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Exploration of bioactive compounds and antioxidant properties of medicinal plants for sustainable applications in post-harvest shelf-life enhancement of *Solanum lycopersicum var. cerasiforme*

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ABSTRACT

This study aims to assess the bioactive compounds of the medicinal plants viz., Centella asiatica, Phyllanthus niruri, and Swertia chirata. Both aqueous and ethanolic plant extracts were prepared, and total phenolic, flavonoid, chlorophyll, and carotenoid contents were analyzed. The highest yield extract was observed in Phyllanthus niruri (18.43 ± 0.60%). Swertia chirata contained the highest chlorophylls and carotenoid contents. Total phenolic and flavonoid contents were highest in Swertia chirata (66.31 ± 1.527 mg GAE/g and 103.108 ± 4.136 mg QE/g, respectively). FTIR analysis confirmed the presence of diverse functional groups, with Phyllanthus niruri showing a comparatively richer phytochemical profile. In the DPPH antioxidant assay, Phyllanthus niruri demonstrated the strongest antioxidant activity. The microbroth dilution method was used to evaluate antimicrobial activity, revealing that Phyllanthus niruri exhibited a significant antibacterial effect, specifically against Bacillus spp. (MIC = 3.125 mg/ml). Application of natural coating to Solanum lycopersicum var. cerasiforme, stored at both room temperature and 4°C, significantly delayed microbial spoilage and preserved quality. By Day 15, Swertia chirata coating showed the lowest weight loss at room temperature (40.09%), while Centella asiatica coating provided superior preservation under 4 °C storage, exhibiting the lowest visual decay index, demonstrating temperature-dependent effectiveness of the plant extracts.

Keywords: Bioactive compounds, medicinal plants, postharvest preservation, shelf-life enhancement,

INTRODUCTION

Post-harvest loss of fresh produce is a major threat to global food security and economic stability, with fruits and vegetables accounting for up to 35–50% of total losses due to their highly perishable nature (Hodges *et al*., 2011; Elik *et al*., 2019). Such losses arise from enzymatic activity, microbial spoilage, mechanical damage, and chemical degradation, resulting in both quantitative and qualitative deterioration of food quality (Ambuko *et al*., 2017; Falguera *et al*., 2012). Cherry tomatoes (*Solanum lycopersicum var. cerasiforme*) are nutrient-rich fruits containing high levels of vitamins, minerals, and dietary fibre. They are an excellent source of vitamin C, vitamin A (in the form of β-carotene), potassium, and folate, and are particularly valued for their high lycopene content. These compounds contribute to their nutritional and medicinal properties, including immune enhancement, anticancer

and antidiabetic effects, as well as the prevention of cardiovascular diseases (Perveen *et al.*,2015). Cherry tomatoes are highly susceptible to rapid spoilage owing to their high moisture content, delicate surface structure, and vulnerability to microbial contamination and oxidative stress.

Although synthetic preservatives are commonly used to extend shelf life of fruits and vegetables, their repeated application raises concerns related to toxicity, allergic reactions, and antimicrobial resistance (Shahidi and Ambigaipalan, 2015). Consequently, there is increasing demand for natural, safe, and eco-friendly alternatives. Medicinal plants, widely used in traditional systems such as Ayurveda, are rich sources of bioactive compounds with antioxidant and antimicrobial properties, making them promising candidates for post-harvest preservation (Kumar *et al.,* 2023; Narayan *et al.,* 2023). These bioactive constituents, including polyphenols, flavonoids, carotenoids, and terpenoids, contribute to oxidative stress reduction and quality maintenance in fresh produce (Dey and Mukherjee, 2022). The present study investigates the phytochemical composition, antioxidant potential, and antimicrobial activity of *Centella asiatica*, *Phyllanthus niruri*, and *Swertia chirata*, and evaluates their effectiveness as natural edible coatings for extending the shelf life of cherry tomatoes under room and refrigerated storage conditions. Cherry tomatoes are consumed raw and easily degraded; hence, there is a need to increase their shelf life. These medicinal plants were chosen based on their therapeutic importance in traditional Indian Ayurvedic medicine and pharmacology (Khare, 2007).

MATERIALS AND METHODS

Medicinal plant samples were collected in and around the Coimbatore district, Tamil Nadu, India, which lies in the Western Ghats, a UNESCO World Heritage Site and a global biodiversity hotspot. The area includes the Nilgiri Biosphere Reserve. Latitude: 11.017363° N. Longitude:76.958885° E (approx.). Sample collection was carried out during the early stages of the year (January 2025 when the area experienced moderate temperatures of 15°C to 30°C at day, 18°C to 19°C at night). *Centella asiatica* and *Phyllanthus niruri* were obtained from a commercial nursery and harvested 2–4 months after planting, whereas *Swertia chirata* was collected from natural populations and harvested at 6–8 months of age. After harvesting, the plant samples were dried in well-ventilated, dry, and shaded areas. Direct sunlight was avoided, as it can degrade heat-sensitive compounds, and low humidity was ensured to prevent mould growth. Plants were dried in clean, uncontaminated environment. Breathable surfaces have been used to place the plants, and plant material has been turned periodically to ensure even drying. A constant temperature of 37°C was maintained for 3 days in a hot air oven (Azwanida, 2015). The dried plants were pulverized into fine powder using an electric grinder, sieved through a 60-mesh sieve and preserved in sealed airtight containers.

The medicinal plant powders of *Centella asiatica, Phyllanthus niruri*, and *Swertia chirata* were extracted using aqueous and ethanolic solvents, taking into account the solubility properties of the bioactive compounds and the requirements of specific experimental assays. Aqueous extraction was employed as water is the highest polar solvent and is essential for extracting polar phytochemicals such as glycosides, phenolics, and tannins (Azwanida, 2015). For experiments where certain compounds or reagents were insoluble in water, ethanol was used as the alternative solvent because it has a greater

solubility range compared to water and is compatible with nonpolar phytochemicals.

Extraction of plant material

Aqueous extracts were prepared by maceration, and ethanolic extracts were prepared by soxhlet extraction (Do et al., 2014). The powdered sample was weighed as per the requirement in the ratio 1:10. 10 g of powder in 100 ml of solvent (Harborne, 1998). Ten grams of powdered sample of each plant were extracted successively with 100 ml of distilled water. The contents of the conical flask were left at room temperature for 72 hours with frequent shaking in the orbital shaker. Ten grams of powdered sample of each plant using a Soxhlet apparatus were successively extracted with 70% ethanol for 24 hours. The plant extracts were filtered using Whatman No.1 filter paper and were concentrated under reduced pressure using rotary evaporator. 10 g (10,000 mg) of dried plant material was used for each extraction to calculate the yield percentage. The concentrated extract was further dried to constant weight, and the crude extract was collected and stored in Eppendorf tubes at 4 °C until use. The yield of the extract obtained was measured and expressed in milligrams.

Yield percentage is given by the formula: Yield (%) = [*Weight of dry extract/Weight of dry plant*] ×*100*

Total chlorophylls and carotenoids estimation

Total chlorophylls and carotenoids were spectrophotometrically determined in ethanol extracts and calculated according to the Lichtenthaler and Wellburn method in 3 different wavelengths, 663nm (chlorophyll a), 645nm (chlorophyll b), and 470nm (carotenoids) (Lichtenthaler and Wellburn, 1983).

Chlorophyll a=*12.21×A (663)- 2.81×A (645);* **Chlorophyll b**=*20.13× A (645)-5.03× A(663)*

Total Chlorophyll = *Chlorophyll a + Chlorophyll b*

Total Carotenoids= *[1000×A (470)-3.27× chlorophyll a -104× Chlorophyll b]/22*

Total phenolic content estimation

To measure the total phenolic content, 1 ml of the (1:10) diluted folin-ciocalteu reagent was added to a test tube, followed by 0.1 ml of the plant extract, and 1 ml of 7.5% sodium carbonate (Na_2CO_3) solution was added. The contents were vortexed to ensure homogeneity. The final volume was made up to 10 ml with distilled water, and they were incubated for 20 minutes at room temperature in the dark to prevent oxidation due to light exposure. After incubation, the absorbance was measured at 765 nm using a UV-Vis spectrophotometer, with distilled water serving as the blank. The results were expressed in mg equivalent of gallic acid per gram dry extract, according to the calibration curve (Ainsworth and Gillespie, 2007).

Total flavonoid content estimation

To measure the total flavonoid content, 0.2 ml of the 1% ferric chloride was added to a test tube, followed by 0.1 ml of the plant extract or standard solution, and 0.2 ml of 1M sodium acetate solution. The mixture was thoroughly vortexed to ensure homogeneity. The final volume was made up to 4 ml with distilled water, and the reaction was allowed to proceed for 20 minutes at room temperature. After incubation, the absorbance was measured at 430 nm using a UV-Vis spectrophotometer, with distilled water serving as the blank. The results will be expressed as mg equivalent of Quercetin per gram dry extract, according to the calibration curve. Quercetin is insoluble in polar solvents; hence, ethanol was used. Total phenolic content was determined using aqueous extracts, whereas total flavonoid content was measured using ethanol extracts. This choice was based on the differential solubility of phenolic compounds, with flavonoids showing higher solubility in

ethanol. Therefore, the higher TFC values compared to TPC can be attributed, in part, to the solvent extraction efficiency differences (Do *et al.,* 2014).

FTIR analysis methodology

The leaves of *Centella asiatica, Phyllanthus niruri,* and *Swertia chirata* were ground into fine powder. Dried powdered samples of the leaves were used for FTIR analysis in the range of 400-4000cm^{-1} by employing the standard KBr pellet technique. Fourier Transform Infrared Spectrophotometer makes use of an interferometer, which is a widely used analytical tool for identifying the types of chemical bonds (Functional groups) present in compounds.

Antioxidant analysis: DPPH assay

The antioxidant activity of the plant extracts was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay. 0.1 mM DPPH solution was prepared in ethanol as a stock solution of 1 mg/ml in a volumetric flask and stored in the dark. Medicinal plant extracts were tested at concentrations ranging from 0.05–0.40 mg/ml. 1 ml of each dilution was prepared, followed by 1 ml of the DPPH solution being added and mixed thoroughly. Incubated at room temperature for 30 minutes in the dark. The absorbance was measured at 517 nm using a UV-Vis spectrophotometer. Ascorbic acid was used as a standard positive control.

DPPH scavenging activity % = $[(A_B - A_T) / A_B] \times 100\%$ where A_B denote Absorbance of blank and A_T denote Absorbance of the sample

Antimicrobial activity estimation using Microbroth dilution method and determination of Minimum Inhibitory Concentration (MIC)

Minimum Inhibitory Concentration (MIC) is defined as the lowest concentration of an antimicrobial agent that inhibits visible microbial growth. For crude plant extracts, MIC values are expressed in mg/ml, whereas for antibiotics, they are expressed in µg/ml (Pankey and Sabath, 2004). Antibacterial activity of *Centella asiatica*, *Phyllanthus niruri*, and *Swertia chirata* extracts was evaluated using the microbroth dilution method in 96-well plates. Plant extracts were prepared at 100 mg/ml in DMSO, and streptomycin (positive control) at 100 µg/ml (0.1 mg/ml). Each well received 100 µl of extract or antibiotic stock. Two-fold serial dilutions were prepared across the plate to achieve concentrations of 100, 50, 25, 12.5, 6.25, 3.125, 1.5625, 0.78125, 0.390625, and 0.1953125 mg/ml for extracts, and 100, 50, 25, 12.5, 6.25, 3.125, 1.5625, 0.78125, 0.390625, and 0.1953125 µg/ml for streptomycin. Wells containing LB broth and bacteria without extract or antibiotic served as negative controls. Each treatment was performed in three independent replicates (n = 3).

Bacterial inoculum (10 µl per well) was prepared to a 0.5 McFarland standard. Plates were incubated at 37 °C for 18–24 hours. Bacterial growth was assessed using Iodonitrotetrazolium chloride (INT) as a metabolic indicator, which turns red in the presence of metabolically active bacteria. Optical density (OD 600) measurements were also recorded using a microplate reader to quantitatively confirm bacterial growth inhibition (Balouiri *et al*., 2016).

Natural coating formulation and treatment of cherry tomatoes

The effectiveness of three natural coatings, *Phyllanthus niruri*, *Centella asiatica*, and *Swertia chirata,* in preserving the post-harvest quality of cherry tomatoes was evaluated through weight retention analysis and visual observation under both room temperature and refrigerated (4°C) storage conditions. Hydroponically grown, uniformly sized tomatoes were purchased from a local market and used for the study.

Fruits were surface-sterilised using 2% sodium hypochlorite for 1-2 minutes and washed meticulously with sterile distilled water. The tomatoes were air-dried and randomly grouped for treatment. The extracts of *Phyllanthus niruri*, *Centella asiatica*, and *Swertia chirata* were dissolved in distilled water containing 0.5% carboxymethyl cellulose (CMC) as a film-forming agent, to achieve a final extract concentration of 1% (w/v) in the coating solution. The mixtures were stirred at 1500 rpm for 45 minutes using a magnetic stirrer. Control fruits were coated only with carboxymethyl cellulose. Coated fruits were stored at room temperature (25 ± 2°C) and refrigerated cold storage (4 ± 2°C) (Dey and Mukherjee, 2022).

Evaluation of shelf-life of cherry tomatoes

Weight loss (%): Tomatoes were weighed at regular intervals, once in 3 days for 15 days, and the percentage of weight loss was calculated as: Weight loss (%) = $[(W_0 - Wt) / W_0] \times 100$ Where W_0 = initial weight and Wt = weight at a specific day (Oms-Oliu *et al.,* 2008).

Visual decay index: *Solanum lycopersicum var. cerasiforme* was examined for decay symptoms such as mould growth, shrivelling, and skin softening. A subjective grading system (0–4 scale) was used: 0 = No decay, 1 = Slight, 2 = Moderate, 3 = Severe, 4 = Fully decayed.
Mean decay grades were evaluated for each treatment and time point (Ali *et al*., 2011).

Statistical analysis

All quantitative experiments were conducted with appropriate replication. Extraction yield, total phenolic content, total flavonoid content, and shelf-life evaluation were performed as three independent experiments. Chlorophyll and carotenoid estimations, antimicrobial assays and antioxidant activity were based on triplicate technical measurements, while FTIR analysis was qualitative in nature. Results are expressed as mean ± standard deviation (SD) where applicable. Statistical analysis was performed using IBM SPSS Statistics version 26, and graphical representations were prepared using Excel. Differences among treatments were evaluated using one-way analysis of variance (ANOVA), and results were considered statistically significant at $p < 0.05$.

RESULTS AND DISCUSSION

Yield percentage and pigment analysis

The extraction yield varied among the plant species; *Phyllanthus niruri* exhibited notably greater crude extract yield (18.43 ± 0.60%), followed by *Centella asiatica* (11.2 ± 0.37%) and *Swertia chirata* (8.90 ± 0.36%), and the differences were statistically significant ($F (2, 6) = 350.32$, $p < 0.001$) (Table 1). In contrast, pigment analysis revealed that *Swertia chirata* contained the highest concentrations of total carotenoids (2.028 µg/ml) and total chlorophyll (14.09 µg/ml), followed by *Phyllanthus niruri* (1.338 µg/ml and 8.675 µg/ml) and *Centella asiatica* (0.364 µg/ml and 3.681 µg/ml, respectively) (Table 2).

Total phenolic content

The total phenolics in aqueous extracts ranged from 66.3 µg/ml to 17.13µg/ml. *Swertia chirata* and *Phyllanthus niruri* had the highest phenolic contents (66.3 ± 1.527 and 57.03 ± 0.95 mg GAE/g, respectively), while the lowest was found in *Centella asiatica* (17.13 ± 1.014 mg GAE/g). The quantification was performed using a calibration curve ($y = 0.00359x + 0.754$, $R^2 = 0.9926$) of gallic acid concentration, ranging from 0 to 100 µg/ml, expressed in gallic acid equivalents (GAE) per gram of dry extract weight (Figure 1 and Table 3). Total phenolic content differed significantly among plant extracts ($F (2, 6) = 1443.23$, $p < 0.001$).

Total flavonoid content

The total flavonoids in ethanol extracts ranged from 63.98 to 103.108 mg QE/g. *Swertia chirata* had the highest flavonoid content (103.108 ± 4.136 mg QE/g), while the lowest was found in *Phyllanthus niruri* and *Centella asiatica* (67.386 ± 2.507 mg QE/g and 63.98 ± 2.027 mg QE/g, respectively). The quantification was performed using a calibration curve (y = 0.0089 + 0.2862, R^2 = 0.9894) of quercetin concentration, ranging from 0 to 100 µg/ml and expressed in quercetin equivalents (QE) per gram dry extract weight (Figure 1 and Table 3). There was a significant difference in total flavonoid content among the three medicinal plant extracts (F = 153.68, $P < 0.001$). Extraction efficiency differences based on solvent polarity are consistent with earlier reports (Handa *et al.,* 2008; Do *et al*., 2014).

Functional group characterization by FTIR

FTIR analysis of *Centella asiatica*, *Phyllanthus niruri*, and *Swertia chirata* revealed the presence of several characteristic functional groups. All three plant extracts showed strong O–H stretching (~3330 cm^{-1}), indicating the presence of alcohols or phenolic compounds, which are related for antioxidant activity. *Phyllanthus niruri* and *Swertia chirata* exhibited clear C=O stretches (~1730 cm^{-1}), suggesting esters, ketones, or aldehydes. C=C aromatic stretches (~1600 cm^{-1}) were observed in all extracts, indicating aromatic phytochemicals such as flavonoids. C–N and C–O stretching bands (~1320–1230 cm^{-1}) were also present, indicating possible amines and esters/ethers. Broad metal- oxygen and lattice vibration bands (~520–410 cm^{-1}) were noted in all three extracts. *Swertia chirata* displayed a slightly sharper and well-resolved C=O stretch at 1728.66 cm^{-1} compared to *Centella asiatica*, along with all the observed functional groups. The FTIR spectra provide qualitative confirmation of the presence of various bioactive functional groups in all three plant extracts (Figure 2).

Free radical scavenging activity (DPPH assay)

The antioxidant activity of standard ascorbic acid was evaluated using the DPPH assay at concentrations ranging from 0.01 to 0.014 mg/ml (Figure 1). The results showed a clear dose-dependent increase in free radical scavenging activity, with percentage inhibition values increasing from 39.88% to 73.61%. The IC_{50} value, which represents the concentration required to inhibit 50% of the DPPH radicals, was approximately 0.011 mg/ml, as the percentage inhibition crossed 50% (51.38%) at this concentration. This confirms that ascorbic acid possesses strong antioxidant activity under the experimental conditions and serves as an effective positive control for comparison. The DPPH assay demonstrated a concentration-dependent antioxidant activity for all three plant extracts. *Phyllanthus niruri* showed the highest antioxidant activity, with percentage inhibition increasing from 23.61% to 63.88% and an IC_{50} value between 0.15–0.20 mg/ml. *Centella asiatica* exhibited percentage inhibition ranging from 11.11% to 59.72%, with an IC_{50} value between 0.25–0.30 mg/ml. *Swertia chirata* showed the lowest antioxidant activity, with percentage inhibition ranging from 5.55% to 62.50% and an IC_{50} value between 0.30–0.40 mg/ml (Figure 1 and Table 3). Compared to ascorbic acid ($IC_{50} \approx 0.011$ mg/ml), all plant extracts exhibited moderate antioxidant potential, with *P. niruri* being the most effective among the tested samples. Similar antioxidant trends in *Phyllanthus niruri* have been reported earlier (Gyawali and Ibrahim, 2014). Dose–response relationships were established by plotting percentage inhibition versus concentration, and IC_{50} values were determined using linear regression analysis. The calibration curve for ascorbic acid exhibited good linearity ($y = 0.083x + 0.31$; $R^2 = 0.964$).

Antibacterial activity and minimum inhibitory concentration (MIC)

The MIC of *Centella asiatica* extract was 25 mg/ml for both *E. coli* and *Bacillus* spp. For *Phyllanthus niruri*, the MICs were 25 mg/ml against E. coli and 3.125 mg/ml against Bacillus spp., indicating a higher sensitivity of *Bacillus*. *Swertia chirata* extract showed an MIC of 25 mg/ml against *E. coli* and 6.25 mg/ml against *Bacillus* spp. (Table 3). Streptomycin exhibited an MIC of 12.5 µg/ml against *E. coli* and 6.25 µg/ml against *Bacillus* spp. The use of the INT indicator, along with OD600 measurements, provided reliable detection of bacterial growth and validated the observed MIC values.

Effect of natural coatings in *Solanum lycopersicum var. cerasiforme*

Weight loss increased over the storage period, with faster deterioration at room temperature. Among the treatments, *Swertia chirata* coating showed better weight retention under ambient conditions, whereas *Centella asiatica* provided superior preservation under refrigerated storage, maintaining fruit firmness and surface integrity up to Day 15. Visual assessments supported the quantitative data, with coated fruits exhibiting reduced wrinkling and shrinkage compared to controls, confirming the effectiveness of medicinal plant–based coatings in extending post-harvest quality (Figure 3).

Shelf-life evaluation parameters

Weight loss (%):

Weight loss of the samples increased over time and was influenced by both storage temperature and the type of plant extract (Figure 3). At room temperature, *Phyllanthus niruri* showed the highest weight reduction (1.39–54.76%), followed by *Centella asiatica* (1.27–48.14%) and *Swertia chirata* (0.68–40.09%), while the control lost 2.21–38.28% of its initial weight. Storage at 4 °C slowed weight loss for all samples, with *Swertia chirata* showing the greatest loss (0–27.92%), *Centella asiatica* and *Phyllanthus niruri* exhibiting moderate losses (20.27% and 14.96%, respectively), and the control showing minimal reduction (0.22–5.27%). Overall, lower temperature reduced moisture loss, and the type of plant extract affected the extent of weight reduction, with *Phyllanthus niruri* being most susceptible at room temperature. The differences among the plant extracts were statistically significant at Day 12 (RT: $F = 12.67$, $P < 0.001$) and Day 15 (4 °C: $F = 55.62$, $P < 0.001$).

Visual decay index:

Visual examination of *S. lycopersicum* var. *cerasiforme* coated with medicinal plant extracts over a 15-day storage period revealed notable differences in decay progression under RT and 4°C conditions (Table 4). Each treatment group included 3 fruits per replicate (n = 3), with three replicates per treatment, and decay was scored using the VDI scale at Days 1, 3, 6, 9, 12, and 15.

Day 1: All samples, including controls, appeared visually undamaged and healthy (VDI = 0).

Day 3: Minor exterior dullness and skin wrinkling appeared in RT-stored control fruits (VDI = 1–2), while treated fruits at 4°C retained firm texture and shine (VDI = 0–1).

Day 6: Moderate wrinkling, dullness, and early fungal signs were observed in RT-stored control and *Phyllanthus niruri*-treated fruits (VDI = 2–3). Coated fruits stored at 4°C showed only mild softening and minor surface depressions (VDI = 1).

Day 9: RT-stored fruits exhibited tissue collapse, advanced wrinkling, and fungal colonisation (VDI = 3–4), whereas at 4°C, fruits maintained structure with slight decay (VDI = 1–2).

Day 12: RT controls and *P. niruri* treatments were severely decayed (VDI = 3.5–4), while 4°C-coated fruits retained better texture (*Centella asiatica*, VDI = 1.5; *Swertia chirata*, VDI = 2; *P. niruri*, VDI = 2.5).

Day 15: All RT fruits were fully decayed (VDI = 4) except for *Swertia chirata* treatment; cold-stored fruits coated with *Centella asiatica* retained partial structural integrity (VDI = 2), indicating superior shelf-life extension.

Statistical analysis confirmed significant differences among treatments and storage conditions ($p < 0.05$), validating the protective effect of medicinal plant coatings in prolonging post-harvest quality.

CONCLUSION

The study demonstrates the potential of *Centella asiatica*, *Phyllanthus niruri*, and *Swertia chirata* as effective natural alternatives to synthetic post-harvest preservatives. The bioactive-rich profile, particularly in *Swertia chirata* and *Phyllanthus niruri* extracts as bio-coatings, significantly extended the shelf life and preserved the quality of *Solanum lycopersicum var. cerasiforme* under both room and refrigerated conditions. The edible coatings developed in this study were formulated using medicinal plants with therapeutic use in ethnomedicinal practices, suggesting an established safety profile at low concentrations. While the use of food-grade carboxymethyl cellulose and medicinal plants suggests a favourable safety profile, further toxicological, migration, and sensory evaluation studies are recommended before large-scale or commercial application.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 1: Yield percentage of crude extracts from *Centella asiatica, Phyllanthus niruri,* and *Swertia chirata.*

Plant	Dry weight (mg)	Yield (%)
Centella asiatica	1120 ± 37	11.2 ± 0.37
Phyllanthus niruri	1843 ± 60	18.43 ± 0.60
Swertia chirata	890 ± 36	8.9 ± 0.36

Table 2: Total chlorophyll (a, b) and carotenoid concentrations

µg/ml	*Centella asiatica*	*Phyllanthus niruri*	*Swertia chirata*
Total carotenoids	0.364	1.338	2.028
Chlorophyll a	2.613	5.654	9.55
Chlorophyll b	1.068	3.021	4.54
Total chlorophyll	3.681	8.675	14.09

Table 3: Phytochemical composition, antioxidant activity, and antimicrobial efficacy of medicinal plant extracts

Medicinal plant	Total phenolics (mg GAE/g)	Total flavonoids (mg QE/g)	DPPH IC50% (mg/ml)	MIC (mg/ml)	
				E.Coli	*Bacillus spp.*
Centella asiatica	17.13 ± 1.014	63.98 ± 2.027	0.25–0.30	25	25
Phyllanthus niruri	57.03 ± 0.95	67.386 ± 2.507	0.15–0.20	25	3.125
Swertia chirata	66.3 ± 1.527	103.108 ± 4.136	0.30–0.40	25	6.25

Table 4: Visual decay index (VDI) of *Solanum lycopersicum* var. *cerasiforme* coated with medicinal plant extracts stored under room temperature and refrigerated (4 °C) conditions at Day 15.

Treatment	VDI at room temperature	VDI at 4 °C
Control	4.0	4.0
Centella asiatica	3.5	2.0
Phyllanthus niruri	4.0	3.0
Swertia chirata	3.0	2.5

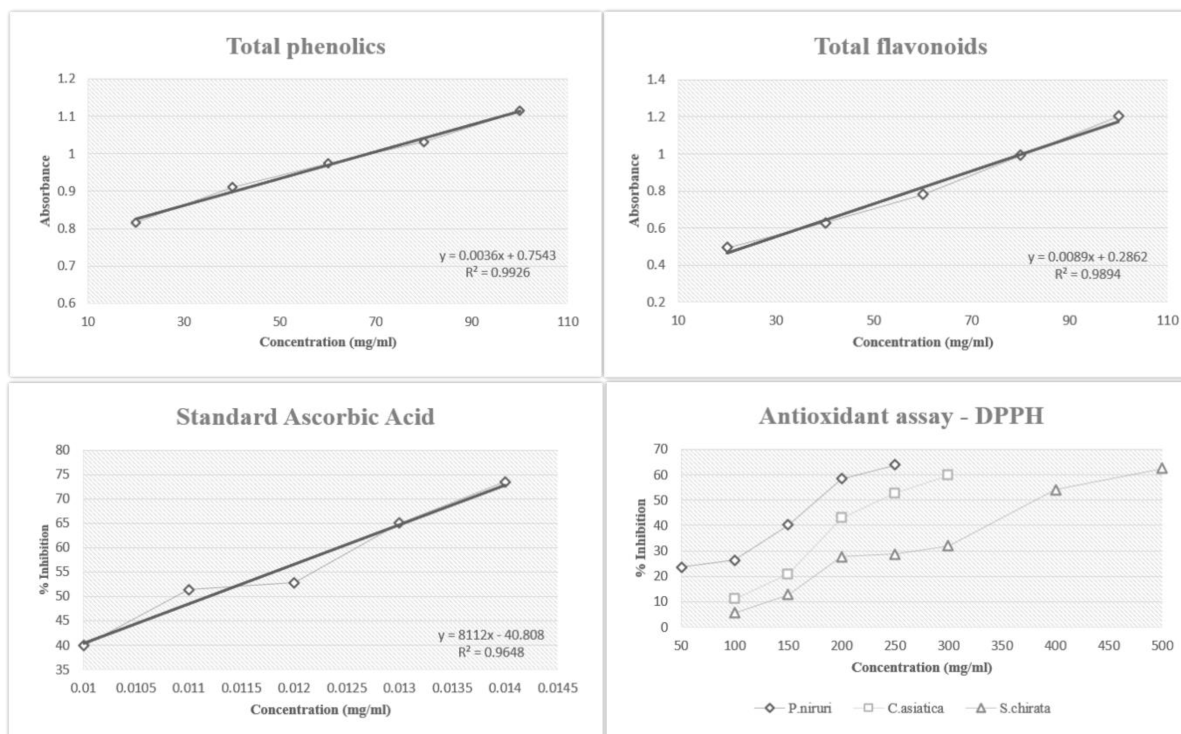

Figure 1. [A] Total phenolic content; [B] Total flavonoid content of aqueous and ethanolic extracts, respectively; [C] DPPH assay standard: ascorbic acid; and [D] Free radical scavenging activity in *Centella asiatica, Phyllanthus niruri,* and *Swertia chirata.*

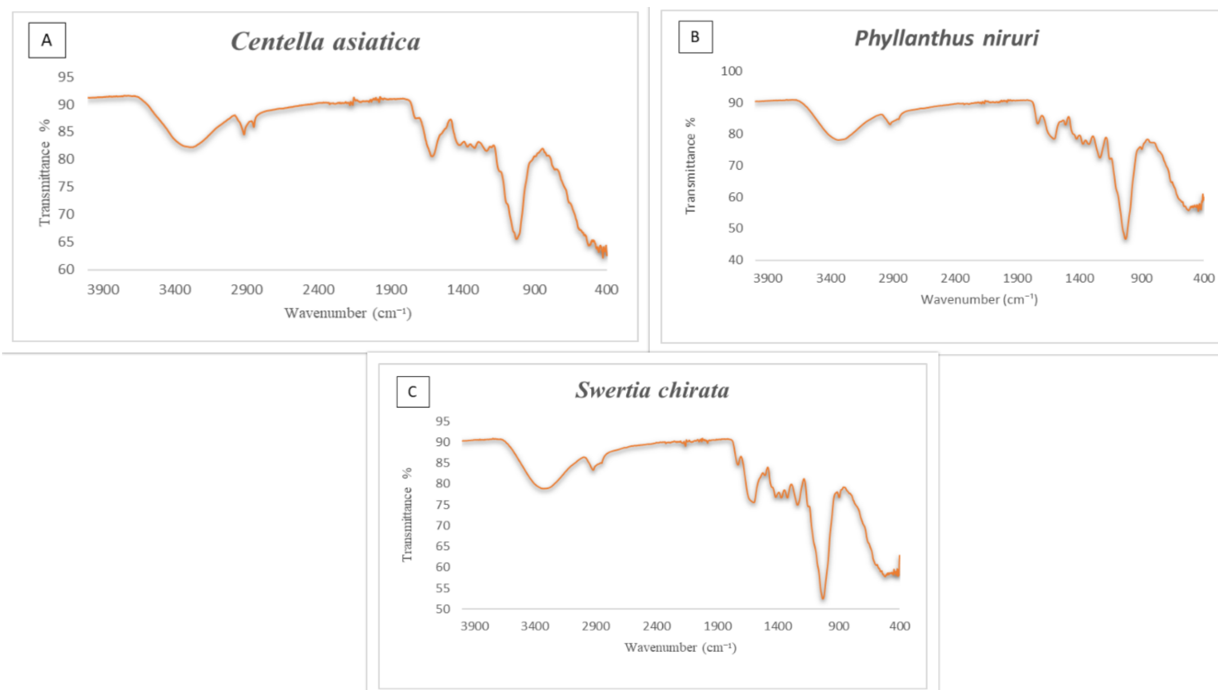

Figure 2: FTIR analysis presentation of functional groups present in the plant extracts, [A]*Centella asiatica,* [B]*Phyllanthus niruri* and [C]*Swertia chirata.*

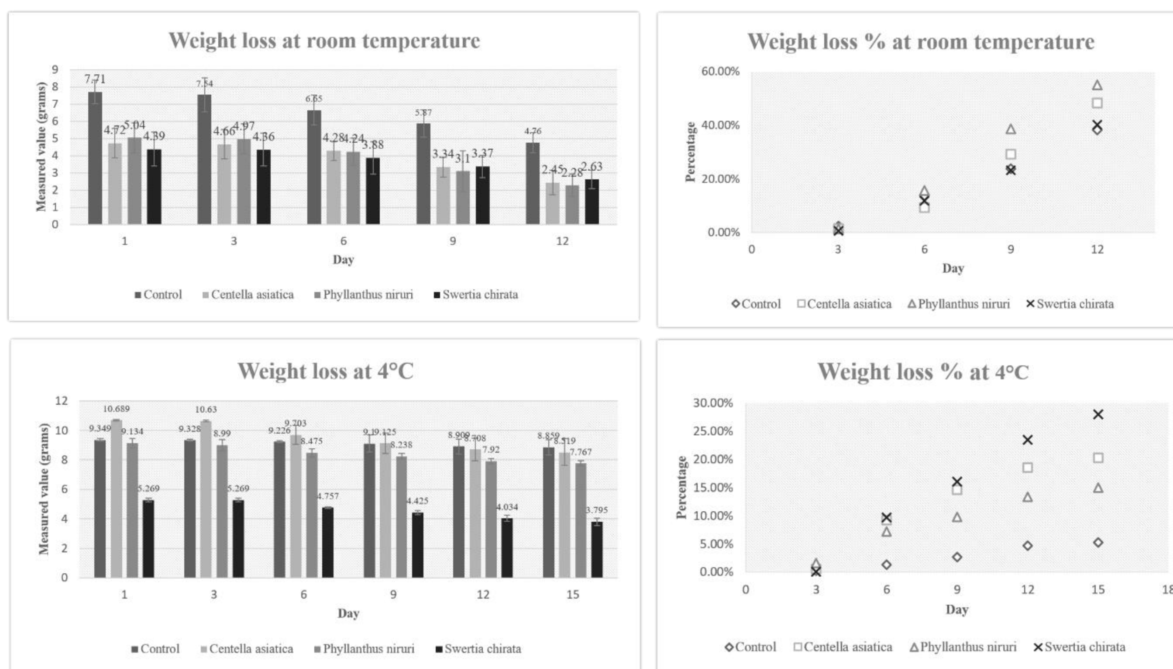

Figure 3: Changes in weight loss of *Solanum lycopersicum* var. *cerasiforme* coated with medicinal plant extracts during storage under room temperature and refrigerated (4 °C) conditions. [A] Measured weight loss (g) at room temperature, [B] weight loss (%) at room temperature, [C] measured weight loss (g) at 4 °C, and [D] weight loss (%) at 4 °C.