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BIOLOGICAL ACTIVITY STUDIES OF GUANIDINE-PHOSPHONATE COMPLEXES OF IRON, COBALT AND ZINC

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ABSTRACT

This research work focused on biological activity studies of guanidine-phosphonate complexes of iron, cobalt and zinc for growth inhibition against *Staphyloccoccus aureus*. *Staphyloccoccus aureus* infected blood was treated with the guanidine-phosphonate complexes and their activities were examined through haematological and enzymatic analyses. Sterile water was used as negative control. The analyses results on packed cell volume, haemoglobin, white blood cell, platelet, neutrophils, lymphocyte, aspartateaminotransferase and alanineaminotransferase were interpreted statistically. Guanidinophosphonateben zothiazole compounds exhibited strongest activity followed by guanidinobenzothiazole compounds. The effectiveness trend was followed by guanidinophosphonatebenzimidazole compounds which performed better than the guanidinobenzimidazole compounds. The compounds therefore indicated that guanidinophosphonatebenzothiazole compounds gave highest antimicrobial property. This was followed by guanidinobenzothiazole compounds which were found to be higher than guanidinephosphonatebenzimi dazole compounds while the least antimicrobial activity was recorded for guanidinobenzimidazole compounds.

Keywords: Benzimidazole**,** Benzothiazole, Complexes, Biological activity

INTRODUCTION

Guanidine compounds are important materials with antimicrobial activities [1]. They are vital in diverse areas of application to life [2]. Derivatives of guanidine are early or awaited in cycle production and development of microorganism potentially [3].

Antimicrobial activities of guanidine metal complexes have made them important even in pharmaceutical and biochemical areas [4] which have increased interest in their research, hence desired for continuous investigation in pharmaceutical, academic research and industrial development. Phosphonate guanidine compounds synthesis and their antimicrobial applications have been reported [5].

Metal complexes antimicrobial activities of guanidines, phosphonates need much to be investigated. It is therefore desired of this research works to examine antimicrobial activity of guanidinated metal complexes.

MATERIALS AND METHODS

Blood samples of rats were used.

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Effect of the guanidine derivatives

Activities of the guanidinobenzimidazole, guanidinophosphonatebenzimidazole, guanidinebenzothiazole and guanidino phosphonatebenzothiazole derivatives were assessed through blood samples of rats. The blood samples were first examined for microorganism effect on packed cell volume, hemoglobin, white blood cell, platelet, neutrophils, lymphocyte, aspartateaminotransferase and alanineamino transferase according to method in literature [6]. Antimicrobial activity of the derivatives was tested and effectiveness deduced through statistical analysis.

Blood Analyses

The blood analysis was carried out to monitor treatment effect of the iron, cobalt and zinc complexes for growth inhibition against *Staphyloccoccus aureus* through observation of haematological data which are packed cell volume, haemoglobin, white blood cell, platelet, neutrophils and lymphocyte. Activity of the complexes was also tested for improvement investigated on the blood through enzymatic data which are aspartateaminotransferase and alanineamino-transferase according to literature method [7].

RESULTS AND DISCUSSION

Antimicrobial activity of the guanidinobenzimidazole, guanidinobenzothiazole, guanidinophosphonatebethiazole and coordinated metals compared with sterile water used as negative control were determined for effect on packed cell volume, haemoglobin, white blood cell, platelet, neutrophils, lymphocyte, aspartateaminotransferase and alanineaminotransferase. Packed cell volume of 25.40±2.34% decrease from 42.60±0.81% due to microorganism effect indicated improvement to 31.40±0.68% after application of guanidinobenzimidazole. Iron-guanidinobenzimidazole complex displayed effectiveness as 24.20±0.97% increase to 33.50±1.38% in expectation of 43.40±0.93% packed cell volume. Cobalt-guanidinobenzimidazole complexes gave 34.10±1.21% improvement closer to 43.00±0.71% compared to 24.80±2.54% packed cell volume. Zinc guanidinobenzimidazole complex showed effectiveness of 35.40±2.23% higher than 25.30±0.49% in expectation of 43.00±1.41%. The sterile water did not produce any antimicrobial change in the 42.60±1.25% packed cell volume compared with the derivatives which proved that the ligand and the complexes have antimicrobial potential. (Table 1). Packed cell volume has been similarly reported on malarial investigation in literature [8].

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Table 1: Antimicrobial activity of guanidinobenzimidazole and complexes

S/N	Sample	PCV(%)	Hb (g/dl)	WBC (X 10^9 /L)	Platelet (X 10^9/L)	Neu(%)	Lym(%)	AST (ug/L)	ALT (ug/L)
Grp 1	Ma	42.60±0.81^{ef}	17.34±1.34^{h}	12.02±0.73^{b}	130.00±3.42^{a}	29.60±3.23^{k}	31.30±1.57^{abc}	12.60±1.29^{hi}	22.00±1.52^{ab}
	Me	25.40±2.34^{ab}	7.46±0.43^{b}	28.54±0.79^{de}	81.80±4.02^{ab}	47.60±1.91ij	46.60±2.66^{fg}	36.00±6.69^{ef}	41.80±5.98^{d}
	Gbm	31.40±0.68^{d}	10.36±1.01^{def}	17.86±0.97^{c}	92.00±2.28^{bcd}	39.80±2.75^{def}	40.50±1.64^{de}	32.40±2.20^{i}	31.90±2.11^{abc}
Grp 2	Ma	43.40±0.93^{fg}	17.86±1.01^{i}	12.18±2.35^{ab}	130.80±2.35^{cd}	28.70±2.16^{abc}	30.80±1.43^{abcd}	13.40±1.86^{j}	22.20±1.53^{a}
	Me	24.20±0.97^{bc}	7.58±0.51^{bc}	29.28±0.95^{d}	82.40±2.54^{efg}	49.00±2.88^{h}	48.20±2.27^{ef}	35.80±7.26^{ab}	42.20±6.09^{de}
	FeGbm	33.50±1.38^{c}	13.66±0.88^{cd}	17.14±1.95^{c}	99.30±3.08^{hi}	37.56±4.03^{efg}	38.40±1.84^{cde}	28.10±3.17^{bc}	27.40±1.89^{bc}
Grp 3	Ma	43.00±0.71^{fg}	17.60±1.98^{hi}	12.66±2.55^{ab}	129.80±2.20^{de}	29.04±2.81^{ab}	31.10±1.39^{bcd}	13.20±1.99^{d}	21.50±0.71^{c}
	Me	24.80±2.54^{b}	7.10±0.67^{de}	27.10±1.21^{def}	85.00±3.32^{def}	47.60±0.93^{d}	48.30±3.93^{gh}	35.60±7.62^{a}	41.70±5.98^{f}
	CoGbm	34.10±1.21^{c}	13.44±1.11^{ef}	17.12±0.73^{cd}	99.56±3.25^{a}	37.60±1.32^{ef}	38.40±3.13^{e}	28.40±3.32^{k}	27.60±1.86^{cd}
Grp 4	Ma	43.00±1.41^{fg}	17.98±0.83^{i}	11.42±1.32^{a}	131.60±0.87^{abc}	28.80±3.50^{bc}	30.50±0.80^{a}	12.70±1.17^{jk}	22.00±0.93^{h}
	Me	25.30±0.49^{b}	7.14±0.51^{bcd}	27.28±1.02^{ghi}	74.20±1.66^{i}	49.20±3.90^{g}	47.50±2.41^{fg}	36.30±6.23^{abc}	41.50±5.34^{bcd}
	ZnGbm	35.40±2.23^{c}	13.88±0.81fghi	15.88±1.45^{abc}	99.60±4.67^{gh}	36.25±2.46^{cdef}	37.20±1.24^{ij}	26.90±2.18^{ghi}	27.40±1.75^{g}

NOTE: Same superscript results in a column means no significant different ($p>0.05$), the same superscript in different columns means cross link relationship. PCV: packed cell volume, Hb: haemoglobin, WBC: white blood cells, Neu: neutrophils, Lym: lymphocyte, AST: aspatateaminotransferase, ALT: alanineaminotransferase, Grp: group, Ma: microorganism absent, Me: microorganism effect, Gbm: guanidinobenzimidazole, FeGbm: iron guanidinobenzimidazole complex, CoGbm-: cobal guanidinobenzimidazole complex, ZnGbm-zinc guanidinobenzimidazole complex.

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Haemoglobin test showed 10.36±1.01 g/dl improvement by guanidinobenzimidazole antimicrobial activity over 7.46±0.43 g/dl attributed to microorganism effect whereas the haemoglobin value in absence of microorganism was 17.34±1.34 g/dl. 13.66±0.88 g/dl, 13.44±1.11 g/dl and 13.88±0.81 g/dl due to antimicrobial effects of iron, cobalt and zinc guanidinobenzimidazole complexes demonstrated good activity in comparison with the sterile water which has no effect. Haemoglobin change has been similarly reported [9]. Higher 28.54±0.79 x 10^9/L than 12.02±0.73 x 10^9/L for white blood cells due to microorganism effect that gave 17.86±0.97 x 10^9/L was attributed to activity of guanidinobenzimidazole while 29.28±0.95 x 10^9/L, 27.10±1.21 x 10^9/L and 27.28±1.02 x 10^9/L due to effect of microorganism gave positive 17.14±1.95 x 10^9/L, 17.12±0.73 x 10^9/L and 14.88±1.45 x 10^9/L for iron, cobalt and zinc guanidinobenzimidazole complexes close to 12.18±2.35 x 10^9/L, 12.66±2.55 x 10^9/L and 11.42±1.32 x 10^9/L white blood cell and therefore demonstrated good effect compared with the sterile water that demonstrated no effect. Platelet and neutrophil tests which produced 130.00±3.42 x 10^9/L and 29.60±3.23% respectively dropped to 81.80±4.02 x 10^9/L for platelet and rose to 47.60±1.91% for neutrophils attributed to microorganism effect. The guanidinobenzimidazole application against microorganism showed activity because 92.00±2.28 x 10^9/L and 39.80±2.75% were recorded. Guanidinobenzimidazole complexes of the iron, cobalt and zinc yielded results between 99.30±3.08 x 10^9/L and 99.60±4.67 x 10^9/L for Platelet counts while the neutrophil occurred from cobalt to zinc between 36.25±2.46% and 37.60±1.32%**.** Both the ligand and complexes demonstrated antimicrobial activity compared with the sterile water that did not show antimicrobial effect. Lymphocyte which changed from 31.30±1.57% to 46.60±2.66% due to microorganism effect turn to 40.50±1.64% when guanidinobenzimidazole was applied. Iron, cobalt and zinc complexes of the guanidinobenzimidazole application indicated 38.40±1.84%, 38.40±3.13% and 37.20±1.24% from 30.80±1.43%, 31.10±1.39% and 30.50±0.80% earlier raised to 48.20±2.88%, 48.30±3.93% and 47.50±2.41% for microorganism effect. Aspatateaminotransferase and alanineaminotransferase which showed 12.60±1.29 µg/L and 22.00±1.52 µg/L in absence of microorganism rose to 36.00±6.69 µg/L and 41.80±5.98 µg/L due to microorganism effect. Guanidinobenzimidazole demonstrated antimicrobial activity with 32.40±2.20 µg/L and 31.90±2.11 µg/L while its Fe, Co and Zn complexes gave 28.10±3.17 µg/L, 28.40±3.32 µg/L and 26.90±2.18 µg/L for aspatateaminotransferase. Antimicrobial activity of the Fe, Co and Zn guanidinobenzimidazole complexes was also positive on alanineaminotransferase with 27.40±1.89 µg/L, 27.60±1.86 µg/L and 27.40±1.75 µg/L respectively. It was deduced from results of the sterile water that antimicrobial activity was produced by the ligand and complexes.

Packed cell volume of 42.10±0.64% which decreased to 25.20±2.14% on account of antimicrobial effect gave 31.70±1.62% attributed to guanidinophosphonatebenzimidazole activity. The

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guanidinophosphonatebenzimidazole demonstrated a little higher antimicrobial effect than the guanidinobenzimidazole which were also observed in the iron, cobalt and zinc complexes of the guanidinophosphonatebenzimidazole with range from 33.80±2.12 - 35.90±1.42%, 13.72±0.84 - 13.90±0.59 g/dl, 14.89±0.88 - 17.07±1.54 x 10^9/L, 99.45±2.40 - 99.98±5.64 x 10^9/L, 35.55±3.76 - 37.16±5.14%, 36.80±3.57 - 38.21±3.25%, 26.18±3.93 - 27.84±5.16 µg/L and 26.80±3.03 - 27.10±1.50 µg/L for the pcv, hb, wbc, platelet, neutrophils, lymphocyte, aspartateaminotransferase and alanineaminotransferase respectively (Table 2).

Guanidinobenzothiazole compounds were observed to be more antimicrobial active than guanidinophosphonatebenzimidazole compounds as the packed cell volume, haemoglobin, white blood cell, platelet, neutrophils, lymphocyte, aspartateaminotransferase and alanineaminotransferase recorded 32.62±1.02%, 11.86±2.18 g/dl, 17.54±0.73 x 10^9/L, 94.13±4.64 x 10^9/L, 42.84±2.56%, 40.50±1.74%, 32.40±1.74 µg/L and 31.73±1.93 µg/L improvement over 24.25±0.81%, 7.44±0.47 g/dl, 28.46±2.47 x 10^9/L, 81.81±3.27 x 10^9/L, 46.88±2.34%, 47.10±1.99%, 36.30±1.17 µg/L and 42.40±5.14 µg/L earlier recorded due to microorganism effect (Table 3).

Guanidinophosphonatebenzothiazole and its iron, cobalt and zinc complexes reflected highest effectiveness in the benzimidazole and benzothiazole antimicrobial tests. The guanidinophosphonatebenzothiazole gave effective values to be 32.88±0.74%, 12.67±0.47 g/dl, 16.22±2.05 x 10^9/L, 95.44±3.18 x 10^9/L, 40.14±2.11%, 39.30±2.19%, 30.20±0.63 µg/L and 30.33±1.47 µg/L for the pcv, hb, wbc, platelet, neutrophils, lymphocyte, aspartateaminotransferase and alanineaminotransferase while values due to antimicrobial activity of complexes ranged from 34.80±1.60 - 37.20±2.79%, 14.91±0.76 - 15.55±1.10g/dl, 14.97±1.23 - 15.42±3.43x 10^9/L, 103.55±3.63 - 105.15±3.74x 10^9/L, 34.32±2.75 - 36.11±2.73%, 35.88±1.91 - 37.13±0.97%, 25.17±5.38 - 26.32±1.93 µg/L and 25.90±1.55 - 26.40±1.23 µg/L (Table 4). The readings showed differences in antimicrobial activities of guanidinobenzimidazole, guanidinophosphonatebenzimidazole, guanidinobenzothiazole, guanidinophosphonatebenzothiazole and the complexes. The variation in values therefore showed differences in properties of the derivatives**.** The sterile water as a control did not show any antimicrobial effect. .

The high property noticed for the coordinated might be related to metal ions action [10]. Performance of the complexes over the ligands could also be due to chelated polar and nonpolar effects [10]. Ion bonding enhances biochemical ability of organic types while lipophilicity is modified by coordination associated to its ability to moderate molecules movement. The metal complexes therefore have more tendencies to indicate higher antimicrobial activities than the uncoordinated ligand and free metal ion which agrees with literature [11].

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Table 2: Antimicrobial activity of guanidinophosphonatebenzimidazole and complexes

S/N	S	PCV (%)	Hb (g/dl)	WBC (X 10^9 /L)	Platelet (X 10^9/L)	Neu (%)	Lym (%)	AST (ug/L)	ALT (ug/L)
Grp5	Ma	42.10±0.64^{i}	17.14±1.24^{hij}	12.22±0.75^{c}	130.10±2.04^{e}	28.50±3.61^{a}	31.10±0.97^{ab}	12.50±4.19^{abc}	22.20±1.03^{i}
	Me	25.20±2.14^{bc}	7.42±1.34^{bc}	28.44±3.85^{b}	81.81±2.95^{n}	47.68±8.69^{ab}	46.20±3.16^{gh}	36.10±4.06^{fgh}	41.70±2.62^{fg}
	Gpbm	31.70±1.62^{d}	10.65±1.12^{def}	17.88±0.22^{a}	92.03±3.08^{cde}	38.63±4.41^{lm}	40.20±1.7efg	32.47±4.24^{ab}	31.93±2.79efg
Grp6	Mai	42.20±0.18^{e}	16.22±1.03^{ghi}	12.26±0.66^{f}	128.00±1.83^{de}	29.10±2.35^{d}	30.10±3.47^{op}	12.20±3.03^{bc}	21.00±1.36^{ab}
	Me	23.90±1.66^{hi}	7.30±0.72^{b}	24.68±4.37^{d}	82.50±5.32^{ab}	48.75±8.29^{t}	47.70±3.89^{fg}	36.80±2.76^{efg}	42.20±0.89^{gh}
	FeGpbm	33.80±2.12^{f}	13.72±0.84^{de}	17.07±1.54^{i}	99.45±2.40^{c}	37.16±5.14^{j}	38.21±3.25^{yz}	27.84±4.16^{fg}	27.10±1.50^{f}
Grp7	Ma	42.60±1.31^{h}	17.55±1.18^{ij}	12.62±2.13^{k}	129.30±1.63^{def}	29.00±3.07^{l}	31.40±2.05^{xy}	13.10±4.09^{ef}	21.40±1.50^{bc}
	Me	23.50±2.44^{j}	7.30±0.72^{c}	27.40±4.22^{bc}	85.02±5.25^{s}	47.46±7.04^{w}	48.33±3.66^{z}	35.50±4.49^{gh}	41.50±1.36^{g}
	CoGpbm	34.40±1.22^{cd}	13.84±1.03^{ef}	17.02±1.31^{de}	99.59±1.28^{cd}	37.46±3.02^{qr}	38.10±3.01no	27.60±5.13^{de}	26.97±2.38^{def}
Grp8	Ma	42.10±1.48^{k}	17.78±1.72^{hi}	11.22±1.08^{j}	131.10±4.28^{e}	28.40±3.80^{jk}	30.52±2.56^{n}	12.50±4.25^{cd}	22.10±1.97de
	Me	24.30±1.43^{gh}	7.11±0.94^{cd}	27.26±6.63^{jk}	74.60±3.41^{b}	49.10±5.54^{ef}	47.30±3.12^{u}	36.10±4.42^{hi}	41.30±0.40^{m}
	ZnGpbm	35.90±1.24^{de}	13.90±0.59^{fgh}	14.89±0.88^{ab}	99.98±5.64^{mn}	35.55±3.76^{pq}	36.80±3.5v	26.18±3.93kl	26.80±3.03^{q}

NOTE: Gpbm: guanidinophosphonatebenzimidazole, FeGpbm: iron guanidinophosphonatebenzimidazole complex, CoGpbm-cobalt guanidinophosphonatebenzimidazole complex, ZnGpbm: zinc guanidinophosphonatebenzimidazole complex

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Table 3: Antimicrobial activity of guanidinobenzothiazole and complexes

S/N	S	PCV (%)	Hb (g/dl)	WBC (X 10^9 /L)	Platelet (X 10^9/L)	Neu (%)	Lym (%)	AST (ug/L)	ALT (ug/L)
Grp9	Ma	41.52±1.02^{j}	18.12±0.77^{ab}	12.44±0.59^{abc}	128.50±2.52^{f}	28.30±3.32z	31.00±2.32^{a}	12.30±1.41^{a}	22.10±1.27^{ab}
	Me	24.25±0.81^{bc}	7.44±0.47^{kl}	28.46±2.47^{hi}	81.81±3.27^{t}	46.88±2.34^{i}	47.10±1.99^{def}	36.30±1.17^{b}	42.40±5.14^{fg}
	Gbt	32.62±1.02^{gh}	11.86±2.18^{a}	17.54±0.73^{def}	94.13±4.64^{cde}	42.84±2.56^{f}	40.00±1.74^{b}	32.40±1.74^{c}	31.73±1.93st
Grp10	Ma	40.20±2.77^{hi}	16.54±0.84^{b}	12.22±0.39^{a}	128.40±2.58^{v}	28.40±1.72^{ab}	30.50±2.25^{ab}	12.10±2.99^{d}	21.50±1.08^{bc}
	Me	23.40±2.34^{b}	7.40±0.22^{t}	28.11±3.16^{i}	83.70±5.17^{b}	48.55±2.91^{gh}	48.20±1.44^{fg}	36.50±5.30^{e}	42.40±4.00^{cd}
	FeGbt	34.50±3.42^{de}	13.99±24.40^{p}	16.24±0.60^{fg}	99.52±2.56^{c}	37.16±1.64wx	38.43±3.49^{lm}	27.71±3.18f	27.40±2.32^{de}
Grp11	Ma	40.60±1.36^{ij}	17.85±2.00^{yz}	12.05±2.45q	129.33±0.73^{ef}	28.700±2.96^{m}	31.60±2.31^{jk}	13.00±3.98^{g}	21.50±1.52^{ef}
	Me	23.20±1.29^{t}	7.50±0.44^{s}	27.45±2.74^{hi}	83.12±4.10^{y}	48.46±1.50^{ghi}	48.14±0.87^{efg}	36.00±5.56^{h}	42.30±4.84^{fg}
	CoGbt	34.80±1.16^{lm}	13.94±1.14^{z}	16.06±2.88^{g}	99.63±1.45^{cd}	37.09±0.73pq	38.43±0.66^{yz}	27.60±4.45i	27.40±2.02^{gh}
Grp12	Ma	40.40±2.71^{xy}	17.88±0.63^{w}	12.00±1.85y	128.80±3.53^{def}	28.42±0.66^{z}	31.43±3.02^{xy}	12.00±2.97^{j}	22.30±1.72^{hi}
	Me	23.10±5.42^{cd}	7.17±0.51^{v}	27.26±2.62^{i}	72.20±2.79^{x}	47.30±4.27^{uv}	47.50±2.14^{u}	36.30±2.92^{k}	41.20±3.56^{ij}
	ZnGbt	36.25±2.65^{f}	14.10±0.59^{m}	15.98±1.88^{cde}	99.99±5.64^{w}	36.25±0.68^{vw}	37.00±2.34^{v}	26.10±4.60^{l}	27.20±1.88^{jk}

NOTE: Gbt: guanidinobenzothiazole, FeGbt: iron guanidinobenzothiazole complex, CoGbt: cobalt guanidinobenzothiazole complex, ZnGbt: zinc guanidinobenzothiazole complex.

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Table 4: Antimicrobial activity of guanidinophosphonatebenzothiazole and complexes

S/N	S	PCV (%)	Hb (g/dl)	WBC (X 10^9 /L)	Platelet (X 10^9/L)	Neu (%)	Lym (%)	AST (ug/L)	ALT (ug/L)
Grp13	Ma	41.43±1.91efghi	18.33±1.34^{ij}	12.50±0.82^{a}	129.00±2.18^{fgh}	28.34±2.42^{abc}	31.20±2.44^{abc}	12.87±0.58^{a}	22.16±1.21^{c}
	Me	24.21±0.87^{cd}	7.40±0.53^{b}	28.61±9.63^{b}	80.65±1.91^{b}	46.18±2.38^{de}	48.00±1.63^{ef}	36.10±2.26^{de}	42.20±1.86^{hi}
	Gpbt	32.88±0.74^{de}	12.67±0.47defg	16.22±2.05^{c}	95.44±3.18^{c}	40.14±2.11^{abcd}	39.30±2.19^{cd}	30.20±0.63^{ab}	30.33±1.47^{d}
Grp14	Ma	41.00±1.54^{ghi}	17.65±1.41^{ij}	12.12±1.50^{d}	128.70±3.11^{fg}	28.20±3.06^{ab}	30.30±0.93^{a}	12.30±1.32^{b}	22.10±1.20^{a}
	Me	22.80±0.74^{bc}	7.20±0.75^{bcd}	28.16±7.60^{e}	81.50±3.53^{d}	48.00±0.58^{ef}	48.10±3.02^{def}	36.60±4.17^{de}	42.20±1.70^{ghi}
	Fe Gpbt	34.80±1.60^{efg}	14.91±0.76^{cde}	15.42±3.43^{f}	103.55±3.63^{cde}	36.11±2.73^{bcde}	37.13±0.97^{abcd}	26.32±1.93^{c}	26.40±1.23b
Grp15	Ma	40.50±2.91^{hi}	18.55±1.13^{hij}	12.31±1.48^{g}	129.00±3.77^{g}	28.10±1.07^{x}	31.00±1.66^{b}	13.13±0.71^{d}	21.70±0.86^{e}
	Me	23.00±3.12^{c}	7.11±0.68^{bc}	28.42±8.94^{h}	82.21±3.85^{k}	48.34±3.40^{f}	48.10±1.40^{de}	36.22±4.24^{e}	42.10±1.03^{i}
	CoGpbt	35.00±2.80efghi	14.94±0.76defgh	15.41±3.11^{i}	103.61±3.58^{q}	36.00±1.21tu	37.10±1.74^{cde}	26.30±0.74^{f}	26.40±1.39^{ef}
Grp16	Ma	41.00±3.05^{h}	17.83±1.49^{ghi}	12.30±0.66^{j}	128.88±3.79^{gh}	28.22±3.18^{uv}	31.33±2.52^{q}	12.12±2.44^{g}	22.00±0.75^{abc}
	Me	23.30±2.60^{cd}	7.26±0.52^{mn}	27.10±8.83^{k}	82.20±4.47^{y}	48.10±10.35^{fg}	47.80±1.50^{f}	36.40±4.18^{h}	41.70±1.50^{x}
	ZnGpbt	37.20±2.79efgh	15.55±1.10^{def}	14.97±1.23^{m}	105.15±3.74defg	34.32±2.75^{lm}	35.88±1.91^{bcd}	25.17±5.38^{jk}	25.90±1.55y

NOTE: Gpbt: guanidinophosphonatebenzothiazole, FeGpbt- iron guanidinophosphonatebenzothiazole complex, CoGpbt: cobalt guanidinophosphonatebenzothiazole complex, ZnGpbt: zinc guanidinophosphonatebenzothiazole complex.

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CONCLUSION

Antimicrobial activities of guanidinobenzimidazole, guanidinophosphonatebenzimidazole, guanidinobenzothiazole and guanidinophosphonatebenzothiazole derivatives were assessed. They demonstrated antimicrobial potential**.** They exhibited different properties. Complex high performance might resulted from metal ions. Activity of complexes over ligands could also be due to chelates polar and nonpolar effects that make cell accessible. Ion bonding enhances biochemical potential process while lipophilicity is modified by coordination due to its ability to control molecules movement into cell. The metal complexes therefore have more tendencies to indicate higher antimicrobial properties than uncoordinated ligand and free metal ion.

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Data availability

All data analysed during this research are included in this article.

Declaration

J. A. Aremu on behalf of authors states that there is no conflict of interest

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