Proposing an Improved Polyvinyl Acetate Based Wood Glue

Elijah DeYoung and Michael Korn, Ph.D.

LIBERTY UNIVERSITY

Background

Polyvinyl acetate (PVAc) (Figure 1) is the base compound in all types of wood glues ranging from crafting glues to commercial grade adhesives. The bonding mechanism of this polymer utilizes the formation of innumerable of hydrogen bonds across a wood surface [1]. The glue is applied in an aqueous form, and as the water evaporates, the carbonyl groups in the PVAc form hydrogen bonds with the hydroxyl groups of the complex matrix of cellulose, hemicellulose, and lignin [2] (Figure 3) across the surface. These hydrogen bonds, while strong under the right conditions are limited in their ability to withstand increased temperatures and humidity conditions. Due to this limitation, there have been several differing strategies to increase the efficacy of PVAc based glues utilizing either additives or cross-linking methodologies, each coming with its own benefits, as well as its limitations. Two of the most successful additive processes involved mixing the PVAc glue with either melamine glue (Figure 4)1 or cellulose nano particles [3] (Figure 5). The additions of these substrates improved both the ability of the bonded joints to withstand increased shear strength in comparison to unadulterated PVAc glue, as well as improved thermostability. However, in the addition of these additives, while both were successful in their purpose, varied in their molecular interaction. The melamine-based glue additives increased the crosslinking interactions between the PVAc and the wood, as well as decreasing the formaldehyde emission from the melamine glue [1], whereas the cellulose nano particles were intended to be an environmentally friendly reinforcer of the polymeric matrix of the adhesive [3].

Research Question

Is it possible for a combination of adding both melamine and cellulose nanoparticles to compound the efficacy of a single glue in comparison to glues with only one of those additives?

Research Methods

Two databases were used as the foundation of the research: CAS SciFinderⁿ and ScienceDirect. In the CAS SciFinderⁿ database, using the Boolean operators "chemistry AND polyvinyl acetate AND wood glue", 65 articles were generated with publishing dates between 1936-present day [4] (Figure 9). There were four different types of articles generated in this search [4] (Figure 6). In the ScienceDirect database, the Boolean operators "polyvinyl acetate AND wood glue AND durability" were used, generating a total of 81 research articles along with various other literature mediums such as reviews, books, conference information, etc. This database yielded results from 1979-present day [5] (Figure 10). One of these articles is displayed in Figure 8. This article comes from a study done in Canada, a nation with 7.7% evangelicals [6]. As displayed from both databases, the popularity of the subject has greatly increased over time, reaching a climax between 2010-2020. The second portion of the research was determining the market value of the chosen topic. Wood glue is clearly an extremely popular product worldwide, being used in a great multiplicity of places and industries every day. To give a glimpse into this, the finish carpentry industry in the US alone is worth over 15 billion USD in revenue per year [7], containing over 87,000 employees [8] who each use wood glue on a regular or semi-regular basis. Furthermore, *Titebond*®*, one of the most popular industry brands of wood glue generates over 26 million USD in revenue per year [9].

*Listing of brand names are employed for illustration purposes only and do not constitute an endorsement or approval of the same by the authors or by Liberty University

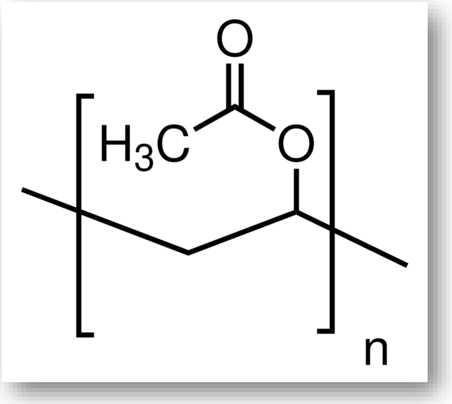

Figure 1. Polyvinyl acetate (portion) [13]

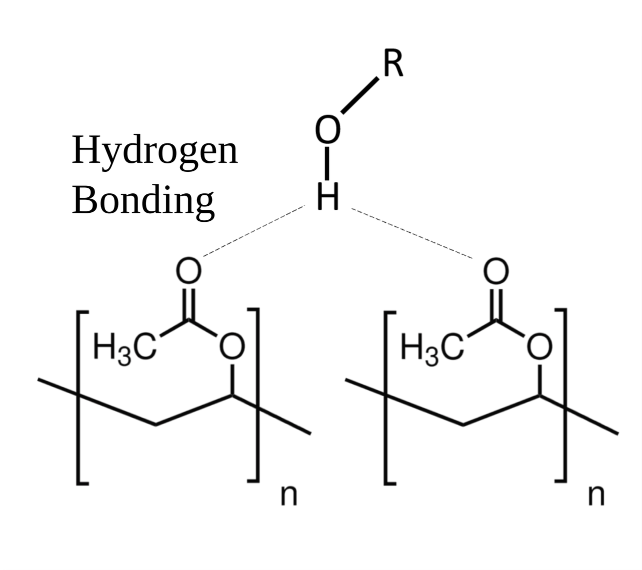

Figure 2. Hydrogen bonding of PVAc glues, modified from [13]

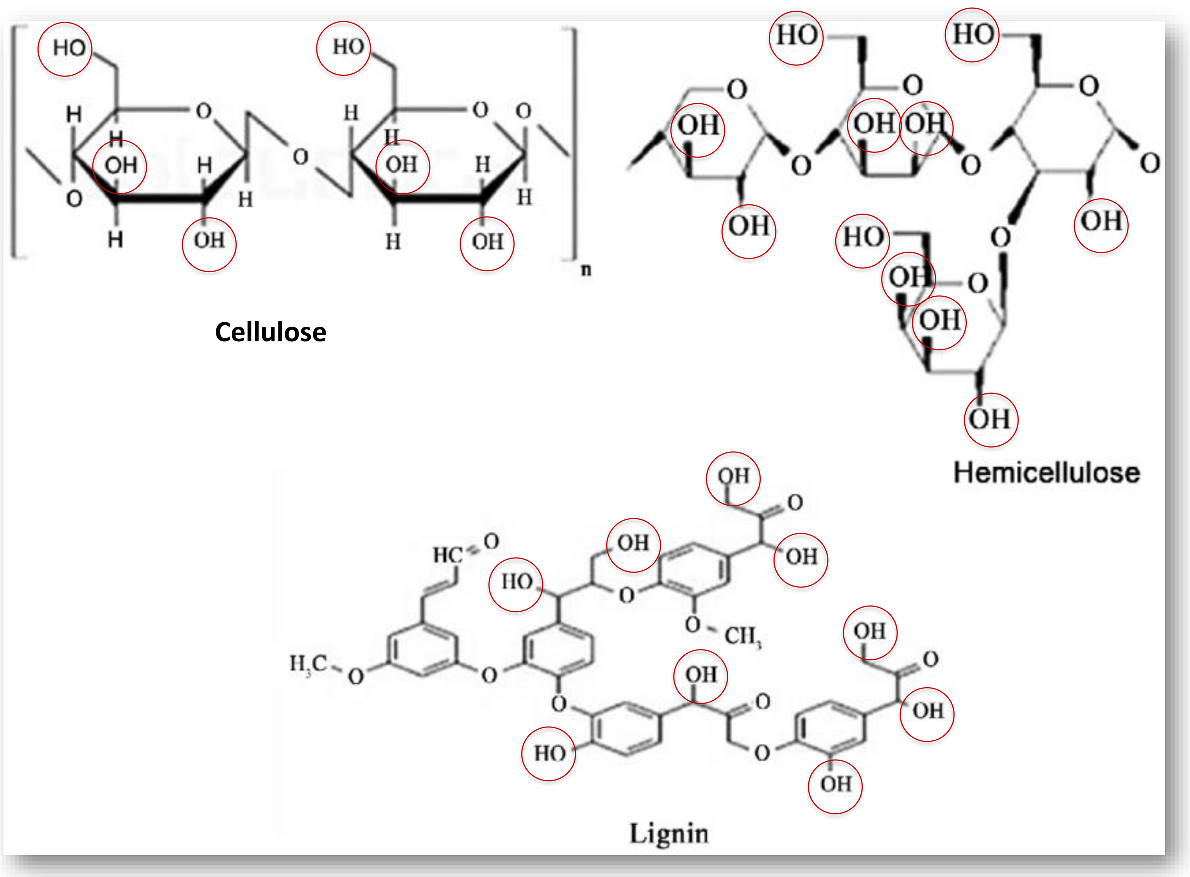

Figure 3. Primary compounds of wood surface (portions), modified from [12]; hydroxyl groups have been circled

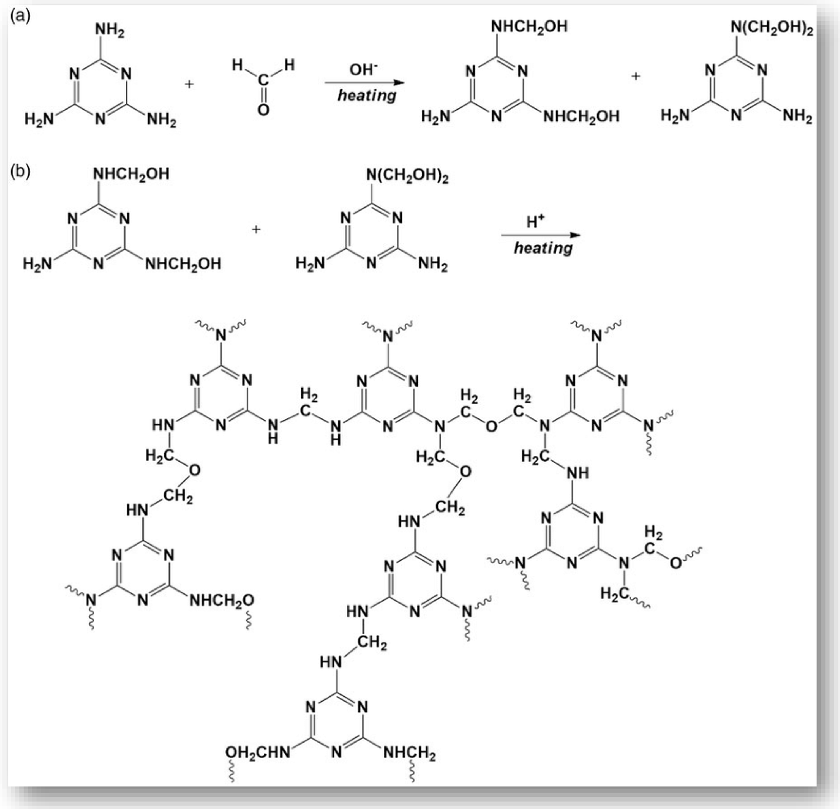

Figure 4. Formation of melamine-formaldehyde resin [12]

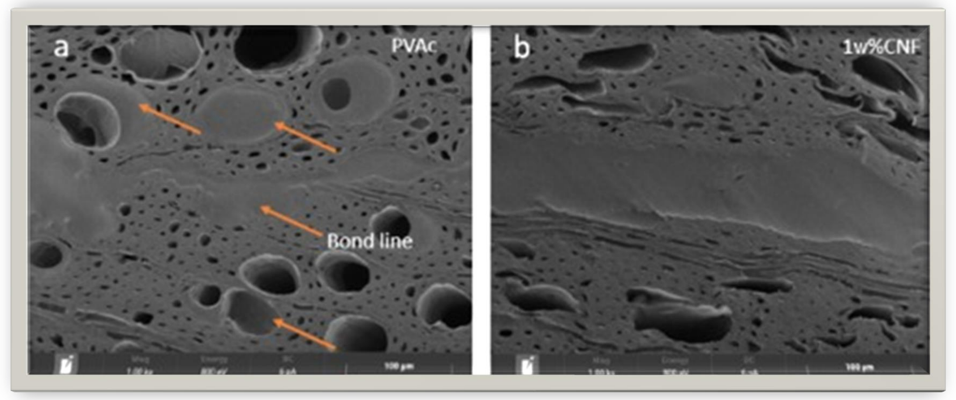

Figure 5. Comparison of glue without (a) and with (b) nanoparticle addition [3]; arrows represent the bond lines/areas

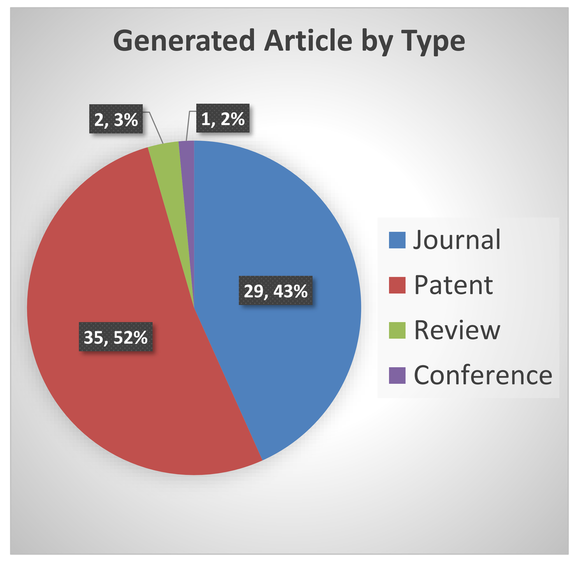

Figure 6. Scifinder topical literature [4]

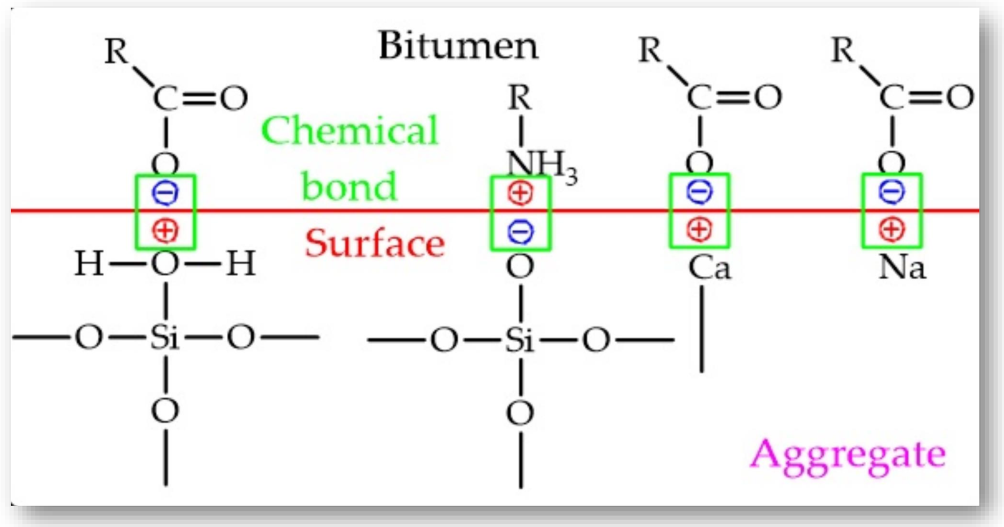

Figure 7. Chemical interactions of bitumen with aggregate systems [11]; interactions exemplified with silicate systems

International Journal of Adhesion & Adhesives

Improving performance of polyvinyl acetate (PVA) as a binder for wood by combination with melamine based adhesives

Alireza Kaboorani, Bernard Riedl*

Figure 8. First page of leading article [1]

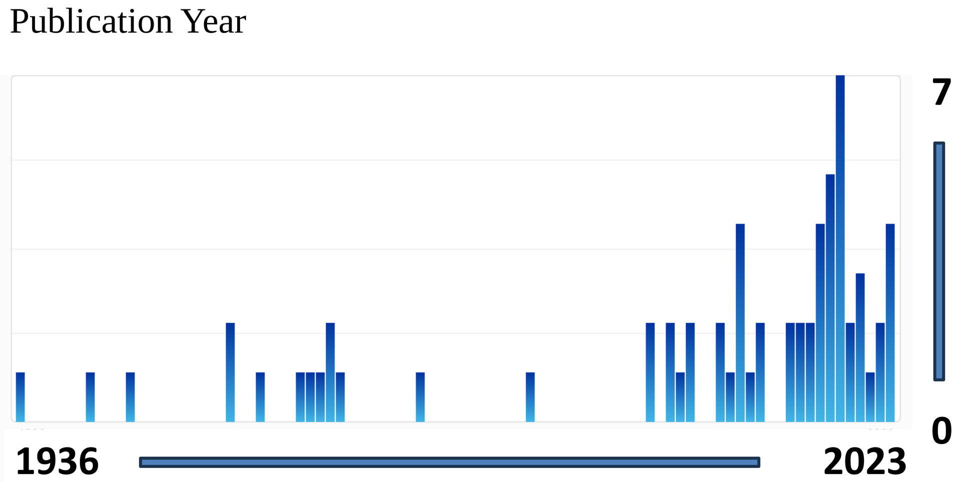

Figure 9. Result literature from Scifinder database [4]

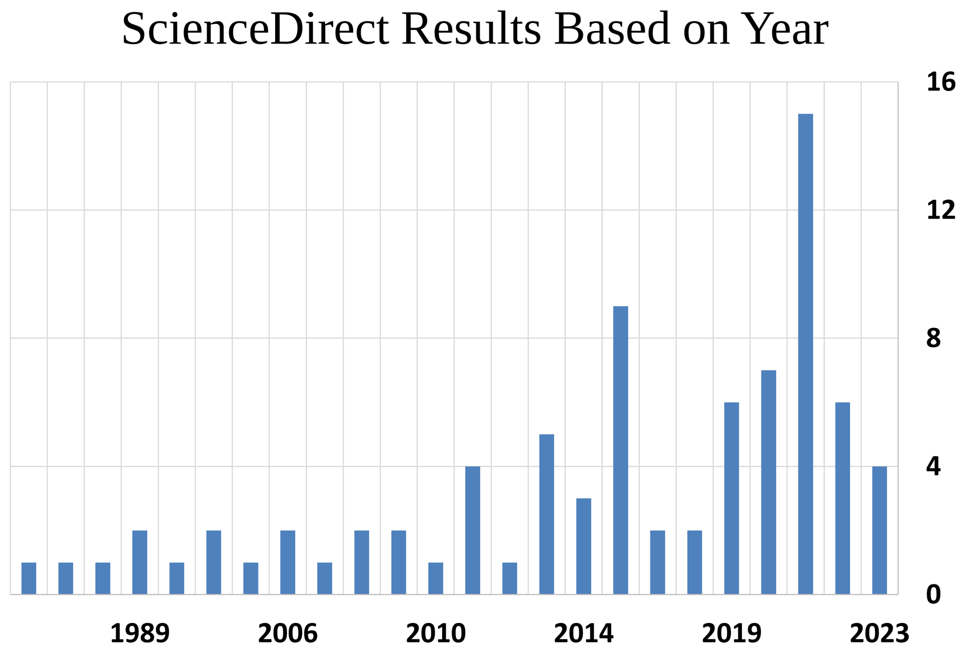

Figure 10. Result literature from ScienceDirect database [5]

Results and Conclusions

While wood glue specifically may not be explicitly mentioned within the pages of Scripture, a chemically similar derivative of it is. In Gen 6:14, God instructs Noah to "Make for yourself an ark…cover it inside and out with pitch." This pitch is most closely analogous in modern science to asphalt, coal tar, or bitumen [10]. This material is characterized by a long series of hydrocarbons. While most of this substrate is non-polar, the bitumen also contains several heteroatomic ends, such as O, S, or N, giving polar regions to interact with the polar ends on a contacted aggregate surface [11] (Figure 7). This interaction of polar ends mirrors the hydrogen bonding interactions of PVAc glue. Even in this scenario is seen the glories of God's creation. Whether in the case of Noah building the ark, or the man-made wood glues utilizing polyvinyl acetate, the foundational chemistry is the same: The interaction of polar groups with other polar aggregates, creating a stable and complex matrix. The theory of polar chemistry also demonstrates a key biblical principle. In polarity chemistry, polar groups can only, and must, interact with other polar groups, it is their nature. In the same way, those whom God has called to himself will, and must, be tied to Him. They cannot loosen themselves from Him and be subject to the world any more than a polar group can simply loosen itself to be bonded to a non-polar group. John 10:27-28, "My sheep hear my voice, and I know them, and they follow me. I give them eternal life, and they will never perish, and no one will snatch them out of my hand."

Future Work

To test the research question, a comparative test would be carried out with the following parameters. There would be 3 control groups: PVAc glue, an 85/15% PVAc/melamine glue [1], and a PVAc glue treated with 1% cellulose nanoparticles [3]. These would be compared against the test group: an 85/15% PVAc/melamine glue treated with 1% cellulose nanoparticles. All four glues would then be used to bond the same type of wood joint using maple (a common finish cabinet industry wood). These joints would be allowed to cure, then tested using a hydraulic shear force test at room temperature. Fresh samples would then be tested at elevated temperatures with the same hydraulic test. Next, fresh samples would be soaked in water for 24 hours, then tested for the shear force under elevated moisture conditions. Finally, A thermogravimetric test would be run to test the thermal stability of the glues. This experiment would be done in triplicates to improve analytical accuracy. The total time necessary to perform all these experiments efficiently would be 2-3 weeks, due to the extended time necessary to properly treat each glue sample with the additive substrate.

References and Acknowledgements

1. Kaboorani, A., & Riedl, B. (2011). Improving performance of polyvinyl acetate (PVA) as a binder for wood by combination with melamine based adhesives. *International Journal of Adhesion and Adhesives*, *31*(7), 605-611. 10.1016/j.ijadhadh.2011.06.007
2. Rowell, R.M. Understanding Wood Surface Chemistry and Approaches to Modification: A Review. Polymers **2021**, 13, 2558. https://doi.org/ 10.3390/polym13152558
3. Kamboj, G., Gaff, M., Smardzewski, J., Haviarová, E., Hui, D., Rezaei, F., & Sethy, A. K. (2022). Effect of cellulose nanofiber and cellulose nanocrystals reinforcement on the strength and stiffness of PVAc bonded joints. *Composite Structures*, *295*, 115821. 10.1016/j.compstruct.2022.115821
4. CAS SciFinderⁿ. Accessed 7 March 2024
5. ScienceDirect. Accessed 7 March 2024
6. https://operationworld.org/locations/canada/: Accessed 29 February 2024
7. https://my.ibisworld.com/us/en/industry/33711/at-a-glance. Accessed 29 February 2024
8. https://www.zippia.com/cabinet-maker-jobs/demographics. Accessed 29 February 2024
9. https://www.zoominfo.com/c/titebond/50659417. Accessed 29 February 2024
10. https://answersingenesis.org/Creationism. Accessed 7 March 2024
11. Pstrowska, K.; Gunka, V.; Sidun, I.; Demchuk, Y.; Vytrykush, N.; Kułażyński, M.; Bratychak, M. Adhesion in Bitumen/Aggregate System: Adhesion Mechanism and Test Methods. *Coatings* **2022**, *12*, 1934. https://doi.org/10.3390/coatings12121934
12. https://www.researchgate.net/figure. Accessed 7 March 2024
13. https://www.sigmaaldrich.com. Accessed 7 March 2024