# Rheological Behavior of an Environmentally Friendly Dry Blood Powder Based Adhesive for the Wood Industry

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ABSTRACT

The aim of this paper is to study the rheological behavior of an environmentally friendly adhesive based on a secondary product of food industry, dry blood powder (DBP), to replace formaldehyde-based adhesive such as urea-formaldehyde (UF) resins in the production of wood composites, increasing the added value of the raw material.

## INTRODUCTION

Petroleum-based adhesives like UF are widely used in plywood, composite wood panels and furniture because of high adhesion strength and low cost. This adhesive has replaced historic based protein products such as casein or blood, which were displaced from the market.

However, highly toxic formaldehyde is emitted during the production and post production process. It is important to notice that formaldehyde was declared a carcinogen by the World Health Organization (WHO) in 2004.[1] Besides, the future shortage of petrochemical-based products supposes a rise in relative price and lack of availability, leading on an increase in the development of “green” products from inexpensive and renewable resources. We decided to work with DBP, which is a secondary product of food industry and easy to get in our country.

Blood consist of plasma, cell fraction and fibrillar fraction. Plasma contains different substances like lipoprotein, fatty acids, sugars, soluble proteins (albumins and globulins) and mineral salts. The cell fraction (erythrocytes, leukocytes and platelets) is rich in hemoglobin. DBP is rich in proteins (see Table 1), complex macromolecules and contain a number of chemically linked amino acid monomers, which form polypeptide chains and constitute the primary structure. These structural features can be changed by physical, chemical or enzymatic treatments. Such treatments alter secondary, tertiary and quaternary structures of the proteins without breaking the covalent bonds and lead to protein denaturalization. It is well known that the native structure of protein can be modified to increase the bonding strength of protein based adhesives. Unfolded protein molecules have increased surface area and hence afford improved interaction with substrates.

Table 1. Chemical composition of DBP.

| Chemical Constituent | Percentage (%) |
|---|---|
| Protein | 80 |
| Ash | 10 |
| Moisture | 8 |
| Fat Moisture | 1 |
| Others | 1 |

MATERIALS AND EQUIPMENT

Reactive

DBP was provided by Willmor S.A.

The Merck p.a. sodium hydroxide (NaOH) was purchased.

As antifoam the TEGO Foamex 1488 was used, provided by INTI-Procesos Superficiales.

For the UF adhesive the Coladur Plus by Jucarbe was used.

Instrumental

Industrial stirrer DALV-50 with 0.5 HP.

Anton Paar Rheometer Physica MCR 301 with Concentric Cone of 27 mm diameter geometry.

Hydraulic press Luis Santin model 100T with 7,5HP.

INSTRON 4467 Dynamometer, with 30 kN charge cell.

METHODOLOGY

Viscosity Determination

Skeist[2] stated that all the protein based adhesives present a non-Newtonian flow, viscosity decreases with the increasing sliding speed (Shear Thinning). Therefore, the mechanism for the measurement must cover all the ranges of viscosities without any change in the slip speed. The range of viscosity values have been suggested for different applications by Kumar et al.[3] For absorbent adhesives the viscosity is between 100 to 150 mPa.s (cP) which is the value of a 50% UF adhesive currently used by the local industry. Adhesion depends on the ability of protein to be dispersed in water and the interactions with the substrate (wood). Stefani et al.[4] indicates the dispersion is achieved through the use of chemical agents that break the secondary proteins structure (denature). These include surfactants, urea and NaOH.

Different adhesives were prepared varying DBP concentration from 20 to 40% increasing in 5% at constant alkali concentration of 0.025% by weight, and compared to UF 50% adhesive.

All adhesives were analyzed in a Rheometer with a rotational viscosity curve at 25 ºC. The initial speed was 0,001 $s^{-1}$ and it was gradually increased to 4000 $s^{-1}$. A Concentric Cone of 27 mm diameter geometry (CC27) was used for the measurement. Results were shown in a viscosity versus share rate diagram.

Shear strength adhesion determination

Five replications with pine wood were prepared with the adhesives used for viscosity determination. The samples were applied in a hydraulic press, according to standard specifications[5], at 70 ºC for 60 minutes and 3 MPa of pressure. Finally, samples were removed from press and stabilized for 2 days at 23 ºC ± 2 ºC and 50 ± 2% humidity. The adhesive weight applied was 400 g/m2. Adhesion was register as tension in MPa and plotted as tension versus DBP concentration.

Pot Life Determination

The optimal DBP adhesive, obtained with the Viscosity Determination was prepared and analyzed as same conditions. Viscosity was measured in the Rheometer over 0, 7 and 14 days (DBP D0, DBP D7, and DBP D14) and compared with UF 50%. Results were presented as viscosity versus shear rate.

Five replications with pine wood for the three samples were applied and measured at same conditions that the Shear strength adhesion determination. Results were presented as tension versus time.

RESULTS

Viscosity Determination

Although viscosity at a low shear rate (steady behaviour) is very different between UF and DBP adhesives, at high shear rate (application condition) the adhesives have similar behaviour. DBP 35% present similar viscosity than UF 50% and therefore, same properties during application conditions with spray (see Fig. 1).

It was shown by Lin and Gunasekaran[6] that at low shear rate, high molecular weight protein chains experience Brownian motion. As the shear rate sufficiently increases to overcome the Brownian motion, the proteins chains become more ordered along the flow field and offer less resistance to flow and lower viscosity.

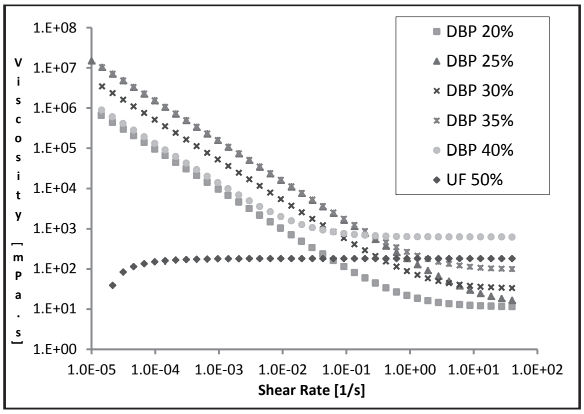


Figure 1. Viscosity curve for UF 50% and DBP adhesives.

Shear strength adhesion determination

All Samples present useful adhesion values although with high dispersion; this is an expected behavior when we used natural raw materials (see Fig. 2). Considering adhesion values and that all the samples presented cohesive failure it was decided to work with the adhesive chosen by Viscosity determination.

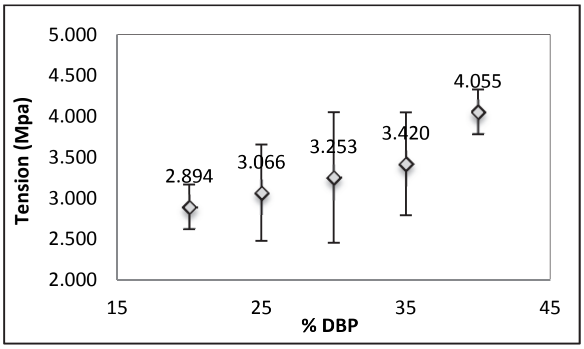


Figure 2. Adhesion of DBP adhesives.

Pot Life Determination

The DBP 35% adhesive was used for this determination (see Table 2) and measured as DBP D0.

All three samples show acceptable adhesion values and wood cohesive failure (see Fig. 3). DBP D7 presents very low viscosity variation and still is an adhesive with desirable rheological behaviour. DBP D14 shows a significant decrease of the viscosity due to alkali reactions which leads to shorter protein chains, leading to an excessive and undesirable water absorption which would make difficult the application process (see Fig. 4).

Table 2. Adhesive formulation with 35% DBP.

| Chemical Constituent | Percentage (%) |
|---|---|
| DBP | 35.0 |
| NaOH 0,5% | 5.0 |
| Antifoam | 0.3 |
| Water | 59.7 |

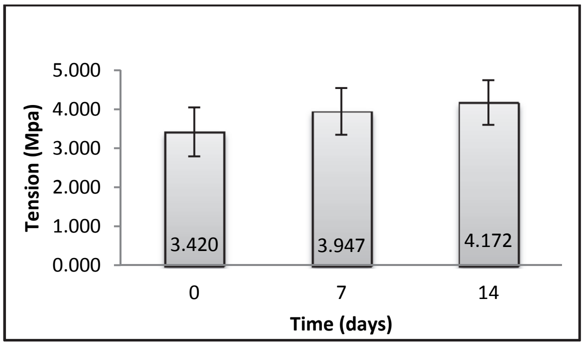


Figure 3. Adhesion versus time for 35% DBP adhesive.

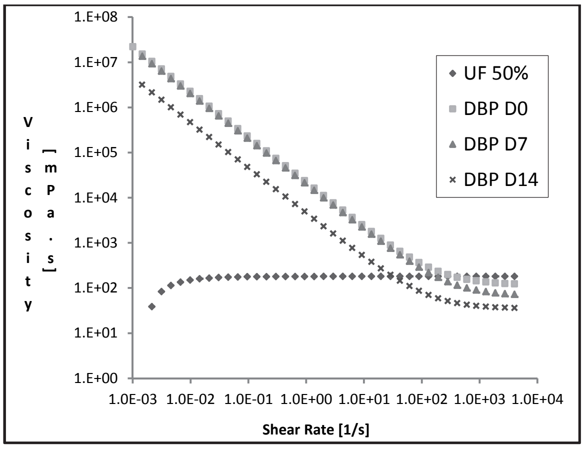


Figure 4. Viscosity curve of DBP at 0, 7 and 14 days.

CONCLUSION

Trough this work, we optimize the DBP percentage in the adhesive formulation, based on their viscosity compared with UF adhesives at application conditions.

The adhesion test allows us to conclude that all the percentages studied present cohesive failure of wood specimens; giving a high performance adhesive for wood industry.

Finally, the pot life determination shows a slight increase in shear strength adhesion within the desired values, but with significant decrease in viscosity, making difficult the application process. Based on the properties analyzed, it was concluded that the useful life of the adhesive is less than 7 days of formulated process.

The viscosity, shear strength adhesion and pot life determination allows us to obtain a zero-emission formaldehyde adhesive as a renewable and environmentally friendly alternative for wood industry.

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