

A Comparative Study Between *Cheilocostus speciosus* (Sea Qust) and *Saussurea lappa* (Indian Qust): Decoding the Spectral, Anti-bacterial, and Anti-cancer Analyses

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Abstract

Background: This study conducted a comprehensive comparative analysis of *Cheilocostus speciosus* (sea qust) and *Saussurea lappa* (Indian qust) using various bioanalytical techniques.

Objectives: To identify the undiscovered traits of these two plants *C. speciosus* (sea qust) and *S. lappa* (Indian qust).

Materials and Methods: Ethanolic extracts were prepared from *C. speciosus* and *S. lappa* roots. Chemical composition was determined using gas chromatography–mass spectrometry (GC–MS) and Fourier transform infrared spectroscopy (FTIR). Inductively coupled plasma optical emission spectroscopy (ICP–OES) was utilized to determine the elemental profiles of both extracts. The anti-bacterial and cytotoxic activities were tested against pathogenic microorganisms and MCF-7 cells, respectively.

Results: According to GC–MS, each extract contained a distinct collection of compounds, some of which were common to the two plants. While *C. speciosus* contained xanthosine, *S. lappa* contained dehydrocostus lactone as the major compound. FTIR analysis confirmed that both extracts contained bioactive functional groups. The two plants have different K, Mn, Cu, Fe, and Zn levels. MCF-7 cells were more responsive to *C. speciosus* extract, with an IC_{50} of 122 ± 11.5 μ g/mL. The tested bacteria were susceptible to both extracts, with variable responses.

Conclusion: Future studies investigating synergistic interactions and creating formulations from extracts of *C. speciosus* and *S. lappa* are warranted. This study offers significant insights to therapists, consumers, and researchers regarding the chemobiological differences between sea and Indian qust.

Keywords

Cheilocostus speciosus, *Saussurea lappa*, comparative analysis, gas chromatography–mass spectrometry, anti-bacterial activity

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Introduction

Saussurea lappa (Decne.) Sch. Bip. (Indian qust), a fragrant herb found in the Himalayan region, has been used in traditional medicine for several centuries. The roots of this plant, known by several regional names, such as kuṣṭha and pa-chu, are highly valued for their anti-inflammatory, analgesic, and anti-bacterial properties. In addition to Ayurvedic and Unani medicine, *S. lappa* has been used in various folk medical remedies. Plants are used to treat cough, diarrhea, and fever in Nepal (Hassan & Masoodi, 2020). It is also used as an insect repellent and in the treatment of skin conditions. Most of the phytoconstituents are sesquiterpene lactones and flavonoids. Animal models have clearly demonstrated the anti-inflammatory and analgesic properties of this herb (Hassan & Masoodi, 2020; Kumar & Pundir, 2022).

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With various traditional uses, *Cheilocostus speciosus* (J. König) C. Specht (sea qust) is a postpartum treatment in Thailand that uses this plant to induce uterine contraction and reduce bleeding. In India, the leaves are used as poultices for skin diseases and wounds (Hussain & Mazumder, 2021). Some cultures hold that plants have aphrodisiac properties. The chemical makeup of *C. speciosus*, the prominent components of plant's flavonoids, especially kaempferol and quercetin—contribute to their anti-inflammatory and antioxidant properties (Rabha et al., 2021). Anti-bacterial and anti-inflammatory terpenoids include β -caryophyllene and α -humulene, respectively. The monoterpenes and sesquiterpenes found in *C. speciosus* essential oils help explain their distinctive scent and possible medicinal properties. Animal models of inflammation and arthritis have shown anti-inflammatory properties. Models that induce pain have shown analgesic effects, indicating the possibility of pain alleviation (Benelli et al., 2018). Furthermore, research has shown encouraging anti-cancer and anti-diabetic properties of *C. speciosus* (Benelli et al., 2018; Hussain & Mazumder, 2021; Rabha et al., 2021; Varghese, 2024).

Prophetic medicine refers to qust. The Prophet Muhammad refers to cupping and al-qustal-bahri as the “best thing for you to treat with” in the hadith. Qust can be used topically on the skin after being blended with olive oil or taken orally after being ground and added to water or honey (Kamil, 2020; Yosri et al., 2023). “Al-qust” was known as a fragment of wood taken from the root of the costus tree, which is found throughout the Indian subcontinent, particularly in China and Kashmir. In the Middle East, “qust” encompasses two distinct medicinal plants, *C. speciosus* and *S. lappa* (Figure 1 and Table 1), which are often used interchangeably despite their unique characteristics (Hamdan et al., 2024). This is

sometimes referred to as Indian costus or sea costus because traders transport it by boat to the Arabian Peninsula. The black-colored costus is referred to as Indian costus, and white-colored costus as sea or Arabian costus (Ahmad, 2024; Hamdan et al., 2024).

This study used a rigorous comparison strategy to identify the undiscovered traits of these two plants. Gas chromatography–mass spectrometry (GC–MS) and Fourier transform infrared spectroscopy (FTIR) were used to differentiate the two plants. To further understand these distinctions, this study tested their biological activities, such as anti-bacterial and anti-cancer activities. The goal was to identify important bioactive components and establish precise plant distinctions. The findings will assist Middle Eastern consumers, practitioners, and researchers in identifying and harnessing the medicinal properties of these plants. Such an explanation would simplify the exploration and production of safe and effective *S. lappa* and *C. speciosus* medicinal substances for responsible and useful use in traditional and modern medicine.

Materials and Methods

Plant Materials and Extraction

To guarantee genuine quality control, the Shamool Company (<https://shmool.net/en>) in Mecca, Saudi Arabia, supplied the gross roots of *C. speciosus* and *S. lappa*. Fifty grams of powdered roots from both plants was extracted using 95% ethanol. The plant materials were soaked three times for a total of 24 h, with sporadic shaking during the extraction process. Extraction was performed at room temperature (Kringel et al., 2020). After drying in a rotary evaporator, the extracts were refrigerated.



Figure 1. The Roots of *Saussurea lappa* (Indian Qust) and *Cheilocostus speciosus* (Sea Qust).

Table 1. Scientific Names, Taxonomy, and Common Names of *Saussurea lappa* and *Cheilocostus speciosus*.

Botanical Name	Synonyms Names	Botanical Family	Common Name
<i>Cheilocostus speciosus</i> (J. Konig) C. Specht	<i>Banksea speciosa</i> (J. Koenig) <i>Hellenia speciosa</i> (J. Koenig) S. R. Dutta <i>Costus sericeus</i> Blume Enum. <i>Costus speciosus</i> (J. Koenig) <i>Amomum arboreum</i> Lour. <i>Amomum hirsutum</i> Lam.	Costaceae	Sea costus; Quste Talkh; Aarathi Kundige; Ai Eupou; Ai Oppo; crape ginger; Anakkuva; Anappu; Bachakanda; Bajraganda
<i>Saussurea lappa</i> (Decne.) Sch. Bip.	<i>Aplotaxis lappa</i> Decne. <i>Aucklandia costus</i> Falc. Ann. <i>Aucklandia lappa</i> (Decne.) <i>Saussurea costus</i> (Falc.) Lipsch. <i>Theodorea costus</i> (Falc.) Kuntze Revis. <i>Dolomiaea costus</i> (Falc.) Kasana and A. K. Pandey	Asteraceae	Indian costus; costus root; Aamaya; agada; amaya; apya; A.; A.e radix; bhasura; cengala; chagal koshtam; changal

GC–MS Analysis and the Identification of Constituents

The extracts were analyzed using a TR-5MS capillary column fitted to a Shimadzu Gas Chromatograph. With a starting temperature of 70°C and a progressively increasing temperature of 290°C, the ideal temperature program enabled the separation of a broad spectrum of chemicals with various volatilities. Analytes are efficiently transported across the column by helium carrier gas (Alhazmi et al., 2019). Several approaches have been used to identify the individual components of extracts. Retention indices offer a trustworthy method of identification when compared to real standards or reference values. To further verify the identification of the compounds, the fragmentation patterns of the mass spectra produced by the Shimadzu QP2010 Ultra MS detector were compared to those kept in extensive libraries, notably NIST08 and Wiley 9.

Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES)

The samples and standard solutions were prepared using ultrapure deionized water produced using a Milli-Q purification system. Sample preparation for analysis was performed using high-performance liquid chromatography HPLC-gradient-grade nitric acid purchased from Sigma–Aldrich. Typical stock solutions of Zn, Cu, Fe, Pb, Cd, K, Ni, Mn, and Co were purchased from St. Louis, Missouri, United States at a concentration of 1,000 mg/L in 0.5% (v/v) HNO₃. Every day, a specific volume of the stock solution was dissolved in Milli-Q water to prepare fresh working standard solutions within the appropriate concentration range for each element. All glassware used in the standard solution preparation was thoroughly cleaned with Milli-Q water, allowed to air dry, and immersed in 2.0% nitric acid overnight before use.

The heavy metal content of the plant samples was determined using an atomic absorption spectrometer (AAS) Thermo

Scientific iCE 3000 Series (Jorhem, 2000). The samples were easily dried at room temperature, and then 1 g of the sample was ignited at 450°C for 10 h until white ash formed. After adding 5 mL of 6 M HCl, the sample was allowed to evaporate until completely dried. The residue was dissolved using 0.1 M nitric acid up to 50 mL in a volumetric flask. The same protocol was applied to all blanks. AAS was used to assess the diluted digested samples. First, the device software was used to choose the desired elements for analysis and a suitable wavelength for the selected element. The instrument was calibrated by injecting the blank sample and expected standards, producing a standard curve, and then analyzing the unknown samples. The concentration is expressed in mg/g.

FTIR Spectroscopy

FTIR spectroscopy was used to detect biomolecular compositions (Khalid et al., 2023). The FTIR spectra of both extracts were analyzed using an FTIR spectrophotometer (Shimadzu IR-Spirit-T FTIR spectrophotometer, Japan). Approximately 0.1 mL samples were placed on silicon carbide discs, the spectra were gathered at 4 cm⁻¹ resolution, and 45 scans were made over the transmittance range of 4,000–400 cm⁻¹.

Anti-cancer Activity

The anti-cancer activity of the samples was assessed using the MTT assay in MCF-7 cells, as described by Syam et al. (2012). Cells were seeded in Dulbecco's modified Eagle medium (DMEM) supplemented with 10% fetal bovine serum (FBS) and 1% penicillin–streptomycin. Cells were seeded in 96-well microplates and subjected to 48 h of treatment with different extract concentrations. MTT reagent was then added to each well, and the absorbance was recorded at 570 nm. Each treatment group had the percentage of cell viability determined in relation to the control, and extracts with lower cell viability indicated more anti-cancer action. The anti-cancer activities of

C. speciosus and *S. lappa* extracts were compared at different concentrations. Statistical analyses were performed to determine the significance of results. The experiment was conducted in triplicate to ensure reproducibility.

Anti-microbial Activity

In this study, human pathogenic *Escherichia coli* (ATCC25922) was used. Each bacterial culture used in this study was

maintained in the microbiology laboratory of the College of Pharmacy by subculturing at predetermined intervals. The culture was standardized using the gradient dilution method with nutrient broth, employing serial dilutions ranging from 10^{-1} to 10^{-7} . The viability of the bacterial cultures was assessed by calculating the colony-forming units per mL (CFU/mL). Anti-microbial susceptibility tests were performed as described previously (Sivakumar & Safhi, 2013). Mueller–Hinton (MH) agar plates were prepared for the anti-bacterial investigation.

Table 2. Major Compounds (>0.8%) of Both Extracts.

<i>Saussurea lappa</i>			<i>Cheilocostus speciosus</i>		
Retention Time	Area (%)	Names	Retention Time	Area (%)	Names
12.033	31.78	Dehydrocostus lactone	8.032	24.41	Xanthosine
11.595	5.59	Dihydrodehydrocostus lactone	12.61	16.11	7-Tetradecenal, (Z)-
11.427	4.2	<i>n</i> -Hexadecanoic acid (palmitic acid)	11.43	6.07	<i>n</i> -Hexadecanoic acid (palmitic acid)
12.552	4.16	9,12-Octadecadienoic acid (Z,Z)-(linoleic acid)	9.311	5.24	3-Deoxy-D-mannoic lactone
11.12	4.09	Hexadecanoic acid, methyl ester	9.508	3.87	Pyrrolidine, 1-(1-cyclohexen-1-yl)-
8.017	3.89	Xanthosine	7.251	2.22	4-Penten-1-ol, TMS derivative
11.04	3.44	Androstan-17-one, 3-ethyl-3-hydroxy-, (5.alpha.)-	5.932	2.02	1,2,3-Propanetriol, 1-acetate
10.915	2.62	Farnesene epoxide, E-	5.076	1.87	1,2,3-Propanetriol
10.975	2.49	(E)-2-Methyl-5-((1S,2R,4R)-2-methyl-3-methylenebicyclo[2.2.1]heptan-2-yl)pent-2-enoic acid	4.345	1.74	1,3,5-Triazine-2,4,6-triamine
11.3	2.43	1H-Cycloprop[e]azulene, decahydro-1,1,4,7-tetramethyl-, [1aR-(1a.alpha.,4.beta.,4a.beta.,7.beta.,7a.beta.,7b.alpha.)]-	14.748	1.7	Pentadecanal-
11.863	1.7	.beta.-Cyclocostunolide	8.303	1.63	.beta.-D-Glucopyranose, 1,6-anhydro-
9.413	1.51	8,11,14-Eicosatrienoic acid, (Z,Z,Z)-	4.986	1.51	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-
12.079	1.5	2(3H)-Benzofuranone, 6-ethenylhexahydro-6-methyl-3-methylene-7-(1-methylethenyl)-, [3aS-(3a.alpha.,6.alpha.,7.beta.,7a.beta.)]-	6.334	1.31	Trimethylsilyl ester of 3-methyl-furan-2-carboxylic acid
9.279	1.22	1,8,11,14-Heptadecatetraene, (Z,Z,Z)-	15.99	1.16	Octadecanoic acid, 2,3-dihydroxypropyl ester
9.332	1.12	.alpha.-D-Galactopyranoside, methyl	5.846	1.07	5-Hydroxymethyl-furfural
7.828	1.11	Adenosine, N6-phenylacetic acid	8.453	1.04	Dodecanoic acid, 3-hydroxy-
5.068	1.02	1,2,3-Propanetriol	15.823	0.94	Silicone oil
7.25	1.02	1-Methyl-1-(3-methylbutyl)oxy-1-silacyclobutane	7.484	0.83	Silane, [3-(2,3-epoxypropoxy)propyl]ethoxydimethyl-
10.354	0.96	2-((2R,4aR,8aS)-4a-Methyl-8-methylenedecahydronaphthalen-2-yl)prop-2-en-1-ol	9.927	0.82	4,4-Ethylenedioxy-pentanenitrile

Bacterial subcultures were prepared from the stock culture and incubated for 24 h before use in anti-bacterial assays. For each injection of the standard anti-biotics and sample analytes, agar well diffusion was performed using different bacterial species. A sterile cotton swab was dipped into the standardized culture (CFU/mL) and streaked onto an MH agar plate to ensure equal distribution. Approximately 10 min after the plates had dried, the sample analytes were added. For the agar well diffusion technique, holes were made in the infected MH agar plates using a sterile stainless steel borer. The anti-bacterial spectrum was measured by looking for inhibitory zones to develop on the plates after a 24-hour incubation period at 37°C. The bactericidal activity of streptomycin (10 µg/disc) was evaluated using the Kirby–Bauer technique (Christenson et al., 2018; Moni et al., 2019). To determine the anti-bacterial spectrum, the inhibitory zones surrounding the discs were determined after incubating the plates at 37°C for 24 h.

Results

GC–MS was used on the roots of both plants to identify the chemicals and to compare their similarities and differences (Table 2). Variations in *S. lappa* and *C. speciosus* were

Table 3. Common Compounds Between the Two Plants and Their Proportions in Each.

Compounds	<i>Saussurea lappa</i>	<i>Cheilocostus speciosus</i>
	%	
β-D-Glucopyranose, 1,6-anhydro-	0.48	1.63
1,2,3-Propanetriol	1.02	1.87
1 <i>H</i> -Purin-6-amine, [(2-fluorophenyl)methyl]-	0.02	0.07
2(3 <i>H</i>)-Furanone, dihydro-4-hydroxy-	0.16	0.51
4 <i>H</i> -Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-	0.83	1.51
5-Hydroxymethylfurfural	0.29	1.07
Dehydrocostus lactone	31.78	0.31
cis-9-Hexadecenal	0.02	0.54
Hexadecanoic acid, methyl ester	4.09	0.02
<i>n</i> -Hexadecanoic acid	4.2	6.07
Xanthosine	3.89	24.41

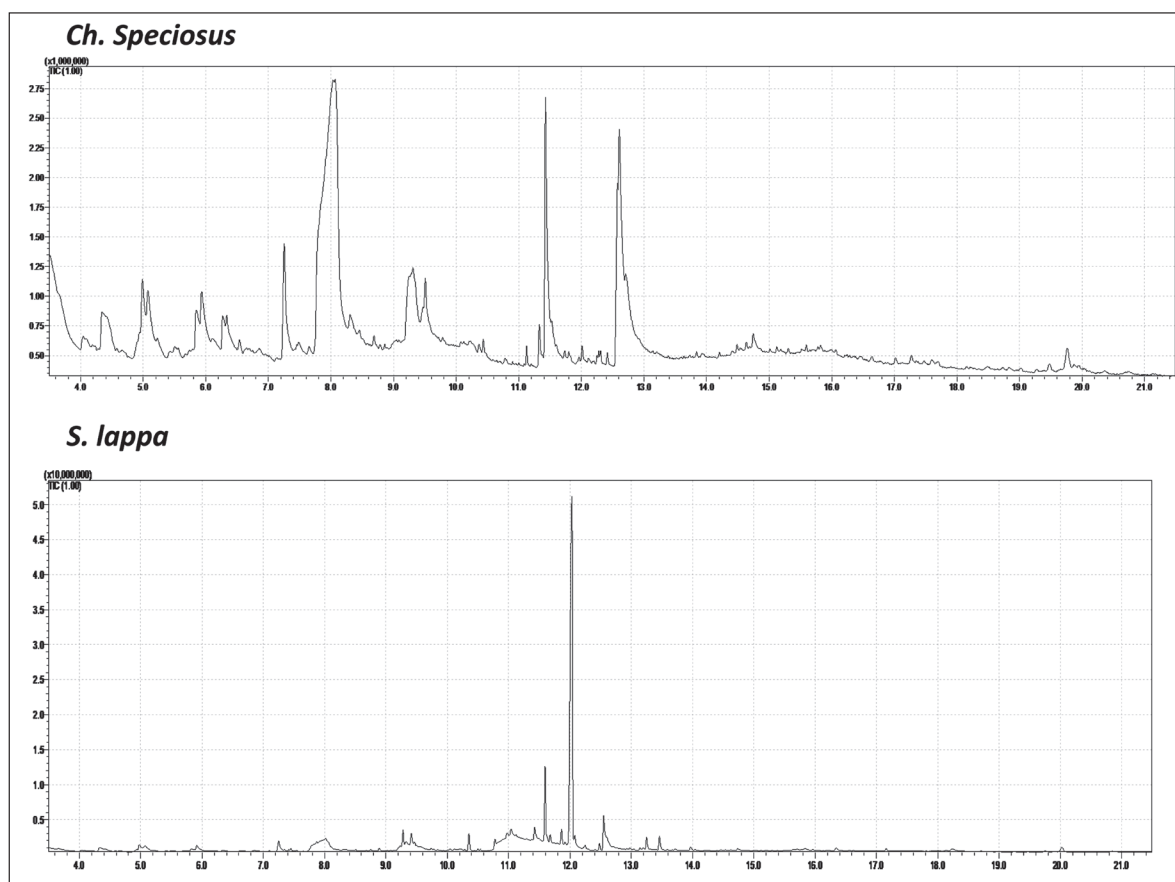


Figure 2. Illustrative Typical Gas Chromatography–Mass Spectrometry (GC–MS) Total Ion Current (TIC) Chromatograms of the Two Samples.

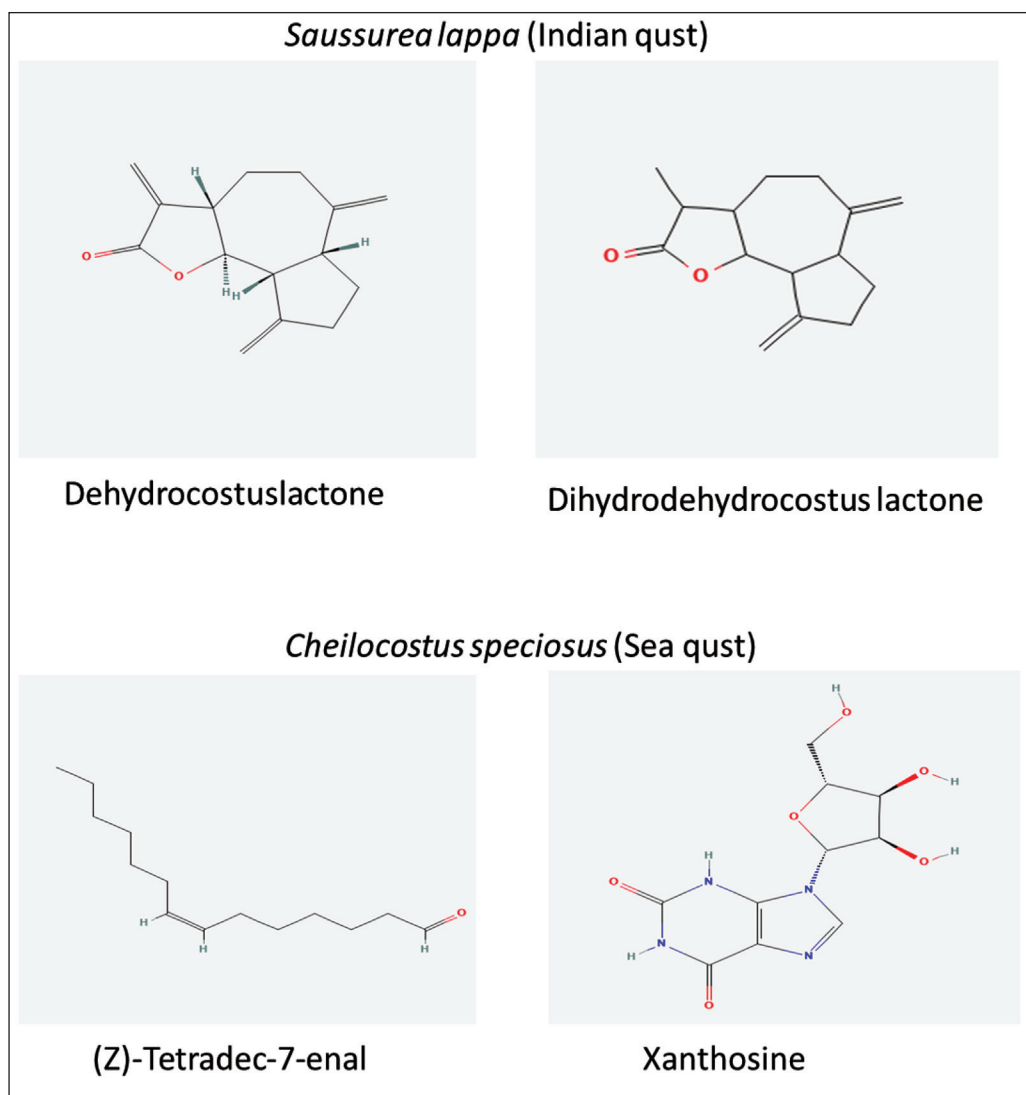


Figure 3. Chemical Structure of the Main Compounds in Both Samples.

determined by GC–MS analysis. Seven common compounds were found in both extracts (Table 3): β -D-glucopyranose, 1,6-anhydro-; 1,2,3-propanetriol; 2(3*H*)-furanone, dihydro-4-hydroxy-; 4*H*-pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-; 5-hydroxymethylfurfural; dehydrocostus lactone, and xanthosine. However, there were several unique constituents in each extract. The major compounds identified in each extract (Table 2 and Figure 2) were dehydrocostus lactone in *S. lappa* (31.78% area) and xanthosine in *C. speciosus* (24.41% area), which may contribute to their distinct biological activities and therapeutic potentials. The chemical structures of the major compounds are shown in Figure 3.

FTIR spectroscopy was used to determine the presence of functional groups in a given sample. FTIR analysis of the ethanolic extracts of *C. speciosus* and *S. lappa* was performed. Numerous bioactive functional groups were found to be present, according to the results (Figure 4 and Table 4). These groups include C–H asym and sym stretching

(alkanes and alkenes), C=O stretching (unsaturated aldehydes, ketones, carboxylic acid), $\text{C}=\text{C}$ stretching (alkenes), C–H bending, O–H bending, C–N stretching (aromatic amines), PO_4 stretching, and C–Cl stretching (alkyl halides). The phytochemicals found in the extract, such as phenols, sugars, glycosides, flavonoids, saponins, and vitamins C and E, were the sources of all these peaks. Table 4 presents the possible compounds present in both plant extracts. This confirmed that the ethanolic extracts of *C. speciosus* and *S. lappa* consisted of most of the common phytoconstituents, supporting the results of the GC–MS study.

The elemental composition analysis revealed notable differences in the concentrations of potassium (3.28 mg/g vs. 4.93 mg/g), manganese (0.00851 mg/g vs. 0.0024 mg/g), zinc (0.02347 mg/g vs. 0.007855 mg/g), copper (0.11 mg/g vs. 0.020 mg/g), and iron (0.02911 mg/g vs. 0.01915 mg/g) between the two plants (Table 5).

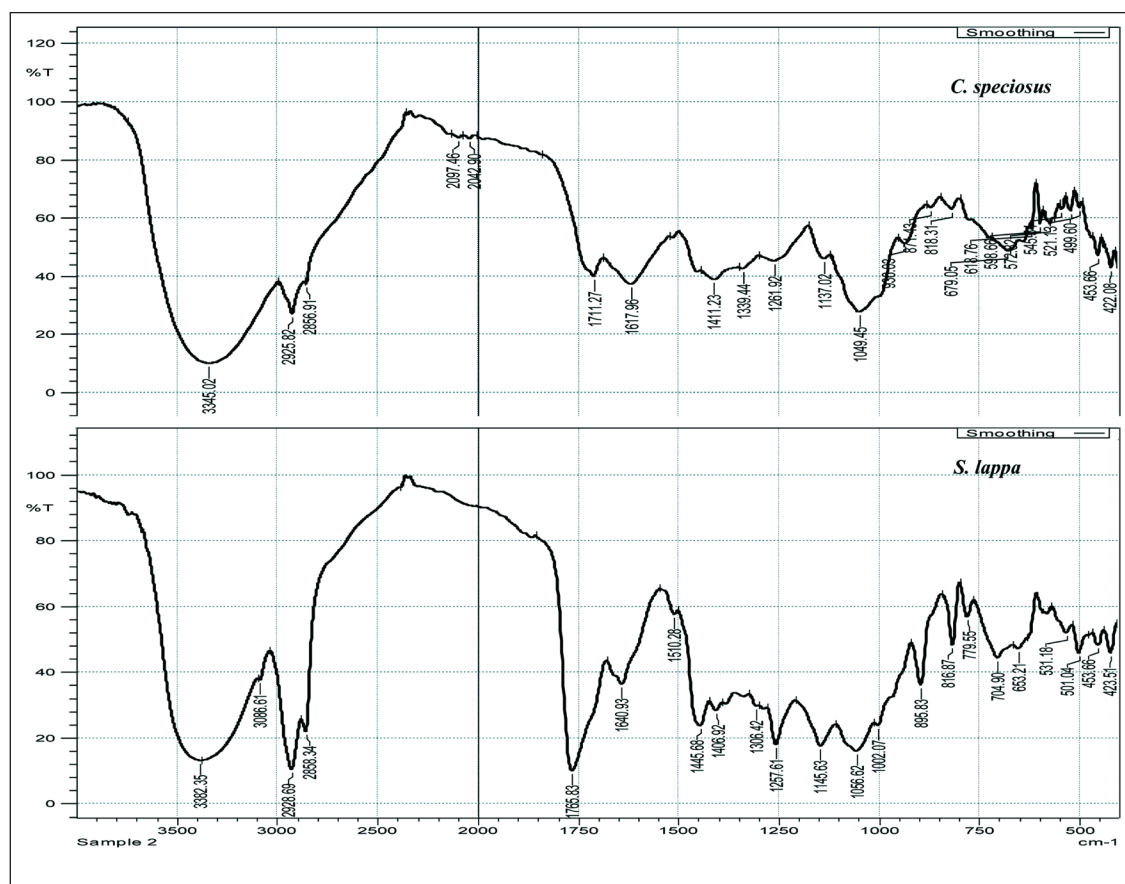


Figure 4. Fourier Transform Infrared Spectroscopy (FTIR) Spectral Pattern of *Cheilocostus speciosus* and *Saussurea lappa* Extracts.

Table 4. Structural Features of *Cheilocostus speciosus* and *Saussurea lappa* Extracts by Fourier Transform Infrared Spectroscopy (FTIR) Spectrum.

Species	Wave Number (cm ⁻¹)	Intensity Estimation	Functional Group/Class	Type of Vibration	Possible Compounds
<i>C. speciosus</i>	3,345	Broad	O–H alcohols/phenols	Stretching	Xanthosine, 5-hydroxymethylfurfural, 3-deoxy-D-mannonic lactone, 4-penten-1-ol, 1,2,3-propanetriol, humic acid
<i>S. lappa</i>	3,382				Xanthosine, 5-hydroxymethylfurfural, adenosine
<i>C. speciosus</i>	2,952 and 2,856	Strong	C–H str. (asym) and CH str. (sym)	Stretching	Xanthosine, dehydrocostus lactone, <i>n</i> -hexadecanoic acid
<i>S. lappa</i>	2,928 and 2,858				Xanthosine, dehydrocostus lactone, <i>n</i> -hexadecanoic acid, 9,12-octadecadienoic acid, 2(3 <i>H</i>)-furanone, 4 <i>H</i> -pyran-4-one, 5-hydroxymethylfurfural, cis-9-hexadecenal, N6-phenylacetic acid, 7-Tetradecenal, 3-deoxy-D-mannonic lactone, pyrrolidine, humic acid
<i>C. speciosus</i>	1,711	Strong	C=O (ketones, aldehydes, carboxylic acid)	Stretching	Xanthosine, dehydrocostus lactone, <i>n</i> -hexadecanoic acid, 9,12-octadecadienoic acid, androstan-17-one, 2(3 <i>H</i>)-furanone, 4 <i>H</i> -pyran-4-one, 5-hydroxymethylfurfural, cis-9-hexadecenal, 8,11,14-eicosatrienoic acid
<i>S. lappa</i>	1,765				

(Table 4 continued)

(Table 4 continued)

Species	Wave Number (cm ⁻¹)	Intensity Estimation	Functional Group/Class	Type of Vibration	Possible Compounds
<i>C. speciosus</i>	1,617	Medium	C=C (alkenes)	Stretching	Xanthosine, 4 <i>H</i> -pyran-4-one, 5-hydroxymethylfurfural, cis-9-hexadecenal, 7-tetradecenal, humic acid
<i>S. lappa</i>	1,640				Xanthosine, farnesene, 4 <i>H</i> -pyran-4-one, 5-hydroxymethylfurfural, cis-9-hexadecenal
<i>C. speciosus</i>	1,411	Medium	C-H	Bending	Xanthosine, 2(3 <i>H</i>)-furanone, 4 <i>H</i> -pyran-4-one
<i>S. lappa</i>	1,445	Medium			
<i>C. speciosus</i>	1,339	Medium	O-H	Bending	Xanthosine, 1,2,3-Propanetriol, beta.-D-glucopyranose
<i>S. lappa</i>	1,306				
<i>C. speciosus</i>	1,261	Medium	C-N (amine)	Stretching	Xanthosine
<i>S. lappa</i>	1,257				
<i>C. speciosus</i>	1,137	Medium	C-O	Stretching	Xanthosine, dehydrocostus lactone
<i>S. lappa</i>	1,145				
<i>C. speciosus</i>	1,049	Medium	Phosphate ion	Stretching	Lecithin
<i>S. lappa</i>	1,056				
<i>C. speciosus</i>	818	Strong	C-Cl	Stretching	Alkyl halides
<i>S. lappa</i>	816				

Table 5. The Elemental Composition of the *Cheilocostus speciosus* and *Saussurea lappa*.

Samples	K	Mn	Zn	Pb	Ni	Co	Cd	Cu	Fe
Concentration (mg/g)									
<i>Saussurea lappa</i>	3.28	0.00851	0.02347	0.039	0.000955	0.000605	0.00022	0.0055	0.02911
<i>Cheilocostus speciosus</i>	4.93	0.0024	0.007855	0.021	0.0008	0.000215	0.000195	0.001	0.01915

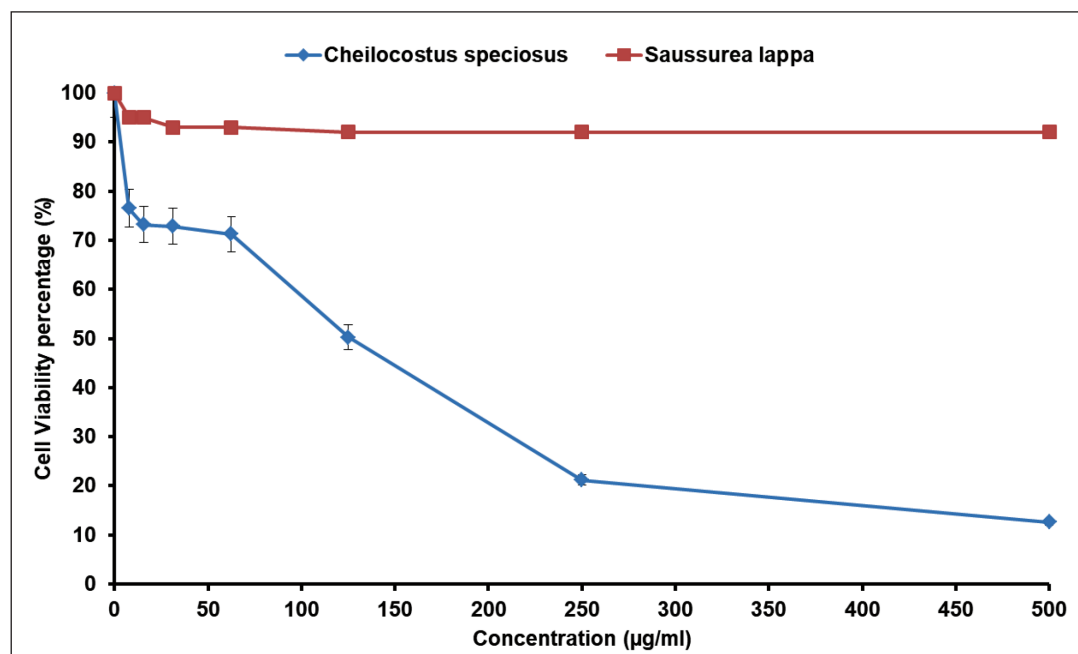
**Figure 5.** Cytotoxic Activity of the Extracts Against MCF-7 Cell Lines (48h IC₅₀ ± SD µg/mL).

Table 6. Anti-bacterial Activities of Ethanolic Extracts of *Cheilocostus speciosus* (MC) and *Saussurea lappa* (IC) Against Bacterial Test Organisms.

Pathogenic microor- ganism	Concentrations (µg/mL)											
	250		100		50		25		10		5	
	Mean zone of inhibition (ZOI) in “mm”											
	MC	IC	MC	IC	MC	IC	MC	IC	MC	IC	MC	IC
<i>Escherichia coli</i>	44 ± 3.5	46 ± 3.1	35 ± 2.4	30 ± 1.3	30 ± 2.4	28 ± 0.97	22 ± 1.81	19 ± 1.3	13 ± 0.51	12 ± 1.7	–	–

Notes: Values represent the mean ± SD of three parallel experiments.

– = No zone of inhibition.

IC: *Saussurea lappa*; MC: *Cheilocostus speciosus*.

C. speciosus extract demonstrated cytotoxic activity against MCF-7 cells, with an IC₅₀ value of 122 ± 11.5 µg/mL. This indicated that at a concentration of 122 µg/mL, *C. speciosus* extract inhibited the growth of MCF-7 cells by 50% (Figure 5). Conversely, *S. lappa* extract did not show a significant cytotoxic effect on MCF-7 cells, suggesting that it may not possess anti-cancer activity against this specific cell line.

Table 6 shows the anti-bacterial activity of the ethanolic extracts of *C. speciosus* and *S. lappa* against *E. coli* at different concentrations (µg/mL). The mean zone of inhibition (ZOI) values in millimeters (mm) are calculated for each concentration. Notably, *E. coli* showed the highest sensitivity to both the extracts. These findings, representing the mean ± SD of three parallel experiments, hold potential for the development of new and more effective anti-bacterial agents.

Discussion

This groundbreaking study compared Indian Qust (*C. speciosus*) and Sea Qust (*S. lappa*) using spectral, elemental, and biological analyses. This study aimed to unveil their unique chemical signatures, evaluate their biological activities, and develop standardized extracts with enhanced efficacy and safety. This study addresses the confusion, paves the way for new drug discovery, and advances herbal medicine.

The chemical compositions of *S. lappa* and *C. speciosus* should be compared to gain an important understanding of their unique characteristics and their use in both traditional and modern medicine. Variations in the chemical compositions of the extracts were determined by GC–MS analysis, with seven common compounds found in both samples. The main substances found in each extract may be related to their unique biological effects and therapeutic potential. Dehydrocostus lactone was reported previously in *C. speciosus* extracts (Varghese, 2024). These variations in chemical composition suggest that *S. lappa* and *C. speciosus* may function through separate pathways to provide therapeutic benefits.

Comparably, the presence of bioactive functional groups, such as phenols, sugars, glycosides, flavonoids, and saponins, was verified by FTIR analysis of the ethanolic extracts of *C. speciosus* and *S. lappa*. These results confirm that both

extracts contain similar phytoconstituents and are consistent with the GC–MS findings. Our knowledge of the possible therapeutic qualities of the plant extracts was improved by FTIR analysis. The results were generally strengthened, and a thorough picture of the chemical composition and possible medical uses of *S. lappa* and *C. speciosus* was provided by the agreement between the GC–MS and FTIR tests.

The amounts of K, Mn, Zn, Cu, and Fe in *C. speciosus* and *S. lappa* were found to be somewhat different by ICP–OES. Higher levels of Mn and Fe were found in *S. lappa* than in *C. speciosus*. These variations in the elemental composition of the two plants account, in part, for their disparate nutritional and therapeutic qualities.

C. speciosus is highly cytotoxic to MCF-7 breast cancer cells, suggesting its potential as a breast cancer treatment. Experimental studies have demonstrated that *C. speciosus* extracts (ethanol, water, ethyl acetate, and methanol) inhibited liver (Gheraibia et al., 2020), colon (H El-Far et al., 2016), prostate (Nafisah et al., 2022), and cancer cell proliferation in a dose-dependent manner. Its ability to induce cell cycle arrest in the G2/M phase in MCF-7 cells (Alhamdi, 2014) suggests a mechanism involving disruption of cell cycle progression. Additionally, in silico investigations have revealed stable interactions between caspases and cell cycle regulators with active components of *C. speciosus*, providing insights into potential apoptotic pathways and molecular targets (Nafisah et al., 2022). These computational predictions align with experimental results, which demonstrate *C. speciosus*'s ability to disrupt the cell cycle and promote cytotoxicity. The high concentration of xanthosine and other bioactive compounds in *C. speciosus* may further support its proapoptotic and anti-proliferative effects. Together, these findings suggest that *C. speciosus* acts through multiple mechanisms, including cell cycle arrest, caspase activation, and possibly other apoptotic pathways, highlighting its potential as a therapeutic agent for breast cancer.

The differential cytotoxic activity of *C. speciosus* and *S. lappa* against MCF-7 breast cancer cells is attributed to variations in their phytochemical composition, as revealed by GC–MS analysis. *C. speciosus* contains a significantly higher concentration of xanthosine (24.41%) compared to *S. lappa* (3.89%), along with greater amounts of β-D-glucopyranose,

4H-pyran-4-one, 5-hydroxymethylfurfural, and lipid-related compounds such as cis-9-hexadecenal and n-hexadecanoic acid, which collectively enhance its anti-cancer activity, potentially through synergistic effects. In contrast, *S. lappa* has a high concentration of dehydrocostus lactone (31.78%), which lacks cytotoxicity against MCF-7 cells, and lower levels of key cytotoxic compounds, contributing to its reduced activity. Conversely, while *S. lappa* contains a high concentration of dehydrocostus lactone (31.78%), this compound has been shown not to affect MCF-7 cell viability (Kim et al., 2014). These findings highlight the critical role of phytochemical composition in determining bioactivity and underscore the need for further research into the mechanisms and therapeutic applications of these plants.

The World Health Organization estimates that almost 80% of people worldwide utilize plant extracts or their active components in traditional therapies (Nwozo et al., 2023). In this study, extracts from both plants showed strong activity against a variety of bacterial strains. *E. coli* was more sensitive to both extracts, and its zones of inhibition were greater than those of other bacteria. This implies that *C. speciosus* and *S. lappa* extracts are strong anti-biotics. These results are consistent with those of previous studies that documented the anti-bacterial properties of these plants (Alaagib & Ayoub, 2015; Shaikh et al., 2022). The conclusions of this investigation have important implications for the development of novel and powerful anti-bacterial medications. The strong anti-bacterial properties of the extracts suggested the presence of bioactive compounds with potential medical applications. Further research is required to identify and segregate these active components, elucidate their mechanisms of action, and assess their safety and efficacy for prospective inclusion in pharmaceutical and complementary medicine formulations.

Conclusion

The chemical compositions, functional groups, elemental profiles, and bioactivities of *C. speciosus* and *S. lappa* extracts were variable. Further suggestions, derived from a comparison study between *S. lappa* (Indian Qust) and *C. speciosus* (Sea Qust), are to identify active compounds, examine mechanisms of action, investigate synergistic interactions, carry out preclinical and clinical trials, create standardized formulations, compare with other plants, and encourage sustainable cultivation techniques. These actions will enhance our understanding of the therapeutic potential of plants and facilitate the development of effective natural remedies and pharmaceutical interventions.

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Authors' Contribution

Siddig Ibrahim Abdelwahab: Writing—original draft, Methodology, Project administration, Formal analysis, Conceptualization, Visualization, Investigation, Funding acquisition, Validation, Supervision. Manal Mohamed Elhassan Taha: Methodology, Writing—review & editing. Syam Mohan: Visualization, Investigation, Data curation. Mukul Sharma: Data curation, Resources, Funding acquisition. Md Shamsher Alam: Data curation, Resources. Mohamed Eltaib Elmobark: Data curation, Resources, Funding acquisition. Sivakumar S Moni: Data curation, Resources. Mohammed Albeishy: Resources, Funding acquisition, Data curation. Ohood Sufyani: Resources, Funding acquisition, Data curation. Afram Koty: Resources, Funding acquisition, Data curation. Adel S. Al-Zubairi: Writing—review & editing, Validation, Visualization.

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Ethical Approval and Informed Consent

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