BIOMA
p-ISSN: 0126-3552
e-ISSN: 2580-9032

DOI: 10.21009/bioma.v22i1.67435 Research article

Isolation and characterisation of lytic bacteriophages for biological control of *Salmonella* spp. (Enterobacteriaceae) in raw vegetables (*lalapan*)

Affan Gaffar[1]*, and Ziana Warsani[1]
[1]*Study Programme of Food Technology, Institut Teknologi dan Kesehatan Aspirasi, Anjani Suralaga street, Dusun Telaga Tampat No. Km 2, Suralaga, East Lombok Regency, West Nusa Tenggara, Indonesia, 83652.*
*Corresponding author: affangaffar19@gmail.com

ABSTRAK

Kontaminasi Salmonella spp. pada sayuran segar, khususnya yang dikonsumsi mentah tanpa perlakuan panas, merupakan risiko penting bagi keamanan pangan. Bakteriofag litik menjanjikan sebagai agen pengendali hayati karena kemampuannya melisis bakteri target secara spesifik. Penelitian ini bertujuan mengisolasi dan mengarakterisasi bakteriofag litik yang aktif terhadap Salmonella *spp. dari sayuran segar. Sampel selada (*Lactuca sativa*), terong (*Solanum melongena*), kubis (*Brassica oleracea *var.* capitata*), dan kemangi (*Ocimum basilicum*) dikumpulkan dari pasar lokal dan diproses menggunakan metode agar lapis ganda. Dua isolat bakteriofag berhasil diperoleh: SLSp dari selada dan TRSp dari terong, sedangkan tidak ditemukan plak pada sampel kubis maupun kemangi. Analisis kisaran inang menunjukkan kedua isolat hanya melisis* Salmonella *spp. tanpa aktivitas terhadap* Bacillus cereus*,* Escherichia coli*, atau* Staphylococcus aureus*. Isolat SLSp memiliki titer lebih tinggi (2,2 × 10⁵ PFU/mL) dibandingkan TRSp (8,9 × 10⁴ PFU/mL). Keduanya tetap aktif pada suhu 30°C dan pH netral, tetapi aktivitas litik menurun pada suhu 60–80°C serta kondisi pH ekstrem (2 dan 12). Temuan ini menunjukkan bahwa SLSp dan TRSp berpotensi dikembangkan sebagai agen biokontrol terhadap* Salmonella *pada pangan segar.*

Kata kunci: bakteriofag litik, biocontrol, keamanan pangan,* Salmonella *spp., sayur lalapan

ABSTRACT

Salmonella spp. contamination in fresh vegetables, particularly those consumed raw without heat treatment, poses a significant food safety risk. Lytic bacteriophages offer promise as biological control agents due to their ability to specifically lyse target bacteria. This study aimed to isolate and characterise lytic bacteriophages active against Salmonella spp. from raw vegetables. Samples of lettuce (*Lactuca sativa*), eggplant (*Solanum melongena*), cabbage (*Brassica oleracea* var. *capitata*), and basil (*Ocimum basilicum*) were collected from local markets and processed using the double-layer agar method. Two bacteriophage isolates were recovered: SLSp from lettuce and TRSp from eggplant, while no plaques were detected in cabbage or basil. Host range analysis revealed that both isolates lysed only *Salmonella* spp., with no activity against *Bacillus cereus*, *Escherichia coli*, or *Staphylococcus aureus*. SLSp exhibited a higher titer (2.2×10^5 PFU/mL) than TRSp (8.9×10^4 PFU/mL). Both isolates remained active at 30°C and neutral pH but showed reduced lytic activity at 60–80°C and under extreme pH conditions (2 and 12). These findings indicate that SLSp and TRSp are promising candidates for development as biocontrol agents against *Salmonella* in fresh foods.

Keywords: biocontrol, food safety, lytic bacteriophage, *Salmonella* spp., vegetables

INTRODUCTION

Vegetables are an important food source rich in vitamins, minerals, fiber, and bioactive compounds that support human health (Septembre-Malaterre et al., 2018). In Indonesia, the consumption of fresh vegetables, such as *lalapan*, is a deeply rooted culinary habit within the culture of the community. *Lalapan* typically consists of

various types of vegetables such as lettuce, basil, cabbage, and cucumber, which are served without any cooking process. The consumption of these raw vegetables offers the advantage of retaining their nutritional content, in contrast to cooked vegetables, which may experience a reduction in nutritional quality (Dias, 2012). Despite their high nutritional value, the consumption of raw vegetables is often associated with an increased incidence of foodborne diseases caused by contamination with pathogenic microorganisms (Mir et al., 2018). Such contamination may originate from various sources including manure, soil, waste, water, and wildlife (Kowalska, 2023; Osafo et al., 2022). In addition, handling processes such as washing, slicing, soaking, packaging, and preparing food are potential sources of contamination by pathogenic microorganisms, particularly enteric bacteria such as *Salmonella* spp. (Apriani et al., 2019). Vegetables are among the types of food that are easily contaminated by *Salmonella* spp. (Lund et al., 2000). Several studies have reported the presence of *Salmonella spp.* on raw, untreated vegetables, making them a potential source of foodborne disease transmission (Corredor-García et al., 2021; Rani & Tang, 2024). This risk is further increased by Salmonella's ability to adhere to vegetable surfaces, form biofilms, and survive in crevices or plant tissues that are difficult to reach with conventional cleaning processes (Palomares-Navarro et al., 2023).

Various efforts have been undertaken to reduce microbial contamination in vegetables, including washing with water, using chemical disinfectants, and storing under specific conditions. However, these methods are not always effective in eliminating *Salmonella*. Several studies have shown that *Salmonella* can persist even after washing and sanitisation, particularly when the bacteria have adapted to plant surfaces or form biofilms (Siahaan, 2010). Furthermore, excessive use of chemical sanitisers may adversely affect product quality and raise concerns about chemical residues on fresh produce (Gadelha et al., 2019).

The potential of bacteriophages as food biocontrol agents has been demonstrated in various food products, particularly for controlling pathogenic bacteria such as *Salmonella* (Gaffar & Suryani, 2022). In fresh horticultural products, bacteriophages have been reported to significantly reduce *Salmonella* populations on fresh tomatoes and melons (Leverentz et al., 2001). Similar findings were reported by Wong et al. (2020), who demonstrated that a lytic bacteriophage cocktail effectively reduced *Salmonella enterica* populations on postharvest romaine lettuce and melons. These findings highlight the considerable potential of bacteriophages as a biological control strategy for fresh fruits and vegetables. In addition to effectively suppressing target bacterial populations, the application of bacteriophage cocktails in horticultural products has been reported to have no adverse effects on product quality or beneficial non-target microflora (Sillankorva et al., 2012) Beyond fruits and vegetables, bacteriophage applications have also been developed for animal-derived food products. In egg products, bacteriophages have been shown to effectively control *Salmonella Enteritidis* on eggshell surfaces and in liquid egg products, indicating their potential as a biopreservation strategy to enhance food safety (Wang et al., 2025).

Based on these previous studies, the application of bacteriophages to fresh raw vegetables (*lalapan*) in this study represents a development and modification of the

DOI: 10.21009/bioma.v22i1.67435

biocontrol concept that has been applied to various fresh food commodities. The main difference lies in the source of the bacteriophage isolates, which were obtained directly from the natural environment of fresh raw vegetables, as well as in the target application, which focuses on *Salmonella spp.* isolates that have the potential to contaminate vegetables commonly consumed raw. Therefore, this study not only evaluates the potential of bacteriophages as biocontrol agents but also provides information on the characteristics of local bacteriophages that may be further developed to enhance the microbiological safety of fresh raw vegetables.

METHODOLOGY

Bacteriophage isolation

Fresh vegetable samples consisted of four species: lettuce (*Lactuca sativa*), cabbage (*Brassica oleracea* var. *capitata*), basil (*Ocimum basilicum*), and eggplant (*Solanum melongena*). Sample selection was carried out purposively in the traditional market, based on the physical condition of the vegetables: they had to be fresh, free from spoilage, non-slimy, and without severe mechanical damage. The samples were then placed in sterile plastic bags, stored in a cool box to maintain temperature stability during transportation, and immediately transported to the Microbiology Laboratory, Faculty of Food Technology and Agroindustry (FATEPA), University of Mataram, for analysis.

Before the bacteriophage isolation process, fresh vegetable samples were cleaned of adhering coarse debris without washing with disinfectants to prevent the reduction of naturally occurring bacteriophages. Each sample was then aseptically cut into small pieces using sterile equipment to increase the surface area in contact with the extraction medium. Subsequently, each sample was immersed in 100 mL of SM buffer and incubated for 24 hours at 4 °C to facilitate the release of bacteriophage particles from the vegetable tissue surface into the solution. After incubation, the samples were transferred into centrifuge tubes and centrifuged at 10,000 rpm for 20 minutes at 4 °C to obtain the supernatant. The supernatant was collected and filtered through a 0.45 µm membrane to obtain the sample filtrate (Tan et al., 2021).

The presence of bacteriophages in the samples was analysed using the double-layer agar method. As the bottom layer, 10 mL of Tryptic Soy Agar (TSA) containing 2.25 mM $CaCl_2$ was poured into a petri dish. A total of 100 µL of early log-phase *Salmonella* sp. culture was transferred into a microtube, followed by the addition of 100 µL of sample filtrate. The mixture was then incubated at 37 °C for 20 minutes. After incubation, the mixture was added to 4 mL of 0.6% TSA containing 2.25 mM $CaCl_2$, and the tube was gently shaken to homogenise. The suspension was subsequently poured onto the surface of the bottom agar layer and incubated at 37 °C for 24 hours. The formation of plaques or clear zones indicated the presence of lytic bacteriophage activity (Hardanti et al., 2018).

Bacteriophage stock preparation and confirmation test

All plaques formed on the top layer of agar were collected with a Drigalski and transferred to a centrifuge tube containing 30 mL of SM buffer and two drops of

DOI: 10.21009/bioma.v22i1.67435

chloroform. The addition of chloroform helps lyse the remaining host cells, allowing the bacteriophage to be removed. The suspension was slowly homogenised and centrifuged at 10,000 rpm for 10 minutes at 4°C. The supernatant was collected and filtered through a 0.45 µm Millipore filter to obtain the bacteriophage stock. The bacteriophage stock was stored in the refrigerator at 4°C. (Gaffar et al., 2024).

The successfully isolated bacteriophage was confirmed using the spot test method. A 100 µL culture of early log-phase *Salmonella* spp. in Tryptic Soy Broth (TSB) was taken, streaked onto TSA medium using a sterile cotton swab, and then allowed to dry at room temperature for 2 hours. A 5 µL stock of bacteriophage was spotted onto TSA medium previously inoculated with Salmonella sp. The suspension was incubated for 24 hours at 37 °C and observed for the formation of a clear zone (Jatmiko et al., 2018).

Bacteriophage host range test

The bacteriophage host range test used the spot test method on cultures of *Staphylococcus aureus, Bacillus cereus,* and *Escherichia coli*. 100 µL of each early log-phase host culture was taken, streaked evenly onto TSA medium, and allowed to dry at room temperature for 2 hours. Five µL of bacteriophage stock was spotted onto TSA medium that had been previously inoculated with host bacteria. Then, it was incubated at 37 °C for 24 hours. Observe the formation of a clear zone (Kinanti et al., 2025).

Determination of bacteriophage density

The bacteriophage density was determined using the serial dilution method. A total of 0.1 mL of bacteriophage stock was added to 0.9 mL of SM buffer to obtain dilutions up to 10^{-6}. From each bacteriophage dilution, 100 µL was taken and added to 4 mL of 0.6% TSA containing 100 µL of early log-phase *Salmonella* sp. culture, followed by homogenisation. The suspension was then poured into six Petri dishes containing 1.5% TSA and incubated at 37 °C for 24 hours. Plaques within the acceptable counting range (30–300) were observed and counted (Gaffar et al., 2024).

Characterisation of bacteriophages against temperature and pH

Bacteriophage characterisation regarding temperature was conducted by applying treatments at 30°C, 60°C, and 80°C, with room temperature (25°C) as the control. After temperature treatment, the stability and lytic activity of the bacteriophages were evaluated by their ability to form plaques (clear zones) on double-layer agar media, which served as an indicator of bacteriophage viability. Meanwhile, bacteriophage characterisation regarding pH was performed by applying pH treatments of 2, 8, and 12, with pH 7 as the control because it represents a neutral condition optimal for most bacteriophages. Observations were carried out on the ability of the bacteriophages to form plaques on the host bacteria after pH treatment, indicating the stability and infectivity activity of the bacteriophages (Huang et al., 2018; Jamal et al., 2015).

Data analysis techniques

DOI: 10.21009/bioma.v22i1.67435

The effects of bacteriophage temperature and pH on reducing *Salmonella* spp. Numbers were analysed quantitatively using One-Way ANOVA followed by Tukey's test at a 95% confidence interval. Statistical analysis of the data was performed using IBM SPSS 26 for Windows.

RESULTS AND DISCUSSION

The results showed that two bacteriophage isolates, SLSp (lettuce) and TRSp (eggplant), obtained from fresh vegetable samples, specifically lysed *Salmonella* sp. (**TABLE 1**). The observed plaque morphology showed nearly identical characteristics: small circular shapes (diameter ± 0.1 mm) evenly distributed across the medium's surface, although several plaques were observed near the edges of the medium (**FIGURE 1**). Plaque formation using the double-layer agar method confirms the presence of lytic activity, consistent with Gallet et al. (2011) observation that clear zones are the main indicator of phage effectiveness in infecting and lysing host bacterial cells.

TABLE 1. Results of bacteriophage isolation from raw vegetables

Number	Source	Isolate Code	Plaque Formation	
			Isolation	Stock
1.	Lettuce	SLSp	+	+
2.	Cabbage	KOSp	+	-
3.	Eggplant	TRSp	+	+
4.	Basil	KMSp	+	-

The absence of plaque formation in cabbage and basil samples indicated that lytic bacteriophages specific to *Salmonella* were not detected on these two types of vegetables. This condition may be associated with the low abundance or absence of suitable host bacteria on the vegetable surfaces, as the presence and abundance of bacteriophages in nature are highly dependent on the availability of target bacteria for replication (Naureen et al., 2020). In addition, the microecological characteristics of each vegetable may influence the occurrence of bacteriophages. Cabbage has a compact and layered leaf structure that can create a distinct microenvironment compared to other vegetables. In contrast, basil is known to contain natural antimicrobial compounds, such as eugenol and linalool, which may inhibit the growth of various microorganisms, including the host bacteria required to sustain bacteriophage populations (Duman et al., 2010). Environmental factors during cultivation, harvesting, and distribution, including irrigation water quality, humidity, temperature, and ultraviolet radiation exposure, may also affect the survival and persistence of bacteriophages on vegetable surfaces (Iriarte et al., 2007).

DOI: 10.21009/bioma.v22i1.67435

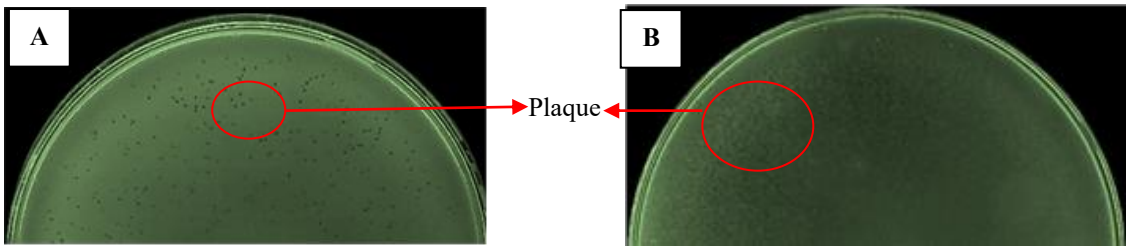

FIGURE 1. Results of bacteriophage isolation (A. SLSp isolate; B. TRSp isolate) that infects *Salmonella* sp.

The narrow host range exhibited by both isolates is likely associated with the high specificity of interactions between bacteriophages and their bacterial hosts (Jia et al., 2023). The bacteriophage infection process begins with the recognition of specific receptors on the bacterial cell surface; therefore, differences in receptor structures among *Bacillus cereus*, *Escherichia coli*, and *Staphylococcus aureus* may prevent bacteriophage adsorption and subsequent infection (Dunne et al., 2021). Furthermore, various bacterial defense mechanisms, such as surface receptor modification, restriction-modification systems, and CRISPR-Cas systems, may also limit the success of bacteriophage infection (Hyman & Abedon, 2010).

TABLE 2. Host Range Test

No	Bakteriofag Isolate	Host Range			
		Salmonella sp.	***B. cereus***	***E. coli***	***S. aureus***
1	SLSp	+	-	-	-
2	TRSp	+	-	-	-

This finding confirms that the obtained bacteriophages are highly specific, and such specificity is advantageous for food safety because it does not disrupt beneficial microbiota, as reported by McCallin et al. (2013), who stated that phages generally do not cause negative effects on eukaryotic cells or non-target bacteria. These findings are also consistent with the study of Kinanti et al. (2025), which reported similar characteristics of lytic phages with a narrow host range.

Furthermore, differences were observed between the two isolates in their bacteriophage densities. The density of bacteriophage SLSp (2.2×10^5 PFU/mL) was higher than that of TRSp (8.9×10^4 PFU/mL), indicating that the SLSp phage has better replication ability and infectivity against *Salmonella* sp. This variation may be caused by genetic factors of the phage as well as the suitability of environmental conditions for the host bacteria. This is consistent with the findings of Ranveer et al. (2024), who showed that bacteriophages may be unable to lyse their hosts due to differences in environmental conditions, faster host growth, and natural defence mechanisms against bacteriophage infection. The number of plaques is also influenced by the bacteria's specificity. Viruses that fail to infect bacteria may result from bacteriophage particles produced during infection that possess incomplete structural components (Lauman & Dennis, 2021; Brachelente et al., 2023). Based on the bacteriophage density measurements, calculations were performed following the requirement of 25–250 plaques.

After determining the basic characteristics and infection capability of the bacteriophages, the next step was to evaluate their stability against environmental

DOI: 10.21009/bioma.v22i1.67435

factors such as temperature and pH. The temperature resistance test showed that both isolates were most stable at 30 °C and experienced a drastic decline in viability at high temperatures (60–80 °C). At 80 °C, no plaques were observed with either isolate, indicating that the phage particles had been completely inactivated (**FIGURE 2**). This phenomenon is consistent with the explanations by Ahmadi et al. (2017), who reported that phage capsid proteins are highly susceptible to denaturation at high temperatures, leading to loss of virion integrity and inability to infect host bacteria. This denaturation typically involves the disruption of non-covalent bonds that maintain the capsid's conformation, resulting in the loss of the phage's ability to adsorb and inject its genetic material.

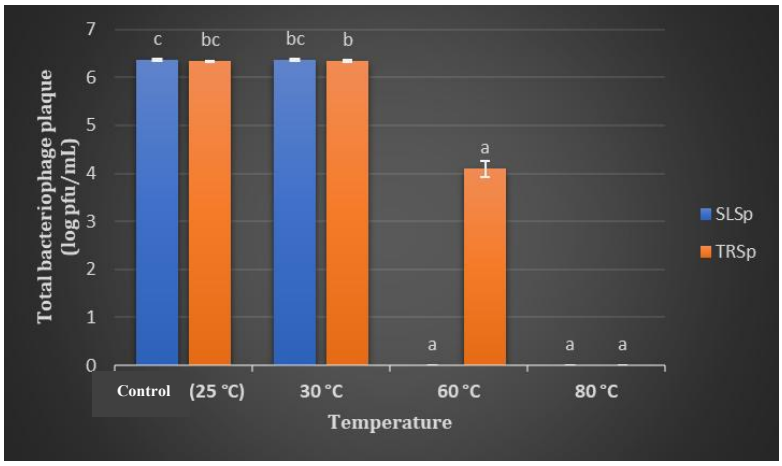

FIGURE 2. Characterisation of bacteriophages SLSp and TRSp against temperature

The optimal temperature range of approximately 30–37 °C is also consistent with Salmonella's natural habitat, allowing adsorption, replication, and assembly of phage particles to occur more efficiently within this range. These findings are consistent with other literature, including Ackermann (2006) and Jończyk et al. (2011), which emphasise that most non-thermophilic bacteriophages are rapidly inactivated at temperatures above 55–60 °C due to the instability of their structural proteins.

In addition to temperature, pH is another environmental factor that determines bacteriophage stability. The characterisation results showed that both phages were stable at neutral pH 7, but their activity decreased at acidic pH 2 and at moderately alkaline pH 8. At extreme pH 12, both isolates completely lost their lytic activity (**FIGURE 3**). The instability pattern of phages under strongly acidic and extremely alkaline conditions has previously been reported by Jamal et al. (2015) and Huang et al. (2018), who explained that extreme conditions may damage the integrity of phage genetic material and the capsid structure. In addition, studies by Jończyk et al. (2011) and Ślopek et al. (1983) also showed that most bacteriophages have a relatively narrow pH tolerance range, with optimum stability under neutral to slightly alkaline conditions.

DOI: 10.21009/bioma.v22i1.67435

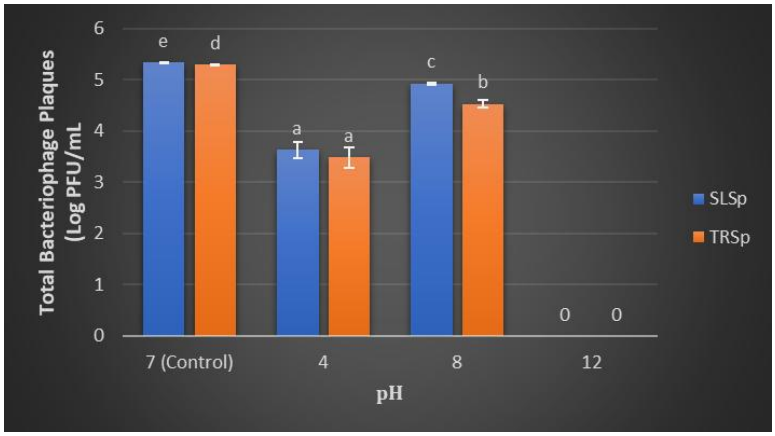

FIGURE 3. Characterisation of bacteriophages SLSp and TRSp against pH

The stability of these phages at neutral to slightly alkaline pH suggests that both isolates are potentially suitable for applications in fresh foods, including raw vegetables, which generally have a pH close to neutral. This is consistent with the report of Hyman & Abedon (2010), which emphasised that environmental stability is a key factor in the successful application of phages in food matrices.

These findings highlight the great potential of bacteriophages as biocontrol agents to reduce Salmonella contamination in fresh vegetables. According to Ranveer et al. (2024), the use of phages in food systems can serve as a safe and environmentally friendly alternative to antibiotics or chemical disinfectants. In addition, the ability of phages to replicate when they encounter their host allows their effectiveness to be maintained on contaminated food surfaces (Abedon, 2008; Fortier & Moineau, 2009).

Overall, this study demonstrates that bacteriophages SLSp and TRSp possess characteristics that support their use as biological control agents against *Salmonella* spp. in fresh vegetables. However, further studies, such as phage genome identification, long-term storage stability, and industrial-scale application testing, are required before they can be commercially implemented.

CONCLUSIONS

This study successfully isolated two lytic bacteriophages from raw vegetables, designated SLSp and TRSp, which effectively lysed *Salmonella* sp. and exhibited high specificity without affecting nontarget bacteria. The SLSp isolate exhibited a higher titer than TRSp, indicating that more infectious bacteriophage particles were produced or remained viable during the assay. However, this difference in titre does not directly reflect the bacteriophages' infectivity, as infectivity is also influenced by phage replication efficiency and phage particle survival. Both bacteriophages were stable at 30 °C and under neutral pH conditions but lost activity at elevated temperatures and extreme pH levels. The lytic characteristics, host specificity, and stability under certain conditions indicate that both isolates have promising potential for further development as candidate biocontrol agents against *Salmonella* sp. However, their effectiveness in real food products still needs to be demonstrated through further studies.

ACKNOWLEDGMENTS

DOI: 10.21009/bioma.v22i1.67435

The authors would like to express their deepest gratitude to Direktorat Jenderal Riset dan Pengembangan (Ditjen Risbang) for the financial support provided through the Penelitian Dosen Pemula (PDP) Grant Scheme for the 2025 fiscal year. This funding has greatly contributed to completing the research and publishing its results.

Conflicts of interest statement

There are no conflicts to declare.

Ethical compliance

This study did not involve human participants or animal experimentation. All bacteriophages were isolated from naturally occurring plant samples collected from local markets, and the bacterial strains used were standard laboratory cultures. As such, no ethical approval was required. The research was conducted in accordance with accepted microbiological laboratory practices and biosafety guidelines.

REFERENCES

Abedon, S. T. (2008). *Bacteriophage Ecology: Population Growth, Evolution, and Impact of Bacterial Viruses*. Cambridge University Press.

Ackermann, H.-W. (2006). Classification of bacteriophages. In R. Calendar (Ed.), *The bacteriophages* (2nd ed., pp. 8–16). Oxford University Press. https://doi.org/10.1093/oso/9780195148503.003.0002.

Ahmadi, H., Radford, D., Kropinski, A. M., Lim, L. T., & Balamurugan, S. (2017). Thermal-stability and reconstitution ability of Listeria phages P100 and A511. *Frontiers in Microbiology*, *8*, 1–11. https://doi.org/10.3389/fmicb.2017.02375.

Apriani, L., Rahmawati, R., & Kurniatuhadi, R. (2019). Deteksi Bakteri Salmonella dan Shigella Pada Makanan Burger di Sungai Raya Dalam Pontianak. *Jurnal Protobiont*, *8*(3), 53–57. https://doi.org/10.26418/protobiont.v8i3.36836.

Brachelente, S., Galli, A., & Cervelli, T. (2023). Yeast and Virus-like Particles: A Perfect or Imperfect Couple? *Applied Microbiology*, *3*(3), 805–825. https://doi.org/10.3390/applmicrobiol3030056.

Corredor-García, D., García-Pinilla, S., & Blanco-Lizarazo, C. M. (2021). Systematic Review and Meta-analysis: Salmonella spp. prevalence in vegetables and fruits. *World Journal of Microbiology and Biotechnology*, *37*(3), 1–14. https://doi.org/10.1007/s11274-021-03012-7.

Dias, J. S. (2012). Nutritional Quality and Health Benefits of Vegetables: A Review. *Food and Nutrition Sciences*, *03*(10), 1354–1374. https://doi.org/10.4236/fns.2012.310179.

Fortier, L. C., & Moineau, S. (2009). Phage production and maintenance of stocks, including expected stock lifetimes. In *Methods in molecular biology (Clifton, N.J.)* (Vol. 501). https://doi.org/10.1007/978-1-60327-164-6_19.

Gaffar, A., & Suryani, E. M. (2022). Bakteriofag Dan Aplikasi Dalam Mengendalikan Bakteri Patogen Untuk Meningkatkan Keamanan Pangan. *Bioma, 18*(2), 42-48. https://doi.org/10.21009/Bioma18(2).1.

Gaffar, A., Jatmiko, Y. D., & Prihanto, A. A. (2024). Isolation and Characterization of

DOI: 10.21009/bioma.v22i1.67435

Salmonella Typhimurium Lytic Bacteriophages from Fermented Shrimp Paste (Terasi). *AIP Conference Proceedings*, *3001*(1), 1–9. https://doi.org/10.1063/5.0183898.

Gallet, R., Kannoly, S., & Wang, I. N. (2011). Effects of bacteriophage traits on plaque formation. *BMC Microbiology*, *11*(1), 181. https://doi.org/10.1186/1471-2180-11-181.

Hardanti, S., Wardani, A. K., & Putri, W. D. R. (2018). Isolasi dan karakterisasi bakteriofag spesifik *Salmonella Typhi* dari kulit ayam. *Jurnal Teknologi Pertanian, 19*(2), 107–116. https://doi.org/10.21776/ub.jtp.2018.019.02.5.

Huang, C., Virk, S. M., Shi, J., Zhou, Y., Willias, S. P., Morsy, M. K., Abdelnabby, H. E., Liu, J., Wang, X., & Li, J. (2018). Isolation, characterization, and application of Bacteriophage LPSE1 against Salmonella enterica in Ready to Eat (RTE) Foods. *Frontiers in Microbiology*, *9*, 1–11. https://doi.org/10.3389/fmicb.2018.01046.

Hyman, P., & Abedon, S. T. (2010). Chapter 7 - Bacteriophage Host Range and Bacterial Resistance. In *Advances in Applied Microbiology* (1st ed., Vol. 70, Issue 10). Elsevier Inc. https://doi.org/10.1016/S0065-2164(10)70007-1.

Jamal, M., Hussain, T., Das, C. R., & Andleeb, S. (2015). Isolation and characterization of a Myoviridae MJ1 bacteriophage against multi-drug resistant Escherichia coli 3. *Jundishapur Journal of Microbiology*, *8*(11), 1–8. https://doi.org/10.5812/jjm.25917.

Jatmiko, Y. D., Purwanto, A. P., & Ardyati, T. (2018). Uji Aktivitas Bakteriofage Litik dari Limbah Rumah Tangga Terhadap Salmonella Typhi. *Jurnal Biodjati*, *3*(2), 36–49. https://doi.org/10.15575/biodjati.v3i2.3471.

Jończyk, E., Kłak, M., Międzybrodzki, R., & Górski, A. (2011). The influence of external factors on bacteriophages: A review. *Folia Microbiologica, 56*(3), 191–200. https://doi.org/10.1007/s12223-011-0039-8.

Kinanti, A. S., Prihanto, A. A., & Jatmiko, Y. D. (2025). Host Range of Lytic Bacteriophages as Biocontrol Agents for Pathogenic Bacteria Causing Foodborne Illnesses in the Vannamei Shrimp *(Litopenaeus vannamei*). *Egyptian Journal of Aquatic Biology and Fisheries*, *29*(1), 1393–1407. https://doi.org/10.21608/ejabf.2025.410648.

Kowalska, B. (2023). Fresh vegetables and fruit as a source of Salmonella bacteria. *Annals of Agricultural and Environmental Medicine*, *30*(1), 9–14. https://doi.org/10.26444/aaem/156765.

Lauman, P., & Dennis, J. J. (2021). Advances in phage therapy: Targeting the Burkholderia cepacia complex. *Viruses*, *13*(7). https://doi.org/10.3390/v13071331.

Lund, B. M., Baird-Parker, T. C., & Gould, G. W. (2000). *Microbiological safety and quality of food (Vol. 1)*. Springer Science & Business Media.

Rani, H. A. M., & Tang, J. Y. H. (2024). Salmonella contamination in raw vegetables: A review. *Journal Of Agrobiotechnology*, *15*(1), 37–43. https://doi.org/10.37231/jab.2024.15.1.386.

McCallin, S., Alam Sarker, S., Barretto, C., Sultana, S., Berger, B., Huq, S., Krause, L., Bibiloni, R., Schmitt, B., Reuteler, G., & Brüssow, H. (2013). Safety analysis of a Russian phage cocktail: From MetaGenomic analysis to oral application in healthy

DOI: 10.21009/bioma.v22i1.67435

human subjects. *Virology*, *443*(2), 187–196. https://doi.org/10.1016/j.virol.2013.05.022.

Mir, S. A., Shah, M. A., Mir, M. M., Dar, B. N., Greiner, R., & Roohinejad, S. (2018). Microbiological contamination of ready-to-eat vegetable salads in developing countries and potential solutions in the supply chain to control microbial pathogens. *Food Control*, *85*, 235–244. https://doi.org/10.1016/j.foodcont.2017.10.006.

Osafo, R., Balali, G. I., Amissah-Reynolds, P. K., Gyapong, F., Addy, R., Nyarko, A. A., & Wiafe, P. (2022). Microbial and Parasitic Contamination of Vegetables in Developing Countries and Their Food Safety Guidelines. *Journal of Food Quality*, *2022*. https://doi.org/10.1155/2022/4141914.

Ranveer, S. A., Dasriya, V., Ahmad, M. F., Dhillon, H. S., Samtiya, M., Shama, E., Anand, T., Dhewa, T., Chaudhary, V., Chaudhary, P., Behare, P., Ram, C., Puniya, D. V., Khedkar, G. D., Raposo, A., Han, H., & Puniya, A. K. (2024). Positive and negative aspects of bacteriophages and their immense role in the food chain. *Npj Science of Food*, *8*(1). https://doi.org/10.1038/s41538-023-00245-8.

Septembre-Malaterre, A., Remize, F., & Poucheret, P. (2018). Fruits and vegetables, as a source of nutritional compounds and phytochemicals: Changes in bioactive compounds during lactic fermentation. *Food Research International*, *104*, 86–99. https://doi.org/10.1016/j.foodres.2017.09.031.

Ślopek, S., Durlakowa, I., Weber-Dąbrowska, B. Kucharewicz-Krukowska, A., Dabrowski, M., & Bisikiewicz, R. (1983). Results of bacteriophage treatment of suppurative bacterial infections. *Archivum Immunologiae et Therapiae Experimentalis*, *31*(3), 293–237.

Tan, C. W., Rukayadi, Y., Hasan, H., Abdul-Mutalib, N. A., Jambari, N. N., Hara, H., Thung, T. Y., Lee, E., & Radu, S. (2021). Isolation and Characterization of Six Vibrio parahaemolyticus Lytic Bacteriophages From Seafood Samples. *Frontiers in Microbiology*, *12*(March), 1–13. https://doi.org/10.3389/fmicb.2021.616548.

DOI: 10.21009/bioma.v22i1.67435