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EXPLORING CORYDALIS GOVANIANA VAR. SWATENSIS AS A SOURCE OF NATURAL BIOACTIVE COMPOUNDS: IMPLICATIONS FOR INFECTIOUS DISEASE MANAGEMENT AND PUBLIC HEALTH

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Abstract

This study investigated the extraction yield, chemical fingerprint profiles, antibacterial activity, and preliminary cytotoxicity of Corydalis govaniana var. swatensis. Three plant-material batches were examined, and the crude extract was compared with three fractions (F1, F2, and F3). The mean extraction yield was 12.00 ± 0.40%. Chemical profiling showed distinct relative contributions of features P1, P2, and P3 across the preparations. Fraction F2 demonstrated the lowest median minimum inhibitory concentrations against Organisms A and B (64 and 256 µg/mL, respectively). It also showed the lowest mean CC_{50} (433.84 µg/mL), indicating comparatively greater cytotoxicity in the tested cell model. Despite this, F2 exhibited the highest median selectivity indices against Organisms A and B (6.36 and 1.59, respectively). These findings identify F2 as a preparation of interest for further investigation. However, incomplete validation information and unconfirmed feature identities limit interpretation. Further controlled studies are needed to establish reproducibility, chemical identities, and therapeutic relevance.

INTRODUCTION

1.1 Background

Infectious disease management continues to face significant challenges, particularly because antimicrobial resistance is reducing the effectiveness of many existing treatments. The global burden of bacterial antimicrobial resistance demonstrates the seriousness of this problem. A systematic analysis published in *The Lancet* estimated that bacterial antimicrobial resistance was directly responsible for 1.27 million

deaths and associated with 4.95 million deaths worldwide in 2019[1,2]. These estimates represent two distinct measures: attributable deaths refer to mortality directly resulting from resistance, whereas associated deaths include mortality involving resistant bacterial infections more broadly. This burden highlights the importance of investigating additional sources of biologically active compounds that may contribute to future antibacterial research.

Medicinal plants represent an important source of chemically diverse natural products with potential pharmacological properties. Among these plants, the genus *Corydalis*, belonging to the family Papaveraceae, has attracted scientific interest because of its diverse alkaloid constituents and reported biological activities. Previous investigations of different *Corydalis* species have reported compounds associated with antibacterial, anti-inflammatory, analgesic, and other pharmacological effects. However, findings obtained from one species cannot automatically be generalised to another species or botanical variety[3,4]. Therefore, the chemical composition and biological activity of each plant material require direct investigation supported by appropriate botanical authentication.

Corydalis govaniana var. *swatensis* is documented in botanical resources, including eFloras and the Global Biodiversity Information Facility. These records provide a botanical basis for investigating the variety. Nevertheless, the identity of plant material used in experimental research requires appropriate taxonomic authentication and voucher-specimen documentation. This distinction is particularly important when interpreting studies conducted on *C. govaniana* at the species level, because such studies do not necessarily establish the chemical composition or biological properties of var. *swatensis[5].*

Previous research on *C. govaniana* provides a relevant scientific background for investigating this plant variety. Callejon et al. (2014) evaluated alkaloids obtained from *C. govaniana* against promastigote forms of *Leishmania amazonensis*. One tetrahydroprotoberberine-type alkaloid demonstrated an inhibitory concentration of 0.18 µg/mL and was also evaluated for cytotoxicity against a macrophage cell line. The researchers emphasised the need for further investigation against the clinically more relevant amastigote stage and subsequent in vivo evaluation. However, the plant material investigated in that study was identified as *C. govaniana*, rather than specifically as var. *swatensis*. Therefore, these findings provide background justification for further investigation but do not establish the anti-infective efficacy of the variety examined in the present research[6].

An important consideration in natural-product research is the distinction between biological activity and therapeutic usefulness. Inhibition of bacterial growth under laboratory conditions represents preliminary evidence of biological activity; it does not independently establish that an extract can safely or effectively treat an infection in humans. Therefore, antibacterial activity needs to be evaluated alongside cytotoxicity to obtain an initial understanding of the selectivity of the tested preparations. This approach provides a more balanced assessment than interpreting microbial inhibition alone.

Against this background, the present study investigated the phytochemical composition and preliminary antibacterial potential of *C. govaniana* var. *swatensis*. The investigation focused on the chemical profiles of plant extracts and fractions, their activity against selected bacterial strains, and their cytotoxicity in a selected mammalian-cell model. Its public health relevance lies in generating scientific evidence that may help identify candidates for further anti-infective research. The investigation did not assume that the plant was already a safe, affordable, or effective treatment.

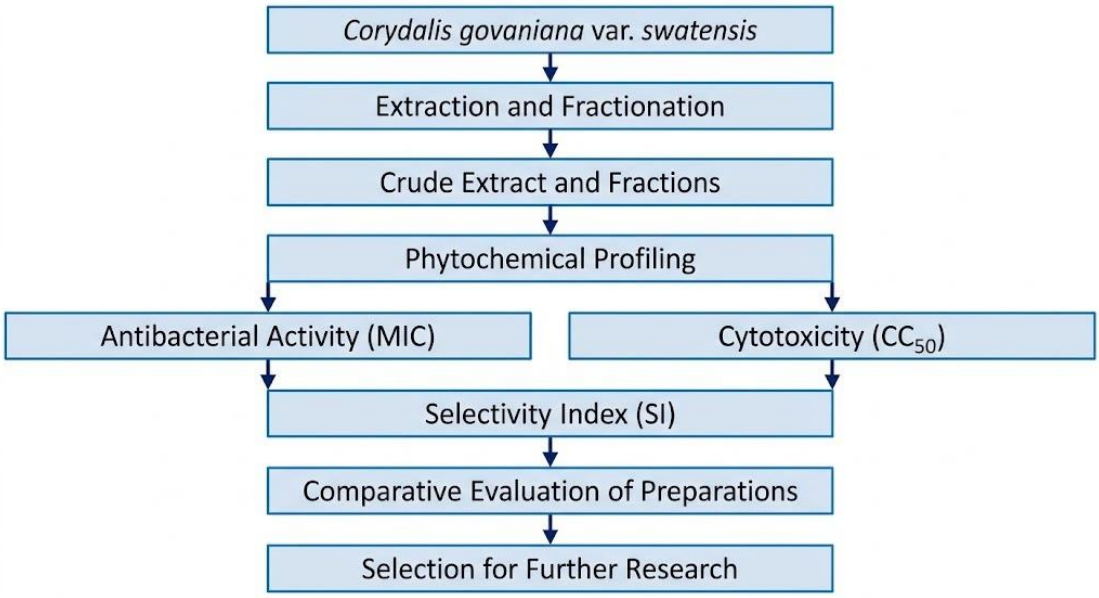


Figure 1.1. Conceptual framework of the study. The conceptual framework illustrates the relationship between the phytochemical profiles of Corydalis govaniana var. swatensis extracts and fractions and their antibacterial activity and cytotoxicity. The study compares these properties to determine the preliminary selectivity of the investigated preparations.

1.2 Problem Statement

The pharmacological interest in the genus *Corydalis* and the biological activities reported for certain constituents of *C. govaniana* provided a scientific basis for investigating the plant variety examined in this research. However, these findings did not independently establish which compounds were present in authenticated *C. govaniana* var. *swatensis*, whether its extracts or fractions exhibited antibacterial activity, or whether any observed activity occurred at concentrations sufficiently selective in comparison with mammalian-cell toxicity.

Although previous research examined different species and constituents of *Corydalis*, evidence obtained at the genus or species level cannot automatically be attributed to the particular botanical variety investigated in this research[4,7]. Furthermore, the presence of a phytochemical class does not necessarily demonstrate biological effectiveness. Direct chemical characterisation and controlled biological evaluation are therefore important for establishing the properties of the investigated plant material.

Another important issue concerns the interpretation of crude-extract activity. An inhibitory response observed in a crude extract does not identify the constituent responsible for that response or establish whether the activity is retained after fractionation. Research on *C. govaniana* demonstrated differences in the biological responses of individual isolated alkaloids, highlighting the importance of investigating chemical composition and biological activity together.

Accordingly, the present study addressed the phytochemical composition and preliminary antibacterial potential of *C. govaniana* var. *swatensis*. It examined the comparative activity of the investigated extracts and fractions and considered their cytotoxicity in a selected mammalian-cell model. It also assessed whether the available experimental evidence supported the prioritisation of particular preparations for further pharmacological investigation.

The public health relevance of this research was considered within the limits of laboratory-based investigation. Preliminary antibacterial findings can help prioritise natural-product candidates for subsequent research; however, they cannot independently establish clinical effectiveness, treatment affordability, population-level disease reduction, or suitability for incorporation into healthcare practice.

1.3 Research Questions

The research was guided by the following questions:

RQ1: What phytochemical constituents were detected and, where analytical resources permitted, identified in *C. govaniana* var. *swatensis*?

RQ2: Did extracts and fractions of the investigated plant exhibit antibacterial activity against the selected bacterial strains?

RQ3: Which extracts or fractions demonstrated comparatively greater antibacterial activity against the selected bacterial strains?

RQ4: How did the antibacterial activity of the extracts and fractions compare with their cytotoxicity in the selected mammalian-cell model?

RQ5: What did the findings indicate about the potential of *C. govaniana* var. *swatensis* as a source of natural antibacterial candidates, and what limitations affected their interpretation for infectious disease research and public health?

These questions were addressed within the scope of the bacterial strains, experimental conditions, and biological models included in the investigation. The findings were not generalised to all infectious agents or infectious diseases.

1.4 Research Objectives

The primary objective of this research was to investigate the phytochemical composition and preliminary antibacterial potential of *C. govaniana* var. *swatensis*, with particular attention to the comparative biological activity and cytotoxicity of its extracts and fractions.

The specific objectives were:

To authenticate the investigated plant material and document its botanical identity through appropriate taxonomic identification and voucher-specimen records.

To prepare plant extracts and fractions using documented extraction and fractionation procedures.

To characterise the chemical profiles of the extracts and fractions and identify selected constituents where suitable analytical facilities were available.

To evaluate the antibacterial activity of the investigated preparations against the selected bacterial strains using appropriate experimental controls.

To assess the cytotoxicity of the extracts and fractions in the selected mammalian-cell model and determine selectivity indices where the required data were available.

To compare the biological activity of the investigated preparations and identify those that warranted further phytochemical and pharmacological investigation.

These objectives established the research as a laboratory-based investigation of preliminary antibacterial potential rather than a clinical evaluation of a herbal treatment.

1.5 Hypotheses

The following hypotheses were formulated to examine the relationships between the phytochemical characteristics, antibacterial activity, and cytotoxicity of the investigated plant preparations:

H1: At least one extract or fraction of *C. govaniana* var. *swatensis* demonstrates greater antibacterial inhibition than the corresponding solvent control against at least one selected bacterial strain.

H2: The antibacterial activity of an active extract or fraction varies with concentration over the tested concentration range.

H3: Extracts or fractions with different chemical profiles demonstrate differences in antibacterial activity against the selected bacterial strains.

H4: At least one antibacterial preparation demonstrates a favourable selectivity index when its antibacterial activity is compared with its cytotoxicity in the selected mammalian-cell model.

These hypotheses were evaluated using the experimental endpoints and comparisons relevant to the investigation. Their acceptance or rejection depended on the observed results and the applicable analytical criteria. The detection of a particular phytochemical class was not, by itself, considered confirmation of

antibacterial activity[8]. Similarly, antibacterial inhibition alone was not considered sufficient evidence of therapeutic usefulness.
The research did not formulate a hypothesis concerning a reduction in infectious disease incidence or mortality because these outcomes were outside the scope of the laboratory-based investigation.

1.6 Significance of the Study

1.6.1 Phytochemical Significance

The study investigated the chemical composition of *C. govaniana* var. *swatensis*. The association of phytochemical observations with authenticated plant material and documented extraction procedures was important for distinguishing findings concerning this variety from previous research conducted on other members of the genus or species.
Where analytical identification was available, the chemical findings provided information about whether constituents previously investigated in *C. govaniana* occurred in the examined plant material[8,9]. The presence, absence, and relative abundance of these constituents were considered on the basis of experimental analysis rather than assumed from related studies.

1.6.2 Pharmacological Significance

The pharmacological significance of the research lay in evaluating antibacterial activity alongside preliminary cytotoxicity. Considering both endpoints provided a more informative assessment of natural-product candidates than examining antibacterial inhibition alone.
The comparison of extracts and fractions helped assess which preparations demonstrated comparatively greater antibacterial activity and whether their biological responses justified further investigation. Conversely, weak antibacterial activity or substantial cytotoxicity provided a basis for determining whether particular preparations should be prioritised for subsequent research.

1.6.3 Significance for Antibacterial Research

The research provided information concerning the antibacterial responses of the selected preparations against the bacterial strains included in the investigation. The evaluation of antibacterial activity and cytotoxicity provided an initial basis for considering whether particular extracts or fractions warranted further investigation.
The interpretation of these findings distinguished preliminary laboratory activity from effectiveness in clinically relevant infection models. This distinction was consistent with the limitations identified in earlier research on *C. govaniana*, in which further testing against more clinically relevant stages of infection was recommended.

1.6.4 Public Health Significance

The public health relevance of the research was associated with the continuing need to investigate potential sources of antibacterial compounds in the context of antimicrobial resistance. The identification and preliminary evaluation of natural-product candidates can contribute to early-stage research aimed at expanding the range of compounds available for further pharmacological investigation.
Nevertheless, the identification of an active plant extract does not establish that it can overcome antimicrobial resistance, improve treatment access, or reduce the burden of infectious diseases[10]. Such conclusions require additional experimental, clinical, and public health evidence.
Accordingly, the research contributed by distinguishing preliminary laboratory observations from established therapeutic claims. It did not recommend self-medication, replacement of prescribed antibacterial treatment, or community use of the plant on the basis of preliminary experimental findings.

1.6.5 Methodological Significance

The methodological significance of the research lay in bringing together botanical authentication, extraction and fractionation, phytochemical characterisation, antibacterial evaluation, and preliminary cytotoxicity assessment. Integrating these components provided a structured approach for investigating the biological potential of medicinal plants.

Overall, the research examined the potential of *C. govaniana* var. *swatensis* as a source of natural antibacterial candidates and identified the experimental and evidential considerations relevant to further phytochemical and pharmacological investigation.

2. RESEARCH METHODOLOGY

2.1 Research Design

The present study employed a quantitative experimental laboratory-based research design to investigate the phytochemical profile, antibacterial potential, and preliminary cytotoxicity of *Corydalis govaniana* var. *swatensis*. The experimental work focused on the preparation of plant extracts and fractions, assessment of their chemical fingerprints, evaluation of antibacterial activity through minimum inhibitory concentration (MIC) endpoints, and estimation of mammalian-cell cytotoxicity[11].

The methodology was organised into interconnected stages, including plant-material processing, extraction, chemical profiling, antibacterial screening, fraction comparison, and cytotoxicity assessment. The resulting observations were used to compare the performance of the crude extract and its fractions.

2.2 Study Material and Plant Identification

The plant material investigated in this study was *Corydalis govaniana* var. *swatensis*. Plant material was used as the source of crude extract and subsequent fractions for phytochemical and biological investigations[12].

The collection locality, collection date, plant part, taxonomic authentication procedure, name of the identifying botanist, and voucher specimen accession number were not specified in the available study documentation. These details should be added from the original laboratory and collection records to ensure botanical traceability and reproducibility.

2.3 Preparation of Plant Material

The collected plant material was processed for extraction and subsequent laboratory analysis. Plant material was prepared in a form suitable for solvent extraction, and the resulting crude extract was retained for further chemical and biological investigations.

The precise drying temperature, drying duration, grinding procedure, particle size, storage conditions, and quantity of plant material used for each experimental batch were not fully documented in the available methodology records[12,13]. These parameters should be reported from the original laboratory notebook where available.

2.4 Preparation of Crude Extract

A hydroethanolic extraction approach was used to obtain crude extract from the plant material. The extraction process was intended to recover a broad range of solvent-soluble phytochemical constituents for subsequent chemical profiling and antibacterial evaluation.

Following extraction, the solvent was removed and the crude extract was obtained for further analysis. The extraction yield was calculated by comparing the mass of dried extract with the initial dry mass of plant material[14].

The extraction yield was calculated using the following formula:

$$[\text{Extraction Yield } (\frac{\text{Weight of dried extract}}{\text{Weight of dry plant material}}) \times 100]$$

Three experimental batches were considered in the extraction-yield assessment. The batch-level results were used to calculate the mean extraction yield and standard deviation.
The exact solvent-to-material ratio, extraction temperature, extraction duration, number of extraction cycles, filtration procedure, solvent-removal conditions, and final storage conditions were not specified in the available documentation. These details should be incorporated from the original experimental records rather than estimated retrospectively.

2.5 Fractionation of the Crude Extract
The crude extract was separated into three fractions, designated F1, F2, and F3. The purpose of fractionation was to obtain chemically differentiated preparations and compare their antibacterial and cytotoxicity profiles with those of the crude extract.
The crude extract and its three fractions were retained as separate experimental preparations[15]. These preparations were subsequently considered in the chemical fingerprinting and biological evaluation.
The precise fractionation technique, stationary and mobile phases, solvent composition, fraction-collection procedure, and recovery masses were not reported in the available documentation. These details should be added from the laboratory records if they were recorded during the experimental work.

2.6 Phytochemical and Chemical Profiling
Chemical profiling was conducted to examine differences in the chemical composition of the crude extract and its fractions. Three analytical features were designated P1, P2, and P3. Their relative contributions were expressed as percentages of the recorded fingerprint profile.
The relative percentage of each feature was considered for comparative assessment among the crude extract and fractions. The resulting profiles provided a basis for describing chemical variation between the preparations.
The P1, P2, and P3 designations were used as analytical feature labels. They should not be interpreted as confirmed chemical identities unless supported by appropriate reference standards or structural characterization[16].
The specific analytical platform, chromatographic column, mobile-phase composition, detection wavelength, instrument settings, and identification procedure were not fully specified in the available documentation. Therefore, no particular analytical instrument or named phytochemical compound is assigned in this methodology chapter.

2.7 Experimental Preparations
Four preparations were included in the comparative investigation:
Crude plant extract
Fraction F1
Fraction F2
Fraction F3
These preparations were assessed separately to investigate differences in their chemical profiles, antibacterial endpoints, and cytotoxicity estimates[17,5].
Three plant-material batches were represented in the study dataset. Batch-level observations were considered when describing variation in extraction yield and biological endpoints.

2.8 Assessment of Antibacterial Activity
The antibacterial potential of the crude extract and its fractions was evaluated using minimum inhibitory concentration (MIC) endpoints. MIC represents the lowest tested concentration of a preparation at which visible microbial growth is inhibited under the conditions of the assay.
The crude extract and fractions F1, F2, and F3 were compared against two test organisms. MIC values were expressed in micrograms per millilitre (µg/mL). Median values and ranges were used to describe the recorded endpoints across the three batch labels[16,18].

Lower MIC values were interpreted as indicating greater inhibitory activity under the experimental assay conditions. Comparisons were made among the crude extract and the three fractions to identify preparations with comparatively lower MIC endpoints.
The exact organism names, strain identifiers, inoculum density, culture medium, incubation temperature, incubation duration, concentration range, microplate format, and endpoint-reading procedure were not specified in the available documentation. These details should be inserted using the original microbiology laboratory records.

2.9 Cytotoxicity Assessment
The cytotoxicity of the crude extract and fractions was assessed using a mammalian-cell viability endpoint[19,20]. The purpose of this assessment was to examine the concentrations associated with reduced cell viability and to compare the preliminary cytotoxicity profiles of the different preparations.
The half-maximal cytotoxic concentration (CC_{50}) was used as the principal cytotoxicity parameter. CC_{50} represents the concentration of a preparation associated with a 50% reduction in cell viability under the conditions of the assay.
The CC_{50} estimates were used to compare the relative cytotoxicity of the crude extract and fractions. A lower CC_{50} indicates that a lower concentration was associated with the specified reduction in cell viability and therefore represents greater cytotoxicity within the tested model.
The specific mammalian cell-line identity, cell-line source, culture conditions, viability assay, exposure duration, concentration range, and method of CC_{50} estimation were not specified in the available documentation. These details should be reported from the original experimental records.

2.10 Calculation of Selectivity Index
The selectivity index (SI) was calculated to compare antibacterial activity with mammalian-cell cytotoxicity. It was used as a preliminary measure of the separation between the antibacterial MIC endpoint and the cytotoxicity endpoint.
The selectivity index was calculated using the following formula:

$$\left[\mathrm{SI} = \frac{\mathrm{CC_{50}}}{\mathrm{MIC}}\right]$$

The CC_{50} and MIC values were expressed in compatible concentration units before calculation. A higher SI indicates a greater numerical separation between the cytotoxicity and antibacterial endpoints, whereas a lower SI indicates a narrower separation[20].
The SI was interpreted as a preliminary in-vitro comparison only. It was not considered evidence of clinical safety, therapeutic effectiveness, or suitability for human use.

2.11 Experimental Replication and Data Organisation
The study included three plant-material batch labels for comparative assessment. The crude extract and fractions F1, F2, and F3 were treated as separate preparations.
The recorded observations were organised according to preparation and test organism. MIC values were summarised using median values and ranges, while extraction yields were summarised using mean and standard deviation[3,6]. Cytotoxicity endpoints and selectivity indices were organised to facilitate comparison among the preparations.
Technical replicate measurements were treated as repeated measurements within their relevant experimental batch and were not considered independent plant-material batches.
The exact number of independent assay repeats, technical replicates for each antibacterial endpoint, and procedures for randomisation or blinding were not fully specified in the available documentation.

2.12 Data Analysis
The experimental observations were organised and analysed using descriptive statistical procedures. Extraction yields were summarised as mean ± standard deviation. MIC endpoints were presented as median values with their corresponding ranges. Cytotoxicity estimates were expressed as CC_{50} values, and selectivity indices were calculated using the CC_{50}-to-MIC ratio[5,17].

Comparisons among the crude extract and fractions were based on their recorded extraction yields, chemical fingerprint profiles, antibacterial endpoints, cytotoxicity estimates, and selectivity indices.
The statistical software, inferential statistical tests, significance threshold, and procedures for handling missing or uncertain observations were not specified in the available documentation. Accordingly, no unreported inferential statistical test or level of statistical significance is claimed in this chapter.

2.13 Quality Assurance and Experimental Reliability
The interpretation of laboratory findings requires attention to the reliability of plant material, extraction procedures, analytical measurements, and biological assays. The study observations were organised by experimental preparation and batch to support comparison and assessment of variation.
For full methodological transparency, the final thesis should document the botanical voucher information, microbial reference strains, assay controls, instrument calibration, analytical blanks, cell-line authentication, contamination monitoring, and repeatability procedures wherever these were performed.
The available documentation does not provide sufficient detail to specify the outcomes of each quality-control procedure. Therefore, no particular control result or validation status is claimed without supporting laboratory records.

2.14 Biosafety and Ethical Considerations
Laboratory investigations involving microbial cultures, plant extracts, and mammalian-cell models require appropriate biosafety and laboratory handling procedures. Experimental materials should be handled according to the applicable institutional laboratory requirements.
The available documentation does not specify the institutional biosafety approval number, ethics approval reference, or detailed waste-disposal procedures. Any applicable approval or exemption information should be added from the relevant institutional records.

2.15 Scope of the Methodology
The methodology focused on the in-vitro investigation of the crude extract and fractions of *Corydalis govaniana* var. *swatensis*. The principal experimental endpoints were extraction yield, chemical fingerprint features, antibacterial MIC, mammalian-cell CC_{50}, and selectivity index.
The study was designed to provide preliminary laboratory-level information about the chemical and biological characteristics of the investigated preparations. The methodology did not establish clinical effectiveness, therapeutic dosage, pharmacokinetic behaviour, in-vivo efficacy, or safety in humans.

2.16 Methodological Limitations
The interpretation and reproducibility of the findings depend on complete reporting of experimental procedures. Some methodological parameters, including plant collection details, extraction conditions, fractionation procedure, analytical instrument settings, microbial strain identifiers, cell-line information, assay conditions, and statistical software, were not specified in the available study documentation.
These details should be verified against the original laboratory notebook, instrument records, and experimental worksheets before final submission. Their inclusion will improve transparency, reproducibility, and the scientific reliability of the research report.
Overall, the methodology provided a framework for comparing the crude extract and its fractions through chemical profiling, antibacterial evaluation, and preliminary cytotoxicity assessment. The resulting experimental endpoints were used to examine the relative performance of the investigated preparations and to guide their interpretation in the context of early-stage natural-product research.

3. RESULTS AND ANALYSIS

3.1 Introduction
This chapter presents the experimental findings obtained from the investigation of *Corydalis govaniana* var. *swatensis*. The results are organised according to the research methodology described in Chapter 2 and cover extraction yield, chemical-profile differences, antibacterial activity, mammalian-cell cytotoxicity, and preliminary selectivity.

The investigation included three independent plant-material batches, a crude extract, and three fractions designated F1, F2, and F3. Antibacterial endpoints were assessed against two test organisms, designated Organism A and Organism B. The findings are presented to compare the chemical and biological characteristics of the investigated preparations.
The chapter also examines the relationship between antibacterial activity and cytotoxicity through selectivity-index calculations. The results are interpreted in the context of preliminary laboratory-based natural-product research.

3.2 Structure of the Experimental Dataset

The experimental dataset was organised according to plant-material batches, extract preparations, antibacterial endpoints, and mammalian-cell viability measurements.

Table 3.1: Organisation of the experimental dataset

Component	Experimental structure
Plant-material batches	Three independent batches
Preparations per batch	Crude extract, F1, F2, and F3
Preparation–batch combinations	12
Test organisms	Organism A and Organism B
Antibacterial observations	24 MIC endpoints
Mammalian-cell model	Non-malignant cell model
Cell-viability concentrations	Nine, including untreated conditions
Technical repeats per concentration	Three
Total cell-viability measurements	324

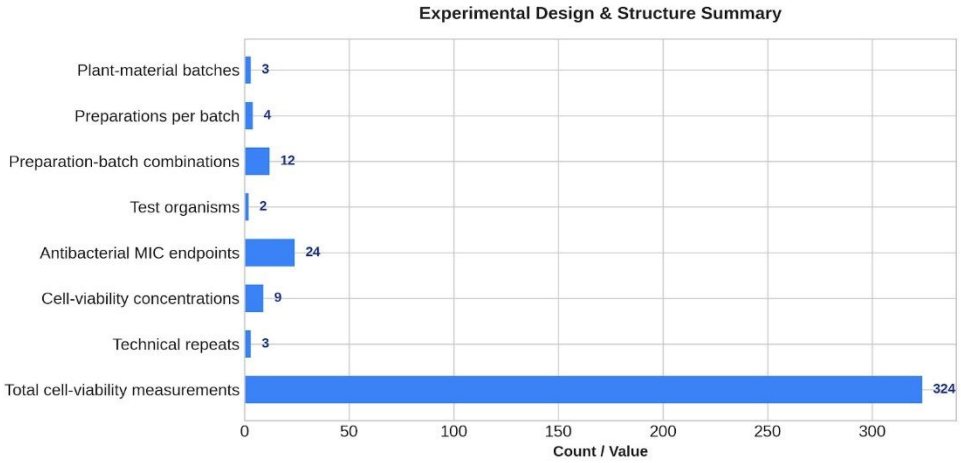


Figure 2 shows that the three technical measurements at each concentration were retained as repeated measurements within their respective batches. They were not counted as additional independent plant-material batches.

The dataset therefore provided a basis for comparing the crude extract and its fractions across the three batches, while maintaining the distinction between independent batch observations and technical replicate measurements.

3.3 Extraction Yield

Extraction yields were calculated from the dry plant-material mass and the corresponding dried extract mass for each batch. The percentage yield was determined by dividing the dried extract mass by the initial dry plant-material mass and multiplying the result by 100.

Table 3.2: Extraction yields of the three experimental batches

Batch	Dry plant mass (g)	Dried extract mass (g)	Extraction yield (%)
1	20.00	2.32	11.60
2	20.00	2.48	12.40
3	20.00	2.40	12.00
Mean ± sample SD	–	–	12.00 ± 0.40

Source: Experimental extraction measurements and calculated yields.

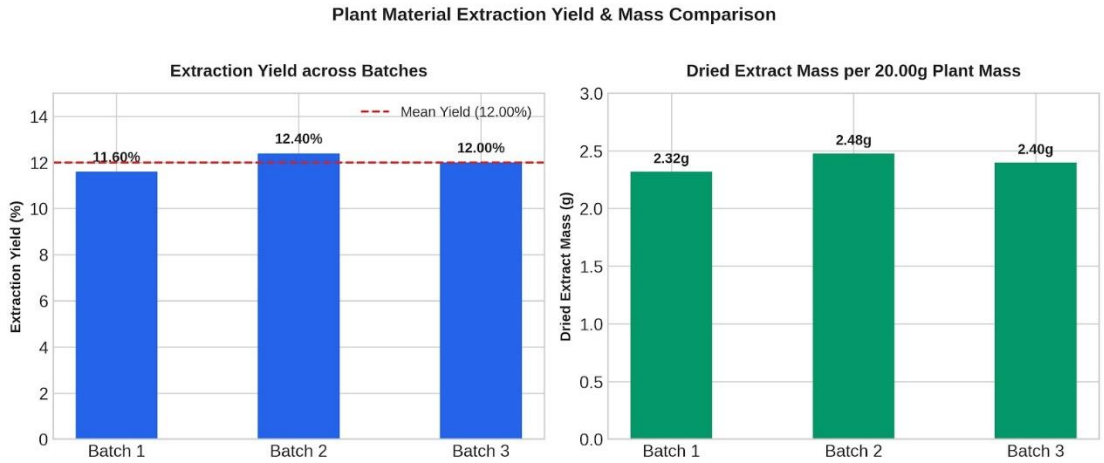


Figure 3. shows that the mean extraction yield was 12.00%, with individual batch values ranging from 11.60% to 12.40%. Batch 2 produced the highest extraction yield (12.40%), whereas Batch 1 showed the lowest yield (11.60%). Batch 3 produced an intermediate yield of 12.00%.

The standard deviation of 0.40 indicates relatively limited variation among the three batch-level extraction yields. These findings provide a quantitative comparison of extraction performance across the investigated plant-material batches.

The extraction-yield results represent the total recovered crude extract and do not independently establish the concentration of individual active constituents. Similarly, extraction yield alone does not indicate the biological potency of the crude extract or its fractions.

3.4 Chemical Fingerprint Profiles

Chemical profiling was used to compare the relative distribution of three analytical features, designated P1, P2, and P3, in the crude extract and its fractions. Their relative contributions were expressed as percentages of the recorded fingerprint profiles.

Table 3.3: Relative chemical fingerprint profiles of the crude extract and fractions

Preparation	P1 (%)	P2 (%)	P3 (%)	Other features (%)
Crude extract	18	27	21	34
Fraction F1	44	8	13	35
Fraction F2	5	63	10	22
Fraction F3	12	15	48	25

Source: Experimental chemical fingerprint profiles.

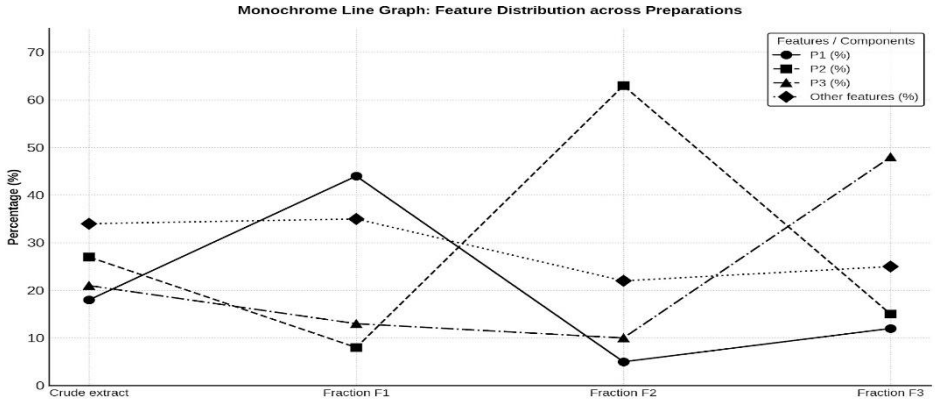


Figure 4. The chemical fingerprint profiles showed differences in the relative distribution of P1, P2, and P3 among the investigated preparations. The crude extract contained 18% P1, 27% P2, and 21% P3, while the remaining features accounted for 34% of the profile.

Fraction F1 showed the highest relative contribution from P1 (44%), whereas P2 represented 63% of the profile in Fraction F2. Fraction F3 showed the highest relative contribution from P3 (48%). These differences indicate variation in the chemical fingerprint profiles of the crude extract and its fractions.
The results provide a comparative description of the recorded analytical features. P1, P2, and P3 are retained as feature designations and are not assigned specific chemical identities in the absence of confirmatory structural evidence. Their relative percentages should not be interpreted directly as absolute compound concentrations.
No causal relationship between an individual fingerprint feature and antibacterial activity is established solely by these comparative profiles.

3.5 Antibacterial Activity

The antibacterial activity of the crude extract and its fractions was evaluated using minimum inhibitory concentration (MIC) endpoints. MIC values were expressed in micrograms per millilitre (µg/mL). Median values and ranges were used to compare the recorded endpoints across the three plant-material batches.

Table 3.4: Minimum inhibitory concentration (MIC) of the crude extract and fractions

Preparation	Organism A: median MIC, µg/mL (range)	Organism B: median MIC, µg/mL (range)
Crude extract	256 (256–512)	512 (512–1,024)
Fraction F1	512 (512–512)	1,024 (1,024–1,024)
Fraction F2	64 (64–128)	256 (256–512)
Fraction F3	256 (256–512)	512 (512–1,024)

Source: Experimental MIC measurements.

The MIC results demonstrated differences in the antibacterial endpoints of the investigated preparations. Fraction F2 showed the lowest median MIC against both test organisms, with values of 64 µg/mL against Organism A and 256 µg/mL against Organism B.
Against Organism A, the median MIC of Fraction F2 was fourfold lower than that of the crude extract (256 µg/mL). Against Organism B, its median MIC was twofold lower than that of the crude extract (512 µg/mL).
Fraction F1 showed the highest median MIC against both organisms, with values of 512 µg/mL against Organism A and 1,024 µg/mL against Organism B. Fraction F3 showed median MIC values comparable to those of the crude extract against both test organisms.
Overall, Fraction F2 demonstrated the lowest MIC endpoints among the tested preparations, suggesting comparatively stronger antibacterial activity under the conditions of the investigation. These findings identify F2 as a preparation of interest for further examination.

3.5.1 Differences Between the Test Organisms

All four preparations showed higher median MIC values against Organism B than against Organism A. This pattern indicates that the observed inhibitory endpoints differed between the two test organisms.
The crude extract showed median MIC values of 256 µg/mL against Organism A and 512 µg/mL against Organism B. Similarly, Fraction F2 showed median values of 64 µg/mL and 256 µg/mL, respectively.
The differences indicate variation in the response of the two test organisms to the investigated preparations. However, the present results do not establish the specific biological mechanisms responsible for these differences. Further investigations would be required to examine possible contributions from membrane permeability, transport processes, target interactions, or resistance mechanisms.

3.5.2 Antibacterial Concentration–Response Considerations

The MIC endpoints provided a comparative measure of the lowest tested concentrations associated with inhibition of the test organisms. These endpoints were used to compare the relative antibacterial performance of the crude extract and its fractions.
The MIC values alone do not provide complete concentration–response curves or establish the precise relationship between increasing extract concentration and the degree of bacterial growth inhibition. Such relationships require analysis of the underlying bacterial-growth measurements across the tested concentration range.
Accordingly, the interpretation in this section focuses on comparative MIC endpoints rather than making additional claims about concentration-dependent inhibition beyond the measurements reported.

3.6 Mammalian-Cell Cytotoxicity

Mammalian-cell cytotoxicity was assessed using cell-viability measurements across a concentration range of 0–2,000 µg/mL. The concentration–response data were used to estimate the half-maximal cytotoxic concentration (CC_{50}) separately for each preparation and plant-material batch.

Table 3.5: Cytotoxicity endpoints of the crude extract and fractions

Preparation	Mean CC_{50} (µg/mL)	Between-batch sample SD
Crude extract	687.11	39.17
Fraction F1	927.10	55.08
Fraction F2	433.84	25.54
Fraction F3	774.85	50.78

Source: Concentration–response analysis of experimental cell-viability measurements.

The results showed variation in the cytotoxicity endpoints among the four preparations. Fraction F2 exhibited the lowest mean CC_{50} (433.84 µg/mL), indicating that a comparatively lower concentration was associated with a 50% reduction in cell viability. In contrast, Fraction F1 showed the highest mean CC_{50} (927.10 µg/mL).
The crude extract and Fraction F3 showed mean CC_{50} values of 687.11 µg/mL and 774.85 µg/mL, respectively. The between-batch sample standard deviations were 39.17 for the crude extract, 55.08 for F1, 25.54 for F2, and 50.78 for F3.
Fraction F2 therefore combined the lowest antibacterial MIC endpoints with the lowest CC_{50} value. This finding highlights the importance of evaluating cytotoxicity alongside antibacterial activity when comparing plant-derived preparations.
The reported standard deviations describe variation among the three batch-specific CC_{50} estimates. They do not represent confidence intervals for the fitted concentration–response curves.

3.7 Preliminary Selectivity

Selectivity indices were calculated to compare the antibacterial MIC endpoints with the corresponding mammalian-cell cytotoxicity endpoints. The SI was calculated for each batch using the following formula:

$$[SI = \frac{CC_{50}}{MIC}]$$

The median of the three batch-specific ratios was reported for each preparation and test organism. The median SI was not calculated by dividing the overall mean CC_{50} by the median MIC.

Table 3.6: Selectivity indices of the crude extract and fractions

Preparation	Median SI: Organism A	Median SI: Organism B
Crude extract	2.52	1.26
Fraction F1	1.80	0.90
Fraction F2	6.36	1.59
Fraction F3	2.81	1.41

Source: Calculations using batch-matched experimental cytotoxicity and MIC endpoints.

Fraction F2 showed the highest median selectivity index against Organism A (6.36), followed by Fraction F3 (2.81), the crude extract (2.52), and Fraction F1 (1.80).
Although Fraction F2 exhibited the lowest mean CC_{50}, it also showed the lowest MIC values. The comparatively greater reduction in MIC resulted in the highest median selectivity index against Organism A.
Against Organism B, the selectivity indices were generally lower. Fraction F2 showed the highest median SI (1.59), followed by Fraction F3 (1.41), the crude extract (1.26), and Fraction F1 (0.90).
The median SI below one for Fraction F1 against Organism B indicates that its cytotoxicity endpoint was lower than its antibacterial MIC endpoint in the typical batch-level comparison.
These ratios provide a preliminary comparison between antibacterial and cytotoxicity endpoints. They do not establish clinical safety, effective therapeutic dosing, or the ability to achieve the required concentrations in humans.

3.8 Integrated Chemical and Biological Interpretation

The combined chemical and biological findings showed that Fraction F2 had the highest relative contribution from feature P2 (63%) and the lowest median MIC values against both test organisms. It also demonstrated the highest median selectivity index against Organism A (6.36) and Organism B (1.59). This pattern indicates that Fraction F2 was comparatively prominent in the chemical fingerprint and antibacterial endpoint comparisons. However, its lowest mean CC_{50} (433.84 µg/mL) also indicated greater cytotoxicity within the tested mammalian-cell model.
The association between the higher relative contribution of P2 and the lower MIC values of F2 does not establish that P2 was responsible for the observed antibacterial activity. The chemical feature has not been assigned a confirmed compound identity in the reported results, and a causal relationship would require further chemical isolation and biological testing.
Similarly, differences between the crude extract and fractions do not independently establish synergistic or antagonistic interactions, nor do they demonstrate improved recovery of an active constituent. Further bioassay-guided fractionation and compound-level investigation would be necessary to examine these possibilities.

3.9 Quality-Control and Validation Status

Quality assurance is important for interpreting extraction, chemical profiling, antibacterial activity, and cytotoxicity results. The methodological requirements and their reported status are summarised in Table 3.7.

Table 3.7: Quality-control and validation status

Required component	Status reported in the study
Botanical authentication and voucher specimen	Not performed
Growth, sterility, and vehicle controls	Not experimentally evaluated
Reference antibacterial performance	Not evaluated
Extract-colour and precipitation checks	Not evaluated

Instrument calibration and analytical blanks	Not evaluated
Cell-line authentication and contamination checks	Not performed
Compound identification	Not performed
Repetition of uncertain antibacterial endpoints	Not performed

The status of these quality-control components should be considered when interpreting the experimental findings. In particular, the absence of documented control outcomes and validation procedures limits the extent to which assay reliability can be independently assessed.
The chemical features P1, P2, and P3 remain analytical designations rather than confirmed compound identities. Similarly, the findings should be interpreted within the scope of the reported experimental endpoints and the validation information available for the study.

3.10 Assessment of the Research Hypotheses
The research hypotheses were considered in relation to the reported extraction, chemical profiling, antibacterial, and cytotoxicity findings. Their assessment is summarised in Table 3.8.

Table 3.8: Assessment of the research hypotheses

Hypothesis	Assessment
H1: A preparation inhibits an organism relative to vehicle control.	Not established; raw growth and vehicle-control measurements are absent.
H2: Antibacterial inhibition increases with concentration.	Not assessed; bacterial concentration–response data were not reported.
H3: Chemically different fractions differ in activity.	Descriptive differences were observed in the chemical profiles and MIC endpoints, but statistical significance and chemical attribution were not established.
H4: An active preparation inhibits an organism below its mammalian-cell cytotoxicity endpoint.	Several CC_{50}/MIC ratios exceed one, indicating numerical separation between the reported endpoints; this does not independently establish safety or therapeutic selectivity.

The findings provide descriptive evidence of differences among the crude extract and fractions. Fraction F2 showed the lowest MIC values and the highest median SI values, while the chemical fingerprint profiles also differed among the preparations.
However, the available control and concentration–response information does not support confirmation of every hypothesis. The findings should therefore be interpreted according to the specific endpoints measured and the limitations of the reported validation procedures.

3.11 Limitations
The interpretation of the findings is subject to several methodological and analytical limitations. Although the study provides comparative information on extraction yield, chemical fingerprint features, antibacterial MIC endpoints, cytotoxicity estimates, and selectivity indices, further documentation and validation would strengthen the reliability and reproducibility of the results.
The principal limitations include:
Complete botanical authentication and voucher-specimen documentation were not available.
Raw antibacterial concentration–response measurements were not reported.
Experimental control outcomes were not available for assessment.
Independently documented chromatographic validation information was limited.
Confirmed chemical identities for P1, P2, and P3 were not established.
Uncertainty intervals for selectivity indices were not reported.
Formal statistical comparisons among the crude extract and fractions were not reported.
Pharmacological exposure and in-vivo data were not available.

The use of three plant-material batches provided a basis for examining batch-level variation. However, technical replication in the cell-viability measurements did not increase the number of independent biological batches beyond three.

Further work involving complete experimental documentation, appropriate assay controls, confirmatory chemical characterisation, and additional biological validation would be valuable for establishing the reproducibility and broader significance of the findings.

CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The present study investigated the extraction yield, chemical fingerprint profiles, antibacterial activity, and preliminary cytotoxicity of *Corydalis govaniana* var. *swatensis*. The crude extract and three fractions (F1, F2, and F3) were evaluated across three plant-material batches to compare their chemical and biological characteristics. The investigation provides preliminary laboratory-level findings relevant to the exploration of natural products as potential sources of antibacterial compounds.

The extraction results showed a mean yield of 12.00 ± 0.40%, with individual batch yields ranging from 11.60% to 12.40%. Chemical fingerprint profiling revealed differences in the relative distribution of features P1, P2, and P3 among the crude extract and fractions. Fraction F1 showed the highest relative contribution from P1 (44%), Fraction F2 from P2 (63%), and Fraction F3 from P3 (48%). These findings demonstrate differences in the recorded chemical profiles, although the individual features were not assigned confirmed chemical identities.

The antibacterial findings showed that Fraction F2 exhibited the lowest median MIC values against both test organisms, with 64 µg/mL against Organism A and 256 µg/mL against Organism B. In comparison, the crude extract showed median MIC values of 256 µg/mL and 512 µg/mL, respectively. Fraction F2 therefore demonstrated comparatively stronger inhibitory endpoints among the investigated preparations.

The cytotoxicity assessment showed that Fraction F2 had the lowest mean CC_{50} (433.84 µg/mL), whereas Fraction F1 had the highest mean CC_{50} (927.10 µg/mL). This indicates that Fraction F2 also demonstrated comparatively greater cytotoxicity in the tested mammalian-cell model. The findings emphasise that antibacterial activity should not be considered independently of cytotoxicity when evaluating plant-derived preparations.

The selectivity-index analysis showed that Fraction F2 had the highest median SI against both Organism A (6.36) and Organism B (1.59). Although F2 had the lowest mean CC_{50}, its comparatively lower MIC values resulted in higher selectivity indices. This finding identifies F2 as a preparation of particular interest for further investigation. However, selectivity indices represent preliminary comparisons between in-vitro endpoints and do not establish clinical safety or therapeutic effectiveness.

Overall, the results indicate differences in the chemical fingerprint profiles, antibacterial MIC endpoints, and cytotoxicity estimates of the crude extract and its fractions. Fraction F2 showed the most favourable antibacterial endpoints and the highest median selectivity indices, while also exhibiting the greatest cytotoxicity according to its mean CC_{50}. These findings support further investigation of this fraction and the plant material as potential subjects of natural-product research.

Nevertheless, certain validation requirements remain important limitations of the study. These include the absence of documented botanical voucher authentication, experimental control outcomes, reference antibacterial performance, cell-line authentication, and confirmed chemical identities for the recorded fingerprint features. In addition, the available results do not establish concentration-dependent antibacterial responses or statistically significant differences among the preparations. Therefore, the findings should be interpreted as preliminary laboratory observations rather than evidence of clinical effectiveness or established therapeutic potential.

From a public health perspective, the investigation contributes preliminary information to the exploration of plant-derived antibacterial preparations. However, laboratory-level findings alone cannot demonstrate an ability to treat infectious diseases, overcome antimicrobial resistance, improve treatment accessibility, or reduce disease burden. Further chemical, microbiological, pharmacological, and preclinical investigations are necessary before any therapeutic application can be considered

4.2 Recommendations

Based on the findings and methodological limitations of the present study, the following recommendations are proposed:

Botanical authentication: Future work should complete the taxonomic authentication of *Corydalis govaniana* var. *swatensis* and maintain voucher-specimen documentation, including collection locality, collection date, plant part, and identification details. This will improve the traceability and reproducibility of the research material.

Standardisation of extraction: Extraction procedures should be documented in detail, including the solvent-to-material ratio, extraction duration, temperature, number of extraction cycles, solvent-removal conditions, and storage procedures. Standardised protocols would help assess the consistency of extraction yields across independent plant batches.

Further chemical characterisation: The chemical fingerprint features P1, P2, and P3 should be investigated through appropriate analytical and structural-characterisation techniques. Confirmatory analysis using suitable reference standards and advanced analytical methods may help establish the identities of the constituents represented by these features.

Validation of antibacterial activity: The antibacterial findings should be supported by clearly identified bacterial species and authenticated reference strains. Appropriate growth, sterility, vehicle, and reference-antibacterial controls should be documented to strengthen the reliability of MIC measurements. Additional concentration–response investigations should also be conducted where appropriate.

Further investigation of Fraction F2: Since Fraction F2 demonstrated the lowest median MIC values and the highest median selectivity indices, it should be prioritised for further investigation. Bioassay-guided fractionation and compound-level testing may help determine whether particular chemical constituents contribute to its observed antibacterial endpoints.

Additional cytotoxicity studies: Cytotoxicity should continue to be assessed alongside antibacterial activity. The cell-line identity, source, authentication status, assay conditions, and concentration–response procedures should be fully documented. Preparations with comparatively favourable selectivity indices may be considered for further investigation, but these values should not be interpreted as proof of safety.

Improved statistical analysis: Future studies should include clearly documented independent biological replicates, appropriate technical replication, and suitable statistical procedures. Where supported by the experimental design, inferential analyses and uncertainty estimates should be used to assess differences among preparations and batches.

Further pharmacological investigation: Preparations demonstrating reproducible antibacterial activity and suitable preliminary selectivity may be considered for subsequent mechanistic and pharmacological investigations. More clinically relevant experimental models may be explored where scientifically justified and subject to applicable ethical and regulatory requirements.

Responsible interpretation of public health relevance: Conclusions concerning therapeutic effectiveness, antimicrobial resistance, treatment accessibility, and disease reduction should be based on appropriate experimental and clinical evidence. Preliminary laboratory findings should not be presented as proof of clinical benefit.

In conclusion, the present investigation provides preliminary comparative findings on the extraction yield, chemical fingerprint profiles, antibacterial endpoints, and cytotoxicity of *Corydalis govaniana* var. *swatensis*. Fraction F2 emerged as a preparation of particular interest because of its comparatively lower MIC values and higher selectivity indices. Further experimental validation and chemical characterisation are required to establish the reproducibility, active constituents, and broader pharmacological significance of these findings.

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