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Research Article

Prevalence and Characterization of Staphylococci from Dried Crayfish in Selected Markets in FCT, Abuja, Nigeria

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Abstract

Staphylococci spp with special reference to *Staphylococcus aureus* play an important role in foodborne diseases and it is one of the most important pathogens found in sea foods. *Staphylococcus aureus* is considered as one of the most frequently occurring food-borne pathogen worldwide and cause food poisoning. The risk of zoonotic transmission to humans highlights the need to understand the prevalence and antibiogram of *staphylococcus aureus* in dried crayfish sold at selected markets in FCT, Abuja Nigeria. A cross sectional epidemiological study method was adopted in the study while a multistage technique was used to select the study sites and sample subjects. A total of 400 dried crayfish samples were collected from six different markets (Wuse, Garki, Gwagwalada, Zuba, Kubwa and Bwari). Samples were collected from June to September 2017 and analyzed using standard procedures on Baird Parker (BP) agar plates with supplements of egg yolk tellurite emulsion. *Staphylococcus* species were identified using conventional biochemical tests. Isolates were further characterized using Microgen TM STAPH-12S KIT. The antimicrobial sensitivity test of the isolates were carried out using disc diffusion method on Mueller Hinton agar and was interpreted according to clinical and laboratory standard institutes. Polymerase Chain Reaction was carried for the detection of *Mec*A gene. The prevalence of *staphylococcus* species isolated from samples indicated (9) 34.6% for *staphylococcus chromogenes,* (8) 30.8% for *staphylococcus aureus,* (4) 15.4% for *staphylococcus hyicus,* (4) 15.4% for *staphylococcus xylosus and staphylococcus sciuri* (1) 3.8%. The antibiogram of *staphylococcus* species from the isolates revealed high sensitivity to some of the antibiotics used such as vancomycin (100%) imipenem (100%) and gentamycin 92.3% while resistance was exhibited for oxacillin (96.2%) and penicillin (76.9%) and 53.8% for cefoxitin. The presence of *Mec*A gene was detected among the *staphylococcus aureus* isolates. The findings from this research revealed that dried crayfish samples from different markets harboured *staphylococcus aureus* amongst other staphylococci which is potentially pathogenic and constitutes an important source of food-borne infection and intoxication. Proper handling, processing, packaging, storage, distribution and transportation methods should be put in place to reduce potential health risks.

Keywords: *Prevalence; Antibiogram; staphylococcus species; Crayfish*

Introduction

Staphylococcal species is one of the major bacterial agents causing food borne illnesses [39]. *Staphylococcus aureus* is a pathogenic organism of the genus staphylococcus which causes diseases in humans as well as animals, and also an important agent of food poisoning all over the world [2,6,59]. *Staphylococcus aureus* in humans can cause a wide range of diseases such as bloodstream infections, minor skin and soft tissue infections, pimples, boils, cellulites as it also causes toxin-mediated syndromes like toxic shock, impetigo, and abscesses to life threatening disease such as pneumonia, septicaemia, meningitis, osteomyelitis, endocarditis, as well as bovine mastitis and food poisoning [14,56,58]. The bacteria are a leading cause of gastroenteritis due to food poisoning, resulting from the consumption of food contaminated with preformed enterotoxins [42].

Food can be contaminated through different ways but the most means is through contact with contaminated food workers carrying bacteria. Several studies have investigated the potential paths of transmission of this dangerous strain by human carriers or environment, such as transport and packaging, contaminated hands and contact with infected respiratory secretions from workers with sea food products [4]. The presence of staphylococci in seafood can be an indication of both post-harvest and processing contamination due to poor personal hygiene [5].

Seafood's, are of great importance for human nutrition and provide health benefits, can also act as sources of various food-borne diseases [18]. Among all the foodborne disease outbreaks reported globally, seafood accounts for up to 10% of all outbreaks [32]. Crayfish (*Procambarus clarkii*) is a freshwater crustacean resembling small lobster and was reported to have high nutritive value with a superior biological value, true digestibility, net protein utilization, high content of essential amino acids, and protein efficiency [23,34].

Like most sea foods crayfish contributes immensely to the nutritional requirement of consumers [33,45,60]. Crayfish are usually prepared for consumption by smoking, and occasionally preserved by sun drying. Many Nigerian riverine Delta women source their livelihood from marketing of smoke-dried crayfish [35].

In open markets, crayfish are often displayed unpackaged which likely enhance microbial contamination via dust-laden air [49]. Crayfish in open markets are constantly touched by prospective buyers with bare hands, an unhygienic practice which could contribute significantly to increased contamination by micro-organisms. [63]. This unhygienic practice can lead to outbreaks of diseases caused by these organisms. It can also be a reasonable source for the transmission of antibiotic resistant genes to the clinical species and vice versa. *Staphylococcus aureus* can be eliminated by heat treatment. Staphylococcal enterotoxins are heat stable, and may be present in food when *staphylococcus aureus* are absent because of their heat tolerance capacity [6,37]. This fact should be considered in risk assessment and planning appropriate public health interventions [37].

Extensive use of antimicrobial drug in human and in animal farming for therapeutic and preventive purpose, is a major cause for the prevalence of drug resistance among foodborne pathogens [1,25]. Antibiotic resistance is a worldwide public health problem that continues to grow due to misuse and abuse of antibiotics in both human and veterinary medicine [19].

The World Health Organization (WHO) on animal health recommended the continuous monitoring and surveillance of resistant microorganisms in aquatic animals [15]. This is to monitor the trend and level of resistance in the aquatic environment. Indiscriminate use of antimicrobial agent can lead to disease and even death [8].

Food and feed safety is essential, and the presence of methicillin resistant *staphylococcus aureus* in the food chain may contribute to the increasing dissemination of methicillin resistant *staphylococcus aureus* worldwide [22].

The scale of the problem of antimicrobial resistance (AMR) is well recognized as a serious threat to public health [65]. Therefore, this present study aimed at prevalence and characterization of *staphylococcus* species from dried crayfish samples being the species widely consumed in various forms by the locales in the study area; and analyse their antibiotics susceptibility with view to determining the multidrug resistance patterns of the isolates.

Materials and Methods

Study area and design

A systematic sampling method was used to select the subject in each cluster (1 in every 5 crayfish seller) This study was conducted in the Federal Capital Territory (FCT), Abuja which was formed in 1976, from parts of Nasarawa, Niger and Kogi States. The territory is located just north of the confluence of Niger and Benue rivers. It is bordered by Niger State to the West and North, Kaduna to the Northwest, Nassarawa to the East and South and Kogi to the Southwest. Abuja has an estimated human population of 1405,201 according to 2006 census (NPC, 2006).

It lies between latitude 8.25 and 9.20 North of the equator, and longitude 6.45 and 7.39 East of Greenwich Meridian. Abuja is geographically located in the centre of the country. The Federal Capital Territory has a land mass of approximately 7,315 km^2 of which the actual city occupies 275.3km^2. It is situated within the savannah region with moderate climatic conditions.

A cross sectional epidemiological study method was adopted in the study while a multistage sampling technique was used. Firstly, 3 area councils namely, Gwagwalada, Bwari and Abuja municipal area council were selected using simple random sampling by balloting. Secondly, clusters of major markets in the selected area council were listed and two each of purposively selected.

Sampling

A total of 400 samples of dried crayfish were collected from six different markets namely Gwagwalada (91), Zuba (17), Garki (106), Wusa (73), Bwari (44) and Kubwa (69) in sterilized polyethylene bags and transported to bacterial Zoonoses Laboratory Department of Veterinary Public Health and Preventive Medicine Ahmadu Bello University Zaria for analyses and isolation of *staphylococcus* species. Ten grams each of dried crayfish sample were weighed using electronic weighing balance and placed in a sterile sample bag and a total of 90ml sterile peptone water added to the sample and homogenized in a stomacher for two minutes for pre-enrichment (Cheesbrough, 2006).

Isolation and identification of *Staphylococcus* species

Using a sterile pastuer pipette, 1 ml of the homogenised sample was inoculated into 9 ml tryptic soy broth (TSB) and incubated at 37°C for 24 hrs. After incubation, a loop full of the homogenate was picked using sterile inoculating wire loop and streaked onto a Baird-Parker agar and incubated at 37°C for 24 hrs. Tinge shiny colonies on Baird-Parker agar were considered presumptive for *staphylococcus aureus*. Presumptive colonies were picked and streaked on nutrient agar slant and incubated for 24 hr. Tinge shiny colonies on Baird-Parker agar were subjected to Gram reaction, and standard biochemical tests such as catalase test, coagulase production, DNase test, haemolysis test and sugar fermentation based on standard procedures [16,31,10]. Microgen™ Staph-12S (MB1561) system (Microgen, Bioproducts, UK) was employed to confirm the identity of the isolated *staphylococcus* species. The identified *staphylococcus* isolates were stored in the refrigerator at 4ºC for further analysis.

Determination of antibiotic susceptibility of *Staphylococcus* species isolates

The agar disc diffusion method was used to determine the antibiotics susceptibility of *S. aureus* isolates. [7] on Muller Hinton agar according to Clinical and Laboratory Standards Institute [12]. The antibiotics and their concentrations include: Gentamycin (CN)10µg,

vancomycin 30µg, ciprofloxacin 5µg, oxacillin 30µg, ampicillin clavulanic acid 30µg, cefoxitin FOX) 30µg, chloramphenicol 30µg, streptomycin 25µg, imipenem 10µg, penicillin 10µg, clindamycin (DA) 2 µg. Pure isolates of *S. aureus* were emulsified in five millilitre of sterile physiological saline and the turbidity adjusted to 0.5 McFarland standard (approximately a cell density of 1.5×10^8 cfu/mL). The standardized suspension was inoculated on Mueller Hinton agar using sterile swab sticks to ensure even distribution and confluent growth. The sensitivity disc of the various antibiotics was aseptically and gently placed using a disk dispenser and gently pressed down to ensure contact and incubated at 37°C for 24 hours. After incubation, the plates were examined, the zones of inhibition were measured, and results were interpreted according to CLSI [13].

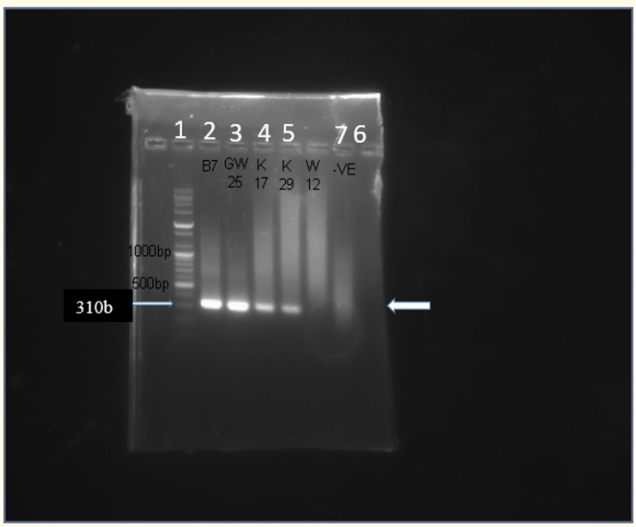

Figure 1: *Agar rose gel electrophoreses of mecA gene; lane 1: bp molecular weight ladder; lane 2 to 5 are tested isolates with negative control amplified mecA as indicated by 310 bp PCR amplicon; (methicillin susceptible S. aureus).*

DNA extraction

Extraction of DNA from all samples were done as described by [29]. DNA extraction was performed using suspension of isolated colonies prepared in sterile distilled water following protocol of bacterial DNA extraction kit (DNA_{zol} ^{R} BD, USA). Two to three well isolated colonies of confirmed methicillin resistant *staphylococcus aureus* isolate were suspended in 0.5 ml autoclaved distilled water. One ml of DNAzol was added in bacterial suspension. The mixture was vortexed vigorously for 15 - 20 seconds and stored at room temperature for 5 minutes then centrifuged for 1 minute at 8000 g. A volume of 0.4 ml of isopropanol was added to the lysate for precipitation of DNA. The precipitated DNA was sedimented by centrifugation at 6000 g for 5 minutes, supernatant was removed and 0.5 ml of DNAzol was added to the DNA pellet. The DNA pellet was vortexed until it was completely dispersed. Then it was centrifuged at 6000 g for 5 minutes. The supernatant was removed and washed, the DNA pellet was mixed with 1ml of 75% chilled ethanol. Again it was centrifuged at 7000 g for 5 minutes. The ethanol wash was decanted and stored in the eppendrof tube vertically for 15 minutes to evaporate any residual ethanol. The DNA pellet was then dissolved in 50 ul molecular grade water.

Detection of *mec*A gene

The detection of *mec*A gene was carried out using polymerase chain reaction. All *Staphylococcus aureus* isolates resistant to methicillin and those that are presumptive MRSA were tested for the presence of *mec*A gene by PCR amplification according to the method described by [52].

PCR amplification was performed in a thermal cycler by using a recombinant Taq DNA polymerase (Ampli Taq Perkin Elmer Cetus Corp Norwalk conn). The reaction mixture consisted of 25ul of lysate, 10ul of 10 × PCR amplification buffer (200 mM Tris- Hcl (pH 8.3) 500 mM KCL, 15 mM MgCl, 0.1% (wt/vol) gelatin, 0.5% Tween 20) and 2.0 µl of each primer. A total of 10 ul of deoxynucleoside triphosphates (1mM each in stock solution) and 25 µl of PCR grade water. Fifty microliter mineral oil was added to inhibit evaporation. PCR cycles were ran under the following conditions. Initial denaturation at 94^0C for 5 minute followed by 30 cycles of DNA Denaturation at 94^0C for 1min, primer annealing at 0.5minute and DNA extension at 72^0C for 1 minute; and ending with final extension at 72^0C for 5 minutes. After amplification, PCR amplicons was analyzed on agarose gel in 1×Tris- borate EDTA at 100 V for 100 minutes for size estimation by visualization of the product. To achieve this, 10 µl of the each PCR product was mixed with 5 µl 5× loading dye and loaded on 1.5% agarose gel for electrophoresis. A 100 base pair molecular weight DNA ladder was used for the validation of length of the amplified products (Vivantis Technologies). The gel was stained with ethidium bromide and visualized using a UV light box.

Results

Prevalence of *staphylococcus* species isolated from dried crayfish samples

Out of the 400 dried crayfish samples collected from six different markets in FCT, Abuja, presumptive staphylococcal isolates were obtained from 136 samples. Amongst the 136 staphylococcal isolates, 61(44.9%) were coagulase positive, 8 (30.8%) of the total isolates were confirmed *staphylococcus aureus* by Microgen Staph ID kits (Table 1 and 2). This implies that the isolation rate of *S. aureus* from the dried crayfish samples was 30.8%.

Location	No. of sample	No. (%) *Staphylococcus* species isolated
Gwagwalada	91	7 (7.69%)
Zuba	17	3 (17.6%)
Kubwa	69	5 (7.2%)
Bwari	44	2 (4.5%)
Wuse	73	4 (5.47%)
Garki	106	5 (4.7%)
Total	400	26 (47.16%)

Table 1: *Total number of Isotates of Staphylococcal species from dried crayfish from six location in FCT, Abuja No significance differences at (P ≤0.05). p- valve 0.15.*

Staphylococcus	Frequency	Percentages
Staphylococcus chromogenes	9	34.6%
Staphylococcus aureus	8	30.8%
Staphylococcus hyicus	4	15.4%
Staphylococcus xylosus	4	15.4%
Staphylococcus scuri	1	3.8%

Table 2*: Frequency of isolates of potential pathogenic Staphylococccus species using Microgen 12s kit.*

Antibiotics susceptibility profile of Staphylococcus species strains isolated

A total of twenty six (26) isolates of staphylococci were tested against eleven (11) commonly used antibiotics (Table 3 and 4). The overall resistance of the isolates showed that resistant to oxacillin was highest with 25 (96.2%) isolates showing resistant to the antibiotics. While resistance to gentamicin and ciprofloxacin was least with 2 (7.7%) resistant to the antibiotics.

Antibacterial Agent	Disk potency µg	Susceptible no%	Intermediate no%	Resistant no%
Penicillin (PEN)	10	6 (23.1)	00 (0%)	20 (76.9%)
Amoxicillin-Clavulanic acid (AUG) 30	30	12 (46.2%)	00 (0%)	14 (53.8%)
Gentamicin (GN)	10	24 (92.3%)	00 (0%)	2 (7.7%)
Clindamycin (CLI)	2	11 (42.3%)	10 (38.5%)	5 (19.2%)
Cefoxitin (FOX)	10	12 (46.2%)	00 (0%)	14 (53.8%)
Oxacillin (OXA)	30	1 (3.8%)	00 (0%)	25 (96.2%)
Chloramphenicol(C)	30	13 (50%)	4 (23.1%)	9 (34.6%)
Streptomycin(S)	25	5 (19.2%)	9 (34.6%)	12 (46.2%)
Ciprofloxacin(CIP)	5	17 (57.7%)	7 (26.9)	2 (7.7%)
Imipenem (IPM)	10	26 (100%)	00 (0)	00 (0)
Vancomycin (VA)	30	26 (100%)	00 (0)	00 (0)

Table 3: *Susceptibility of Staphylococcus aureus isolates from dried crayfish to 11 commonly used antibiotics.*

Key: PEN = Penicillin; AUG = Amoxicillin-Clavulanic acid; Fox = Cefoxitin; Cip = Ciprofloxacin; VA= Vancomycin; GN= Gentamicin; C= Chloramphenicol; IMP =Impenem; OXA = Oxacillin; CLI = Clindamycin; S = Streptomycin.

Isolates	Resistance pattern	MARI
GW10	PEN, CLI, FOX, OXA, AUG	0.45
B7	PEN, CLI, OXA, AUG, S	0.45
GK21	PEN, CLI, FOX, OXA, C	0.45
GW2	PEN, OXA, AUG, C, S	0.45
K29	PEN, OXA, AUG, C, S	0.45
GWA25	PEN, OXA, AUG, C, S	0.45
W35	CN, FOX, OXA, C, S	0.45
K4	PEN, CLI, OXA, AUG	0.36
Z1	PEN, FOX, AUG, OXA	0.36
Z4	PEN, OXA, AUG, S	0.36
K17	PEN, FOX, OXA, CIP	0.36
B3	PEN, FOX, OXA, C	0.36
K24	PEN, OXA, AUG, S	0.36
Z2	PEN, OXA, FOX, AUG	0.36
GK3	PEN, FOX, OXA, C	0.36
GW14	PEN, OXA AUG S	0.36
W12	PEN, OXA, AUG	0.30
K19	PEN, OXA, FOX	0.30
W19	PEN, FOX, OXA	0.30
GK7	PEN, CN, OXA	0.30
GW41	PEN, OXA, AUG	0.30
G8	PEN, AUG, S	0.30
W9	CLI, FOX, C	0.30
W5	PEN, OXA, CN	0.30
B1	OXA, S	0.20
GW7	OXA, S	0.20

Table 4: *The resistance profiles of Staphylococcus species from dried crayfish in FCT.*

Key: PEN = Penicillin; AUG = Amoxicillin-Clavulanic acid; Fox = Cefoxitin; Cip = Ciprofloxacin; VA= Vancomycin; CN= Gentamicin; C= Chloramphenicol; IMP =Impenem; OXA = Oxacillin; CLI = Clindamycin; S = Streptomycin. Percentage = %, where n = 8 (Total number Bacterial isolates).MRAI = multiple antibiotic resistance index.

Discussion

The isolation of other potential pathogens staphylococci with special reference *Staphylococcus aureus* in this study is of practical impact and shows that most of the seafood products might have been contaminated from source. It is an evidence of poor sanitary conditions. *S*taphylococcus *aureus* are pathogenic as well as normal flora of human and animals, their presence in food are indications of excessive human handling [11]. Crayfish may have been exposed to a lot of human handling during preparation and at the points of sale.

A prevalence of 8 (30.8%) of *staphylococcus aureus* recorded in this study is lower than the prevalence reported by other workers [3,36,44] who recorded 54.5%, 45% and 41% percent from antibiotics susceptibility study of *staphylococcus aureus* isolates from dry catfish sold in some open markets in Zaria, Kaduna State**,** smoked dried mangrove oysters sold in Port Harcourt and also from the prevalence of pathogenic bacteria in smoked fish sold in major retail markets in Benin, Nigeria respectively. Market environments might have played a role in the observed disparity.

Similarly, [47] reported 15.3% from antimicrobial resistance profile and molecular detection of MecA gene in methicillin resistant *staphylococcus aureus* from patients in selected general hospitals in Abuja municipal, Nigeria, [55] also reported 13.33% from the isolation and characterization of MRSA from locally processed meat hacked in Gombe state, [43] reported 12.5% from the isolation and identification of bacteria associated with Balungu (roasted meat products) sold in Bauchi State, Nigeria respectively. The low percentage recorded could be that crayfish are displayed in open markets.

The impact on human health of *staphylococcus aureus* infections in community and hospital settings has led to intensive investigation of this organism over the years [30]. The number of effective antibiotics has been reduced by the emergence of resistance to penicillin, methicillin and vancomycin [41] a problem that has been compounded by the emergence of methicillin resistant *staphylococcus aureus* (MRSA) carriage and disease in the community [50]. This trend may have been because of possible transfer of resistant strains from humans and droplets onto crayfish during processing, distribution, and marketing as well as environmentally by wind current since adequate packaging were lacking in the open markets surveyed. From this study all the twenty six (26) isolates of staphylococci demonstrated 100% susceptibility to vancomycin and imipenem. This study is in agreement with [21,28,38,46] who reported 100% susceptibility to vancomycin. (92.3%) susceptibility to gentamycin from this study is not in agreement with [36, 48] who reported 100% susceptibility to gentamycin from, fresh fish in Lokoja, catfish, kindrimo and manshanu in Kaduna State, Nigeria. However, the reports of [27] contradicts this study by reporting gentamicin resistance of 89.5% and 64.1 respectively in Maiduguri, Nigeria.

The other staphylococcus species isolated in this study though not of much public health significance have been associated with disease of domestic animals and man [62]. This finding agrees with [54] that this potential pathogens (*staphylococcus sciuri*, *staphylococcus xylosus, staphylococcus* chromgenes *staphylococcus* and *hyicus*) are commonly present in ready to eat foods such as crayfish and milk.

Antibiotic resistance has continued to constitute problems not only in human medicine but also in animal husbandry, livestock management and veterinary medicine [64]. It is also a global health challenge with greater effect on low-income countries.

The resistance of *staphylococcus aureus* from this study showed that oxacillin 25 (96.2%) and 20 (76.9%) to penicillin had the highest level of resistance followed by cefoxitin 13 (50%) and amoxicillin 14 (53.8%) which does not correlate with the report of [15] who reported 100% resistance to oxacillin, 75% to cefoxitin and 38% to amoxicillin from *staphylococcus aureus* isolates from door handles and other points of contact in public hospital.

Resistance to cefoxitin from this study is in disagreement with [36] who reported 28.4% from dry catfish in Zaria, Kaduna state.

This trend of resistance is therefore a matter of concern for humans, for livestock disease management and production in general owing to the existing emergence of bacterial strains resistant to other major antibiotics. The use of antibiotics in food animals had been reported to enhance the spread of bacteria resistance to antibiotics via the food to humans and cause human infection [53].

The implication of multidrug resistant pathogen is that, it becomes more pathogenic compared to non-multiple drug resistant pathogen [24]. Multidrug resistant pathogens have a greater risk of producing death, for example, Methicllin resistant *staphylococcus aureus* (MRSA) infected individuals have been estimated to be 64% more likely to die, than Methicillin susceptible *staphylococcus aureus* (MSSA) infected individuals.

Multidrug resistance for this study is defined as resistance of isolate to three or more antibiotics [40,51]. Multiple antibiotic resistance index (MARI) was calculated as the ratio of number of antibiotics to which an organism is resistant to total number of antibiotics to which an organism is exposed [26].

Multiple antibiotic resistance index (MARI) values greater than 0.2 indicates improper use and abuse of the antibiotics [26]. Multiple antibiotic resistance index (MARI) in bacteria is most commonly associated with the presence of plasmids which contain one or more resistance genes, each encoding a single antibiotic resistance phenotype [17].

Staphylococcus aureus isolates obtained from dried crayfish samples in this study were observed to have exhibited multiple resistance to the antibiotics tested. On the whole 11 resistance phenotypes were observed with varying combinations of three, four and five antibiotics, while no isolate was resistance to only one antibiotic. Generally, all the antibiotics used in this study were highly effective *in vitro* as only few drugs has its efficacy below 50% with clindamycin tending towards ineffective by showing high level of intermediate susceptibility of 38.5% (Table 3).

In this study, PCR amplification of *Mec*A gene was able to detect 4 isolates harboring mecA. The result from this finding is not in agreement with the finding of [20] who studied the genetic diversity and virulence potential of *staphylococcus aureus* isolated from crayfish (*Procambarus clarkia*) and found nono of the examined isolates positive for MecA gene conferring methicillin resistance. The detection of *Mec*A gene in 4 out of 8 *staphylococcus aureus* isolates may be that some are not harboring the mecA gene or they might have lost the gene during sub-culturing [61]. Since there are report indicating the risk of losing *MecA* gene bearing plasmids during sub-culturing and storage. The detection of *Mec*A from this study indicates contamination of dried crayfish with MRSA. This could be due to humans carrying MRSA coming in contact with dried crayfish during processing, handling, storage, transportation and at the point of sell. And it may also be that MRSA gene is circulating in the sample location (CA-MRSA).

The presence of MRSA in crayfish raises public health concern as crayfish is a potential source of protein and is widely consumed, hence the ease of spread of pathogens to the community. The isolation of *staphylococcus aureus* from dried crayfish in this study may be due to open display, open drainages in the markets and touching by prospective buyers.

In conclusion this present study has demonstrated the presence staphylococcus aureus and its MRSA gene in dried crayfish in the study area and also other staphylococci indicated that dried crayfish can be infected with a variety of staphylococcal organisms.

Crayfish farmers and sellers should be enlighten and educated on improved hygiene on how to maintain adequate hygiene during production, handling, storage, transportation and distribution of their products. This be can achieve through workshops and seminars by the relevant authorities.

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