Assessment of metal organic framework as a new formulation for the treatment of main zoonotic foodborne pathogens

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Background
Foodborne diseases pose serious threats to the health of people. *Escherichia coli* is the most important foodborne pathogen of public health interest.
Objectives
To assess metal organic framework (MOF) nanoparticles with antimicrobial activity and incorporating the antibiotics onto MOFs for controlled release of antibiotics and also to solve the problem of antibiotic resistance, which is one of the most pressing issues in global public health.
Materials and methods
A total of 615 samples of animal and human origins were collected. Samples of poultry and poultry products (215), of meat and meat products (240), and of milk products (120), as well as stool samples from contact persons and food handlers (40) were collected from different localities in Cairo, Giza, and Qaluobya governorates during the period from October 2020 to September 2021. All samples were bacteriologically examined and morphologically characterized. The suspected isolates that have characteristics of *E. coli* species were identified to the serotype level. Antibiotic susceptibility testing of identified *E. coli* serotypes to the commonly used antibiotics in Egypt was carried out.
Results and conclusion
The results showed that the total percentage of *E. coli* spp. was 31.16%. *E. coli* spp. of 28, 35.7, 30, and 30% were isolated from sausage, beef, luncheon, and minced meat, respectively. *E. coli* spp. isolated from poultry liver, breast muscle, and wings were 35.33, 35.33, and 10%, respectively. The Karish cheese (55%) and yoghurt (35%) contained *E. coli* spp. Only 20% of human stool had *E. coli*. The total percentages of *E. coli* spp. in Cairo, Giza, and Qaluobya were 28.5, 39.33, and 36.66%, respectively. Serotypes identified from *E. coli spp*. were mainly O157 and non –O157 (O164, O26, O27, O53, O71, O95, O103, O111, O124, O125, O127, and O145). The isolated *E. coli* serotypes expressed high resistance to most of the used antibiotics (10/13, 76.9%) before adding nanoparticles. Three antibiotics showed the lowest resistance [imipenem (34.4%), cefotaxime (65.6%), and ceftriaxone (68.8%)] and after adding nanoparticles to the antibiotic discs, antibiotic resistance decreased to 29.5, 62.3, and 62.9%, respectively.
Conclusion
Regular epidemiological surveillance should be undertaken in monitoring the occurrence and distribution of *E coli spp*. Nanotechnology techniques can solve the problem of antibiotic resistance crisis in targeted organisms. Nanoparticles can penetrate the cell membrane of pathogenic microorganisms and interfere with important molecular pathways, formulating unique antimicrobial mechanisms. In combination with optimal antibiotics, nanoparticless have demonstrated synergy and may aid in limiting the global crisis of emerging bacterial resistance. MOF nanoparticles have antimicrobial activity, and incorporating the antibiotics onto MOFs to control the release of antibiotics helps to decrease the problem of antibiotic resistance.

Keywords:
public health, foodborne pathogens, antibiotic resistance, silver nanoparticles

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Introduction

Most pathogens that play a significant role in foodborne diseases are of animal origin [1]. Foodborne diseases pose a serious threat to the

health of people. The WHO estimates that foodborne illnesses affect 600 million people and cause 420 000 deaths globally [2]. A major problem in food hygiene is the fecal contamination of beef and chicken meat with *Enterobacteriaceae* such *Escherichia coli* [3]. Dairy, meat, poultry, and ready-to-eat products are mostly involved in multistate foodborne outbreaks according to the Foodborne Outbreak Online Database [4].

E. coli O157:H7 and other non-O157:H7 *E. coli* strains account for the most prevalent bacterial foodborne pathogens that frequently result in hospitalization [5]. Pathogenic *E. coli* is of significant public health concern, as it is associated with both outbreaks and sporadic cases of human gastrointestinal illness worldwide. Enterohemorrhagic *E. coli* can cause bloody diarrhea in humans, and few can cause hemolytic uremic syndrome [6]. More than 100 serotypes (based on the somatic antigen) of *E. coli* have been associated with human disease [7]. *E. coli* 0157:H7 is the predominant serotype implicated in foodborne infections worldwide and the cause of outbreaks in many countries [8]. However, several non-O157 *E. coli* types have also been associated with sporadic cases and outbreaks [7]. Moreover, in Europe, infections caused by non-O157 STEC strains (O164, O26, O27, O53, O71, O95, O103, O111, O124, O125, O127, and O145) are more common than those caused by O157:H7 strains [8].

Food handlers play a major role in ensuring food throughout the chain of producing, processing, storage, and preparation, and therefore, they need regular follow-up for current infection or carrier state. Mishandling and disregard for food hygiene measures by handlers may result in food contamination, which of course will have nondesirable attendant consequences [9,10].

The continued emergence of antibiotic resistance and especially multidrug resistance among foodborne pathogens may contribute to unsuccessful treatment outcomes, thereby increasing costs associated with foodborne diseases. Antibiotic resistance among *E. coli* strains has significantly increased owing to overuse of antibiotics in food-producing animals such as ruminants, which are the animal reservoir for pathogenic *E. coli* [11].

Antimicrobial effects of nanoparticles and contrasts nanoparticles with antibiotic role in the fight against pathogenic microorganisms were recognized. Future prospects revolve around developing new strategies and products to prevent, control, and treat microbial infections in humans and other animals, including viral infections seen in the current pandemic scenarios [12].

Metal organic framework (MOF) nanoparticles show several outstanding advantages, such as high surface area and porosity for high loading of therapeutic agents and facile modification of physical (e.g. pore size and shape) and chemical properties of MOFs through inorganic clusters and/or organic ligands. In addition, desired functional groups can be added onto the organic ligands by predesigning of the ligands or postsynthetic modification approaches. Other merits of MOFs include diffusion of substrates to interact with the incorporated molecules via the MOF's open windows and pore and moderate strength of coordination bonds, making MOFs biodegradable and well-defined structures beneficial for host–guest interaction studies. With these unique properties, MOFs have been considered as one of the best candidates for drug delivery and cancer therapy [13]. This study aimed to investigate the prevalence of *E. coli* spp. contamination in animal-origin products and human origin samples and the sensitivity and resistance of the isolates to different antibiotics with and without silver nanoparticles prepared by the MOF.

Materials and methods

Ethical approval

Ethical clearance to use human participants was obtained from the designated health facility (National Research Centre, Giza, Egypt) No 19/138. Written consent was obtained from each person on information of the use of samples. Samples from animals were collected upon the owners' approval after the purpose of the collection was verbally explained to them.

Collection of samples

A total of 615 samples were collected from different localities in Cairo, Giza, and Qaluobya governorates during the period from October 2020 to September 2021. Of 215 meat products purchased from retail markets and groceries, 50 samples of minced meat, 70 samples of beef luncheon, 75 samples of oriental sausages, and 20 samples of beef burger were included. Poultry products (n=240) purchased from retail markets and groceries included 30 sample from poultry muscle, 150 samples from chicken livers, and 60 samples from wings. Milk products (n=120) samples represented 60 samples of Karish cheese and 60 samples of yogurt samples were purchased from

markets and small-scale farms outlets (n=575). Human stool samples (n=40) were collected from people in contact and food handlers from different areas. All samples were collected in a sterile polyethylene bags', labeled and placed in an ice box, and immediately transferred to the laboratory for further examination.

Isolation of *Escherichia coli*

Overall, 25 g of each sample was taken, cut into small pieces, transferred to tubes containing 225 ml of tryptic soya broth (TSB, Oxoid, England), blended, and incubated at 37°C for 24 h. A loopful from each of the previously incubated enrichment broth tubes was streaked over eosin methylene blue agar (EMB, Oxoid, England) and sorbitol MacConkey agar plates and then incubated at 37°C for 24 h [14].

Biochemical identification of isolated *Escherichia coli*

Pure colonies of suspected *E. coli* were confirmed biochemically using GNB 12 A kit (Oxoid) for gram-negative bacilli.

Serotyping of *Escherichia coli*

The identified EC isolates were serotyped by slide agglutination test in the central laboratories of Ministry of Health and Population (Cairo, Egypt) using standard polyvalent and monovalent EC antisera according to Edwards and Ewing [15].

Determination of the antibiotic resistance of isolated organisms

E. coli serotypes were tested using disk diffusion method on Muller-Hinton agar plates (Oxoid) for susceptibility to 13 commonly used antibiotics (Oxoid). Four to five colonies of *E. coli* strains with similar morphology were transferred using a sterile loop wire to tube containing 5 ml of Mueller-Hinton broth and then incubated at 37°C for 18–24 h. The turbidity of incubated broth was then adjusted to match McFarland 0.5 barium sulfate standard tube [16]. Antibiotic discs used in this study included ciprofloxacin (CIP 10), tetracycline (TE 30), doxycycline (DO 30), azithromycin (AZM 15), amoxicillin/clavulanic acid (AMC 30), polymyxin B (PB300), streptomycin (S10), nalidixic acid (NA30), cefotaxime (CTX30), imipenem (IPM10), ceftriaxone (CRO30), levofloxacin (LEV5), and ampicillin (AM 10).

Preparation of NH_2-MIL-125

NH_2-MIL-125 was synthesized according to the literature [17], with some slight modifications: titanium isopropoxide (1 ml, 3.38 mmol) and 2-aminoterephthalic acid (1 g, 5.5 mmol) were dissolved in a mixture of dimethylformamide (DMF)/methanol (2 : 1 v/v) at room temperature. The obtained slurry was sealed and placed in an oven at 150°C for 20 h. Finally, a light-yellow product was obtained. The product was filtered off and washed with DMF to remove the unreacted organic ligand, and then washed again with methanol to exchange DMF.

Preparation of antibiotic/NH_2-MIL-125 formulation

Overall, 0.10 g of NH_2-MIL-125 was added to 50 ml of methanol. The mixture solution was ultrasonicated for 30 min and slowly added to the disc of antibiotics. The samples were dried under vacuum at 60°C for 12 h.

Sample characterization

Radiograph diffraction (XRD) patterns for NH_2-MIL-125 powder samples were obtained by using an X'Pert MPD Philips diffractometer with monochromated Cu K_α radiation. XRD scanning was performed at room temperature over the 2θ region of 3.5–80° at a rate of 2°/min (45 kV, 40 mA). EDS measurements were carried out on a scanning electron microscope (SEM) (Hitachi SU-70, JP) with a field emission gun. Fourier-transform infrared spectroscopy (FTIR, Mattson 5000) was carried out in the range of 4000–350 cm^{-1} in the transmission mode. The pellets were prepared by adding MOFs (1–2 mg) to KBr (200 mg). The mixture was then carefully mixed and pressed at a pressure of 10 kPa to form transparent pellets.

Statistical analysis

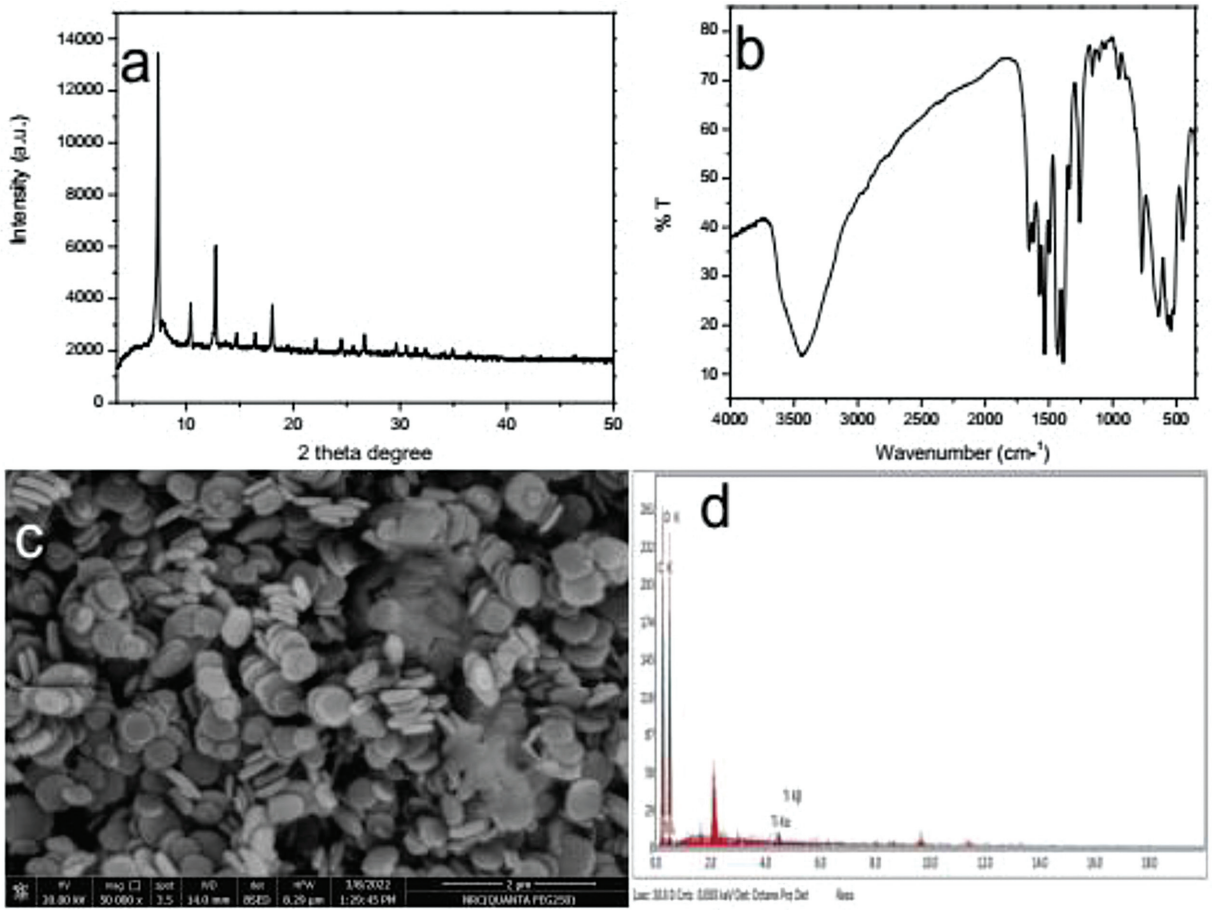
Data were analyzed using Statistical Program for the Social Sciences, IBM SPSS statistical software version 20.0 (2011) using simple one-way analysis of variance to determine the effect of the treatments on the studied parameters. Duncan's multiple range test was used to differentiate between significant means. The quantitative data were expressed as mean±SD. Nonparametric data were expressed as frequency and percentage. The statistical significance variance was considered significant when P value was less than 0.05.

Results

Characterizations of NH_2-MIL-125 nanoparticles

Crystal structure of MIL-125-NH_2 was determined using PXRD. NH_2-MIL-125 shows peaks at 6.7, 9.7, 11.6, 15.2, 16.6, 17.9, 19.5, 21.5, 22.6, and 25.3°, which were in good agreement with the simulated PXRD patterns of MIL-125 (Fig. 1a). The FTIR spectra of NH_2-MIL-125 show peaks at 1600 and

Figure 1



(a) PXRD of NH_2-MIL-125, (b) FTIR of NH_2-MIL-125, (c) SEM of NH_2-MIL-125, and (d) EDX of NH_2-MIL-125. SEM, scanning electron microscope.

1500 cm^{-1}, assigned to carbonyl asymmetric stretching vibrations, peaks at 1440 and 1400 cm^{-1} assigned to carbonyl symmetric stretching vibrations, and peaks at 1250 cm^{-1} belong to the C–H symmetric stretching vibrations of the benzene ring. The region of 400–800 cm^{-1} shows the Ti–O–Ti–O vibrations, and the bands at 3500 and 3380 cm^{-1} are due to the NH_2 group (Fig. 1b). The analysis for MIL-125-NH_2 with SEM was done (Fig. 1c). The shape of particles is tetragonal plates, and the average particle size is 500 nm. The elemental composition analysis (using EDX) of synthesized MOFs (Fig. 1d) indicates the presence of Ti, C, and O in the case of MIL-125-NH_2, indicating a good preparation of MIL-125-NH_2.

Characterizations of most effective formulation

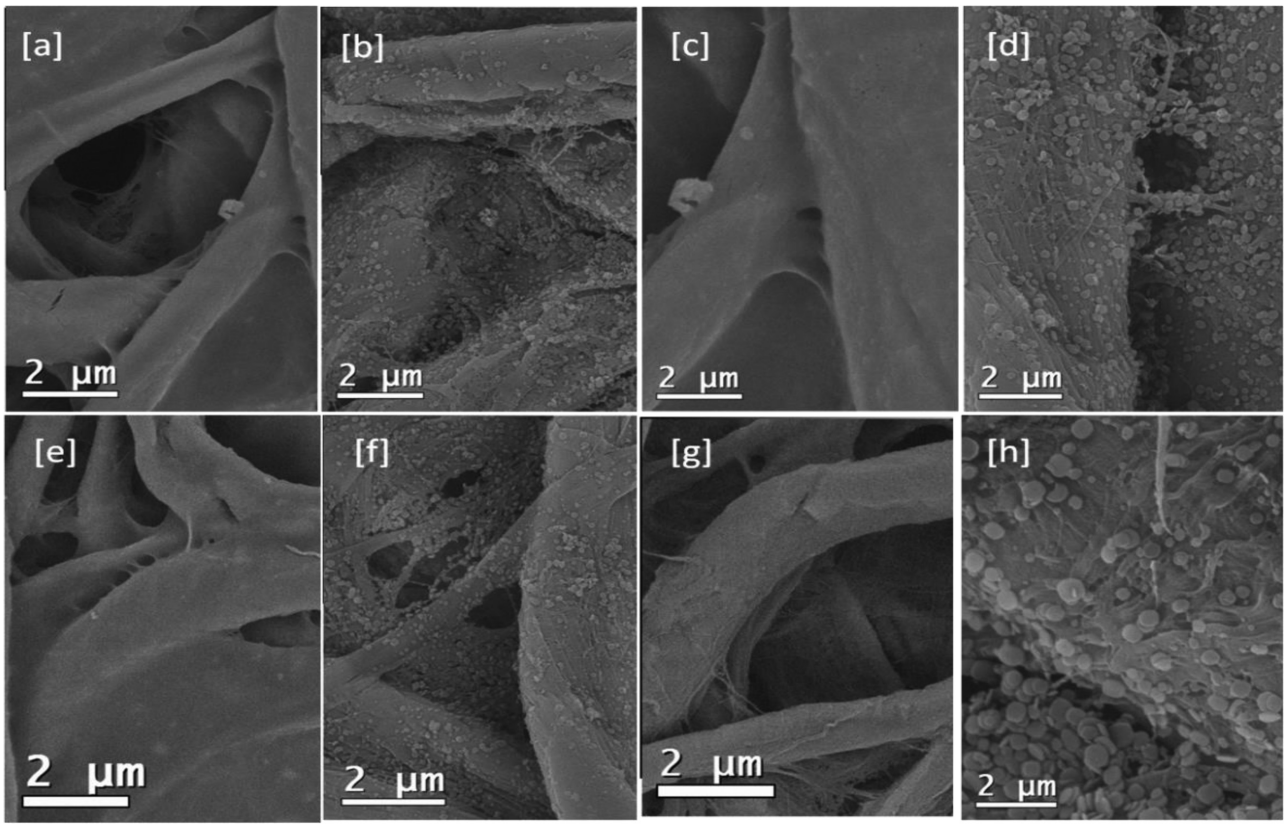
SEM was used to examine the surface of untreated and treated antibiotic disc. As shown, each sample has been scanned at the same magnification. The morphological structure of untreated antibiotic discs (Fig. 2a, c, e, g) revealed that the native antibiotic disc has smooth surface with no noticeable deposition of nanoparticles. On the contrary, the surface is changed up on treated with a solution of MOF particles. The surface of antibiotic discs that were impregnated with MOF particles (Fig. 2b, d, f, h) was rough owing to the deposition and incorporation of MOF particles. The shape and size of MOF particles in the treated antibiotic disc were spherical particles with very small size and distributed well.

Serotyping of *Escherichia coli* isolates

Results showed the existence of 14 *E. coli* serotypes in the processed meat products (20.9%; Table 1), 40 serotypes in milk byproducts (74.07%; Table 2), 19 serotypes in the poultry products (25.33%; Table 3), and 8 serotypes in human stool specimens (100%; Table 4).

From the samples of animal origin, Karish cheese showed the highest percentage of isolated *E. coli* serotypes (90.91%) followed by yoghurt (47.62%; Figs 3 and 4) and then chicken wings (33.33%) and breast muscles (31.25%; Fig. 5).

Figure 2



SEM of [a]ciprofloxacin, [b] MIL-125-NH_2 at ciprofloxacin, [c]amoxicillin clavulanic,. [d] MIL-125-NH_2 at amoxicillin clavulanic, [e]ampicillin, [f] MIL-125-NH_2 at ampicillin, [g] Levofloxacin, and [h] MIL-125-NH_2 at levofloxacin. SEM, scanning electron microscope.

Table 1 Serotypes of the isolated *Escherichia coli* following slide agglutination test in samples collected from processed meat products

Serotypes	Minced meat (*N*=15) [*n* (%)]	Beef-luncheon (*N*=25) [*n* (%)]	Beef burger (*N*=6) [*n* (%)]	Oriental sausage (*N*=21) [*n* (%)]	Total (*N*=67) [*n* (%)]
O157	0	0	0	2 (952)	2 (299)
O26	0	1 (400)	0	0	1 (149)
O27	0	1 (400)	1 (1667)	0	2 (299)
O53	0	0	0	0	0
O71	0	0	0	0	0
O95	0	0	0	0	0
O103	1 (667)	1 (400)	0	0	2 (299)
O111	0	1 (400)	0	0	1 (149)
O124	0	0	0	0	0
O125	1 (667)	1 (400)	0 (000)	0	2 (299)
O127	1 (667)	1 (400)	0 (000)	0	2 (299)
O145	0	0	0	0	0
O164	1 (667)	1 (400)	0	0 (1905)	2 (299)
Positive	4 (267)	7 (2800)	1 (1667)	2 (95)	14 (20 9)
Negative polyvalent	11 (733)	18 (7200)	5 (8333)	19 (905)	53 (79 1)

Antibiotic sensitivity test

Antibiotic sensitivity test of the pathogenic *E. coli* serotypes (Table 6) identified the resistance before and after applying nanoparticles. After adding nanoparticles, a marked reduction in drug resistance of *E. coli* isolates was observed against imipenem (14.8%), cefotaxime (25.9%), and ceftriaxone (29.6%; Fig. 7).

Table 2 Serotypes of the isolated *Escherichia coli* following slide agglutination test in milk byproducts

Serotypes	Milk products 54		*Escherichia coli* isolates total (*N*=54) [*n* (%)]
	Escherichia coli isolates from Karish (*N*=33) [*n* (%)]	Yoghurt (*N*=21) [*n* (%)]	
O157	0	0	0
O26	1 (303)	1 (476)	2 (370)
O27	0	0	0
O53	3 (909)	0	3 (556)
O71	0	0	0
O95	3 (909)	2 (952)	5 (926)
O103	0	0	0
O111	2 (606)	1 (476)	3 (556)
O124	6 (1818)	2 (952)	8 (1481)
O125	0	0	0
O127	7 (2121)	2 (952)	9 (1667)
O145	0	0	0
O164	8 (2424)	2 (952)	10 (1852)
Positive	30 (9091)	10 (4762)	40 (7407)
Negative polyvalent	3 (909)	11 (5238)	14 (2593)

Table 3 Serotypes of the isolated *Escherichia coli* following slide agglutination test from poultry products

Escherichia coli isolates	Liver (*N*=53) [*n* (%)]	Breast muscle (*N*=16) [*n* (%)]	Wings (*N*=6) [*n* (%)]	Total chicken parts (*N*=75) [*n* (%)]
O157	1 (189)	0	0	1 (133)
O26	1 (189)	1 (625)	0	2 (267)
O27	1 (189)	0	0	1 (133)
O53	0	0	0	0
O71	0	0	0	0
O95	0	0	0	0
O103	1 (189)	0	0	1 (133)
O111	0	0	0	0
O124	0	0	0	0
O125	2 (377)	0	1 (1667)	3 (400)
O127	2 (377)	1 (625)	0	3 (400)
O145	0	0	0	0
O164	4 (755)	3 (1875)	1 (1667)	8 (1067)
Positive	12 (2264)	5 (3125)	2 (3333)	19 (2533)
Negative polyvalent	42 (7736)	11 (6875)	4 (6667)	56 (7467)

Table 4 Serotypes of the isolated *Escherichia coli* following slide agglutination test in human stool specimens

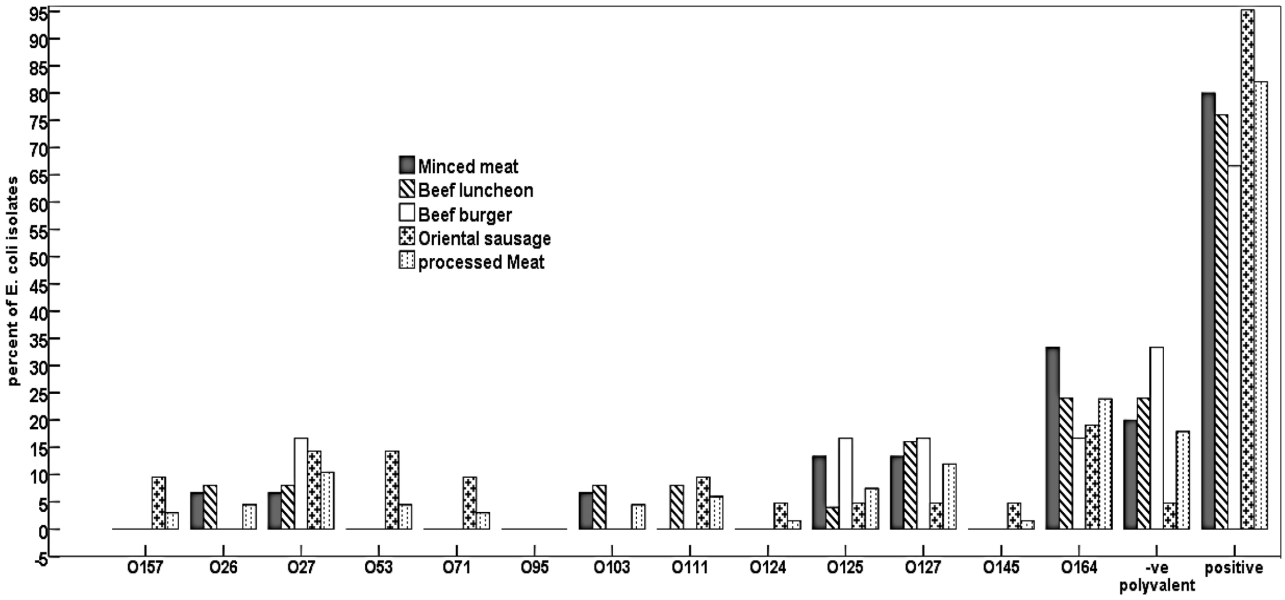
Escherichia coli isolates	Human stool (*N*=8) [*n* (%)]
O157	2 (25)
O26	0
O27	2 (25)
O53	0
O71	0
O95	0
O103	0
O111	0
O124	0
O125	1 (12.50)
O127	1 (12.50)
O145	0
O164	2 (25)
Positive	8 (100)
Negative polyvalent	0

Discussion

E. coli, a member of *Enterobacteriaceae* family, is the main inhabitant of human and animal guts. It has been accepted as the indicator microorganism for contamination with fecal and enteric pathogens [18]. Pathogenic *E. coli* represents a hazardous public health problem worldwide, causing various human gastrointestinal tract diseases, including watery or bloody diarrhea and might develop life-threatening diseases, such as hemorrhagic colitis, thrombotic thrombocytopenic purpura and hemolytic-uremic syndrome, and the latter is characterized by thrombocytopenia, microangiopathic hemolytic anemia, and acute renal failure [19].

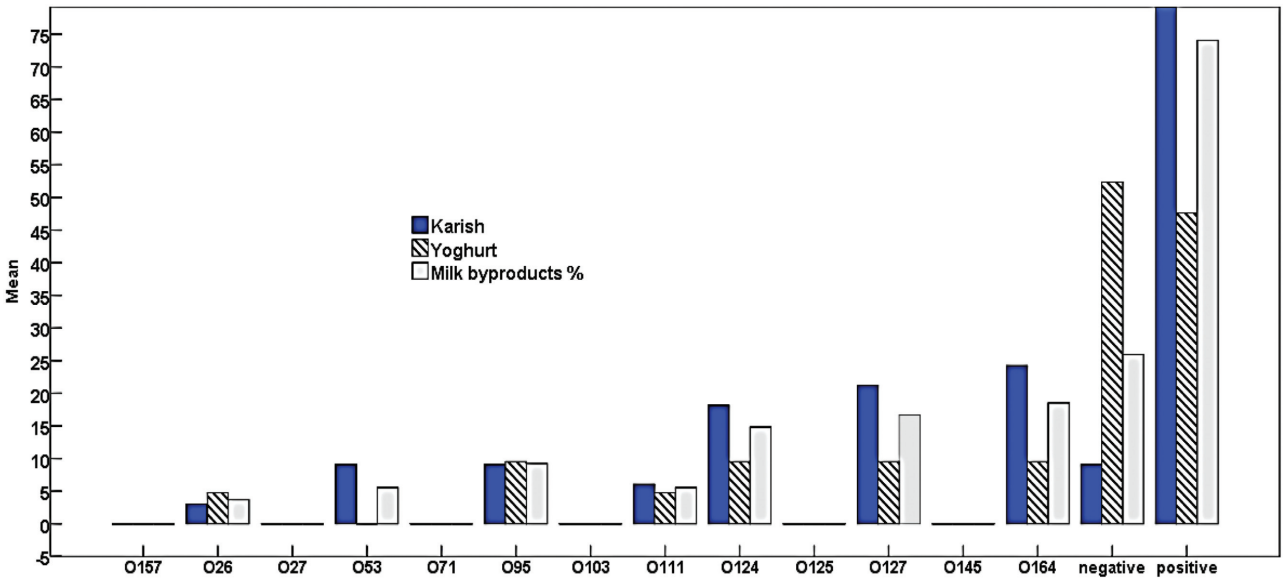
E. coli serotypes were recovered from 14 *E. coli* spp. isolated from 67 (20.9%) meat products, that is,

Figure 3



The percentage of different *Escherichia coli* serotypes isolated from different kind of processed meat items.

Figure 4



The percentage of different *Escherichia coli* serotypes isolated from milk products.

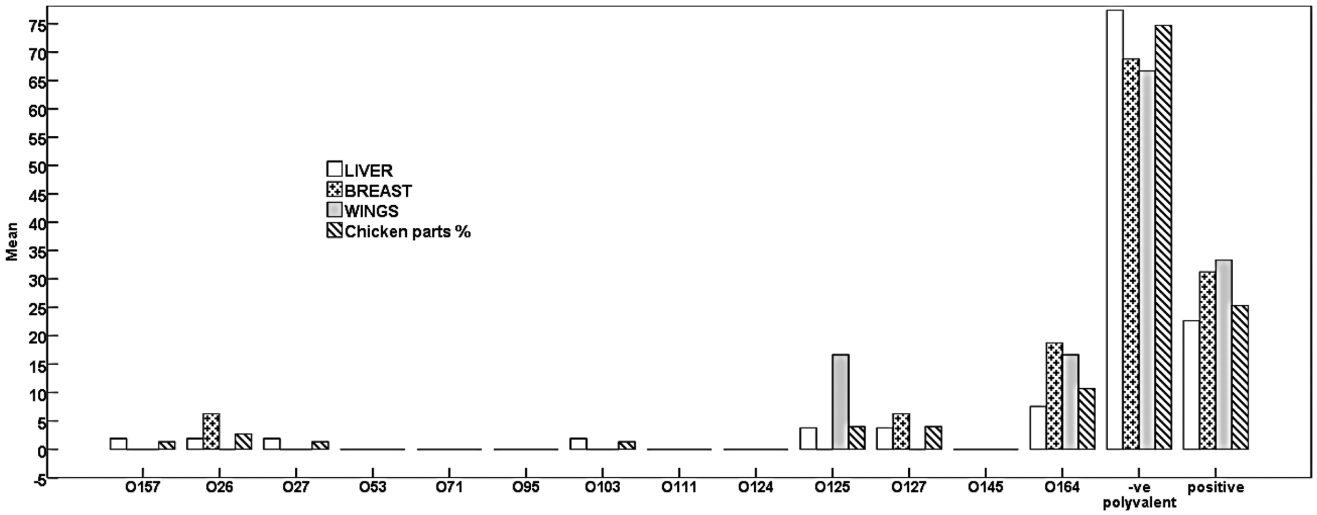
oriental sausage (9.5%), beef luncheon (28%), beef burger (16.67%) and minced meat (26.7%), with the highest percentage by beef luncheon (Table 1).

Regarding milk products, *E. coli* serotypes were isolated from 40 (74.07%) out of 54, with Karish cheese showing the highest percentage (90.92%; Table 2). In line with our results, *E. coli* (91.7%) was isolated from food products and human stool in Egypt [20]. One of the most popular Egyptian diets is cheese due to its high protein content, low fat, and price [21]. Karish cheese is usually made from raw milk and has been incriminated in foodborne outbreaks [22].

Moreover, *E. coli* spp. were isolated from 19 (25.33%) of 75 poultry samples, that is, liver (22.64%), breast muscle (31.25%), and wings (33.33%; Table 3).

Three major surface antigens [O (somatic), H (flagellar), and K (capsule) antigens] are used to serologically differentiate the *E. coli* isolates [18]. Shiga toxin-producing *E. coli* (STEC) strains are the

Figure 5



The percentage of different *Escherichia coli* serotypes isolated from different kinds of edible chicken items F.

Table 5 Antibiotic sensitivity test of the pathogenic *Escherichia coli* serotypes before and after applying nanoparticles

Strain	*Escherichia coli* spp.				*Escherichia coli* spp. NPs			
Antibiotic	R	S	T	R%	R	S	T	R%
Ciprofloxacin	67	14	81	82.7	61	20	81	75.3
Tetracycline	81	0	81	100	81	0	81	100
Doxycycline	72	9	81	88.9	70	11	81	86.4
Azithromycin	69	12	81	85.2	67	14	81	82.7
Ampicillin	77	4	81	95.06	75	16	81	92.6
Amoxicillin clavulanic	73	8	81	90.1	73	8	81	90.1
Polymyxin	75	6	81	92.5	73	8	81	90.1
Streptomycin	81	0	81	100	81	0	81	100
Nalidixic acid	81	0	81	100	81	0	81	100
Cefotaxime	32	49	81	39.5	21	60	81	25.9
Imipenem	19	62	81	23.5	12	69	81	14.8
Ceftriaxone	29	52	81	35.8	24	57	81	29.6
Levofloxacin	37	44	81	45.7	33	48	81	40.7

NP, nanoparticles; R, resistant; S, sensitivity; spp., species; T, total.

non-O157 strains (O26, O45, O103, O104, O111, O121, and O145) and O157: H7, being the most important serotype [23]. Although *E. coli* O157: H7 serogroup is responsible for most cases of STECs in humans, it is reported that non-O157 STEC strains are increasingly causing diseases [18,24]. The important serotypes that have been associated with human illness are O157 and non-O157 (O111, O26, O103, O113, O91, O117, O118, O121, O145, O128, and O146) [25]. Pathogenic infections are mainly foodborne; foods of high risk for transmission are poultry products, meat products, and dairy products [26]. In the present study, *E. coli* serotypes O157 and non-O157 (O164, O26. O27, O53, O71, O95, O103, O111, O124, O125, O127, O145) were isolated from examined meat, poultry, and milk products.

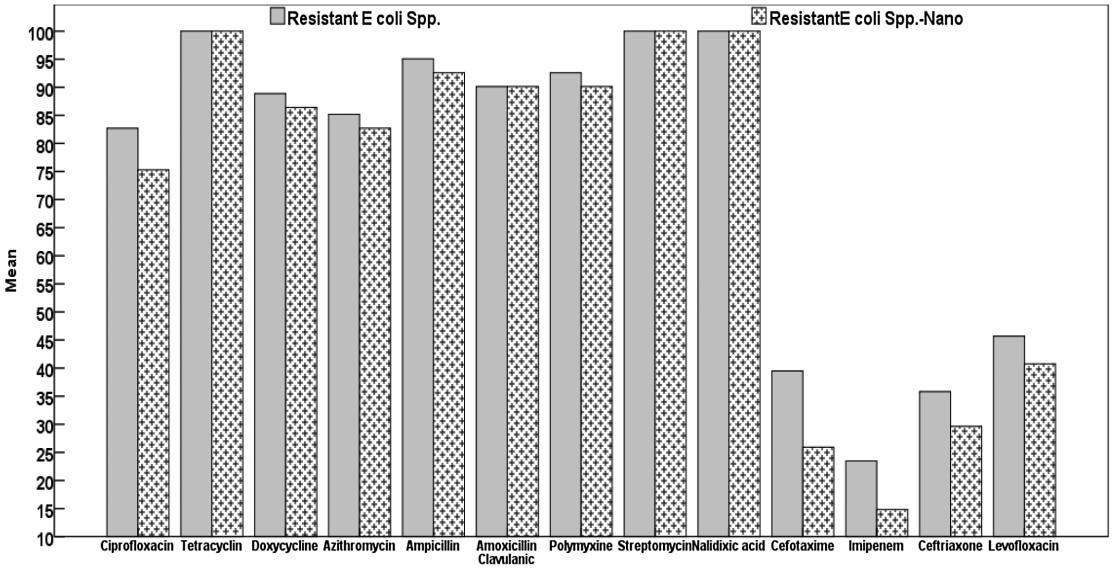
Our results indicated that the incidence of the pathogenic serotyped *E. coli* in examined samples of meat products was 26.7, 28, and 16.67% for minced meat, beef luncheon, and beef burger, respectively. Higher incidence of 46.67, 40, and 26.67% for beef kofta, burger, and luncheon, respectively, was obtained. However, *E. coli* failed to be detected in the examined samples of beef luncheon [27].

The current incidence of *E. coli* in the examined samples of beef burger (16.6%) was lower than those previously recorded (40 and 64%) [27,28] but is higher

than other reported incidences that ranged from 10 to less than or equal to 13.3% [29–31]. The incidence of *E. coli* in the examined samples of beef luncheon (28%) of the current research is low compared with 40% in the study by Abou Hussein and Reham [32], and much lower results ranging from 2.5 to 16% have been recorded [31,33–35]. Similar to the results obtained in the current study, samples of beef luncheon had a 26.67% *E. coli* prevalence in the study by Saad *et al.* [27].

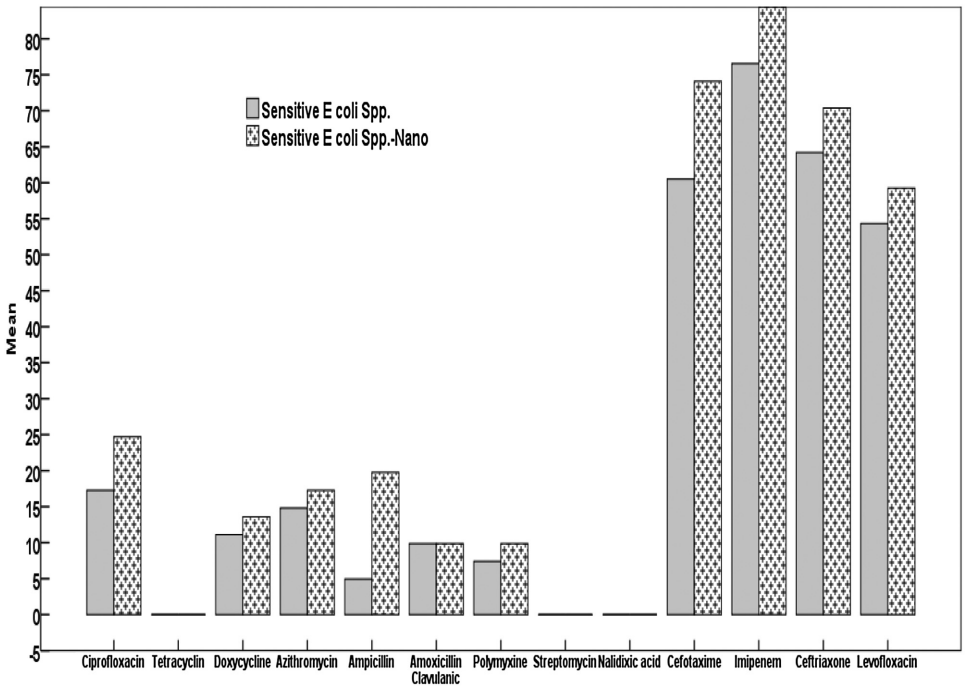
Biomedical applications of MOFs for drug delivery have attracted more attention. When the size of MOF particles was scaled down to nanoscale, these nano-MOFs can act as efficient nanocarriers to deliver agents for imaging, chemotherapy, photo-thermal therapy, or photodynamic therapy [36]. Antimicrobials, such as antibiotics, are essential to treat infections caused by bacteria, including foodborne pathogens. However, their overuse and misuse in veterinary and human

Figure 6



Antibiotic resistance of *Escherichia coli* to different antibiotics before and after adding nanoparticles.

Figure 7



Escherichia coli drug sensitivity before and after adding nanoparticles.

medicine has been linked to the emergence and spread of resistant bacteria, rendering the treatment of infectious diseases ineffective in animals and humans [37].

In the current work, the isolated 81 pathogenic *E. col* strains were subjected to antibiotic sensitivity test using 13 antibiotic discs: ciprofloxacin (CIP 10), tetracycline (TE 30), doxycycline (DO 30), azithromycin (AZM 15), amoxicillin/clavulanic acid (AMC 30), polymyxin B (PB300), streptomycin (S10), nalidixic acid (NA30), cefotaxime (CTX30), imipenem (IPM10), ceftriaxone (CRO30), levofloxacin (LEV5), and ampicillin (AM 10). The 81 isolated serotyped *E. coli* showed high antibiotic resistance to the used antibiotics as follow: tetracycline (100%), streptomycin (100%), nalidixic acid (100%), ampicillin (95.06%), azithromycin (85.2%), polymyxin B (92.5%), doxycycline (88.9%), amoxicillin/clavulanic acid (90.1%), ciprofloxacin (82.7%), levofloxacin (78.7%), ceftriaxone (68.8%), cefotaxime (39.5%), and imipenem (23.5%; Table 5).

After adding nanoparticles, marked degree of decrease in drug resistance occurred, especially with imipenem (14.8%), cefotaxime (25.9%), and ceftriaxone (29.6%; Figs 6 and 7).

Governments should make food safety a public health priority, as it plays a pivotal role in developing policies and regulatory frameworks and establishing and implementing effective food safety systems. Food handlers and consumers need to understand how to safely handle food while at home or when selling at restaurants or local markets.

Conclusion

E. coli is the common foodborne pathogen in raw milk and poultry products. Multidrug-resistant *E. coli* could be treated using mixed antibiotic and nanoparticles technology.

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Conflicts of interest

There are no conflicts of interest.

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