



Potato waste to natural antimicrobials: Exploring the antimicrobial potential of potato peel extract

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Abstract

Potato peel waste contains several bioactive components that are known to confer health advantages to humans and animals. Potato peel is a phenolic-rich plant byproducts with various benefits. They fall under different categories such as antioxidants, antimicrobials, antidiabetics, etc. Here we report antimicrobial potential of potato peel extract (PPE) against the Gram positive (*Bacillus subtilis*, *S. aureus*) and Gram negative (*E. coli*, *Salmonella enterica*) bacteria that are mostly responsible for food spoilage. The antimicrobial potential of PPE was assessed by agar well diffusion and dilution methods. Caffeic and chlorogenic compounds were used as a reference phenolics. Ampicillin (100 µg/mL) and the vehicle control were used as positive and negative controls, respectively. Results indicated that potato peel extract exhibited antimicrobial activity against *Bacillus subtilis*, *S. aureus*, *E. coli* and *Salmonella enterica* at concentrations of 10, 3, 10, and 20 mg/mL, respectively. These findings demonstrate the potential for utilising potato peel waste into value-added compounds with antimicrobial properties in food products.

Keywords: Potato peel, antimicrobial activity, microdilution, phytochemicals

Introduction

Globally, fruit and vegetable-based industries generate tremendous amounts of food waste and by-products. The postharvest processing and storage of food items result in a significant amount of waste as a result of poor processing methods and generate numerous by-products. (Ali *et al.*, 2025) [1]

The environmental concerns posed by these biowastes largely result from their high moisture content, which makes them prone to enzymatic and microbial spoilage, as well as their high organic matter content (Gebrechistos & Chen, 2018) [3]. The high organic content of agri-food residues may contribute to their persistence and slow degradation in the environment. Consequently, improper disposal through landfills or uncontrolled release into natural ecosystems, such as rivers, lakes, and seas, can result in substantial environmental pollution and potentially pose adverse effects on ecosystems and the health and well-being of both humans and animals. (Kumar *et al.*, 2020, 2020) [7].

Potatoes (*Solanum tuberosum*) is a staple food for approximately 1.3 billion people hence it is grown worldwide and the world production volume was recently estimated at more than 376 million tons in 2021. In terms of the total amount of potatoes that has been processed, this percentage thus translates into approx. An estimated 70,000–140,000 tonnes of potato peel waste are produced globally every year (Makris, D.P., 2024) [12].

Potato peel waste (PPW) is a significant by-product of the potato processing industry, generated during the production of chips, French fries, starch, and other potato-based products. (Gharbi *et al.*, 2026, 2026) [5]. With respect to its nature, it is suggested that potato peel waste (PPW) would be a preferable source for the production of a variety of bioproducts, decreasing the amount of wastes, and developing a circular bioeconomy in the long run. However,

taking into consideration the range of products that could be developed from PPW, this approach would evidently contribute to several UN Sustainable Development Goals (SDGs), among which are the SDG 12 “Responsible Consumption and Production,” as well as the SDG 7 “Affordable and Clean Energy” and the SDG 13 “Climate Action” (Khanal *et al.*, 2023) [16].

Food preservation is another crucial issue for the food industry. Synthetic preservatives and antioxidants are widely used to prevent microbial growth, oxidizing processes, and products' shelf-life extension. However, nowadays, consumers are trending towards clean-label and natural ingredients, and scientists are looking for innovative solutions to replace chemical additives. Thus, natural antimicrobial compounds produced from food-processing by-products could be a sustainable alternative to currently used preservatives and antioxidants. In this regard, the use of potato peel waste to produce natural antimicrobial compounds is a promising solution to ensure food safety and shelf-life while minimizing food waste (Chauhan & Rao, 2024) [2].

In this regard, the present study focuses on evaluating the antimicrobial potential of PPE for its application in food products. This study aims to assess the antimicrobial potential of PPE against selected Gram-positive and Gram-negative bacteria which are commonly found in spoiled foods, so as to provide a natural food preservative.

Materials and method

Plant materials

Fresh potato peels were collected from a local restaurant in Mumbai. The peels were cleaned physically by removing foreign material, washed and dried. Oven was used to dry the peels at 70°C. The dried peels were ground and sieved to

obtain a fine powder. The potato peel powder was kept in an airtight container at -22°C until further usage.

Preparation of Potato Peel Extract (PPE)

Bioactive compounds were extracted from dried potato peels (Rowayshed *et al.*, 2015) [9]. About 10g of dried potato peel powder was weighed, 100ml of 70% ethanol was added to it. The extract was obtained by shaking this 10% suspension on shaker at 120rpm for 24hr at 37°C. Following 24 hr of maceration, Whatman filter paper No 1 was used for filtration and filtrate obtained was concentrated using rota vapour (Superfit Rotar Vacuum Evaporator) at 40°C until dryness. The concentrated extract was stored in an amber colour bottle at -18°C until further usage.

Antimicrobial activity of potato peel extract (PPE)

Bacterial strains: A total of four strains for this study were procured from CSIR-NCIM, Pune, India for testing the antimicrobial potential of potato peel extract. The Gram-positive strains included *Bacillus subtilis* (ATCC 6051) and *Staphylococcus aureus* (ATCC 6538), whereas the Gram-negative strains included *Escherichia coli* (ATCC 8439) and *Salmonella enterica* (ATCC13314) as well-known foodborne pathogens. These bacterial strains were subcultured by inoculating 10 µL of culture into 10 mL of Mueller-Hinton Broth, followed by a 24hr incubation at Room Temperature and 37°C.

Antimicrobial activity of the potato peel extract (PPE) using agar-well diffusion assay

Agar well diffusion method was used to study the antimicrobial activity of the PPE (Gebrechistos *et al.*, 2020) [4]. Sterile Mueller-Hinton agar plates were prepared and inoculated with the respective bacterial cultures to obtain a uniform lawn. After the uniform swabbing of the bacterial cultures, wells measuring 7 mm in diameter were aseptically made in the MH agar plate using a sterile well borer. PPE was used at concentrations 20, 30, and 50 mg/mL, with 50 µL of each dispensed into the corresponding wells. Caffeic acid and chlorogenic acid were used as reference phenolic compounds and tested at concentrations ranging from 1–4 mg/ml and 2–10 mg/ml, respectively. These compounds are known to be present in the PPE. Ampicillin was used as the positive control, whereas 70% ethanol was used as the vehicle (negative) control to determine whether the solvent itself has any inhibitory effect on bacterial growth. The plates were incubated at Room Temperature for 24 hr for *Bacillus subtilis* and *S. aureus*. For *E. coli* and *Salmonella enterica*, the plates were incubated at 37°C for 24hr, after which, zones of inhibition around the wells were recorded.

Antimicrobial activity of PPE by microdilution method

The antimicrobial activity of PPE was determined for the four microorganisms by microdilution method (Gebrechistos *et al.*, 2020 and Singh *et al.*, 2022) [4]. Caffeic acid was used at concentrations ranging from 0.1-5 mg/ml, while for chlorogenic acid, concentrations ranging from 0.25–2.5 mg/ml were used. Ampicillin was used at a concentration of 100 µg/ml. Normal growth curve of the respective microorganisms in the culture medium was plotted. The inhibitory effects of vehicle alone, reference phenolics and PPE samples at different concentrations were determined. SpectraMax iD3 Multi-Mode Microplate Reader was used to observe the growth pattern for 24 hr at Room Temperature for *Bacillus subtilis* and *S. aureus*. For *E. coli* and *Salmonella enterica*, the plates were incubated at 37°C for 24hr. Vehicle controls were run alongside in a percentage equivalent to the percentage of the ethanol in the PPE concentration used so as to be sure that the inhibition is due to the compounds present in the extract and not due to the presence of ethanol in it. Hence, vehicle control (ethanol) was taken at 5%, 7%, and 10% for the study.

Statistical analysis

All experiments were conducted in triplicate across three independent trials. Data are expressed as the mean ± standard deviation (SD). Statistical analyses were performed using Real Statistics software. Analysis of variance (ANOVA) was employed to determine significant differences among experimental groups. Normality was assessed using Q–Q plots, and the independence of observations was verified using the Durbin–Watson test, where applicable. When the ANOVA yielded significant results, Tukey's post-hoc test was performed for multiple comparisons between groups. Statistical significance was defined as $p < 0.05$.

Results and Discussion

1. Antimicrobial activity of PPE using agar well diffusion: Agar-well diffusion assay was performed for PPE against four selected microorganisms. The zone of inhibition was measured after 24hr. The results obtained are shown in Table 1. It was observed that the PPE at concentrations of 20, 30 and 50mg/ml did not produce any detectable zone of inhibition against any of the tested microorganisms as seen in Fig 1, Fig 2, Fig 3 and Fig 4. Similarly, 70% ethanol which is a negative control showed no zone of inhibition, confirming that the observed antimicrobial effects of the standards were not due to the extraction solvent.

Table 1: Zone of inhibition observed against different microorganisms

S.no.	Components	Concentration (per ml)	Zone of inhibition (mm)			
			<i>B. subtilis</i>	<i>S. aureus</i>	<i>S. enterica</i>	<i>E. coli</i>
1.	Caffeic Acid	1 mg	-	-	-	-
		2 mg	-	-	-	-
		3 mg	-	11	12	11
		4 mg	-	14	13	12
2.	Chlorogenic Acid	10 mg	-	12	-	-
		7.5 mg	-	-	-	-
		4.5 mg	-	-	-	-
		2 mg	-	-	-	-
3.	Ampicillin	100 µg	24	27.5	16	-
		75 µg	1.9	32	-	-

		45 µg	-	30	-	-
		20 µg	-	36	-	--
4.	Sample (PPE)	50 mg	-	-	-	-
		30 mg	-	-	-	-
		20 mg	-	-	-	-
5.	70% Ethanol (Negative Control)	70%	--	-	-	-

Key: (-) No zone of clearance

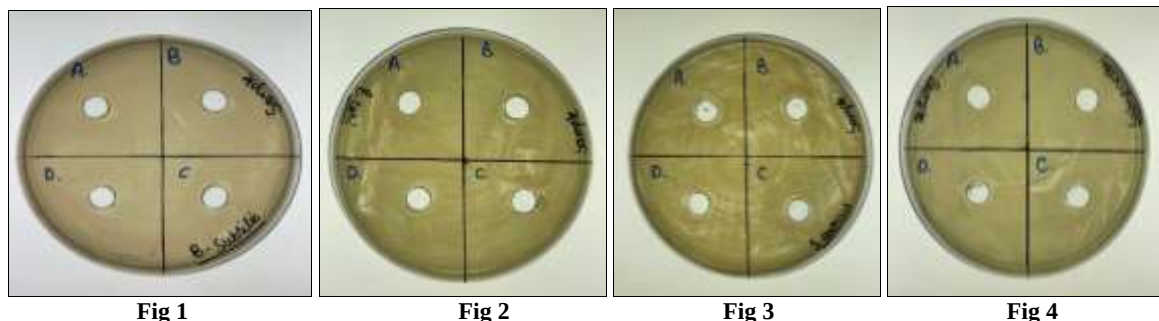


Fig 1

Fig 2

Fig 3

Fig 4

Fig 1, Fig 2, Fig 3 and Fig 4, Agar well diffusion assay showing the antimicrobial activity of PPE against *Bacillus subtilis*, *E. coli*, *Staphylococcus aureus* and *Salmonella enterica* respectively: A – 20 mg/ml of PPE, B – 30 mg/ml of PPE, C – 50 mg/ml of PPE, and D – 70% ethanol (negative control)

Caffeic acid showed inhibition at 3mg/ml and 4mg/ml. For chlorogenic acid, a zone of inhibition was observed only against *Staphylococcus aureus* at a concentration of 10mg/ml, whereas no detectable inhibition was observed against the other microorganisms. No zone of inhibition observed for PPE against tested organisms in agar-well diffusion method. The possible reason is the presence of compounds in the crude extract that are large making it difficult to diffuse through the agar matrix. Hence, broth dilution method would be more suitable for the present study as sample extract will be in direct contact with the bacterial culture.

2. Antimicrobial activity of the potato peel extract (PPE) by microdilution

The antimicrobial activity of PPE was assessed using 96-well plate. The growth response of the selected test microorganisms in the presence of PPE, reference phenolic

compounds, ampicillin, and the vehicle control was observed for 24 hr using Multimode plate reader (SpectraMax iD3). The antimicrobial potential was determined by comparing the optical density (OD) of the different compounds and the concentration at which inhibition was seen was recorded.

In presence of ampicillin (positive control), no growth of the organisms was observed as expected. The growth of the organisms in presence of vehicle control showed limited inhibition. It indicates that the inhibition seen with PPE was due to the presence of the compounds present in the PPE, and not because of the ethanol in it. MH media alone showed no turbidity as expected. The normal growth of the organism was also recorded where no treatments were given. Table given below shows the ethanol concentrations in the final assay mixture at every concentration of the standard/sample PPE.

Table 2: Concentration of ethanol corresponding to the standard/ sample concentrations used

Caffeic Acid (CA)		Chlorogenic Acid (CGA)		Sample PPE		Vehicle control (VC)
Concentration (µg/ml)	Percentage of ethanol present (%)	Concentration (mg/ml)	Percentage of ethanol present (%)	Concentration (mg/ml)	Percentage of ethanol present (%)	Percentage of ethanol present (%)
100	0.7	0.25	0.7	5	6.75	5
400	2.8	1	2.8	10	13.51	7
700	4.9	2	5.6	20	27.02	10
1000	7	2.5	7			

2.1 PPE activity against *Bacillus subtilis*

The growth response of *Bacillus subtilis* in the presence of PPE, caffeic acid, chlorogenic acid and vehicle control is represented in Figure 5a. For comparison among the treatment groups, the mean OD recorded at the 24th hour was considered. PPE showed a concentration-dependent inhibitory effect on the growth of *B. subtilis*, more inhibition at higher concentration. The inhibition in the presence of PPE on the growth of *B. subtilis* was observed at a concentration of 10 mg/ml or higher. Among the reference phenolic compounds, caffeic acid showed inhibition at 700 µg/ml, whereas chlorogenic acid showed inhibition at 2.5 mg/ml.

Whenever assessment was made about the efficacy of the compound or the extract, the concentration of ethanol was taken into account (refer Table 2). For example, for CGA and *B. subtilis* experiment, CGA at 2mg/ml corresponds to ethanol concentration of 5.6% and for 2.5mg/ml, ethanol concentration is 7%. Looking at the ODs reached at 24th hour, it can be seen that the OD in the presence of the CGA (0.093111±0.530) is lower than the OD of the corresponding ethanol concentration (0.507±0.065). The ANOVA analysis ($p < 0.05$) further confirmed that the differences among treatments were highly significant.

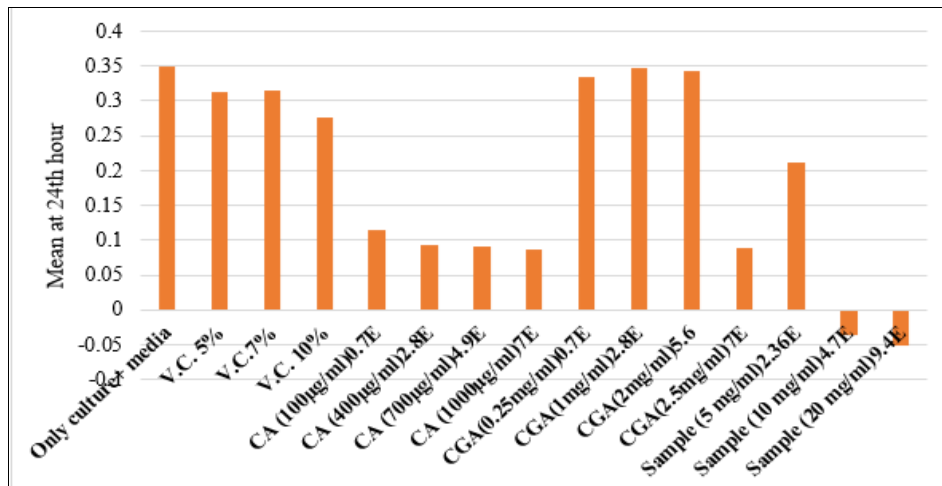


Fig 5 a: Growth Absorbance with Respect to sample PPE extract, Vehicle Control, and Culture (*Bacillus subtilis*)

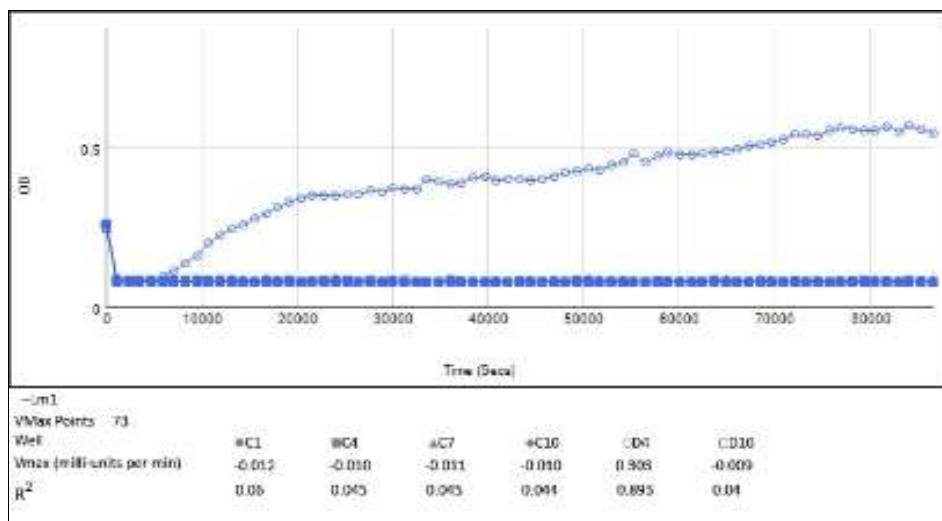


Fig 5b: Growth curve of *Bacillus subtilis* in presence of Ampicillin (Positive Control) – filled circles, filled squares, filled triangles, filled diamonds, untreated control (Media+ Culture) – open circles, only Media (Negative control) – open squares.

2.2 PPE activity against *S. aureus*

The growth response of *S. aureus* in the presence of PPE, vehicle control, caffeic acid, chlorogenic acid and untreated culture is represented in Figure 6a. The inhibition in presence of PPE against *S. aureus* was observed at a concentration approximately at 3 mg/ml or higher. This finding is comparable to the study conducted by Gebrechristos *et al.* who reported an MIC of 4.7 ± 1 mg/ml for PPE against *S. aureus* (Gebrechristos *et al.*, 2020) [4].

The inhibitory concentration for caffeic acid and chlorogenic acid against *S. aureus* was found to be 700 µg/ml and 2.5mg/ml, respectively. Similar to *Bacillus*, vehicle control for *S. aureus* was taken into account for determining the inhibition due to the compounds. Statistical analysis further supported these findings, with one-way ANOVA showing a highly significant difference among the treatment groups ($p < 0.5$).

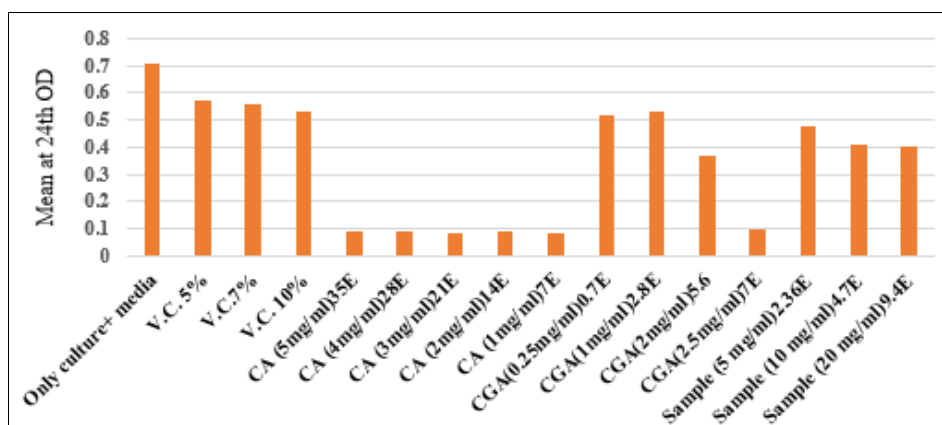


Fig 6a: Growth Absorbance with Respect to sample extract, Vehicle Control, and Culture (*S. aureus*)

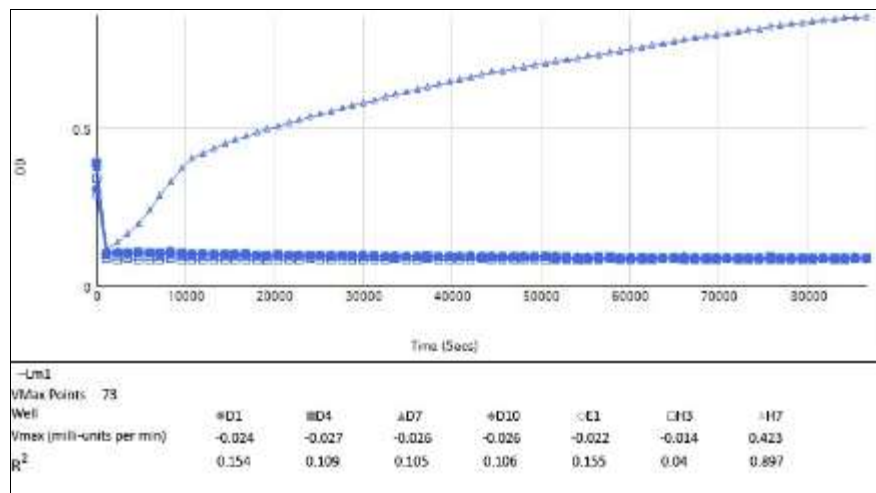


Fig 6b: Growth curve of *S. aureus* in presence of Ampicillin (Positive Control)- filled circle, filled square, filled triangle and filled diamond; untreated control (Media+ Culture)- open triangle; only Media (Negative control)-open square

2.3 PPE activity against *E. coli*

PPE significantly inhibited the growth of *Escherichia coli* (refer Fig7a). The inhibitory effect was observed at a concentration of 10 mg/ml or higher. This result is similar to the finding of Gebrechristos where MIC was found to be 7.5 ± 2 mg/ml in potato peels.

The inhibitory effect for caffeic acid and chlorogenic acid was found to be 700 μ g/ml and 2.5mg/ml respectively. This is similar to the response seen with *S. aureus*. ANOVA analysis shows that the observed differences among treatments were highly significant ($p < 0.05$).

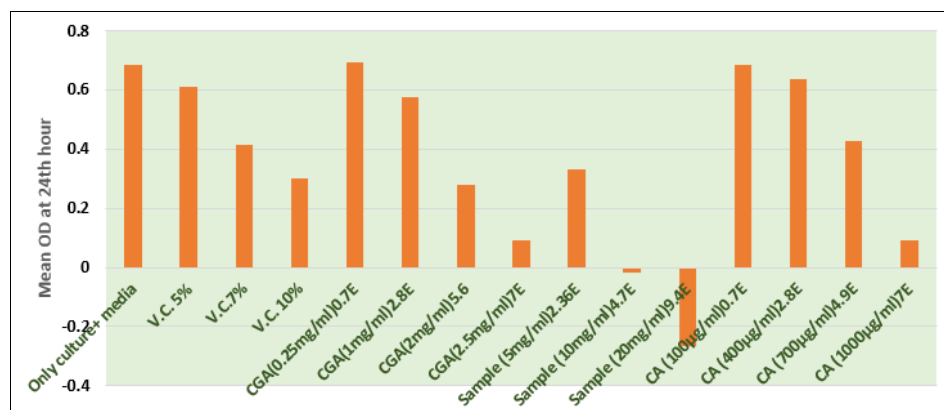


Fig 7a: Growth Absorbance with Respect to sample extract, Vehicle Control, and Culture (*E. coli*)

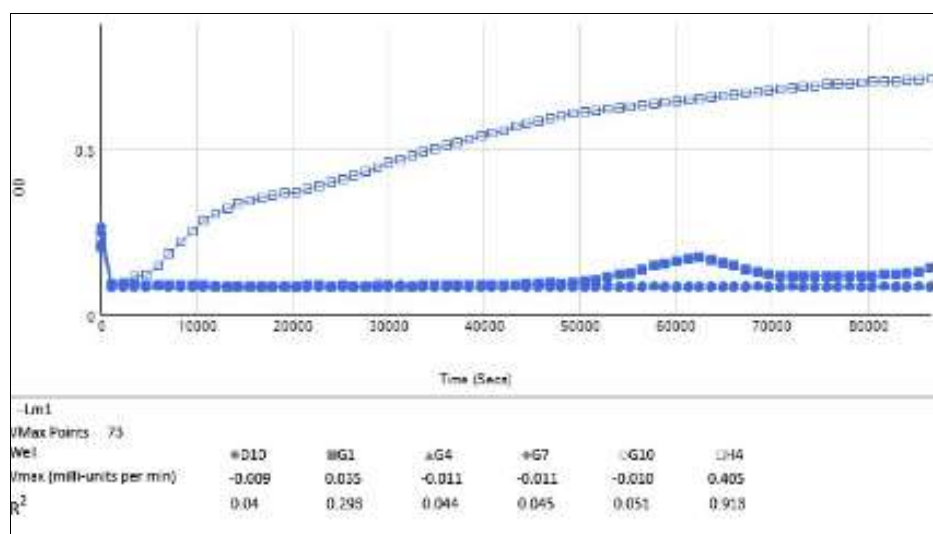


Fig 7b: Growth curve of *E. coli* in presence of Ampicillin (Positive Control)- filled circle, filled square, filled triangle and filled diamond, untreated control (Media+ Culture)-open quare, only Media (Negative control)- open circle

2.4 PPE activity against *Salmonella enterica*

PPE effectively inhibited the growth of *Salmonella enterica* (Fig 8a). The inhibitory effect was observed at a concentration 20 mg/mL or higher. This finding is different from the results of Gebrechristos *et al.*, who reported an MIC of $5.8 \pm 2\text{mg/ml}$ for PPE (Gebrechristos *et al.*, 2020)^[4]. The observed difference in inhibitory potential may be attributed to variations in potato peel varieties, which contributes to differences in concentration and composition

of phenolic compounds present in the extracts. Caffeic acid inhibited bacterial growth at a concentration 1 mg/mL or higher, whereas chlorogenic acid showed inhibition at approximately 2.5 mg/mL or higher. Similar to other tested organisms, vehicle control was taken into account for determining inhibitory values. ANOVA analysis confirmed that the observed differences among treatments were highly significant ($p < 0.05$).

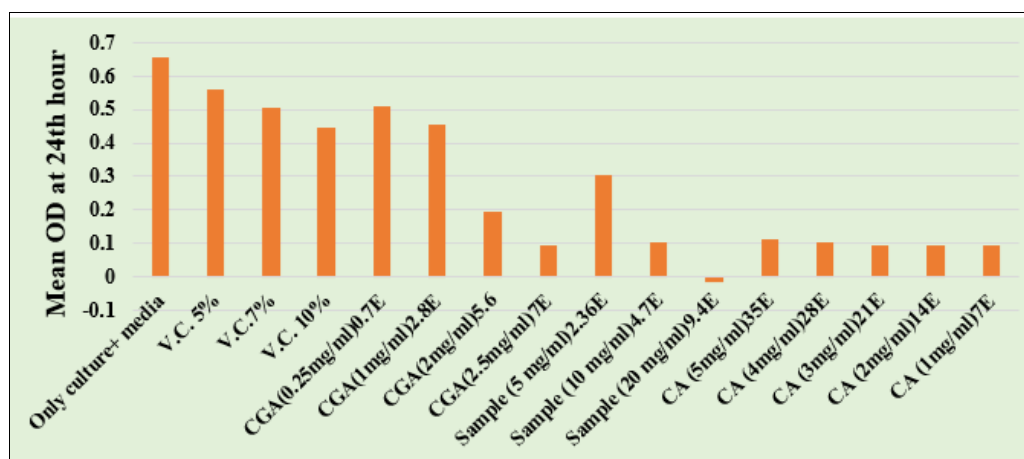


Fig 8a: Growth Absorbance with Respect to sample extract, Vehicle Control, and Culture (*Salmonella enterica*)

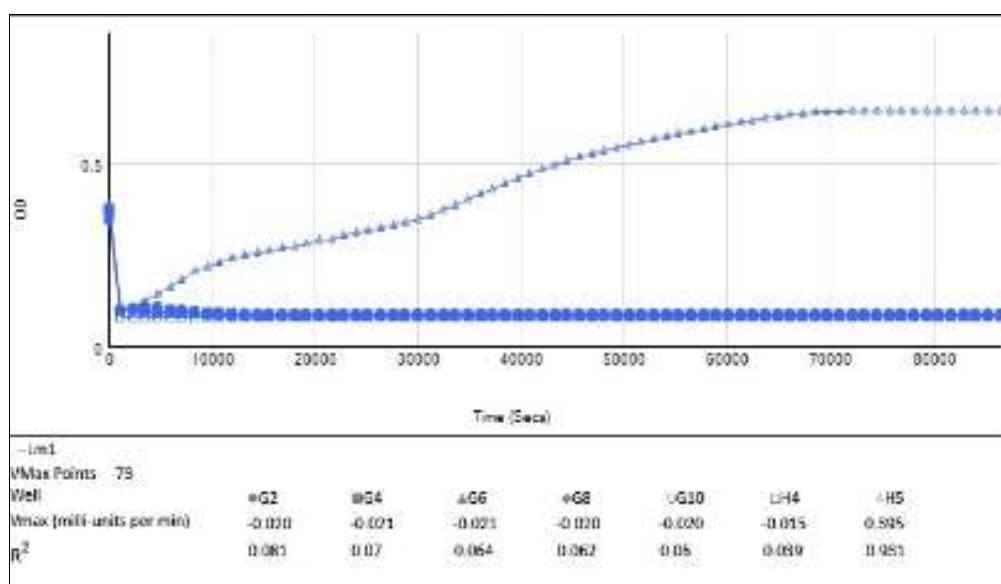


Fig 8b: Growth curve of *Salmonella enterica* in presence of Ampicillin (Positive Control)- filled circle, filled square, filled triangle and filled diamond, untreated control (Media+ Culture)-open triangle, only Media (Negative control)- open square.

Conclusion

This study demonstrates the antimicrobial properties of PPE against Gram-positive bacteria (*Bacillus subtilis* and *Staphylococcus aureus*) and Gram-negative bacteria (*Escherichia coli* and *Salmonella enterica*). For the present study, 96-well microtitre plate method was found to be more appropriate as compared to agar-well diffusion method. The results suggest that potato peel, an underused byproduct of food processing, is a promising source of natural antimicrobial agents. Its utilization in food products could contribute to the development of sustainable alternatives to synthetic preservatives. Nevertheless, further investigations are warranted to establish its antimicrobial efficacy, safety, stability, and applicability in different food systems.

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Conflict of interest statement

The authors declare no conflict-of-interest present in the given manuscript

References

1. Ali MQ, Ahmad N, Azhar MA, Munaim MSA, Ruslan NF. Fruit and vegetable by-products: Extraction of bioactive compounds and utilization in food

- biodegradable material and packaging. Food Materials Research. 2025;5(1):0-0 <https://doi.org/10.48130/fmr-0025-0003>
2. Chauhan K, Rao A. Clean-label alternatives for food preservation: An emerging trend. Heliyon. 2024;10(16):e35815 <https://doi.org/10.1016/j.heliyon.2024.e35815>
 3. Gebrechristos HY, Chen W. Utilization of potato peel as eco-friendly products: A review. Food Science & Nutrition. 2018;6(6):1352-1356 <https://doi.org/10.1002/fsn3.691>
 4. Gebrechristos HY, Ma X, Xiao F, He Y, Zheng S, Oyungerel G, *et al.* Potato peel extracts as an antimicrobial and potential antioxidant in active edible film. Food Science & Nutrition. 2020;8(12):6338-6345 <https://doi.org/10.1002/fsn3.1119>
 5. Gharbi M, Gharbi D, Karkouch I, Forero AM, Rodríguez J, Chaouachi M, *et al.* Potato (*Solanum tuberosum* L. cv. Spunta) peels promote the production of broad spectrum antibacterial chemicals by *Bacillus velezensis* B38. Molecules. 2026;31(16):2747 <https://doi.org/10.3390/molecules31162747>
 6. Khanal S, Karimi K, Majumdar S, Kumar V, Verma R, Bhatia SK, *et al.* Sustainable utilization and valorization of potato waste: State of the art, challenges, and perspectives. Biomass Conversion and Biorefinery. 2023;13:1-20 <https://doi.org/10.1007/s13399-023-04521-1>
 7. Kumar H, Bhardwaj K, Sharma R, Nepovimova E, Dhanjal DS, Verma R, *et al.* Fruit and vegetable peels: Utilization of high value horticultural waste in novel industrial applications. Molecules. 2020;25(12):2812 <https://doi.org/10.3390/molecules25122812>
 8. Makris DP. Potato processing waste as a reservoir of bioactive hydroxycinnamates: a critical review. Biomass. 2024;5(1):2.
 9. Rowayshed G, Sharaf AM, El-Faham SY, Ashour MMS, Zaky AA. Utilization of potato peels extract as source of phytochemicals in biscuits. 2015.
 10. Saleem M, Saeed MT. Potential application of waste fruit peels (orange, yellow lemon and banana) as wide range natural antimicrobial agent. Journal of King Saud University – Science. 2020;32(1):805-810 <https://doi.org/10.1016/j.jksus.2019.02.013>
 11. Singh R, Upadhyay SK, Singh M, Gupta M, Singhal P, Goyal S, *et al.* Antibacterial and antifungal activities of some fruits peel extracts: The best possible source of low cost natural antimicrobial agents. 2022.