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Determination the Effects of Laser Radiation on Adhesion and Biofilm Formation of Some Gram-negative Bacteria in Al-Diwaniyah and Babylon Slaughterhouse

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Abstract This study was conducted to understand the effect of laser radiation on *E. coli* and *Klebsiella pneumoniae* bacteria found on the walls, floors, knives, and equipment of slaughterhouses. The current study involved collecting 160 clinical samples from slaughterhouses in Al-Diwaniyah and Babylon Governorates, Iraq.To ascertain how laser treatment affects bacterial adherence and biofilm formation, *K. pneumoniae and E. coli.*

The outcomes for *E. coli* and *k. pneumoniae* showed that laser irradiation affected the production of biofilms and bacterial adhesion, especially when the total number of hits rose. The impact was greatest at 10 hits with 300jw energy. Overall, the findings demonstrated that lasers had reduced the bacterial biofilm and adhesion formation.

Keywords: Laser, adhesion, biofilm, slaughterhouse.

Introduction Animals are murdered in slaughterhouses to satisfy the need for meat for consumption by humans. Animal byproducts make up the majority of wastes. Slaughterhouse waste contributes to the pollution as the population grows. Many operations, including keeping the animal, killing it, cleaning the corpse, dressing it, and getting rid of and cleaning the stomach, internal organs, unsuitable for eating meat and fats, waste products, includes blood, etc., result in a huge volume of solid and liquid waste. Based on the amount of waste they generate, slaughterhouses and packinghouses (slaughtering and meat handling) can be categorized into two classes (1). Types of slaughterhouses simple abattoir: Only a tiny amount of the animals' wastes is dealt with at this facility after they are killed (1) and Complex slaughterhouse kills animals and thoroughly processes their waste. Rendering, managing paunch and internal organs, processing blood, and processing hide and hair are all common procedures. Abattoir waste management is a significant issue on a global scale, and legislation pertaining to its treatment is currently patchy. The dangers to human and animal health from infections and environmental deterioration, including the potential for surface and groundwater pollution, are increased when abattoir waste is disposed of directly. Like other wastes like plastic, aquatic vegetation, and municipal trash, it also clogs the drainage system (2).

Any animal that produces meat must be killed by removing its meat from two contaminating surfaces: the hide and the digestive system. It is unavoidable that part of the meat will become contaminated with microorganisms, some of which might cause food-borne diseases in people, regardless of how thoroughly this process is carried out. Therefore, minimizing bacterial contamination of the carcasses and eliminating any existing contamination are the slaughter industry's main objectives for food safety (3). Meat, an important component in daily meals, has a number of health benefits (4).

Because of their high protein, water, fat, mineral, and Due to their vitamin content, all varieties of meat are classified as decomposable foods. This rendered it susceptible to internal enzymatic activity, increasing its vulnerability to oxidation and bacterial invasion (5). Meat serves as an ideal substrate for bacterial growth and reproduction due to its requisite growing factors: neutral pH, elevated moisture content, and mineral constituents. Bacteria R.K. may infect meat and meat products during slaughtering and processing, as well as from blades, air, personnel, carts, containers, and equipment in general. Pathogenic and spoilage microorganisms are the two principal categories of bacteria. Although no health hazards are identified with decaying bacteria, their existence may lead to a deterioration in food quality and freshness (6). The two predominant foodborne

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pathogenic bacteria responsible for bacterial illnesses in humans are *E.coli* and *Klebsiella spp.* (7).Red meat contains Klebsiella and E. Coli. Meat must be handled, stored, and consumed with prudence because it spoils easily and can get infected with dangerous bacteria and toxins produced by bacteria that humans may contract by eating it under certain conditions (8). A laser is a machine that uses optical amplifiers that rely on stimulated release of electromagnetic energy to produce light. Originally, the term "laser" meant light amplification by stimulating the release of light (9).

The applications like lithography, because the coherent light emitted by a laser's beam sets it apart from other types of light. It is also utilized in lidar, laser pointers, and free-space optical communications because it enables a laser beam to remain narrow over long distances (collimation). Additionally, lasers may produce light with a very narrow frequency spectrum due to their great temporal coherence. Ultrashort bursts of broad-spectrum light, which can last as few as one attosecond, can also be produced using this temporal coherence (10,11). Fiber-optic and free-space communication through optical fibers, optical disc drives, laser printers, barcode scanners, manufacturing of semiconductors (photolithography and etching), laser treatment, skin therapy, cutting and welding materials, target marking tools for the military and legal system, speed and range determination, and entertainment laser lighting displays are just a few of the many uses for lasers (12,13).

A gain medium, an energizing mechanism, and an optical feedback mechanism make up a laser. Anthony *E. Siegman*. (1986) A material known as the gain medium is defined by its capacity to intensify light via stimulated emission. When a specific wavelength of radiation passes through the gain medium, it is amplified, which raises the power. The optical frequency that corresponds to the tip of the gain-frequency curve is amplified as a result of feedback facilitating stimulated emission. A coherent beam will arise as a result of one frequency eventually dominating all others as stimulated emission rises (14).

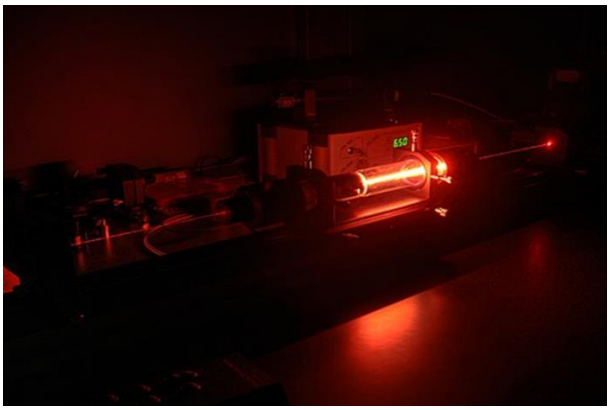

Figure (1): Typical laser components

Escherichia coli or *E.coli* On MacConkey medium, *E. coli* is pink, rod-shaped, and gram-negative. The Enterobacteriaceae family includes *E. coli*. A Gram-negative rod known as Bacteria coli commune is frequently found in the flora of healthy people's digestive tracts, according to research done in 1885 by German physician Theodor Escherich. Later, these rods were dubbed Escherichia coli in his memory. A few decades later, in 1935, they were first identified as pathogens after being connected to a severe episode of gastroenteritis known as "cholera infantum," which primarily affected infants (15). Numerous studies have been conducted on *E. coli*, describing it from a range of perspectives, including molecular, genetic, antibiotic resistance, and serological analysis. In his honor, the scientific name Escherichia coli was later applied to these rods. A few decades later, in 1935, they were first identified as pathogens after being connected to a severe gastroenteritis outbreak known as "*cholera infantum*," which primarily afflicted newborns (15).

As a result, it is today regarded as one of the best-characterized bacteria. Many elements of this bacteria remain unknown, despite the fact that it continues to cause devastating illnesses such meningitis, pneumonia, diarrhea, wound infections, septic shock, and urinary tract infections in both healthy and immunodeficient people (16).

The *Klebsiella pneumonaie* It was discovered in 1834 by the German microbiologist Edwin Klebs, who also gave it its present name. Except for *Klebsiella mobilis*, Fried Landers was the first to discover *Bacillus klebsii,* commonly known as the Fried Landers bacteria. Some strains produce a bactericidal chemical known as klebcin, and it is non-sporulating (17). The entire cell surface of gram-negative bacteria is covered in a polysaccharide shell. Because of their relatively thick shell, the colonies seem mucoid and shimmering when seen on agar

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plates. The enteric and extraintestinal pathotypes of *E. coli* isolates have similar virulence factors and tactics (18). In addition, the Biofilm in their natural environments, bacteria commonly grow and self-organize into multicellular structures called biofilms (19). Biofilms form when bacteria attach onto a solid surface and divide while embedding themselves in a matrix of extracellular polymeric substances (EPS) (20).

Numerous every day, medical, and industrial environments include biofilms, which can contaminate tools and endanger human life. Bacteria may exist in a static 'biofilm' form, where cells exchange resources and offer protection from adverse conditions, or in a movable, 'planktonic' state, where they spread out freely in pursuit of nutrients (21). The way that each species reacts to specific environmental conditions determines the elements that lead bacteria to change from a moving form to a biofilm lifestyle. These elements include the generation of certain chemical signals, the availability of nutrients, and cellular traits including microbial concentration, growth rate, and diffusing behavior (22).

Moreover, Adhesion the first stage of colonizing and biofilm formation is known as microbial adhesion, and it is defined by the accumulation of bacteria and extracellular materials on a solid basis. Biofilms have the potential to endanger both industrial processes and human health by causing infections connected to medical implants (23) pathogen-host cell interaction (24, 25) periodontitis or dental caries, food contamination from processing equipment 26, 27), increased metal corrosion (28), marine biofilms on ship hulls (29), and more. On the other hand, microbial adhesion can be advantageous, such including the degradation of ecologically toxic compounds in sand (30), bioreactors for wastewater treatment (31) or off-gas treatments, as well as the agricultural applications of root nodules as microbes in the rhizosphere (32).

Materials and Methods

Ethical approval

The project was approved (226 in 15/1/2025) by the Committee for Research Ethics at the College of Veterinary Medicine, University of Al-Qadisiyah, Iraq.

Techniques

A sample is taken from the slaughterhouse and cultured in a culture medium and LB broth. Then, it is incubated at 37°C for 16 to 18 hours. After colonies appear, they are cultured in sub-plates, after which biochemical tests are performed.

Biochemical tests for identification of bacterial isolates

Oxidase test

The test had been conducted by spreading a colony of the organism on a filter paper, followed by the addition of drops of the oxidase reagent. A color change from colorless to purple had indicated a positive oxidase test within 10 seconds.

MacConkey agar test

MacConkey agar is a kind of selective medium that is used for the purpose of isolating gram-negative enteric bacteria and differentiating between strains that are capable of lactose fermenting and non-lactose fermenting strains. The bacterial culture was started by streaking it onto MacConkey agar plates and then incubating it at 37°C for 24 hours to promote growth (33).

Chromogenic Test

Use to detect the E.cli and K.pneumoniae, Brilliance ESBL agar (Oxoid; Thermo Fisher Scientific, UK) is a selective and differential chromogenic agar for the detection of ESBL-producing organisms. Brilliance ESBL agar contains two chromogens that are targeted by specific enzymes: glucuronidase and ß-galactosidase. The presence of glucuronidase and ß-galactosidase enzymes in E. coli results in a blue colony; however, ßgalactosidase negative E. coli will produce a pink colony. K. neumoniae produces ß-galactosidase, resulting in green colonies. Using the microtiter plate method for biofilm assay:

The assay was performed for 20 isolates based to a method performed by Piechota et al., 2018 with little modification. freshly pure colonies from each isolate was put on Luria Bertani broth supplemented with dextrose 0.5% and incubated at 37°C for 24 hours without shaking. After the incubation procedure an inoculum of bacterial cell suspension (by dilution with sterile Luria Bertani broth) was ready to be matched with 0.5 McFarland standard that equivalent to 108CFU/ml. Then 200 µl of the suspension of each isolate was passed on into wells of 96-well flat-bottom polystyrene plate and incubated without shaking at 37°C for 24 hours, after the second incubation, the excessive medium was eliminated and washed 2 times with 200 µl of sterile PBS (pH 7.4) to eliminate non-attached bacterial cells, the following step was fixation of biofilm by heat, the plate was retained in oven at 60°C for one hour, then stained with 200 µl of crystal violate 1% for 5 minutes. after this, the plate was washed with PBS and air-dried for one hour. Colorant was solved in 96% ethanol and absorption was measured by microplate reader at 490 nm (BioTeck, USA), each test was conducted in duplicate to calculate the average results. Sterile LB broth was used as a negative control. The following

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formula was used to determine the rate of biofilm formation:

The formula is BR = AT - ANC, where BR is the biofilm result, AT is the tested strain's absorbance as measured at OD490 nm, and AC is the OD490 nm of the negative control wells that contained only plain broth. A biofilm formation absorbance value of ≥0.12 was deemed positive, as were weak biofilm producers at <0.2, moderate producers at 0.2-0.4, and strong producers at >0.4 (34).

Results and discussion

The current study included the collection of 160 clinical specimens in Al-Diwaniyah and Babil Sluaghterhouses during the period from October 2024 to April 2025, *E. coli and K. pneumoniae* bacteria were determined as having the highest ratio in the aerobic microbial culture.Cleanliness, residential location of Sluaghterhouses, and the use of certain chemical disinfectant are the primary causes of the variation in isolation rates. *K. pneumoniae* may have spread as a result of the isolation time (35). The unique morphological traits of the K. pneumoniae and E. coli isolates allowed for their identification. The strain of *E. coli* produced pink colonies when grown on MacConkey agar. Furthermore, characteristics of the bacteria, such as the structure and content of the cell wall, have a significant impact on the disinfection efficacy. For instance, compared to Gram-positive bacteria, which had thicker peptidoglycan layers, Gram-negative bacteria had extremely thin peptidoglycan cell walls. Gram-positive bacteria have so demonstrated greater resistance to physical and chemical stresses (36).

Laser effect on *E. coli* biofilm:

After completing the collection of samples from the slaughterhouses of Diwaniyah and Babylon and isolating and identifying some Gram negative bacteria, it appeared that the highest percentage were Escherichia coli and *Klebsiella pneumoniae*.The procedure of forming biofilms for both Escherichia coli and *Klebsiella pneumoniae* was completed to prepare them for treatment with laser rays. Under a known number of hits, known energy, and fixed frequency, the isolates were divided into three groups based on laser energy, number of hit, and frequency. Then were treated with laser. After treatment, a large difference in the results was found, as the effect of laser rays on the biofilms of *E. coli* and *Klebsiella pneumoniae*. (In the same way as before in the case of adhesion).

The obtained results showed that the bacterial biofilm formation was significantly P<0.05 affected by laser treatment, this effect was increased by the energy and the number of hits, the highest effect was at 10 hits in 300jw energy (0.03650), while the minimum effect was at 1 hits in 100 jw energy (0.0005000) with Mean (0.01134) and Standard Deviation (0.009029) and Standard Error (0.002071) As shown in Table (1,2)

Table (1) OD_{490} values of cultured *Escherichia coli*

Escherichia coli			
N0	**Sample ID**	**Biofilm Before LASER**	**Biofilm After LASER**
1	E2	0.026	0.0365
2	E3	0.077	0.0285
3	E15	0.024	0.0185
4	E12	0.0505	0.017
5	E1	0.024	0.015
6	E4	0.0165	0.014
7	E9	0.0185	0.0125
8	E13	0.0225	0.012
9	E10	0.0435	0.0095
10	E17	0.031	0.0085
11	E18	0.044	0.0085
12	E11	0.023	0.006
13	E16	0.0165	0.006
14	E19	0.0355	0.006
15	E6	0.0145	0.0055
16	E14	0.0365	0.0045
17	E8	0.0095	0.0035
18	E7	0.007	0.003
19	E20	0.0475	0.0005
20	E5	0.1105	-0.001

Table (2) Descriptive analysis of *E. coli* Biofilm:

	Escherichia coli	
	Biofilm Before LASER	Biofilm After LASER
Minimum	0.007000	0.0005000
25% Percentile	0.01650	0.005500
Median	0.02400	0.008500
75% Percentile	0.04350	0.01500
Maximum	0.07700	0.03650
Mean	0.02987	0.01134
Standard Deviation	0.01710	0.009029
Standard Error	0.003924	0.002071
Lower 95% CI	0.02162	0.006990
Upper 95% CI	0.03811	0.01569

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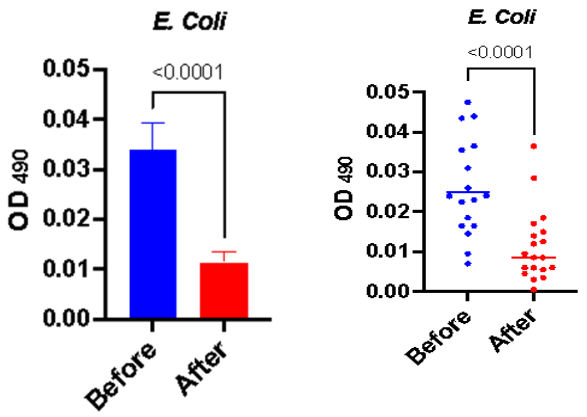

Figure (2) Statistics using GRAPH PAD PRISM 10 software

Laser effect on *k. pneumonia* biofilm

The obtained results showed that the bacterial biofilm formation was significantly P<0.05 affected by laser treatment, this effect was increased by increase the energy and the number of hits, the highest effect was at 10 hits in 300jw energy (0.05350), while the minimum effect was at 1 hits in 100 jw energy (0.003500) with Mean (0.01471) and Standard Deviation (0.01161) and Standard Error (0.002817) As shown in Table (3,4).

Table (3) OD_{490} values of cultured *Klebsiella pneumonia*

	Klebsiella pneumonia	
Sample ID	**Biofilm Before LASER**	**Biofilm After LASER**
K1	0.0095	0.007
K2	0.0445	0.0165
K3	0.0745	0.01
K4	-0.003	0.006
K5	0.0195	0.01
K6	0.016	0.009
K7	0.0075	-0.0005
K8	0.0255	0.016
K9	0.0505	0.0125
K10	0.0295	0.021
K11	0.0325	0.0175
K12	0.1025	0.0535
K13	0.086	0.026
K14	0.018	0.0085
K15	0.0155	0.005
K16	0.0445	0.0085
K17	0.005	0.0035
K18	0.027	0.009
K19	0.073	0.0165
K20	0.049	-0.001

Table (4) Descriptive analysis

	Klebsiella pneumonia	
	Biofilm Before LASER	**Biofilm After LASER**
Minimum	0.005000	0.003500
25% Percentile	0.01700	0.008500
Median	0.02950	0.01000
75% Percentile	0.06175	0.01700
Maximum	0.1025	0.05350
Mean	0.03962	0.01471
Standard Deviation	0.02876	0.01161
Standard Error	0.006975	0.002817
Lower 95% CI	0.02483	0.008734
Upper 95% CI	0.05440	0.02068

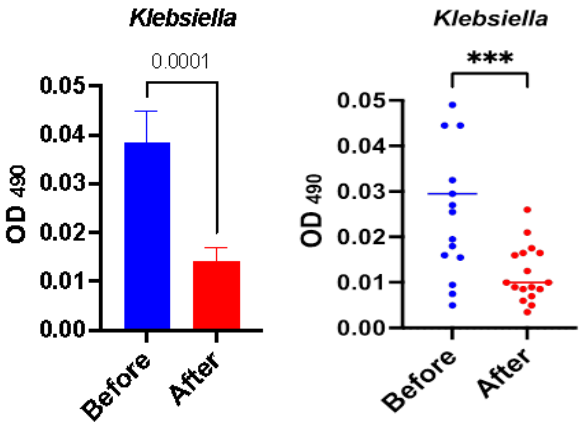

Figure (3) Statistics using GRAPH PAD PRISM 10 software.

Laser effect on *E. coli* adhesion:

The present study, showed that the bacterial adhesion was significant statically P<0.05 affected by Laser treatment, this effect was increased by increase the energy and the number of hit, the highest effect was at 10 hits in 300jw energy as Strong adhesion (+++), while the minimum effect was at 1 hit in 100 jw energy (+or 0) shown Table (5,6,7,8).

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Table (5) Adhesion of *E. coli* before the exposure to the laser

Isolate	Dilution (CFU/ml)					
	1.5 X 10^8	7.5 X 10^7	3.7 X 10^6	1.8 X 10^6	9 X 10^6	4 X 10^6
E01	+++	+++	+++	++	+	0
E02	+++	+++	+++	++	+	0
E03	+++	+++	+++	++	+	0
E04	+++	+++	+++	+++	++	+
E05	+++	+++	+++	++	+	0
E06	+++	++	+	0	0	0
E07	+++	+++	+++	+++	++	+
E08	+++	+++	+++	++	+	
E09	+++	+++	++	+	0	0
E10	+++	+++	++	+	0	0

Table (6) Adhesion of *E. coli* after the exposure to the laser

Isolate	Dilution (CFU/ml)					
	1.5 X 10^8	7.5 X 10^7	3.7 X 10^6	1.8 X 10^6	9 X 10^6	4 X 10^6
E01	+++	++	+	0	0	0
E02	+++	++	+	0	0	0
E03	+++	+++	++	+	0	0
E04	+++	++	+	0	0	0
E05	+++	++	+	0	0	0
E06	+++	+++	++	+	0	0
E07	+++	++	+	0	0	0
E08	+++	+++	++	+	0	0
E09	+++	++	+	0	0	0
E10	**+++**	**++**	**+**	**0**	**0**	**0**

Table (7) Interpretation of the results

+++	**Strong adhesion**
++	**Moderate adhesion**
+	**Weak adhesion**
0	**No adhesion**

Table (8) *E. coli* (Mean ±SE)

Type of treatment	Adhesion score
Before exposure	**2.90±0.06a**
Laser 100 J.W energy 1 bits	1.35±0.13b
Laser 200 J.W energy 5 bits	0.350±0.13c
Laser 300 J.W energy 10 bits	0.05±0.05d
LSD(P<0.05)	0.28

Laser effect on *k. pneumoniae* adhesion:
The present study, showed that the bacterial adhesion was significant statically P<0.05 affected by Laser treatment, this effect was increased by increase the energy and the number of hits, the highest effect was at 10 hits in 300jw energy as Strong adhesion (+++), while the minimum effect was at 1 hit in 100 jw energy (+or 0) shown Table (9,10,11).

Table (9) Adhesion of *Klebsiella pneumonia* before the exposure to the laser

Isolate	Dilution (CFU/ml)							
	1.5 X 10^8	7.5 X 10^7	3.7 X 10^6	1.8 X 10^6	9 X 10^6	4 X 10^6	2 X 10^6	1 X 10^6
K01	+++	+++	+++	+++	+++	+++	++	0
K02	+++	+++	+++	+++	+++	+++	++	+
K03	+++	+++	+++	+++	+++	+++	+++	+
K04	+++	+++	+++	+++	+++	+++	++	0
K05	+++	+++	+++	+++	+++	+++	++	+
K06	+++	+++	+++	+++	+++	+++	+++	++
K07	+++	+++	+++	+++	+++	+++	+++	++
K08	+++	+++	+++	+++	+++	+++	+++	++
K09	+++	+++	+++	+++	+++	+++	+++	++
K10	+++	+++	+++	+++	+++	+++	++	+

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Table (10) Adhesion of *Klebsiella pneumonia* after the exposure to the laser

Isolate	Dilution (CFU/ml)							
	1.5 X 10^8	7.5 X 10^7	3.7 X 10^6	1.8 X 10^6	9 X 10^6	4 X 10^6	2 X 10^6	1 X 10^6
K01	+++	+++	+++	+++	++	+	0	0
K02	+++	+++	+++	+++	++	+	0	0
K03	+++	+++	+++	+++	++	+	0	0
K04	+++	+++	+++	+++	++	+	0	0
K05	+++	+++	+++	+++	++	+	0	0
K06	+++	+++	+++	+++	+++	++	+	0
K07	+++	+++	+++	+++	+++	++	+	0
K08	+++	+++	+++	+++	+++	++	+	0
K09	+++	+++	+++	+++	+++	++	+	0
K10	+++	+++	+++	+++	+++	++	+	0

Table (11) Klebsiella (Mean ±SE)

Type of treatment	Adhesion score
Before exposure	3±0a
Laser 100 J.W energy 1 bits	1.30±0.14b
Laser 200 J.W energy 5 bits	0.400±0.11c
Laser 300 J.W energy 10 bits	0±0d
LSD(P<0.05)	0.26

Conclusions

The results showed that the highest percentage of bacteria isolates was *E. coli*, followed by *K. pneumoniae* and the Laser rays effect of the adhesion of *E. coli* and Klebsiella, and its effect increased with energy and number of hits. The Laser rays effect of on biofilm formation of *E. coli* and *K. pneumoniae* increases with energy and number of hits.

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Conflict of interest

No conflict of interest is found for the present study.

References

1- Trabsky, Marc (2014). "Institutionalising the Public Abattoir in Nineteenth Century Colonial Society". Australian Feminist Law Journal. 40 (2): 180. doi:10.1080/13200968.2014.981357. S2CID 142813253. https://doi.org/10.1080/13200968.2014.981357

2- Tolera ST, Alemu FK. Potential of abattoir waste for bioenergy as sustainable management, eastern Ethiopia, 2019. J Energy. 2020;2020:1-9. https://doi.org/10.1155/2020/6761328

3- Grandin T. Sample designs of cattle races and corrals. Dr. Temple Grandin's Web Page. 2011.

4- Noted. "Following the call of New Zealand's abandoned freezing works". Noted. Archived from the original on 2019-05-25. Retrieved 2019-06-19.

5- Doulgeraki AI, Ercolini D, Villani F, Nychas G-JE. 2012. Spoilage microbiota associated to the storage of raw meat in different conditions. Intl J Food Microbiol 157 (2): 130-141. DOI: 10.1016/j.ijfoodmicro.2012.05. https://doi.org/10.1016/j.ijfoodmicro.2012.05.020

6- Mboto, C.I., Agbo B. E., Ikpoh, I.S., Agbor, R.B., Udoh, D.I., Ambo, E. E. and Ekim, M.A. (2012). Bacteriological study of raw meat of Calabar Abattoir with public health and veterinary importance. J. Microbiol. Biotech. Res., 2(4), 529 - 532.

7- R.K. Gautam, et al., 2023Evaluation of long-term operational and treatment performance of a high-biomass submerged anaerobic membrane bioreactor treating abattoir wastewater,Chem. Eng. J. (2023), Article 142145.

8- Pennacchia C, Ercolini D, Villani F 2011: Spoilage-related microbiota associated with chilled beef stored in air or vakuum pack. Food Microb 28: 84-93. https://doi.org/10.1016/j.fm.2010.08.010

9- Taylor, Nick (2000). Laser: The Inventor, The Nobel Laureate, and The Thirty-Year Patent War. Simon & Schuster. p. 66. ISBN 978-0684835150.

10- Castelvecchi, Davide; Sanderson, Katharine (October 3, 2023). "Physicists who built ultrafast 'attosecond' lasers win Nobel Prize". Nature. 622 (7982): 225-227. Bibcode:2023Natur.622..225C. doi:10.1038/d41586-023-03047-w. PMID 37789199. Retrieved November 14, 2024.

https://doi.org/10.1038/d41586-023-03047-w

11- Trainer, Matthew (2010). "The 50th anniversary of the laser". World Patent Information. 32 (4): 326-330. Bibcode:2010WPatI..32..326T. doi:10.1016/j.wpi.2010.06.005. https://doi.org/10.1016/j.wpi.2010.06.005

12- Saleh, Bahaa (2016), Al-Amri, Mohammad D.; El-Gomati, Mohamed; Zubairy, M. Suhail (eds.), "The Laser", Optics in Our Time, Cham: Springer International Publishing, pp. 71-85, Bibcode:2016oot..book...71S, doi:10.1007/978-3-319-31903-2_4, ISBN 978-3-319-31902-5. https://doi.org/10.1007/978-3-319-31903-2_4

13- Pearsall, Thomas (2020). Quantum Photonics, 2nd edition. Graduate Texts in Physics. Springer. doi:10.1007/978-3-030-47325-9. ISBN 978-3-030-47324-2. S2CID 240934073. Archived from the original on February 25, 2021. Retrieved February 23, 2021. https://doi.org/10.1007/978-3-030-47325-9

14- Escherich, T. (1988, 1989). (Translations): The intestinal bacteria of the neonate and breast-fed infant. Rev. Infect. Dis. 10, 1220-1225; 11, 352-356. https://doi.org/10.1093/clinids/10.6.1220

15- Gomes, T. A. T., Dobrindt, U., Farfan, M. J., & Piazza, R. M. F. (2021). Interaction of pathogenic escherichia coli with the host :pathogenomics, virulence and antibiotic resistance. In Frontiers in Cellular and Infection Microbiology (Vol. 11, p. 654283). Frontiers Media SA. https://doi.org/10.3389/fcimb.2021.654283

16- Chiu, S.-K., Wu, T.-L., Chuang, Y.-C., Lin, J.-C., Fung, C.-P., Lu, P.-L., Wang, J.-T., Wang, L.-S., Siu, L. K., & Yeh, K.-M. (2013). National surveillance study on carbapenem non-susceptible Klebsiella pneumoniae in Taiwan: the emergence and rapid dissemination of KPC-2 carbapenemase. PloS One, 8(7), e69428. https://doi.org/10.1371/journal.pone.0069428

17- Okuno, M., Arimizu, Y., Miyahara, S., Wakabayashi, Y., Gotoh, Y., Yoshino, S., Harada, T., Seto, K., Yamamoto, T., & Nakamura, K. (2023). Escherichia cryptic clade I is an emerging source of human intestinal pathogens. BMC Biology, 21(1), 81. https://doi.org/10.1186/s12915-023-01584-4

18- Neamati, F., Firoozeh, F., Saffari, M., & Zibaei, M. (2015). Virulence genes and antimicrobial resistance pattern in uropathogenic Escherichia coli isolated from hospitalized patients in Kashan, Iran https://doi.org/10.5812/jjm.17514

19- Spaulding, C. N., Klein, R. D., Ruer, S., Kau, A. L., Schreiber, H. L., Cusumano, Z. T., Dodson, K. W., Pinkner, J. S., Fremont, D. H., & Janetka, J. W. (2017). Selective depletion of uropathogenic E. coli from the gut by a FimH antagonist. Nature, 546(7659), 528-532. https://doi.org/10.1038/nature22972

20- Wu, Wang, A. H. J., & Jennings, M. P. (2008). Discovery of virulence factors of pathogenic bacteria. Current Opinion in Chemical Biology, 12(1), 93-101. https://doi.org/10.1016/j.cbpa.2008.01.023

21- Alegbeleye, O. O., Singleton, I., & Sant'Ana, A. S. (2018). Sources and contamination routes of microbial pathogens to fresh produce during field cultivation: A review. Food Microbiology, 73, 177-208.https://doi.org/10.1016/j.fm.2018.01.003

22- Davey MEO'Toole GA (2000) Microbial biofilms: from ecology to molecular genetics Microbiology and Molecular Biology Reviews 64:847-867. https://doi.org/10.1128/MMBR.64.4.847-867.2000

23- Hall-Stoodley LCosterton JWStoodley P (2004) Bacterial biofilms: from the natural environment to infectious diseases Nature Reviews Microbiology 2:95-108. https://doi.org/10.1038/nrmicro821

24- Adler J .,(1966) Chemotaxis in bacteria Science 153:708-716. https://doi.org/10.1126/science.153.3737.708

25- Berg HC (2018) Random Walks in Biology Princeton University Press. https://doi.org/10.2307/j.ctv7r40w6

26- Y. Tanji et al. ,J. Biosci. Bioeng (1999). Structural analysis of a biofilm which enhances carbon steel corrosion in nutritionally poor aquatic environments https://doi.org/10.1016/S1389-1723(00)87674-4

27- E.J. Bouwer et al., (1993). Bioremediation of organic compounds-putting microbial-metabolism to workTrends Biotechnol. https://doi.org/10.1016/0167-7799(93)90159-7

28- I.W. Marjaka et al.(1996). Augmentation of self-purification capacity of sewer pipe by immobilizing microbes on the pipe surface 31- A.M. Raichur et al.Flocculation and flotation of coal by adhesion of hydrophobic Mycobacterium phlei ,Colloids Surf. B.

29- R. Bos et al.(1999). Physico-chemistry of initial microbial adhesive interactions-its mechanisms and methods for study FEMS Microbiol. Rev.

doi.org/10.29079/qjvms.2025.161295.1095
ISSN P: 1818-5746
E: 2313-4429
qjvms@qu.edu.iq

https://doi.org/10.1016/S0168-6445(99)00004-2

30- C.H. Bolster et al.(2001). Effect of surface coatings, grain size, and ionic strength on the maximum attainable coverage of bacteria on sand surfaces J. Contam. Hydrol. https://doi.org/10.1016/S0169-7722(01)00106-1

31- C.R. Bunt et al.(1995). The effects of pH, ionic strength and polyvalent ions on the cell surface hydrophobicity of Escherichia coli evaluated by the BATH and HIC methods Int. J. Pharm. https://doi.org/10.1016/0378-5173(94)00205-J

32- D.G. Jewett et al., (1995) Bacterial transport in laboratory columns and filters: influence of ionic strength and pH on collision efficiency Water Res. https://doi.org/10.1016/0043-1354(94)00338-8

33- Q. Li et al., (1999) Enhancing bacterial transport for bioaugmentation of aquifers using low ionic strength solutions and surfactants Water Res.

34- M. Hermansson (1999).The DLVO theory in microbial adhesion Colloids Surf. B https://doi.org/10.1016/S0927-7765(99)00029-6

35- H.H.M. Rijnaarts et al.(1995). Reversibility and mechanism of bacterial adhesion Colloids Surf. B https://doi.org/10.1016/0927-7765(94)01146-V

36- Zita et al.(1997). Determination of bacterial cell surface hydrophobicity of single cells in cultures and in wastewater in situ FEMS Microbiol. Lett. https://doi.org/10.1016/S0378-1097(97)00214-0.