Scientific Research Publishing

Open Journal of Medical Microbiology, 2025, 15(2), 100-109
https://www.scirp.org/journal/ojmm
ISSN Online: 2165-3380
ISSN Print: 2165-3372

Molecular Characterization of Virulence Factors in *Escherichia coli* Isolated from Elderly Patients with Urinary Tract Infection

Eric Joël Tahou[1*], Foungotin Hamidou Coulibaly[1], Germain Droh[1], Ama Kra Inès Kouadio[1], Assanvo Simon-Pierre N'guetta[1], Nathalie Guessennd[2]

[1]Laboratory of Biotechnology, Agricultural and Valorization of Biological Resources, University Félix Houphouët Boigny, UFR Biosciences, Abidjan, Ivory Coast
[2]Institut Pasteur, Abidjan, Ivory Coast
Email: *tahoujojo@gmail.com

How to cite this paper: Tahou, E.J., Coulibaly, F.H., Droh, G., Kouadio, A.K.I., N'guetta, A.S.-P. and Guessennd, N. (2025) Molecular Characterization of Virulence Factors in *Escherichia coli* Isolated from Elderly Patients with Urinary Tract Infection. *Open Journal of Medical Microbiology*, **15**, 100-109.
https://doi.org/10.4236/ojmm.2025.152008

Received: February 11, 2025
Accepted: June 17, 2025
Published: June 20, 2025

Abstract

Introduction: Urinary tract infections (UTIs) in elderly patients represent a major clinical challenge due to their high frequency, their often atypical presentation, and the potential complications that can arise in this vulnerable population. **Objective:** The aim of this study was the molecular characterization of virulence factors in *Escherichia coli* isolated from UTI patients over 50 years of age. **Materials and Methods:** The methods used included phenotypic identification of 80 strains by conventional microbiological techniques, thus confirming their 100% identity. In addition, molecular characterization was performed by PCR to detect the fimH and hlyA virulence genes, while antibiotic susceptibility testing was carried out. The results show that 80% of strains come from outpatient clinics and 20% from urology departments. Moreover, 74% of patients were male, compared with 26% female. High rates of antibiotic resistance were observed: 73.75%, 81.5% and 78.75% respectively for amoxicillin/clavulanic acid, cefepime and ceftriaxone. Strains tested against ciprofloxacin showed a high resistance rate of 78.57%. With regard to virulence genes, 80% of strains had the fimH gene, but none had the hlyA gene. **Conclusion:** These results underline the importance of the fimH gene in urinary tract infections in the elderly, and suggest appropriate therapeutic management.

Keywords

Escherichia coli, Urinary Tract Infection, Virulence Factors, FimH, HlyA

1. Introduction

Urinary tract infections (UTIs) represent a major public health problem, particu-

larly in the elderly [1]. Indeed, these infections, among the most common, are characterized by the significant presence of bacteria in urine. Moreover, they occur in the urinary tract, whether in the mucosa of the urinary tract or in the renal parenchyma, and are systematically accompanied by leukocyturia. These infections rank 2nd among infectious pathologies after those of the respiratory tract, and their incidence is estimated at around 150 million cases per year worldwide [2]. As a result, these infections are a very frequent reason for consultation at general emergency departments [3], are responsible for over 7 million office visits each year and over 100,000 hospital admissions each year in the USA. Furthermore, the overall prevalence of urinary tract colonization in the general population is estimated at 3.5%, and increases linearly with age [4]. *E. coli* is the pathogen most frequently implicated in these infections [5]. This predominance is explained by the presence of specific virulence factors, such as fimbriae, toxins and secretion systems [6], which enable the bacteria to adhere to, invade and cause damage to urinary tract tissue [7]. However, although data from Africa are more limited, available studies indicate a high prevalence of UTIs accompanied by increasing antimicrobial resistance among pathogens [8]. In Ivory Coast, urinary tract infections are recurrent in hospitals. According to a study carried out at the pediatric nephrology unit of the Centre Hospitalier Universitaire (CHU) de Yopougon, nephrotic syndrome in children accounts for 25% of consultation activity and 33% of hospital activity [9]. Later in 2014, Boni and colleagues, in their study aimed at determining the bacteriological profile of germs isolated in urinary tract infections in children, found that *Escherichia coli* was the most isolated bacterium (38%), followed by Klebsiella sp. with 24% [10]. A recent study by Gbegbe *et al.* [11] in Ivory Coast revealed that UTIs accounted for around 20% of urology consultations, with *E. coli* responsible for over 70% of cases. Consequently, patients aged 50 and over are particularly vulnerable to UTIs due to factors such as decreased immune function [12], frequent use of medical devices, and associated comorbidities. Against this background, the main aim of this study is to characterize the virulence factors of *E. coli* strains isolated from UTI patients aged 50 and over in Ivory Coast.

2. Materials and Methods

2.1. Bacterial Strain

The biological material for this study consisted of *Escherichia coli* strains isolated from ambulant UTI patients aged between 50 and 92 years. The material was collected at the Biological Resource Center of the Institut Pasteur de Ivory Coast (IPIC). A total of 80 bacterial strains of human origin were isolated from urine and urinary catheters of patients during 2022 at the IPCI's Clinical Bacteriology Department. All these strains were stored either in brain broth with added glycerol at −80˚C.

2.2. Confirming the Identity of Collected Strains

Revivification and isolation of collected strains

Bacterial strains preserved in preservation agar were revivified from heart-brain broth (BCC) and incubated at 37˚C for 24 hours. The broth was then streaked onto EMB agar. The seeded medium was incubated under the same conditions as before.

Re-identification of collected strains

After 24 hours of culture, colonies were selected for re-identification by determining biochemical characters using Le Minor's reduced rack.

2.3. Determination of Bacterial Susceptibility to Antibiotics

All strains were tested using the agar disk diffusion method, in accordance with the recommendations Antibiogram Committee of the French Society of Microbiology [13]. For the detection of resistance phenotypes, the antibiotics used were: amoxicillin-clavulanic acid (20/10 µg), ceftriaxone (30 µg), cefepime (30 µg), ertapenem (10 µg), aztreonam (30 µg), ciprofloxacin (5 µg), amikacin (30 µg), gentamicin (10 µg). The reference strain *E. coli* ATCC 25922 was used during antibiotic susceptibility testing as an internal control.

2.4. Detection of Virulence Genes: FimH and HlyA in the Strains Tested

DNA extraction from *Escherichia coli* and reference strains *E. coli* ATCC 29522 and *K. pneumoniae* ATCC 70603 was carried out using the alkaline lysis with phenolysis method. A conventional Polymerase Chain Reaction (PCR) was used to detect the virulence genes encoding type I fimbriae (FimH) and hemolysin (HlyA). Specific primer pairs were used to amplify genes (Table 1). PCR amplification was performed in a 30 µl volume using a thermal cycler (Perkin® Elmer Gen Amp Lapplied Biosystems 9700). Amplification conditions included an initial DNA denaturation step lasting 15 min at 95˚C. This step was followed by 35 amplification cycles comprising denaturation at 95˚C for 30 s, hybridization at 60˚C for 30 s, elongation at 72˚C for 1 min and a final elongation step at 72˚C for 10 min. The reaction medium consisted of 8 µl of DNA, primers at a volume of 1 µl, ultrapure water 4.7 µl and a master mix containing (Taq polymerase, dNTPs, 5X Buffer and magnesium) at a volume of 17.3 µl. Another DNA-free reaction mixture was used as a negative control. Amplified products were analyzed by electrophoresis on 1.5% agarose gel (Invitrogen) stained with ethidium bromide. Readings were taken on the ultra-violet plate (Gel doc).

Table 1. Primer list for virulence gene detection.

Genes	Primers	Sequence (5'-3')	Hybridization temperature	Size
fimH	fimH-f	TGCAGAACGGATAAGCCGTGG	60	508
	fimH-r	GCAGTCACCTGCCCTCCGGTA		
hlyA	hlyA-f	ACGATGTGGTTTATTCTGGA	60	328
	hlyA-r	CTTCACGTCACCATACATAT		

3. Results

3.1. Confirmation of the Identity of the *E. coli* Strains Collected

In the course of this study, 80 *E. coli* strains were collected over the period from January to December 2022. These strains came from the biological collection of the Institut Pasteur de Ivory Coast. Re-identification confirmed that these collected strains are all *E. coli*.

3.2. Distribution of *E. coli* Strains by Hospital Department

The *E. coli* strains collected came from urology and outpatient departments. Analysis of the distribution of strains collected according to hospital department revealed that 80% came from outpatient departments, compared with 20% from urology departments.

3.3. Gender Distribution of Infected Patients

The graphical distribution (Figure 1) showed a dominant prevalence of *E. coli* in males. Indeed, 74% of *E. coli*-infected patients were male, while 26% were female.

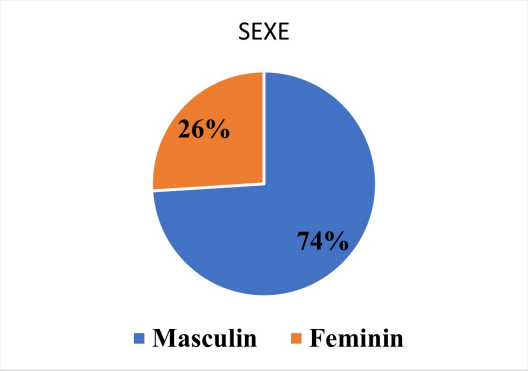

Figure 1. Distribution of *E. coli* strains by sex.

3.4. Antibiotic Resistance of *Escherichia coli* Strains

Resistance of Escherichia coli to beta-lactam antibiotics

The beta-lactam antibiotics tested on all strains showed different levels of resistance in the 80 strains tested. Antibiogram results revealed 73.75, 81.5 and 78.75% resistance to amoxicillin/clavulanic acid, cefepime and ceftriaxone respectively. These values indicate very high rates of resistance. In contrast, ertapenem has a much lower resistance rate of 6.25% (Table 2).

Escherichia coli resistance to aminoglycosides and fluoroquinolones

With regard to aminoglycosides, only gentamicin and amikacin were tested. Resistance rates were low, at 25 and 12.5% respectively. Strains tested against ciprofloxacin showed a high resistance rate of 78.57%.

4. Virulence Genes FimH and HylA

Analysis of the electrophoretic results showed that the FimH gene was detected

Table 2. Antibiotic resistance rates of the studied *E. coli* strains.

Antibiotic	Number of Strains	Number of resistant strains (R + I)	Resistance rate (%)
		β-lactams	
AMC	80	59	73.75
FEP	80	65	81.25
CRO	80	63	78.75
ERT	80	5	6.25
ATM	40	20	50.00
		Aminoglycosides	
GMN	80	20	25.00
AKN	80	10	12.50
		Fluoroquinolones	
CIP	70	55	78.57

R + I: Resistance + Intermediate. AMC: amoxicillin-clavulanic acid; FEP: Cefepime; CRO: ceftriaxone; ERT: Ertapenem; ATM: Aztreonam; GMN: Gentamicin; AKN: Amikacin; CIP: Ciprofloxacin.

in 64 of the 80 *E. coli* strains, *i.e.* a rate of 80%. Figure 2 shows the FimH bands corresponding to a size of 508 bp. On the other hand, no HlyA marker was found in any of the 80 strains tested.

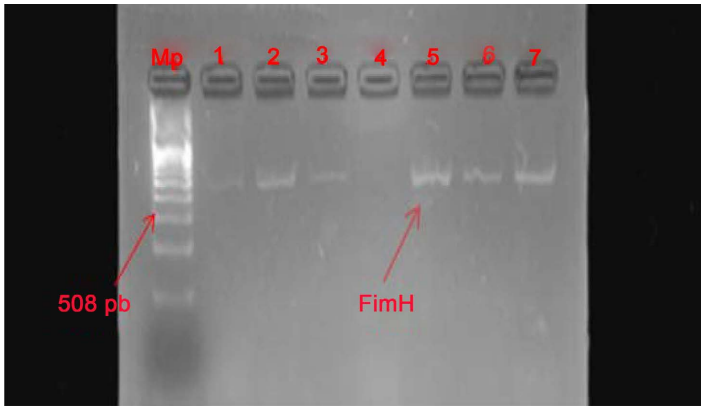

Figure 2. 1.5% agarose gel electrophoresis showing a simplex PCR for the detection of the fimH virulence gene. Lane M: Molecular weight marker; Lane 7: Positive control (508 bp); Lanes 1, 2, 3, 5, 6: Samples positive for fimH; Lane 4: Negative sample.

5. Discussion

Urinary tract infections (UTIs) in elderly patients represent a major clinical challenge due to their high frequency, often atypical presentation, and the potential complications that can arise in this vulnerable population. In this age group, the results obtained in this study show that of the 80 strains collected, 59% or 74%

were isolated from men and 21% or 26% from women, with a sex ratio of 2.8. This male predominance was reported by Foxman *et al.* [14]. This author showed a male predominance with a sex ratio of 2.7. Another study conducted by Doucouré *et al.* [15] at the University Hospital du Point G showed that 48 cases of urinary tract infections were diagnosed, representing a prevalence of prevalence of 4.30%. The sex ratio was 0.65 in favor of men (19/29). Indeed, this male predominance among elderly patients in our study is explained by the fact that male individuals have an increased risk of urinary tract infections due to prostate-related problems, such as benign prostatic hypertrophy or urinary retention, and the increased incidence of urinary catheterization. Nicolle *et al.* [16] have pointed out that in men over 50, urinary tract obstruction, incomplete bladder emptying, catheterization and chronic illnesses such as diabetes and heart failure are important risk factors. Furthermore, 80% of these strains came from outpatient clinics and 20% from the urology department, reflecting the tendency for the majority of urinary tract infections to be managed on an outpatient basis. This departmental distribution is also explained by another study [17], which reported that most cases of uncomplicated urinary tract infections in the elderly are treated in outpatient clinics, with a small proportion requiring referral to specialist departments, notably urology. On the other hand, patients with more severe or recurrent infections, such as pyelonephritis or prostatitis in men, are more likely to be referred to a specialist department such as urology [14]. This may explain why, in this study, 20% of strains came from this department. In addition, with regard to antibiotic resistance in the strains tested, our results reveal a worrying situation, particularly for betalactam antibiotics and fluoroquinolones, which are commonly used in the treatment of urinary tract infections in Ivory Coast [18]. High rates of resistance to betalactam antibiotics may be attributed to the production of extended-spectrum β-lactamases (ESBLs) by *E. coli*, which has been observed in several studies carried out in Ivory Coast.

For example, Daoudi [19] also highlighted increasing resistance to 3rd and 4th generation cephalosporins, notably ceftriaxone and cefepime, similar to the high rates observed in our study. This may be due to the frequent use of C3Gs in the treatment of bacterial infections, and to self-medication or overuse of antibiotics [20]. With regard to aminoglycosides, the low level of resistance to amikacin (12.5%) confirms the continued efficacy of this antibiotic, as reported in the work of Tahou and colleagues, who noted that amikacin remains a therapeutic option of choice against resistant urinary tract infections in several health centers in Ivory Coast [21]. The alarming rate of resistance to ciprofloxacin (78.57%) also reflects trends already observed in Ivory Coast, where this molecule is widely used to treat urinary tract infections. Indeed, excessive use of ciprofloxacin has contributed to a significant increase in resistance rates, necessitating a reassessment of treatment protocols [22]. This situation justifies the need to reinforce antibiotic stewardship, promote awareness among prescribers and consider appropriate therapeutic alternatives. In addition, the virulence of *E. coli* strains, as a major pathogen of uri-

nary tract infections (UTIs), expresses a variety of virulence genes that enable it to colonize the urinary tract, evade the host's immune defenses and cause infection [23]. These virulence genes include adhesion factors, toxins, enzymes and secretion systems, which vary between strains of uropathogenic *E. coli*. In elderly patients, the ability of *E. coli* to cause recurrent or severe urinary tract infections is often linked to the expression of these factors. Virulence genes common in *E. coli* are FimH: a gene coding for type 1 fimbrial adhesins, papG: coding for P fimbriae, involved in severe kidney infections, hlyA: this gene codes for hemolysin alpha, a toxin that destroys host cells, cnf1: coding for cytotoxic necrotizing factor 1 and iroN: a siderophore receptor enabling the bacterium to capture iron [24]. In this study, only the FimH and hlyA genes were analyzed, and the results showed that they were present in 80% of the strains tested. These results are similar to those obtained by Johnson *et al.* [25] in the USA, with a rate of 80%. Furthermore, another study showed that over 80% of isolated uropathogenic *E. coli* strains possessed the FimH gene [26]. This presence of the gene underlines its essential role in uroepithelial cell adhesion and urinary tract colonization. Furthermore, other research has confirmed the high prevalence of FimH in strains isolated in urinary tract infections, particularly in vulnerable populations such as the elderly and pregnant women, due to the ability of this gene to promote the establishment and persistence of infections [27]. For example, Russo and Johnson demonstrated that *E. coli* strains carrying FimH are more likely to cause recurrent infections, confirming that this virulence factor is crucial for persistent pathogenicity, particularly in elderly patients [28]. On the other hand, the complete absence of the hlyA gene in this study differs from some previous research. Yamamoto *et al.* [29] found that hlyA was present in around 30% of isolates from patients with complicated urinary tract infections. One study also reported a low prevalence of HlyA in *E. coli* strains responsible for uncomplicated UTIs [25]. This absence could be explained by genetic variability: the HlyA gene, coding for hemolysin A (a toxin), is present in some bacterial strains, but not in all. The study may have involved strains naturally lacking this gene. In elderly patients, urinary tract infections are often linked to physiological changes such as weakened immunity, changes in microbial flora and incomplete bladder emptying. These factors can favor the proliferation of less virulent but more opportunistic strains of *E. coli*.

6. Conclusion

This study revealed that elderly male patients were the most infected compared with females, with a sex ratio of 2.8. In terms of antibiotic resistance, the *E. coli* strains studied showed a high rate of resistance to third-generation cephalosporins, including 81.25% for cefepime and 78.75% for ceftriaxone. Most strains were resistant to fluoroquinolones, with a rate of 78.57% for ciprofloxacin. As for molecular characterization, 80% of the strains analyzed possessed the FimH gene. On the other hand, the HlyA gene, coding for a hemolysin, was totally absent in all

strains. These results underline the urgency of implementing effective antibiotic stewardship strategies, as well as ongoing resistance surveillance initiatives in Ivory Coast, as recommended in several public health reports.

Acknowledgements

We would like to thank the Observatory of microbial resistance to anti-infectives in Ivory Coast and the staff of the Institut Pasteur bio-bank for the collection of *E. coli* strains. This study also benefited from the technical support of the molecular biology platform of the Genetics laboratory and the Antibiotics, Natural Substances and Surveillance of Microorganism Resistance to Anti-Infectives unit of the Institut Pasteur of Ivory Coast.

Authors' Contributions

Design, planning and data acquisition were carried out by Tahou Eric Joël and Droh Germain. Analysis and interpretation of study results were carried out by Coulibaly Foungotin Hamidou and Kouadio Kra Ama Inès. All co-authors contributed to the content, revision and final editing of the manuscript, in particular N'guetta Assanvo Simon-Pierre and Guessennd Kouadio Nathalie.

Conflicts of Interest

The authors do not declare any conflict of interest.

References

[1] Essen, M.B. (2023) Urinary Infections in the Pharmacy: Current Situation and Outlook. Master's Thesis, University Clermont Auvergne.

[2] Bertholom, C. (2016) Épidémiologie des infections urinaires communautaires et nosocomiales. *Option/Bio*, **27**, 23-24. https://doi.org/10.1016/s0992-5945(16)30116-7

[3] Niska, R., Bhuiya, F. and Xu, J.M. (2010) National Hospital Ambulatory Medical Care Survey: 2007 Emergency Department Summary. *National Health Statistics Reports*, **6**, 1-31.

[4] Rakotovao-Ravahatra, Z.D., Randriatsarafara, F.M., Rasoanandrasana, S., Raverohanta, L. and Rakotovao, A.L. (2017) Resistant Phenotypes of *Escherichia coli* Strains Responsible for Urinary Tract Infection in the Laboratory of the University Hospital Joseph Raseta Befelatanana, Antananarivo. *Pan African Medical Journal*, **26**, Article 166. https://doi.org/10.11604/pamj.2017.26.166.11828

[5] Flores-Mireles, A.L., Walker, J.N., Caparon, M. and Hultgren, S.J. (2015) Urinary Tract Infections: Epidemiology, Mechanisms of Infection and Treatment Options. *Nature Reviews Microbiology*, **13**, 269-284. https://doi.org/10.1038/nrmicro3432

[6] Tenaillon, O., Skurnik, D., Picard, B. and Denamur, E. (2010) The Population Genetics of Commensal *Escherichia coli*. *Nature Reviews Microbiology*, **8**, 207-217. https://doi.org/10.1038/nrmicro2298

[7] Manges, A.R. and Geum, H. (2020) Population-Based Epidemiology and Microbiology of Urinary Tract Infections. *Infectious Disease Clinics*, **34**, 209-218.

[8] Ouedraogo, A.S., Jean Pierre, H., Bañuls, A.L., Ouédraogo, R. and Godreuil, S. (2017) Emergence and Spread of Antibiotic Resistance in West Africa: Contributing Factors

and Threat Assessment. *Médecine et Santé Tropicales*, **27**, 147-154. https://doi.org/10.1684/mst.2017.0678

[9] Amorissani, M.F., M'bengue, A.K., Dainguy, E., Faissal, N.A. and Houenou, Y. (2006) Neonatal Urinary Tract Infections: Clinical and Bacteriological Profiles. *International Journal of Medical Sciences*, **8**, 45-49.

[10] Boni, C., Zaba, F., Meite, S., Mlan, A., Adonis-Koffi, L., Guessennd, N., Faye, K.H. and Dosso, M. (2014) Bacteriological Profile of Urinary Tract Infections in Pediatrics. *Journal of Pharmaceutical and Biological Sciences*, **15**, 34-41.

[11] Gbegbe, D.A., N'zi, N.P., Monthaut, S., Alle, A.P. and Angaman, D.M. (2023) Study on the Prevalence and Microbial Ecology of Tract Infections Urine at the Daloa CHR, Côte d'Ivoire. *Journal of Applied Biosciences*, **192**, 20319-20330.

[12] Smith, C.A. and Jones, B.T. (2018) Immune Function and Its Impact on Susceptibility to Infections in Elderly Populations. *Journal of Clinical Immunology*, **35**, 123-130.

[13] EUCAST-CASFM: Antibiogram Committee of the French Society of Microbiology (2023). https://www.sfmmicrobiolo-gie.org/wpcontent/uploads/2023/06/CASFM2023_V1.0.pdf

[14] Foxman, B. (2014) Urinary Tract Infection Syndromes: Onset, Recurrence, Bacteriology, Risk Factors and Burden of Disease. *Infectious Disease Clinics of North America*, **28**, 1-13. https://doi.org/10.1016/j.idc.2013.09.003

[15] Doucouré, D., Kéita, B.S., Kéita, M.S., Goita, D., Traoré, M., Konaté, I., Samaké, M., Dembélé, M., Doumbia, Y., Diarra, S., Magassouba, O., Sogoba, D., Samaké, M. and Dao, S. (2020) Bacterial Urinary Tract Infections in PLWHA: A Transversal Study at the Infectious Diseases Department of CHU Point G. *Health Sciences and Disease*, **21**, 56-61.

[16] Nicolle, L.E. (2014) Urinary Tract Infection in Older Adults. *Clinical Geriatric Medicine*, **30**, 713-724.

[17] Laupland, K.B., Ross, T., Pitout, J.D.D., Church, D.L. and Gregson, D.B. (2007) Community-onset Urinary Tract Infections: A Population-Based Assessment. *Infection*, **35**, 150-153. https://doi.org/10.1007/s15010-007-6180-2

[18] Coulibaly, T. (2021) Antibiotic Sensitivity of Bacteria Isolated from Urine at the Nianakoro Fomba Hospital in Segou. Ph.D. in Pharmacy at the University of Sciences, Techniques and Technologies of Bamako, p. 78.

[19] Daoudi, I. (2014) Study of the Antibiotic Resistance of Bacterial Strains Causing Urinary Tract Infections at Ouargla EPH. Ph.D. Thesis, Kasdi Merbah University.

[20] Rubin, M.A. and Samore, M.H. (2002) Antimicrobial Use and Resistance. *Current Infectious Disease Reports*, **4**, 491-497. https://doi.org/10.1007/s11908-002-0034-y

[21] Tahou, E.J., Guessennd, K.N., Konan, F., Gba, K.M.K., Makaya, N., Gbonon, V., Ouattara, M.B. and N'Guetta, A.S.P. (2017) Klebsiella Pneumoniae Multi-Resistant to Antibiotics, Involved in Bacterial Infections in Patients Hospitalized in Abidjan (Ivory Coast). *International Journal of Advanced Scientific Research*, **6**, 9-12.

[22] N'guessan, B. (2023) Analysis of the Resistance Profile of Bacteria Isolated from Urinary Tract Infections in Abidjan. Review on Urinary Tract Infections and Antimicrobial Resistance in Ivory Coast. *African Journal of Microbiology Research*, **2**, 985-1011.

[23] Farfan, A.B.P., Llimpe, Y.M.B., Yarihuamán, M.M.M., Fortunato, M.P.L., Paredes, M.B.P., Santos, J.C.C. and Heli, J.B.P. (2025) Phylogenetic Analysis of *Escherichia coli* According to Phenotypic Resistance in Urinary Tract Infections in Children, Lima, Peru. *Infection & Chemotherapy*, **57**, 93-101.

https://doi.org/10.3947/ic.2024.0101

[24] Phan, M., Thomas, R. and Heine, K. (2011) Social Media and Luxury Brand Management: The Case of Burberry. *Journal of Global Fashion Marketing*, **2**, 213-222. https://doi.org/10.1080/20932685.2011.10593099

[25] Johnson, J.R. and Russo, T.A. (2005) Molecular Epidemiology of Extraintestinal Pathogenic (Uropathogenic) *Escherichia coli*. *International Journal of Medical Microbiology*, **295**, 383-404. https://doi.org/10.1016/j.ijmm.2005.07.005

[26] Wiles, T.J., Kulesus, R.R. and Mulvey, M.A. (2008) Origins and Virulence Mechanisms of Uropathogenic *Escherichia coli*. *Experimental and Molecular Pathology*, **85**, 11-19. https://doi.org/10.1016/j.yexmp.2008.03.007

[27] Wurpel, D.J., Beatson, S.A., Totsika, M., Petty, N.K. and Schembri, M.A. (2013) Chaperone-Usher Fimbriae of *Escherichia coli*. *PLOS ONE*, **8**, e52835. https://doi.org/10.1371/journal.pone.0052835

[28] Russo, T.A. and Johnson, J.R. (2000) Proposal for a New Inclusive Designation for Extraintestinal Pathogenic Isolates of *Escherichia coli:* ExPEC. *The Journal of Infectious Diseases*, **181**, 1753-1754. https://doi.org/10.1086/315418

[29] Yamamoto, S., Terai, A., Yuri, K., Kurazono, H., Takeda, Y. and Yoshida, O. (1995) Detection of Urovirulence Factors in *Escherichia coli* by Multiplex Polymerase Chain Reaction. *FEMS Immunology & Medical Microbiology*, **12**, 85-90. https://doi.org/10.1111/j.1574-695x.1995.tb00179.x