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Antibacterial Effect of *Aloe Vera* Gel Extract on *Escherichia coli* and *Salmonella enterica* Isolated from the Gastrointestinal Tract of Guinea Fowls

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ABSTRACT

Aloe vera has a long history as a medicinal plant with diverse therapeutic applications. This study was conducted to assess the antibacterial effect of *Aloe vera* gel extract against *Escherichia coli* and *Salmonella enterica* isolated from the gastrointestinal tract (GIT) of guinea fowls. The conventional method was used for the isolation of *Escherichia coli* and *Salmonella enterica.* The antibacterial activity of *Aloe vera* gel extracts (50, 100 and 200 mg/ml) and standard antibiotics were evaluated using the disk diffusion method. The prevalence of *Escherichia coli in* the GIT of the guinea fowls was 100% (15/15). All the *Escherichia coli* were susceptible to ciprofloxacin. At 48h and 72h of incubation, all the *Escherichia coli* were susceptible to gentamicin but not at 24h. Inhibition zones using the *Aloe vera* gel extract ranged from 7.87-12.23mm (50 mg/ml), 8.53-17.23mm (100 mg/ml) and 7.43-10.67mm (200 mg/ml) for *Escherichia coli.* Also, antibacterial test for *Escherichia coli* using the *Aloe vera* gel extract revealed an inhibition zone of 9.10-12.23mm for *Escherichia coli* isolate GIT1, 7.8-8.57mm for *Escherichia coli* isolate GIT2 and 7.43-17.23mm for *Escherichia coli* isolate GIT7. The prevalence of *Salmonella enterica* in the GIT of the guinea fowls was 40% (6/15). All *Salmonella enterica* were susceptible to gentamicin. At 48h and 72h of incubation, all the *Salmonella enterica* were susceptible to suphamethoxazole/trimethoprim and tetracycline but not at 24h. Inhibition zones using *Aloe vera* gel extract ranged from 7.13-12.57mm (50 mg/ml), 4.2-6.7mm (100 mg/ml) and 0-9.23mm (200 mg/ml). Furthermore, antibacterial test for *Salmonella enterica* using the *Aloe vera* gel extract revealed an inhibition zone of 5.3-12.57mm for *Salmonella enterica* isolate GIT9, 0-7.8mm for *Salmonella enterica* isolate GIT10 and 4.2-9.0mm for *Salmonella enterica* isolate GIT15. The study revealed that *Aloe vera* gel extract possessed antibacterial properties. Therefore, it can be added to the feed of guinea fowls as a prophylactic to reduce bacterial infections.

Key words: Aloe vera, Antibiotics, *Escherichia coli*, Gut, *Salmonella enterica*

INTRODUCTION

Avian pathogenic *Escherichia coli* strains can cause avian colibacillosis in guinea fowls. Colibacillosis is characterized by colisepticemia, hemorrhagic septicemia, coligranuloma, and chronic respiratory disease, which contributes to economic losses for the world's poultry industries (Nolan et al., 2013). *Salmonella enterica* causes salmonellosis in guinea fowl. *Salmonella enterica* serovars Pullorum and Gallinarum are particularly involved in poultry salmonellosis. They can cause death in chicks, poults and adult poultry. Poultry including guinea fowls infected with *Salmonella enterica* huddle near a heat source are anorectic, appear weak and have whitish diarrhoea around the vent. They also show symptoms of fever, are pale, dehydrated, have diarrhea, swollen liver, brittle and often bile-stained (Schepop, 2017).

Escherichia coli and *Salmonella enterica* infections are controlled by the use of antibiotics. Nevertheless, the use of antibiotics for prophylactics and treatment of these infections especially anarchically contribute to antimicrobial resistance. Berghichen et al. (2018) noted a massive use of antibiotics and mostly used without adhering to their principles of application in Algeria. Resistance of bacteria to multiple antimicrobials is a concern to public health and scientific studies (Raja et al., 2017; van den Honert et al., 2018; WHO, 2018; Adzitey et al., 2019; Berghiche et al., 2019; Tay et al., 2019). This is so because, the use of antimicrobial drugs in veterinary medicine and animal husbandry may compromise human health if resistant bacteria develop in animals and are transferred to humans through the food chain and environment (McNulty et al., 2016). The evolution and development of multiple drug resistant pathogenic

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microorganisms has necessitated the search for new source of antimicrobial substances, including plant metabolites (Nostro et al., 2000). Hence, the assessment of the efficacy of plant-based drugs in traditional veterinary medicine is of paramount importance because these drugs educe few side effects, affordable and easily available. Sofowora (2003) reiterated that the use of traditional veterinary medicine may be due to its low cost, availability and ease of application compared to modern veterinary medicine. Many plants have beneficial multifunctional aspects which are derived from their specific bioactive components (Mothana and Lincleqist, 2005; Kar and Bera, 2018). Many plants have also been subjected to pharmacological test, and a substantial number of new antibiotics have been developed from them (Mothana and Lincleqist, 2005).

Aloe vera is an ancient plant with its origin in African continent and has been reported to have beneficial effects on the growth performance, gut microflora, hematological characteristics, carcass characteristics and immune response of poultry (Kaithwas et al., 2008; Yadav, 2017; Kar and Bera, 2018). It can survive under a wide variety of conditions and has been shown to have many medicinal and antibiotic properties (Christaki and Florou-Paneri, 2010; Kar and Bera, 2018). Jain et al. (2016) reported that *Aloe vera* gel has been used for management of various infections since ancient times as it has anti-inflammatory, anti-microbial, and immune-boosting properties. Guinea fowls (*Numida meleagris*) in Ghana are dominated by local or traditional breeds reared mostly in Northern part of Ghana. The meat of guinea fowls is cherished and relished by many Ghanaians (Adzitey et al., 2015). Nonetheless, they are kept mainly under the extensive and semi-extensive systems, and are exposed to a variety of bacteria during scavenging (Teye et al., 2000; Adzitey et al., 2015). The gastrointestinal tracts of animals are well known to harbor bacteria such as *Campylobacter spp.*, *Clostridium spp.*, *Escherichia coli*, *Lactobacillus spp.*, *Salmonella spp.*, *Shigella spp*. and *Vibrio spp*. Guinea fowls can feed on plants which may include *Aloe vera* during scavenging.

This study was conducted to determine the antibacterial effect of *Aloe vera* extracts on *Escherichia coli* and *Salmonella enterica* isolated from the gastrointestinal tract of guinea fowl.

MATERIALS AND METHODS

Study area, sample collection and analysis

This study was conducted at the Microbiology Laboratory (in the Spanish laboratory) of University for Development Studies, Nyankpala Campus, Ghana. Fresh *Aloe vera* plants (harvested from backyard garden) and the gastrointestinal tract (collected from slaughter slab) of 15 guinea fowls (*Numida meleagris*) were obtained from the Tamale metropolis. The gastrointestinal tracts were analyzed immediately upon reaching the laboratory for the presence of *Escherichia coli* and *Salmonella enterica* following the procedures in the bacteriological analytical manual of the FDA-USA (Feng et al., 2017; Andrews et al., 2018).

Isolation and confirmation of *Escherichia coli* and *Salmonella enterica*

For the isolation of *Escherichia coli*, one g of gastrointestinal tract content was pre-enriched in 10 ml of Buffered Peptone Water (BPW) and incubated at 37^{o}C for 18-24 h. After which, the aliquots were plated on Levine Eosin-Methylene Blue Agar and incubated again at 37^{o}C for 24 h. For *Salmonella enterica,* aliquots from BPW were further enriched in Rappaport Vassiliadis (RV) and Selenite (SN) Broths. Samples in RV broth were incubated at 42^{o}C for 24 h while those in SN broth were incubated at 37^{o}C for 24-48 h. After incubation, the aliquots from RV and SN broths were plated on xylose lysine deoxycholate and brilliant green agar, and incubated at 37^{o}C for 24 h. Presumptive *Escherichia coli* and *Salmonella enterica* were purified on trypticase soy agar (incubated at 37^{o}C for 24 h) and confirmed using the appropriate biochemical tests as stated by Feng et al. (2017) and Andrews et al. (2018), and serological tests using *Escherichia coli* and *Salmonella* latex agglutination test kits (Oxoid, Basingstoke, UK). All incubations were done under aerobic conditions and all media used were purchased from Oxiod, Basingstoke, UK.

Extraction of *Aloe vera* gel extract

The *Aloe vera* gel extract was prepared according to Thiruppathi et al. (2010). Briefly, the *Aloe vera* gel was extracted under aseptic condition, dried in an oven at 70^{o}C for 24 h and then milled into powder. 10g of the oven-dried *Aloe vera* gel powder was suspended in 50ml of 80% ethanol and kept on a shaker for 24 h for proper dissolution. This was then filtered through Whitman paper no.1 and allowed to evaporate in an oven at 80^{o}C for 24 h. The dried extract was dissolved in Dimethyl Sulfoxide (DMSO) and stored in the refrigerator at 4^{o}C for further uses.

Preparation of standard concentrations of *Aloe vera* extract and bacteria inocula

200, 100 and 50 mg of *Aloe vera* gel powder were separately dissolved in one ml of DMSO. Single colony of pure cultures of *Escherichia coli* and *Salmonella enterica* were isolated and grown in Trypticase Soy Broth (TSB) and incubated at 37^{o}C for 24 h. Then, the concentration was adjusted to 0.5 McFarland turbidity using sterile TSB.

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Antibiotic susceptibility test using standard antibiotics and *Aloe vera* gel extract

These were done using the disc diffusion method of Bauer-Kirby (1966). For the conventional standard method, the isolates (in TSB adjusted to 0.5 McFarland turbidity) were swabbed onto Mueller-Hinton (MH) agar using a sterile cotton swab. Eight different standard antibiotics, notably: Ampicillin (Amp) 10 µg, Chloramphenicol (C) 30 µg, Gentamicin (Cn) 10 µg, Ceftriaxone (Cro) 30 µg, Ciprofloxacin (Cip) 5 µg, Erythromycin (E) 15 µg, sulfamethoxazole/Trimethoprim (Sxt) 22 µg, and Tetracycline (Te) 30 µg were placed on the HM agar at a distance to prevent overlapping of the inhibition zones. The MH agar was incubated aerobically at 37^{o}C for 24 h, 48 h and 72 h, and the inhibition zones measured in millimeters (mm). The inhibition zones were interpreted according to the Clinical Laboratory Standard Institute (2014).

For the antibacterial test using *Aloe vera* gel extracts at different concentrations, blank antibiotic discs purchased from Oxoid, Basingstoke, UK were individually impregnated with different concentrations (200mg, 100mg and 50mg) of the *Aloe vera* extract, and were placed on the surface of the MH agar which has been inoculated with the isolates. Then, it was incubated at 37^{o}C for 24 h, 48 h and 72 h, and the inhibition zones measured in mm. All the antibiotic discs were placed at a distance to avoid overlapping of inhibition zones.

Statistical analysis

The data obtained in this study were analyzed using One-way ANOVA of the GenStat Release 12 Edition. Significant differences were determined at 95% ($P<0.05$)

RESULTS

Prevalence of *Escherichia coli* and *Salmonella enterica* in gastrointestinal tract of guinea fowls

The prevalence of *Escherichia coli* and *Salmonella enterica* in the gastrointestinal tract (gut) of the guinea fowl was 100% (15/15) and 40% (6/15), respectively.

***Escherichia coli* and *Salmonella enterica* sensitivity tests**

The antibiotic resistance of three randomly selected *Escherichia coli isolates* is shown in table 1. Out of the three *Escherichia coli isolates* subjected to antibiotic susceptibility test, 37.5% were susceptible, 45.8% were resistant and 16.7% were intermediate resistant. *Escherichia coli* isolates were 100% resistant to Amp and Te at 24 h but not at 48 h and 72 h. The *Escherichia coli* isolates were all susceptible to Cip (100%) at all incubation periods (24, 48 and 72 h). The *Escherichia coli* isolates also exhibited some intermediate resistances to Cro (at 24 h), G (at 24 h), Sxt (at 24 h) and E (at 24, 48 and 72 h). Resistance to C and Cro were not the same at 24, 48 and 72 h of incubation whilst it was the same for Sxt and E. The antibiotic activity of the *Salmonella enterica* isolates is presented in table 2. Overall, 70.8% of the *Salmonella enterica* isolates were susceptible, 29.2% were resistant and none exhibited intermediate resistant. All the *Salmonella enterica* isolates were susceptible to gentamicin at 24 h, 48 h and 72 h. With the exception of Sxt and Te, the results for all the antibiotics against the *Escherichia coli* isolates were the same for all the incubation periods. Results for Sxt and Te were however, the same at 48 h and 72 h of incubation.

Evaluation of antibacterial activity of *Aloe vera* extracts against *Escherichia coli* and *Salmonella enterica*

The exhibition zones for the *Escherichia coli* isolates ranged between 9.10 to 12.23 mm for *Escherichia coli* isolate GIT1, 7.8 to 8.57 mm for *Escherichia coli* isolate GIT2 and 7.43 to 17.23 mm for *Escherichia coli* isolate GIT7 (Table 3). Inhibition zones for the *Escherichia coli* isolates (GIT1, GIT2 and GIT3) did not significantly differ ($P>0.05$) at 50 mg/ml and 200 mg/ml but significantly differed ($P<0.05$) at 100 mg/ml. The inhibition zones for 50 mg/ml, 100 mg/ml and 200 mg/ml *Aloe vera* gel extract ranged between 7.87 to 12.23 mm, 8.53 to 17.23 mm and 7.43 to 10.67 mm, respectively. The results in table 3 indicated that *Aloe vera* extracts at 100 mg/ml was the most effective in controlling of *Escherichia coli* isolates. At 100 mg/ml, most of the *Escherichia coli* isolates produced higher inhibition zones compared to other concentrations (50 mg/ml and 200 mg/ml).

The exhibition zones for the *Salmonella enterica* ranged between 5.3 to 12.57 mm for *Salmonella enterica* isolate GIT9, 0 to 7.8 mm for *Salmonella enterica* isolate GIT10 and 4.2 to 9.0 mm for *Salmonella enterica* isolate GIT15 (Table 4). Also in table 4, inhibition zones for the *Salmonella enterica* isolates (GIT9, GIT10 and GIT15) differed significantly ($P<0.05$) at 50 mg/ml and 200 mg/ml but not at 100 mg/ml ($P>0.05$). The inhibition zones for 50 mg/ml, 100 mg/ml and 200 mg/ml *Aloe vera* gel extract ranged between 7.13 to 12.57 mm, 4.2 to 6.7 mm and 0 to 9.23 mm, respectively. The results in table 4 revealed that *Aloe vera* gel extracts at 50 mg/ml was effective in controlling *Escherichia coli* isolates. At 50 mg/ml, most of the *Salmonella enterica* isolates produced higher inhibition zones ($P\leq0.05$) compared to other concentrations (100 mg/ml and 200mg/ml).

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Table 1. Percentage antibiotic activity of *Escherichia coli* isolated from gastrointestinal tract of guinea fowl at 24, 48 and 72 hours in the Tamale Metropolis, Ghana

Antibiotics	No. of Isolates	24 hours			48 hours			72 hours		
		S (%)	I (%)	R (%)	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)
Ampicillin (AMP)	3	0.00	0.00	100	0.00	33.3	66.7	0.00	33.3	66.7
Chloramphenicol (C)	3	33.3	0.00	66.7	33.3	33.3	33.3	33.3	33.3	33.3
Ciprofloxacin (Cip)	3	100	0.00	0.00	100	0.00	0.00	100	0.00	0.00
Ceftriaxone (Cro)	3	33.3	33.3	33.3	66.7	0.00	33.3	66.7	0.00	33.3
Gentamicin (Cn)	3	66.7	33.3	0.00	100	0.00	0.00	100	0.00	0.00
Erythromycin (E)	3	0.00	33.3	66.7	0.00	33.3	66.7	0.00	33.3	66.7
Sxt	3	66.7	33.3	0.00	66.7	33.3	0.00	66.7	33.3	0.00
Tetracycline (Te)	3	0.00	0.00	100	33.3	33.3	33.3	66.7	33.3	0.00

No: number, S: susceptible, I: Intermediate, R: resistant, Sxt: Suphamethoxazole/trimethoprim.

Table 2. Percentage antibiotic activity of *Salmonella enterica* isolated from gastrointestinal tract of guinea fowl at 24, 48 and 72 hours in the Tamale Metropolis, Ghana

Antibiotics	No. of Isolates	24 hours			48 hours			72 hours		
		S (%)	I (%)	R (%)	S (%)	I (%)	R (%)	S (%)	I (%)	R (%)
Ampicillin (AMP)	3	66.7	0.00	33.3	66.7	0.00	33.3	66.7	0.00	33.3
Chloramphenicol (C)	3	66.7	0.00	33.3	66.7	0.00	33.3	66.7	0.00	33.3
Ciprofloxacin (Cip)	3	66.7	0.00	33.3	66.7	0.00	33.3	66.7	0.00	33.3
Ceftriaxone (Cro)	3	66.7	0.00	33.3	66.7	0.00	33.3	66.7	0.00	33.3
Gentamicin (Cn)	3	100	0.00	0.00	100	0.00	0.00	100	0.00	0.00
Erythromycin (E)	3	66.7	0.00	33.3	66.7	0.00	33.3	66.7	0.00	33.3
Sxt	3	66.7	0.00	33.3	100	0.00	0.00	100	0.00	0.00
Tetracycline (Te)	3	66.7	0.00	33.3	100	0.00	0.00	100	0.00	0.00

No: number, S: susceptible, I: Intermediate, R: resistant, Sxt: Suphamethoxazole/trimethoprim.

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Table 3. Zones of inhibition by *Aloe vera* extract against the *Escherichia coli* isolated from gastrointestinal tract of guinea fowl at 24, 48 and 72 hours in the Tamale Metropolis, Ghana

***E.coli* isolates**	**24 hours**			**48 hours**			**72 hours**		
	200 mg/ml	100 mg/ml	50 mg/ml	200 mg/ml	100 mg/ml	50 mg/ml	200 mg/ml	100 mg/ml	50 mg/ml
GIT 1	9.13	9.10[b]	11.23	10.3	9.10[b]	12.23	10.67	9.33[b]	12.33
GIT2	7.8	8.53[b]	7.87	8.1	8.53[b]	8.13	8.33	8.57[b]	8.23
GIT7	7.43	14.43[a]	9.2	9.2	17.10[a]	10.37	9.67	17.23[a]	10.3
SEM	3.258	1.986	3.032	5.1	3.186	2.928	4.568	3.706	3.236
P value	0.577	0.002	0.164	0.704	0.003	0.081	0.616	0.006	0.113

Escherichia coli: Escherichia coli, GIT: Gastrointestinal tract, The GIT 1, GIT2 and GIT7 were randomly selected from positive *Escherichia coli* isolates, SEM: Standard Error of Means. Means with different superscript along the columns are different at $P \leq 0.05$.

Table 4. Zones of inhibition by *Aloe vera* extract against the *Salmonella enterica* isolated from gastrointestinal tract of guinea fowl at 24, 48 and 72 hours in the Tamale Metropolis, Ghana

***E.coli* isolates**	**24 hours**			**48 hours**			**72 hours**		
	200 mg/ml	100 mg/ml	50 mg/ml	200 mg/ml	100 mg/ml	50 mg/ml	200 mg/ml	100 mg/ml	50 mg/ml
GIT 1	8.23[a]	5.3	9.00[a]	9.13[a]	6.7	12.57[a]	9.23[a]	6.7	12.57[a]
GIT2	0.00[c]	4.3	7.13[b]	0.00[b]	4.7	7.77[b]	0.00[b]	4.7	7.87[b]
GIT7	6.67[b]	4.2	7.67[b]	8.23[a]	4.6	7.77[b]	9.00[a]	4.8	7.80[b]
SEM	0.722	6.8	1.022	1.468	7.66	1.178	1.942	7.74	1.176
P value	0.001	0.938	0.026	0.001	0.83	0.001	0.001	0.85	0.001

GIT: Gastrointestinal tract, The GIT 9, GIT10 and GIT15 were randomly selected from positive *Salmonella enterica* isolates, SEM: Standard Error of Means. Means with different superscript along the columns are different at $P \leq 0.05$

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DISCUSSION

Escherichia coli and *Salmonella enterica* were found in the gastrointestinal tract (gut) of the guinea fowls. It is common to find these bacteria in the gastrointestinal tract of animals since it is a natural habit for microorganisms. However, they can pose problems to poultry and consequently humans when they are present in large numbers. Also, pathogenic *Escherichia coli* and *Salmonella enterica* strains can cause *Escherichia coli* and *Salmonella* infections, respectively. The presence of *Escherichia coli* and *Salmonella enterica* in the gastrointestinal tract of guinea fowls present opportunity for cross contamination unto carcasses during processing. Adzitey et al. (2015) found *Escherichia coli* and *Salmonella enterica* in fresh and smoked guinea fowls and attributed them to poor processing during dressing and cross contamination from their natural habitat. Kilonzo-Nthenge et al. (2018) isolated *Salmonella enterica* from 23% of whole carcass rinses of guinea fowl.

This study revealed that the *Escherichia coli* isolates exhibited overall susceptibility (37.5%), resistant (45.8%) and intermediate resistant (16.7%). There were some changes in resistant patterns with incubation time which was observed for ampicillin, chloramphenicol, ceftriaxone, gentamicin and tetracycline. Bacteria can develop resistance to antibiotics via mutation or the acquisition of resistant genes from other bacteria (Wintersdorff et al., 2016). Furthermore, intermediate resistances were found at 24 h, 48 h, and/or 72 h for all the antibiotics except ciprofloxacin. Any isolate that exhibited intermediate resistant has the tendency to become resistant (Adzitey et al., 2016; Adzitey, 2018). Kilonzo-Nthenge et al. (2008) reported that *Escherichia coli* isolated from guinea fowls were resistant to ampicillin but susceptible to ciprofloxacin, erythromycin and tetracycline, which was similar to this present work.

In this study, most of the *Salmonella enterica* isolates were susceptible (≥66.8%) to the eight different antibiotics tested. Intermediate resistant was not observed for the *Salmonella enterica* isolates, however, some of the *Salmonella enterica* isolates exhibited 33.3% resistance. All the *Salmonella enterica* isolates were susceptible to Cn. The reason for the development of resistant among pathogens including *Salmonella enterica* have been linked to the indiscriminate use of antibiotics for therapeutic and growth purposes in animals (Wintersdorff et al., 2016). *Salmonella enterica* species isolated from guinea fowls were resistant to Amp and Te, but susceptible to Cip and E (Kilonzo-Nthenge et al., 2008). In this study 33.3% resistance was found at 24 h for Amp and Te, but 66.7% susceptibility for Cip and E at 24 h. At 48 h and 72 h, all the *Salmonella enterica* isolates were susceptible to Sxt and Te. These results suggested that the mentioned antibiotics require more than 24 h to be bactericidal for *Salmonella enterica* isolates examined in this study.

The antibacterial activity of *Aloe vera* gel extract was investigated against *Escherichia coli* and *Salmonella enterica* isolates of guinea fowl gastrointestinal tract origin using the disc diffusion method. The results obtained revealed that *Aloe vera* gel extract had antibacterial activities. Isolates of *Escherichia coli* treated with 100 mg/ml concentration of *Aloe vera* gel extract caused the highest overall inhibition zone than those treated with 50 mg/ml and 200 mg/ml of *Aloe vera* gel extract. Irshad et al. (2011) reported that *Aloe vera* extract produced an average inhibition zone of 2 mm against *Escherichia coli*. Ferro et al. (2003) found an inhibition zone of 12.66 mm for *Escherichia coli* isolates. The inhibition zones in this study were generally higher than the findings of Irshad et al. (2011) and had some similarity with findings of Ferro et al. (2003). Irshad et al. (2011) reported that that *Aloe vera* extracted using acetone exhibited stronger activity against *Escherichia coli* as compared to aqueous or ethanol extracts. Ferro et al. (2003) reported that sap water extract was more effective than leaf extract against *Escherichia coli*. In this study, *Aloe vera* gel extract exhibited antibacterial activity against all the *Escherichia coli* isolates, and was the highest at 100 mg/ml.

The growth of *Salmonella enterica* isolates was inhibited at 50 mg/ml than those treated with 100 mg/ml and 200 mg/ml of *Aloe vera* gel extracts across 24 h, 48 h, and 72 h of incubation. Qadir et al. (2013) found that the best concentration of *Aloe vera* water extract inhibition for *Escherichia coli* was at 75%, with inhibition zone of 9.75 ± 0.25 mm. Inhibition zones lower or higher than 9.75 mm were found in this study. Jonson et al. (2011) examined 35 clinical *Salmonella enterica* isolates and reported that, 17 isolates had inhibition zone of 7 to 32 mm in 0.007 mg/ml of the extract. The highest zone of inhibition produced by the *Aloe vera* gel extract in this study against *Salmonella enterica* isolate was 12.27 mm which was lower than the 32 mm reported by Jonson et al. (2011).

Kaithwas et al. (2008) studied the antimicrobial activity of *Aloe vera* gel by using disc diffusion method and reported that, the gel was effective against *Salmonella enterica*. Kar and Bera (2018) indicated that, the *Aloe vera* gel is rich in variety of secondary metabolites, such as anthraquinones glycosides, glycoproteins, gamma-lanoline acid, prostaglandins and mucopolysaccharides, which are mainly responsible for its antimicrobial activity. In this study, there were differences in the antimicrobial activities of the *Aloe vera* gel extract. Azwanida (2015) revealed that differences in antibacterial activity of *Aloe vera* plant extracts can be attributed to the age of the plant, physical factors such as temperature, light, water, time of harvesting of plant and drying method used before the extraction process.

CONCLUSION

This study confirmed the potential of *Aloe vera* gel extract as an antibacterial agent in poultry farming. *Aloe vera* gel extracts can be used as prophylactic antibiotics to reduce over dependence on conventional antibiotics that can lead to the

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development of resistant strains. It is recommended that, toxicity studies of the *Aloe vera* gel extract should be done to determine the safety indices of the extracts. Clinical trials should also be carried out to explore the potential of *Aloe vera* extracts in the treatment of bacterial infectious diseases of poultry.

DECLARATIONS

Competing interests

All authors declare that they have no conflict of interest.

Author's contribution

Adzitey F, Udoka JU and Agbolosu AA conceived and designed the experiment. Adzitey F and Udoka JU performed the experiment. Adzitey F and Agbolosu AA analyzed and wrote the manuscript. All authors read and approved this manuscript.

Concept to publish

All authors gave their informed consent prior to their inclusion in the study.

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