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Statical Significant Analysis of Hardness of Poly Vinyl Alcohol Crosslinked Glutaraldehyde using Turnkey HSD Method

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Abstract

The non-biodegradable polymer occupying the world leads to many issues concerning global warming and other related problems. Due to these issues, there is a need for biodegradable polymers to overcome these issues. This paper focussed on processing polyvinyl alcohol (PVA) crosslinked with glutaraldehyde (GLUT) and studying the harness of crosslinked polymer. The polyvinyl alcohol is crosslinked from 0 to 40 volume per cent of glutaraldehyde than post cured immersed in 2 mole of sulfuric acid (H_2SO_4) for 24 hours to attain complete crosslinking. The Excel Durometer Shore D Hardness tester was used to determine the hardness of PVA and PVA crosslinked GLUT polymer composites as per ASTM D2240 standards. The influence of glutaraldehyde crosslinking drastically improves the polymer's hardness by up to 15%, and further marginal changes are found. The Tukey HSD method is used to study the significant level and accomplish the optimum crosslinking percentage. From the Tukey HSD test, it is found that the f value more than 5.35 are high level statically significant.

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

1.0 Introduction

Non-biodegradable wastes such as pesticides gradually accumulate at each nutritional stage and damage the organism. Non-biodegradable materials such as plastics release toxic chemicals to the environment that, when burned, can lead to air pollution. It causes water, land air and soil pollution. Non-biodegradable wastes such as pesticides gradually accumulate at each nutritional stage and damage the organism. Non-biodegradable materials such as plastics release toxic chemicals to the environment that, when burned, can lead to air pollution. It causes water, land air and soil pollution. Global warming is a major sustainability issue. Human activity that contributes to climate change is unsustainable by definition as it transforms the planets on which we depend for all needs. However, climate change also makes sustainable solutions to other problems more difficult. In recent years, studies have confirmed that PVA does not adversely affect environmental health when water treatment facilities are available due to sustainability issues. The water treatment plant contains the appropriate micro-organisms to completely decompose the material. Today, the world is involved in the use of environmentally friendly materials such as soyabean oil-based resins, cellulose fibers, polylactic acid (PLA), PVA-based fibers and their mixtures in the building materials, automotive parts, and civilian fields. more and more focused. And construction [1-5]. PVA applications also work significantly with biomedical

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devices such as interfering screws, ligament-attaching studs, meniscal repairs, suture anchors, rods, and pins [6]. The search for new biomaterials in this regard is extremely diverse and powerful. The use of biomaterials helps reduce the greenhouse effect. Maya and Thomas [7] conducted a survey in 2008 and reported that biomaterials play an important role in reducing environmental hazards. Imre et al. [8] found that the use of blended biopolymers showed a dramatic increase since 2010 as they showed better performance compared to the base material. Parina's et al. [9-15] conducted studies on polyvinyl alcohol (PVA) and polyvinyl alcohol/polyvinyl pyrrolidone (PVP) biomedical foams prepared by high-speed mechanical mixing and lyophilization processes. From this study, PVA80/20PVP foam showed greater flexibility than pure PVA. This may be due to the uniformly open pore structure of the produced material. Reindeer boat. Al. [10-18] studied the static and dynamic mechanical properties of ultra-high performance concrete reinforced with PVA fibers. This study shows that PVA fiber concrete has relatively good ductility, toughness, and deformability compared to reinforced concrete under static load conditions. Theresa et al. [19-23] studied the effects of Cloisite Na +, Nanofil (NF), and Cloisite (30B) montmorillonite fillers on PVA, and composites with organically modified montmorillonite had the lowest water absorption compared to the base material. Found to show a rate. Eun siletal. [24-26] worked on lignin / PVA nano-composite fibers by varying the concentration of lignin developed by electrospinning and concluded that PVA nano-composites are highly functional and environmentally friendly. Jin and Seungsin [27-28] have shown that polyvinyl alcohol nano-fiber membranes containing Coptidis Rhizoma extract have considerable potential for ensuring effective antibacterial wound dressings. Jagadish et al. [29] conducted an experiment on a proton-conducting solid polyelectrolyte film composed of diazonium hydrogen phosphate (DAHP) and PVA. Samples were prepared by a solution casting process and it was observed that the addition of nanofillers improved the physicochemical properties of the DAHP / PVA composite.

Shad pour et al. [30] observed that the enhancement of Al_2O_3 nano-particles by PVA leads to improved thermal properties. In addition, the nano-particles in the polymer matrix show strong hydrogen bonds between the O-H groups of PVA and the O-H groups of AL_2O_3 nano-particles. Noretal. [31] used electrospinning to study the mechanical properties of polyvinyl alcohol nano-particles filled with ã-Fe_2O_3 nano-particles. To understand the modulus response, five variable input elements were considered: nano-particle content, voltage, flow rate, distance of rotation, and speed of rotation. From this study, about 9% of the filler content of PVA showed improved mechanical properties. Jibril et al. [32] studied the effects of single-walled carbon nano-tube nano-composites and found that the inclusion of ozone treatment improved the dispersion of nano-particles and their interfacial adhesions. PVA is crosslinked with GLUT for different volume fractions using conventional vacuum-assisted pressure compression methods as discussed in paper.

2.0 Materials and methods

a. Materials

PVA and GLUT are supplied from Leo Chem India, Bangalore, India. PVA (CH_2CH (OH)) n is used as a biodegradable matrix material with a molecular weight of 85,000-124,000 g/mol and a degree of hydroxylation of 87-89. The viscosities of 4% aqueous solution at 20°C vary. 23-38 Cps (centipoise), pH varies from 4.5 to 6.5, and ash content is up to 0.75%. Melting points and boiling points are 200°C and 228°C, respectively. The density of PVA is 1.19 g/cm³. Glutaraldehyde (OHC (CH_2) 3CHO) is a 25% aqueous solution with a density of 1.06 g/cm³. Glutaraldehyde is a colourless liquid with a pungent odor that quickly becomes a shiny polymer. According to the Society of the Plastics Industry Inc, the odor threshold is 0.04 ppm (parts per million).[33].

b. Processing of polymer composites

The polyvinyl alcohol is crosslinked from 0 to 40 volume percentage of glutaraldehyde using vacuum compression mounding method. The prepared polymer composites are post-cured for 24 hours at 60°C using conventional air oven, and then immersed in 2 mole of sulfuric acid (H_2SO_4) for 24 hours to attain complete crosslinking.

c. Methods

Hardness

The Excel Durometer Shore D Hardness tester was used to determine the hardness of PVA and PVA crosslinked GLUT polymer composites. The test was conducted as per ASTM D2240 standards. Durometer hardness is used to determine the relative hardness of soft materials, usually plastic and polymer based composites. The test measures the penetration of a specified indentor into the material under controlled environmental conditions. The testing temperature was maintained at 25 to 28ºC as PVA/PVA-GLUT polymer storage modules decreased more than 30ºC, directly affecting the materials' hardness. The test sample of 20mm width, 20mm bredth and 4mm thickness used to mesure five trials. The PVA/PVA-GLUT polymer is first placed on a hard flat surface. The indentor for the instrument is then pressed into the sample, ensuring that it is parallel to the surface. The hardness is measured using analog indicator.

ANOVA

The ANOVA test method used to study the significance difference between the averages of PVA and PVA-GLUT crosslinked composites. The significance level is 0.05 by considering outliers included with large effect. Tukey HSD method used to study the influence of hardness by various weight percentage of GLUT in PVA. The accept and reject hypothesis are used to study the influence, (i) if p value $<\alpha$, null hypothesis so rejected. (ii) if p value $<\alpha$, null hypothesis so accepted. Also if the averages of group and difference between groups are considered to study the influence of crosslinking on hardness.

3.0 Results and Discussion

The hardness of PVA and PVA crosslinked GLUT as measured by varying weight percentage of GLUT in PVA at an interval of 5 percentage and the results are tabulated in Table 1. The neat PVA considered as first independent treatment and denoted as A, by adding various percentage of GLUT in PVA from 0 to 40% further treatment denotes as B and so on denoted in Table 1.

The one way ANOVA results of Table 2, indicates that significant difference between treatment, P value is nearer or equals to zero indicates that stronger significance by adding GLUT in PVA. If P value is nearer or equals to 1, it indicates week in significant level. If P value is between 0 to 1, indicates moderately significant. The test statistic F equals 128.620918, which is not in the 95% region of acceptance: $[-\infty : 2.2085]$. The observed effect size f is large (5.35). That indicates that the magnitude of the difference between the averages is large. The η^2 equals 0.97. It means that the group explains 96.6% of the variance from the average. From the Tukey HSD method it is indicated that SE value is 0.449691184 and critical mean value is 2.096815252.

From the Table 3, it can clearly indicates that, by adding GLUT to PVA the significance level is high and mechanical properties are influenced drastically. This may be due to the plastic area. This can also be due to connections (atoms, electrons, or ions) between different long backbones in the polymer, called crosslinks. As a result, the coupled chain is three-dimensionally reinforced so that it can be moved or moved, slid, and broken long chains by external conditions. This may also be due to the fact that PVA is self-crosslinking due to the high density hydroxyl groups found in its side chains. It is also clear that cross-linking results in bond formation between the chains, which reduces the mobility of the chains. The reduced mobility of the chain means that the chains will not flow from each other when the mass deforms. The chain reaches its limit of mobility with small deformations, and external stresses distort the chemical bonds (attempt to ”bend”). For pure PVA materials, the modules are driven because the chains are difficult to flow with each other due to entanglement. Cross-linking forms a stiffer, less fluid mass compared to entanglement. From the Table 4 and Figure 1 it can clearly indicate if the f value is more than 5.35 the treatments are significant. It means from the Tukey HSD test method the following pairs are significantly different: A-B, A-C, A-D, A-E, A-F, A-G, A-H,

Table 1: Hardness results of five trials and various volume percentage of GLUT in PVA

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

Table 2: ANOVA results between the PVA and PVA-GLUT composites

Source	DF	Sum of Square	Mean Square	F Statistic	P-value
Groups (between groups)	8	1040.4	130.05	128.6209179	0
Error (within groups)	36	36.39998901	1.011110806		
Total	44	1076.799989	24.47272702		

Table 3: Significance level between treatment of volume percentage crosslinking

Pair	Difference	Q	Lower CI	Upper CI	p-value	Significant level
A-B	9.6	21.34798354	7.503184748	11.69681525	7.04336589e-12	High
A-C	9.8	21.7927332	7.703184748	11.89681525	7.04225567e-12	High
A-D	14.2	31.57722565	12.10318475	16.29681525	7.04114544e-12	High
A-E	15	33.35622428	12.90318475	17.09681525	7.04114544e-12	High
A-F	15	33.35622428	12.90318475	17.09681525	7.04114544e-12	High
A-G	15.4	34.2457236	13.30318475	17.49681525	7.04114544e-12	High
A-H	15.2	33.80097394	13.10318475	17.29681525	7.04114544e-12	High
A-I	15	33.35622428	12.90318475	17.09681525	7.04114544e-12	High
B-C	0.2	0.444749657	-1.896815252	2.296815252	0.999996344	Low
B-D	4.6	10.22924211	2.503184748	6.696815252	5.53250339e-7	Medium
B-E	5.4	12.00824074	3.303184748	7.496815252	1.40439411e-8	Medium
B-F	5.4	12.00824074	3.303184748	7.496815252	1.40439411e-8	Medium
B-G	5.8	12.89774006	3.703184748	7.896815252	2.39468734e-9	Medium
B-H	5.6	12.4529904	3.503184748	7.696815252	5.76188941e-9	Medium
B-I	5.4	12.00824074	3.303184748	7.496815252	1.40439411e-8	Medium
C-D	4.4	9.784492456	2.303184748	6.496815252	0.00000141754159	Medium
C-E	5.2	11.56349108	3.103184748	7.296815252	3.46393942e-8	Medium
C-F	5.2	11.56349108	3.103184748	7.296815252	3.46393942e-8	Medium
C-G	5.6	12.4529904	3.503184748	7.696815252	5.76188941e-9	Medium
C-H	5.4	12.00824074	3.303184748	7.496815252	1.40439411e-8	Medium
C-I	5.2	11.56349108	3.103184748	7.296815252	3.46393942e-8	Medium
D-E	0.8	1.778998628	-1.296815252	2.896815252	0.936916307	Low
D-F	0.8	1.778998628	-1.296815252	2.896815252	0.936916307	Low
D-G	1.2	2.668497943	-0.896815252	3.296815252	0.626513783	Low
D-H	1	2.223748286	-1.096815252	3.096815252	0.812895027	Low
D-I	0.8	1.778998628	-1.296815252	2.896815252	0.936916307	Low
E-F	0	0	-2.096815252	2.096815252	1	Low
E-G	0.4	0.889499314	-1.696815252	2.496815252	0.99929714	Low
E-H	0.2	0.444749657	-1.896815252	2.296815252	0.999996344	Low
E-I	0	0	-2.096815252	2.096815252	1	Low
F-G	0.4	0.889499314	-1.696815252	2.496815252	0.99929714	Low
F-H	0.2	0.444749657	-1.896815252	2.296815252	0.999996344	Low
F-I	0	0	-2.096815252	2.096815252	1	Low
G-H	0.2	0.444749657	-1.896815252	2.296815252	0.999996344	Low
G-I	0.4	0.889499314	-1.696815252	2.496815252	0.99929714	Low
H-I	0.2	0.444749657	-1.896815252	2.296815252	0.999996344	Low

Table 4: Tukey HSD significant analysis for various volume percentage of GLUT in PVA

Group	B	C	D	E	F	G	H	I
A	9.6	9.8	14.2	15	15	15.4	15.2	15
B	0	0.2	4.6	5.4	5.4	5.8	5.6	5.4
C	0.2	0	4.4	5.2	5.2	5.6	5.4	5.2
D	4.6	4.4	0	0.8	0.8	1.2	1	0.8
E	5.4	5.2	0.8	0	0	0.4	0.2	0
F	5.4	5.2	0.8	0	0	0.4	0.2	0
G	5.8	5.6	1.2	0.4	0.4	0	0.2	0.4
H	5.6	5.4	1	0.2	0.2	0.2	0	0.2

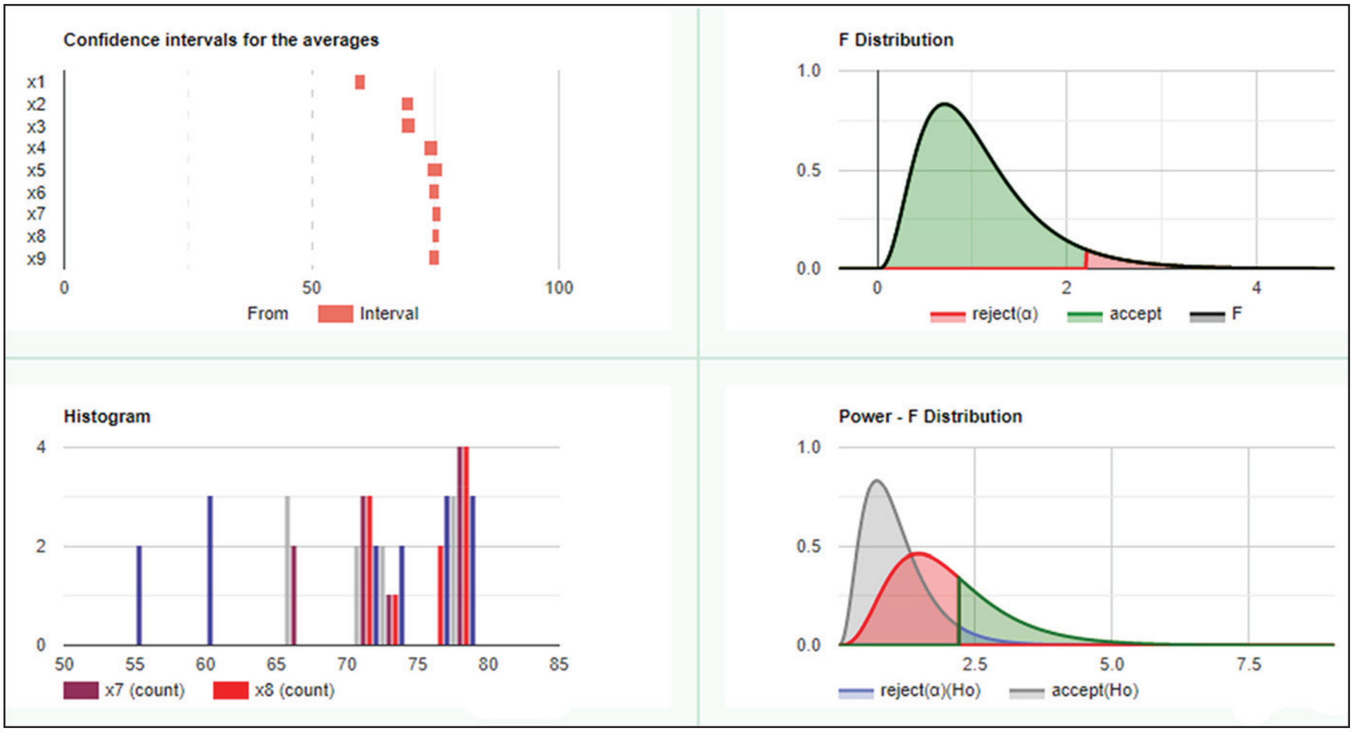

Figure 1: Confidence interval average, F distribution, Histogram and power F distribution.

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. Other condition, if the priori power is lower than 0.3502, hypothesis is rejected. The equality of variances was analysed and the population's variances consider to be equal. (p-value = 0.944), Levene's test power considered to be weak (0.35).

4.0 Conclusions

The polyvinyl alcohol is crosslinked from 0 to 40 volume percentage of glutaraldehyde and hardness was determined. The following conclusions reported are:

- The crosslinking of glutaraldehyde in polyvinyl alcohol improved the mechanical properties of the polymer.
- The crosslinked polymer immersed in 2 mole of sulfuric acid solution exhibit better properties than another polymer.
- The improvement of hardness was found up to 15% of glutaraldehyde in polyvinyl alcohol further marginal changes was found.
- The treatment between the group was analysed and found Tukey HSD test supports to study the significant level of crosslinking.

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