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ATTENUATING POTENTIAL OF ALUMINUM SULPHATE (ALUM) ON TESTOSTERONE PROPIONATE-INDUCED BENIGN PROSTATIC HYPERPLASIA IN MALE WISTAR RATS

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ABSTRACT

The effect of aluminum sulphate (alum) on Testosterone propionate (TP)-induced Benign Prostatic Hyperplasia (BPH) in male Wistar rats was studied. Eighty mature male Wistar rats, with an average weight of 210g, were randomly distributed into eight groups comprising ten rats. Group 1 received only food and water, while Groups 2, and 4 to 8 were given 3 mg/kg b.w of TP subcutaneously and Group 3 received only 25 % alum solution for 28 days. Thereafter, Groups 4 to 8 were treated with 10%, 20%, 25%, 30%, and 40% alum solution respectively while group 2 remained untreated for another 28 days. The animals were fed with standard rat chow and clean water ad libitum. Sperm morphology and characteristics were observed and measured. A variety of haematological and biochemical markers were assessed. Histopathology of the testes was examined. The volume (0.10 ± 0.00 ml) viability (68.33 ± 4.41 %), activity (41.25 ± 1.25 %), and sperm count (36.67 ± 3.33 $\times 10^6$) were significantly decreased ($p<0.05$) in group 2 when compared with the respective values obtained in group 1. Treatment with different concentrations of Alum solution significantly ($p<0.05$) reversed abnormal sperm features observed in group 2. Superoxide dismutase (0.90 ± 0.01 U/L) was significantly increased ($p<0.05$) in group 2, but the values were restored to normal after treatment with varying concentrations of Alum solutions. Photomicrographs of the testis of group 2 rats revealed a distorted testis, however, there was a significant recovery after treatment which suggested that treatment with Alum reduces TP-induced BPH.

Keywords: Testosterone propionate, Alum, Prostatitis, Testes, Seminal fluid, Histology

INTRODUCTION

Prostatitis, benign prostatic hyperplasia (BPH), and prostate cancer are the most common prostate issues and all can contribute to male infertility. In young people, the prostate weighs about 1.5 g at birth and grows to 10 g to an average of 20 g by early adolescence. About half of all men by the age of 50, and 90% of males over the age of 80 have enlarged prostate compared to their adolescence size. BPH is the pathological term for this growth, which is also known as benign prostatic enlargement (BPE) or benign prostatic obstruction in clinical terms. It's assumed that the transitional zone prostate tissue's normal interactions between epithelial and fibromuscular stromal components are disrupted, resulting in a lower epithelial/stromal ratio and hence micronodular remodelling that defines BPH (Vignozzi *et al*., 2014). In aging men, BPH is the most common benign condition and the leading cause of lower urinary tract symptoms (LUTS). It interferes with everyday activities and reduces men's quality of life by progressively increasing prostate volume (PV) and causing LUTS, recurrent urinary tract infections, acute urine retention, and other

clinical symptoms in men. (Welch *et al.*, 2002; Roehrborn and McConnell 2002; McConnell *et al.*, 2003).

Benign prostatic hyperplasia is believed to affect 50 percent to 70 percent of males over the age of 50 (Napalkov *et al.*, 1995). Prostatitis is an inflammatory and irritating illness that affects the prostate organ. The most common symptoms of prostatitis include discomfort, voiding symptoms, and pelvic pain (McNaughton *et. al.*, 2001). The development of LUTS, which is commonly characterized by irritative and obstructive symptoms, is a common side effect of BPH. An alpha-adrenergic–receptor antagonist (alpha-blocker), which reduces smooth-muscle tone in the prostate and bladder neck, or a 5-reductase inhibitor, which reduces prostate volume by inducing epithelial atrophy, is the preferred medical treatment for many men with symptomatic benign prostatic hyperplasia (Roehrborn *et al.*,2002). The necessity to screen for potential sources of more effective treatment with low or no side effects has arisen as a result of the adverse effects and high cost of present treatment alternatives. Locally, aluminum sulphate (alum), a common flocculant, has been used to treat prostate disorders such as prostatitis and BPH. As a result, a scientific evaluation of the attenuating ability of aluminum sulphate (alum) on Testosterone propionate-induced BPH in male Wistar rats was conducted.

MATERIALS AND METHODS

Sample collection and preparation

Aluminum Sulphate (Alum) was obtained from Rumuosi market in Obio/Akpor Local Government Area of Rivers State. After collection, it was ground with a blender. Five different concentrations (10%, 20%, 25%, 30%, and 40%) were prepared by dissolving 10g, 20g, 25g, 30g, and 40g of alum in 100ml distilled water. The solution was left to stand for 24 hours. The pH of the alum solution was measured using a pH meter before and after standing and stored at 4^{O}C.

Study Design

A total of eighty adult male Wistar rats (each weighing between 152g and 280g) were purchased from the animal house at the Department of Pharmacology, University of Port Harcourt, River State, Nigeria. They were housed by weight in numerous cages with renewable beddings. They were fed with standard rat chow and clean water *ad libitum* and allowed to undergo acclimatization for 14 days under normal temperature, humidity, and a 12-hour light-dark cycle. After acclimatization, the animals were randomly placed into three control groups and five treatment groups. Group 1 (Normal Control) was given food and water only, Groups 2 (Negative control), and Groups 4-8 were given 3 mg/kg b.w testosterone propionate by subcutaneous injection for 28 days, while Group 3 was given 25% alum solution only. After 28 days, Groups 4 - 8 were treated with 10%, 20%, 25%, 30%, and 40% alum solution respectively while group 2 remained untreated throughout the experiment.

Methods

Semen Analysis

Semen analysis was carried out using the haemocytometer method as described by WHO, (2010). The epididymis was lacerated to press out the semen. It was then emulsified with 0.5% Eosin dye and examined using ×10 and ×40 objective lens. The semen sample was examined to check for viable cells which is the percentage of stained cells as against the unstained ones. It was also examined to check for other morphological features and

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characteristics. The sperm count was done using a counting chamber.

Haematological and Biochemical analysis:

Haematology test was done using the method described by Cheesbrough (2006), Alanine aminotransferase (ALT), Aspartate aminotransferase (AST) and Alkaline phosphatase (ALP) were analyzed by kinetic methods kits from Randox (United Kingdom) using a double-beam spectrophotometer. Determination of Sodium and Potassium were done using a flame photometer as described by Chuang *et al*., 2005), Urea and Creatinine concentrations were analyzed using methods as described by Tietz, (2004). The determination of activities of Superoxide Dismutase (SOD), Catalase (CAT), and levels of Malondialdehyde (MDA) were carried out as described by Usoh *et al*., (2005), while Lactate Dehydrogenase was carried out as described by Babson and Babson, (1973). Prostate-specific antigen, Carcinoembryonic antigen, Follicle-Stimulating Hormone, Testosterone, Creatine Kinase-MB (CK-MB), D-Dimer, and Myoglobin were measured using enzyme-linked immunosorbent assay (ELISA), kit (Boditech Med Incorporated, Republic of Korea), using the ichroma machine (Boditech: BOD13303, Korea), while Total serum Protein was measured using biuret method (Sagar, 2021).

Histopathological examination

Histopathological slides were prepared at Anatomical Pathology Laboratory, University of Port Harcourt Teaching Hospital (UPTH), Port Harcourt, River State. The testes were harvested immediately after sacrifice to prevent post-mortem degeneration. They were cut into very small sizes with a sharp knife and fixed using 10% formal saline to preserve the various constituents of the cell and also harden the tissue. The tissues were subjected to standard routine histological procedures (Kiernan, 2008). The slides were viewed using the light microscope and histopathological changes were observed and recorded at x400 magnification identifying both the normal and atrophied seminiferous tubules and spermatocytes

Data Analysis

Statistical analysis was done using IBM package that is statistical social science (SPSS) version 20.0. The data were analyzed using one-way analysis of variance (ANOVA) and significant differences were determined using Least Significant Difference (LSD) for the Post Hoc test of multiple comparisons at $p<0.05$. Values were reported as mean ± standard error of the mean (M ± SEM).

RESULTS

Semen Analysis of testosterone propionate-induced BPH rats treated with Alum

The results of several indices of semen analysis, such as volume, viability, morphology, activity, and total sperm count, in testosterone propionate-induced prostatitis, are shown in Table 1. The percentage of abnormal cells, sluggish cells, and dead cells observed in group 2 were significantly increased ($p<0.05$), while the semen volume, percentage of normal cells, viability, and sperm count significantly decreased ($p<0.05$) when compared to groups 1, 3, 5, 6 and 7.

Tables 2A and 2B present the findings of haematological indicators such as PCV, Hb, WBC, Platelet, Differential WBC, RBC, MCV, MCH, MCHC in rats given TP and treated with Alum.

The WBC of group 2 (6.80 ± 0.58) significantly decreased $p<0.05$ when compared to group 1 (10.00 ± 0.58). The

increased WBC count in other groups suggested that aluminum sulphate aided in WBC generation to combat infection. Group 1 had a blood platelet count of 320.00 ± 2.89, whereas group 2 had a level of 140.00 ± 5.77. When the platelet count of the animals in group 2 was compared to that of group 1, it was observed that TP significantly lowered p<0.05 blood platelets. Blood platelets were likewise significantly lower in groups 4, 5, and 8, while they were significantly higher in groups 6 and 7.

The levels of oxidative stress markers and hormones observed in testosterone propionate-induced BPH rats treated with alum are shown in Table 3. The results showed that LDH levels in group 2 rats were not significantly lower than those in group 1 (p>0.05). The results revealed that Group 3 (the group treated with Alum alone) had a significant increase (p<0.05) when compared to Groups 2, 4, 5, 7, and 8. Malondialdehyde levels in groups 1, 2, and 3 significantly dropped (p0.05) in comparison to groups 6, 7, and 8 while SOD levels in groups 6, 7, and 8 significantly decreased (p<0.05) in comparison to groups 1, 2, and 3. The levels of FSH and testosterone increased non-significantly (p>0.05) when group 2 and group 1 were compared.

Table 1: Semen Analysis of TP-induced BPH rats treated with Alum

Groups	Volume (ml)	Viability (%)	Normal (%)	Abnormal (%)	Activity (%)	Sluggish (%)	Dead (%)	Sperm count ($\times 10^6$)
1	0.15 ± 0.05	82.5 ± 2.50^{d}	75.00 ± 5.00^{d}	25.00 ± 5.00^{d}	67.50 ± 2.50^{d}	10.00 ± 0.00	22.50 ± 2.50^{d}	450 ± 50.00^{d}
2	0.10 ± 0.00^{g}	68.33 ± 4.41	51.25 ± 2.40^{abcefgh}	48.75 ± 2.39^{acefgh}	41.25 ± 1.25^{abcefgh}	12.67 ± 1.67	36.67 ± 3.33^{abcefgh}	300 ± 57.74
3	0.24 ± 0.03	79.38 ± 2.20^{d}	75.63 ± 2.67^{de}	24.37 ± 2.67^{bde}	75.00 ± 2.50^{de}	9.38 ± 1.13	15.00 ± 1.89^{de}	525 ± 51.76^{d}
4	0.11 ± 0.03^{g}	62.50 ± 5.20^{ac}	65.00 ± 2.89^{d}	35.00 ± 2.89^{c}	60.00 ± 0.00^{d}	10.00 ± 0.00	31.75 ± 1.25^{cd}	301.25 ± 6.58^{acgh}
5	0.20 ± 0.03	71.00 ± 4.00	65.00 ± 2.24^{cd}	35.00 ± 2.24^{cd}	59.00 ± 2.92^{cd}	10.00 ± 1.23	29.00 ± 3.32^{cd}	314.00 ± 65.92
6	0.23 ± 0.06	73.75 ± 3.75	71.25 ± 4.27^{d}	28.75 ± 4.27^{d}	67.50 ± 6.29^{d}	10.00 ± 0.00	22.50 ± 6.29^{d}	320.00 ± 89.82
7	0.28 ± 0.06^{bd}	75.00 ± 4.47	73.00 ± 5.39^{d}	27.00 ± 5.39^{d}	70.00 ± 7.25^{d}	10.00 ± 1.58	20.00 ± 6.33^{d}	390.00 ± 132.44^{d}
8	0.20 ± 0.05	74.00 ± 6.96	68.00 ± 6.44^{d}	32.00 ± 6.44^{d}	68.00 ± 8.46^{d}	9.00 ± 1.00	23.00 ± 8.00^{d}	354.00 ± 124.56^{d}

Values are expressed as mean ± standard error of the mean (N=5). Mean values with the same superscripts are statistically significant at p<0.05.

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Table 2A: Haematogram profile of TP-induced BPH rats treated with Alum

Groups	PCV (%)	HB (g/dl)	WBC (x10^9/L)	N	L	M	E	B
1	48.00± 0.58^{bcdefgh}	16.00 ± 0.58^{defh}	10.00 ± 0.58^{bcdefh}	64.00 ± 0.58^{bcdefgh}	30.00± 0.58^{bcdefgh}	2.00 ± 0.48^{cdefgh}	4.00 ± 0.62^{cdfgh}	0.00 ± 0.00
2	46.00 ± 0.58^{adefgh}	15.30 ± 0.58^{d}	6.80 ± 0.58^{adfgh}	59.00 ± 2.31^{acdefgh}	35.00 ± 2.89^{acdefh}	2.00 ± 0.58^{cdefgh}	4.00 ± 0.57^{cdfgh}	0.00 ± 0.00
3	45.00 ± 0.58^{adefh}	15.00 ± 0.58^{d}	7.60 ± 0.58^{adfgh}	42.00 ± 1.16^{abdfgh}	46.00 ± 0.58^{abegh}	4.00 ± 0.58^{abgh}	8.00± 0.58^{abdefgh}	0.00 ± 0.00
4	40.00± 0.58^{abcefgh}	13.30 ± 0.58^{abc}	12.20 ± 0.58^{abcefg}	45.00 ± 0.58^{abcefh}	45.90 ± 0.58^{abeg}	4.00 ± 0.62^{abgh}	2.00 ± 0.48^{abceg}	0.00 ± 0.00
5	42.00 ± 0.58^{abcdg}	14.00 ± 0.58^{a}	7.40 ± 0.58^{adfgh}	41.00 ± 0.58^{abdfgh}	51.00± 0.58^{abcdfgh}	4.00 ± 0.58^{abgh}	4.00 ± 0.58^{cdfgh}	0.00 ± 0.00
6	43.00 ± 0.58^{abcd}	14.30 ± 0.12^{a}	18.80 ± 0.58^{abcdegh}	49.00 ± 0.58^{abcdeh}	44.00 ± 0.58^{abeg}	5.00 ± 0.58^{abgh}	2.00 ± 0.46^{abceg}	0.00 ± 0.00
7	44.00 ± 0.58^{abde}	14.60 ± 0.54	9.40 ± 0.58^{bcdefh}	47.00 ± 0.58^{abceh}	38.00 ± 0.58^{acdef}	9.00 ± 0.65^{abcdefh}	6.00± 0.57^{abcdefh}	0.00 ± 0.00
8	43.00 ± 0.57^{abcd}	14.30 ± 0.55^{a}	12.80 ± 0.58^{abcefg}	35.00 ± 0.58^{abcdefg}	41.00 ± 0.52^{abce}	14.00± 0.47^{abcdefg}	2.00 ± 0.58^{abceg}	0.00 ± 0.00

Values are expressed as mean ± standard error of the mean (N=5). Mean values with the same superscripts are statistically significant at $p<0.05$.

Table 2B: Hematogram profile of TP-induced BPH rats treated with Alum

Groups	PLT (x 10^9/L)	RBC (x 10^{12}/L)	MCV (FL)	MCH (Pg)	MCHC (g/dL)
1	320.00 ± 2.89^{bcdefgh}	8.55 ± 0.67	53.35 ± 0.45^{cdeg}	17.80 ± 0.20^{g}	33.35 ± 0.15^{df}
2	140.00 ± 5.77^{acdfgh}	7.62 ± 0.64	53.30 ± 0.90^{cdeg}	17.60 ± 0.60^{g}	33.23 ± 0.52^{df}
3	216.00 ± 2.89^{abdfgh}	7.99 ± 0.28	56.71 ± 0.62^{abg}	18.46 ± 0.31^{g}	32.51 ± 0.25
4	202.00 ± 1.16^{abcefgh}	7.35 ± 0.19	57.03 ± 0.90^{ab}	18.08 ± 0.25^{g}	31.70 ± 0.15^{ab}
5	212.00 ± 5.77^{adfgh}	8.10 ± 0.31	57.24 ± 0.57^{abh}	17.94 ± 0.32^{g}	32.34 ± 0.45
6	348.00 ± 4.62^{abcdegh}	8.00 ± 0.29	55.48 ± 1.10^{g}	17.98 ± 0.46^{g}	31.93 ± 0.36^{ab}
7	388.00 ± 4.62^{abcdefh}	7.75 ± 0.27	59.14 ± 1.36^{abcfh}	20.10 ± 0.75^{abcdefh}	32.28 ± 0.22
8	384.00 ± 2.31^{abcdefg}	7.76 ± 0.34	54.54 ± 1.22^{eg}	18.22 ± 0.29^{g}	32.24 ± 0.18

Values are expressed as mean ± standard error of the mean (N=5). Mean values with the same superscripts are statistically significant at $p<0.05$.

Table 3: Oxidative stress markers and hormonal profile of TP-induced BPH rats treated with Alum

GROUPS	LDH (U/L)	SOD (U/L)	MDA (U/L)	FSH (IU/ml)	TESTOSTERONE (ng/mL)
1	34.40 ± 7.90	0.67 ± 0.12^{fgh}	0.37 ± 0.06^{fgh}	3.00 ± 0.40	2.30 ± 0.30
2	22.60 ± 0.10^{c}	0.90 ± 0.01^{fgh}	0.29 ± 0.01^{defgh}	3.40 ± 0.13^{f}	2.83 ± 0.20
3	44.25 ± 1.25^{bdegh}	0.70 ± 0.03^{fgh}	0.33 ± 0.03^{fgh}	3.01 ± 0.29^{f}	2.31 ± 0.17
4	28.20 ± 1.10^{c}	0.60 ± 0.02^{gh}	0.39 ± 0.01^{bfgh}	2.53 ± 0.45^{f}	2.13 ± 0.54
5	28.60 ± 8.60^{c}	0.58 ± 0.07^{h}	0.41 ± 0.06^{bfgh}	2.40 ± 0.19^{f}	1.86 ± 0.27
6	31.30 ± 6.90	0.45 ± 0.02^{abch}	0.53 ± 0.03^{abcde}	2.60 ± 0.22^{f}	1.63 ± 0.34
7	29.15 ± 2.95^{c}	0.43 ± 0.05^{abcd}	0.53 ± 0.02^{abcde}	3.26 ± 0.49^{f}	2.14 ± 0.41
8	28.75 ± 0.55^{c}	0.28 ± 0.02^{abcdef}	0.60 ± 0.03^{abcde}	3.27 ± 0.24^{f}	2.14 ± 0.44

Values are expressed as mean ± standard error of the mean (N=5). Mean values with the same superscripts are statistically significant at $p<0.05$.

The results of the kidney function markers (creatinine, urea, sodium, and potassium) are presented in Figure 1. There were no significant changes ($p>0.05$) in creatinine, urea, sodium, and potassium levels between the groups.

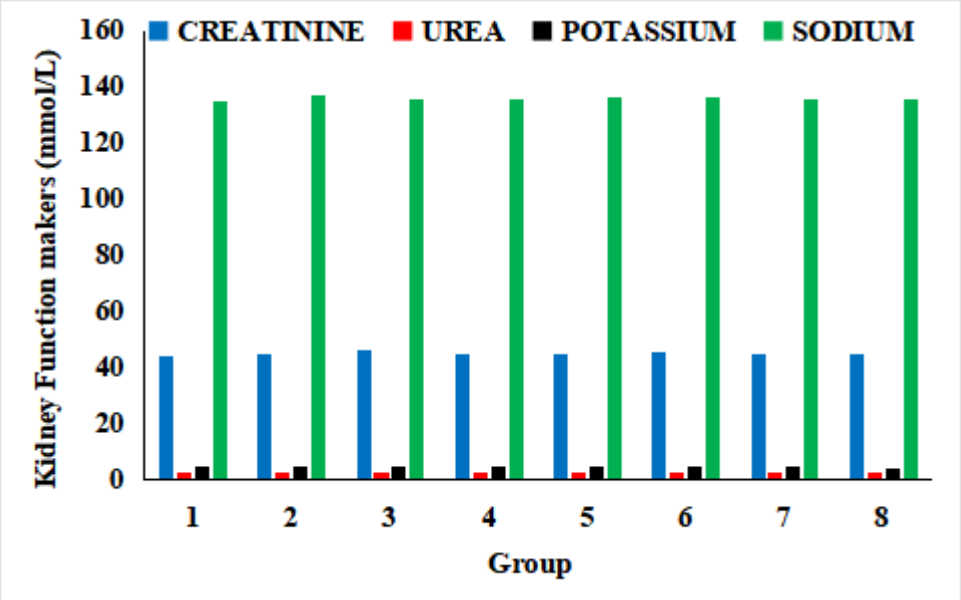

Figure 1: Attenuating potential of Alum on Kidney function markers of TP-induced BPH rats treated with Alum

Figure 2 displays the outcomes of cancer and cardiac indicators in male Wistar rats given TP and treated with alum. When compared to groups 1, 3, 4, 5, 6, 7, and 8, group 2's PSA readings showed a non-significant rise ($p>0.05$). Similarly, there was no significant difference between groups 1, 3, 4, 5, 6, 7, and 8 and group 2 in terms of CEA, CK-MB, and D-Dimer levels ($p>0.05$). Figure 3 show the results of the liver function tests for testosterone propionate-induced BPH rats treated with alum,

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including the levels of Alkaline Phosphatase (ALP), Alanine Transaminase (ALT), and Aspartate Aminotransferase (AST). The treated groups' ALP was higher than that of groups 1 and 2

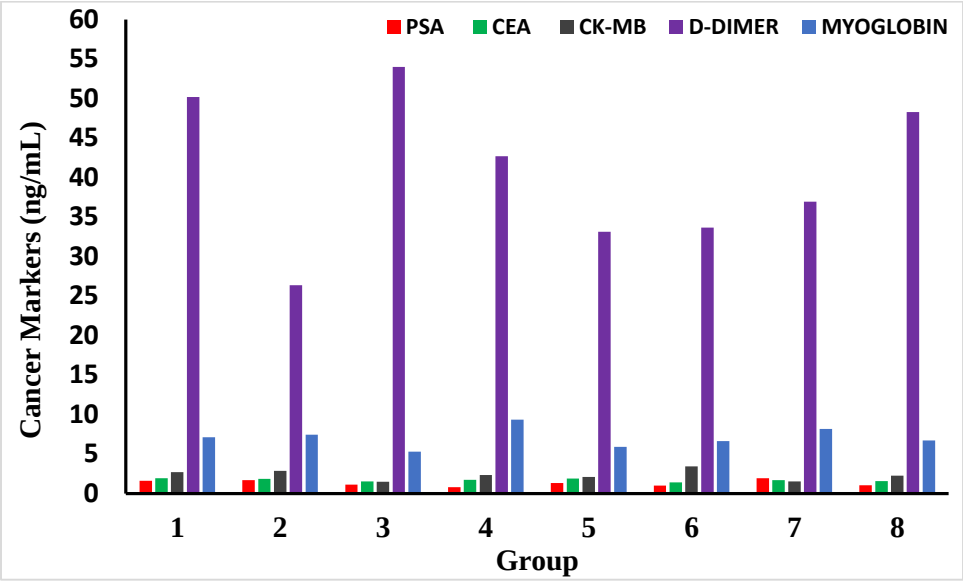

Figure 2: Attenuating potential of Alum on Cancer and Cardiac markers of TP-induced BPH rats treated with Alum

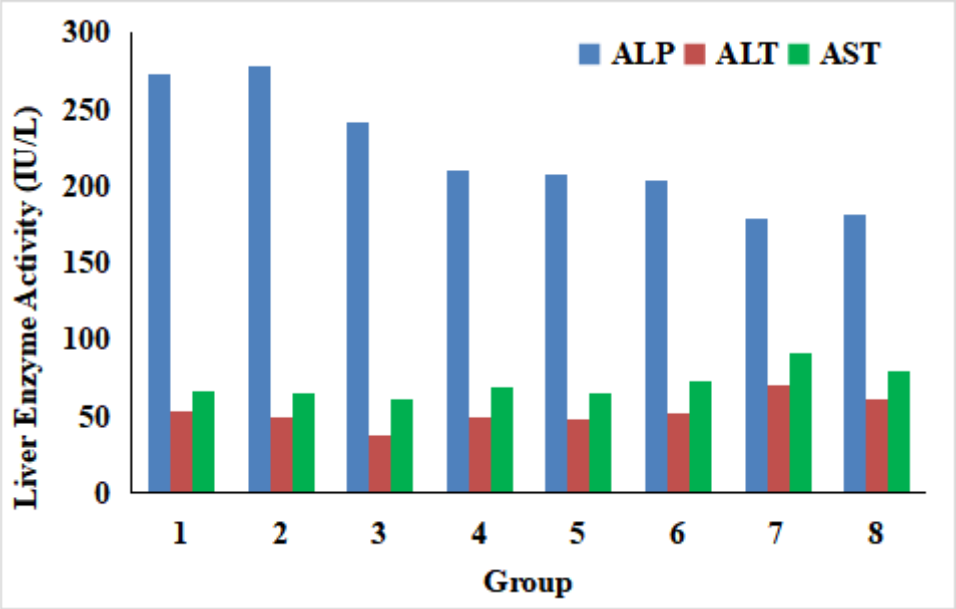

Figure 3 Activities of liver enzymes of TP-induced BPH rats treated with Alum

Histology Results

Photomicrographs of thin sections (5 µm) of the testes of testosterone propionate-induced BPH rats were harvested at the end of 28 days of treatment with different concentrations of Alum (Plate 1) and stained with H&E (400x).

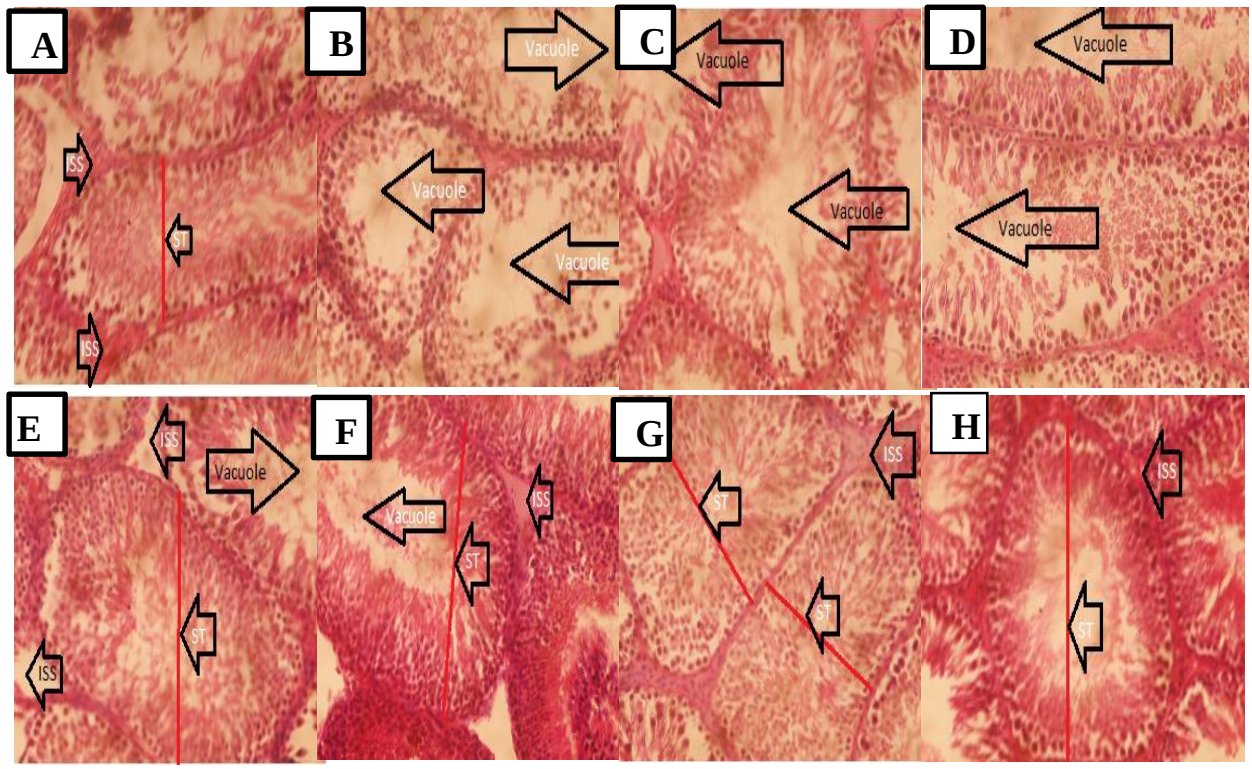

Plate 1: Photomicrograph of the testis of rats from **A** - Group 1 showed normal testes, seminiferous tubule containing spermatogenic cells, and spermatozoa. Interstitial spaces containing interstitial cells of Leydig. ST = Seminiferous Tubule, ISS = Interstitial Spaces. **B** - Group 2 showed histologically distorted testicular architecture, and vacuolated seminiferous tubule. The interstitial spaces are normal containing Leydig cells. **C** - Group 3 showed histologically distorted testes and a vacuolated seminiferous tubule. **D** - Group 4 showed distorted testes, seminiferous tubule containing spermatogenic cells, and spermatozoa. Interstitial spaces containing interstitial cells of Leydig. **E** - Group 5 showed partially distorted testes and vacuolated seminiferous tubules. **F** - Group 6 showed mildly distorted testes and vacuolated seminiferous tubules. ST = Seminiferous Tubule, ISS = Interstitial Spaces. **G** - Group 7 showed normal testes and vacuolated seminiferous tubule. **H** - Group 8 showed normal testes, seminiferous tubule containing spermatogenic cells, and spermatozoa. Interstitial spaces containing interstitial cells of Leydig.

DISCUSSION

Herbs and herbal products are commonly used in the treatment of diverse diseases and illnesses in so many parts of the world. In developing countries like Nigeria, herbal medicines are becoming more popular. Locals had reported utilizing aluminum sulphate as a therapy for prostate problems such as BPH and prostate cancer. This study was conducted to evaluate the attenuating potentials of Alum on testosterone propionate-induced BPH in male Wistar rats to objectively authenticate these local claims.

The pH of the semen in both the control and treated groups of male Wistar rats administered with testosterone propionate and treated with Alum was observed to be at 8.00 throughout the experimental period. However, negative sperm characteristics and morphology were observed in group 2 when compared to the rest groups. This is consistent with observations indicating androgenic anabolic steroids (AAS), such as testosterone propionate, have a significant impact on total sperm quality in males (Torres-Calleja *et al.*, 2001). Similarly, Onyegeme-Okerenta *et al.* (2022) reported that testosterone propionate reduces sperm quality and distorts the morphological characteristics of sperm cells. However, sperm characteristics and morphology were increased significantly

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($p<0.05$) in the normal control group, experimental group, and treatment groups. This implies that the graduated Alum dosage utilized enhanced the semen profile of male Wistar rats significantly. Muselin *et al*. (2016), in a three-generation study, suggested that chronic exposure to aluminum sulphate was significantly deleterious, producing a pronounced decrease in the sperm count and testosterone levels in all experimental groups.

A significant decrease in haematology index was observed in group 2 when it was evaluated. A reduction in packed cell volume (PCV) and haemoglobin (Hb) suggests either erythrocyte destruction or decreased production, both of which can lead to anaemia (Amadi *et al.,* 2018). The treatment with graded doses of Alum did not have any significant positive effect on the haemoglobin level of the experimental animals. However, the WBC and blood platelet count of the rats in the TP treatment groups increased significantly ($p<0.05$). This could be attributed to the recovery of the animals from BPH due to the ameliorating potential of Alum.

Superoxide dismutase was significantly increased ($p<0.05$) in group 2 due to treatment with TP. However, a consistent reduction in SOD levels was observed in groups 3 to 8 treated with graded doses of Alum. The results from group 2 suggested that testosterone propionate is capable of inducing oxidative stress in rats. Landis and Tower (2005), as well as Yasui and Baba (2006), reported that SOD protects against ROS-mediated damage, acts as an anti-inflammatory, and can even protect against pre-cancerous alterations. Also, Choobineh *et al.* (2016) suggested that exogenous testosterone has pro-oxidant properties. Finding from this research suggests that Alum at a concentration of 10 - 40% significantly reduced the level of ROS generated by TP and can be said to have antioxidant properties.

Malondialdehyde (MDA) is one of the most frequently used biomarkers indicating the overall lipid peroxidation level. Lipid peroxidation plays a role in the pathogenesis of tissue damage induced by numerous toxic substances (Dzoyem *et al.*, 2014). Malondialdehyde was significantly increased in the treatment groups when compared with groups 1, 2, and 3. Lactate dehydrogenase (LDH) was significantly elevated in group 3 (Alum only group). This could be attributed to the combined effects of TP and Alum on the tissue membrane of the treatment groups. In a similar study carried out by Amadi *et al*. 2018 and Onyegeme-Okerenta *et al*. (2022), it was observed that rats given *Annona muricata* extracts had lower levels of oxidative stress produced by sodium fluoride and testosterone propionate respectively. In Group 2, there was a substantial increase ($p<0.05$) in testosterone and FSH levels which support the findings of Morse *et al*. (1972), who reported that testosterone propionate boosts plasma testosterone approximately twofold.

Aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP) are reliable markers for hepatotoxicity (Edwards *et al.,* 1997). An increase in AST and ALT concentrations reflects hepatocyte necrosis while ALP levels reflect damage to biliary epithelial cells or canalicular membrane (Giannini *et al.,* 2005, Padda *et al.,* 2011). Relative to groups 1 and 2, ALP was significantly reduced in groups 3 to 8. Alanine transaminase (ALT) and aspartate aminotransferase (AST) were significantly increased ($p<0.05$) in group 7 when compared with groups 1 and 2. Also, it was noticed that ALT was significantly depleted in group 3 when compared with the other groups. The

significant decrease of ALP, ALT, and AST in group 3 suggests that Alum is not hepatotoxic and at such did not harm the hepatocytes.

PSA levels can rise in situations such as prostate inflammation, bacterial prostatitis, benign prostatic hyperplasia (BPH), and urinary tract infection, even if they are not directly linked to prostate cancer (Ozden *et al*., 2007). There PSA level of group 2 animals was raised when compared to those treated with Alum and the normal control. This suggests that TP caused an increase in the PSA level of these animals and that the different concentrations of Alum administered to respective groups ameliorated the negative effect of TP in those experimental rats. This is consistent with the findings of Azab *et al*. (2012), who found a reduction in mean PSA levels after antibiotic treatment. Similarly, there was no significant difference ($p>0.05$) between the groups when cardiac and renal indicators were evaluated. It was concluded that both testosterone propionate and Alum did not affect the heart and kidney functions of the animals.

The histologically distorted testis with a vacuolated seminiferous tubule observed in the photomicrographs of experimental animals showed that testosterone propionate affected the testis which in turn may affect male fertility. However, the marked recovery observed in groups treated with different concentrations of Alum is a pointer that Alum may be considered a therapeutic agent in the management and treatment of BPH.

CONCLUSION

According to the findings of this study, alum at a concentration of 25% to 40% could be used to treat prostate disorders such as BPH and possibly prostate cancer. This study backs up locals' claims about the usage of alum in the treatment of BPH and other prostate-related issues. The usage of alum improved the overall activity of the sperm count and quality. This study found that chronic testosterone propionate exposure had a negative overall effect on sperm profile and sperm cell deformation, which could lead to BPH and possibly prostate cancer.

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