Production of dissolving wood pulp from sawdust waste material

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Summary

- **Low timber utilisation rate and waste generation** and accumulation poses large challenges in the Forestry, Pulp and paper (FTTP) sector.
- 218 sawmills in SA **-440 006 tons** per annum of **sawdust waste** was generated [1]
- Wood waste -primarily from timber processing **at saw mills** and from the wood chipping and screening processes at the **pulp and paper mills**
- Dissolving wood pulp (DWP) is a **high purity cellulose product**-increased demand over last few years
- Proposed study **-proprietary technology**, evaluating a process with minimal steps to achieve a grade of DWP from sawdust.
- Process will be optimized on a benchtop scale and then upscaled.
- Final DWP will be characterized against commercial grades
- Foresees great dual benefits in support of a bio-based and circular economy

Introduction

- Dissolving wood pulp has a **diversified end-user product chain** each with growing demands and markets

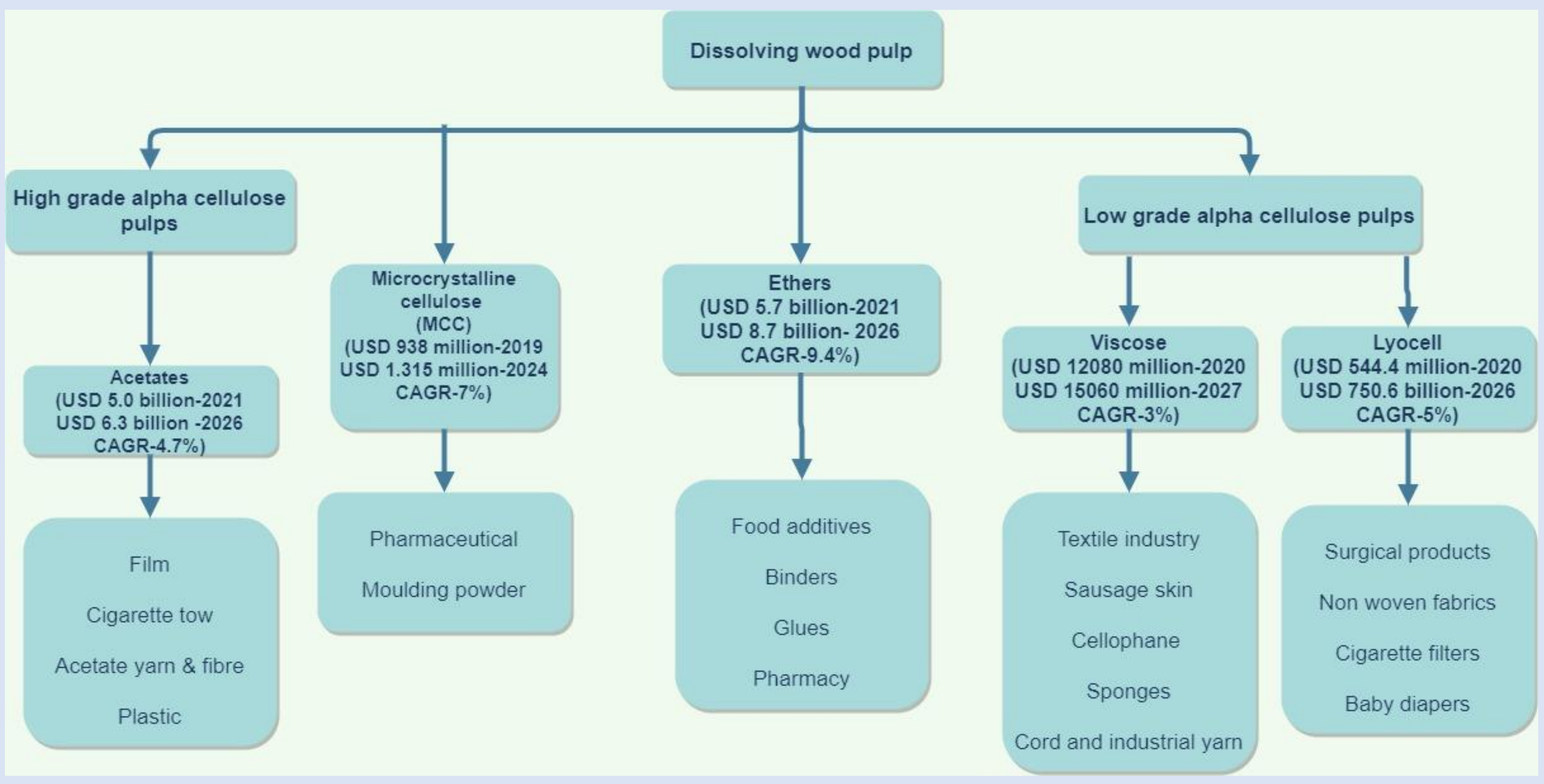

Figure 1: DWP derived end-user applications with current and projected markets- CAGR (compound annual growth rate)- [2-6]

- DWP mainly produced from **wood** (limited resource) and **cotton** (expensive resource)
- Shortages of wood fibre-driving need to explore new raw material
- Sawdust waste from landfill is a solution- dual benefit (waste beneficiation and improved waste management)
- Current methods in industry; Prehydrolysis kraft process **(PHK)** and Acid sulphite **(AS)** process is complex, water and chemical intensive

Methodology

- Raw material preparation- Milling and particle size distribution (PSD), screening to size <1180 um
- Stage 1 process on benchtop level – screening and optimization tests according to DOE
- Stage 1 process followed by washing and drying, pulp filtrate neutralized to pH 7
- Pulp chemical characterization

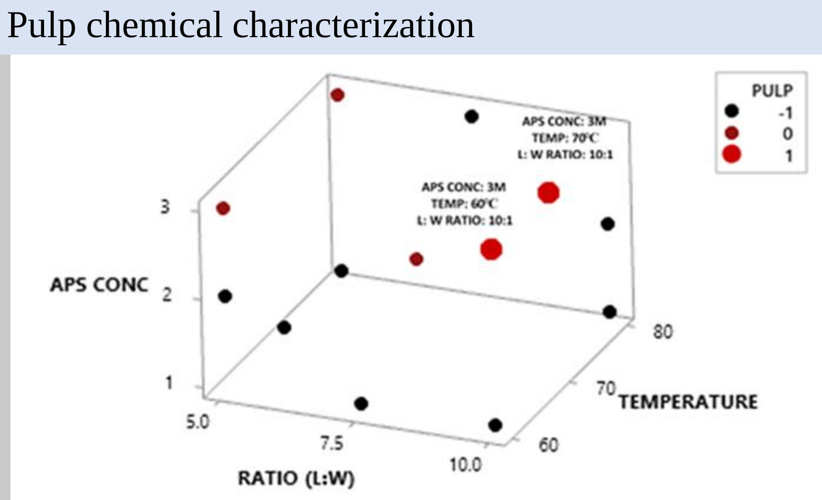

Figure 2:Design of experiments for stage 1 optimisation tests

Pulp response factor levels	Meaning
-1	Unpulped
0	Semi pulped
1	Pulped, little to no rejects

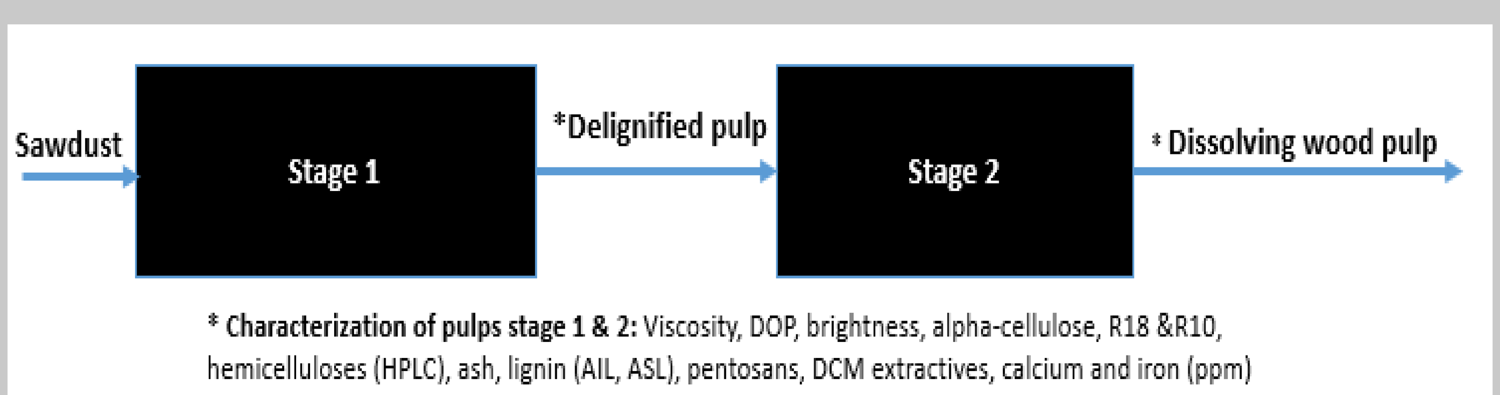

Figure 3: Proposed stages from sawdust to DWP-chemical application

Table 1: Key processing conditions applied for stage 1

Process step	Parameter	Conditions
Stage 1 (Screening tests- Screening experimental design)	Temperature	60-90 °C; Δ10 °C
	Time	6h
	Chemical concentration	1, 2 and 3 M
	Liquid to wood ratio (L: W)	5:1, 7.5:1, 10:1
	Wood species	-Control untreated -Hardwood - Softwood
Stage 1 (Optimisation tests- Full factorial design)	Concentration; Temperature, L:W ratio ,Time	3 M, 60 and 70 °C, 10:1, 3-6 h

Results and discussion

- Optimum conditions for obtaining a fully pulped product;
  -3 M Conc, 60 °C, L:W ratio 10:1 and 6 hours for softwood
  -3 M Conc, 70 °C, L:W ratio 10:1 and 3 hours for hardwood
- **Low intrinsic viscosity** and corresponding degree of polymerization (DOP), between 110-304 ml/g and 283-934 ml/g respectively- attributed to the possibility of **cellulose degradation** due to reduced polymer chains [7]
- MCC requires a DOP < 400 corresponding to a viscosity of 148.03 mL/g.
- Brightness measurements ranged between 65-67%
- Lignin concentrations (AIL and ASL) showed significant decreases compared to the original sawdust samples (70-80% reduction)
- Hemicellulose content overall following stage 1 was compared for xylose and mannose-> 70% reduction . A **low hemicellulose content** is a key requirement for DWP grades [8].
- Previous studies have shown that removal of hemicellulose prior to the process may aid in delignification, thus **requiring milder delignification conditions** and provides **further beneficiation** from process [9-12] (Miao et al., 2014, Christopher, 2017, Liu et al., 2013, Koradiyaa et al., 2016) .

Table 2: Pulp characterization results emanating from stage 1 process in comparison to conventional processes

Measurement	Hardwood sawdust pulp	Softwood sawdust pulp	Conventional dissolving wood pulp
Yield (%)	44-60	53	Process dependent Unbleached PHK~35-40 Unbleached AS~45-46 [13]
Intrinsic viscosity (ml/g)	110-180	304	Unbleached : 908-1100 [14]
Degree of polymerization (DOP)	283-505	934	1250-2100 [13]
Acid soluble lignin (ASL) (%)	1.17-1.53	1.29	Unbleached AS total lignin: 0.15-0.25 [15] Unbleached PHK total lignin – (0.9-2%) [13]
Acid insoluble lignin (AIL) (%)	4.27-4.89	5.13	
ISO brightness (%)	65-67	66	Final bleached: >85 [16] Unbleached PHK 33.6-42.9 [13]
Monosaccharides (%)			
Glucose	74.59-80.37	90.14	
Mannose	Not detected	6.74	Bleached: 1-6% [16]
Arabinose	Not detected	Not detected	
Xylose	2.63-5.15	1.04	
Galactose	Not detected	Not detected	

Figure 4: Sawdust derived pulps from stage 1 delignification process

Conclusion and recommendations

- Optimum conditions established to consistently produce a low viscosity and moderate brightness grade dissolving pulp
- Potential feedstock for applications such as Microcrystalline cellulose (MCC) –useful to pharmaceutical and possibly the food industry at large for multiple end-user products
- Novel approach and promising energy and water savings-reduced processing costs (using moderate temperatures and reduced times in comparison to conventional processes)

Future work:

- Evaluate the use of a suitable cellulose protector to prevent degradation of cellulose
- Investigate pre-hydrolysis of sawdust to recover hemicelluloses (milder conditions for delignification may be required for pre-hydrolysed sawdust)
- Improved techno-economic viability of the process

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