Ovalbumin as a Wood Adhesive

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Introduction

Use of proteins to bond wood dominated industrial production until the middle of the 20th century (1). The ensuing creation of the plywood and glulam beam industries allowed for more efficient use of wood resources than is possible with solid wood products. Many protein sources have been used as adhesives, including plant (soybean) and animal (blood, fish scales, collagen, casein from milk). Development of the petroleum industry led to replacement of these biobased materials by synthetic adhesives providing better water resistance, ease of use, and lower cost.

In recent years, use of biomass for adhesives and other applications has garnered increasing interest. Using natural materials can often be advantageous because they are polymeric materials that usually have functional groups for adhesion to a variety of surfaces or for further modification. However, problems with biomass materials often result from having to live with the structures provided by nature. These include the presence of undesired components and variability in composition, in contrast to synthetic materials that are made from quite pure monomers.

Soy flour has been used extensively in wood adhesives, is quite consistent in composition, and is available in large quantities and at a low cost. However, the flour contains only about 45% protein with a nearly equal amount of carbohydrate. The protein can be separated out to provide the commercially available soy protein isolate, but the cost goes up by a factor of about 10 (2). In addition, like many proteins and carbohydrates, the dispersions are viscous and/or the solid content very low. The commercial soy protein isolates are a mixture of proteins (3) and are very different in properties from the laboratory isolate (not published), but the latter is very tedious to make in any great quantity. In studying protein adhesives, we decided to examine ovalbumin from egg whites as a wood adhesive because it is quite pure and readily available.

Experimental

Cargill Inc. (Cedar Rapids, IA) provided Prolia™ 200-90; ADM (Decatur, IL) provided soy protein isolate. Sigma Life Science (St. Louis, MO) provided ovalbumin (over 90% purity); Ballas Eggs (Zanesville, OH) provided dried egg products. Ashland (Wilmington, DE) supplied the polyamidoamine-epichlorohydrin (PAE) CA 1920A co-reactant. Columbia Forest Products supplied hard maple veneer.

Soy or egg protein was dispersed in water at the established level; if the PAE co-reactant was used, it was added at this stage at a 5 wt% solids level based on the protein material solids. Adhesive was applied to 5 mm on the end of one piece of maple veneer (117 × 20 × 0.6 mm), which was overlapped 5 mm with another piece of veneer. An ABES (automatic bonding evaluation system), Model 311c (Adhesive Evaluations Systems Inc., Corvallis, OR) was used for bonding and testing shear strength of the samples. Samples were hot pressed in the ABES at 0.2 MPa for 120 seconds at 120°C. The bonded wood samples were equilibrated at 21°C and 50% relative humidity at least overnight before testing dry or wet after soaking in water for 4 hours at room temperature. Five specimens were tested in tensile shear for each condition; the average and one standard deviation are shown.

Results and Discussion

Table 1 points out the large difference in strength between commercial soy flour (about 45% protein) and soy protein isolate (SPI, about 95% protein), especially when the shear bond is tested under wet conditions. Although the major soy proteins have been separated and tested as adhesives (4), it seemed that using a fairly pure commercially available protein might allow a better understanding of the protein adhesion. Ovalbumin is readily available in natural form (egg whites) and is easily purified. Thus, the ovalbumin was compared to the soy products.

Table 1. Properties of adhesives with the viscosity given in Pas and ABES lap strength given in MPa.

Property =>	Viscosity	Bond Strength, MPa	
Adhesive	Pa.s	Dry	Wet
Soy flour, 30% solids	17.0	5.0 ± 1.2	0.3 ± 0.2
Soy protein isolate, 15% solids	7.4	7.2 ± 1.3	3.0 ± 0.4
Ovalbumin, 20% solids	0.8	5.6 ± 1.4	2.7 ± 1.0

Ovalbumin showed that it was a good adhesive compared to the SPI (Table 1). More surprisingly, ovalbumin was much lower in viscosity than the soy products at slightly higher solids content. The lower strength may be due to the very low viscosity because thin solutions often behave poorly in veneer bonding due to overpenetration of the wood and a starved bondline. One limitation of soy adhesives is that solids content cannot be raised without it becoming too thick. However, this is not true of ovalbumin, which can be used up to 50% solids with reasonable viscosity compared to 15% for SPI and 25% for soy flour. Strength improved going to higher levels (4.6 MPa wet shear strength), and wet strength improved further to 6.5 MPa when 5 wt% of PAE co-reactant was added.

One question was why ovalbumin is so much lower in viscosity than commercial SPI. Although individual polypeptide units within the soy are smaller than those of the ovalbumin (16–35 vs. 45 kDa, respectively), the major soy proteins are aggregates between 170 and 380 kDa. In addition, most of the sulfur groups are as disulfide bridges for the soy, but many are thiol groups for ovalbumin (3 and 5). Thus, ovalbumin may not serve as a good model for understanding the function of protein in soy, but it makes a good wood adhesive when hot bonded.

Because ovalbumin was effective as an adhesive, we investigated the egg white (DEW) from which ovalbumin is isolated, the egg yellow (DEY), and the whole egg (DWE), with all being available as dried products. These products were tested, and their dry and wet ABES shear strengths are shown in Figure 1. In addition to the egg protein by itself at 35% solids, the protein was used with 5 wt% (based on egg) PAE co-reactant added.

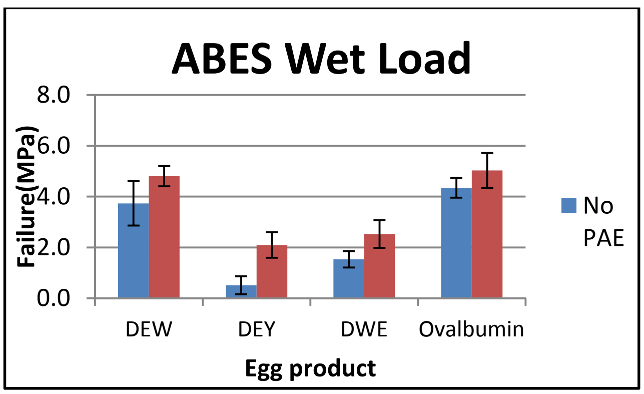

Figure 1. ABES wet shear strength of DEW (dried egg whites), DEY (dried egg yellows), DWE (dried whole eggs), and ovalbumin with all the egg products at 35% solids, except ovalbumin at 30%.

Egg white was almost equal in wet strength to ovalbumin, with egg yellow the lowest and whole egg in between. Given the low protein content of egg yellow (30% minimum) compared to whole egg (45% minimum) and egg white (80% minimum), this was an expected result. The other main components of egg yellow and whole egg are fats.

Conclusions

Although the egg white protein ovalbumin is quite compositionally and structurally different from soy proteins, it is a very good adhesive for wood bonding. Egg products, including dried whole, whites, and yellows, will bond wood. The egg whites and purified ovalbumin give good bonds that hold up to wet conditions, and the performance is further improved by using 5% (solids/solids of protein material) polyamidoamine-epichlorohydrin co-reactant. Thus, this research reveals more proteins that are good wood adhesives. The real advantage of ovalbumin is the low viscosity compared to soy and other protein dispersions; the higher solids at low viscosity allow better application of the adhesive and less steam pressure being generated during the hot press bonding due to the lower water content.

Acknowledgements

Support from Ashland was received as part of cooperative research and development agreement on the use of polyamidoamine-epichlorohydrin resin.

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In: The Adhesion Society's 37th Annual Meeting February, 23-26, 2014, Bahia Resort Hotel, San Diego, CA. from CD TEH801043052B03.


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TEH801043052B03