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The Impact of Crosslinking Polyvinyl Alcohol with Glutaraldehyde on Toughness: A Statistical Analysis Using the Turnkey HSD Method

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Abstract

The widespread use of non-biodegradable polymers exacerbates problems with global warming and other environmental difficulties. These problems necessitate the development of biodegradable polymers as a solution. In this research, we analyze the utilization of crosslinked polymer by its processing of polyvinyl alcohol (P V A) crosslinked with glutaraldehyde (G L U T). After curing for 24 hours in 2 moles of sulfuric acid (H2SO4), the plasticized alcohol has been cross-linked from 0 % to 4 0 % by volume of glutaraldehyde. The Shore D hardness of P V A and P V A cross-linked G L U T polymer composites was measured using an Excel Durometer by ASTM D2240 standards. The polymer's hardness is increased by as much as 15% thanks to the crosslinking effect of glutaraldehyde, and minor further improvements are discovered. The Tukey HSD test determines the cutoff for statistical significance and the optimal crosslinking percentage. Tukey's test for multiple comparisons indicates that a f value greater than 5.35 is statistically meaningful.This study focuses mainly on the significant improvement in the hardness of polyvinyl alcohol (PVA) when crosslinked with glutaraldehyde. The research found that the hardness of the polymer improved by up to 15% due to glutaraldehyde crosslinking. This study also suggests a research investigation into the effects of crosslinking polyvinyl alcohol (PVA) with glutaraldehyde on the toughness properties of the material. The widespread use of non-biodegradable polymers has raised concerns related to global warming and environmental issues. To address these challenges, biodegradable polymers are essential. In this study, we focus on polyvinyl alcohol (PVA) crosslinked with glutaraldehyde (GLUT) and investigate the hardness of the resulting crosslinked polymer.

Keywords: Glutaraldehyde, Polyvinyl alcohol, Hardness, Tukey HSD method, Crosslinking.

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INTRODUCTION

Biopolymers and natural fiber composites are being developed to replace petroleum-based, non-biodegradable polymers [1-3]. There are emerging signs that processing man-made materials' behaviour over the past decades may have contributed to climatic shifts [4]. PVA allows for the creation of eco-friendly, thermally stable products. PVA-based polymers have been the subject of extensive study for use in the packaging industry, biomedical implants, and civil and structural applications [5, 6]. PVA is a promising polymer because of its useful biodegradable properties. Due to their high cost and slow breakdown, PVA materials are limited in application, especially anaerobically [7]. Given these limits, PVA is often combined with

other affordable biodegradable polymers to improve tensile strength, elongation at break, and toughness [8, 9]. Biodegradable composites bonded with natural and synthetic fibres ease disposal problems. The development and characterization of biopolymer films and their composites have attracted the attention of many researchers [10, 11].

Theresa et al. [12-16] found that P V A composites with Cloisite Na+, Nanofil (NF), and Cloisite (30B) fillers made of morgillonite had the lowest water absorption. The rate was detected. Please be quiet.Researchers [17–20] created lignin/PVA nano-composite fibres with excellent functional and ecological qualities by changing lignin amounts during electrospinning. Jin and Seungsin [21-22] found that P V A nano-fibre membranes with an Extract of Coptidis Rhizome could provide antibacterial treatments that work for wounds. Jagadish et al. evaluated a DAHP – P VA proton-conducting solid polyelectrolyte film [23]. In solution-cast samples, nanofillers improved the physicochemical parameters of the D A H P / P V A composite.

Shad et al. [24] discovered that PVA-enhanced Al_2O_3 nanoparticles exhibited better thermalcharacteristics. PVA and AL_2O_3 nano-particles O-H groups form strong hydrogen bonds with the polymer matrix. Noretal used electrospinning. [25] to study Fe_2O_3-doped polyvinyl alcohol nanoparticle mechanical characteristics. The modulus response was evaluated using nanoparticle content, voltage, flow rate, rotating distance, and speed. According to this research, a P V A filler content of about 9% enhances mechanical strength. Jibril et al. [26] found that ozone treatment improved nano-particle dispersion and interfacial adhesions in nanocomposites made of single-walled carbon nanotubes. Standard vacuum-assisted pressure compression can crosslink PVA with GLUT at different volume fractions, according to the report.

The focus and scope of this study suggest a research investigation into the effects of crosslinking polyvinyl alcohol (PVA) with glutaraldehyde on the toughness properties of the material. Polyvinyl Alcohol (PVA): PVA is a polymer widely used in various applications due to its excellent film-forming, adhesive, and mechanical properties. Glutaraldehyde: Glutaraldehyde is a chemical compound commonly used as a crosslinking agent in polymer chemistry. Crosslinking refers to the formation of covalent bonds between polymer chains, which can enhance the mechanical properties of the material. Toughness: Toughness is a material property that measures its ability to withstand impact without fracturing. It is an important characteristic in applications where materials may experience sudden or repeated stress. Statistical Analysis: The study involves statistical analysis to quantify and understand the effects of cross-linking on the toughness of PVA. The Turnkey HSD (Honestly Significant Difference) method is mentioned, indicating a specific statistical approach used in the analysis. Scope: The scope of the study likely includes experimental work to crosslink PVA with glutaraldehyde under different conditions (such as concentration, reaction time, temperature, etc.). The resulting materials would then be tested for toughness using appropriate methods (e.g., impact testing). Statistical analysis would be performed to determine any significant differences in toughness between crosslinked and non-crosslinked PVA samples. Overall, this study aims to provide insights into the relationship between crosslinking with glutaraldehyde and the toughness of PVA, utilizing statistical methods to analyze the data and draw meaningful conclusions. It could have implications for various fields, including materials science, polymer chemistry, and engineering, where PVA-based materials are utilized.

SUBSTANCES AND TECHNIQUES

Substances

P V A and G L U T. P V A (CH_2CH (OH)) n is an ecological medium mass-based molecular material of 85, 000 – 1, 24, 000 g / mol and hydroxylation of 87 - 89. At 20 °C, 4% aqueous solutions have varied viscosities. Centipoise (Cps) is 23–38, pH is 4.5–6.5, and ash can reach 0.75 per cent. The melting and steaming points are 200 and 228 °C. The density of P V A is 1.19 g / cm3. The water density of 25% glutaraldehyde (OHC (CH2) 3CHO) is 1.06 g/cm3. From translucent, odorous liquid, glutaraldehyde solidifies swiftly into a glossy polymer,[26] setting the plastics industry's odour entry at 0.04 p p m.

Composite polymer processing

By volume, vacuum compression mounding crosslinks polyvinyl alcohol with 0–40% glutaraldehyde. Polymer composites are post-cured at 6 0 °C in a conventional air oven for 24 hours and submerged in 2 moles of H2SO4 to crosslink.

Techniques

Hardness

Excel Shore D Durometer Hardness testers examined P V A and P V A – cross linked G L U T composites. The process followed A S T M D 2 2 4 0. Durometers can measure the hardness of polymers and polymer composites. A predefined indentor determines how deep the material can be pressed in the lab. As the P V A/P V A – G L U T polymer storage modules' hardness dropped by over 30°C, the testing environment was kept between 25 and 28 degrees Celsius. Five trials were run on a 2 m x 2 m x 4 m m sample. P V A / P V A – G L U T polymer is put on a flat, solid ground. The indentor is pressed into the sample after checking its perpendicularity. Analogue indicators measure hardness.

ANOVA

An examination of differences was used to contrast the mean values of P V A and P V A – G L U T composites crosslinked to see if there was a statistically considerable dissimilarity. When large-impact outliers are taken into account, the p-value drops to 0.05. Tukey's honestly noticeable contrast (H S D) test was performed to analyze the effect of GLUT concentration on hardness. (i) If the p-value is minor enough, the null hypothesis can be considered rejected when studying the effect of a variable. (ii) The null hypothesis is accepted if the p value is small. When investigating the impact of crosslinking on hardness, it is helpful to look at both group averages and differences between groups.

Table 1 displays the findings of a study that compared the hardness of P V A, and P V A Cross-linked G L U T by increasing the weight percentage of G L U T in P V A at intervals of 5%. In Table 1, "A" represents the "neat PVA" treatment, which is regarded as the "first independent treatment," and "B" means the "second independent treatment," and so on.

The addition of GLUT to PVA increases its significance, as shown by the one-way ANOVA results in Table 2 (where a P rate of less than 0. 05 indicates a considerable dissimilarity between treatments). When the P-value is close to 1, it means that the level of significance is low. The importance is only mild if the P value is between 0 and 1. The value of the test statistic F (128.620918) is beyond the 95% confidence interval ([-: 2.2085]). The impact size that was measured is quite sizable (5.35). That suggests a sizable gap exists between the two mean values. In this case, 2=0.97. It indicates that 96.6% of the variation from the mean can be attributed to the group as a whole. The S E value is 0.4 4 9 6 9 1 1 8 4, and the critical mean value is 2 . 0 9 6 8 1 5 2 5 2, as calculated using the Tukey HSD technique.

Table 3 shows that GLUT has a large effect on the mechanical characteristics of P V A, with a high significance level. The plastic component might be to blame for this. This may also result from crosslinks, which are linkages (atoms, electrons, or ions) between the polymer's many lengthy backbones. Therefore, the connected chain is strengthened in all three dimensions to withstand dragged, slid, or snapped throughout its length. This could be because of the elevated hydroxyl group concentration on the side cuffs of P V A, which causes the molecule to crosslink with itself. It is also evident that the mobility of the chains is diminished due to crosslinking due to the development of bonds between the chains. The chain's decreased mobility prevents it from flowing from neighbouring chains when the mass deforms. External stresses disrupt chemical bonds to "bend" the chain, and small deformations limit its mobility. Due to entanglement, the chains in pure PVA materials make it impossible for the modules to flow with each other, so they must be driven. Crosslinking, in contrast to entanglement, results in a stiffer and less fluid mass. Treatments are statistically significant if the f value exceeds 5.35, as seen in Table 4 and Figure 1. This indicates that the following pairs are statistically

distinct using the Tukey HSD test method: Alphabet letters: (A – B), (C – D), (E – F), (G – H)

Table1. Comparison of GLUT concentrations in PVA volumes yielding five different hardness outcomes.

Treatment	Neat PVA (A)	PVA-5% GLUT(B)	PVA-10% GLUT(C)	PVA-15% GLUT(D)	PVA-20% GLUT(E)	PVA-25% GLUT(F)	PVA-30% GLUT(G)	PVA-35% GLUT(H)	PVA-40% GLUT(I)
Input Data/Hardness results for five trials	60.0	69.0	71.0	74.0	73.0	75.0	76.0	75.0	74.0
	59.0	68.0	70.0	72.0	76.0	74.0	75.0	76.0	75.0
	61.0	70.0	69.0	75.0	76.0	75.0	76.0	75.0	76.0
	59.0	71.0	70.0	74.0	75.0	76.0	75.0	74.0	74.0
	60.0	69.0	68.0	75.0	74.0	74.0	74.0	75.0	75.0

Table2. Comparison of PVA and P V A – G L U T composites using analysis of variance.

Basis	D F	Square summed	Statistical Centre	F sign	P-rate
Group (group to group)	8.00	1040.4	130.05	128.6209179	0
Fault (amongst themselves)	36.00	36.399989	1.0111108		
sum	44.00	1076.7999	24.472727		

Table 3. Significant difference between volume % crosslinking treatments.

Pair	Disparity	Q	Minor CI	Higher CI	P-rate	Important level
(A – B)	9.6	20 .347983	6.5031847	10.696815	6.043365e-12	lofty
(A – C)	9.8	20 .792733	6.7031847	10.896815	6.042255e-12	lofty
(A – D)	14.2	30 .577225	11.103184	15.296815	5.041145e-12	lofty
(A – E)	15 .0	32.356224	11.903184	16.096815	6.041145e-12	lofty
(A – F)	15 .0	32 .356224	11.903184	16.096815	6.041145e-12	lofty
(A – G)	15.4	33.245723	12.303184	16.496815	6.041144e-12	lofty
(A – H)	15.2	32 .800973	12.103184	16.296815	6.041145e-12	lofty
(A – I)	15 .0	32 .356224	11.903185	16.096815	6.041144e-12	lofty
(B – C)	0.2	0. 3447496	-0.8968152	1.2968152	0.9999944	lofty
(B – D)	4.6	9 .229242	1.5031848	5.6968152	4.532509e-7	middle
(B – E)	5.4	11 .008240	2.3031847	6.4968152	0.404391e-8	middle
(B – F)	5.4	11 .008240	2.3031848	6.4968152	0.404391e-8	middle
(B – G)	5.8	11.897740	2.7031847	6.8968152	0.394687e-9	middle
(B – H)	5.6	11.452990	2.5031847	6.696812	4.761889e-9	middle
(B – I)	5.40	11.008240	2.3031847	6.4968152	0.404394e-8	middle
(C – D)	4.40	8 .7844924	1.3031847	6.4968152	0.00000141754	middle
(C – E)	5.20	10 .563491	2.1031847	6.2968152	2.463939e-8	middle
(C – F)	5.20	10 .563498	2.1031847	6.2968152	2.463939e-8	middle
(C – G)	5.60	11 .45204	2.5031847	6.6968152	4.761889e-9	middle
(C – H)	5.40	11 .008240	3.3031847	6.4968152	0.404394e-8	middle
(C – I)	5.20	10 .563491	3.1031847	6.2968152	2.463939e-8	middle
(D – E)	0.80	0 .5789986	-0.2968152	1.8968152	0.9369163	little
(D – F)	0.80	0 .7789986	-0.2968152	1.8968152	0.9369163	little
(D – G)	1.20	1 .6684979	-1.8968152	2.2968152	0.6265137	little
(D – H)	1 .00	1 .2237482	-2.0968152	2.0968152	0.8128950	little
(D – I)	0.80	0 .7789986	2.2968152	1.8968152	0.9369163	little
(E – F)	0 .00	0.00	-3 .0968152	1.0968152	1.00	little

(E – G)	0.40	0.8894993	-2 .6968152	1.4968152	0.9992971	little
(E – H)	0.20	0.4447496	-2 .8968152	1.2968152	0.99999634	little
(E – I)	0 .00	0.00	-3 .0968152	1.0968152	1.00	little
(F – G)	0.40	0.8894993	-2.6968152	1.4968152	0.999297	little
(F – H)	0.20	0.4447496	-2.8968152	1.2968152	0.9999963	little
(F – I)	0 .00	0.00	-3.0968152	1.0968152	1.00	little
(G – H)	0.20	0.4447496	-2.8968152	1.2968152	0.9999963	little
(G – I)	0.40	0.8894993	-2.6968152	1.4968152	0.999297	little
(H – I)	0.20	0.4447496	-2.8968152	1.2968152	0.9999963	little

Table 4. Tukey's honestly noticeable dissimilarity test for P V A volumes with various G L U T concentrations.

Set	B	C	D	E	F	G	H	I
A	8 .60	8.80	13.20	14.00	14.00	14.40	14.20	14.00
B	0 .00	0.20	4.60	5.40	5.40	5.80	5.60	5.40
C	0.20	0.00	4.40	5.20	5.20	5.60	5.40	5.20
D	4.60	4.40	0.00	0.80	0.80	1.20	1.00	0.80
E	5.40	5.20	0.80	0.00	0.00	0.40	0.20	0.00
F	5.40	5.20	0.80	0.00	0.00	0.40	0.20	0.00
G	5.80	5.60	1.20	0.40	0.40	0.00	0.20	0.40
H	5.60	5.40	1.00	0.20	0.20	0.20	0.00	0.20

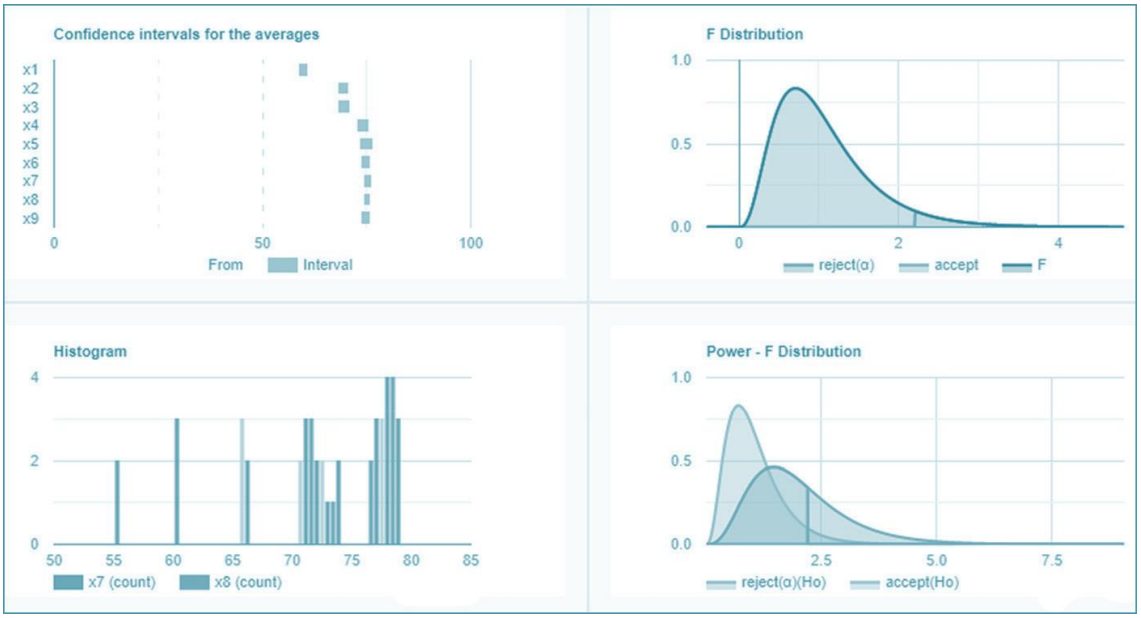

Figure1. Power F sharing, Histogram, and the average of the confidence intervals for the distributions.

It goes as follows: (A – I), (B – D), (B – E), (B – F), (B – G), (B – H), (B – I), (C – D), (C – E), (C – F), (C – G), (C – H), (C – I). The hypothesis is rejected as an alternative if the priori power is below 0.3502. The population's variations are evenly distributed after careful analysis. Levene's test power was low (0.35), and the p-value was high (0.944).

CONCLUSIONS

The hardness of polyvinyl alcohol cross-linked with glutaraldehyde at concentrations ranging from 0 to 40% by volume was measured.The results are summarized as follows:

- Glutaraldehyde crosslinking in polyvinyl alcohol enhanced the polymer's mechanical characteristics.
- When submerged in a 2-mole sulfuric acid solution, the crosslinked polymer outperforms the other polymer regarding its physical qualities.
- Adding up to 15% glutaraldehyde to polyvinyl alcohol resulted in a noticeable increase in hardness.

After analyzing the treatment differences, Tukey's HSD test confirmed the significance of the crosslinking between the groups. As for the future scope, the degree of crosslinking of the PVA membrane can be easily changed by controlling the reaction variables, which means that the properties of the resulting material can be tailored for specific applications. For example, the crosslinking process could be optimized to create a material with improved toughness and durability for use in harsh environments. Additionally, the use of crosslinked PVA in the development of new membrane-based technologies, such as water treatment and gas separation, could be explored. Moreover, the effect of crosslinking on the hydrophilicity and mechanical strength of the PVA membrane is an area that requires further investigation. This could lead to a better understanding of how the crosslinking process affects the properties of the material, and ultimately, to the design of new materials with improved performance.

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