

Biological Activity Of Bacteriocin Produced By *Lactobacillus Pentosus* Isolated From Fermented Milk

Faiza Zubair*

Department of Zoology, University of Sargodha, Pakistan
faiza.zubair@uos.edu.pk

Saima Arshad

Department of Zoology, University of Sargodha, Pakistan

Naila Riaz

Department of Zoology, University of Sargodha, Pakistan

Rida Imtiaz

Department of Zoology, University of Sargodha, Pakistan

Sadia Zafar

Department of Zoology, University of Sargodha, Pakistan

ABSTRACT

Isolated lactic acid bacteria (LAB) from a variety of foods are significant because they have the ability to suppress microorganisms, including bacteria that are resistant to drugs. The objectives of this research were to isolate and identify antibacterial substances producing LAB from fermented milk (yogurt) and to optimize the production of bacteriocin present in cell free supernatant (CFS) against bacterial strains responsible for food borne illness. For current studies *Lactobacillus pentosus* was isolated from yogurt by serial dilutions and grown on nutrient agar. Agar well diffusion assay was used to study antibacterial activity of bacteriocin against *E. coli*, *Bacillus subtilis*, *Bacillus cereus* and *Staphylococcus aureus*. The zone of inhibition was measured to track antibacterial activity. Different range of temperature (40°C, 60°C, 80°C, 100°C and 120°C), pH (3, 5, 7, 9 and 11) and concentrations (25mg/ml, 50mg/ml, 75mg/ml, 100mg/ml) of bacteriocin were investigated in relation to cell free supernatant (CFS) activity. Bacteriocin showed maximum antibacterial effect against *B. subtilis* at 60°C which is 3 ± 0.10 and against *B. cereus* at pH 5 as 4.6 ± 2.08 and the concentration was 100mg/ml at which bacteriocin showed maximum antibacterial effect against *E. coli* as 2.8 ± 0.3 . On the other hand, minimum antibacterial effect was shown by bacteriocin against *S. aureus* at 120°C as 1.06 ± 0.2 and no effect was shown by bacteriocin at pH 11. 50mg/ml showed minimum antibacterial effect which is 1.0 ± 0.32 . The action of bacteriocin was compared with antibiotic Amoxil (500mg) as a positive control. Mean values for zone of inhibition for variables under study were compared using one-way ANOVA. The outcomes of this study suggested that

bacteriocin's heat stability makes it possible for the food industry to employ it as preservative of food and to prevent poisoning caused by *B. cereus* and other pathogenic strains.

Keywords: Bacteriocin, Antibacterial, *L. Pentosus*, Fermented Milk, Zone Of Inhibition

Introduction

Bacteriocins are ribosomal produced peptides with antibacterial activity against closely related strains of bacteria. They are not only used as antibiotics but also act as natural preservatives for food (Cotter and Ross, 2013; Ahmad et al., 2023). The promising group of bacteria is Lactic acid bacteria that are used without any fear and are known as Probiotic (Sriphannam and Kummasook, 2020). When they are added in food, especially dairy products like yogurt and cheese, as supplements they cause many health benefits (Ghosh et al., 2019).

Bacteriocins belong to heterogenous class of bactericidal proteins or peptides produced by archaea and bacteria. Most of bacterial species produce at least one bacteriocin and most of them are unknown. The immunity associated with bacteriocins are due to special protein encoded in bacteriocin operon (bacterial genome). Bacteriocins belong to heterogenous class of bactericidal proteins or peptides produced by archaea and bacteria. Most of bacterial species produce at least one bacteriocin and most of them are unknown. The immunity associated with bacteriocins are due to special protein encoded in bacteriocin operon (bacterial genome) (Darbandi et al., 2022).

Usually bacteriocins are classified into four distinct classes according to their molecular weight. These are Class I, Class II, Class III and Class IV bacteriocins (Dai et al., 2021; Bilal, 2021). Gram-negative and positive both produce bacteriocin. Those from Gram-positive bacteria are of particular interest because several strains which are industrially used are from this group, particularly LAB, generally recognized as safe (GRAS) (Zimina et al., 2020).

Bacteriocins are thermally stable and have wide range for pH. They are odourless, colourless which increase their potential and their uses are increased in different fields. Proteolytic enzymes digest them so they are having short life in human body and environment (Bilal et al., 2024). So, the interaction between target cell and degraded bacteriocins are reduced. Many bacteriocins were isolated earlier like acidocin, lactosin, nisin, pediocin, plantaricin, sakacin and curvacin. In dairy products, fruits, vegetables, wine and meat nisin has been used as biopreservative. Its antimicrobial activity was shown in cheese against *S. aureus*, *B. cereus*, *B. subtilis* (Bilal, 2021; Darbandi et al., 2022).

Agar well diffusion assay was used to study antibacterial activity against *E. coli*, *Bacillus subtilis*, *Bacillus cereus* and *Staphylococcus aureus*. The zone of inhibition was measured to track antibacterial activity. Different range of temperature (40°C, 60°C, 80°C, 100°C and 120°C), pH (3, 5, 7, 9 and 11) and concentrations (25mg/ml, 50mg/ml, 75mg/ml, 100mg/ml) of bacteriocin were investigated in relation to cell free supernatant (CFS) activity. Bacteriocin's heat stability makes it possible for the food industry to employ it as preservative of food and to prevent poisoning caused by *B.*

cereus and other pathogenic strains. The action of bacteriocin was compared with antibiotic Amoxil (500mg) as a positive control.

Materials and Methods

Sampling: Yogurt was taken from Sargodha market. It was closed in tight jar to avoid any contamination. Anaerobic condition was provided. Sample was used to isolate, identify and biochemically characterize the *Lactobacillus* by serial dilutions. Nutrient agar plates were used to maintain the bacterial strain following Xin et al., 2022. When the plates were ready, spreading and streaking of diluted sample was done. Plates were incubated for 24 hours at 37°C under anaerobic conditions. These plates having colonies of bacteria were further used for the morphology of colony (shape, size, margins, color, texture, elevation, etc). For biochemical characterization, the biochemical tests (gram staining, oxidase test, catalase test, sugar fermentation test) were performed for their characterization.

Isolation of crude bacteriocin:

Isolated *Lactobacillus* strain was inoculated in the autoclaved MRS broth with the help of inoculating loop. The inoculated broth was incubated for 48 hours under anaerobic conditions at 37° C. After the incubation period, the broth was centrifuged at 6000 rpm for 20 minutes. To counteract the effects of organic acids, filtered CFS was further treated with 1M NaOH. A 0.22 µm millipore cellulose acetate filter was used to filter the cell-free supernatant. CFS's pH was changed to be 7. Similarly, to counteract the inhibitory effects of H₂O₂, neutral CFS was given catalase treatment and incubated at 37° C for 2 hours. For the purpose of examining the antibacterial activity against the test strains, this CFS was utilized as crude bacteriocin. To investigate the protein components in CFS, two preliminary protein detection tests were carried out. These tests comprised the ninhydrin and biuret tests. To further demonstrate the proteinaceous nature of the antibacterial compounds in CFS, it was treated with the proteinase K enzyme and incubated for 2 hours at 37° C. CFS treated with enzymes after a 2-hour incubation period was heated for 5 minutes at 100° C to denature the activity of the enzymes (Mercado & Olmos., 2022).

Purification of Bacteriocin

50 ml of fermentation broth was added to 5 tiny beakers after centrifugation at 40 C. After coding, it was put in an ice box with chilly air. Different amounts of ammonium sulfate were added to these 5 little beakers to create saturation concentrations of 40%, 50%, 60%, 70%, and 80%, respectively. After thorough stirring, ammonium sulphate was added and completely dissolved. The protein content of the supernatant was determined following centrifugation for 10 minutes at 40 °C and precipitation with various amounts of ammonium sulfate. The precipitates were re-suspended in deionized water to test the precipitates' bacteriostatic effectiveness. Finally, 70% of the ammonium sulphate concentration caused precipitation (Cui et al., 2020).

Characterization of Bacteriocin:

Temperature:

Anti-bacterial effect of bacteriocin was checked at different temperature range; 40°C,

60⁰C, 80⁰C, 100⁰C and 120⁰C. Bacteriocin was heated in a water bath for half hour at these temperatures and then its anti bacterial potential against pathogenic strains were checked.

PH:

Anti-bacterial effect of bacteriocin was checked at different p H like 3,5,7,9 and 11. pH of bacteriocin was set at these p H and their antibacterial potential was checked at these pH. 1Molar solutions of acid and base were prepared and p H of bacteriocin was adjusted at these pH and then anti bacterial potential against pathogenic strains were checked.

Concentration:

The anti-bacterial effect of bacteriocin was checked at different concentrations. 25%, 50%, 75% and 100% solutions of bacteriocin were made. 25% solution was made by addition of de-ionized water and bacteriocin in ratio of 4:1. 50% solution was made by putting de-ionized water and bacteriocin in ratio of 2:1. 75% solution was made by mixing de-ionized water and bacteriocin at ratio of 4:3.

Fourier transform infrared (FTIR):

FTIR is used to get emission or absorption spectrum for solid, liquid or gas. It can helpful in detection of functional groups in organic compounds. The instrument of FTIR was perfected by Albert Michelson in 1887, who used it for several times for measuring relativity and light.

RESULTS

Study of Test strain

The strain had size of 0.7-1µm diameter and shape was rod like. Its margins were wavy and color was grayish to white. Elevation was shown as convex and texture was dry. It was translucent. Based on these characters, strain was identified as *L. pentosus*.

Biochemical Characterization of *L. pentosus*:

For further confirmation of bacterial strain, biochemical testing was performed. The biochemical tests performed in this regard were Gram staining, Oxidase test, Catalase test, Sugar fermentation test, H₂S test and Methyl red test. Sugar fermentation test included testing like Glucose gas production, Lactose gas production Maltose gas production, Sucrose gas production and Arabinose gas production. These tests confirmed the strain as *L. Pentosus*.

Morphological study of Test strains

The bacterial strains were gathered through sampling, and their examination was done in order to be recognized and given morphological characterization. In order to identify the strain being tested, size, shape, quantity, margin, color, elevation, texture, and opacity were examined.

The size of the first test strain which we studied was 2-3µm. Its shape was observed as rod-like. Margin was undulate (wavy). Its color was milky white. Elevation was observed as flat. When its texture was examined, it was noticed as dry or rough. This

strain was opaque. All these characteristics led to the identification of strain as *B. subtilis*.

The second test strain studied was 1µm in diameter. Its shape was observed as circular. Number of individual cells in the sample was 85. Its margin was entire. Its colour was golden yellow. Elevation was observed convex. Its texture was rough. This strain was opaque. All these characteristics led to the identification of strain as *S. aureus*.

The size of the third test strain studied was 3-4µm. Its shape was rod-like. Its margin was undulate (wavy) and was of pinkish orange color. Elevation was observed to be circular. When its texture was observed, it was noticed that it forms a smooth colony initially, which changes into a rough colony later on. This strain was opaque. All these characteristics led to the identification of strain as *B. cereus*.

The size of the fourth test strain studied was 0.25-1.0µm. Its shape was observed circular. It had an entire margin. It was colorless and was non-pigmented, that is why it gave a transparent appearance. Elevation was observed raised. When its texture was examined, it was smooth and shiny. All these characteristics led us to the identification of strain as *E. coli*.

Antibacterial effect of crude bacteriocin

Crude bacteriocin showed zone of inhibition against selected bacterial strains. This bacteriocin was not purified. Mean values were compared and P value calculated by ANOVA. P value was found significant for *B. subtilis*, *B. cereus* and *E. coli* (table 1).

Purified bacteriocin showed zone of inhibition against selected bacterial strains. Mean values were compared and P value calculated by ANOVA. P value was observed significant for *S. aureus*, *B. cereus* and *E. coli* (table 1). Amoxicillin (500mg) was used as positive control.

Table 1: Antibacterial effect of bacteriocin compared with amoxicillin

Bacterial Strains	Crude Extract		Purified Extract		Amoxicillin (500mg)	
	Zone of Inhibition	p Value	Zone of Inhibition	p Value	Zone of Inhibition	p Value
<i>Bacillus subtilis</i>	2.3±0.49	0.03**	2.0±0.21	0.188	2.2±0.25	0.014
<i>Staphylococcus aureus</i>	2.4±0.41	0.48	1.36±0.12	0.001**	2.1±0.20	0.010
<i>Bacillus cereus</i>	2.13±0.26	0.02**	1.8±0.08	0.013**	2.1±0.08	0.003
<i>Escherichia coli</i>	2.63±0.32	0.00***	1.4±0.18	0.023**	1.8±0.69	0.009

Mean± SD (n=3). p≤0.05=significant*, **, ***, p≥0.05=non-significant

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>**Antibacterial effect of bacteriocin at different temperatures**

Bacteriocin showed zones of inhibition at different range of temperature as shown in figure 1. *S. aureus*, *B. subtilis*, and *B. cerus* showed zone of inhibition at all treating temperature. These pathogenic strains were found thermally resistant and zones were formed at all temperatures. By comparing means of all temperatures, the results were observed non significant for *B. cerus* and *B. subtilis* and non-significant for *S. aureus* and *E. coli*.

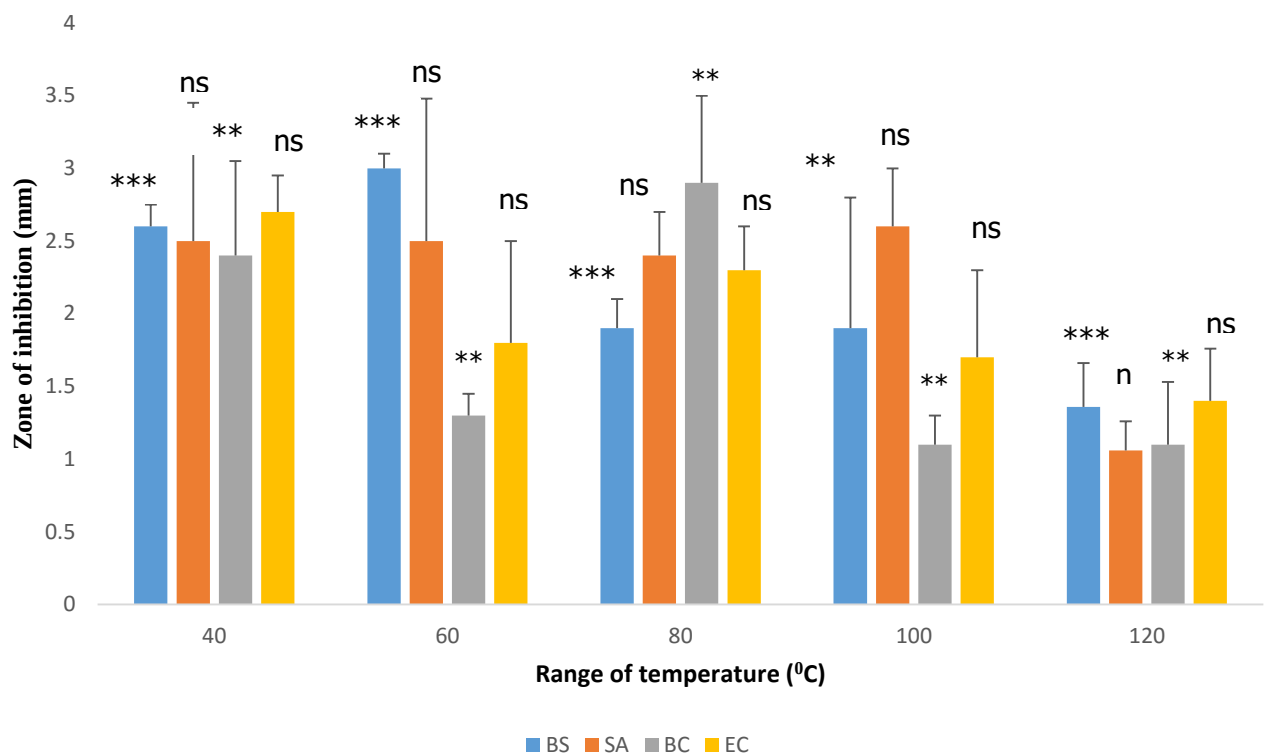


Figure 1: Antibacterial effect of bacteriocin at variable temperature range; mean bars with standard deviation, P value was computed using ANOVA, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$; ****, $p < 0.0001$; ns, no significant difference

Antibacterial effect of bacteriocin at different pH

The antibacterial effect of bacteriocin was examined by altering 5 different ranges of pH as shown in Figure 2. The pathogenic strains *S. aureus*, *B. subtilis*, *B. cerus* and *E. coli* showed more zone of inhibition at acidic and neutral pH as compared to basic pH. By comparing the means of all the values of pH, P value was found to be non-significant for all the pathogenic strains.

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

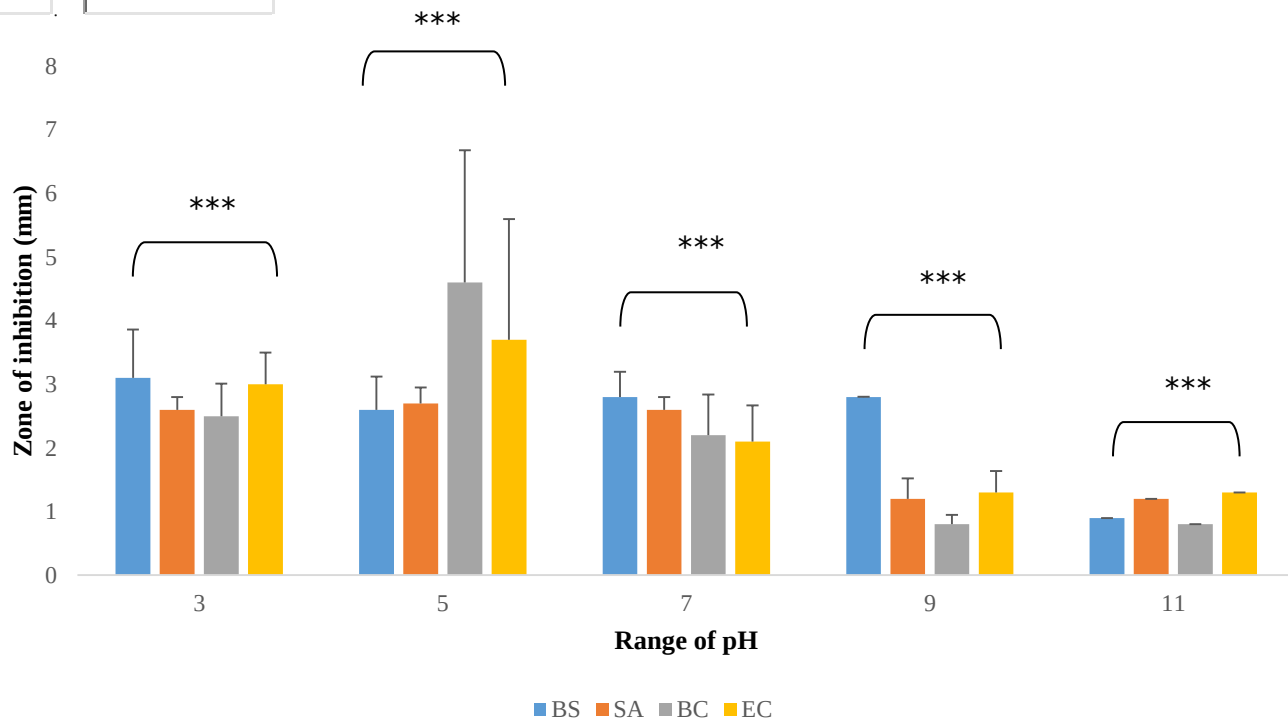


Figure 2: Antibacterial effect of bacteriocin at variable pH range; mean bars with standard deviation, P value was computed using ANOVA, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$; ****, $p < 0.0001$; ns, no significant difference

Antibacterial effect at different concentrations

Bacteriocin showed different zones of inhibition at four alternating concentrations. More zones were formed when 50% solution of bacteriocin. Mean values were compared and P value calculated which was found significant for *S. aureus*, *B. subtilis*, *B. cereus* and *E. coli*. (Figure 3)

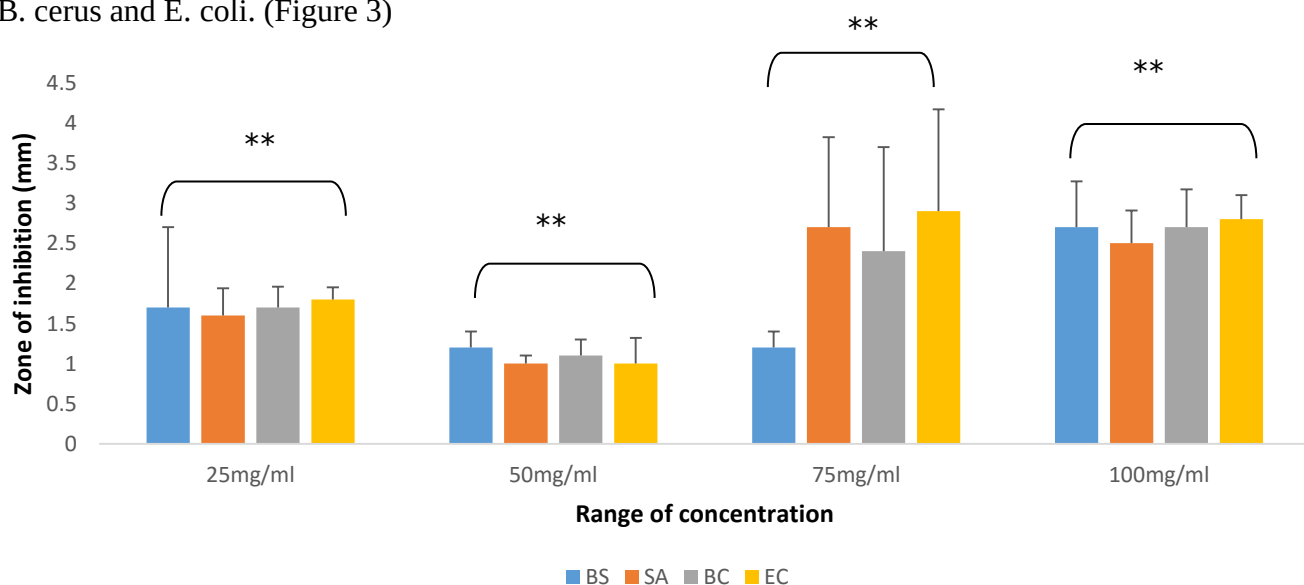


Figure 3: Antibacterial effect of bacteriocin at variable Concentrations; mean bars with

standard deviation, P value was computed using ANOVA, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$; ****, $p < 0.0001$; ns, no significant difference

Results of FTIR

The FTIR spectrum of bacteriocin from *L. pentosus* is shown in table 2 and figure 4. The shift of bacteriocin towards low frequency absorbance was noticed as 3280 cm^{-1} . This absorbance shift band indicated adsorption of water molecule. Moreover, deformation in 2117 cm^{-1} shows $\text{C}\equiv\text{N}$ O changes occur. The shift 1632 which is between $1500\text{--}1700\text{ cm}^{-1}$ indicates the change of NH^+

Table 2 Results of FTIR

Peak Number	Wavenumber (cm^{-1})	Intensity
1	417.46184	24.64152
2	1632.57397	64.05532
3	2117.12789	96.01632
4	3280.05730	44.07728

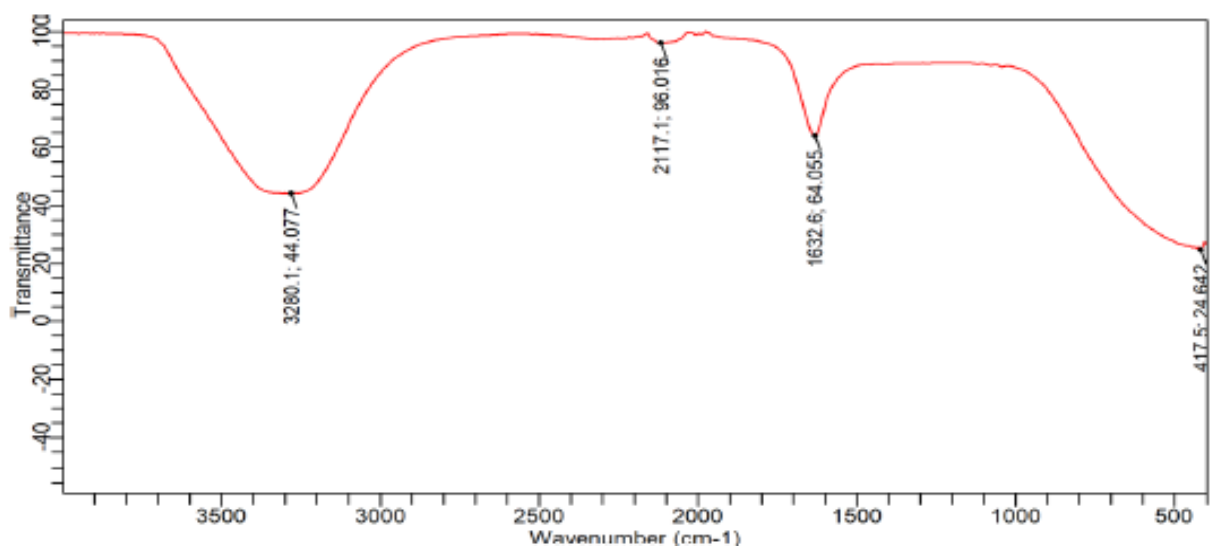


Figure 4: Graph showing results of FTIR against wavelength and transmittance.

Discussion

This research was conducted to evaluate the antibacterial effect of *L. pentosus* against the selected pathogenic strains and to evaluate how *L. pentosus* inhibits the growth of

these strains. Depending on the morphological, biochemical and molecular characterization, strains were identified as *L. pentosus*, *S. aureus*, *B. subtilis*, *B. cerus* and *E. coli*. The growth in anaerobic conditions of on MRS agar plates, further confirmed their identification as *Lactobacillus*. You et al. (2020) also isolated *Lactobacillus* strains on MRS media. Oxidase, catalase, sugar fermentation and gram staining tests results were similar to results of Chavan et al. (2022) and Mushtaq et al. (2025).

Bacteriocins require various separation and purifying procedures. Similar to Virk et al. (2022), bacteriocin was isolated using the ammonium sulphate precipitation method. We followed a similar process to Cui et al. (2020), which involved centrifuging at 40°C and then adding 50 ml of fermentation broth to 5 beakers which are small. After coding, it was placed in an ice box at a low temperature. Different concentrations of ammonium sulfate were added to these 5 beakers to create saturation concentrations of 40%, 50%, 60%, 70%, and 80%, respectively. Ammonium sulphate was put in and thoroughly mixed after being introduced. The protein content of the supernatant was determined following centrifugation for 10 minutes at 40 C and precipitation with various amounts of ammonium sulfate. For the purpose of evaluating the bacteriostatic action, the precipitates suspended in de-ionized water. Finally, precipitation reached 70% of the ammonium sulphate concentration.

Luo et al. (2021) and Noor et al. (2021) indicated that bacteriocin was able to stop growth of many bacteria. These findings are similar with present study because *Lactobacillus* has inhibited the growth of pathogenic strains. Manandhar et al. (2019) used well assay diffusion method to examine antagonistic activity of *Lactobacillus*. CFS from LAB which produce bacteriocin, inhibited the growth of pathogenic strains. In present study well assay diffusion method has shown the formation zone of inhibition due to antibacterial effect of *Lactobacillus* against *S. aureus*, *B. subtilis*, *B. cerus* and *E. coli*.

When considering how temperature affects antibacterial activity of *Lactobacillus* against different strains. These results of current study were similar to Pato et al. (2022) and Bilal (2021) who reported that bacteriocin is thermally resistant and showed zones of inhibition at even higher temperatures. The findings of the current study also demonstrated that inhibitory action of bacteriocin was not significantly affected by temperature changes.

Bacteriocin was heated for 30 min in water bath to examine effects of temperature on antibacterial effectiveness of bacteriocin like Peng et al. (2023). So, bacteriocin was heated and it was ready to observe its effects. Its agar well assay was done against our selected pathogenic strains.

The impact of pH on activity of bacteriocin was identified by Leslie et al. in (2021) produced by LAB. Their findings demonstrated that bacteriocin was effective throughout a broad pH range of 3–7. Compared to neutral and basic pH, bacteriocin has more antibacterial activity at an acidic pH. The activity was reduced at pH 8–11. In present study same technique was used to adjust pH. The results showed the similar trend as observed by Leslie et al. (2021).

Sebiomo et al., 2011 determined the effects of antibiotic against pathogenic bacteria including *S. aureus*. He noticed the significant effect on zone of inhibition. Our results

showed antibacterial effect against pathogenic strains. Xu et al. (2023) also noticed the antibacterial effect of bacteriocin against pathogenic strains like *E. coli* and *S. aureus*.

Conflict of interest: All authors declared that they have no conflict of interest.

Ethical approval: The study design followed the institutional guidelines for the animal care and experiment and was duly approved by concerned institutional body.

Consent to participate: All authors voluntarily participate in the study.

Consent to publish: The consent to the publication of manuscript was approved by all authors

Availability of data and materials: This published article contains all the generated data of this study

Author Contributions: all authors have equal contribution in this study

Funding: No funding was received for this work.

References

- Ahmad, R. Z., Khan, M. S., Bilal, A., Ali, U., & Sattar, R. Z. (2023). Effect of locus of control and depression among young adults in Multan (Pakistan). *Journal of Asian Development Studies*, 12(4), 684-692.
- Bilal, A. (2021). Clinical diagnosis and treatment of absence seizures: Case study. *MAR Ophthalmology*, 2(1).
- Bilal, A. (2021). Rabies is a zoonotic disease: a literature review. *Occup. Med. Health Aff*, 9(2).
- Chavan., Dharmapa., Khatoon, Halima., Anokhe., Archana., Kalia., & Vinay. (2022). Oxidase test: A biochemical method in bacterial identification. *AgriCos e-Newsletter*, 3(1), 131.
- Cotter, P.D., Ross, R.P., & Hill, C. (2013). Bacteriocins — a viable alternative to antibiotics? *Nature Review Microbiology*. 11:95–105.
- Cui, G., Pan, C., Xu, P., Li, Y., Wang, L., Gong, B., ...& Huang, S. (2020). Purification and characterization of a novel bacteriocin produced by *Enterococcus faecalis* CG-9 from human saliva. *Biotechnology & Biotechnological Equipment*, 34(1), 1224-1233.
- Dai, M., Li, Y., Xu, L., Zhou, Q., & Gu. (2021). A novel Bactericin from *Lactobacillus Pentosus* ZFM94 and its Antibacterial Mode of Action, 8(2), 710862.
- Darbandi, A., Asadi, A., Mahizade., & Ari, M. (2022). Bacteriocins: Properties and potential use as antimicrobials. *Journal of Clinical Laboratory Analysis*, 17(3), 189-190.
- Bilal, A., Anjum, M. I., Naveed, N., Saif-ur-Rehman, M., Ali, U., & Iftikhar, A. (2021). Impacts of abusing drugs on our society. *J Med Res Surg*, 2(3), 1-3.
- Galli, V., Venturi, M., Coda, R., Maina, N.H., & Granchi, L. (2020). Isolation and characterization of indigenous *Weissella confusa* for in situ bacterial exopolysaccharides (EPS) production in chickpea sourdough. *Food research international*, 138, 56.
- Ghosh T, A. Beniwal, A. Semwal., & N. K. Navani. (2019). Mechanistic insights into probiotic properties of lactic acid bacteria associated with ethnic fermented

- dairy products, *Frontiers in Microbiology*, 3(10), 50.
- Hossain, T.J. (2023). Methods for Screening and Evaluation of Antimicrobial Activity: A review of Protocols, Advantages and limitations. *Advantages and Limitations*, 24(2), 115–121.
- Leslie, V. A., Alarjani, K. M., Malaisamy, A., & Balasubramanian, B. (2021). Bacteriocin producing microbes with bactericidal activity against multidrug resistant pathogens. *Journal of Infection and Public Health*, 14(12), 1802-1809.
- Bilal, A., Tanvir, F., Ahmad, S., Shah, S. H. A., Ahmad, H. A., & Kanwal, N. (2024). Pre-clinical study of the bioactive compound Asiaticoside against the proteins inducing human mammary carcinoma using molecular docking and ADME analysis. *Remittances Review*, 9(2), 3543-3576.
- Luo, L., Yi, L., Chen, J., Liu, B., & Lü, X. (2021). Antibacterial mechanisms of bacteriocin BM1157 against *Escherichia coli* and *Cronobactersakazakii*. *Food Control*, 123, 107730.
- Manandhar, S., Luitel, S., & Dahal, R.K. (2019). In Vitro Antimicrobial Activity of some Medicinal plants against Human Pathogenic bacteria. *Journal of tropical medicine*, 14(1), 15-19.
- Mercado, V., & Olmos, J. (2022). Bacteriocin production by *Bacillus* species: Isolation, Characterization and Application. *Probiotics and antimicrobial proteins*, 14(6), 1151-1169.
- Mushtaq, H., Tanvir, F., Bilal, A., Sarwar, K., Iqbal, A., Javed, A., & Shah, S. H. A. (2025). Evaluation of dimethoate-induced toxicity on blood physiology, lipid metabolism, biochemical markers, and thyroid hormonal balance in Nile tilapia. *Journal of Medical & Health Sciences Review*, 2(3).
- Noor, A., Bilal, A., & Ali, U. (2024). Towards personalized cancer care: A report of CRISPR-Cas9 applications in targeted therapies and precision medicine. *Journal of Health and Rehabilitation Research*, 4(2), 1375-1380.
- Peng, Z., Xu, X., Fan, P., Qiao, B., Xie, M., Huang, T., & Xiong, T. (2023). Identification and characterization of a novel pH and heat stable bacteriocin-like substance lactococcin036019 with food preserving potential. *Food Control*, 148, 109682.
- Sriphannam C and A. Kummasook. (2020). Evaluation of probiotic properties of lactic acid bacteria isolated from kimchi produced in Iran. *Naresuan University Journal: Science and Technology*, 28(2), 11–22.
- Virk., Verinder., Verma., Garima., Ram., & Chand. (2022). Production, Purification and Characterization of Bacteriocin produced by novel *L. pentosus* MW857478 for enhancement of food Safety and Shelf-life of Paneer. *Indian journal of forensic Medicine & Toxicology*, 16(1) 1219-1228.
- Xin YT, Wai KT, Pek CL., & Hann LW. (2022). Isolation of a bacteria with plant growth-promoting activities from a foliar biofertilizer. *Malaysian Journal of Microbiology*, 18(3), 315-321.
- Xu, Z., Wang, J., Zheng, W., Zhao, S., Yang, Q., Yu, D., & Zhu, Y. (2023). Antibacterial activity and mechanism of a novel bacteriocin produced by *Lactiplantibacillus plantarum* against *Escherichia coli* and *Staphylococcus aureus*. *International Journal of Food Science & Technology*, 58(1), 181-193.

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

- You, X., Yang, L., Zhao, X., Ma, K., Chen, X., Zhang, C., & Li, W. (2020). Isolation, purification, characterization and immunostimulatory activity of an exopolysaccharide produced by *Lactobacillus pentosus* LZ-R-17 isolated from Tibetan kefir. *International journal of biological macromolecules*, 158, 408-419.
- Zimina, M., Babich, O., Prosekov, A., Sukhikh, S., & Ivanova S. (2020). Overview of Global Trends in Classification, methods of preparation and application of Bacteriocins. *MPDI* 9(9).