
- **Tissue** – fiber reduction by light-weighting. Potential savings $30-$40/ ton paper.
- **Specialty papers** – various (eg low porosity improves coating holdout; significant increases in wet web strength enables low GSM papers on machines configured for much higher GSM).

Surface application

- **White liner** - Upgrade brown boxboard to WTL with minimal capex.
- **Barriers** – MFC can form a layer which greatly improves oil and grease resistance and oxygen barrier properties for food packaging. MFC can also form a suitably smooth surface for water barrier application.

FiberLean MFC Grinders

(Vertical Wet) Stirred Media Mills: 1



How it works

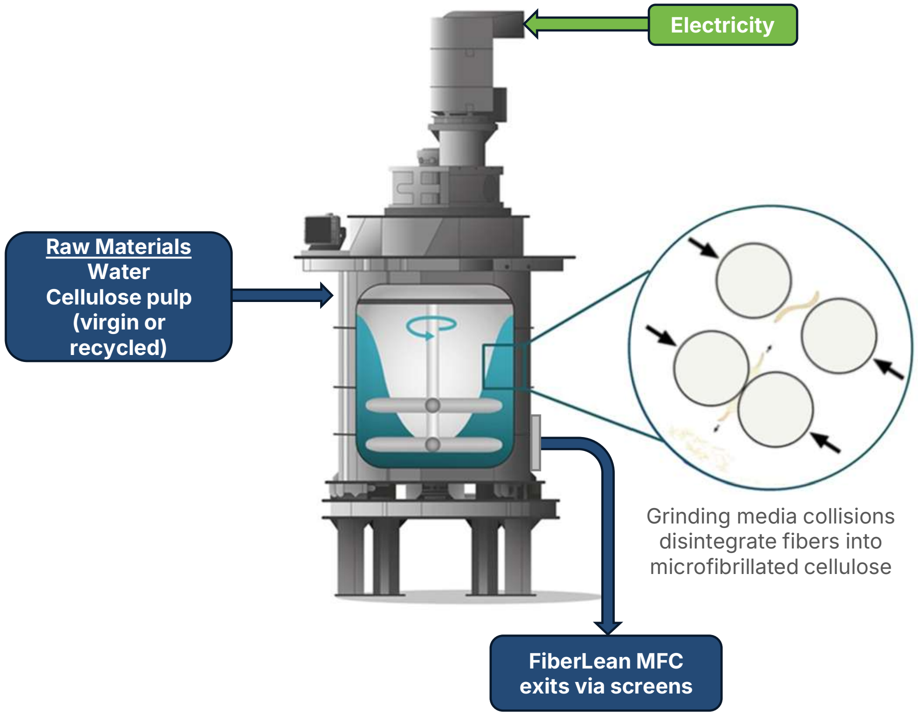
- Stirred vessel, charged with water, pulp and ceramic grinding media.
- Widely used in minerals and mining industry, adapted by FiberLean to fibrillate fibers into MFC.
- Fibrillation occurs when pulp gets trapped between colliding grinding media particles.
- Grinding media are the 'working surfaces' for fibrillation; very high active surface area; permits high throughput and efficient production of MFC.
- Continuous, single pass operation.

FiberLean MFC Grinders

(Vertical Wet) Stirred Media Mill Grinders: 2

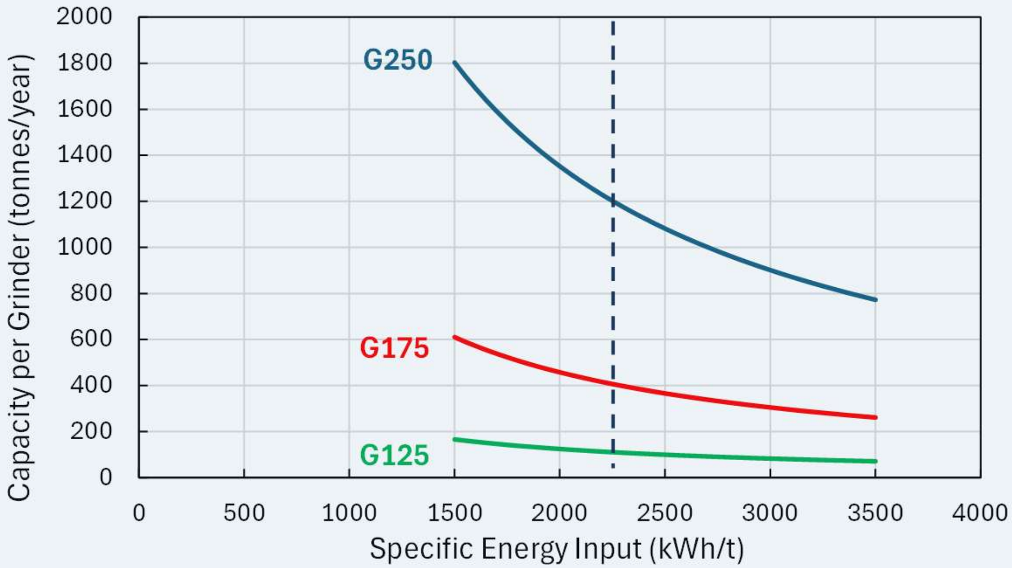
How it works

- Pulp suspension is added continuously to top of mill.
- Product exits continuously through screens near bottom of mill.
- Energy input is controlled with outlet flow rate and motor power.
- Robust, reliable, simple, cost-effective, energy efficient design.
- Mechanical, additive-free process.
- Production solids ~ 1-2% - on-site production.



Large-scale SMM in Operation

SMM sizing

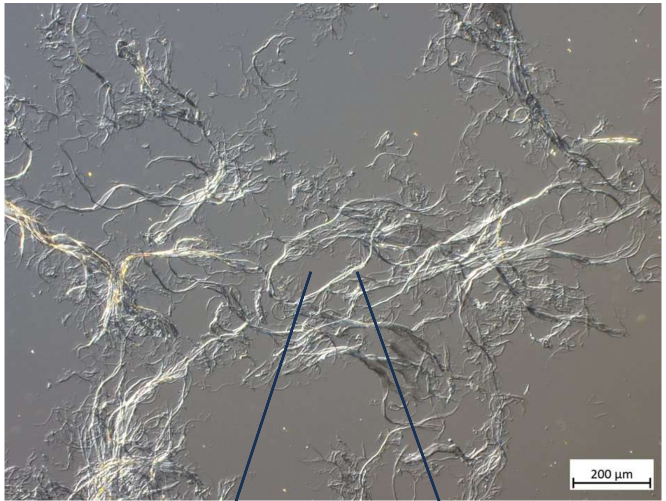


Model	Capacity (dry tonnes of MFC per year)	Typical use
G125	100	Moulded fiber producers
G175	400	Tissue mills, small paper mills
G250	1200	Medium to large paper and board mills

Morphology of SMM Produced MFC: Coarse but highly fibrillated

- SMM-produced MFC is best described as '**surface-nanostructured macromaterial**'.
- Micrometre and nanometre scale fibrillar surface structure on a sub-millimetre scale macrostructure.
- **Fine** and long **micro and nano fibrils** in the **nanostructure** enhance **bonding** at fiber-fiber joints and with filler particles.
- A **coarse macrostructure** improves **bridging** between fibers and **improves MFC retention**.
- The objective is usually to efficiently generate a **high level of microfibrillation whilst retaining coarse macrostructure**.

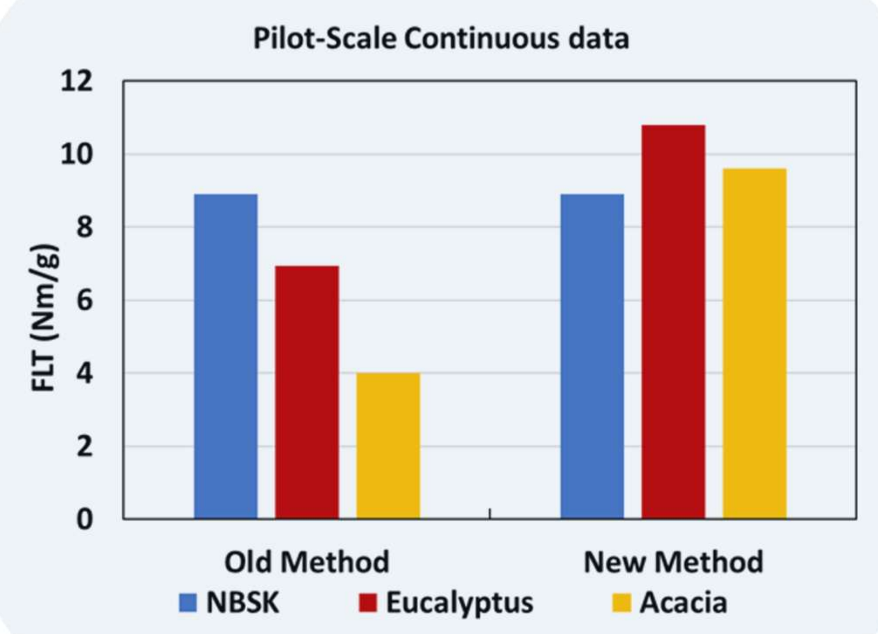
Optical micrograph showing MFC **coarse macrostructure**.



SEM showing MFC fibrillar **micro and nano structure**.

SMM optimisation

- Effective MFC production requires **high levels of micro** and **nano fibrillation** whilst retaining **long fibrils** and **coarse macrostructure.**
- SMMs have the key advantage that the ***strength of forces can be varied by many orders of magnitude with little to no equipment modification***.
  - Machine parameters – specific energy input, impeller speed, media fill fraction, impeller geometry.
  - Grinding media parameters – density, elasticity, size, shape, surface roughness.
  - Feedstock parameters – fibre dimensions, fibre strength, fibre chemistry (hemicellulose, lignin), solids content.

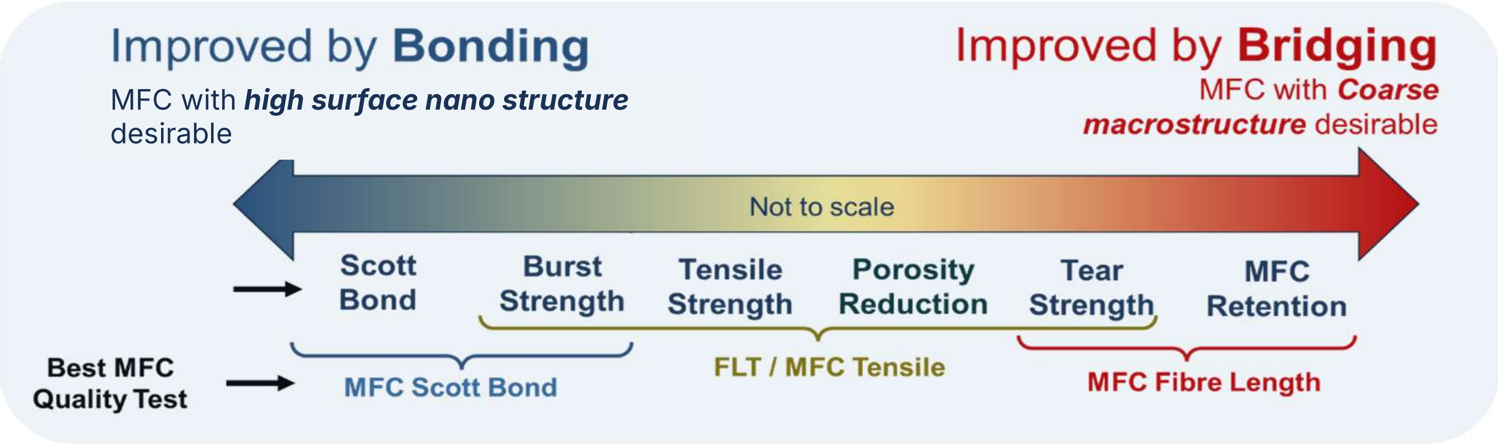


High quality MFC can be produced from a wide range of feed fibres.

Effect of Morphology:

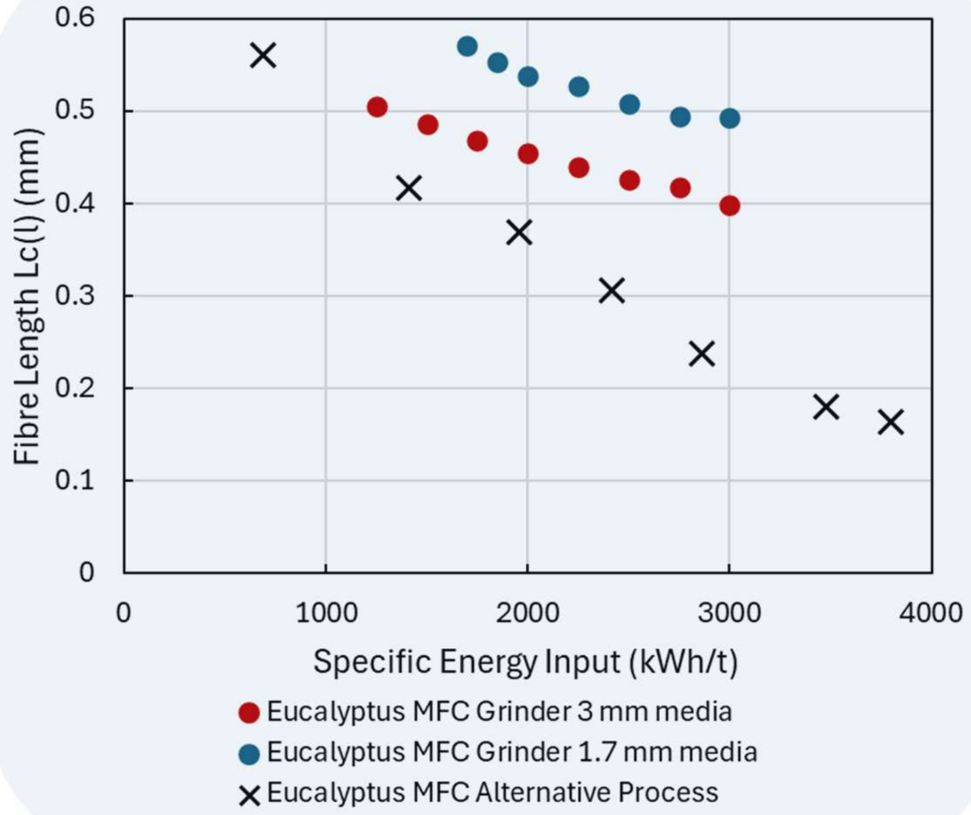
Bonding vs. Bridging

- **Bonding**: strength of bonding at particular fiber-fiber joints. Related to **MFC nanostructure**.
- **Bridging**: ability of MFC particles to overlap multiple fibers in a sheet. **Related to MFC macrostructure**.
- Different paper properties have different dependencies depending on the nature of the failure mechanisms.
- Improvements in bonding and bridging are not **necessarily mutually exclusive**. One can optimise for both by having a **high degree of fibrillation and a coarse macrostructure**.



SMM MFC 'Size' vs. Alternative MFC

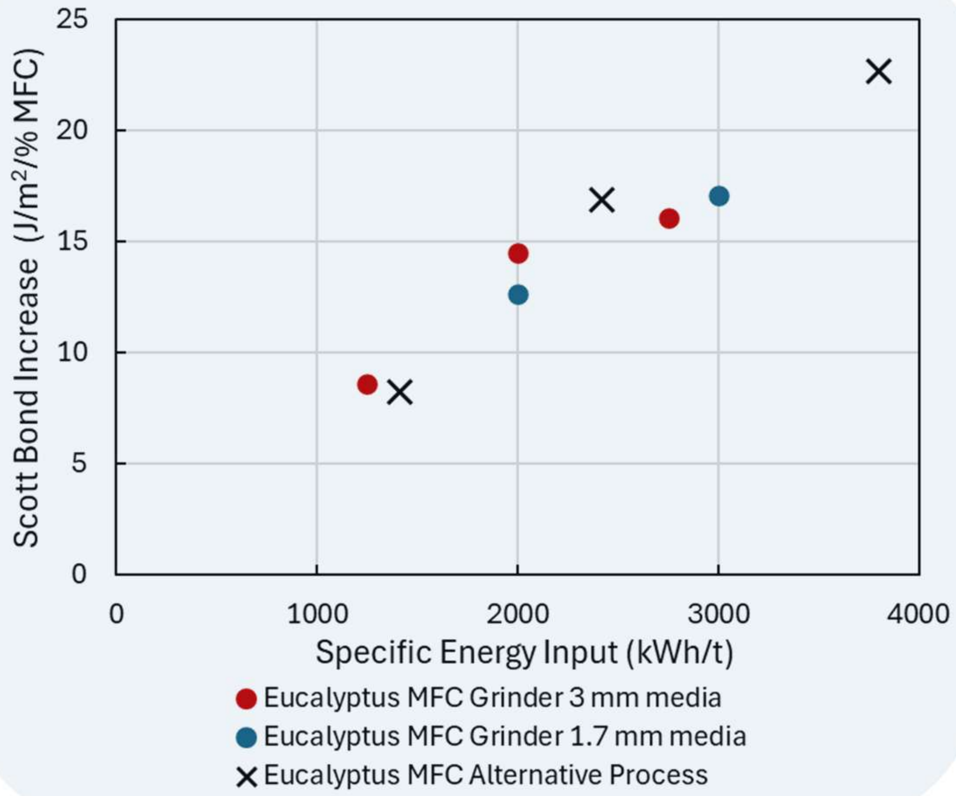
- **SMM MFC** optimised for general improvements in paper properties **retains a coarse macrostructure whilst comprising fine and high quality microfibrils**.
- Shown is a comparison of fiber lengths of such grinder products versus an alternative MFC production method.
- **The alternative method has higher fiber breakage / size reduction**.



Performance of MFC in Paper:

Scott Bond

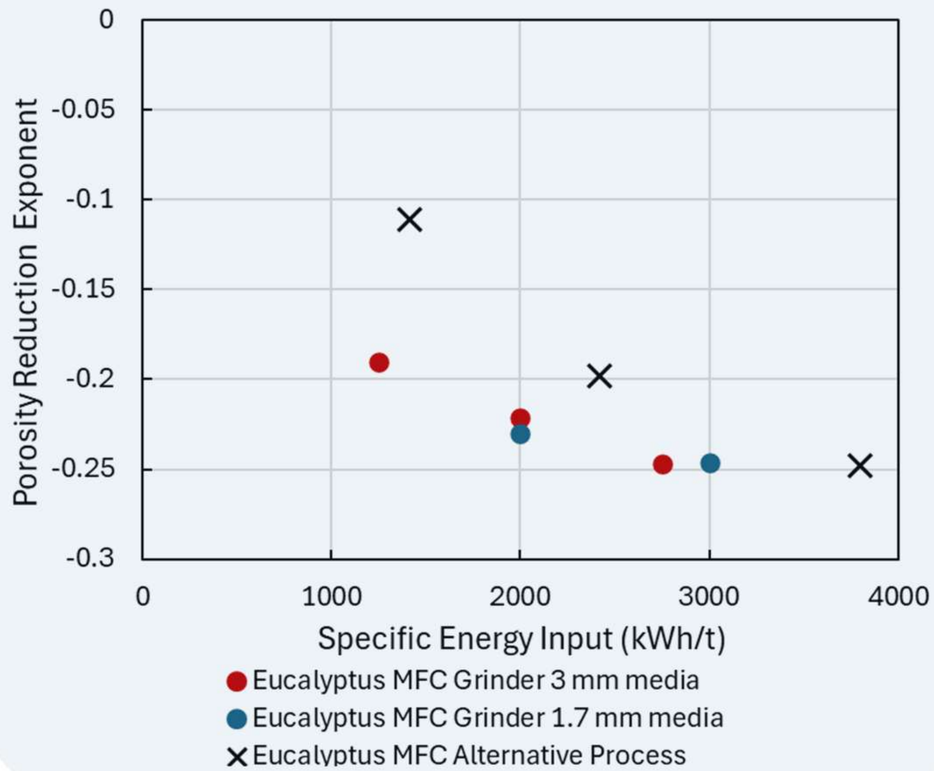
- Small amount of MFC added to paper furnish in handsheet study.
- Scott Bond is relatively pure measurement of bonding (i.e. nanostructure).
- Not strongly affected by bridging (i.e. insensitive to macrostructure).
- In this example, SMM MFC and alternative method **are equivalently efficient at generating bonding-capable nanostructure**.



Performance of MFC in Paper:

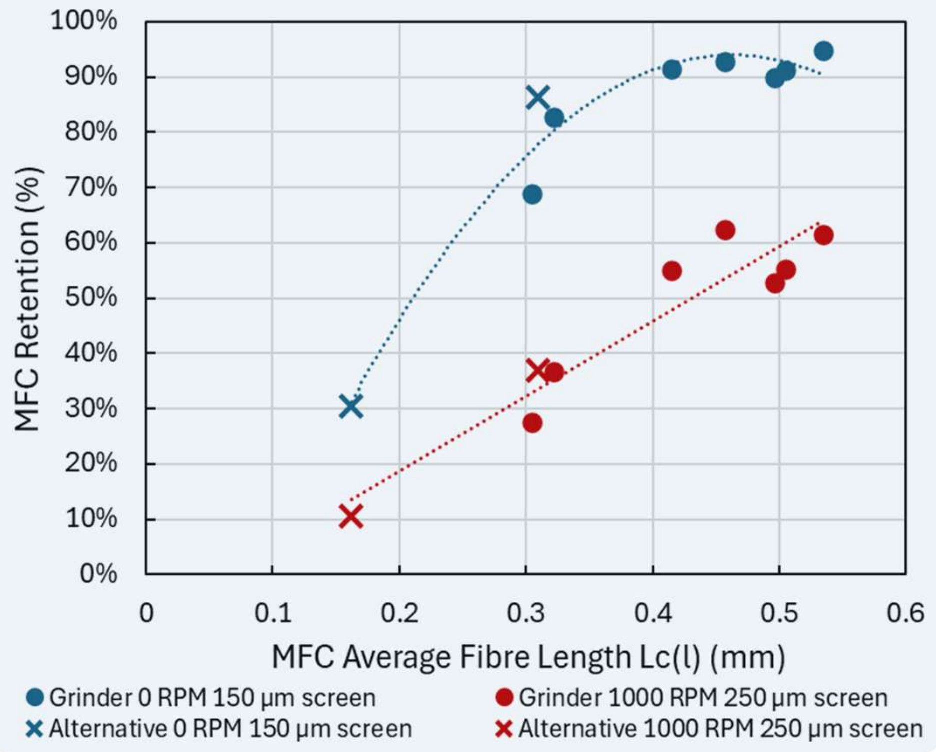
Porosity

- **Sheet porosity is sensitive to the bridging ability of MFC to close up pores in the sheet**.
- Porosity shows an exponential decay relationship with MFC addition. Graph plots the value of the exponent. **More negative value mean more efficient porosity reduction**.
- By maintaining a coarse macrostructure, **SMM MFC is more efficient at reducing porosity** than the alternative method, despite similar bonding ability.



MFC Retention

- **A major benefit of maintaining coarse macrostructure is improvement in MFC retention.**
- In these experiments, self-retention of MFC was measured in a Britt jar (agitated vessel with a screen bottom) at equivalent concentration to 4% MFC addition to a paper furnish.
- Two conditions shown:
  - 150 µm screen, no agitation (best case)
  - 250 µm screen, 1000 rpm agitation (worst case)
- No furnish present, and no retention chemicals, so **MFC retention values presented are minimum values in practice.**
- Unsurprisingly, coarser MFC retains better.
- WSMM MFC and alternative route MFC follow the same curve.



SMM-produced MFC:

Regulatory, End-of-life, ESG

BfR, FDA, ANVISA, Canadian and **Chinese food contact paper clearance**.

FDA FCN 002413, BfR Recommendations XXXVI, XXXVI/1, XXXVI/2 & XXXVI/3.

Not a nano-material according to US EPA and EU definitions*.

No negative health effects found.

- Dietary Study
- Physical, chemical, and toxicological characterisation
- Inhalation risk analysis

MFC not a final product but we have carried out the following testing to confirm MFC has no negative impact on end of life:

- **Recyclable** – PTS-RH 021:2012 – bleached and unbleached MFC coated papers passed.
- **Biodegradable** – OECD 301B – MFC suspensions with and without biocide were biodegradable.
- **Compostable** – ISO 14855 – bleached and unbleached MFC coated papers were biodegradable under industrial composting conditions.

Allows lighter products, reducing transport related emissions.

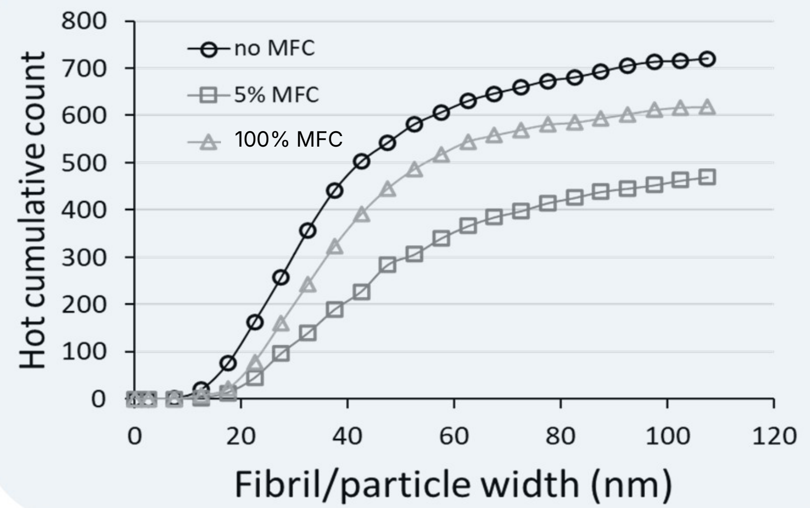
Supports recyclability and circular economy by enabling plastic replacement in packaging.

*Daniel Hewson, Kathryn Gee, Lenka Koptasikova, Christian Hacker, David Skuse, 2024. EU nano or not nano: An unbiased approach to classifying FiberLean microfibrillated cellulose. Cellulose, 31, pp.5987-5996.
https://doi.org/10.1007/s10570-024-05980-z

Food contact clearances: Migration studies

- Demonstration of lack of migration from food packaging sheets is critical for food contact clearance.
- A quantitative SEM technique was developed to analyse migrated MFC after standard migration tests.

(An Unbiased Approach to Quantitative Analysis of Migrated material from Microfibrillated Cellulose based Food Packaging Using Scanning Electron Microscopy, D. J. Hewson, J. S. Phipps, J. A. Shatkin and D. R. Skuse, submitted for publication)



Conclusions

- Fewer counts from sheets made with MFC than from sheets made with standard furnish.
- 16-83% less migration from cold water tested samples.
- 14-58% less from hot water migration samples.
- 29-75% less from dry abrasion tested samples.
- ***SMM MFC may have a role to play where limiting migration is key***.

Conclusions

- Stirred media grinders are an efficient, high throughput, well established method for producing MFC.
- High quality MFC can be produced from a wide range of feed fibres with little to no equipment modification.
- The resultant MFC has:
  - High levels of surface micro and nano fibrillation whilst maintaining a coarse macrostructure.
  - Broad food contact clearance, is not a nano-material according to US EPA and EU definitions and no observed negative health effects.
  - Recyclable, biodegradable and compostable.
- Use of MFC from stirred media grinders allows lighter products, reducing transport related emissions and supports recyclability and the circular economy by enabling plastic replacement in packaging.
- Use of MFC in paper and board leads to enhanced mechanical properties and reduced porosity sheets and, hence, offers opportunities for considerable cost savings in many specialty paper and board segments.

Thank you for your attention

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