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PROBIOTIC APPROACHES TO E. COLI IN MEAT AND CHICKEN PRODUCTS: PREVALENCE, RESISTANCE, AND VIRULENCE

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ABSTRACT

This study explores the prevalence of coliforms and pathogenic *E. coli* in chilled beef and poultry meat products sold in Qena City, Egypt, and assesses the efficacy of certain lactic acid bacteria (LAB) against these strains. A total of 320 samples, including various meat products, were examined using PCR, serological, and culture-based methods for *E. coli* identification. Antibacterial activities of LAB cell-free supernatant (CFS) were measured using the liquid-broth method. All samples showed coliform and fecal coliform contamination. *E. coli* counts above the acceptable limit (>0 cfu/g) were found in 80% of beef minced meat, 72.5% of beef sausage, 62.5% of beef kofta, 67.5% of beef burgers, 60% of chicken burgers, 75% of chicken liver, 80% of chicken nuggets, and 55% of chicken wings. Diverse diarrheagenic pathotypes, including UPEC, ETEC, EPEC, and STEC, were identified. Frequently detected serogroups included O158, O142, O63, O119, O55, O169, and O124. The *hlyA* and *papC* genes were present in 36.2 and 24.43% of isolates, respectively, while *mcr1* and *qnrB* genes, coding for extended-spectrum β-lactamase (ESBL), were found in 5.43 and 5.88% of isolates. *E. coli* isolates exhibited high antimicrobial resistance and various resistance profiles, producing different biofilm phenotypes. LAB CFS significantly reduced *E. coli* CFU by eleven log10 orders. *E. coli* producing ESBL is commonly isolated from meat in Egypt, posing a significant public health risk due to poor sanitation in food processing facilities, leading to the transfer of resistant bacteria to humans.

Keywords: *E. coli*; meat products; Lactic acid bacteria (LAB); antibacterial activity.

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INTRODUCTION

Fecal coliforms, including *Escherichia coli* (*E. coli*), can ferment lactose at higher temperatures (44.5-45.5 ˚C) and indicate poor hygiene and sanitation. *E. coli* is particularly effective in signaling fecal contamination, suggesting the presence of harmful enteropathogenic or toxigenic microorganisms (Ijoma, 2010; Umana *et al.,* 2017; Adzitey *et al.,* 2021).

E. coli contamination in meat products is a significant public health concern. These products can become contaminated during processing, handling, or packaging, leading to potential outbreaks of foodborne illnesses. Pathogenic strains like Extraintestinal Pathogenic *E. coli* (ExPEC) can survive and proliferate in these environments, posing a risk to consumers. Therefore, ensuring proper hygiene and sanitation practices in producing and handling ready-to-eat meat products is crucial to prevent contamination and protect public health (Dale *et al.,* 2015; Baloch *et al.,* 2019; Sarowska *et al.,* 2019).

E. coli can possess various virulence factors like adhesins, toxins, and iron acquisition systems, which help it evade the host's immune response. ExPEC are pathogens derived from normal intestinal flora and cause infections outside the intestines. ExPEC differs from non-pathogenic *E. coli* by the presence of genes that allow it to colonize specific hosts. These genes, located on pathogenicity islands, include various iron uptake systems (such as enterobactin and salmochelin), adhesins (such as P fimbriae), and toxins (such as α-hemolysin, and pap-type toxins) (Bien *et al.,* 2012; Pitout, 2012; Lüthje *et al.,* 2014; Lindstedt *et al.,* 2018; Parvez *et al.,* 2018; Desvaux *et al.,* 2020; Pakbin *et al.,* 2021).

Quinolones are significant antimicrobial agents for treating *E. coli* outbreaks in chicken farms. Despite this, the prevalence of quinolone resistance genes in microbes is a growing concern. Quinolones function by inhibiting enzyme gyrase and topoisomerase IV activity, resulting in bacterial chromosome disruption. Following up mutations in such genes, which cause resistance. Plasmid quinolone resistance genes, including diverse *qnr* alleles, are located on plasmids or bacteria's chromosomes and are mostly linked to Enterobacteriaceae (Rodríguez-Martínez *et al.,* 2016; Yanat *et al.,* 2017; Ferreira *et al.,* 2018).

Colistin resistance, expressed by the *mcr1* gene, was recently identified in gram-negative bacteria isolated strains from people, food, and cattle. Colistin resistance is mainly caused by changes in the bacterial outer membrane's synthesis of lipid enzymes. Colistin is now often used to deal with diseases induced by multidrug-resistant gram-negative microbes, specifically β-lactamase-resistant Enterobacteriaceae. The widespread use of colistin in the livestock industry to enhance performance and prevent infections has led to the establishment of colistin resistance in *E. coli* (Veldman *et al.,* 2016; Alba *et al.,* 2018; Valiakos *et al.,* 2021). Colistin is widely utilized in livestock production in poor countries, such as Egypt. Germs with *mcr* have been reported from meat-producing animals in various underdeveloped nations, where inadequate sanitation and hygiene in the food processing industries facilitate the transfer of these germs to consumers. (El-Shazly *et al.,* 2017; Adel *et al.,* 2021). *Mcr* genes are known to transfer horizontally between bacterial species and are found in a variety of sources around the world. microorganisms with *mcr* genes tend to be resistant to colistin, limiting treatment choices, and subsequently posing a severe public health hazard. (Huang *et al.,* 2017; Bitrus *et al.,* 2018; Anyanwu *et al.,* 2020; Luo *et al.,* 2020). In Egypt, multi-drug-resistant *E. coli* is regularly identified from different food-producing animals and meat sectors, whereas *mcr1* is recognized in several sources, such as ready-to-eat meat products, the environment, and people

(Ahmed *et al.,* 2021; Sabala *et al.,* 2021; Badr *et al.,* 2022; Ahmed *et al.,* 2023)

Microbial biofilms pose significant challenges in both human and veterinary healthcare, as well as in food safety, due to their ability to enhance bacterial resistance against various physical and chemical hygiene measures in the food industry. These biofilms consist of communities of microorganisms that establish permanent associations, producing an extracellular polymeric substance (EPS) composed of carbohydrates or exopolysaccharides. These substances attach to living or inert surfaces and are encased in a self-generated polymeric matrix (Mah *et al.,* 2001). Biofilms deliver bacteria various benefits, since sessile cells are more resistant against environmental variations, host immune-logical responses, and antibiotic therapy (Costerton *et al.,* 1993)

Chemical preservatives are usually used to eliminate *E. coli* contamination in raw materials and final products, therefore controlling the epidemic. Despite the proven efficiency of these chemical preservatives, their repeated applications have tremendous effects on human health (Shan *et al.,* 2007). The growing consumer demand for high quality, safe, preservative-free food with extended shelf life has focused efforts on the discovery of new natural preservatives. Biological preservatives involve the use of microorganisms that can protect food and prevent illnesses caused by food contamination, as well as the correct treatment of food through fermentation. Bio detoxification is more efficient, accurate, and secure for customers than physicochemical methods (Diab *et al.,* 2021). Lactic acid bacteria (LAB) are vital in the process of fermentation of food. Organic acids, hydrogen peroxide, bacteriocins, hydroxylated fatty acids, diacetyl, and reuterin are the most common inhibitory metabolites generated by LAB used to safeguard food (Eddine *et al.,* 2021). *Streptococci* and *Lactobacilli* species have long been utilized as starting cultures due to their antibacterial capabilities, which target a variety of bacteria. As a result, they play a crucial part in the food fermentation process, preservation, and shelf life (Stupar *et al.,* 2021). Using LAB as a natural antimicrobial agent for keeping food safe may be an interesting alternative to physical and chemical approaches, and it has lately attracted great attention (Shi and Maktabdar, 2022)

Thus, the aims of this investigation were:

1) Determine the presence of fecal coliforms and *E. coli* in chilled beef and poultry products from Qena City, Egypt.
2) Identifying *E. coli* by serology.
3) Identification of virulent and antibiotic resistance genes.
4) Analyze antibiotic susceptibility of isolated bacteria for 12 antimicrobial agents.
5) Isolated *E. coli* strains were tested for their biofilm formation capability.
6) Investigated the antibacterial activity of lactic acid bacteria (LAB) against *E. coli* strains in vitro

MATERIALS AND METHODS

1. Collection of samples: From January to June of 2024, a total 320 samples were purchased from regional marketplaces and retailers, comprising 160 chilled beef products (40 samples each of minced meat, sausage, kofta, and burger) and 160 chilled poultry meat products (40 samples each of burger, liver, nuggets, and wings) were randomly procured from various shops in Qena City, Egypt. Upon purchase, they were transferred to the laboratory in plastic bottles with screw-top and refrigerated at (4 ˚C) for further analysis

2. Serial Dilution of Samples: From each sample, twenty-five grams mixed with peptone water (225 ml) in stomacher bags and homogenized (200 rpm/ 2 min). The homogenates were serially diluted with peptone water.

3. Total Coliforms and Fecal Coliform Counts (FDA, 2002): by using Violet Red Bile (VRB) agar media incubated for 24 hrs at 37 °C and 44.5 °C for isolation of total coliforms and fecal coliforms, respectively

4. *E. coli* counting, isolation, identification (FAO, 1992): by using Levine eosin methylene blue agar (EMB) incubated for 24 hrs at 37 °C. Moreover, typical colonies of *E. coli* purified on MacConkey agar, microscopically and biochemically examined including IMVIC reactions (Konemann *et al.,* 1997; Lee and Nolan, 2008).

5. *E. coli* serological identification (Lee *et al.,* 2009; Ahmed *et al.,* 2022, A): A total of 221 *E. coli* serotypes were serologically analysed and categorized into 18 distinct serogroups using rapid diagnostic antisera (polyvalent and monovalent) (DENKA SEKIN CO, Japan)

6. Exploration of virulence and antibiotic Resistance *E. coli* Genes: Virulence genes (*hlyA* and *papC*) and antibiotic resistance genes (*QnrB* and *Mcr1*) were detected by PCR using PCR Master Mix (Dream Taq Green) with agarose gel electrophoresis and following instructions of QIAamp DNA mini kit (Sambrook *et al.,* 1989). Primer sequences, amplicon sizes, and PCR programs are detailed in Table (1).

7. Antibiogram pattern of *E. coli*: Disc diffusion method were applied according method proposed by Ahmed *et al.* (2020, B), *E. coli* antibiogram pattern was conducted against a selection of 12 antibiotics, chosen for their prevalent application in human and veterinary medical fields in Egypt. The antibiotics included ampicillin, amikacin, colistin, erythromycin, gentamicin, kanamycin, linezolid, nalidixic acid, penicillin G (10 units), streptomycin, tetracycline, and vancomycin at concentration of 10, 30, 10, 15, 120, 5, 30, 30, 10, 30, 30 µg, respectively. All antibiotics sourced from Oxoid, UK. The isolates resistance or sensitivity interpreted according to the CLSI standards (2007)

8. Detection of biofilm formation: The microplate (MP) technique for evaluating biofilm development was modified from Ahmed *et al.* (2022, B). Fresh sterile BHI broth (200 µl) was put into flat bottomed polystyrene microtiter plates 96 well (Nunc). In triplicate, 20 µl aliquots of overnight cultures of *E. coli* isolates with a cell density of 1×10^9 cells/ml put in wells. Negative control wells (contain only broth). After being covered, the plates incubated for 24 hours at 30 °C in an aerobic environment. Following incubation, the bacterial culture removed, and 250 µl of PBS buffer (Sigma) added to each well three times. After fixing the biofilm for 15 minutes with 200 µl of 99% ethanol, subsequently removed. After allowing the plates to dry at room temperature, stained for five minutes with 200 µl of crystal violet solution, rinsed with running water to get rid of any remaining stain, and allowed to dry. Every well contained 160 µl of 33% (v/v) glacial acetic acid to re-solubilize the adherent dye. At 570 nm, absorbance was determined with a plate reader. The calculation of optical density (OD) and cut-off OD (ODc) as well as classification of biofilm formation adopted according to Zadernowska and Chajęcka-Wierzchowska (2017).

9. Antibacterial activity of some lactic acid bacteria (LAB) against *E. coli*:

9.1. Microorganisms: Prior to assay, virulent recovered *E. coli* strains enriched and cultivated in tryptic soy broth and on MacConkey agar, respectively at 37 °C/ 24 hrs.

9.2. Antibacterial assay: The MRS broth contained grown LAB strains (37 °C/ 24 h), then centrifuged (19000 x g, 4 °C/ 15 min), and membrane filtered (0.20 mm pore size) to obtain the cell free supernatant (CFS). Bactericidal activity of LAB strains cell free supernatants (CFS) against *E. coli* strain were assessed by liquid broth method

adopted according to El-Zamkan *et al.* (2021). Kill log CFU/ml was used to represent the results as a function of the test medium's cell free supernatants (CFS) concentrations. The results represent the average of three individual tests, and each assay was run in triplicate (Ahmed *et al.*, 2020, A)

10. Ethics Statement

The Research Ethics Committee Board of Faculty of Science, South Valley University reviewed and approved the protocols used for this study under code No (013/12/2024).

RESULTS

1. Bacteriological analysis

The examined samples showed heavy coliforms and fecal coliforms contamination (Tables 1 and 2). Our results revealed that all investigated samples were contaminated with coliforms and fecal coliforms based on the results of growth on Violet Red Bile agar, with mean values of 2.35×10^7, 4.82×10^5, 2.48×10^5, 3.65×10^6, 3.42×10^6, 5.84×10^7, 2.57×10^5 and 4.74×10^5, for coliform; and fecal coliform were 4.27×10^5, 2.24×10^4, 2.39×10^4, 5.34×10^5, 7.88×10^5, 2.16×10^5, 4.31×10^4 and 8.74×10^4, for beef minced meat, beef sausage, beef kofta, beef burger, chicken burger, chicken liver, chicken nuggets and chicken wings, respectively as shown in Tables (2 and 3).

Moreover, Table (4) showed contaminated samples with *E. coli* at percentages 80, 72.5, 62.5, 67.5, 60, 75, 80 and 55%, respectively with mean values of 6.42×10^3, 2.75×10^3, 2.63×10^3, 2.56×10^4, 2.64×10^4, 3.81×10^4, 7.63×10^3 and 2.87×10^3, respectively. According to the aforementioned results in Table (4), *E. coli* isolates can be classified depending on biochemical test characters into biotypes (I) and (II). *E. coli* biotype (I) is regarded as a real fecal type, and its existence gave strong proof of recent fecal contamination of products meant for consumers. (FDA, 2002). The analysis showed that 80, 72.5, 62.5, 67.5, 60, 75, 80 and 55% of the examined beef minced meat, beef sausage, beef kofta, beef burger, chicken burger, chicken liver, chicken nuggets and chicken wings, respectively had *E. coli* counts above the allowed limit (> 0 cfu/g), according to the limits proposed by EOSQC (2005), (Table 4).

2. Serotyping of *E. coli* isolates

Serological tests were performed on biochemically classified *E. coli* strains (Table 5). Two hundred and eight typable *E. coli* isolates (94.12%) and thirteen untypable isolated strains (5.88%) were found. Serogroups O158, O142, O63, O119, O55, O169, and O124 were the most commonly identified. Along with isolates related to serogroups O114, O27, O127, O111, O78, O86, O146, O26, and O153.

3. Polymerase chain reaction

The PCR experiment was conducted on serologically classified *E. coli* strains via primers specified for virulence and antibiotic resistance genes (Table 6). The *hlyA* and *papC* virulence genes' related indicators were primarily noticed (36.2 and 24.43%, respectively) within *E. coli* isolates from the samples tested. The *Mcr1* and *qnrB* genes, which code for ESBL resistant to colistin and fluoroquinolones, were found in 5.4.3 and 5.88% of the cases, respectively. Fig. (1) depicts a typical gel electrophoresis profile of amplified products from the virulent and antibiotic resistance coding genes under investigation.

4. Antibiogram pattern of *E. coli* isolates

221 *E. coli* samples were tested for antimicrobial susceptibility to 12 antimicrobial drugs routinely used in veterinarian clinics and fields (Table 7 and Fig. 2). Regardless of their origin (chilled beef and poultry meat product samples), the isolates were primarily resistant to Penicillin G (91.86%), Colistin (90.95%), Erythro-mycin (90.06%), Tetracycline (89.59%), Ampicillin (87.78%), and Nalidixic acid (80.54%). They were, however, sensitive to

various antibiotics, including Gentamicin (17.2%), Kanamycin (21.27%), Amikacin (21.72%), and Vancomycin (42.53%)

5. Biofilm formation activity of *E. coli* isolates:

From the 221 *E. coli* isolates, 175 (79.19%) strains formed biofilm to varying degrees; 32.58, 29.86, and 16.74% of the biofilm-producing bacteria were classified as strong, moderate, or weak biofilm producers. These isolates were spread over 83 (73.45%) chilled beef meat product samples and 92 (85.19%) chilled poultry meat product samples. Biofilm-producing *E. coli* isolated from chilled beef meat products produced strong, moderate, and weak biofilms at incidences of 33.6, 24.8, and 15%, respectively. The percentages for chilled poultry meat products were 31.5, 35.2, and 18.5%, respectively. Table (8) shows the occurrence of biofilm patterns in each of the sample categories analyzed.

6. Antimicrobial activity of LAB strains against *E. coli*

Lactic acid bacteria (LAB) were examined for their antibacterial activity against *E. coli* isolate using a bactericidal assay method (Fig. 3). Explored LAB exhibited greatly enhanced bactericidal activity against *E. coli* isolate. Their activity was measured as (log CFU) per tested LAB CFU treated with the *E. coli* bacteria for 24 hours. Interestingly, LAB showed more pronounced dose-dependency and potent decrease in CFU of the *E. coli* strains (about 11 log-order of killing), respectively (Fig. 3).

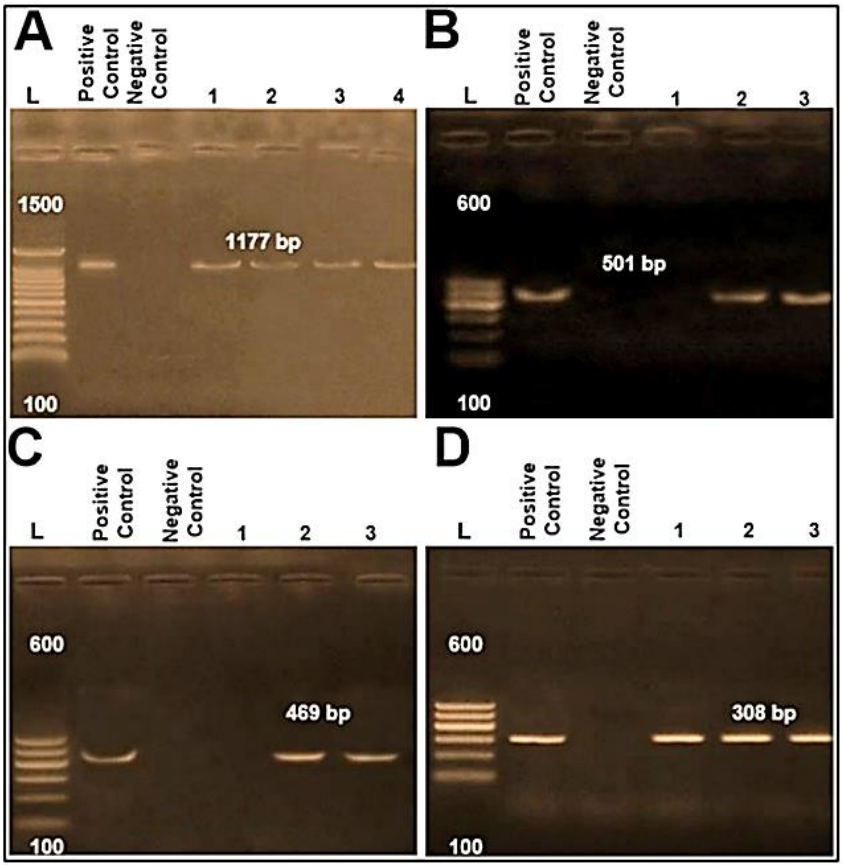

Fig. 1: PCR products of amplified virulent (A and B) and antibiotic resistant (C and D) genes identified in *E. coli* visualized on agarose gel electrophoresis. The expected molecular size of amplified DNA: 1177 bp for *hlyA* gene (A), 501 bp for *papC* gene (B), 469 bp for *QnrB* gene (C), and 308 bp for *Mcr1* gene (D). Lane 1-10: samples and Lane (L) DNA ladder 100 bp.

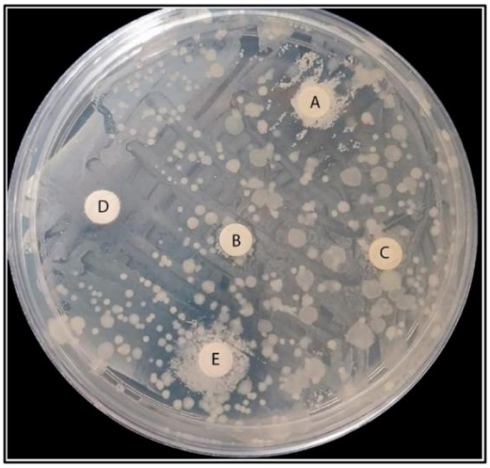

Fig. 2: Disc diffusion test; from A-E samples of disc diffusion test for Penicillin G, Colistin, Erythromycin, Gentamicin, Nalidixic acid.

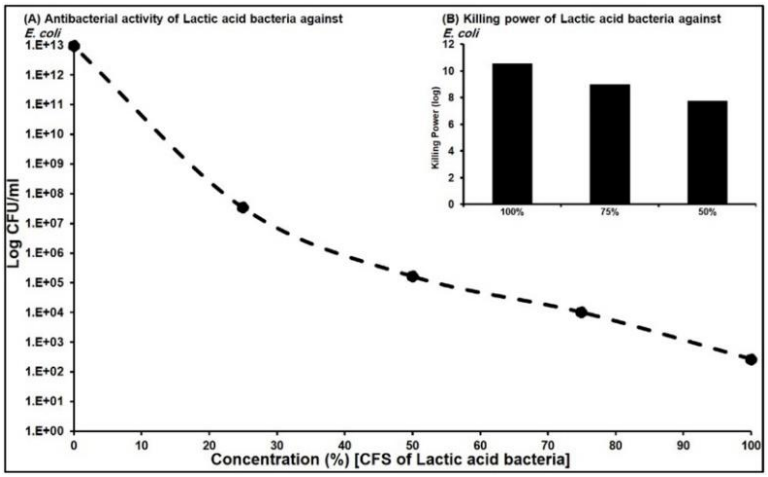

Fig. 3: Antibacterial activity of CFS from the Lactic acid bacteria (LAB) strains against *E. coli* at different concentration %. The data is presented as log CFU/ml. (Inset) Killing power of CFS from the Lactic acid bacteria (LAB) strains (100, 75 and 50 %) against *E. coli*. The assays were performed in triplicate.

Table 1: PCR protocol including primer sequences, Amplicon size and amplification reactions

Target gene	Primers sequences	Amplified segment (bp)	Primary denaturation	Amplification (35 cycles)			Final extension	Reference
				Secondary denaturation	Annealing	Extension		
hlyA	AACAAGGATAAGCAC TGTTCTGGCT ACCATATAAGCGGTC ATTCCCGTCA	1177	94 ˚C 5 min.	94 ˚C 30 sec.	60 ˚C 50 sec.	72 ˚C 1 min.	72 ˚C 10 min.	Piva *et al.*, 2003
papC	TGTATCACGCAGTCA GTAGC CCGGCCATATTCACA TAA	501	94 ˚C 5 min.	94 ˚C 30 sec.	58 ˚C 40 sec.	72 ˚C 45 sec.	72 ˚C 10 min.	Jin *et al.*, 2003
QnrB	GATCGTGAAAGCCAG AAAGG ACGATGCCTGGTAGT TGTCC	469	94 ˚C 5 min.	94 ˚C 30 sec.	55 ˚C 45 sec.	72 ˚C 45 sec.	72 ˚C 10 min.	Robicsek *et al.*, 2006
Mcr1	CGGT CAGTCCGTTTGTTC CTTGGTCGGTCTGTA GGG	308	94 ˚C 5 min.	94 ˚C 30 sec.	55 ˚C 40 sec.	72 ˚C 45 sec.	72 ˚C 10 min.	Newton-Foot *et al.*, 2017

Table 2: Statistical analytical results of total coliforms count (Total coliforms count /g) in examined samples (N=40).

Type of sample		Positive samples		cfu/g		
		No	%	Minimum	Maximum	Mean±S.E
Beef products	Minced meat	40	100	2.80×10^{2}	6.30×10^{8}	$2.35\times10^{7}\pm2.42\times10^{6}$
	Sausage	40	100	2.64×10^{3}	5.11×10^{6}	$4.82\times10^{5}\pm1.87\times10^{5}$
	Kofta	40	100	9.60×10^{3}	2.17×10^{6}	$2.48\times10^{5}\pm3.87\times10^{5}$
	Beef Burger	40	100	4.21×10^{3}	2.90×10^{7}	$3.65\times10^{6}\pm2.28\times10^{5}$
Poultry meat products	Chicken Burger	40	100	3.27×10^{4}	6.37×10^{7}	$3.42\times10^{6}\pm6.27\times10^{5}$
	Liver	40	100	2.23×10^{3}	1.27×10^{8}	$5.84\times10^{7}\pm3.36\times10^{6}$
	Nuggets	40	100	2.48×10^{5}	2.34×10^{6}	$2.57\times10^{5}\pm5.16\times10^{4}$
	Wings	40	100	2.72×10^{5}	2.39×10^{6}	$4.74\times10^{5}\pm2.45\times10^{4}$

Table 3: Statistical analytical results of fecal coliforms count (Fecal coliforms count /g) in examined samples (N=40).

Type of sample		Positive samples		cfu/g, ml, cm^2		
		No	%	Minimum	Maximum	Mean±S.E
Beef products	Minced meat	40	100	1.94×10^{2}	5.20×10^{7}	$4.27\times10^{5}\pm1.32\times10^{5}$
	Sausage	40	100	5.24×10^{2}	5.25×10^{5}	$2.24\times10^{4}\pm1.64\times10^{4}$
	Kofta	40	100	2.58×10^{2}	2.64×10^{5}	$2.39\times10^{4}\pm5.72\times10^{3}$
	Beef Burger	40	100	4.10×10^{2}	2.71×10^{6}	$5.34\times10^{5}\pm2.41\times10^{3}$
Poultry meat products	Chicken Burger	40	100	8.64×10^{2}	1.40×10^{6}	$7.88\times10^{5}\pm2.75\times10^{3}$
	Liver	40	100	2.37×10^{1}	8.26×10^{6}	$2.16\times10^{5}\pm2.71\times10^{3}$
	Nuggets	40	100	1.61×10^{2}	2.78×10^{5}	$4.31\times10^{4}\pm2.45\times10^{3}$
	Wings	40	100	2.28×10^{2}	1.34×10^{5}	$8.74\times10^{4}\pm2.50\times10^{3}$

Table 4: Statistical analytical results of *E. coli* count (*E. coli* count /g) in examined samples, and Frequency distribution of *E. coli* biotypes (N=40).

Type of sample		*E. coli* (%)		cfu/g			*E. coli* Free EOSQC (2005)		*E. coli* biotypes			
									E. coli biotype I		*E. coli* biotype II	
		No	%	Minimum	Maximum	Mean±S.E	No	%	No	%	No	%
Beef products	Minced meat	32	80	2.40×10^{2}	5.36×10^{4}	$6.42\times10^{3}\pm1.62\times10^{3}$	32	80	27	84.4	5	15.6
	Sausage	29	72.5	2.90×10^{2}	5.82×10^{4}	$2.75\times10^{3}\pm3.29\times10^{2}$	29	72.5	21	72.4	8	27.6
	Kofta	25	62.5	2.80×10^{2}	8.62×10^{4}	$2.63\times10^{3}\pm3.52\times10^{2}$	25	62.5	20	80	5	20
	Beef Burger	27	67.5	3.54×10^{2}	1.71×10^{5}	$2.56\times10^{4}\pm6.34\times10^{3}$	27	67.5	21	77.8	6	22.2
Poultry meat products	Chicken Burger	24	60	2.70×10^{2}	1.64×10^{5}	$2.64\times10^{4}\pm2.34\times10^{3}$	24	60	19	79.2	5	20.8
	Liver	30	75	8.67×10^{2}	1.67×10^{5}	$3.81\times10^{4}\pm5.49\times10^{3}$	30	75	25	83.3	5	16.7
	Nuggets	32	80	2.80×10^{3}	1.38×10^{4}	$7.63\times10^{3}\pm2.38\times10^{3}$	32	80	28	87.5	4	12.5
	Wings	22	55	3.11×10^{3}	4.31×10^{4}	$2.87\times10^{3}\pm1.66\times10^{2}$	22	55	18	81.8	4	18.2

Table 5: Incidence and serotyping of *E. coli* Strains isolated from the examined samples (N=40).

Serodiagnosis		Beef products								Poultry meat products							
Polyvalent sera	Monovalent sera	Minced meat		Sausage		Kofta		Beef Burger		Chicken Burger		Liver		Nuggets		Wings	
		No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Polyvalent 1	O26	1	3.12	1	3.45	0	0.00	2	7.41	1	4.17	1	3.33	2	6.25	0	0.00
	O86	1	3.12	2	6.90	1	4.00	0	0.00	2	8.33	2	6.67	1	3.13	1	4.55
	O111	0	0.00	1	3.45	2	8.00	1	3.70	0	0.00	3	10.00	2	6.25	2	9.09
	O119	2	6.25	3	10.33	2	8.00	0	0.00	1	4.17	1	3.33	3	9.37	1	4.55
	O127	0	0.00	1	3.45	1	4.00	2	7.41	2	8.33	2	6.67	1	3.13	2	9.09
Polyvalent 2	O55	3	9.38	4	13.79	1	4.00	1	3.70	0	0.00	1	3.33	2	6.25	1	4.55
	O125	0	0.00	1	3.45	1	4.00	1	3.70	1	4.17	2	6.67	1	3.13	0	0.00
	O146	1	3.12	1	3.45	0	0.00	1	3.70	0	0.00	2	6.67	2	6.25	2	9.09
Polyvalent 3	O114	0	0.00	1	3.45	2	8.00	2	7.41	1	4.17	3	10.00	3	9.37	0	0.00
	O142	5	15.63	3	10.33	2	8.00	1	3.70	1	4.17	2	6.67	1	3.13	1	4.55
	O158	6	18.76	2	6.90	3	12.00	3	11.12	3	12.50	1	3.33	1	3.13	1	4.55
Polyvalent 4	O6	1	3.12	1	3.45	0	0.00	1	3.70	1	4.17	1	3.33	1	3.13	0	0.00
	O27	0	0.00	2	6.90	2	8.00	1	3.70	2	8.33	1	3.33	3	9.37	1	4.55
	O78	1	3.12	1	3.45	1	4.00	3	11.12	1	4.17	1	3.33	1	3.13	2	9.09
Polyvalent 5	O63	3	9.38	2	6.90	1	4.00	2	7.41	2	8.33	1	3.33	2	6.25	2	9.09
	O153	2	6.25	0	0.00	1	4.00	1	3.70	1	4.17	1	3.33	1	3.13	1	4.55
Polyvalent 6	O169	2	6.25	1	3.45	2	8.00	1	3.70	2	8.33	1	3.33	2	6.25	2	9.09
Polyvalent 7	O124	1	3.12	0	0.00	2	8.00	2	7.41	2	8.33	3	10.00	1	3.13	2	9.09
Untypable	------	3	9.38	2	6.90	1	4.00	2	7.41	1	4.17	1	3.33	2	6.25	1	4.55
Total		32	100	29	100	25	100	27	100	24	100	30	100	32	100	22	100

Table 6: Virulence and antibiotic resistance genes profile of *E. coli* strains screened by PCR

Genes profile		Beef products				Poultry meat products				Total (221) No. (%)
		Minced meat (32) No. (%)	Sausage (29) No. (%)	Kofta (25) No. (%)	Beef Burger (27) No. (%)	Chicken Burger (24) No. (%)	Liver (30) No. (%)	Nuggets (32) No. (%)	Wings (22) No. (%)	
Virulence genes	*hlyA*	12 (37.5)	10 (34.48)	9 (36)	7 (25.93)	10 (41.67)	12 (40)	9 (28.13)	11 (50)	80 (36.20)
	papC	9 (28.13)	7 (24.14)	5 (20)	4 (14.81)	9 (37.5)	10 (33.33)	8 (25)	2 (9.10)	54 (24.43)
Antibiotic resistant genes	*Mcr1*	2 (6.25)	1 (3.45)	2 (8)	0 (0)	1 (4.17)	3 (3.33)	2 (6.25)	1 (4.55)	12 (5.43)
	Qnr B	3 (9.38)	1 (3.45)	0 (0)	2 (7.41)	0 (0)	2 (6.67)	3 (9.38)	2 (9.1)	13 (5.88)

Table 7: Antibiogram resistance pattern of *E. coli* isolates.

Antibiotic	Beef products				Poultry meat products				Total (221) No. (%)
	Minced meat (32) No. (%)	Sausage (29) No. (%)	Kofta (25) No. (%)	Beef Burger (27) No. (%)	Chicken Burger (24) No. (%)	Liver (30) No. (%)	Nuggets (32) No. (%)	Wings (22) No. (%)	
Ampicillin	30 (93.75)	22 (75.86)	23 (92)	21 (77.78)	23 (95.83)	26 (86.67)	29 (90.63)	20 (90.91)	194 (87.78)
Amikacin	5 (15.63)	3 (10.34)	5 (20)	7 (25.93)	6 (25)	7 (23.33)	8 (25)	7 (31.82)	48 (21.72)
Colistin	30 (93.75)	26 (89.66)	23 (92)	24 (88.89)	21 (87.5)	27 (90)	30 (93.75)	20 (90.91)	201 (90.95)
Erythromycin	29 (90.63)	26 (89.66)	22 (88)	24 (88.89)	23 (95.83)	26 (86.67)	30 (93.75)	19 (86.36)	199 (90.06)
Gentamicin	3 (9.38)	5 (17.24)	4 (16)	4 (14.81)	6 (25)	5 (16.67)	5 (15.63)	6 (27.27)	38 (17.20)
Kanamycin	7 (21.86)	7 (24.14)	6 (36)	4 (14.81)	7 (29.17)	9 (30)	3 (9.38)	4 (18.18)	47 (21.27)
Linezolid	9 (28.13)	13 (44.83)	10 (40)	11 (40.74)	12 (50)	17 (56.67)	15 (46.88)	13 (59.09)	100 (45.25)
Nalidixic acid	27 (84.38)	23 (79.31)	20 (80)	20 (74.07)	19 (79.17)	25 (83.33)	27 (84.38)	17 (77.27)	178 (80.54)
Penicillin G	30 (93.75)	27 (93.10)	24 (96)	22 (81.48)	23 (95.83)	26 (86.67)	30 (93.75)	21 (95.45)	203 (91.86)
Streptomycin	15 (46.88)	10 (34.48)	9 (36)	12 (44.44)	10 (41.67)	17 (56.67)	17 (53.13)	13 (59.09)	103 (46.61)
Tetracycline	31 (96.88)	26 (89.66)	20 (80)	25 (92.59)	20 (83.33)	27 (90)	29 (90.63)	20 (90.91)	198 (89.59)
Vancomycin	12 (37.5)	11 (37.93)	9 (36)	14 (51.85)	10 (41.67)	15 (50)	13 (40.63)	10 (45.45)	94 (42.53)

Table 8: Biofilm formation by *E. coli* isolates.

Biofilm Type	*E. coli* (No.)								Total (221) No. (%)
	Minced meat (32) No. (%)	Sausage (29) No. (%)	Kofta (25) No. (%)	Beef Burger (27) No. (%)	Chicken Burger (24) No. (%)	Liver (30) No. (%)	Nuggets (32) No. (%)	Wings (22) No. (%)	
Strong	10 (31.25)	7 (24.14)	12 (48)	9 (33.33)	6 (25)	10 (33.34)	13 (40.63)	5 (22.73)	72 (32.58)
Moderate	6 (18.75)	9 (31.3)	8 (32)	5 (18.52)	11 (44.83)	7 (23.33)	9 (28.12)	11 (50)	66 (29.86)
Weak	5 (15.63)	2 (6.91)	4 (16)	6 (22.22)	5 (20.83)	6 (20)	6 (18.75)	3 (13.64)	37 (16.74)
Non biofilm producer	11 (34.37)	11 (37.92)	1 (4)	7 (25.93)	2 (8.33)	7 (23.33)	4 (12.5)	3 (13.64)	46 (20.81)

DISCUSSION

Unsanitary food handling, preparation, and storage processes encourage transferring MDR bacteria, especially ESBL-producing *E. coli*, to consumers. To minimize the spread of antibiotic-resistant germs, effective detection techniques, and hygienic meat-handling procedures must be implemented (Tadesse *et al.*, 2018). As a result, there is a critical need to build food monitoring systems, specifically for meat and meat products, to improve food manufacturing quality and safety (El Sheikha *et al.*, 2018).

The prevalence of coliforms and fecal coliforms in the investigated samples are presented in Tables (2 and 3). The highest fecal coliform counts were observed in beef products, specifically in minced meat, kofta, and sausage, with mean values of 4.27×10^5, 2.39×10^4 and 2.24×10^4, respectively. In chicken products, the highest counts were found in liver, burger, and nuggets, with mean values of 2.16×10^4, $7.88\times10^{3,}$ and 4.31×10^3, respectively. These findings match with those reported by Hassanin *et al*. (2016) and Hassan *et al*. (2023). Coliform infection is frequently related to variables such as cutting, dressing carcasses, unhygienic hands, cutting boards, knives used for processing and preparation, and polluted water (Elsaid *et al.*, 2019). Overall, the counts on the EMB media showed that the samples were significantly contaminated with *E. coli* (Table 4). *E. coli* was found in 32 (80%) of the 40 investigated beef minced meat and chicken nuggets samples. *E. coli* biotype I was detected in 27/32 (84.4%), 21/29 (72.4%), 20/25 (80%), and 21/27 (77.8%) of the tested minced beef meat, beef sausage, beef kofta, and beef burger, respectively. In chicken products, *E. coli* was found in 25/30 (83.3%) of chicken liver, 28/32 (78.5%) of chicken nuggets, and 18/22 (81.8%) of chicken wings.

Decisions regarding the acceptability of food or water samples for human consumption in Egypt are based on Egyptian and international standards (EOSQC, 2005). According to the results in Table (5), a significant proportion of beef and chicken products available to consumers did not meet these standards. Our findings align with previous studies by Egyptian researchers, who reported that *E. coli* contamination in beef meat products often exceeds the limits set by national and international standards (Abou Hussein, 2007; Gwida *et al*., 2014; Sabala *et al*., 2021). Ahmed *et al.* (2023) observed comparable results with duck meat (81.8%).

The meat sector in less developed nations, particularly Egypt, is frequently contaminated with germs due to traditional manual slaughtering and evisceration practices (Gwida *et al*., 2014; Shilenge *et al*., 2017). Our results indicate higher contamination levels of *E. coli* in ready-to-eat beef products in Egypt, ranging from 30 to 50%, as described by Salem *et al.* (2016) and Hussein *et al*. (2018). These levels are also higher than those reported for chicken

meat and chicken meat products by Abdel Tawab *et al*. (2015); Gaafar *et al*. (2019); Hassan *et al*. (2023).

The obtained results findings were consistent with studies from other countries, such as Thailand (Tansawai *et al*., 2019) and China (Yassin *et al*., 2017). Chicken offal, particularly chicken liver, is a traditional fast food in Egypt and underdeveloped countries due to its affordability, ease of preparation, and high protein content (Hassanin *et al*., 2017). The prevalence of contamination in the chicken liver in our study was 3.81×10^3, similar to the results of *E. coli* contamination in chicken offal noticed in northern Egyptian cities (Badr *et al*., 2022). Therefore, stringent hygienic measures should be implemented to reduce meat contamination levels. Furthermore, all food industries should have quality control measures and conduct frequent evaluations.

The identified strains in *E. coli* study were belonging to serogroups (O158, O142, O63, O119, O55, O169, O124, O114, O27, O127, O111, O78, O86, O146, O26 and O153). These serogroups have been linked to outbreaks and certain human illnesses (Gomis *et al.*, 2004). The results achieved of the present study agreed with Ahmed-Neven (2016); Hamed *et al.* (2017); Badr-Sarah (2018); Saad *et al.* (2019) who recorded serotypes O26, O111, O55, O86, O119, and O124 to be the most commonly serotypes in contrast to other serotypes. Hamed *et al.* (2017) declared that the most important STEC serotypes which have been associated with human illness are O26, O111, O146. The majority of STEC infections are foodborne; meat items including minced beef, sausage, hamburgers and luncheons are foods that are very likely foods of high risk for transmission.

Serotypes O55, O86, O119 have been described among different studies to be EPEC and EAEC (Abd El-Tawab *et al.*, 2014). Because EPEC can colonize the intestinal epithelium and then generate distinctive effacement and lesions that result in watery and bloody diarrhea, it is a prevalent cause of infantile diarrhea in impoverished nations (Hussain, 2015). As ETEC strains, serotypes O146 and O27 have been linked to diarrheal illnesses in children and travelers that have been deadly for those under five (Tamura *et al.*, 1996). Moreover, serotypes O142 and O158 are involved as EPEC strains (Gomis *et al.*, 2004). The identified serotype O114 has been considered ETEC, EPEC and DAEC (Tamura *et al.*, 1996). In both industrialized and developing nations, it is linked to watery diarrhea. The recurrent urinary tract infections are also caused by it. Diarrhea caused by DAEC has been extensively documented, especially in children older than one year (Hussain, 2015).

During the Assembly of World Health Organizations in 2015, European Union member states agreed to the 'One Health' definition, which aims to prevent and track antimicrobial resistance in human, agriculture, and veterinary sectors besides supporting high levels of global collaboration. Antibiotic usage and misuse have accelerated the establishment and spread of bacterial drug resistance. (Gootz, 2010).

ExPEC isolates exhibit pathogenic potential due to various virulence factors that enable them to colonize and overcome host defense mechanisms. We studied identified virulence genes, including *papC*, for the ExPEC pathotype. It is known that the interplay of various virulence factors, essential for host colonization and spreading of ExPEC, including adhesives, toxins, and iron acquisition systems, is associated with an increased chance of intestinal migration. (Clermont *et al.*, 2011; Mellata *et al.*, 2013).

In the present study, 36.20 and 24.43% of the samples carried potentially pathogenic *E. coli*, possessing hly and *papC* genes, respectively. There is emerging proof that contaminated animal-derived food might

facilitate the expansion of extraintestinal pathogenic *E. coli* in the population (Ramchandani *et al.,* 2005).

E. coli's alpha-hemolysin (*hly*) is a major virulence agent that destroys erythrocytes and has substantial cytotoxic and cytolytic impacts on diverse nucleated cells (Söderström *et al.,* 2017). *Hly* typically originates by strains of extra-intestinal pathogenic *E. coli* (ExPEC), with uncommon contributions from ETEC, STEC, and EPEC (Burgos and Beutin, 2010). Previous studies have detected the *hly* gene in 4.6% of retail meat samples in Egypt (Ali *et al.,* 2020; Ahmed *et al.,* 2023) and 34.69% in China (Nong *et al.,* 2021).

In this investigation, 54 isolates (24%) tested positive for the *papC* gene. Arisoy *et al.* (2006) and Bashir *et al.* (2012) showed comparable *papC* gene prevalence levels of 23% and 24%, respectively. Usein et al. (2001), Santo *et al.* (2006), Tiba *et al.* (2008), Firoozeh *et al.* (2014), and Jolanta Sarowska *et al.* (2022) all reported higher incidence rates of 36%, 32%, 32.7%, 34.6%, and 37.7%, respectively. The capacity of UPEC isolates to adhere to urinary epithelial cells and begin infections using a range of adhesives accounts such as pap gene (Neamati *et al.,* 2015).

The current study's isolates exhibited a colistin resistance incidence of 5.43%, which is consistent with earlier research on *mcr1* colistin-resistant *E. coli* from beef, which ranged from 3% to 5% (Mulvey *et al.,* 2016; Kuo *et al.,* 2016; Sabala *et al.,* 2022). In contrast, this frequency is less than that published by Sadek *et al.* (2019). These outcomes indicate that the presence of *mcr* genes in a variety of foods leads to colistin resistance in gram-negative microbes. Previous research has identified that 2% of ready-to-eat cheese in Egypt contains *mcr-1* positive, colistin-resistant *E. coli* (Zaki *et al.,* 2018).

Our findings, which are higher than earlier research, can be attributed to an elevated incidence of mcr1 genes among ESBL-producing *E. coli* strains among animals. However, the prevalence is still limited in non-ESBL strains. This shows that extended-spectrum cephalosporins may have aided in the spread of *mcr1* (Haenni *et al.,* 2016; Perrin-Guyomard *et al.,* 2016). Research in Turkey discovered a close genetic link between mcr1 genes detected in chicken flesh and human isolates, demonstrating the propagation and transmission of mcr1-mediated colistin resistance in *E. coli* throughout many sources with zoonotic relevance in the food chain (Adiguzel *et al.,* 2020). The fact of widespread use of colistin in animal husbandry and its effectiveness in reducing multi-resistant Gram-negative infections in humans, it is critical to track the spread of colistin resistance.

In our study, the *qnrB* resistance gene was found in 13 isolates from poultry and beef products, which is considerably less than the results stated by Yu *et al.* (2015). Lately, plasmid-mediated quinolone resistance (PMQR) has become increasingly common, and it is transmitted through horizontal gene transfer. The most common gene is *qnr* (Ogbolu *et al.,* 2011; Poirel *et al.,* 2012; Ruiz, 2019).

Our findings showed that the virulence patterns and resistance characteristics of food-derived isolates imply that chicken meat has the greatest pathogenic risk. The contrast in levels of contamination between chicken and other food animal meat might be attributed to variations in production techniques, which are more intense in the poultry business than in other food animal husbandry (Smet *et al.,* 2010; Dahshan *et al.,* 2015). The disparity in ESBL-E prevalence between nations might be ascribed to inadequate antibiotic usage laws in the Middle East, as opposed to the tougher rules implemented by EU countries (Filippini *et al.,* 2006).

Public health is at risk due to the antibiotic resistance profiles of *E. coli* isolates. Twelve antibiotics were used to screen antimicrobial resistance in each isolate. Isolates of *E. coli* demonstrated resistance to penicillin G, colistin, erythromycin, tetracycline, ampicillin, and nalidixic acid with 91.86, 90.95, 90.06, 89.59, 87.78 and 80.54%, respectively. Antimicrobial susceptibility test findings were mostly in line with earlier research from other countries (Moawad *et al.,* 2017; Aktar *et al.,* 2023).

Abdel-Rahman *et al.* (2023) investigated the antimicrobial resistance of *E. coli* strains to 18 different antibiotics. The greatest antibiotic resistance rates in this investigation varied from 95 to 86.7% for ampicillin, penicillin, nalidixic acid, tetracycline, clavulanic acid, revealing the antimicrobials' particular effectiveness in treating E. coli infections in livestock and poultry. Ramadan *et al.* (2020) determined antimicrobial susceptibility of the *E. coli* bacteria of retail food that originated from animals and poultry. Antimicrobial resistance detected against ampicillin, tetracycline, streptomycin, nalidixic acid, leaving few possibilities for therapeutic. Fortunately, isolate obtained in the present study was susceptible to gentamicin, kanamycin, amikacin, and vancomycin, suggesting that these antibiotics might be used as a strategy to treat MDR bacterial infections (Table 7).

It is commonly recognized that biofilms can harbor human foodborne pathogens (Ahmed *et al.,* 2022, B). However, the role and contributing factors underlying the production of biofilms in this particular instance of *E. coli* are slightly diverse (Dourou *et al.,* 2011). Monisha *et al.* (2022) stated that biofilm formation was discovered enhanced by media rich in glucose. Stainless steel also exhibited the greatest biofilm formation compared to the other surfaces. Moreover, biofilm formation increased antibiotic resistance through allowing cells persistence. Studies involving a wide variety of strains provide evidence that *E. coli* can produce biofilms (Al-Shabib *et al.,* 2017; Risal *et al.,* 2018; Katongole *et al.,* 2020; Monisha *et al.,* 2022). In addition, Milojević *et al.* (2017) indicated that biofilm formation by *E. coli* might not produce biofilm.

The little isolates number in further research, as well as the differences in how results are interpreted across studies, render it challenging to compare the current study's findings with those of other investigations. However, our results disagree with Narisawa *et al.* (2005) and Milojević *et al.* (2017). Most of the *E. coli* strains were either weak or non-biofilm producers, and none of the strains showed a showedantial capacity to create biofilm. On the other hand, our findings harmonize with others, such as Barilli *et al.* (2020), who discovered that a substantial proportion of *E. coli* strains has adhesive qualities, and with Wang *et al.* (2016), who declared that biofilm formation ability was greater in samples of meat products.

One of *E. coli's* key virulence factors is its capacity to create biofilm. The development of biofilm-harboring bacteria, which are often more resistant to routine cleaning and sanitizing processes, may result from its persistence on equipment or in clinical settings (Barilli *et al.,* 2020). Pathogens' ability to produce biofilms has two impacts. Clinically, the capacity to create it is a characteristic that indicates the pathogenicity of the strain. Bacteria are protected from drugs and immunological responses (phagocytosis) by components of a biofilm matrix (Verma *et al.,* 2018). It was shown that bacteria that produced strong or moderate biofilms were more antibiotic resistant than those that did not. Compared to weak or non-biofilm-producing bacteria, it was discovered that strong or moderate biofilm-producing bacteria were more resistant to antibiotics (Risal *et al.,* 2018). Furthermore, strains capable of forming biofilms on processing surfaces might pose a serious threat from an industrial standpoint

because they are more difficult to remove from these surfaces, less disinfectant susceptible, and frequently cause cross-contamination in the food industry (Shi and Zhu, 2009).

Keeping people safe from the negative impacts of pathogenic *E. coli* has become quite difficult. Chemical preservatives' detrimental effects on human health, restricted application, toxicity, sensitivity as well as microbial resistance, make it more important than ever to find potentially safe, healthy natural antibacterial alternatives with a unique method of combating dreadful infections. Therefore, LAB strains are biological preservatives that may be employed to guarantee food safety and health without the adverse effects associated with chemical preservatives. Additionally, their antibacterial activity can provide a crucial component of treatment for *E. coli* infections that traditional antibacterial agents cannot provide. We demonstrated that the algae had potent dose-dependent bactericidal action against *E. coli*. In the present study, the antibacterial activity of CFS from LAB strains against *E. coli* was evaluated. Notably, complete *E. coli* killing by CFS from LAB strains was observed and were probably beneficial against the investigated pathogen with variations in potency (about 11 log-order of killing).

The obtained data enables us to know the capability of exploring LAB strains CFS to promote as an antibacterial agent owing to the presence of stable biologically active compounds. Shaikh and Shah (2013) investigated LAB antibacterial potential against *E. coli* because bacteriocin-like peptides, hydrogen peroxide, organic acids, and diacetyl compounds produced.

The data gathered offers valuable insights into the design of new antibacterial agents that combat harmful *E. coli*, which in turn provides the powerful catalyst required to develop antimicrobial formulations for use in healthcare or food preservation. Our results align with earlier surveillances carried out worldwide, which demonstrate that LAB strains have antibacterial properties (Panebianco *et al.*, 2021; Adugna and Andualem, 2023). Pyar and Peh (2014) stated that there are a variety of physiologically active metabolites, such as diacetyl, organic acids, bacteriocins, and other compounds produced by probiotics and thought to be abundant in LAB. Because they inhibit other microorganisms' growth and suppress harmful germs, these substances help reduce microbiological risk.

CONCLUSION

The findings of this investigation revealed that *E. coli* was widely dispersed in the samples examined, posing significant health risks to consumers. The present study highlighted possible origins of virulent *E. coli* contamination and fecal coliforms in beef and poultry meat products, reflecting poor hygienic practices. The high incidence of *E. coli*, especially antibiotic-resistant ones, and their variants diversity underscore the serious issue of these bacteria serving as reservoirs in the meat industry, threatening public health through the food chain. The frequent use of antibiotics to prevent animal infections without veterinary guidance contributes to this problem, as evidenced by the presence of genes responsible for antibiotic resistance identified in the highlighted data. Additionally, production of biofilms, which have a high survival rate in the environment, is a concerning issue. Inadequate cleaning and disinfection in the meat industry, along with inadequate sanitation procedures at nearby stores, have made it easier for virulent *E. coli* bacteria to survive and proliferate in meat products in the studied areas. Therefore, it is crucial to implement effective measures to ensure the hygienic quality of meat and its products at all stages of production, to minimize cross-contamination risks and protect public health. Furthermore, this research demonstrates the potential of explored LAB strains as antibacterial agents because of the

stable, physiologically active chemicals they contain. Additionally, it sheds light on how to create new antibacterial treatments for harmful *E. coli*, which is a powerful catalyst for the creation of antibacterial solutions for therapeutic use or food preservation.

Abbreviations: CFU, Colony-forming unit; CFS, Cell free supernatant; DEC, Diarrheagenic *Escherichia coli*; EAEC, Enteroaggregative *E. coli*; EHEC, Enterohemorrhagic *E. coli*; EIEC, Enteroinvasive *E. coli*; EPEC, Enteropathogenic *E. coli*; ETEC, Enterotoxigenic *E. coli*; EOSQC, Egyptian Organization for Standardization and Quality Control; ESBLs, Extended spectrum β-lactamases; ExPEC, Extraintestinal Pathogenic *E. coli*; LAB, Lactic acid bacteria; *hlyA*, Hemolysin gene A; *papC*, P fimbriae; *Mcr1*, Mobile colistin resistance 1 gene; NMEC, Neonatal Meningitis *E. coli*; *qnrB*, Quinolone resistance gene; SEPEC, Sepsis-associated *E. coli*; UPEC, Uropathogenic *E. coli*.

REFERENCES

Abd El-Tawab, A.A.; Maarouf, A.A.A.; Abd El Al, S.A.; El Hofy, F.I. and El Mougy, E.E.A. (2014): Detection of some virulence genes of avian pathogenic *E. coli* by polymerase chain reaction. Benha Veterinary Medical Journal, 26(2): 159-176.

Abdel 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 Veterinary Medicine Journal, 29(2): 47-59.

Abdel-Rahman, M.A.A.; Hamed, E.A.; Abdelaty, M.F.; Sorour, H.K.; Badr, H.; Hassan, W.M.; Shalaby, A.G.; Halem, A.A.E.; Soliman, M.A. and Roshdy, H. (2023): Distribution pattern of antibiotic resistance genes in *Escherichia coli* isolated from colibacillosis cases in broiler farms of Egypt, Veterinary World, 16(1): 1–11.

Abou Hussein, R.A. (2007): Detection of food mediated pathogens in some meat and chicken products by using recent techniques. Ph. D. Thesis (Meat Hygiene), Faculty of Veterinary Medicine, Banha University, Egypt.

Adel, W.A.; Ahmed, A.M.; Hegazy, Y.; Torky, H.A. and Shimamoto, T. (2021): High prevalence of ESBL and plasmid-mediated quinolone resistance genes in Salmonella enterica isolated from retail meats and slaughterhouses in Egypt. Antibiotics, 10(7): 881.

Adiguzel, M.C.; Baran, A. Wu, Z.; Cengiz, S.; Dai, L. and Oz, C. (2020): Prevalence of Colistin Resistance in Escherichia coli in Eastern Turkey and genomic characterization of an mcr-1 positive strain from Retail Chicken meat. Microb Drug Resist, 27(3): 424–32.

Adugna, M. and Andualem, B. (2023): Isolation, characterization and safety assessment of probiotic lactic acid bacteria from metata ayib (Traditional spiced cottage cheese). Food and Humanity, 1: 85-91.

Adzitey, F.; Huda, N. and Shariff, A.H.M. (2021): Phenotypic antimicrobial susceptibility of Escherichia coli from raw meats, ready-to-eat meats, and their related samples in one health context. Microorganisms, 9(2): 326.

Ahmed, A.S.; Diab, H.M.; Alkahtani, M.A.; Alshehri, M.A.; Saber, H.; Badr, H. and Ahmed, A.E. (2022, A): Molecular epidemiology of virulent E. coli among rural small scale dairy herds and shops: Efficacy of selected marine algal extracts and disinfectants. International journal of environmental health research, 32(1): 72-94.

Ahmed, A.S.; Diab, H.M.; Hendy, B.A.; Batiha, G.E.S.; Dandrawy, M. and El-Zamkan, M.A. (2022, B): Molecular Characterization of Y. enterocolitica Isolated from Dairy Environment with Special Reference to the Antimicrobial

Activity of Milk Proteins Hydrolysates. Journal of Advanced Veterinary Research, 12(2): 118-127.

Ahmed, A.E.; Al-Kahtani, M.M.; El-Diasty, E.M.; Ahmed, A.S.; Saber, H.; Abbas, A.M. and Hussein, M.A. (2020, A): Diversity of toxigenic molds and mycotoxins isolated from dairy products: antifungal activity of Egyptian marine algae on Aspergillus and Candida species. Journal of Pure & Applied Microbiology, 14(1): 215-232.

Ahmed, A.S.; Alsayeqh, A.F. and Diab, H.M. (2020, B): Enterotoxigenic profiles of virulent Bacillus cereus isolated from dairy environments: antimicrobials resistant pattern and sporicidal disinfectants efficacy. Adv. Anim. Vet. Sci., 8(5): 543-557.

Ahmed, W.; Neubauer, H.; Tomaso, H.; El Hofy, F.I.; Monecke, S.; Abd El-Tawab, A.A. and Hotzel, H. (2021): Characterization of enterococci-and ESBL-producing Escherichia coli isolated from milk of bovides with mastitis in Egypt. Pathogens, 10(2): 97.

Ahmed, H.A.; Elsohaby, I.; Elamin, A.M.; El-Ghafar, A.E.A.; Elsaid, G.A.; Elbarbary, M. and El Bayomi, R.M. (2023): Extended-spectrum β-lactamase-producing E. coli from retail meat and workers: genetic diversity, virulotyping, pathotyping and the antimicrobial effect of silver nanoparticles. BMC microbiology, 23(1): 212.

Ahmed, H.A.; Elsohaby, I.; Elamin, A.M.; El-Ghafar, A.E.A.; Elsaid, G.A.; Elbarbary, M.; ... and El Bayomi, R. M. (2023): Extended-spectrum β-lactamase-producing E. coli from retail meat and workers: genetic diversity, virulotyping, pathotyping and the antimicrobial effect of silver nanoparticles. BMC microbiology, 23(1): 212.

Ahmed-Neven, M. (2016): Traceability Diarrheogenic E. coli in meat products with special reference to Enterohemorrhagic Srtains. PhD, Thesis (Meat Hygiene), Faculty of Veterinary Medicine, Benha University, Egypt.

Aktar, T.; Fakhruzzaman, M.; Akter, M.R. and Sarker, M.T.I. (2023): Isolation, characterization and antibiogram studies of bacteria isolated from ready-to-eat foods sold at different places of Dinajpur district, Bangladesh. Asian-Australasian Journal of Food Safety and Security, 7(1): 1-9.

Alba, P.; Leekitcharoenphon, P.; Franco, A.; Feltrin, F.; Ianzano, A.; Caprioli, A. and Battisti, A. (2018): Molecular epidemiology of mcr-encoded colistin resistance in Enterobacteriaceae from food-producing animals in Italy revealed through the EU harmonized antimicrobial resistance monitoring. Frontiers in microbiology, 9: 1217.

Ali, S.S.; Sonbol, F.I.; Sun, J.; Hussein, M.A.; Hafez, A.E. and Abdelkarim, E.A. (2020): Molecular characterization of virulence and drug resistance genes-producing Escherichia coli isolated from chicken meat: metal oxide nanoparticles as novel antibacterial agents. Microb Pathog., 143: 104164.

Al-Shabib, N.A.; Husain, F.M.; Ahmad, I.; Khan, M.S.; Khan, R.A. and Khan, J.M. (2017): Rutin inhibits mono and multi-species biofilm formation by foodborne drug resistant Escherichia coli and Staphylococcus aureus. Food control, 79: 325-332.

Anyanwu, M.U.; Jaja, I.F. and Nwobi, O.C. (2020): Occurrence and characteristics of mobile colistin resistance (mcr) gene-containing isolates from the environment: a review. International journal of environmental research and public health, 17(3): 1028.

Arisoy M.; Aysev D. and Ekim M. (2006): Detection of virulence factors of Escherichia coli from children by

multiplex polymerase chain reaction. Int. J. Clin. Pract. 60: 170-173.

Badr, H.; Reda, R.M.; Hagag, N.M.; Kamel, E.; Elnomrosy, S.M.; Mansour, A.I. and Ali, H.R. (2022): Multidrug-resistant and genetic characterization of extended-spectrum beta-lactamase-producing E. coli recovered from chickens and humans in Egypt. Animals, 12(3): 346.

Badr-Sarah. (2018): Follow up of E. coli and Staphylococcus aureus in some locally manufactured meat products. M.V.Sc., Thesis (Meat Hygiene), Faculty of Veterinary Medicine, Benha University, Egypt.

Baloch, A.B.; Yang, H.; Feng, Y.; Xi, M.; Wu, Q.; Yang, Q. and Xia, X. (2017): Presence and antimicrobial resistance of Escherichia coli in ready-to-eat foods in Shaanxi, China. Journal of food protection, 80(3): 420-424.

Barilli, E.; Vismarra, A.; Frascolla, V.; Rega, M. andBacci, C. (2020): Escherichia coli strains isolated from retail meat products: evaluation of biofilm formation ability, antibiotic resistance, and phylogenetic group analysis. Journal of food protection, 83(2): 233-240.

Bashir S.; Haque A. and Sarwar Y. (2012): Virulence profile of different phylogenetic groups of locally isolated community acquired uropathogenic E. coli from Faisalabad region of Pakistan. Ann.Clin. Microbiol. Antimicrob, 11(23): 1-6.

Bien, J.; Sokolova, O. and Bozko, P. (2012): Role of uropathogenic Escherichia coli virulence factors in development of urinary tract infection and kidney damage. International journal of nephrology, 2012(1): 681473.

Bitrus, A.A.; Chuanchuen, R. and Luangtongkum, T. (2018): Emergence of colistin resistance in extended-spectrum beta lactamase producing Enterobacteriaceae isolated from food animals and its public health implication: A review. Journal of Advanced Veterinary & Animal Research, 5(1).

Burgos, Y. and Beutin, L. (2010): Common origin of plasmid encoded alpha hemolysin genes in Escherichia coli. BMC Microbiol. 10: 193.

Clermont, O.; Olier, M.; Hoede, C.; Diancourt, L.; Brisse, S.; Keroudean, M.; Glodt, J.; Picard, B.; Oswald, E. and Denamur, E. (2011): Animal and human pathogenic Escherichia coli strains share common genetic backgrounds. Infect. Genet. Evol. 11: 654–662.

Clinical and Laboratory Standards Institute (CLSI) (2007): Performance standards for antimicrobial disk susceptibility tests. Vol. 27, Clinical and Laboratory Standards Institute, Wayne, Pennsylvania, USA.

Costerton, J.W.; Khoury, A.E.; Ward, K.H. and Anwar, H. (1993): Practical measures to control device-related bacterial infections. Int. J. Artif. Organs. 16(11): 765–70.

Dahshan, H.; Abd-Elall, A.M.M.; Megahed, A.M.; Abd-El-Kader, M.A. and Nabawy. E.E. (2015): Veterinary antibiotic resistance, residues, and ecological risks in environmental samples obtained from poultry farms. Egypt Environ Monit Assess. 187(2): 1–10.

Dale, A.P. and Woodford, N. (2015): Extra-intestinal pathogenic Escherichia coli (ExPEC): disease, carriage and clones. Journal of Infection, 71(6): 615-626.

Desvaux, M.; Dalmasso, G.; Beyrouthy, R.; Barnich, N.; Delmas, J. and Bonnet, R. (2020): Pathogenicity factors of genomic islands in intestinal and extraintestinal Escherichia coli. Frontiers in microbiology, 11: 2065.

Diab, H.; Ahmed, A.S.; Alkazmi, L.; Batiha, G.E.S. and El-Zamkan, M.A. (2021): Antifungal disinfectants efficiency on aspergillus strains from camel's milk and drinking water: Biological detoxification of Aflatoxin-M1. Assiut

Veterinary Medical Journal, 67(171): 75-102.

Dourou, D.; Beauchamp, C.S.; Yoon, Y.; Geornaras, I.; Belk, K.E.; Smith, G.C.; Nychas, G.E. and Sofos, J.N. (2011): Attachment and biofilm formation by Escherichia coli O157:H7 at different temperatures, on various food-contact surfaces encountered in beef processing International Journal of Food Microbiology, 149(3): 262-8.

Eddine, S.D.; Yasmine, S.; Fatima, G.; Amina, Z.; Battache, G. and Mebrouk, K. (2021): Antifungal and Antibacterial Activity of Some Lactobacilli Isolated from Camel's Milk Biotope in the South of Algeria. Journal of Microbiology, Biotechnology and Food Sciences, 871–877.

Elsaid, S.; Reham, A.; Amin, and Eeilwa-Nesreein, Z. (2019): Assessment of bacterial contamination in cattle carcasses at Gharbia Abattoirs. Benha Veterinary Medical Journal, 36: 247-251.

El-Shazly, D.A.; Nasef, S.A.; Mahmoud, F.F. and Jonas, D. (2017): Expanded spectrum β–lactamase producing Escherichia coli isolated from chickens with colibacillosis in Egypt. Poultry science, 96(7): 2375-2384.

El Sheikha, A.F.; Levin, R.E. and Xu, J. (2018): Molecular techniques in food biology: safety, biotechnology, authenticity & traceability. 1st ed. John Wiley & Sons, Ltd., Chichester, UK.

El-Zamkan, M.A.; Hendy, B.A.; Diab, H.M.; Marraiki, N.; Batiha, G.E.S.; Saber, H. and Ahmed, A.S. (2021): Control of virulent Listeria monocytogenes originating from dairy products and cattle environment using marine algal extracts, silver nanoparticles thereof, and quaternary disinfectants. Infection and Drug Resistance, 2021(15): 2721-2739.

EOSQC "Egyptian Organization for Standardization and Quality Control" (2005): Egyptian Organization for Specification and Quality Control for frozen beef burger No. 1688-2005; for frozen kofta No. 1973-2005; for frozen sausage No. 1972-2005, Ministry of Industry.

FAO "Food and Agriculture Organization", (1992): Manual of food quality control. 4. Rev. 1. Microbiological analysis. Food and Agriculture Organization of the United Nations, Rome, Italy.

FDA "Food and Drug Administration". (2002): BAM: Enumeration of E. coli and the Coliform Bacteria. Bacteriological Analytical Manual, Chapter 4, Enumeration of E. coli and the Coliform Bacteria. http://www.fda.gov/food/scienceresearch/LaboratoryMethods/BacteriologicalAnalyticalManualBAM/.

Ferreira, J.C.; Penha Filho, R.A.C.; Kuaye, A.P.Y.; Andrade, L.N.; Junior, A.B. and Da Costa Darini, A.L. (2018): Identification and characterization of plasmid-mediated quinolone resistance determinants in Enterobacteriaceae isolated from healthy poultry in Brazil. Infection, Genetics and Evolution, 60: 66-70.

Filippini, M.; Masiero, G. and Moschetti, K. (2006): Socioeconomic determinants of regional differences in outpatient antibiotic consumption: evidence from Switzerland. Health Policy. 78(1): 77–92.

Firoozeh, F.; Saffari, M.; Neamati, F. and Zibaei, M. (2014): Detection of virulence genes in Escherichia coli isolated from patients with cystitis and pyelonephritis. Int J Infect Dis., 29: 219-22.

Gaafar, R.; Hassanin, F.S.; Shaltout, F. and Zaghloul, M. (2019): Hygienic profile of some ready to eat meat product sandwiches sold in Benha city, Qalubiya Governorate, Egypt. Benha Veterinary Medical Journal. 37(1): 16-21.

Gomes, T.A.T.; Irino, K.; Girão, D.M.; Girão, V.B.C.; Guth, B.E.C.; Vaz,

T.M.I.; Moreira, F.C.; Chinarelli, S.H. and Vieira, M.A.M. (2004): Emerging Enteropathogenic Escherichia coli Strains?. Emerging Infectious Diseases. 10(10).

Gootz, T.D. (2010): The global problem of antibiotic resistance. Crit. Rev. Immunol., 30: 79–93.

Gwida, M.; Hotzel, H.; Geue, L. and Tomaso, H. (2014): Occurrence of enterobacteriaceae in raw meat and in human samples from Egyptian retail sellers. International Scholarly Research Notices, 1–4.

Haenni, M.; Métayer, V.; Gay, E. and Madec, J.Y. (2016): Increasing trends in mcr-1 preva- lence among extended-spectrum-β-lactamase-producing Escherichia coli isolates from french calves despite decreasing exposure to colistin. Antimicrob Agents Chemother. 60(10): 6433–4.

Hamed, O.M.; Sabry, M.A.; Hassanain, N.A.; Hamza, E.; Hegazi, A.G. and Salman, M.B. (2017): Occurrence of virulent and antibiotic-resistant Shiga toxin-producing Escherichia coli in some food products and human stool in Egypt, Veterinary World, 10(10): 1233-1240.

Hassan, M.A.; Batiha, G.E.; Saad, S.A. and Mahrous, E. (2023): Study on enterotoxigenic Escherichia coli producing extended spectrum beta lactamase (ESBL) from chicken meat and its products. International Journal of Veterinary Science, 12(5): 652-658.

Hassanin, F.S.; Hassan, M.A.; Shaltout, F.A.; Shawqy, N.A. and Abd-Elhameed, G.A. (2017): Bacteriological criteria of chicken giblets. Benha Veterinary Medical Journal, 33(2): 447-456.

Hassanin, M.; El-Sabagh, R.A.; Marionet, Z.N. and Mohammed, S.R. (2016): Bacterial and chemical quality of frozen chicken meat received at governmental hospital modern. Benha Veterinary Medical Journal, 30(1): 109-117.

Huang, X.; Yu, L.; Chen, X.; Zhi, C.; Yao, X.; Liu, Y. and Liu, J.H. (2017): High prevalence of colistin resistance and mcr-1 gene in Escherichia coli isolated from food animals in China. Frontiers in Microbiology, 8: 562.

Hussain, T. (2015): An introduction to the Serotypes, Pathotypes and Phylotypes of Escherichia coli. International Journal of Microbiology and Allied Sciences (IJOMAS). 2(1): 9-16.

Hussein, M.A.; Eldaly, E.A.; Seadawy, H.G. and El-Nagar, E.F. (2018): Virulence and antimicrobial resistance genes of Escherichia coli in ready to eat sandwiches in Sharkia governorate. Slovenian Veterinary Research, 55(Suppl_20): 383–392..

Ijoma, G.N. (2010): Antibiotic Resistance of Coliform Bacteria in the Rietspruit River. Magister Technologiae Magister Technologiae, Vaal University of Technology, Vanderbijlpark.

Jin, W.; Zheng, Z.; Zhang, Y.; Qin, A.; Shao, H.; Liu, Y.; Wang, J. and Wang, Q. (2008): Distribution of virulence-associated genes of avian pathogenic Escherichia coli isolates in China. Agric. Sci. China. 7(12): 1511–1515.

Katongole, P.; Nalubega, F.; Florence, N.C.; Asiimwe, B. and Andia, I. (2020): Biofilm formation, antimicrobial susceptibility and virulence genes of Uropathogenic Escherichia coli isolated from clinical isolates in Uganda. BMC Infectious Diseases, 20: 1-6.

Konemann, E.; Allen, S.; Janda, W.; Schreckenberger, C. and Winn, W. (1997): Color Atlas and text book of Diagnostic Microbiology (pp. 55-73). 5th Ed. Lippincott, Philadelphia, New York.

Kuo, S.C.; Huang, W.C.; Wang, H.Y.; Shiau, Y.R.; Cheng, M.F. and Lauderdale, T.L. (2016): Colistin resistance gene mcr-1 in Escherichia coli isolates from humans and retail meats, Taiwan.

Journal of Antimicrobial Chemotherapy, 71(8): 2327–2329.

Lee, M.D. and Nolan, L.K. (2008): Colibacillosis. In L. Dufour-Zavala (Eds). Isolation, Identification, and Characterization of Avian Pathogens. 5th Ed. American Association of Avian Pathologists. Athens, GA.

Lee, G.Y.; Jang, H.I.; Hwang, I.G. and Rhee, M.S. (2009): Prevalence and classification of pathogenic Escherichia coli isolated from fresh beef, poultry, and pork in Korea. International Journal of Food Microbiology. 134(3): 196-200.

Lindstedt, B.A.; Finton, M.D.; Porcellato, D. and Brandal, L.T. (2018): High frequency of hybrid Escherichia coli strains with combined Intestinal Pathogenic Escherichia coli (IPEC) and Extraintestinal Pathogenic Escherichia coli (ExPEC) virulence factors isolated from human fecal samples. BMC infectious diseases, 18: 1-12.

Luo, Q.; Wang, Y. and Xiao, Y. (2020): Prevalence and transmission of mobilized colistin resistance (mcr) gene in bacteria common to animals and humans. Biosafety and Health, 2(2): 71-78.

Lüthje, P. and Brauner, A. (2014): Virulence factors of uropathogenic E. coli and their interaction with the host. Advances in microbial physiology, 65: 337-372.

Mah, T.F. and O'Toole, G.A. (2001): Mechanisms of biofilm resistance to antimicrobial agents. Trends Microbiol. 9(1): 34–9.

Mellata, M. (2013): Human and avian extraintestinal pathogenic Escherichia coli: Infections, zoonotic risks, and antibiotic resistance trends. Foodborne Pathog. Dis. 10: 916–932.

Milojević, L.; Velebit, B.; Baltić, T.; Nikolić, A.; Mitrović, R. and Đorđević, V. (2017): Characterization of biofilms produced by Escherichia coli O157 isolated from cattle hides. In IOP Conference Series: Earth and Environmental Science. IOP Publishing, 85(1): 012076.

Moawad, A.A.; Hotzel, H.; Awad, O.; Tomaso, H.; Neubauer, H.; Hafez, H.M. and El-Adawy, H. (2017): Occurrence of Salmonella enterica and Escherichia coli in raw chicken and beef meat in northern Egypt and dissemination of their antibiotic resistance markers. Gut pathogens, 9: 1-13.

Monisha, B.A.; Bharathy, L.S.; Premkumar, K. and Sathiyamurthy K. (2022): Antbiotc Resistance and Bioflm Development of Escherichia coli on Different Surfaces. J. Pure. Appl. Microbiol. 16(3): 1884-1892.

Mulvey, M.R.; Mataseje, L.F.; Robertson, J.; Nash, J.H.E.; Boerlin, P. and Toye, B. (2016): Dissemination of the mcr-1 colistin resistance gene. The Lancet Infectious Diseases, 16(3): 289–290.

Narisawa, N.; Furukawa, S.; Ogihara, H. and Yamasaki, M. (2005): Estimation of the biofilm formation of Escherichia coli K-12 by the cell number. Journal of bioscience and bioengineering, 99(1): 78-80.

Neamati, F.; Firoozeh, F.; Saffari, M. and Zibaei, M. (2015): Virulence Genes and Antimicrobial Resistance Pattern in Uropathogenic Escherichia coli Isolated From Hospitalized Patients in Kashan, Iran. Jundishapur journal of microbiology, 8(2): e17514.

Newton-Foot, M.; Snyman, Y.; Maloba, M.R.B. and Whitelaw, A.C. (2017): Plasmid-mediated mcr-1 colistin resistance in Escherichia coli and Klebsiella spp. Clinical isolates from the Western Cape region of South Africa. Antimicrob. Resist. Infect. Control, 6(3): 78.

Nong, F.; Zhang, P.; Meng, J.; Xie, Q.; Li, Y. and Pan, Y. (2021): Characterization of shigatoxin producing Escherichia coli (STEC) isolated from retail raw meats in

Southeast China. Food Control, 126: 108061.

Ogbolu, D.O.; Daini, O.A.; Ogunledun, A.; Alli, A.O. and Webber, M.A. (2011): High levels of multidrug resistance in clinical isolates of gram-negative pathogens from Nigeria. Int. J. Antimicrob. Agents, 37: 62–66.

Pakbin, B.; Brück, W.M. and Rossen, J.W. (2021): Virulence factors of enteric pathogenic Escherichia coli: A review. International journal of molecular sciences, 22(18): 9922.

Panebianco, F.; Giarratana, F.; Caridi, A.; Sidari, R.; De Bruno, A. and Giuffrida, A. (2021): Lactic acid bacteria isolated from traditional Italian dairy products: Activity against Listeria monocytogenes and modelling of microbial competition in soft cheese. Lwt, 137(2021): 110446.

Parvez, S.A. and Rahman, D. (2018): Virulence factors of uropathogenic E. coli. Microbiology of Urinary Tract Infections-Microbial Agents and Predisposing Factors, 7-21.

Perrin-Guyomard, A., Bruneau, M.; Houée, P.; Deleurme, K.; Legrandois, P. and Poirier, C. (2016): Prevalence of mcr-1 in commensal Escherichia coli from French livestock, 2007 to 2014. Eurosurveillance, 21(6): 30135.

Pitout, J.D. (2012): Extraintestinal pathogenic Escherichia coli: a combination of virulence with antibiotic resistance. Frontiers in microbiology, 3: 9.

Piva, I.C.; Pereira, A.L.; Ferraz, L.R.; Silva, R.S.N.; Vieira, A.C.; Blanco, J.E.; Blanco, M.; Blanco, J. and Giugliano, L.G. (2003): Virulence Markers of Enteroaggregative Escherichia coli Isolated from Children and Adults with Diarrhea in Brasília, Brazil. Journal of Clinical Microbiology, 1827–1832.

Poirel, L.; Cattoir, V.and Nordmann, P. (2012): Plasmid-mediated quinolone resistance; interactions between human, animal, and environmental ecologies. Front. Microbiol. 3: 24.

Pyar, H. and Peh, K.K. (2014): Characterization and identification of Lactobacillus acidophilus using biolog rapid identification system. International journal of pharmacy and pharmaceutical sciences, 6(1): 189-193.

Ramadan, H.; Jackson, C.R.; Frye, J.G.; Hiott, L.M.; Samir, M.; Awad, A. and Woodley, T.A. (2020): Antimicrobial resistance, genetic diversity and multilocus sequence typing of Escherichia coli from humans, retail chicken and ground beef in Egypt. Pathogens, 9(5): 357.

Ramchandani, M.; Manges, A.R.; DebRoy, C.; Smith, S.P.; Johnson, J.R. and Riley, L.W. (2005): Possible animal origin of human-associated, multidrug-resistant, uropathogenic Escherichia coli. Clinical Infectious Diseases, 40(2): 251–257.

Risal, G.; Shrestha, A.; Kunwar, S.; Paudel, G.; Dhital, R.; Budha, M.B. and Nepal, R. (2018): Detection of biofilm formation by Escherichia coli with its antibiogram profile. Int J Community Med Public Health, 5(9): 3771-3775.

Robicsek, A.; Strahilevitz, J.; Jacoby, G.A.; Macielag, M.; Abbanat, D.; Park, C.H.; Bush, K. and Hooper, D.C. (2006): Fluoroquinolone-modifying enzyme:A new adaptation of a common aminoglycoside acetyltransferase. Nat. Med., 12(1): 83–88.

Rodríguez-Martínez, J.M.; Machuca, J.; Cano, M.E.; Calvo, J.; Martínez-Martínez, L. and Pascual, A. (2016): Plasmid-mediated quinolone resistance: two decades on. Drug Resistance Updates, 29: 13-29.

Ruiz, E.; Saenz, Y.; Zarazaga, M.; Rocha-Gracia, R.; Martinez-Martinez, L.; Arlet, G. (2012): Qnr, aac(6′)-Ib-cr and qepA genes in Escherichia coli and klebsiella spp.: genetic environments and plasmid and

chromosomal location. J. Antimicrob. Chemother. 67: 886–897.

Ruiz, J. (2019): Transferable mechanisms of quinolone resistance from 1998 onward. Clin. Microbiol. Rev. 32: e00007-19.

Saad, M.S.; Shaltout, F.A.; Saad, M.; Abo El-Roos, N. and Saber, E. (2019): Incidence of Staphylococci and E. coli in Meat and Some Meat Products. EC Nutrition, 14(6).

Sabala, R.F.; Usui, M.; Tamura, Y.; Abd-Elghany, S.M.; Sallam, K.I. and Elgazzar, M.M. (2021): Prevalence of colistin-resistant Escherichia coli harbouring mcr-1 in raw beef and ready-to-eat beef products in Egypt. Food Control, 119: 107436.

Sabala, R.F.; Usui, M.; Tamura, Y.; Abd-Elghany, S.M.; Sallam, K.I. and Elgazzar, M.M. (2021): Prevalence of colistin-resistant Escherichia coli harbouring mcr-1 in raw beef and ready-to-eat beef products in Egypt. Food Control, 119: 107436.

Sadek, M.; Poirel, L.; Nordmann, P.; Nariya, H.; Shimamoto, T. and Shimamoto, T. (2019): Draft genome sequence of a mcr-1/IncI2-carrying multidrug-resistant Escherichia coli B1: ST101 isolated from meat and meat products in Egypt. Journal of Global Antimicrobial Resistance, 20: 41–42.

Salem, N.; Gamel, A.; Khalifa, A.l AbdElHady, H. and Zeid, M. (2016): Microbial status of shawerma sandwiches in Kafr El-Sheikh governorate. Alexandria Journal of Veterinary Sciences, 51(2): 303–309.

Sambrook, J.; Fritsch, E.F. and Montias, T. (1989): Molecular Biology. In: Molecular cloning. Laboratory manual. 2nd ed. USA: Cold Spring Harbor Laboratory press; P. 268.

Santo, E.; Macedo, C. and Marin, J. (2006): Virulence factors of uropathogenic Escherichia coli from a University Hospital in Ribeirão Preto, São Paulo, Brazil. Rev. Inst. Med. trop., 48(4): 185-188.

Sarowska, J.; Futoma-Koloch, B.; Jama-Kmiecik, A.; Frej-Madrzak, M.; Ksiazczyk, M.; Bugla-Ploskonska, G. and Choroszy-Krol, I. (2019): Virulence factors, prevalence and potential transmission of extraintestinal pathogenic Escherichia coli isolated from different sources: recent reports. Gut pathogens, 11: 1-16.

Sarowska, J.; Olszak, T.; Jama-Kmiecik, A.; Frej-Madrzak, M.; Futoma-Koloch, B.; Gawel, A. and Choroszy-Krol, I. (2022): Comparative characteristics and pathogenic potential of Escherichia coli isolates originating from poultry farms, retail meat, and human urinary tract infection. Life, 12(6): 845.

Shaikh, M. and Shah, G. (2013): Determination of probiotic properties of lactic acid bacteria from curd. Global Journal of Biology, Agriculture & Health Sciences, 2: 119-122.

Shan, B.; Cai, Y.; Brooks, J.D. and Corke, H. (2007): The in vitro antibacterial activity of dietary spice and medicinal herb extracts. Int. J. Food Microbiol., 117: 112-119.

Shi, C. and Maktabdar, M. (2022): Lactic Acid Bacteria as Biopreservation Against Spoilage Molds in Dairy Products – A Review. Front. Microbiol., 12: 819-684.

Shi, X and Zhu, X. (2009): Biofilm formation and food safety in food industries. Trends in Food Science & Technology, 20(9): 407-13.

Shilenge, L.B.; Shale, K.; Matodzi, T.; Machete, F. and Tshelane, C. (2017): A review of microbial hazards associated with meat processing in butcheries. African Journal of Science, Technology, Innovation and Development, 9(1): 1–6.

Smet, A.; Martel, A.; Persoons, D.; Dewulf, J.; Heyndrickx, M.; Herman, L.; Haesebrouck, F. and Butaye, P.

(2010): Broad-spectrum β-lactamases among Entero- bacteriaceae of animal origin: molecular aspects, mobility and impact on public health. FEMS Microbiol Rev., 34(3): 295–316.

Söderström, C.M.; Fagerberg, S.K.; Brogaard, M.B.; Leipziger, J.; Skals, M. and Praetorius, H.A. (2017): Loop Diuretics Diminish Hemolysis Induced by α Hemolysin from Escherichia coli. J Membr Biol. 250(3): 301-313.

Stupar, J.; Holøymoen, I.G.; Hoel, S.; Lerfall, J.; Rustad, T. and Jakobsen, A.N. (2021): Diversity and Antimicrobial Activity to-wards Listeria spp. and Escherichia coli among Lactic Acid Bacteria Isolated from Ready-to-Eat Seafood. Foods, 10: 271.

Tadesse, H.A.; Gidey, N.B.; Workelule, K.; Hailu, H.; Gidey, S.; Bsrat, A. and Taddele, H. (2018): Antimicrobial resistance profile of E. coli isolated from raw cow milk and fresh fruit juice in Mekelle, Tigray, Ethiopia. Veterinary medicine international, 2018(1): 8903142.

Tamura, K.; Sakazaki, R.; Murase, M. and Kosako, Y. (1996): The Pathological Society of Great Britain and Ireland Serotyping and categorisation of Escherichia coli strains isolated between 1958 and 1992 from diarrheal diseases in Asia. J. Med. Microbiol. 45: 353-358.

Tansawai, U.; Walsh, T.R. and Niumsup, P.R. (2019): Extended spectrum ß-lactamase-produc- ing Escherichia coli among backyard poultry farms, farmers, and environ- ments in Thailand. Poult Sci., 98(6): 2622–31.

Tiba, M.; Yano, T. and Leite, D. (2008): Genotypic characterization of virulence factors in Escherichia coli strains from patients with cystitis. Rev. Inst. Med. trop. 50(5): 255- 260.

Umana, S.; Ekpo, U.; Bassey, M.; Uko, M. and Abiaobo, N. (2017): Virulence Factors of Bacteria Isolated from Fish Sold at Open Air Market Centre in Okepedi, Itu, Akwa Ibom State, Nigeria. Journal of Applied Life Sciences International, 14(4): 1-14.

Usein, C.; Damian M. and Tatu-Chitoiu D. (2001): Prevalence of virulence genes in Escherichia coli strains isolated from Romanian adult urinary tract infection cases. J. Cell. Mol. Med., 5:303-310.

Valiakos, G. and Kapna, I. (2021): Colistin resistant mcr genes prevalence in livestock animals (swine, bovine, poultry) from a multinational perspective. A systematic review. Veterinary Sciences, 8(11), 265.

Veldman, K.; Van Essen-Zandbergen, A.; Rapallini, M.; Wit, B.; Heymans, R.; Van Pelt, W. and Mevius, D. (2016): Location of colistin resistance gene mcr-1 in Enterobacteriaceae from livestock and meat. Journal of Antimicrobial Chemotherapy, 71(8): 2340-2342.

Verma, P.; Saharan, V.V.; Nimesh, S. and Singh, A.P. (2018): Phenotypic and virulence traits of Escherichia coli and Salmonella strains isolated from vegetables and fruits from India. Journal of applied microbiology, 125(1): 270-281.

Wang, Y.; Yi, L.; Wang, Y.; Wang, Y.; Cai, Y.; Zhao, W. and Ding. C. (2016): Isolation, phylogenetic group, drug resistance, biofilm formation, and adherence genes of Escherichia coli from poultry in central China. Poult. Sci. 95: 2895–2901.

Yanat, B.; Rodríguez-Martínez, J.M. and Touati, A. (2017): Plasmid-mediated quinolone resistance in Enterobacteriaceae: a systematic review with a focus on Mediterranean countries. European Journal of Clinical Microbiology & Infectious Diseases, 36: 421-435.

Yassin, A.K.; Gong, J.; Kelly, P.; Lu, G.; Guardabassi, L. and Wei, L. (2017): Antimicrobial resistance in clinical Escherichia coli isolates from poultry

and livestock, China. PLoS ONE, 12(9): e0185326.

Yu, T.; Jiang, X.; Fu, K.; Liu, B.; Xu, D.; Ji, S. and Zhou, L. (2015): Detection of Extended-Spectrum β-Lactamase and Plasmid-Mediated Quinolone Resistance Determinants in Escherichia coli Isolates from Retail Meat in China. Journal of food science, 80(5): M1039–M1043.

Zadernowska, A. and Chajęcka-Wierzchowska W. (2017): Prevalence, biofilm formation and virulence markers of Salmonella sp. and Yersinia enterocolitica in food of animal origin in Poland. LWT, 75: 552-556.

Zaki, M.E.; ElKheir, N.A. and Mofreh, M. (2018): Molecular study of colistin resistant clinical isolates of Enterobacteriaceae species. Journal of Clinical and Molecular Medicine, 1(1): 1–4

النهج البروبيوتيكي للإشريكية القولونية في منتجات اللحوم والدواجن: الانتشار، المقاومة، والضراوة

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تم التخطيط لهذه الدراسة لاستكشاف انتشار الكوليفورم والإشريكية القولونية الممرضة في منتجات اللحوم البقرية والدواجن المبردة المباعة في الأسواق المحلية ولدى البائعين في مدينة قنا، مصر، ثم تقييم فعالية بعض بكتيريا حمض اللاكتيك (LAB) ضد السلالات الممرضة المعزولة. تم فحص ٣٢٠ عينة تشمل منتجات اللحوم البقرية والدواجن المبردة. تم استخدام طرق تفاعل انزيم البلمرة المتسلسل (PCR) والطرق التعريفية والسيرولوجية لتحديد الإشريكية القولونية. تم قياس الأنشطة المضادة للبكتيريا لبعض المستخلصات لبكتيريا حمض اللاكتيك باستخدام طريقة (liquid broth). أظهرت جميع العينات تلوثًا بالكوليفورم والكوليفورم البرازي. كانت نسبة ٧٢,٥٪ من اللحم البقري المفروم، ٦٢,٥٪ من السجق البقري، ٦٧,٥٪ من الكفتة البقري، ٦٠٪ من البرجر البقري، ٧٥٪ من البرجر الدجاج، ٨٠٪ من اكباد الدجاج، ٥٥٪ من الناجتس والأجنحة تحتوي على أعداد من الإشريكية القولونية تتجاوز القيمة القصوى المسموح بها. تم اكتشاف تنوع عالي من الأنماط الممرضة للإسهال، والتي تنتمي في الغالب إلى UPEC، ETEC، EPEC، وSTEC. كانت المجموعات المصلية O158، O142، O63، O119، O55، O169 وO124 هي الأكثر تكرارًا في سلالات الإشريكية القولونية. كانت الجينات hlyA وpapC الأكثر تكرارًا (٣٦,٢٪ و٢٤,٤٣٪ على التوالي) وتم اكتشاف جينات Mcr1 وqnrB بنسبة ٥,٤٣٪ و٥,٨٨٪ على التوالي بين عزلات الإشريكية القولونية من العينات المستكشفة. أظهرت عزلات الإشريكية القولونية مقاومة عالية للمضادات الحيوية مع ملفات مقاومة متنوعة. بالإضافة إلى ذلك، أنتجت العزلات المستكشفة أنماطًا مختلفة من الأغشية الحيوية. كانت مستخلصات CFS لبعض بكتيريا حمض اللاكتيك فعالة للغاية ضد الإشريكية القولونية، مما أدى إلى انخفاض كبير في CFU البكتيرية (إحدى عشرة مرتبة لوغاريتمية من القتل). تم عزل الإشريكية القولونية المنتجة لإنزيمات البيتا لاكتاماز واسعة الطيف بشكل كبير من اللحوم والحيوانات المنتجة للأغذية في مصر. بسبب سوء التنظيف والنظافة في مرافق معالجة الأغذية، تنتقل مسببات الأمراض من هذه الحيوانات إلى البشر من خلال الطعام بشكل أكثر تكرارًا مما هو عليه في البلدان المتقدمة. هذا الوضع مقلق بشكل خاص مع البكتيريا الحاملة لجينات mcr وqnr، حيث أن هذه البكتيريا مقاومة لكل من الكوليستين والكينولونات، مما قد يسبب التهابات بكتيرية شديدة مع خيارات علاج محدودة.