Menoufia Veterinary Medical Journal
(MVMJ)

Menoufia Veterinary Medical Journal
https://vmmj.journals.ekb.eg

MVMJ. Vol. 1 (1): … September 2025

Menoufia University

Detection and molecular characterization of Methicillin resistant *staphylococcus aureus* (MRSA) in some meat products.

Ashraf A. Abd El Tawab[1], Ahmed S. Alfayomy, [2] Marwa A. Saad, and Heba E. El-Shora[4], Shireen M. Kozaa[5]

[1] Bacteriology, Immunology and Mycology Department Faculty of Veterinary Medicine, Benha University, Egypt. [2] Anatomy Department Faculty of Veterinary Medicine Shebin El-com Menofia University, Egypt. [3] Food Hygiene and control Shebin El-com Menofia University, Egypt. [4] Animal Health Research Institute, Tanta Branch, Egypt. [5]Bacteriology, Immunology and Mycology Department Faculty of Veterinary Medicine, Shebin El-com Menofia University, Egypt

Key words:
S.aureus, Burger, meat products and Resistant genes.

***Correspondence to**
shireenkozaa@gmail.com

Article History
Received: 17 oct 2023.
Accepted: 22 oct 2023.

ABSTRACT

Food poisoning is one of the most important problems that can affect large part of population. *Staphylococcus aureus (S. aureus)* is one of the main causes of bacterial food poisoning. A hundred random samples of burger, chicken nuggets, luncheon and kofta (25 of each) obtained from retail outlets were examined bacteriologically for the occurrence of methicillin resistance *Staphylococcus aureus (*MRSA*).* A total of 25 *S.aureus* isolates was recovered from - burger 9/25 (36%), chicken nuggets 7/25 (28%), luncheon 6/25(24 %) and kofta 3/25 (12%) Application of antibiotic sensitivity test on isolated *S.aureus* cleared that the highest resistance was exhibited against penicillin (96%) followed by flucloxacillin (92%), cefotaxime (68%), erythromycin (60%), clindamycin (61.54%), linezolid (36%) and vancomycin (28%) , using Polymerase chain reaction (PCR) on *S.aureus* to detect their virulence and resistance genes Hemolysin virulence gene (*hlg)* which was detected in (50%) of the examined isolates, while beta- lactam resistance gene (*bla*Z) and met hicillin resistance gene (*mec* A) were found in (50%) and (100%) of tested *S.aureus*, respectively.

1.INTRODUCTION

Food safety is an important issue that affects everyone throughout the world. Unsafe food causes more than 200 diseases, ranging from diarrhea to cancers (**Radovanovic, 2011and Gao *et al.*, 2022**).

S.aureus is a significant food pathogen in many nations , and it causes; Staphylococcal Food Poisoning (SFP) , which is characterized by vomiting , sepsis-related infections, pneumonia, and toxic shock syndrome (TSS) (**Fisher *et al.*, 2018**). Upon contamination of food by *S. aureus*, it developed heat – stable staphylococcal enterotoxins (SE) which causes SFP **(Sergelidis and Angelidis, 2017)**

S.aureus can potentially infect food when it is being prepared, processed, or stored under temperature-inappropriate circumstances that promote bacterial growth and the development of enterotoxins. *S. aureus* can thrive and exhibit virulence in a variety of environmental circumstances, including pH ranges from 4.5 to 9.0 and NaCl concentrations up to 9% (**Le Loir *et al.*, 2003).**

Staphylococci are famous for rapidly evolving resistance to many antibiotics. MRSA was previously only known as a clinical infection, but as evidenced by its appearance in retailed meat products, it can now be linked to food safety, creating a challenge for occupational employees in the food business. (**Voss *et al*., 2005, Kock ¨ *et al.*, 2012,** and **Kadariya *et al.*, 2014).** Since food products contaminated with MRSA may not exhibit any visual spoilage appearance or bad smell, it is challenging for consumers to detect the contaminated foods.

Penicillin and cephalosporin are among the numerous medications known as -lactams that MRSA is resistant to. Penicillin and other -lactam antibiotics work to kill bacteria by preventing the manufacture of their cell walls. Recently, *S. aureus* strains expressing penicillinase (an enzyme that breaks down penicillin) were discovered, which was discovered not long after penicillin was initially used to treat human infections. It was estimated that more than 80% of *S. aureus* strains produce penicillinase. The *mec*A gene, which produces the low affinity penicillin binding protein (PBP) 2a or PBP2' with a poor affinity for -lactam antibiotics, is what causes methicillin resistance **(Davies *et al.*, 2011**). It is well recognized that MRSA in humans is primarily acquired from meat and meat products (**Contreras *et al.*, 2015)**

Therefore, the present study was conducted to investigate the occurrence of coagulase-positive *S. aureus* and methicillin-resistant *S. aureus* (MRSA) strains in different popular meat products (Burger, chicken nuggets, luncheon and kofta) at Gharbia Governorate.

2.MATERIALS AND METHODS

2.1 Samples collection:

A total of 100 random samples of meat products burger, chicken nuggets, Luncheon and Kofta. (25 of each kind). was collected from various shops and supermarkets at Gharbia Governorate, Egypt. The collected samples were sent directly to the animal health laboratory under complete strict conditions in icebox within one hour and examined for bacteriological detection *S. aureus* and MRSA strains contamination.

2.2 Bacteriological examination (APHA, 2001 and Quinn *et al.*, 2002)

Samples were homogenized in 0.1% peptone water and maintained for 1 hr at 25 ◦C then the prepared samples were pre-enriched into nutrient broth and incubated at 37˚C for 24 hrs. A loopful from incubated nutrient broth was streaked on Baired parker agar plates (oxoid) and incubated at 37^{o} C 24-48 hrs: where *S.aureus* grew (black shiny colonies with clear halo zone around colonies and opaque zone of precipitation). Also, a loopful from incubated nutrient broth was streaked on Mannitol salt agar (Oxoid) and incubated at 37 ^{o}C for 24 -48 hrs; Positive samples (showed yellow colonies and turned media to colorless). In order to do PCR testing and Biochemical identification on these colonies, Brain Heart infusion broth was used.

2.3 Morphological examination (Cruickshank *et al.*, 1975).

The suspected *S.aureus* isolate**s** were stained with Gram stain for Morphological examination.

2.4 Biochemical identification (Quinn *et al.*, 2002 and Arora 2003):

Indol test, Oxidase test, Coagulase production test

and β – hemolysis test.

2.5 Antibiotic sensitivity test:

The collected bacterial isolates underwent in vitro testing to determine which antimicrobial discs they were susceptible to.: penicillin (P) 10 mcg, flucloxacillin (FL) 5 mcg, erythromycin (E) 15 mcg, vancomycin (VA) 30 ml , clindamycin(DA) 2 mcg, cefotaxime (CTX) 30 mcg and linezolid (LNZ) 30 mcg. According to (**Bauer *et al.*, (1966)** and the degree of sensitivity was interpreted according **(CLSI2021)**

2.6 Molecular detection of MRSA:

DNA was extracted from the isolated *S.aureus* using QIAamp DNA mini kit. It was applied on

6 random isolates. PCR reaction Mix and cycling conditions of the primers during PCR was prepared according to Emerald Amp GT PCR master mix (Takara) kit. PCR was used for confirmation of *S.aureus* isolates by using primers specific to *S.aureus* , 23S rRNA . Also ,it used for detection of Hemolysin virulence gene (*hlg)* , beta -lactam resistance gene (*bla*Z) and methicillin resistance gene (*mec*A) Oligonucleotide primers sequence and amplicon size as were shown in (**table1**) . DNA samples were amplified in a total volume of 25µl as follows: 12.5 µl of Emerald Amp GT PCR master mix, 1 µl of each primer of 20 pmol concentrations, 4.5 µl of water and 6 µl of template DNA. The reaction was performed in a Biometra thermal cycler. Temperature and time conditions of the primers during PCR were applied (**table 2)** .Aliquots of amplified PCR products were electrophoresed in 1.5 % agarose gel (ABgene) in 1x TBE buffer at room temperature. For gel analysis, 15 µl of PCR products were loaded in each gel slot . A 100 bp DNA ladder (QIAGEN Inc, Valencia, CA, USA) was used to determine the fragment sizes. The gel was photographed by a gel documentation system and the data was analyzed through computer software.

. **Table (1):** Sequence and amplicon size of the primers used for detection of *S. aureus* , virulence and resistance genes.

Target gene	Sequence	Amplified product	Reference
S. aureus 23S rRNA	F- AC GGAGTTACAAAGGACGAC	1250 bp	Bhati et al., 2016
	R- AGCTCAGCCTTAACGAGTAC		
mecA	F-GTA GAA ATG ACT GAA CGT CCG ATA A	310 bp	McClure et al., 2006
	R- CCA ATT CCA CAT TGT TTC GGT CTA A		
blaZ	F-TACAACTGTAATATCGGAGGG	833 bp	Bagcigil et al. 2012
	R-CATTACACTCTTGGCGGTTTC		
Hlg	F-GCCAATCCGTTATTAGAAAATGC	937 bp	Kumar et al., 2009
	R- CCATAGACGTAGCAACGGAT		

Table (2): Cycling conditions of the primers during cPCR:

Target gene	Primary denaturation	Secondary denaturation	Annealing	Extension	No. of cycles	Final extension
S. aureus 23S rRNA	94˚C 5 min.	94˚C 30 sec.	55˚C 40 sec.	72˚C 12 min.	35	72˚C 12 min.
MecA	94˚C 5 min.	94˚C 30 sec.	50˚C 30 sec.	72˚C 30 sec.	35	72˚C 7 min.
blaZ	94˚C 5 min.	94˚C 30 sec.	50˚C 40 sec	72˚C 50 sec	35	72˚C 10 min.
Hlg	94˚C 5 min.	94˚C 30 sec.	55˚C 40 sec.	72˚C 50 sec.	35	72˚C 10 min.

3.RESULTS:

3.1. Incidence of *S. aureus* isolated from examined samples.

.1. According to phenotypic and biochemical identification. A total of 25 isolates of S. aureus were recovered from 100 Samples represented as 9/25 (36%) from burger, 7/25 (28%) Chicken nuggets, 6/25(24 %) luncheon and 3/25 (12%) from kofta, respectively. (Table 3)

Table (3): Incidence *S. aureus* isolated from examined samples:

Samples	No.of samples	No.of isolates.	%
Burger	25	9	36
Chicken nuggets	25	7	28
Luncheon	25	6	24
Kofta	25	3	12
Total	100	25	25

3.2.Morphological character and Colonies appearance .

The isolated strains were cultured, on Baired-Parker
agar: showed black shiny colonies with clear halo zone around colonies and opaque zone of precipitation **figure (1)**, on Mannitol salt agar: showed (yellow colonies and turned media to colorless) **figure (2).** Morphological examination of suspected *S.aureus* colonies revealed non-motile Gram-positive Cocci (**figure3).**

Biochemically, Negative results were recorded on Indol test, Oxidase test while positive results were recorded on coagulase test **(fig 4**) and β – hemolysis test **(fig5)**

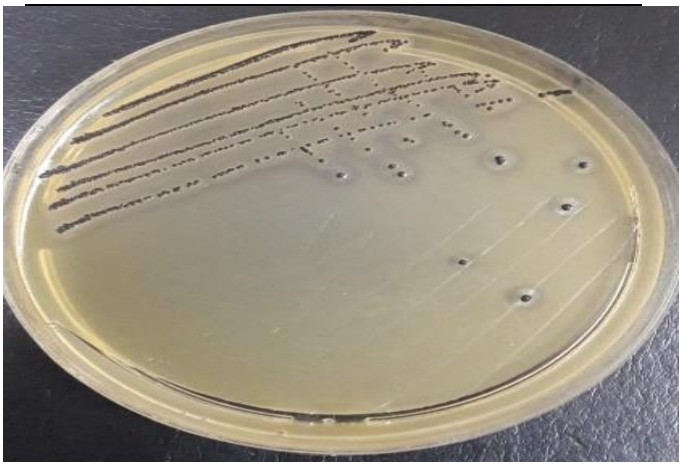


Fig (1) Colonies of *S.aureus* on baired parker agar media.

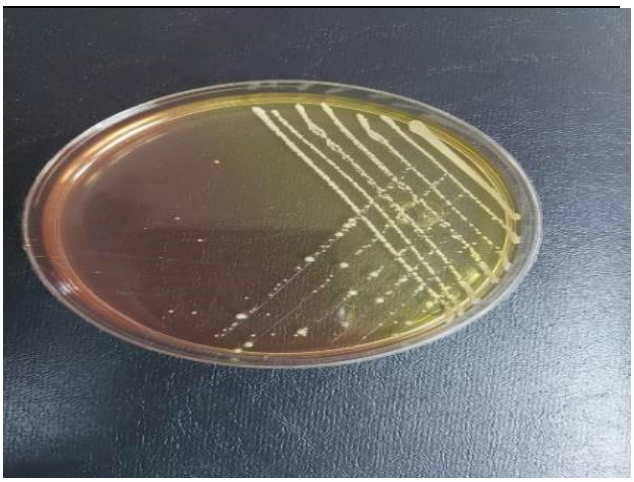


Fig. 2 showed**.** *S.aureus* on mannitol salt agar

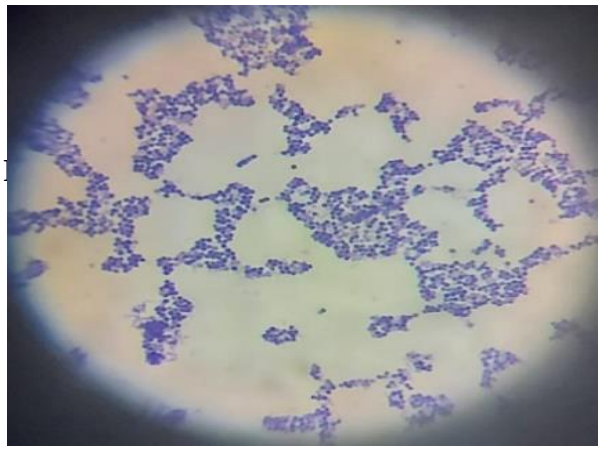


Fig (3) *S.aureus* under microscope after Gram' s staining appear as grape like cluster**.**

Fig (4) Positive coagulase test show that clot form when bacterial cell are incubated with plasma.

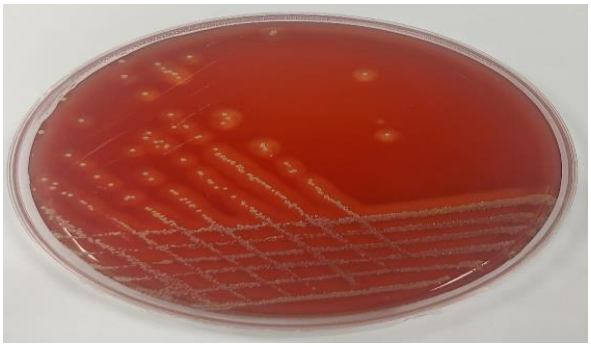
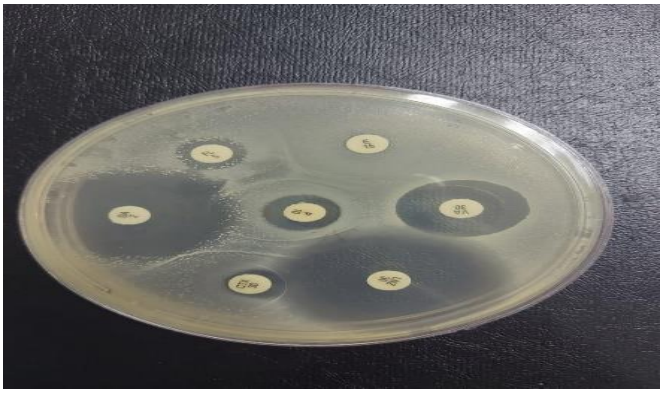


Fig (5). *S.aureus* showed β – hemolysis on blood agar media.

3.3. Antibiotic sensitivity test.

Application of antibiotic sensitivity test on 25 of *S. aureus* isolates recovered from meat products exhibited the highest resistance against penicillin (96 %) followed by flucloxacillin. (92 %) , cefotaxime (68%) , erythromycin (60 %) , clindamycin (61,54 %) , linezolid (36%)and vancomycin (28%) . Figure (6).



. **Fig (6).** Antibiotic sensitivity test of *S.aureus*

3.4 Detection of virulence and resistant genes of *S.aureus* by PCR.

S.aureus isolates were examined for detection of staphylococcal virulence and resistance genes by uniplex PCR; the result revealed that 50% of the examined isolates harbored Hemolysin virulence gene (*hlg*), resistance genes, *bla*Z *and mec*A resistant genes by uniplex PCR. The results revealed that all the tested isolates harbored 50%and 100% *blaZ* and *mec*A respectively

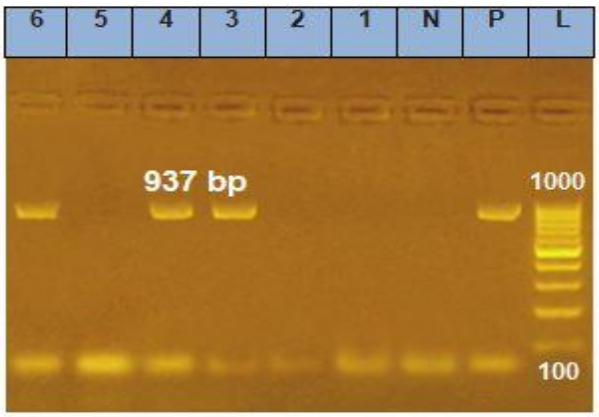
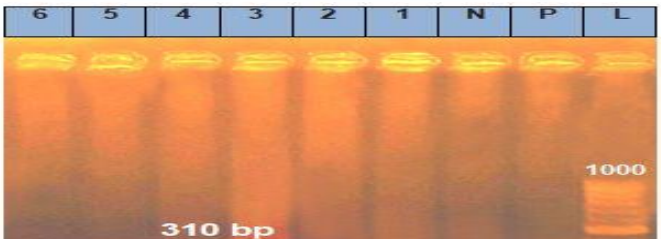


Fig (7): PCR pattern for the detection of staphylococcal hemolysin (*hlg)* genes at 937 bp on agarose gel electrophoresis.

L: Ladder from 100 bp to 1000 bp

Neg: Negative control: Field isolate that were tested and confirmed to be negative by PCR for the related genes in R.L.Q.P

Pos: Positive contro



Lane 1, 2, 5: Negative amplification of staphylococcal hemolycin (*hlg)* gene.

Lane 3, 4, 6: Positive amplification of staphylococcal hemolycin (*hlg)* gene at 937 bp

.

Fig. (8): PCR agarose gel electrophoresis pattern for *S. aureus mec*A gene identification at 310 bp**.**

L: Ladder from 100 bp to 1000 bp

Pos: Positive control: *S.aureus* ATCC 25923

Neg: Negative control: Field isolate that were tested and confirmed to be negative by PCR for the related genes in R.L.Q.P

Lane 1, 2, 3, 4, 5, 6: Positive amplification of *mec*A gene at 310 bp

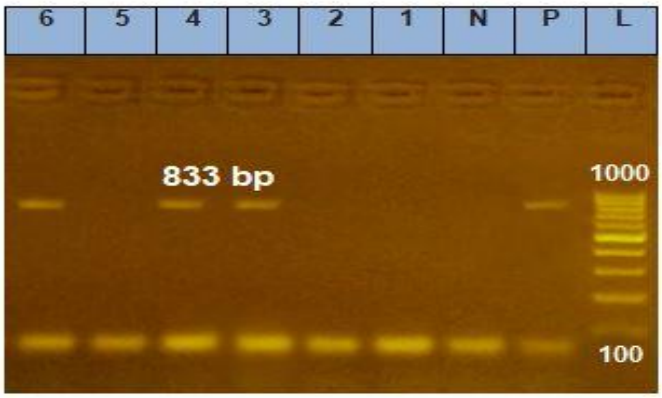


Fig. (9): PCR agarose gel electrophoresis pattern for *blaZ* gene of S. aureus detection at 833 bp**.**

L: Ladder from 100 bp to 1000 bp.

Pos: Positive control: *S.aureus* ATCC 25923.

Neg: Negative control: Field isolate that were tested and confirmed to be negative by PCR for the related genes in R.L.Q.P

Lane 3, 4, 6: Positive amplification of *blaZ* gene at 833 bp

Lane 1, 2, 5: Negative amplification of staphylococcal beta- lactam resistance (*blaZ)* gene.

4.DISCUSSION.

Incidence of foodborne illnesses has increased in recent years, creating a significant global public health issue. **Law *et al.,* (2015)**. Staphylococci pose a serious threat to public health since *S. aureus i*s widely acknowledged as a significant food-borne pathogen due to its capacity to produce a variety of toxins and virulence factors, which often induce quick onset of nausea, vomiting, and abdominal cramps. **Unal and Cinar, (2012)**

In the current study 25 isolates of *S. aureus* (25 %) were recovered from 100 samples which nearly agreed with the results of **Ammar *et al.,* (2016)** and **Abd El Tawab *et al.,* (2016**) who reported that *S. aureus* isolates in meat product samples were (23.81%) and (23.4%) respectively , But it disagreed with **Saif *et al.,* (2019**) who isolated *S.aureus* at incidence rate (50.8%), this high result was due to unhygienic conditions of food handlers and contamination of meat products during cutting and preparation.

S. aureus was isolated from burger samples at an incidence of (36%). Similar results were obtained by **Ahmed (2015) and Hazaa (2015**) who reported an incidence of (40%) and (33.3 %) respectively. Conversely, these results were considered low when compared to that of **Ammar *et al.,* (2016)** and **Shylaja *et al.,* (2018**) who detected *S.aureus* at an incidence of (71.43%) and (56.6%) respectively The low incidence rate from burger may be attributed to the addition of some food additives that have antibacterial activity or due to the processing temperature during burger manufacture **Ahmed *et al.,(1999***). While, the occurrence of isolation of *S. aureus* from chicken nuggets samples was(28%) which similar to **Radwan (2004)** who reported *S. aureus* in chicken nuggets at (28%) and **Magdy *et al.,* (2022)** who reported occurrence of *S. aureus* in chicken nuggets in a percentage of (23.3%). The obtained result in this study were lower than **Shylaja *et al., (*2018) w**ho isolated *S.aureus* from chicken nuggets by (60%) which was attributed to poor hygiene of meat handlers as well as lack of sterilization of utensils.

While, the incidence of isolation of *S. aureus* from luncheon samples was (24%).

This result was similar to **Abu Khadra (2010)** and **Atiah (2016**) who isolated *S. aureus* from luncheon (24%) and (25%) respectively. While higher results reported by **Saif *et al.,* (2019)** , Who isolated *S. aureus* from luncheon in a percentage of (56.6%), this may be attributed to excessive handling of luncheon with contaminated cutting knifes and slicing machines. **El-Shora (2019).**

S. aureus was isolated from kofta samples with percentage 12% this result nearly similar to **Lela. (2016**) and **Younes *et al.,* (2019**) who detected *S.aureus* at an incidence of (8%)and (12%) respectively . On the opposite side, **Saif *et al.,* (2019)** reported that occurrence of

S. aureus from kofta at percent 66.6 % this higher incidence may be due to microbial contamination during handling which indicate poor personal hygiene practices (**Musa and Okande 2002**).

Antimicrobials are widely used in the veterinary field either as growth promoters or as prophylaxis. Antibiotic-resistant strains may emerge as a result of uncontrolled use of antibiotics or their administration at doses below therapeutic levels. (**Beninati *et al.,* 2015**)

All identified isolates in the current study were at least somewhat resistant to one or more of the employed antibiotics.

Twenty-five. *S. aureus* isolates were further examined for their susceptibility to antimicrobials. *S.aureus* were highly resistant for penicillin (96 %) followed by flucloxacillin. (92 %) , cefotaxime (68%) erythromycin(60 %) , clindamycin (61.54 %) , linezolid (36%) and vancomycin(28 %).

Nearly, similar results were obtained by **Shathish *et al.,* (2018)** , who reported that *S.aureus* was 100% resistance to Penicillin , but lower result were detected by **Castro *et al.,* (2017)** , (83,6%).

Also, nearly similar result were obtained by **Ammar *et al.,* (2016) ;** 57,5% **Castro *et al.,* (2017);** 52% and **El-Shora; (2019**) 60% for erythromycin and 30% for vancomycin ; Moreover the susceptibility of the isolates to cefotaxime (68%) was close to that obtained by **Abd El Tawab *et al.,* (2018)** and **Saif *et al.,* (2019),** who found it (58 .3%) and (55.7%) respectively; As well **Magdy *et al.,* (2022)** recorded high resistance of S.*aureus* to clindamycin (81.5%) **,** Conversely, these results disagreed with that reported **Hanson *et al.,* (2011)** for erythromycin (14.8%), **Sallam *et al.,* (2015)** for vancomycin (5.9%), **Abd El Tawab *et al.,* (2015)** for

cefotaxime (10%) , **Shathish *et al., (*2018**) and **Naas *et al*., (2019)**

for vancomycin (100%) and (0%) respectively ; **Saleh *et al.,* (2016)** for penicillin (20.8%) and **Eko *et al.,* (2015**) who reported that none of the isolates were resistant to linezolid .

The low susceptibility of *S. aureus* to beta-lactam antibiotics observed in this study may be due to the production of beta-lactamase enzymes caused by modification of the drug target site (**Cantón *et al.,* 2008**).

Polymerase chain reaction (PCR) has become, since its discovery in the 1980s, a powerful diagnostic tool for the analysis of microbial infections as well as for the analysis of microorganisms in food samples (**Malorny *et al.,* 2003).**

Staphylococci have two primary resistance mechanisms to β -lactam antibiotics. One is the expression of β -lactamase enzymes, which destroy β -lactams by hydrolysis and are expressed by activation of the *bla*Z gene. The other is the expression of penicillin-binding protein 2a (PBP 2a), which is not susceptible to inhibition by beta-lactam antibiotics and are expressed by *mec*A gene that results in higher-level β -lactam resistance (MRSA) **(Fuda *et al.,* 2005).**

Staphylococci have virulence gene hemolysin (*hlg)*; it could have an impact on virulence *S.aureus* is **Tarabees *et al*.,(2016).**

The findings of the present investigation showed that 50% the examined *S. aureus* isolates (3/6) harbored *blaZ* gene. which disagreed with **El Seedy *et al.,* (2017**) who detected *blaZ* gene in all the examined isolates (8/8) and **Podkowik *et al.,* (2012)** who detected *bla*Z gene in(24/25) of the examined isolates.
While, *mec*A gene was found in (6/6) of tested *S. aureus* isolates. This result agreed with **Edris *et al*., (2018)** who detected it 6 out of 8 studied *S. aureus* strains , **Momtaz *et al.,* (2013**) found *mec*A gene in 68/82 of the examined isolates but our result disagreed with **Ruban *et al.,(*2018**) who reported that 13 out of the 25 (52%) *S. aureus* isolates harbored *mec*A gene. Also, it disagreed with **Podkowik *et al.,* (2012**) who failed to detect *mec*A gene.

In this study, 3/6 (50%) of tested *S. au reus* isolates harbored *hlg* gene, disagreed with **Eid *et al.,* (2018)** who reported that 15 out of 20 (75%) S. aureus isolates from meat, luncheon, burger, minced meat and sausage harbored (*hlg*) gene.

CONCLUSION:

The results obtained from this study indicated that a high prevalence of *S. aureus* in examined meat products while MRSA was mainly isolated from burger (36%), chicken nuggets (28%), luncheon (24%) and kofta (12%), This bacterium species' presence in examined meat products may be a result of contamination during the products' production, shipment, storage, cutting, packaging, and retail sale. This subsequently raises consumer health risks, hence every precaution should be taken to maintain proper cleanliness during production, handling, and storage in order to manage these dangerous microorganisms and reach the highest level of consumer safety.

References.

Abd El Tawab, A. A., El-Hofyand, F. I., Maarouf, A. A., & Mousa, D. H. (2016): Bacteriological and molecular studies on methicillin-resistant Staphylococcus aureus (MRSA) isolated from chicken meat and its

products in Kaliobia Governorate. Benha Veterinary Medical Journal, 31(1), 64-72.

Abd El Tawab, A. A. M., A. A. and El-Rais, E. M. A. . (2018): Bacteriological and molecular studies on antibiotic resistant Staphylococcus aureus isolated from meat and its products in Qaliobaya, Egypt. Benha Vet. Med. J, 29(2), 47-59.

Abd El Tawab, A. A.; Maarouf, A. A.; El-Hofy, F. I and El-Said, A. A. (2015) : Bacteriological studies on some foodborne bacteria isolated from Chicken meat and meat products in Kaliobia Governorate. Benha Vet. Med. J., 29 (2) :47-59.

Ahmed, A. A.; Terplan, G.; and Simon, E. (1999): Enterotoxigenicity of Staphylococcal strains isolated from milk and dairy products. J. Biol. Sci., 5: 555-566.

Ahmed, N. k. H. (2015): Detection of toxin-forming genes in Staphylococcus aureus isolated from meat and their products in EL-Fayoum Governorate by using PCR.

Ammar, A., Attia, A., Abd El-Hamid, M., El-Shorbagy, I., & Abd El-Kader, S. (2016): Genetic basis of resistance waves among methicillin resistant Staphylococcus aureus isolates recovered from milk and meat products in Egypt. Cellular and Molecular biology, 62(10), 7-15.

Abu Khadra, A.M.A (2010): Detection of some food poisoning microorganism in some meat products. M.V.Sc Thesis, (Meat Hygiene), Fac. Vet. Med., Alex.Univ.

APHA(American Public HealthAssociation)(2001): Compendium of methods for the microbiological examination of foods, 4th edition. American Public Health Association (APHA). Washington, DC USA.

Atiah, A. A. A. (2016): E- coli and S. aureus in some meat and poultry products Ph.D.V.Sc. Thesis, (Meat Hygiene) ,Fac.Vet.Med., Benha Univ., Egypt.

Arora, D. R. (2003): Text Book of Microbiology. 2nd Edition (Cultural characterisics of Staphylococcus pp (202-2013). Publishing by Satish Kumar Jain for CBS publishers

Bauer, A., Kirby, W., Sherris, J. C., & Turck, M. (1966): Antibiotic susceptibility testing by a standardized single disk method. American journal of clinical pathology, 45(4_ts), 493-496.

Bagcigil, A.B.; Taponen, S.; Koort, J.; Bengtsson, B.; Myllyniemi, A, and Pyörälä, S. (2012): Genetic basis of penicillin resistance of S. aureus isolated in bovine mastitis. Acta Veterinaria Scandinavica 2012, 54:69.

Bhati, T.; Nathawat, P.; Sharma, S.K.; Yadav, R.; Bishnoi, J. and Kataria, A.K. (2016): Polymorphism in spa gene of Staphylococcus aureus from bovine subclinical mastitis. Veterinary World, 2016; 9:421-424.

Beninati, C., Reich, F., Muscolino, D., Giarratana, F., Panebianco, A., Klein, G., & Atanassova, V. (2015): ESBL-producing bacteria and MRSA isolated from poultry and turkey products imported from Italy. Czech Journal of Food Sciences, 33(2), 97-102

Cantón, R., Novais, A., Valverde, A., Machado, E., Peixe, L., Baquero, F., & Coque, T. M. (2008): Prevalence and spread of extended-spectrum β-lactamase-producing Enterobacteriaceae in Europe. Clinical Microbiology and infection, 14, 144-153.

Castro, A., Palhau, C., Cunha, S., Camarinha, S., Silva, J., & Teixeira, P. (2017): Virulence and resistance profile of Staphylococcus aureus isolated from food. Acta Alimentaria, 46(2), 231-237.

Cruickshank, R.; Duguid, J.; Marmion, B. and Swain, R.H. (1975): Medical Microbiology.12th Ed., Edinburg, London and New York

Contreras, C.P., Nunes Da Silva, L.N., Ferreira D.C., Ferreira, J.D., Almeida, R.C. (2015): Prevalence of methicillin-resistant Staphylococcus aureus in raw hamburgers and ready-to-eat sandwiches commercialized in supermarkets and fast food outlets in Brazil. J. Food and Nutrition Sciences, 6:1324-1331

Clinical Laboratory Standards Institute (CLSI) (2021): Performance standards for antimicrobial Susceptibility Testing;. M100 31th Edition. Clinical and Laboratory Standards Institute for antimicrobial susceptibility testing.

Davies, P. R., Wagstrom, E. A., and Bender, J. B. (2011): Lethal necrotizing pneumonia caused by an ST398 Staphylococcus aureus strain. Emerging infectious diseases, 17(6), 1152.

Edris, A., Maarouf, A., Amin, R., and Bahbah, E. (2018): Prevalence of staphylococci in meat products with special reference to methicillin-resistant Staphylococcus aureus (MRSA) at Kaliobia governorate. Benha Veterinary Medical Journal, 35(2), 364-374.

El-Shora, H. E.(2019): Application of recent techniques for detection of some food borne pathogens isolated from different sources. Ph. DV Sc Thesis (Bacteriology,

Immunology and Mycology) Fac. Vet. Med., Benha Univ].

El Seedy, F., Samy, A., Salam, H., Khairy, E., and Koraney, A. (2017): Polymerase chain reaction detection of genes responsible for multiple antibiotic resistance Staphylococcus aureus isolated from food of animal origin in Egypt. Veterinary World 10 (10), 1205–1211.

Eko, K. E., Forshey, B. M., Carrel, M., Schweizer, M. L., Perencevich, E. N., and Smith, T. C. (2015): Molecular characterization of methicillin-resistant Staphylococcus aureus (MRSA) nasal colonization and infection isolates in a Veterans Affairs hospital. Antimicrobial resistance and infection control, 4(1), 1-7.

Eid, H., Mohamed, G., and El Borolos, I. (2018): Phenotypic and Genotypic Detection of Virulence Factors of Staphylococcus aureus Isolated from Meat and Meat Products. Suez Canal Veterinary Medical Journal. SCVMJ, 23(2), 59-79.

Fisher, E. L., Otto, M., and Cheung, G. Y. (2018): Basis of virulence in enterotoxin-mediated staphylococcal food poisoning. Frontiers in microbiology, 9, 436.

Fuda, C., Fisher, J., and Mobashery, S. (2005): β-Lactam resistance in Staphylococcus aureus: the adaptive resistance of a plastic genome. Cellular and molecular life sciences, 62, 2617-2633.

Gao, X., Li, C., He, R., Zhang, Y., Wang, B., Zhang, Z.-H., and Ho, C.-T. (2022): Research advances on biogenic amines in traditional fermented foods: Emphasis on formation mechanism, detection and control methods. Food Chemistry, 134 -911.

Hanson, B., Dressler, A., Harper, A., Scheibel, R., Wardyn, S., Roberts, L., Kroeger, J., and Smith, T. (2011): Prevalence of Staphylococcus aureus and methicillin-resistant Staphylococcus aureus (MRSA) on retail meat in Iowa. Journal of infection and public health, 4(4), 169-174.

Hazaa, W. (2015): Bacterial hazards associated with consumption of street vended meat products in kalyobia governorate Thesis, Master of Veterinary Medicine, Benha University, Egypt].

Köck, R., Loth, B., Köksal, M., Schulte-Wülwer, J., Harlizius, J., and Friedrich, A. W. (2012): Persistence of nasal colonization with livestock-associated methicillin-resistant Staphylococcus aureus in pig farmers after holidays from pig exposure. Applied and Environmental Microbiology, 78(11), 4046-4047.

Kumar JD, Negi YK, Gaur A, Khanna D (2009): Detection of virulence genes in Staphylococcus aureus isolated from paper currency. International Journal of Infectious Diseases 13: e450-e455.

Kadariya, J., Smith, T. C., and Thapaliya, D. (2014). Staphylococcus aureus and staphylococcal food-borne disease: an ongoing challenge in public health. BioMed research international, 2014, 9.

Law, D. R., Yan, R., Bershady, M. A., Bundy, K., Cherinka, B., Drory, N., MacDonald, N., Sánchez-Gallego, J. R., Wake, D. A., & Weijmans, A.-M. (2015): Observing strategy for the SDSS-IV/MaNGA IFU galaxy survey. The Astronomical Journal, 150(1), 19.

Le Loir, Y., Baron, F., and Gautier, M. (2003): [i] Staphylococcus aureus [/i] and food poisoning. Genetics and molecular research: GMR, 2(1), 63-76.

Lela, R.A.M. (2016): Impact of some natural preservatives on bacterial profile in meat products. Ph.D.V.Sc. Thesis, (Meat Hygiene), Fac.Vet.Med. Benha Univ.

Magdy, O. M., Tarabees, R., Badr, H., Hassan, H. M., and Hussien, A. M. (2022): Methicillin-Resistant Staphylococcus Auras (MRSA) from poultry meat products regarding mecA Gene, antibiotic Sensitivity, and biofilm Formation. Alexandria Journal for Veterinary Sciences, 75(2).

Malorny, B. T., P. T.; Radstrom, P.; Cook, N.; Wagner, M. and Hoorfar, J. . (2003): Standardization of diagnostic PCR for the detection of foodborne pathogens. . International journal of food microbiology.

, 83(1), 39-48.

McClure J-A, Conly JM, Lau V, Elsayed S, Louie T, Hutchins W, Zhang K. (2006): Novel multiplex PCR assay for detection of the staphylococcal virulence marker Panton-Valentine leukocidin genes and simultaneous discrimination of methicillin-susceptible from -resistant staphylococci. J Clin Microbiol 44: 1141-114

Momtaz, H., Dehkordi, F. S., Rahimi, E., Asgarifar, A., and Momeni, M. (2013): Virulence genes and antimicrobial resistance profiles of Staphylococcus aureus isolated from chicken meat in Isfahan province, Iran. Journal of Applied Poultry Research, 22(4), 913-921.

Musa, O., and Akande, T. (2002): Effect of health education intervention on food safety practice among food vendors in Ilorin. Sahel Medical Journal, 5(3), 120.

Naas, H. T., Edarhoby, R. A., Garbaj, A. M., Azwai, S. M., Abolghait, S. K., Gammoudi, F. T., Moawad, A. A., Barbieri, I., and Eldaghayes, I. M. (2019): Occurrence, characterization, and antibiogram of Staphylococcus aureus in meat, meat products, and some

seafood from Libyan retail markets. Veterinary World, 12(6), 925.

Podkowik, M., Bystroń, J., & Bania, J. (2012): Prevalence of antibiotic resistance genes in staphylococci isolated from ready-to-eat meat products. Polish Journal of Veterinary Sciences(2).

Quinn, P., Markey, B. K., Carter, M., Donnelly, W., and Leonard, F. (2002): Veterinary microbiology and microbial disease. Blackwell science.

Radovanovic, R. (2011): Food safety: the global problem as a challenge for future initiatives and activities. Advances in Food Protection: Focus on Food Safety and Defense,

Ruban, S. W., Babu, R. N., Abraham, R. J., Senthilkumar, T., Kumraswamy, P., and Rao, V. A. (2018): Prevalence of methicillin resistant Staphylococcus aureus in retail buffalo meat in Chennai, India. Buffalo Bulletin, 37(1), 51-58.

Radwan, S. A. S. (2004): Microbiological criteria of poultry meat products. M.V.Sc Thesis. Meat Hygiene, Fac . Vet. Med, Alex. University.

Saif, M., Saad, S., Hassanin, F. S., Shaltout, F., and Zaghloul, M. (2019): Prevalence of methicillin-resistant Staphylococcus aureus in some ready-to-eat meat products. Benha Veterinary Medical Journal, 37(1), 12-15.

Saleh, E., El-Mohsen, A., Reham, G., & Ibrahim, M. S. (2016): Molecular Identification of Staphylococcus Aureus in Imported Frozen and Locally Slaughtered Meat. Alexandria Journal for Veterinary Sciences, 51(1).

Sallam, K. I., Abd-Elghany, S. M., Elhadidy, M., & Tamura, T. (2015): Molecular Characterization and Antimicrobial Resistance Prof ile of Methicillin-Resistant Staphylococcus aureus in Retail Chicken. Journal of food protection, 78(10), 1879-1884.

Sergelidis, D., and Angelidis, A. (2017): Methicillin-resistant Staphylococcus aureus: a controversial food-borne pathogen. Letters in applied microbiology, 64(6), 409-418.

Shylaja, M. S., S. S. G.; Samatha, K. and Pradeep, C. H. . (2018): Studies on the incidence of Staphylococcus aureus and its enterotoxins in different meat and meat products The Pharma Innovation Journal,7(4): 669-673., 7(4), 669-673.

Shathish Sharma, B.J., S. Rathnapraba, S. Meignanalakshmi, S. Manoharan, S. Saranya and Vijayarani, K.(2018): Incidence and Molecular Characterization of Staphylococcus aureus Isolated from Meat Products. Int.J.Curr.Microbiol.App.Sci. 7(09): 3163-3169

Tarabees, R. Z., Hassanin, Z. H., Sakr, M. A., and Zidan, S. A. (2016): Molecular Screening of Some Virulence Factors Associated With Staphylococcus Aureus Isolated From Some Meat Products. Alexandria Journal for Veterinary Sciences, 48(1).

Ünal, N., and Çinar, O. D. (2012): Detection of stapylococcal enterotoxin, methicillin-resistant and Panton–Valentine leukocidin genes in coagulase-negative staphylococci isolated from cows and ewes with subclinical mastitis. Tropical animal health and production, 44, 369-375.

Voss, A., Loeffen, F., Bakker, J., Klaassen, C., and Wulf, M. (2005): Methicillin-resistant Staphylococcus aureus in pig farming. Emerging infectious diseases, 11(12), 1965.

Younes, O., Ibrahim, H., Hassan, M., and Amin, R. (2019): Detection of Staphylococcus aureus and enterotoxin genes from meat products by using conventional and modern identification methods. Benha Veterinary Medical Journal, 36(2), 229-237.