LIGNIN AS A PERFORMANCE ADDITIVE WHEN REPLACING UREA FORMALDEHYDE RESIN. SAVINGS, PERFORMANCE AND SUSTAINABILITY.

Borregaard

INTRODUCTION

The use of custom lignin-based biopolymers as an additive in fiberboard, particle board and other applications for UF resin may bring savings from a 1:1 substitution of a portion of the resin. In addition to savings from resin substitution, it is possible to achieve increased board performance, reduced emissions and increased sustainability. Rather than attempting to mix lignin and ingredients to formulate new resin, which can be problematic for several reasons, dosing liquid lignin separately as a performance additive in the manufacturing process should be investigated. This can bring unique advantages related to the properties of Borregaard biopolymers that are described below, and summarised as follows:

- **OPEX savings: 1:1 replacement of UF resin up to 30% has been demonstrated in the past**
  - Logistics are favourable, with multiple global Borregaard locations

- **Increased performance**
  - Cure acceleration
  - Reduced paint consumption
  - Reduced tool and refiner wear
  - Lower disk refiner energy consumption
  - Reduced water adsorption
  - As a functional filler in polymethylenediisocyanate (PMDI) systems

- **Reduced formaldehyde emissions**
  - Allow for use of more reactive resins
  - Replace part of existing formaldehyde scavenger

- **Lignin biopolymers are sustainable products**
  - Claimed as higher bio-based content, 1 for 1
  - CO_2 emissions & life cycle analysis

ECONOMICS AND OPEX SAVINGS

Logistics

Shipping costs play an significant role in the wood adhesives industry, and Borregaard has numerous production facilities around the globe. This provides the opportunity for short transport routes and favourable logistics for liquid products. Prior to any trials, an economic analysis for the specific application should be completed. Borregaard can assist with these economic calculations and, if positive, additional lab tests or field trials may be considered to gauge performance potential.

Case History

Previously, lignosulfonates have been used as UF extenders, and there are many examples of UF resin extension in the literature. As one example, please see the particle board trial report from 1991 for reference (1). Currently, few board manufacturers use lignosulfonate in the way illustrated in the trial report. This is likely due to lack of availability, performance and cost savings. Given the new Borregaard joint venture plant in Fernandina Beach Florida (2), these issues are addressed sufficiently to achieve success in the Southeastern U.S. Wood Basket. To our knowledge, lignosulfonate has almost always been pre-blended as part of the UF resin prior to application. Unfortunately, mixing with resin can cause problems related to decreased pot life and resin viscosity changes. The application of lignosulfonate as a resin extender prior to the disk refiner in MDF manufacture has not knowingly been attempted.

Laboratory studies have been conducted to evaluate the mechanical effect of Borregaard biopolymers in MDF (3). Substantial savings and sustainability benefits can be achieved by complete removal of UF resin in novel systems (4,5).

INCREASED PERFORMANCE

Cure acceleration

The ammonium lignosulfonate from LignoTech Florida (LTF), LignoBond 870L (870L), has been found to polymerise more quickly than other grades of lignosulfonate. Based on Borregaard 's experience, this ammonium lignosulfonate is one the most reactive lignosulfonates we have observed (6). Figures 1. shows the predicted reaction rates without crosslinker. Figure 2. shows the actual rate of reaction at various conditions with, and without glyoxal crosslinker.

Figure 1. Three-dimensional plot of predicted gel rates for 870L across pH and temperature (52% dry matter and no added cross-linking agent)

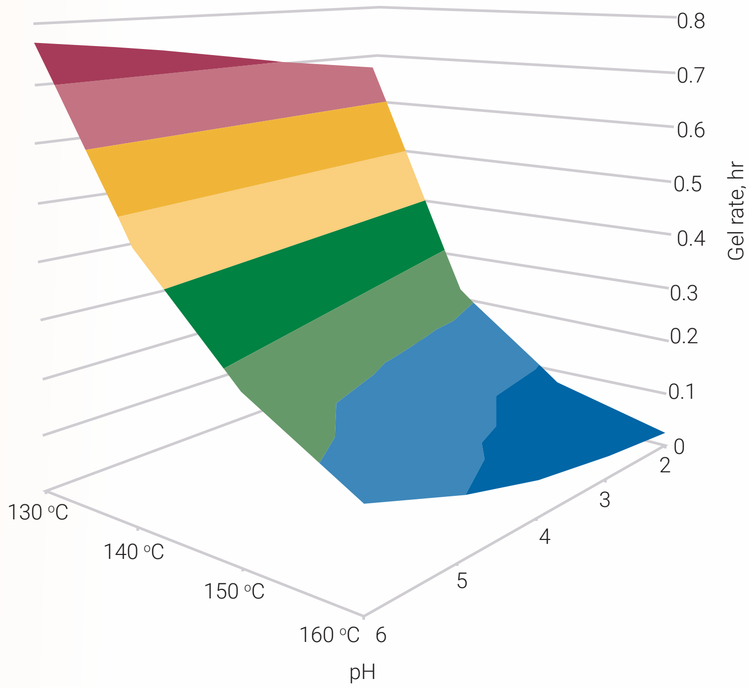
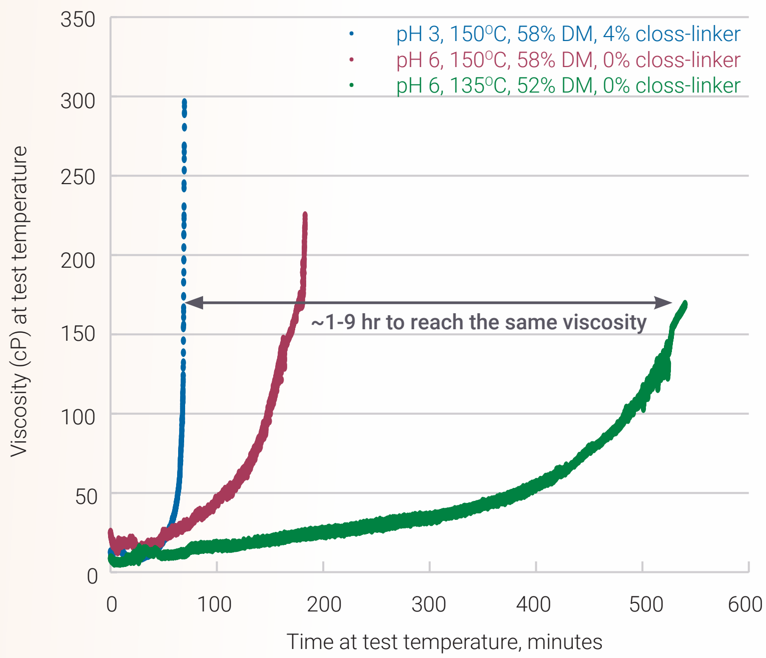


Figure 2. Viscosity vs time for 870L at different temperatures, pH, dry matter content and crosslinkers.



Like ammonium chloride and ammonium sulfate, the non-volatile ammonium ions present in the lignin should accelerate the cure time of the UF resin. Replacement of up to 30% w/w of the resin in the board is likely possible while eliminating urea scavenger and increasing the bio-based content of the board. Using scanning calorimetry at our central laboratory, we can predict the reactivity with various UF resin products. Figure 3. shows an example of the acceleration of a ULEF UF resin alone, and at 5% replacement with 870L. This technique gives a better understanding of the target substitution rates.

By adding lignosulfonate prior to the fibreboard digestion process, not only will sugars be converted to natural crosslinkers at digestor temperatures, but the Lignobond 870L will have an opportunity to be primed prior to resin addition. Since lignosulfonate will polymerise via a similar mechanism to resin, but more slowly, adding it prior to the refiner will allow for "pre-polymerization" in a controlled fashion, allowing the added Lignobond 870L to function as a more effective resin extender.

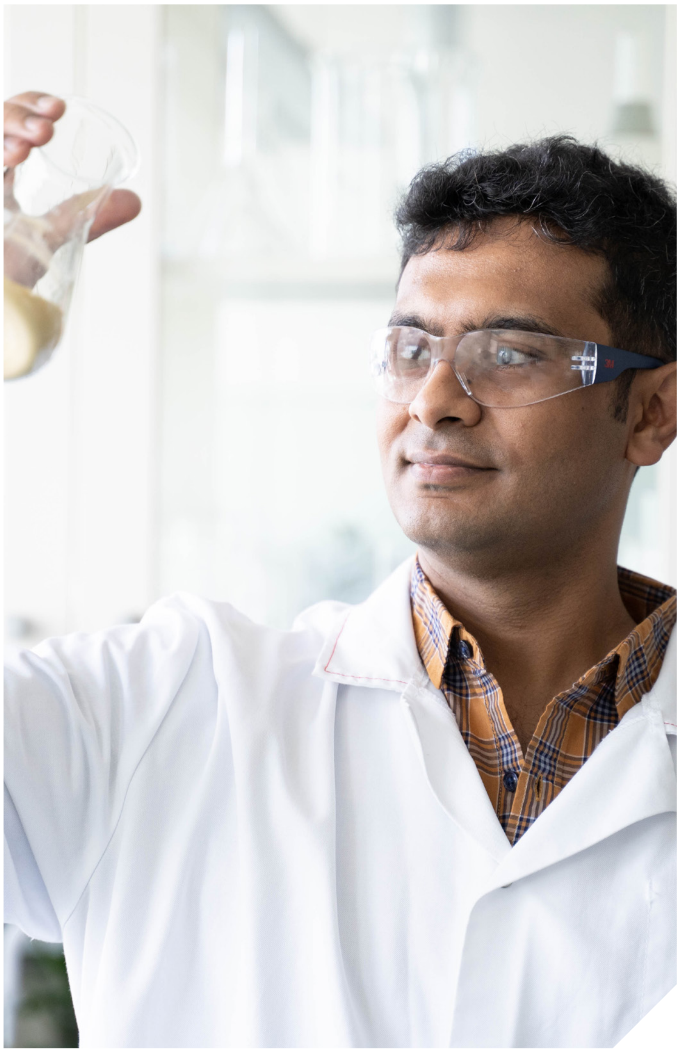
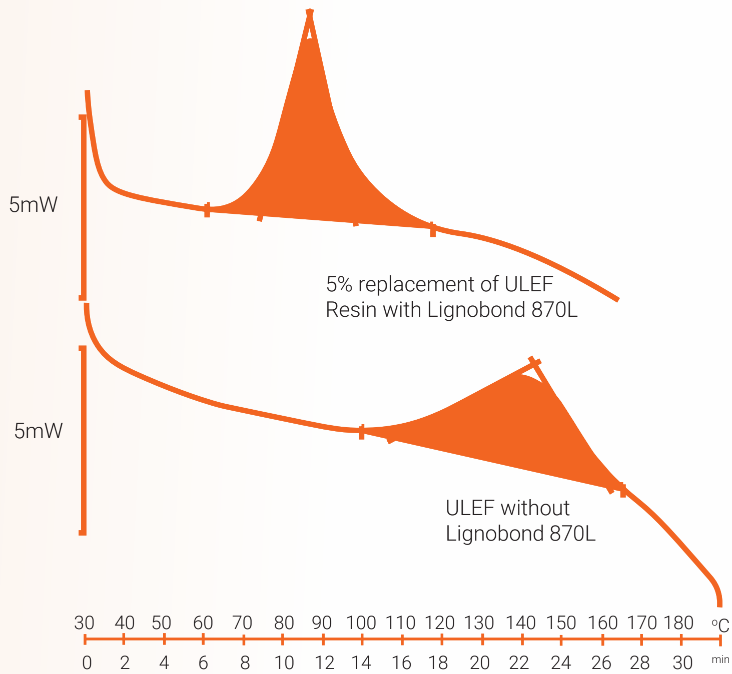


Figure 3. Typical Differential Scanning calorimetry of a ULEF urea formaldehyde resin for MDF. Temperature / time parameters are listed on the x axis. The lower graph shows resin alone, the upper graph with 5% of the resin solids replaced with 870L.



ENERGY AND WEAR

Lignosulfonates are known to provide a lubrication effect in other applications, for example wood pelleting (7). If production trials are run, Borregaard is prepared to provide on-site technical support for such trials to measure improvements in energy consumption, paint consumption, and reduced tool wear.

As a filler in PMDI systems

Research and patents recently have disclosed adhesive systems where NAF PMDI and lignosulfonate are formulated into single, stable formulations (8,9). However, this stability comes at a very high cost. Providing a stable formulation of the two requires a very complex formulation. We believe the most economical way to consider lignosulfonate with pMDI crosslinked systems would be addition at the board plant prior to pMDI addition. For the MDF plant, this would mean addition prior to the digester which may bring additional advantages as described under Energy and wear, in that the lignosulfonate may act as a lubricant, increasing disk grinding efficiency and decreasing wear on equipment. More importantly, in this system lignin will also act as a filler, decreasing paint consumption. It is also possible to decrease sanding energy while increasing smoothness.

Reduced water adsorption

Laboratory examples of MDF production show certain lignin products, particularly ammonium lignosulfonate produced by Borregaard, have positive impacts on strength, as well as moderately positive impacts on board swelling (10). Borregaard continues research on ways to use economical cross-linkers like lignosulfonate to further lower swelling and water adsorption in MDF.

Board N2	Content of calcium lignosulfonate Px, %	Density p, kg.m^{-3}			Swelling in thicknesses Gt,%			Water absorption A,%		
		Average	STDV		Average	STDV	P-value	Average	STDV	
1	0	843.96	89.05	0.037	53.76	7.14	0.047	88.01	10.94	0.044
2	5	845.98	44.97	0.019	45.23	5.86	0.046	76.63	3.86	0.018
3	10	836.18	31.17	0.013	41.88	5.18	0.044	72.47	6.93	0.039
4	15	839.19	68.46	0.029	23.04	2.94	0.045	63.14	4.82	0.027
5	20	844.45	66.28	0.028	22.25	3.06	0.049	61.16	6.44	0.037

Table 1. Experimental results for physical and mechanical properties of MDF (from Ref. 10)

FORMALDEHYDE REDUCTION

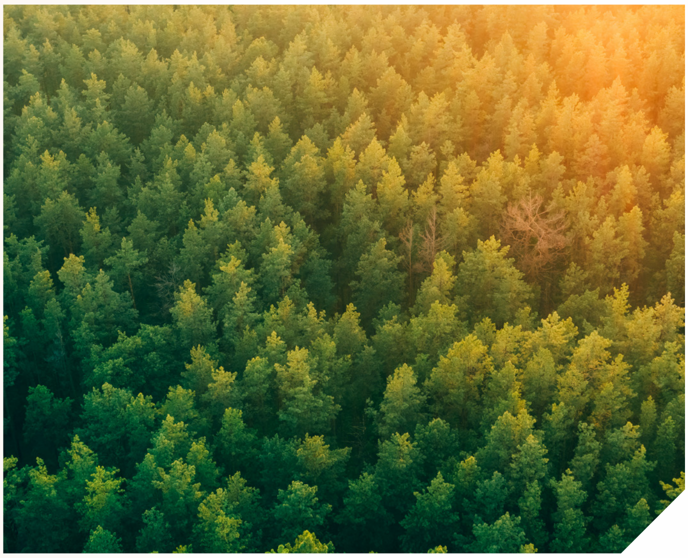
Several examples exist in the literature describing reduced formaldehyde emissions in MDF board manufacture when UF resin is used in combination with Lignobond 870L as an additive. In this open access cited example, the emissions of the board produced were similar to natural wood (11).

Adhesive	UF resin content, %	Ammonium lignosulfonate content, %	Formaldehyde content, mg/100g
UF + ALS	3	6	1.0 ± 0.1
UF + ALS	3	8	0.8 ± 0.1
UF + ALS	3	10	0.7 ± 0.1
UF	6	-	4.3 ± 0.1

Table 2. Experimental results for change of formaldehyde content with 870L (from Ref. 11)

BIO-BASED CONTENT AND SUSTAINABILITY

Many Borregaard biopolymers are PEFC chain of custody certified and can be considered "wood" content. This means that the board plant will likely be able to claim a higher wood content in their board compared to other manufacturers. This could provide a marketing advantage in addition to the benefits of potentially lower cost with equivalent performance. Finally, our products are very low in carbon intensity owing to their bio-based content.



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