

# **Producing Microfibrillated Cellulose using a Stirred Media Mill Grinder**

**Lewis Taylor, Chris Bonds, David Skuse**

**FiberLean Technologies**

Presented by: Lewis Taylor



# Outline

- Introduction
- Applications of MFC
- Stirred media mills
- Product characterisation
- Influence on particle size and fibrillation
- Optimisation for various fibre substrates



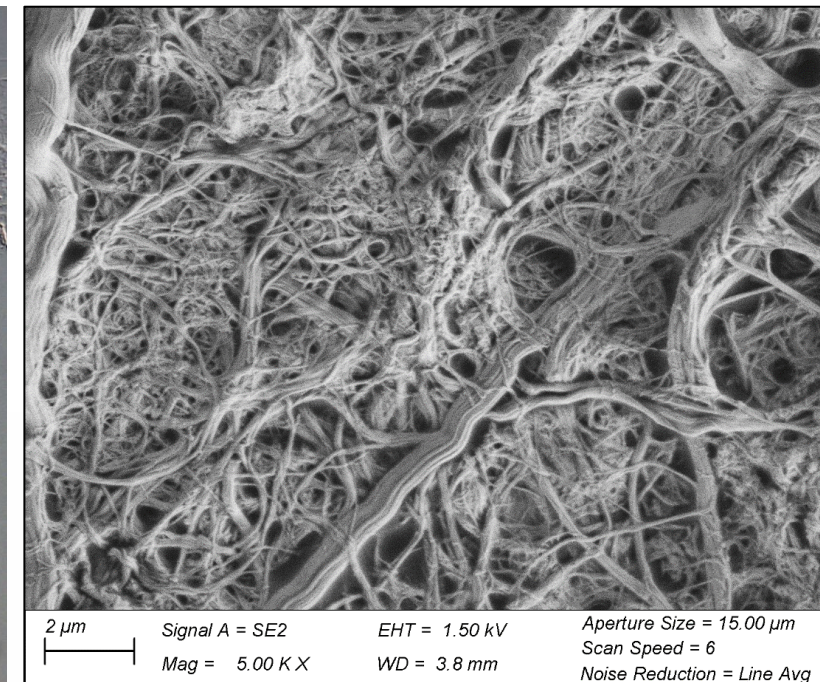
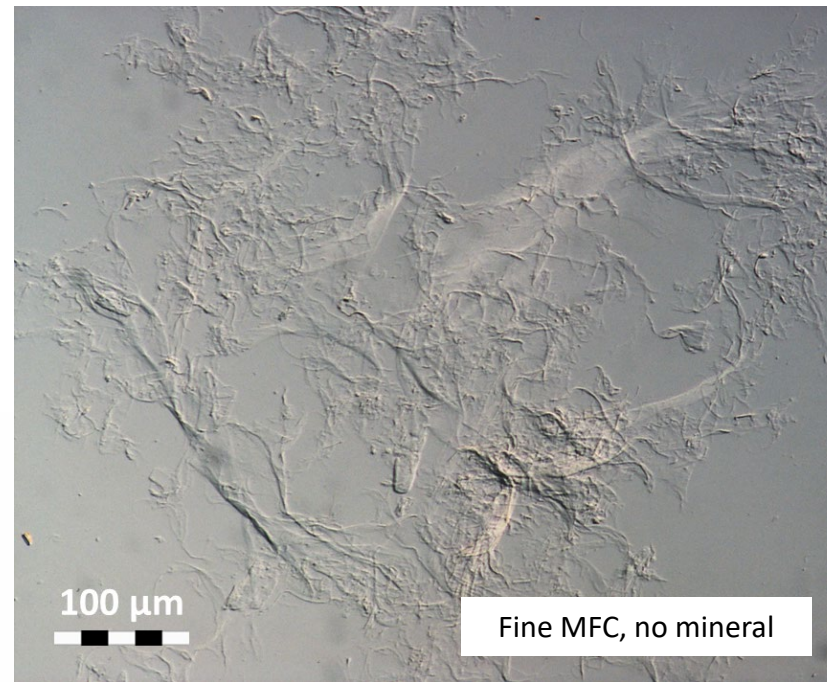
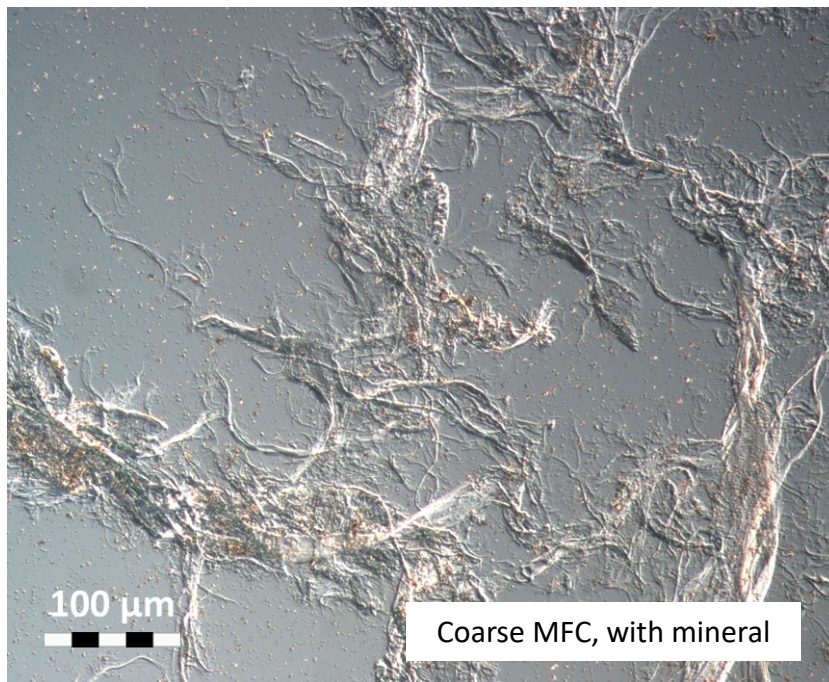


# Introduction

- **MFC** – produced by **mechanical treatment** of cellulose
- Highly viscous aqueous suspension
- Typically **satellite production** adjacent to final use location
- **Continuously produced at large scale using stirred media mills**
- **Flexible process enables a wide variety of product characteristics**

## Product families

- **MFC from 100% virgin pulp**
- **MFC from recycled fibres**
- **MFC mineral composites**
- **NB Two of these families have no added minerals. MFC only**





# Pilot-Plant Production Facility, and Product Forms

## Slurry



Production plant in the UK, **2000 dry metric tonnes pa of fibril capacity**. Operational since Q4 2013: **Slurry** (< 2% fibre solids) and **press-cake** (10 – 20% fibre solids) product forms

## Press cake



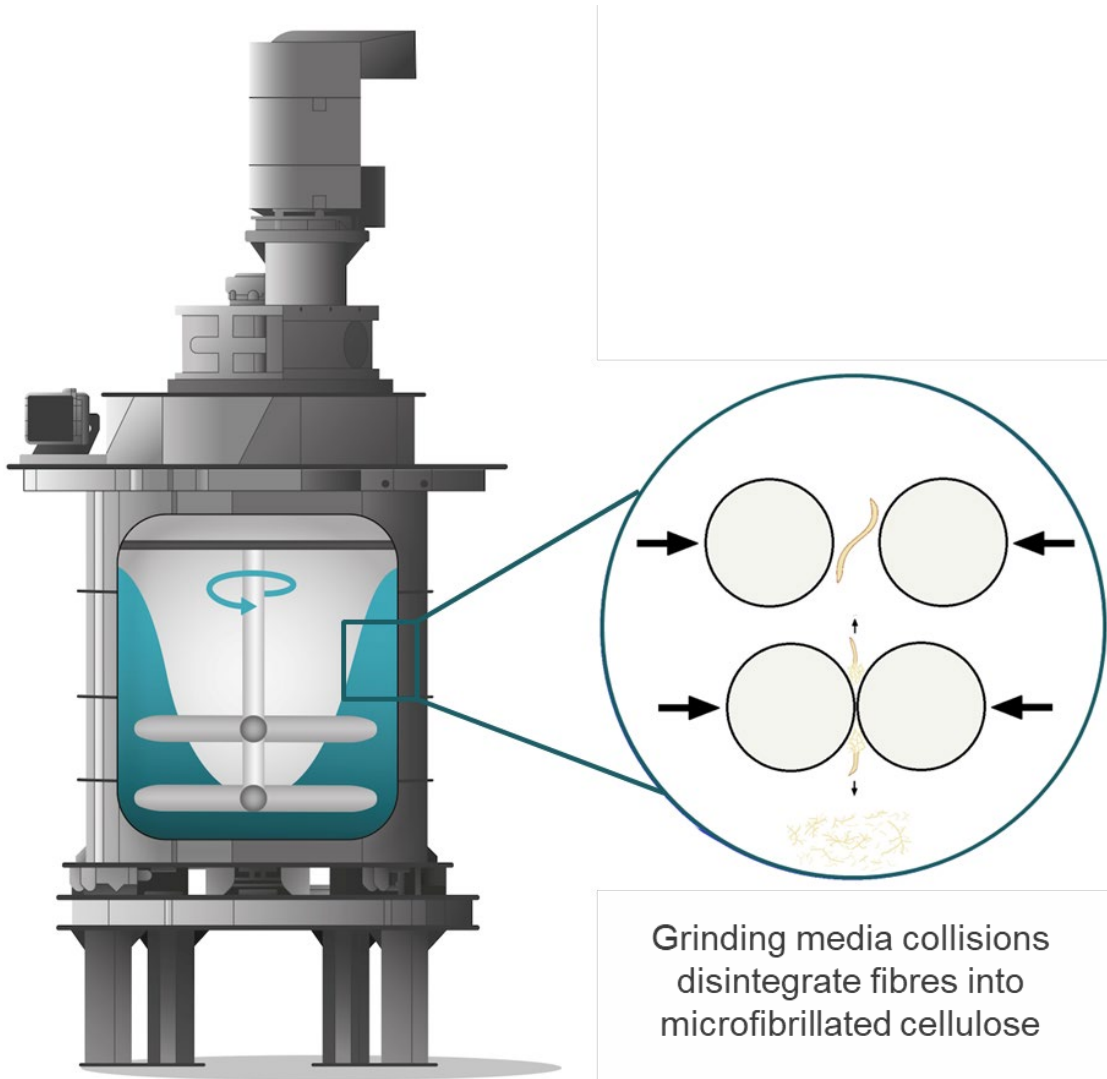
# MFC Applications

**The strengthening and viscosifying properties of MFC have shown benefits in applications such as:**

- **Paper and board** – generally improved mechanical properties, increased filler, softwood replacement, lightweighting, new products and grade development.
- **White top liner:**
  - Improved optical properties from formation and filler increase, significant reduction in fibre use.
  - Wet-end coating of MFC to upgrade brown boxboard to WTL with minimal capex.
- **Barriers** – MFC forms a barrier layer which greatly improves oil and grease resistance and oxygen barrier properties for food packaging, is a recyclable and compostable alternative to PFAS.
- **Specialty papers** – various (e.g. low porosity improves coating holdout in thermal papers; significant increases in wet web strength enables low GSM papers on machines configured for much higher GSM).
- **Construction materials** – binders in furniture (MDF, particle boards, substitutes), ceiling tiles.
- **Agriculture** – in fruit coatings to delay ripening and increase shelf life / reduce food waste.
- **Rheological additives** – highly shear-thinning, robust to pH / salt / degradation.



# Stirred Media Mills – Introduction



Grinding media collisions disintegrate fibres into microfibrillated cellulose

- **Stirred vessel**, where **collisions between grinding media beads** break intervening particles.
- Widely used in minerals and mining industry due to efficiency, scale, and flexibility.
- We have adapted this technology to **break and fibrillate fibres into MFC**; requires modifying theory and operating principles.
- **Very high active surface area** of media and **inherent scalability of stirred vessels** permits **high throughput** and **continuous production** of MFC.





# Stirred Media Mills – Advantages

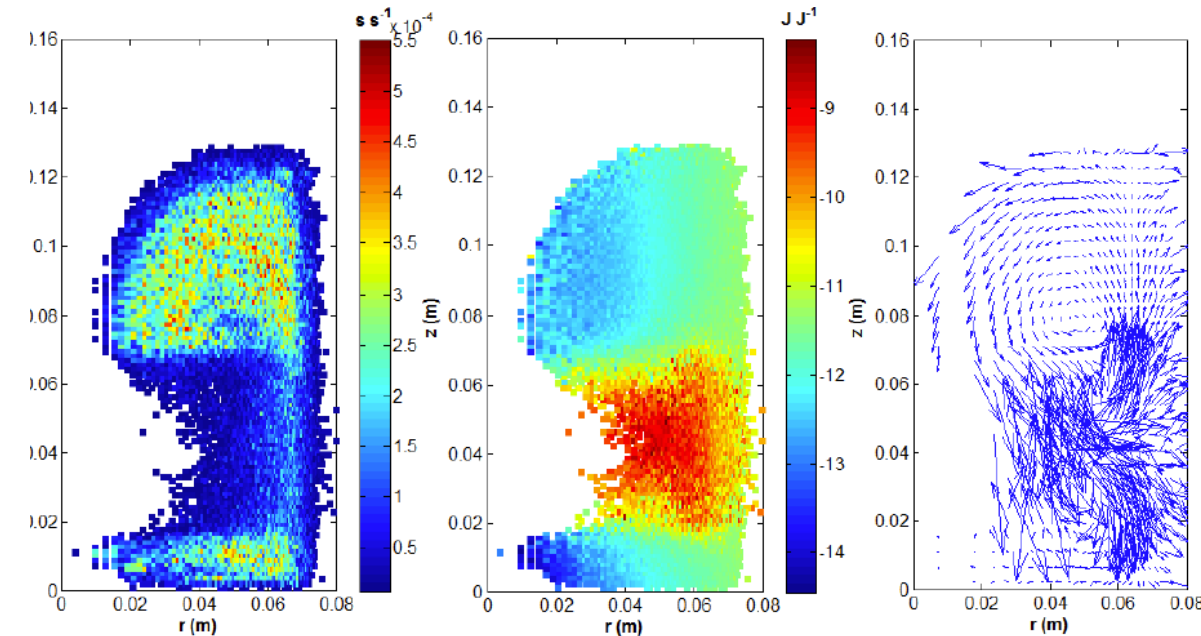
For large-scale MFC production, stirred mills confer many benefits:

- Robust technology, operational since 1950s for minerals processing, since 2013 for MFC
- No close tolerances or precision engineered components
- Continuous single stage process
- Availability > 95%
- Low capital and running costs
- High throughput in a small footprint (typically >1000 dry tonnes / annum per grinder)
- Modular easily-scalable design
- No additives or pre-treatments
- Flexibility in tailoring MFC properties



# Stirred Media Mills – Optimisation

- Unlike minerals processing, where minimising particle size is usually the goal, effective MFC production requires **high surface area generation whilst maintaining fibril aspect ratios**.
- Stirred mills are **conceptually simple**, though **optimising is complex** due to the number of parameters (charge formulation, grinding media properties, machine operation parameters, grinder geometry); a purely empirical approach is not sensible.
- Effective optimisation requires the following:
  1. An **intimate understanding of the feed fibre properties** (i.e. what forces are required for breakage and fibrillation).
  2. Tailoring the **type, frequency and magnitude, of forces** applied by the media to the fibres.
  3. Modifying the energy distribution within the vessel by **controlling flow patterns**.
- Stirred mills have the key advantage that the **strength of forces can be varied by many orders of magnitude with little to no equipment modifications**.



**PEPT tracking of a lab-scale grinder – (left) occupancy, (middle) kinetic energy distribution, (right) velocity vectors.**



# Product Characterisation

- **Particle size and morphology analysis** - Microscopy, fibre analysers, laser diffraction
- **Viscosity / rheology** - Over a range of shear conditions
- **Permeability and drainage**
- **In-application testing**
- **Mechanical properties** – “FLT” – (FiberLean Tensile) strength test (hereafter referred to as *high loading tensile index*) - Good correlation with in-application mechanical properties.

**Particle size alone is not sufficient to characterise MFC performance.**

**A test of performance is also required**

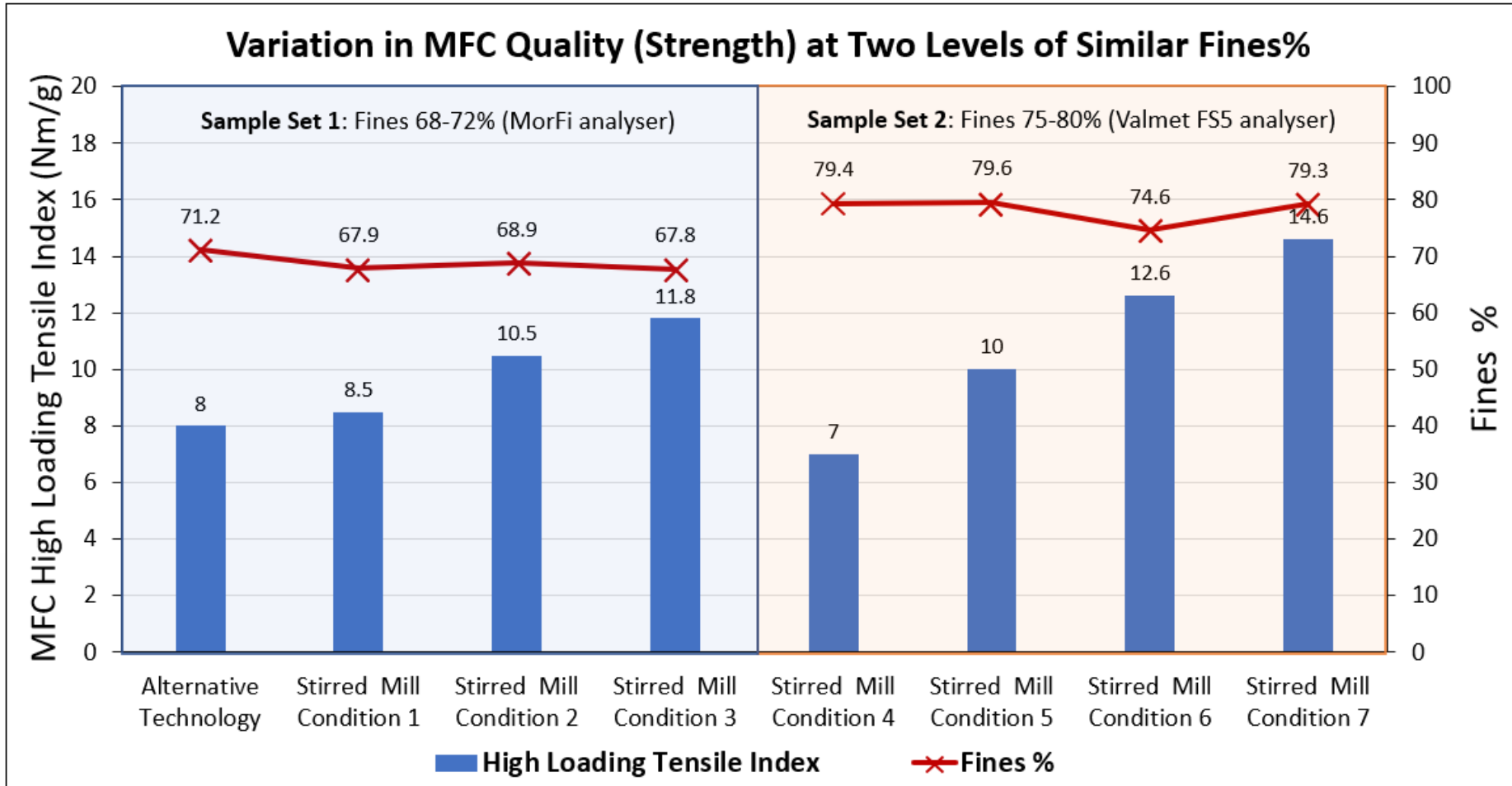


# High Loading Tensile Index

- Since **particle size alone** (e.g. laser diffraction  $d_{50}$ , Fines%) **says nothing about the extent of fibrillation or quality of fibrils**, we instead use such measurements largely to aid understanding of the process, and for process control and diagnostics.
- Many MFC applications rely on the **bonding ability of the MFC**; measuring a proxy for this can be expected to correlate more generally with performance.
- The high loading tensile index test does this using a direct measurement of the **tensile strength of an MFC - mineral film**.
  - A sheet of 100% MFC will be so heavily bonded that the sheet will largely fail by breakage of fibril cross-sections (i.e. zero-span strength) rather than bonding failure.
  - Therefore, the **high loading tensile index test is performed at extreme mineral loadings** (many times more mineral than fibre) to greatly weaken sheet bonding, thereby **forcing bonding failure** to be the dominant failure mechanism.
- Such a measurement gives a **good general correlation with performance** in many applications, that is largely **robust to changes in pulp type and processing conditions**.

# Fibre Breakage and Fibrillation (i)

- Using a stirred media mill, parameters can be changed to **decouple fibre breakage from fibrillation**, and control them independently based upon application requirements.

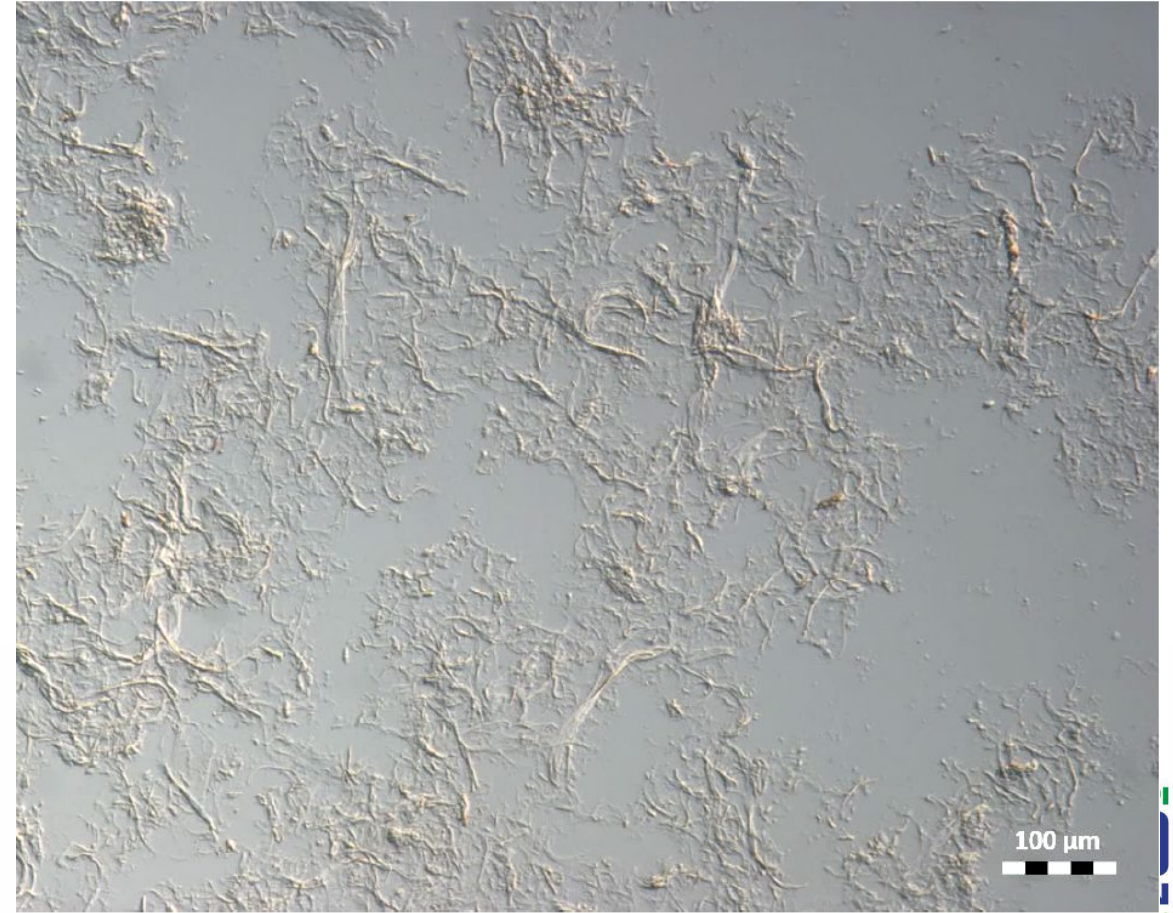
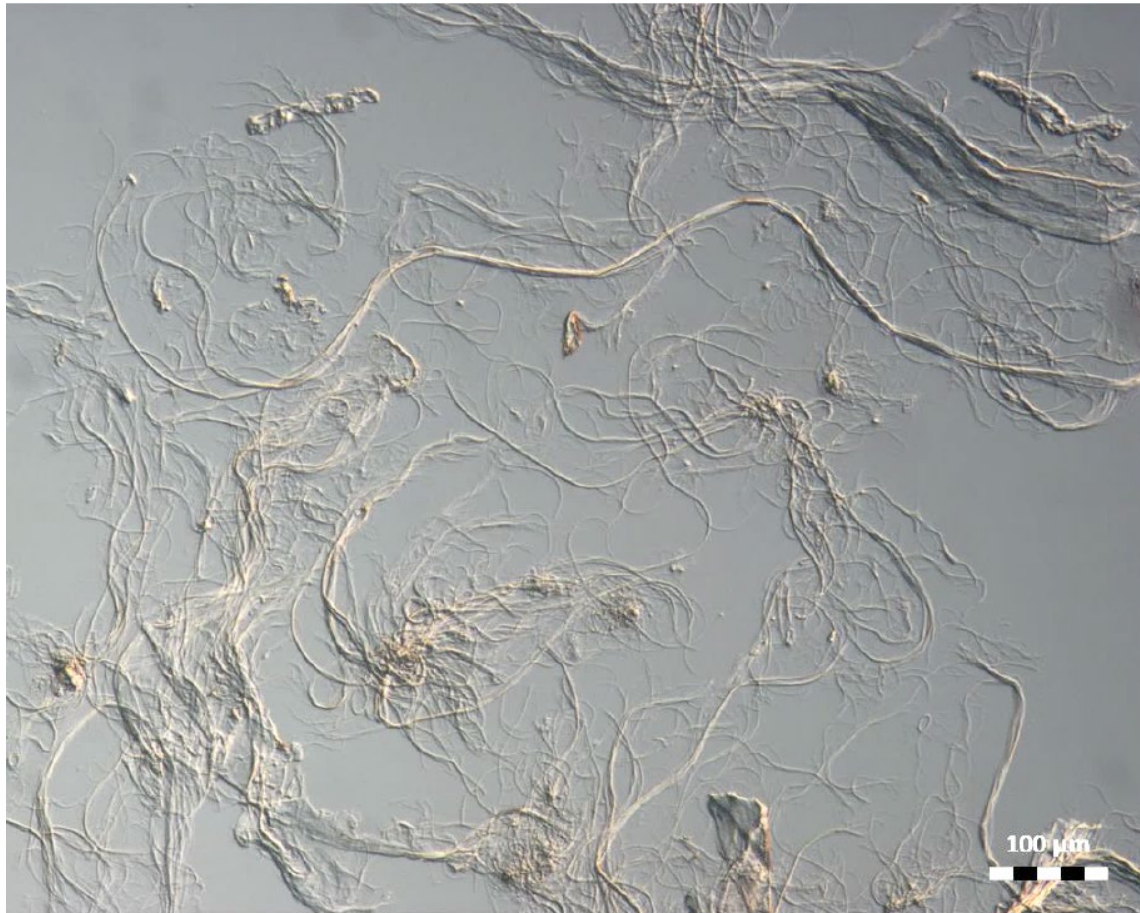




# Fibre Breakage and Fibrillation (ii)

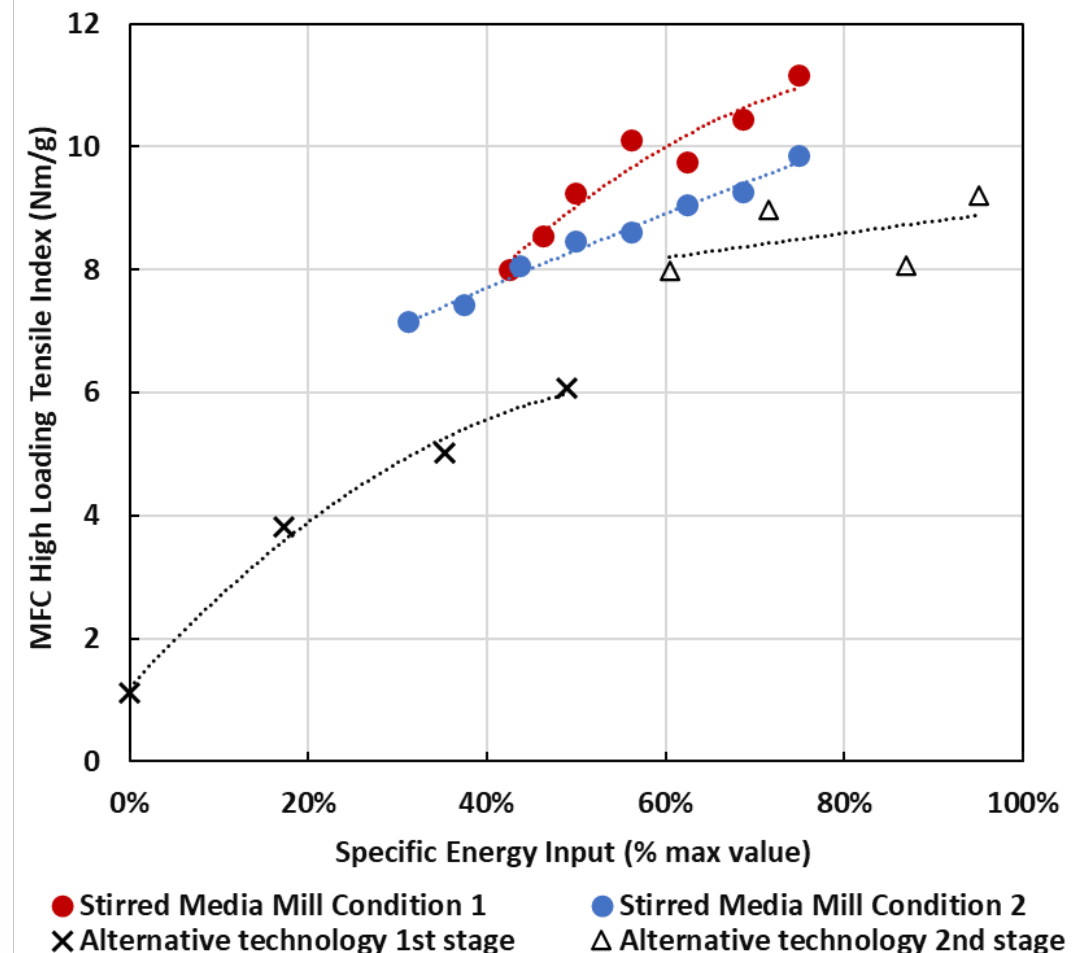
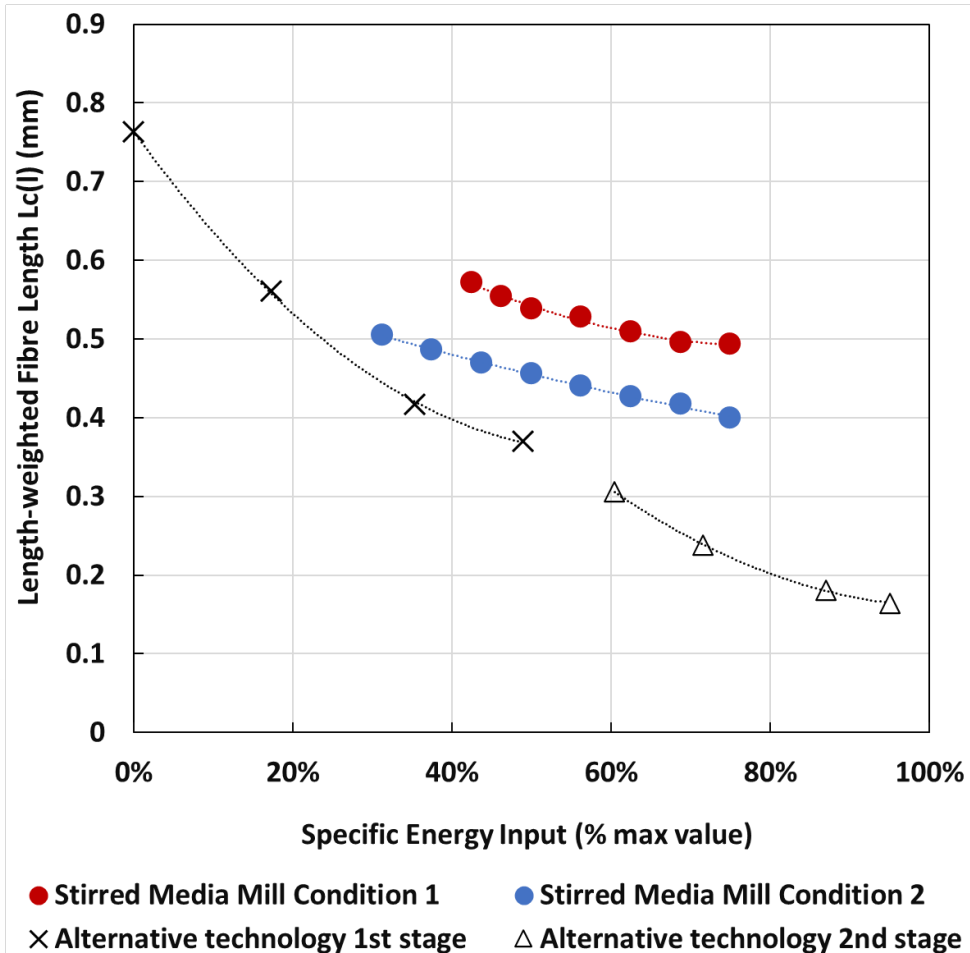
**Very different product morphology possible with the same feedstock.**

- Below have very different particle sizes, but similar high loading tensile index (bonding) values.



# Performance / Energy Balance

Stirred media mills are economical at generating a highly fibrillated product compared to alternative technology, though tends to maintain larger particle dimensions.

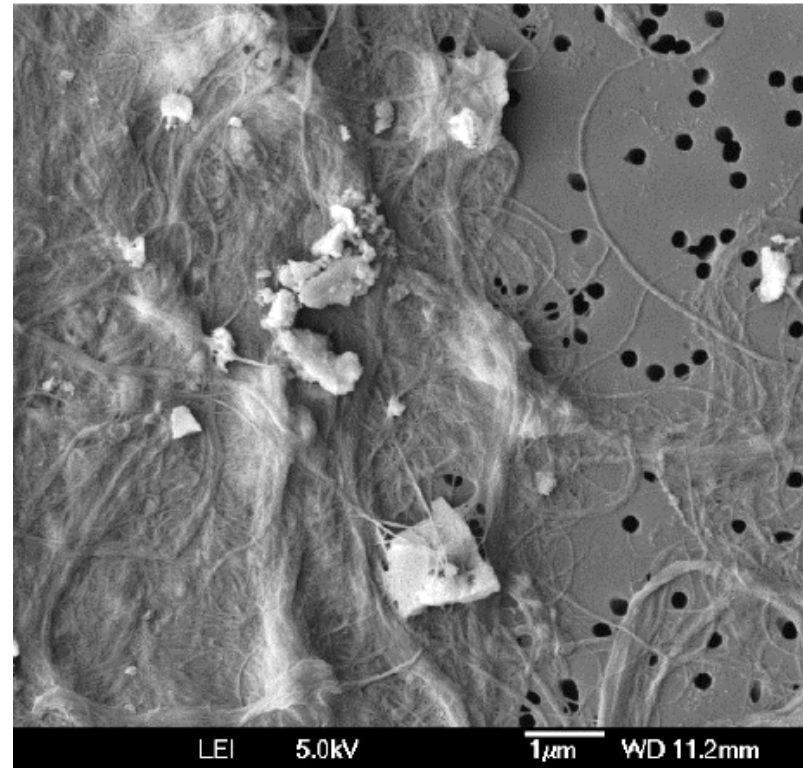




# Optimisation for Fibre Substrate (i)

## Fibre Hemicellulose Content

- Hemicellulose is a polysaccharide that forms a weak, amorphous layer **spacing apart microfibrils**.
- All else being equal, a fibre with a **high amount of hemicellulose** more readily **generates finer microfibrils**, improving bonding ability / high loading tensile index.
- Such fibre chemistry advises on suitable grinder operating conditions.

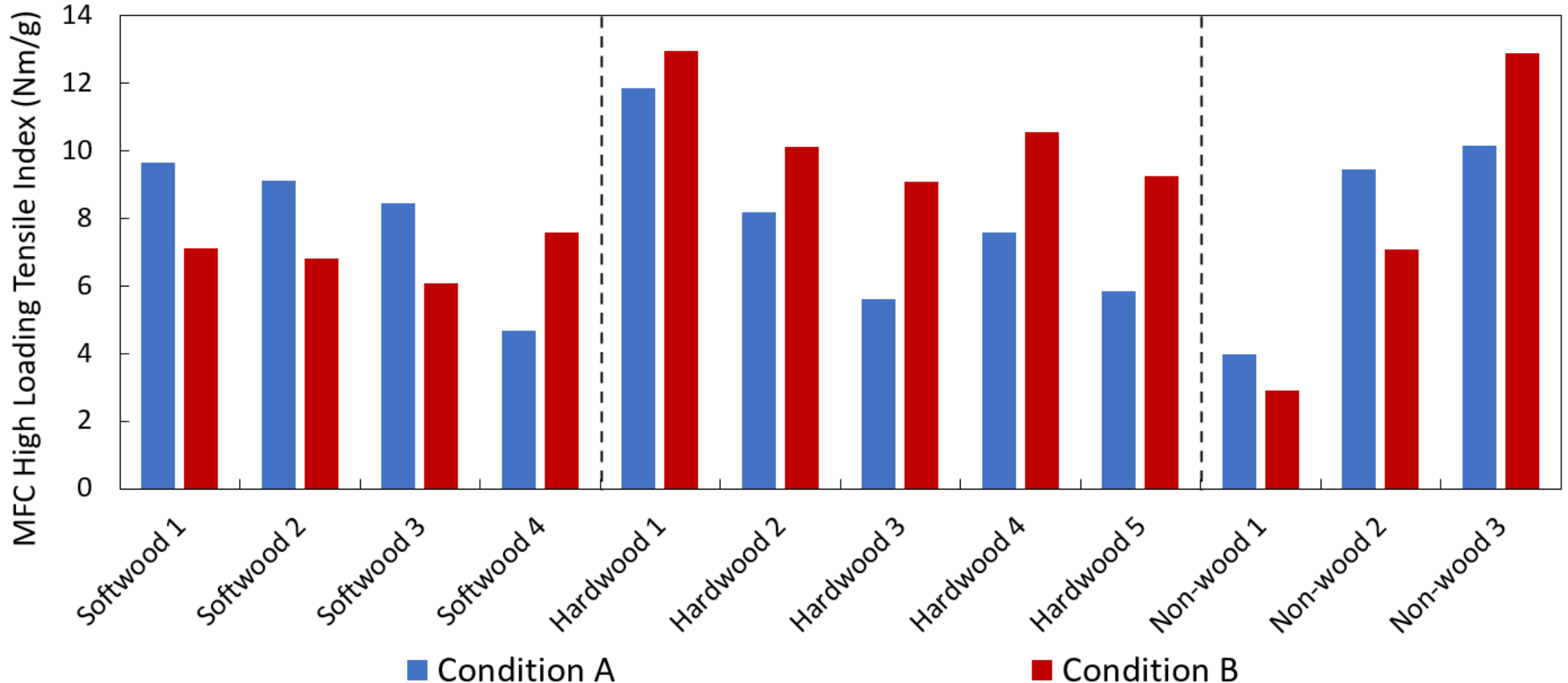


**MFC – mineral composite produced from fibres with high hemicellulose content (left) and low hemicellulose content (right)**



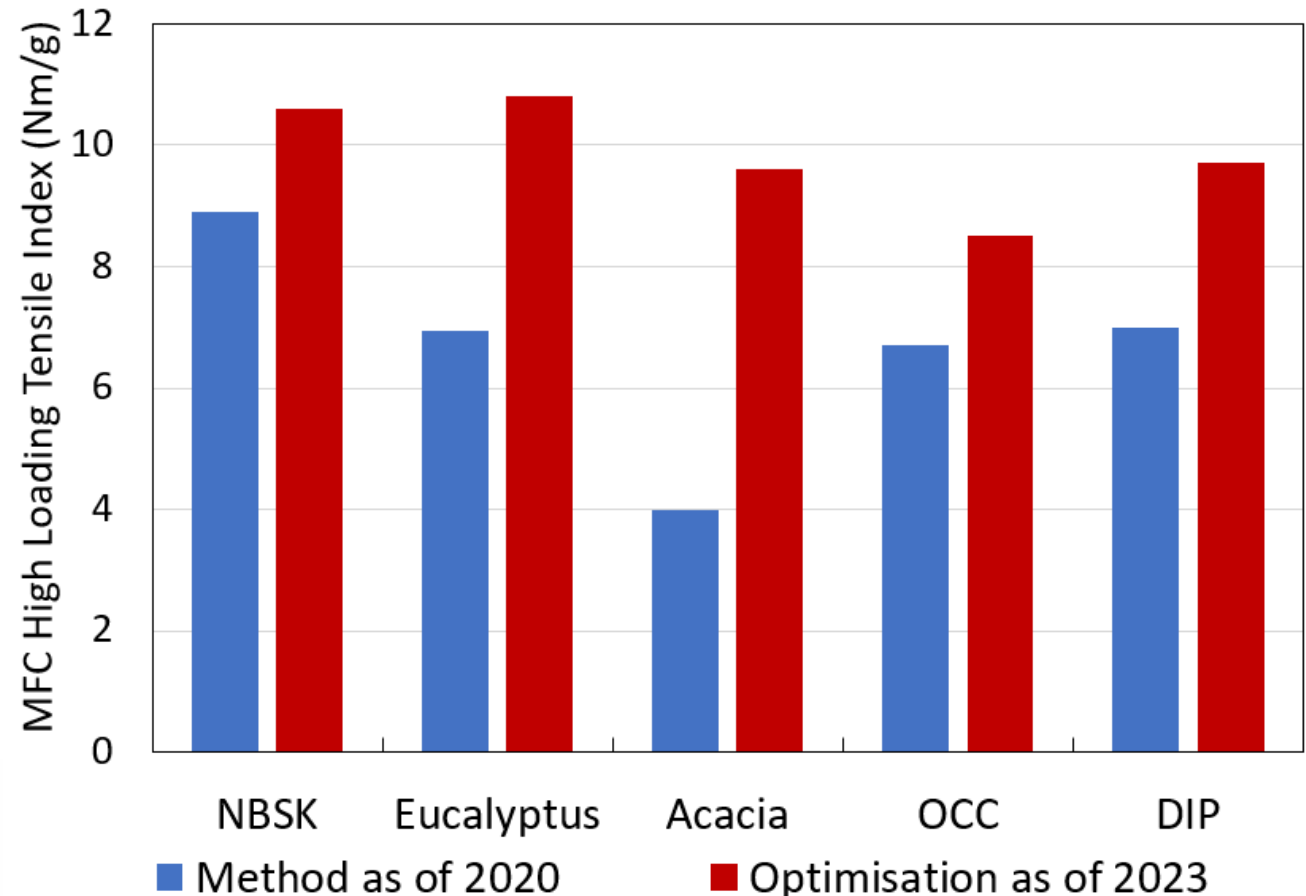
# Optimisation for Fibre Substrate (ii)

Optimum conditions change based upon fibre type and properties



# Improvements Since 2020

- Understanding how to adapt the process conditions based upon the properties of the feed fibres has:
  - **Improved product quality** at a given energy input.
  - **Lowered the energy required** to obtain a target quality.
  - Produced good quality MFC out of **previously nonviable substrates**.
  - Enabled us to produce **100% MFC products without requiring minerals** as a co-grinding aid.



MFC quality produced in **continuous mode at pilot scale** with various substrates. Specific energy input is maintained as constant.

# Conclusions

- **MFC and mineral / MFC composites** are produced from **virgin and recycled pulps**, and are important additives for a wide range of paper, board, and other applications.
- Stirred media mills efficiently and continuously produce MFC at large scale.
- Their nature allows for effective **decoupling of fibre breakage and fibrillation**.
- Stirred media mills are **highly tuneable**, giving flexibility for a **wide range of product characteristics** depending on application need.
- Although **conceptually simple**, they are **complex to optimise**.
- **Efficient optimisation requires an intimate understanding of the feedstock and process physics**.
- **Several key fibre characteristics influence optimum operating conditions**, and adapting the process accordingly has yielded substantial efficiency and quality benefits.





# Thanks for your attention

**Any Questions / Comments?**

Presented by:

Lewis Taylor

FiberLean Technologies

[lewis.taylor@fiberlean.com](mailto:lewis.taylor@fiberlean.com)

