DEVELOPMENT OF SOYBEAN FLOUR-BASED FOAMED PLYWOOD GLUES

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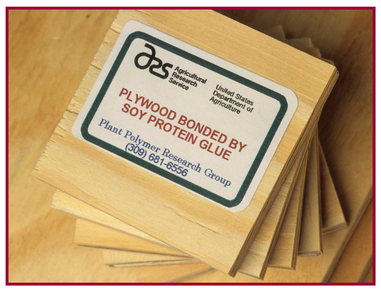

SUMMARY

- We developed a soybean protein-based foamed plywood adhesive that is now being used commercially by a major plywood manufacturer.
- Technology transfer was made possible by a Trust Agreement between the USDA-Agricultural Research Service and the United Soybean Board.
- The glue is designed for foam extrusion, a method of applying glue to plywood in which glue is foamed with air and then extruded into long strands of such diameter as to cover the entire wood surface when pressed.
- Soybean flour, an inexpensive and readily available protein source, was used to replace spray-dried animal blood, the industry's current protein extender in the glue mix.
- Soybean flour does not pose a health threat to mill workers, unlike animal blood, which may harbor disease-causing agents.
- The soybean flour-based glue had mixing performance, foaming quality, and adhesive strength that equaled those of the plywood industry's current foamed glue.
- The cost of the soy-based glue was cheaper by $0.84/100 kg of glue mix compared to the blood-based glue, which means considerable annual savings in production costs to the plywood-making industry.
- Using soybean flour as protein extender in foamed plywood glues will consume up to half-million bushels of soybeans per year.

PUBLICATIONS

- Hojilla-Evangelista, M.P., and L.B. Dunn, Jr., 2001. Foaming Properties of Soybean Protein-Based Plywood Adhesives, *J. Amer. Oil Chem. Soc. 78*:567-572.
- Hojilla-Evangelista, M.P. 2002. Adhesive Qualities of Soybean Protein-Based Foamed Plywood Glues, *J. Amer. Oil Chem. Soc. 79*:1145-1149.
- Hojilla-Evangelista, M.P. 2004. Development of Soy Protein-Based Foamed Plywood Glues, *Abstracts of the 228th ACS National Meeting,* Aug. 22-26, Philadelphia, American Chemical Society.
- McGraw, L. 2001. Foaming Soy Adhesives Could Help Soybeans Bond with Lumber Industry. *Agricultural Research Magazine,* January issue, p. 9.
- Gorman, J. 2001. Soybeans Could Beef Up Plywood Glues, *Science News,* January 13 issue, p. 20.

BACKGROUND

The Problem. Several studies on soybean-based plywood adhesives have been reported, but none of them involved soybean proteins in foamed glue applications, so there was the need for fundamental groundwork in this specific research area. Additionally, outbreaks of Bovine Spongiform Encephalopathy several years ago prompted concerns about handling or inhaling blood particulates that may contain disease agents. This was an important issue because plywood glues for foam extrusion use spray-dried animal blood as protein extender. The limited number of suppliers of spray-dried animal blood and short shelf-life of the blood-based foamed glue were also contributing factors in the search for an alternate protein extender.

Why Soybean Flour? Using soybean flour as the protein extender in foamed plywood glues eliminated the health concerns about animal blood. Soybean flour was also an inexpensive and readily available protein source with excellent foaming properties that are essential to the success of the glue's performance.

FORMULATION STUDIES

Materials. We evaluated soybean flours from various processors that were commercially available in the United States. The flours contained 55% crude protein on average and less than 0.5% residual oil. Oil is a defoamer, so its presence is not desired in foamed plywood glue. Phenol-formaldehyde (P-F) resin was provided by Georgia- Pacific Resins Inc.

Glue Formulations. The compositions of the industry standard and soy flour-based foamed glue mixes are given in Table 1. Soy flour replacement of spray-dried animal blood was done on protein content basis. The amount of filler (Glu-X) in the soy-based glue was reduced to meet viscosity requirements.

Table 1. Composition of Industry Standard and Soy Flour-Based Foamed Glues

Ingredients	Quantity (g/100 g glue mix)	
	Standard	Soy-Based
Water	18.1	18.1
Filler (Glu-X)	5.4	2.8
Spray-dried Animal Blood	3.5	---
Soy Flour	---	6.2
P-F Resin	69.9	69.9
50% Sodium Hydroxide	3.0	3.0

FOAMING TESTS

One-kg glue mixes were prepared and tested for foaming ability in an Oakes mixer/foamer. The quality of foam stands and motor speed required to produce acceptable foams were recorded. Foamed glue was de-foamed by centrifugal force, fed into the mixer/foamer again and tested for re-foaming ability. Re-foaming ability is important in the start-stop operations of a plywood mill.

Testing Glues in the Oakes Mixer/Foamer

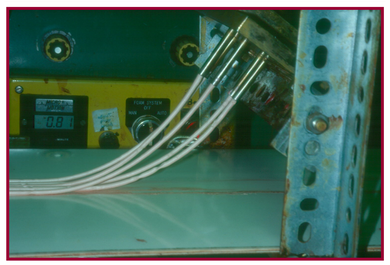

Table 2. Mixing and Foaming Properties of Standard and Soy-Based Plywood Glues

Protein Extender	Min. Mixer Speed (rpm)	Re-foam Mixer Speed (rpm)	Foam Quality
Animal Blood	750	1100	Very good*
Honeysoy 90	825	965	Very good
Iowa St. U - CCUR	850	1025	Good
Nutrisoy 7B	800	975	Very good
Soyafluff	850	1060	Fair

** Very good: Smooth foam strand with no breaks*

The soy-based glues produced acceptable foam strands at mixer speeds that were only slightly higher than that observed for the standard blood-based glue (Table 2). Foam quality of the soy glues varied, but all were able to re-foam at mixer speeds that were less than or equal to that of the standard. **This meant that existing equipment can produce foamed soy glues without using added energy.**

BOND STRENGTH TESTING

Laboratory-Scale Plywood Production

- Wood sample – 10 in x 10 in Southern Pine
- Glue application – 9 g/single side of veneer
- Veneer assembly – alternating wood grain
- Cold-pressing – 140 psi, 5 min
- Total assembly time – 60 min
- Hot-pressing - 325°F, 225 psi, 3.5 min
- Storage in insulated cabinet

Testing Adhesion Strength

- Shear specimens – 1 in x 3 ⅛ in
- Vacuum/pressure soak – 30 min each cycle
- Shear test – Globe Plywood Testing Machine minimum 200 psi for strong glue bond

Veneer Assembly Before Hot-Pressing

Determining Bonding Strength Using the Globe Plywood Testing Machine

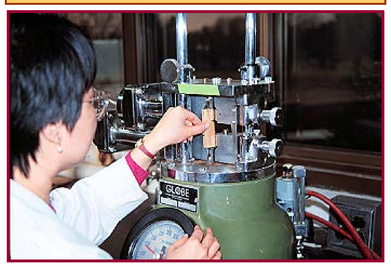

Table 3. Tensile Strengths of Plywood Bonded By Standard and Soy-Based Foamed Glues

Protein Extender	Wet Tensile Strength (psi)	
Animal Blood	235	46
Honeysoy 90	242	36
Iowa St. U - CCUR	231	40
Nutrisoy 7B	247	30
Soyafluff	231	48

Plywood bonded by the soy flour glues had tensile strengths that were comparable to that of the standard glue. Tensile strength of the Nutrisoy 7B-glue was especially notable. **These data show that the soy flour-based glues were just as strong as the industry standard glue.**

PILOT-SCALE EVALUATIONS

SparTek, Portland, OR

Soy flour glues were foamed by using the 10-gal capacity SparTek foam extrusion system.

Soy flour glues produced foam strands that were smooth, did not break apart, did not collapse easily, had good adhesion to wood, and gave a light-colored glue line in plywood.

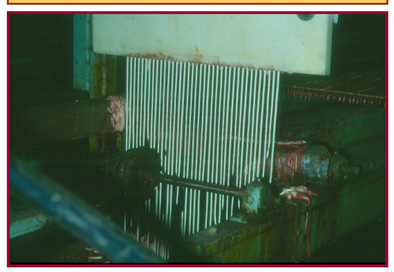

Table 4. Pilot-Scale Tests: Mixing, Foaming, and Re-Foaming Properties of Standard and Soy-Based Foamed Plywood Glues

Protein Extender	Foamer Speed (rpm)		
	Fresh Glue	First De-Foam	Second De-Foam
Animal Blood	220	280	330
Honeysoy 90	220	330	330
Nutrisoy 7B	180	260	250

Table 5. Cost Comparisons of Standard and Soy Flour-Based Foamed Plywood Glues**

Glue Formula	Extender/ Filler	Unit Cost ($/kg)	Amount (kg)/100 kg glue	Cost ($)/ 100 kg glue
Standard	Blood	0.88	3.50	3.08
	Glu-X	0.27	5.35	1.44
			Total Cost	4.52
Soy Flour-Based	Soy Flour	0.48	6.15	2.95
	Glu-X	0.27	2.71	0.73
			Total Cost	3.68

*** Calculated based on the amounts of filler, soy flour, and animal blood only.*

ADVANTAGES: SOY FLOUR FOAMED PLYWOOD GLUES

- Cheaper by $0.84/100 kg of glue mix compared to the blood-based glue;
- Same mixing, foaming and adhesive properties as the industry's current glue;
- Produce a light-colored glue-line in plywood products that is aesthetically pleasing and desirable in some wood applications;
- Longer shelf-life (4-5 days *vs.* 2 days);
- Produced using existing equipment in plywood mills, so there are no expected additional costs for its utilization;
- Soybean flour does not pose a health threat to mill workers, unlike animal blood, which may harbor disease pathogens;
- Soybean flour is readily available from several major commercial processors.

TECHNOLOGY IMPACT

- U.S. soybean growers and plywood mills that use foam extrusion technology are the primary beneficiaries of the soy-based glue.
- Soybean flour-based foamed plywood glues will consume up to half-million bushels of soybeans per year, which would translate into added value for soybeans and higher income for U.S. soybean growers.
- **A large plywood manufacturer based in southeastern USA used our soy flour-based adhesive in two of their mills.**
- Other companies, such as SparTek (formerly Pacific Adhesives Co.) and Willamette Valley Industries continued with further optimization studies.