

Targeted Elimination of *Acinetobacter baumannii* Contamination in the Local Dairy Chain Using Tailored Lytic Bacteriophage Cocktails

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ABSTRACT

This study addresses the challenge of combating *Acinetobacter baumannii* ("Iraqibacter") contamination in the local dairy chain and its role in urinary tract infections (UTI) through the innovative use of redirected lytic bacteriophage cocktails. *A. baumannii*, known for its recalcitrant biofilm formation and multidrug-resistant (MDR) phenotype, poses significant threats to public health. Lytic bacteriophages with broad-spectrum antimicrobial activity were isolated from Abu-Ghraib fresh ropy yogurt in Baghdad. These phages were assessed for their efficacy against *A. baumannii* strains recovered from dairy products and UTI cases, which demonstrated resistance to multiple generations of antibiotics and ultraviolet irradiation. The study utilized advanced methodologies, including isolation of bacteriophages from yogurt, experimental contamination of ultra-high-temperature (UHT) milk units with *A. baumannii*, and the application of refrigeration preservation cascades. The efficacy of bacteriophage cocktails was validated using plaque assays and scanning electron microscopy (SEM) to document the interaction between bacteriophages and *A. baumannii*. The SEM micrographs revealed significant disruption of biofilm structures and bacterial cell integrity upon exposure to phages. The findings demonstrate that redirected lytic bacteriophages offer a highly specific and eco-friendly alternative to traditional antimicrobial approaches, effectively eliminating *A. baumannii* contamination in the dairy chain without evidence of forbidden transduction or prophage activation. This study highlights the potential of bacteriophage-based biocontrol as a sustainable intervention against MDR pathogens in food safety and clinical settings.

Keywords: *Acinetobacter baumannii*, Multi Stress Hardening, Yogurt, Lytic Bacteriophages

INTRODUCTION

Acinetobacter baumannii is an opportunistic, Gram-negative coccobacillus that has emerged as a significant public health concern due to its exceptional capacity to develop resistance to a wide range of antimicrobial agents. It is a prominent member of the ESKAPE group of pathogens—*Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter*spp.—which are collectively responsible for the majority of nosocomial infections and are known for their multidrug-resistant (MDR) phenotypes. Of particular concern is *A. baumannii*'s ability to survive under extreme environmental conditions, form biofilms, and acquire mobile genetic elements that contribute to its resistance profile. Its persistence in clinical and non-clinical environments, including the food supply chain, poses significant risks for both hospital-acquired infections and community transmission [1]. In recent years, the detection of *A. baumannii* in non-clinical settings, especially in food products such as dairy items, has raised alarms about potential cross-contamination and zoonotic transmission. Dairy products, particularly those produced under suboptimal hygienic conditions, can serve as reservoirs for MDR bacteria, contributing to the silent dissemination of these organisms into the human population [2]. The contamination of ultra-high-temperature (UHT) milk and other dairy derivatives by *A. baumannii* introduces a novel route of exposure, especially in vulnerable populations such as infants, immunocompromised individuals, and the elderly. Conventional antimicrobial interventions are becoming increasingly ineffective against *A. baumannii* due to its intrinsic and acquired resistance mechanisms, including efflux pumps, β -lactamases, and resistance to ultraviolet (UV) irradiation. This

scenario necessitates the exploration of alternative, eco-friendly, and target-specific antimicrobial strategies. One such promising approach is the use of bacteriophages—viruses that specifically infect and lyse bacterial cells. Lytic bacteriophages offer several advantages over traditional antibiotics, including high specificity, minimal impact on normal flora, and the ability to disrupt bacterial biofilms [3]. In the context of microbiological laboratory research, the application of tailored bacteriophage cocktails represents a highly strategic and precise method for pathogen control. This study focuses on the isolation, characterization, and application of lytic bacteriophages against *A. baumannii* strains recovered from contaminated dairy products and clinical urinary tract infection (UTI) samples in Baghdad. Phages were isolated from fermented dairy products using standard double-layer agar plaque assays and subsequently characterized using electron microscopy and molecular techniques. The effectiveness of these phages was assessed against laboratory-confirmed MDR *A. baumannii* isolates through in vitro assays, including biofilm degradation and SEM (scanning electron microscopy) analysis [4-8]. The primary aim of this study is to evaluate the efficacy of phage therapy in eliminating *A. baumannii* contamination from the dairy supply chain using a laboratory-based approach. This includes the experimental contamination of UHT milk units, application of lytic phage cocktails under controlled conditions, and monitoring of bacterial elimination using standard microbiological methods [9, 10]. The broader goal is to provide a proof-of-concept for integrating bacteriophage biocontrol into routine microbial quality assurance in food safety and to highlight its potential application in both medical and environmental microbiology.

Methodology

Colloquially, Lytic Bacteriophages Susceptibility Pattern verified via Phage Ø buffer 76 (NaCl 6 gm + MgSO₄ 2 gm + CaCl 2 gm + Tris 8 gm + Gelatin 0.1 gm) in 1 liter distilled water deciphered in downstream Table (1). Hot-Cold Module [2, 7, 11] for preparation of Lytic Bacteriophages Cocktails enrolled by One Part Yogurt to Five Parts Buffer mixed (50-100 ml yogurt to 250-500 ml buffer). Overnight incubation inside a refrigerator at 4 C. Propagating if lytic phages by mixing freshly prepared 10 logs MacFarland broth of bacteria in TSBYE as 1 ml to 250 ml of overnight yogurt upstairs, then incubation overnight at 37 C. Centrifugation and filtration by filter paper drop by drop and the decanted residual water like suspension is a raw bacteriophages cocktail. Plaques Spots technique enrolled via Mixing 0.1 MacFarland bacteria with 0.1 ml concentrated Ø incubation at 37 C for one hour (Resident A). Modified Verified Roll Pour Plate technique enrolled via Mixing melted warm TSAYE in a cup containing Resident A for a minute with rolling the pouring into a plate to solidify, then incubate overnight at 37 C. Appearance of holes or spots or plaques. Verification via Scanning Electron Microscope. A VIP critical augmented redirected processing enrollment via Adding freshly prepared 0.1 ml McFarland dTSBYE76 *A. baumannii* to assigned 50 ml volume plastic cup containers (ten logs CFU.ml⁻¹), Followed by decantation and mixing 25 ml UHT tetra packs KDD white full cream milk units (Experimental Contamination Module). Add freshly prepared 0.1 ml McFarland dTSBYE76 lytic bacteriophages cocktail recovered and redirected from fresh ropy pooled yogurt (ten logs PFU.ml⁻¹). Incubate two hours at 37 C to accommodate the specific receptor reaction. Segregate two subunits (Direct & Resuscitation Indirect). First culturing with modified verified roll-cup pore plate technique. Second overnight incubation of phages processed UHT milk units inside a refrigerator at 4 C. Sub culturing cooled subunit with upstairs roll-cup pore plate technique [2].

Table 1: Lytic Bacteriophages (WYVØ) Extraction Buffer (Verified by Al-Shammary,[12])

Phage Ø buffer 76 Components in 1 Litter Distilled Water
NaCl 6 gm
MgSO ₄ 2 gm
CaCl 2 gm
Tris 8 gm
Gelatin 0.1 gm

Interpreting validating the recovered phage mixtures necessitated the use of a customized combination protocol. The revised spot-plaques Ø pattern morphology assay utilized the Kirby Bauer antibiotic sensitivity diffusion and McFarland Log modulation assay on Muller Hinton agars. The standardized clone swabbing formula entails dispensing and spreading 20 microliters of contaminated samples from each collected Ø. Following incubation at 37 °C overnight, the spots-plaques (lytic zones mimicking antibiotic inhibition zones) were calculated and enumerated as plaques forming units (PFU.ml⁻¹). The morphology, size, purity, clarity, and turbidity of each spot were assessed. The recovered drinks were compared with the modified procedure. The verified pour plate approach is combining 0.1 ml of concentrated Ø with 0.1 ml of standardized clone log and incubating the mixture at 37 °C for one hour. The freshly synthesized TSAYE was mixed with enrollment and poured into sterile cups. A circular vortex was created and maintained for one minute. The mixture was then poured into plates and incubated overnight at 37 °C. This process was repeated upstairs. The Tbilisi (Ø RTD) modified routine test dilution

assay is used to determine the threshold cut-off values using titration. The titer logs for recovered Ø as minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) were produced using PBS-dependent dual and mixed tenfold cascaded twofold dilutions with upstairs plaques, depending on phenotypic criteria. The molecular scanning three-dimensional crystallographic micrographs were altered and verified by concentrating mixtures of freshly generated Exodia vs. Chimaera combos on sterile glassware measuring one cm in diameter, either circular or cubic in shape, for electron microscopy. The VEGA 3 TESCAN laser electron microscopy technique enhanced the recovery module by accurately identifying the specificity and sensitivity of the recovered material on the chimaera biofilm-capsule layers. It also revealed the insertion of DNA and termination of the super clonal genotype by the phage module, as demonstrated by plaque techniques. The redesign and redirection techniques were established using validated sources [2, 3, 7, 8, 13-30].

Results and Discussion

Biostatistical integration was a predominant tool for deciphering and matching displayed calculated cascaded results series at confidence intervals 95 & 99 % in which, all observed results were analyzed by statistical analysis system [31] software program throughout interconnected values of significant and non or insignificant probability index of $p \leq 0.05$ & $p \leq 0.01$ via dependent analysis of variance (ANOVA) with least significant difference (LSD) cascaded by Chi square (χ^2) to understanding normal distribution nature of samples and their replicates. Significant values mean significant clinical observed and calculated trials of experimental design and dissertation aim & objectives. Nonetheless, it is important to note that results that are deemed non-significant or insignificant do not necessarily imply a lack of clinical or scientific importance [32-36]. The significance of these results depends primarily on the virulence indices exhibited by the evolved isolates, which refers to their genetic makeup as genetically modified microorganisms. This is particularly relevant in the context of bioterrorism, as it pertains to the priority topic of the food chain and its interconnected predisposing factors and ecosystems, specifically in terms of the zone of infection and the timing of episodes. In conclusion, clinical observational trials were highly significant despite the lack of statistical significance in certain circumstances [37-40]. Emergent Risk Assessment Patterns illustrated and deciphered via an abnormal naturally and genetically modified, highly infectious forbidden foci derive from unknown portals of entrance or Era gates throughout cascaded bridges to be resident and deposited within Iraqi environment with continuous stress adaptation and hardening cis-trans accommodation strategies. These emergent forbidden, biohazard and bioterror *Acinetobacter baumannii* are genetically well-equipped foreign entity augmented to survive harsh environments with other infectious and contagious foci inside a recalcitrant barrier of biofilm to create an abnormal dangerous and sophisticated struggling entity with diverse and versatile, drift shift antigenic transformations ending with forbidden sequels [41]. According to legendary futurist inventor and innovator Nikola Tesla and their AI cascaded researches in field of electromagnetic energy patterns constructions verification models with built-in forbidden sequels of negative energy and death irradiations oscillation poured by HARPA and DARPA projects for destroying every living thing and lifestyle changes, terminated with

bioterrorism highly infectious agents resident in food chain [2, 3, 35, 42-47]. The dairy chain ecosystems in Baghdad province have been found to contain multi-stress resistant entities that have adapted to different antimicrobial antibiotics (MDR) and exhibit irradiation tolerance behaviours (UVT). These entities possess broad-spectrum genetic plasticity and have been exposed to a significant amount of depleted uranium as a result of the Iraqi wars. The uranium has been transmitted to the Iraqi environment through infected and carrier US soldiers, resulting in the emergence of forbidden Iraqi Atomic Chimaeras (IAC). These entities, which underwent natural and intentional mutations, were able to change their genetic contents from the clinical phase to the antigenic drift and shift food-adapted contaminant phase. They exhibited clever artificial intelligence behaviours to hide and regulate virulence biomarkers. Altered, altered offspring with new characteristics could be transformed from generational sequences into interconnected robots resembling brains. Quorum sensing networks are regulated by sigma factors using clever tactics, which are enhanced by temporary tolerant transient phases that have undergone epigenetic drift. These phases allow the organisms to persist in different environmental conditions [2, 3, 48-51]. The HARPA project investigates the emergence and resurgence of stress-adapted *A. baumannii* entities with multidrug resistance, which are analogous to chainsaw puzzles in the ESKAPE model. These entities are found in archaic organisms that have been concealed under the Siberian ice, a result of climate change. The prediction of the adaptation phenomenon of the nosocomial human pathogen *A. baumannii*, which undergoes phase or phenotype variation under stress, transforming from a host-specific phase to an adaptive versatile phase, is a new emergent phenomenon [52, 53]. This pathogen resides on the food chain and utilises unknown mechanisms for survival and revival. It is deposited within the Human-Dairy ecosystem in Baghdad, forming "CHIMAERAS" (CRISPR-CAS genes sharing strategies built-in an artificial intelligence brain machines chips of quorum sensing behaviours within an enclosed biofilm barriers patterns) [2, 54-59]. Prokaryotic DNA sequences designed as clustered regularly interspaced short palindromic repeats (CRISPR-CAS). The simultaneous occurrence of complex augmenting shifting to genetic mutant phases is facilitated by forbidden conjugating plasmids bridges instead of chromosomal cassettes and pathogenicity islands. This process involves the acquisition of forbidden foreign DNA machinery, resulting in the production of new proteins weapons. Additionally, transduction with forbidden infrastructural integrity leads to the formation of prophages chips. These emerging entities can undergo rearrangement and mixing, known as re assortment, in the lifestyle of viruses. This occurs during the generation time in a controlled manner, resulting

in the production of offspring with morphological characteristics similar to their parent cells. The purpose of this process is to safeguard the crucial main core mother cell, which carries the genetic ancestral resistant memory. This memory is programmed to trigger a self-destructive behavior called apoptosis, which protects the virus against the host's immune system during invasion and also aids in the tolerance of food decontamination modules. Fortunately, these emerging forbidden entities have a low microbial count. However, the associated risk must be carefully considered in the future. These entities exhibit predominant clonal segregation patterns, replicating without restrictions and releasing broad-spectrum uniform forbidden clones. These clones cleverly eliminate any susceptible offspring that are not categorized, fortified with augmented genetic materials and fresh self-building units [2, 3, 48-51]. The emergent entities were discovered in a validated cross-sectional study on locally produced dairy products from cows in the Baghdad province. The biohazard denominators were thoroughly examined and found to be present in alarming and unusual frequency and distribution patterns within randomly selected sections of Al-Sadrya, Abu-Ghraib, and Al-Fudhaliyah. Scanned samples of various dairy products from seven popular Iraqi brands were verified using ecomaps segregation categorised criteria. The samples included raw milk, fresh ropy yoghurts, curd soured yoghurts, fresh soft cheeses, brined soft cheeses, butters, and creams. The purpose was to test null cascaded alternative hypotheses about lunges cascades. Additionally, the study examined the cases of human individuals infected and carriers (dairy workers and normal customers) with urinary tract infections (UTI) that were associated with these products. Comparison of the similarity index patterns between *A. baumannii* and the documented cases of foodborne illnesses occurring upstairs. Recorded and documented inside Iraqi ecosystems are a number of UTI cases that have led to the transmission of zoonotic and reverse zoonotic infections. These pathogens have been observed to spread through different and versatile epidemiological segregation Eco maps [1, 2, 5, 7-9, 11, 27, 42, 43, 60-67]. Recovered & redirected lytic bacteriophages ($\emptyset$) from fresh ropy fermented Cows yogurt from Abu-Ghraib against selected multi-stress resistant Chimeras *A. baumannii* recovered from dairies & UTI cases, terminate significantly, clinically & permanently all these forbidden emergent Chimeras without any residual forbidden transduction CRISPR foe prophage entity. Downstream Table (2), Figure (1,2,3) deciphers these dramatic encountered events. The End of Journeys and the Triumph of "Allah" over Resident Evil. And this confirms what He said, Glory be to Him, the Highest, so "He sent upon them birds, Ababil, that pelted them with stones of baked clay, so He made them like an eaten chaff."

Table 2: Redirected Lytic Bacteriophages Cocktails Susceptibility Index for Selected Prohibited MDR-UVT *A. baumannii* Recovered from Baghdad.

Selected MDR-UVT	Plaques ($\emptyset$) Mean Log Count PFU ml ⁻¹						Total Mean
	$\emptyset$ D L	$\emptyset$ D S	$\emptyset$ ID1 L	$\emptyset$ ID1 S	$\emptyset$ ID2 L	$\emptyset$ ID2 S	
Abu-Ghraib	10.477	12.301	10.602	12.698	11.041	13.477	11.766 a
Al-Fudhaliyah	10.439	12.698	10.301	12.698	10.602	12.301	11.506 a
Al-Sadrya	10.243	12.477	10.243	12.698	11.447	13.698	11.801a
P-Value	-	-	-	-	-	-	0.713NS

Lytic Bacteriophages Cocktails recovered from fresh ropy yogurt from Abu-Ghraib. Plaques-Spot forming units (PFU.ml⁻¹) ≥ 5 MacFarland Logs indicate termination bactericidal problems of MDR-UVT selected Prohibited entities isolates (Iraqi Atomic Chimeras). D L = Direct Large Circular Clear Plaques Mean Log Count Growth Patterns of $\emptyset$ -processed cultured plates at 37°C for 24 hours. $\emptyset$ D S = Direct Small Diffuse Clear Plaques Mean Log Count Growth Patterns of $\emptyset$ -processed cultured plates at 37°C for 24 hours. $\emptyset$ ID1 L = Direct Large Circular Clear Plaques Mean Log Count Growth Patterns of $\emptyset$ processed contaminated UHT milk units at 37°C for 24 hours. processed contaminated UHT milk units at 37°C for 24 hours. $\emptyset$ ID2 L = Direct Large Circular Clear Plaques Mean Log Count Growth Patterns of resuscitated $\emptyset$ -processed contaminated UHT milk units at 4 °C for 24 hours. $\emptyset$ ID2 S = Direct Small Diffuse Clear Plaques Mean Log Count Growth Patterns of resuscitated $\emptyset$ -processed contaminated UHT milk units at 4 °C for 24 hours.

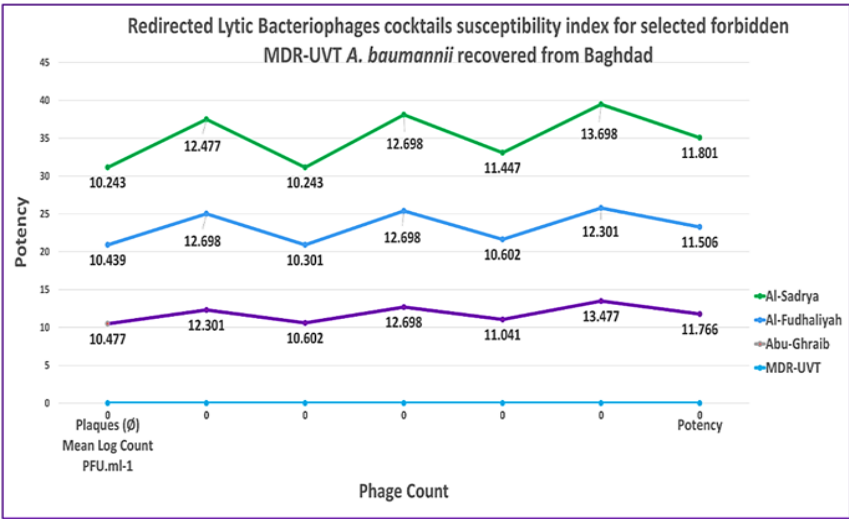


Figure 1: Processing of Redirected Lytic Bacteriophages Cocktails on Atomic Chimeric Entities of MDR-UVT *A. baumannii* recovered from Dairy Chain in Baghdad

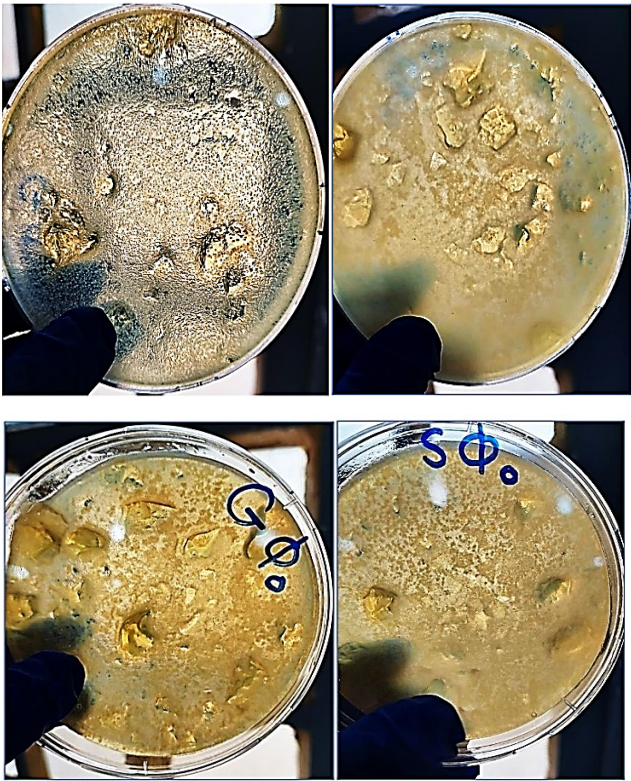
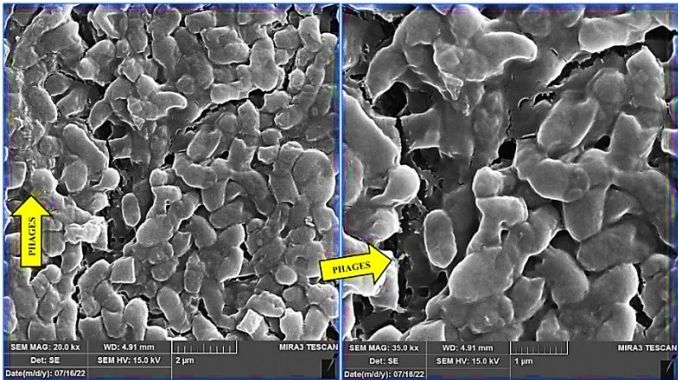


Figure 2: Apoptotic Dead Chimeras of *A. baumannii* with large & Small Diffuse Plaques, Spots & Patches of Clear & Turbid Redirected Lytic Bacteriophages on Surface of TSAYE.



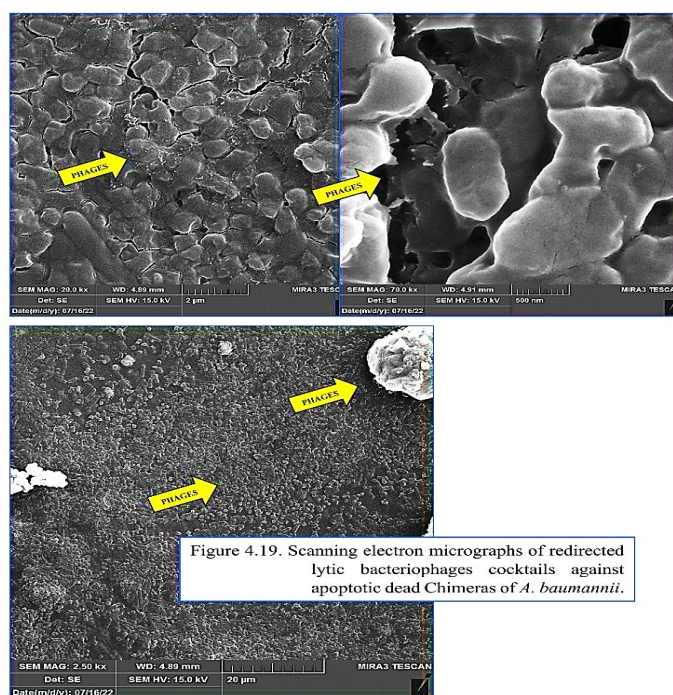


Figure 3: Scanning Electron Micrographs of Redirected Lytic Bacteriophages Cocktails Against Apoptotic Dead Chimeras of *A. baumannii*.

Redirected cocktails of lytic bacteriophages were encountered from Cows raw milk & dairy series in Baghdad against multi-stress resident *Listeria monocytogenes*, vancomycin resistant *Enterococcus faecalis-faecium complex* (VRE), methicillin resistant *Staphylococcus aureus* (MRSA) Chimeras [8], re-constitutive host specific but stress adapted *Mycoplasma pneumoniae* [27], and azoles resistant *Candida albicans* as Exodia [3]. Eradicate forcefully all these prohibited defiant emerging infectious bioterrorism and biohazard sources residing and deposited within biofilm structures. The processing, penetration, and eradication of a complex aggregate of multidrug resistant *A. baumannii* resident and deposited within a recalcitrant biofilm is challenging. This task cannot be achieved without overcoming cascaded and potentiation hurdles using clever tactics, such as redirected lytic bacteriophages cocktails. Confirmed lytic phages have the potential to provide a lasting treatment for emerging biohazards and bioterrorism. ESKAPE Chimeras that impact both animals and humans [36, 68-71]. Therapeutic & prophylactic enrollment of probiotic phages in Human & animal lifestyle with a selection to not invade friend eukaryotic cells & not disrupt normal flora of intestine as well as, eco-friendly in food & water chain industries as complementary hygienic bio-preservation technology had a priority special topic issue order now. Specificity & sensitivity patterns with significant targeting forbidden denominator vis lytic bacteriophages had approved with safety, potency & economic strategy to combat forbidden new struggling. Biodegradation module phages against complex matrix of biofilm surrounding the forbidden issue provides & open the gates to kill these hiding creatures such as UTI denominators [72]. This special topic issue thesis significant & excellent results in corporation sanitation disinfectant processing of locally dairy animals, feeds, waters, locally dairy products, etc. in Baghdad via recovered & redirected lytic phages cocktails in association with ultraviolet irradiation within food chain versus potentiate traditional or new antibiotics during treatment or prophylactic era to terminate these forbidden emergent sophisticated entities. A significant difference in microbial quality hygienic patterns was satisfying incorporation of

bacteriophages in processing of food chain [68-71]. Shifting Era of biosafe lytic phages for improving hygienic quality of food chain, is a promising future tool for terminating evolved problems. Complexity in clearance & decontaminate recycled wastewater and their residues could be solved with phages decontamination module as in this verified thesis. Hygienic Exodia phages could prevent cleaver programmed information & taking spreading of forbidden resistance genes from pathogens within food & water chains, thus verify an excellent behavior without any side effect built-in selective toxicity pressure on plants, animal & human lifestyles [8, 67]. Cascade increase updates of multi-stress tolerant versus resistant pathogens is a frightening behavior struggling spreads extensively with dependent & independent manners throughout coordinated, organized, intentional, & spontaneous worldwide. Frequency & distribution patterns of these new emergent struggling “DENJI” *A. baumannii* within Baghdad food chain & from UTI cases considered as chainsaw puzzles in association with forbidden chain of ESKAPE top pathogens. A CRISPR-CAS immune lysogenic prophage “DENJI” was tolerant & resistant to lytic bacteriophages, & fortunately not encountered nor recovered from dairy sources & UTI patients in Baghdad yet. Foreign genes verification & modification throughout cascaded transmission of genetic material from evolved ancestor to new emergent progeny with an AI dependent cleaver strategy made these susceptible pathogens tolerant & resistant to traditional therapy as antibiotics & transmission to contamination phase in food & waters ecosystems as insufficient food processing cascaded by post decontamination, pasteurization & sanitation contamination forbidden residents struggling especially within matrixed biofilm barrier [67-71]. Prohibited Sequels A cascaded result Food terrorism is the intentional contamination of food with chemical, biological, or radio nuclear agents (CBRN) to injure or kill civilians and disturb social, economic, or political stability. Agricultural bioterrorism or agro terrorism targets livestock and crops during production, harvesting, storage, and transport. Terrorism targeting processed foods refers to the intentional act of directing harm or disruption against processed foods at any stage

of their production, including processing, manufacture, storage, transport, distribution, or service. Agro terrorism, sometimes known as bioterrorism, is a form of warfare that specifically targets livestock and crops with the intention of causing economic damage. Economic warfare refers to the deliberate infliction of damage on a country's agricultural or ecological infrastructure through the deployment of a biological weapon. Terrorism aimed at processed foods entails the deliberate contamination of food items at any stage of processing, production, storage, transport, distribution, or service. The type of contaminated food and biological agent can cause a slow, broad, or explosive outbreak. The government has launched several prevention, surveillance, and control programmes to target forbidden struggling [2]. Most industrialised and emerging nations view biological warfare as remote. However, bioterrorism—extremists using biological agents to attack civilians—is a problem. Creating fear and panic and influencing government behaviour to achieve political goals. Nation and rebel groups have the motive and capabilities to selectively create deadly germs and use them for terrorism. A successful bioterrorist assault could have terrible effects, although it is hard to anticipate. Bioterrorism and its repercussions can put a strain on the public health care system. To prevent bioterrorist attacks, a solid public health care system with disease surveillance, timely epidemiological and laboratory investigation, efficient medical management, and IEC is needed [73, 74]. The biological agents could be changed to boost their virulence, antibiotic and vaccination resistance, or ability to spread by air, water, food, or touch. Bioweapon development programmes have produced missiles, bombs, grenades, rockets, and spray-tanks for aircraft, vehicles, and boats. The UN has also documented efforts to manufacture assassination and sabotage delivery devices, including sprays, brushes, injection systems, and food and clothing contaminators. Contaminating food is a common way to terrorise civilian populations during wartime or for other reasons, such as economic (to financially impact a commercial entity or industry unit), political (to make a statement, influence an election, force a political outcome), or malicious incitements. Many state governments, especially those with little conventional armament, nevertheless use food source terrorism as a powerful strategic tool that can have a major economic and social impact [75, 76]. A significant number of domestic laboratories have been discovered globally, including in the United States, that produce flammable devices, ricin, anthrax, illnesses, and substances that can cause chemical pollution or explosions. While explosive devices are commonly used by environmental, animal rights, and political terrorists, there have also been instances of agents being used to contaminate consumer goods, foods, and illicit drugs worldwide. For example, there were allegations of botulinum toxin contamination in black tar heroin in the northern United States in August 2006 [77]. When examining the utilisation of biological preparations to contaminate food, it is crucial to take into account three significant factors. Biological agents possess a high level of concealability. A minimal quantity can be adequate to inflict significant damage on extensive populations and trigger epidemics throughout a wide geographical area. Furthermore, the highly transmissible nature of certain infectious diseases implies that individuals who have been exposed and affected have the potential to further transmit the disease to others, depending on the specific pathogen involved. Furthermore, during the most alarming and covert assault, it is probable that medical personnel in emergency rooms, physician offices, and outpatient clinics may react. Delaying the treatment and control procedures of the terrorist-induced epidemic

prolongs its duration. Intentional contamination of foods is feasible due to the inherent challenges in isolating and detecting various chemical, radiological, and biological contaminants inside complex matrices such as food. Several pollutants have negligible impact on the taste of food and would not cause alarm among food vendors or consumers. The highest vulnerability is with perishable, pre-prepared items that would be delivered and consumed prior to the identification of the hazard. Food is efficiently distributed over vast distances to large populations in various places, with the capacity to exert significant impact [75, 78-81]. The food manufacturing and distribution systems present hazards. Terrorists frequently obtain food and agricultural products during the various stages of production, harvesting, processing, storage, and delivery. Unit activities in food production, such as mixing, blending, diluting, or size reduction, have the potential to disperse harmful substances throughout a batch or numerous batches of product. This can also lead to contamination of the facility, rendering it unusable until it undergoes decontamination, which can be expensive. Rendering plants undertake extensive and expensive measures to thoroughly clean and decontaminate their facilities. This is done to minimise the possibility of spreading prions from infected bovine tissue into the food and animal feed supply. These measures are necessary even after processing a single cow infected with BSE, and serve as an example of the precautions that a food processing operation may need to take following an intentional contamination event [75, 78-81]. Hot food processing or ultraviolet light sterilisation removes most biological treats. Despite processing, anthrax spores remain. Radioactive agents, which can be liquids or solids, can cause immediate and chronic health problems. Natural or industrial byproducts can contain any radioactive material. Nuclear agents are non-natural radiological agents that should be treated for food contamination. Radio nuclear attacks are rare due to raw material scarcity. The type and quantity of the CBRN agent, its point of entry, human resistance, medical treatment, and national or local authorities' finding speed determine the size of a food chain CBRN attack. Dangerous biological agents are fatal or highly infectious, resistant to environmental variables, not readily destroyed, low infective dose, air, water, and food-borne, man-to-man, inexpensive, and easily [75, 78-81]. It is difficult to distinguish between terrorism and criminal activity because biological, chemical, and radiological agents can cause significant harm or instill fear and panic. When forecasting outcomes and impacts, one should consider cultural and geographical variances, as well as varied food production, processing, transit, storage, and preparation methods. Thus, actual hazards must be assessed individually. Bioterrorism and biocrime can utilise pathogens and poisons as bioweapons. Because bioweapon assaults are possible and easy, forensic science must be ready to help bring offenders to justice and deter future attacks. A new subfield of forensics, microbial forensics, characterises evidence from bioterrorism, bio criminality, hoaxes, and accidental releases. Microbiological forensic investigations are similar to other processing forensic investigations. The topics covered encompass crime scene investigation, chain of custody, evidence collection, handling, preservation, shipping, analysis, interpretation, and court presentation. Aside from gathering and examining typical forensic evidence, the forensic inquiry will endeavour to determine the causal agent and a etiology, similar to an epidemiological study. Accurate attribution necessitates more detailed and precise characterization. Genetic- and nongenetic-based assays and informatics are employed to determine or eliminate the source of a sample. In addition, chemical and physical testing can provide

information on the methods used to prepare, store, or spread the bioweapon. A successful microbiological forensics programme must develop and/or verify all steps of the forensic investigation process, starting from sample collection and ending with interpretation. Methods such as Quality Assurance (QA) and Quality Control (QC) that are utilised in forensic DNA science are being utilised. Ultimately, due to the absence of certain analysis skills in the conventional forensic laboratory, collaboration with other laboratories will be vital [75, 78-81]. Hazard Analysis and Critical Control Points (HACCP) is frequently employed in the process of evaluating the potential risks associated with food safety. HACCP-based assessments are effective in addressing food safety and food defence concerns. The World Health Organisation and other experts endorse them as a food defence model. HACCP would develop and enforce preventive measures to minimise the risk of deliberate contamination of a food product in a food facility and during distribution, after identifying the most probable hazards of purposeful contamination. An effective security plan for a facility should be built upon the foundation of a well-designed HACCP plan, incorporating the security and food safety elements of GMPs, a practical sanitation standard operating procedure, and a current product recall programme. No matter the methodology, a food defence plan must work with these programmes. Food defence safeguards the national food supply system from targeted contamination and unauthorised entry. Prevention, reaction, and system recovery are the three main food safety steps. In order to prevent intentional food contamination, the company or country's management structure should develop a strategy for facility monitoring, food product withdrawal, suspicious activity investigation, and programme assessment. A food/water defence plan is essential for national and sector food management. Knowing all the flaws of the food/water supply chain system, symptoms of deliberate contamination, and assessment errors is crucial. The entire supply chain must be assessed for losses that could cause purposeful contamination or long-term damage. With a food defence plan to prevent intentional supply chain contamination, this is doable [75, 78-81]. Notes: Homeland security protects and defends national essential infrastructures and the food and water supply chain for the primary food sector in all phases (land agriculture, livestock, processing and food production, transportation, storehouses and retail). A nation should pass a food and water supply chain defence policy and directives for state agencies to respond to food terrorism or intentional contamination. The strategy should be suggested or required for counties or larger cities with substantial food/water industries or system critical points [75, 78-82]. All potential dangers (chemicals, poisons, insecticides, microbiological material, radioactive materials) should be secured and monitored by local or

national agencies. A country should be able to survive a terrorist strike, thus secure at least one important food/water supply line. Only functional food defence systems that are periodically examined and self-monitored secure national food/water systems. Food/water supply systems of any size can use food defence systems. Food defence systems should first identify and assess a food system or supply chain's critically vulnerable locations. Second, action plans should include mitigation methods for all crucial locations. Self-evaluation and responsible party verification of this action plan are needed.

Conclusion

This study provides compelling evidence for the effectiveness of tailored lytic bacteriophage cocktails in targeting and eliminating *Acinetobacter baumannii* contamination within the local dairy chain. The successful isolation of potent lytic phages from naturally fermented dairy sources, followed by their in vitro evaluation against multidrug-resistant *A. baumannii* strains from both dairy products and urinary tract infection (UTI) clinical isolates, underscores the promising role of phage therapy as an alternative biocontrol strategy in food safety and clinical microbiology. Laboratory assays, including plaque formation, bacterial growth inhibition, and scanning electron microscopy (SEM), demonstrated the capacity of phages to disrupt biofilm structures and lyse resistant bacterial cells effectively. These findings are particularly significant given the increasing global threat posed by *A. baumannii*, a member of the ESKAPE group of pathogens, notorious for its resilience, biofilm formation, and resistance to multiple antibiotic classes and environmental stressors, including UV radiation. The results of this study suggest that bacteriophages, especially when used in carefully designed cocktails, can serve as a precise and eco-friendly antimicrobial intervention in the food production chain, potentially reducing the risk of transmission of MDR pathogens to humans. Moreover, the dual applicability of these phages to both foodborne and clinically isolated *A. baumannii* strains reinforces their potential in controlling infections that span both community and healthcare settings. In conclusion, the integration of lytic bacteriophage therapy into microbial quality control protocols may represent a transformative step in managing MDR pathogens in both the food industry and public health domains. Continued research, including genomic characterization of phages, in vivo validation, and safety profiling, will be essential to advance this approach toward regulatory approval and real-world application. This study contributes valuable laboratory-based evidence supporting bacteriophages as a viable complement or alternative to traditional antimicrobial treatments in an era of escalating antibiotic resistance.

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