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Active Essence of *Chrysanthemum morifolium*: Comprehensive Study of Chemical Characteristics and Bioactivity

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Medicinal Plant Research, 2024, Vol.14, No.1 doi: 10.5376/mpr.2024.14.0004
Received: 06 Jan., 2024
Accepted: 10 Feb., 2024
Published: 22 Feb., 2024
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Preferred citation for this article:
Cai R.R., Zhao L.F., and Suo M.R., 2024, Active essence of *Chrysanthemum morifolium*: comprehensive study of chemical characteristics and bioactivity, Medicinal Plant Research, 14(1): 45-56 (doi: 10.5376/mpr.2024.14.0004)

Abstract The primary goal of this study was to comprehensively analyze the chemical characteristics and bioactivity of the active essence of *Chrysanthemum morifolium*. The study identified a rich presence of bioactive compounds, including flavonoids, caffeoylquinic acids, and essential oils, in *Chrysanthemum morifolium*. Liquid chromatography mass spectrometry revealed the presence of 7 caffeoylquinic acids, 21 flavones and flavonols, 4 carotenoids, and 13 other compounds across various cultivars. Ultrasonic-assisted extraction optimized the analysis of eight bioactive compounds, enhancing the efficiency and sensitivity of the extraction process. The essential oils exhibited significant antimicrobial, antiviral, and antioxidant activities, with camphor being a major constituent. Additionally, the flower extract demonstrated potential in ameliorating obesity-induced inflammation and enhancing muscle mitochondrial content and AMPK/SIRT1 activities in obese rats. Metabolomics approaches identified kaempferol, 4-hydroxybenzoic acid, and apigenin as key xanthine oxidase inhibitors, suggesting their role in anti-hyperuricemic potential. The study also highlighted the importance of chlorogenic acid and other compounds as quality markers for antioxidant activity. The findings underscore the significant bioactive potential of *Chrysanthemum morifolium*, supporting its traditional use in food, beverages, and medicine. The identified compounds and their bioactivities suggest potential applications in developing natural preservatives, anti-inflammatory agents, and treatments for metabolic disorders.
Keywords *Chrysanthemum morifolium*; Bioactive compounds; Flavonoids; Caffeoylquinic acids; Essential oils; Antioxidant activity; Anti-inflammatory; Metabolomics; AMPK/SIRT1; Xanthine oxidase inhibitors

1 Introduction

Chrysanthemum morifolium, commonly known as chrysanthemum, is a flowering plant that has been extensively cultivated for its ornamental value and medicinal properties. The flowers of *C. morifolium* are rich in bioactive compounds, including flavonoids, caffeoylquinic acids, and various phenolic glycosides, which contribute to its diverse pharmacological activities (Chen et al., 2020; Yang et al., 2019a; 2019b). The plant is widely used in China and Japan, not only as a decorative plant but also as a food, beverage, and traditional medicine (Yang et al., 2019a; 2019b).

In traditional Chinese medicine (TCM), the flower head of *Chrysanthemum morifolium*, known as Juhua, is highly valued for its therapeutic properties. It is commonly used to treat respiratory and cardiovascular diseases, and it exhibits significant antimicrobial, anti-inflammatory, anticancer, and neuroprotective activities (Yuan et al., 2020). The use of Juhua in TCM highlights the importance of dietary herbal medicines, which have been an integral part of Chinese healthcare for thousands of years (Yuan et al., 2020). Recent studies have shown that *C. morifolium* flower extract can ameliorate obesity-induced inflammation, enhance muscle mitochondrial content, and activate the AMPK/SIRT1 pathway, further supporting its medicinal value (Lee et al., 2021).

The aim of this study is to provide a comprehensive analysis of the chemical characteristics and bioactivity of *Chrysanthemum morifolium*. This includes an in-depth examination of its phytochemical composition, the pharmacological effects of its bioactive compounds, and its applications in traditional and modern medicine. By synthesizing findings from recent research, this study seeks to enhance our understanding of the therapeutic potential of *C. morifolium* and to identify areas for future investigation. The scope of this study encompasses the identification and quantification of key bioactive compounds, their mechanisms of action, and their potential health benefits.

2 Botanical Characteristics of *Chrysanthemum morifolium*

2.1 Morphological description

Chrysanthemum morifolium, commonly known as the florist's chrysanthemum, is a perennial herbaceous plant that belongs to the Asteraceae family. It is characterized by its diverse flower forms, which can range from single to double blooms, and its wide array of colors including white, yellow, pink, and purple. The plant typically has a bushy growth habit with deeply lobed leaves that are alternately arranged on the stem. The flowers are composite, consisting of a central disc floret surrounded by ray florets, which contribute to its ornamental value (Wang et al., 2019; Wen et al., 2022) (Figure 1).

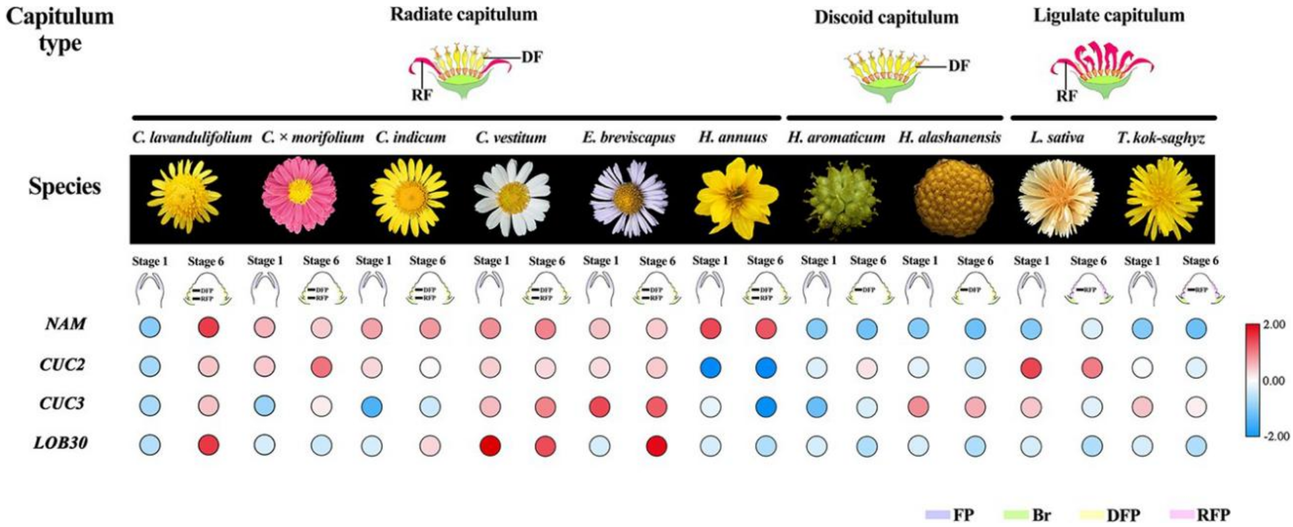

Figure 1 The expression patterns of *NAM/CUC* and *LOB30* homologous genes in ten *Asteraceae* species (Adopted from Wen et al., 2022)

Image caption: Transcriptomic profiling of development stages in radiate, discoid and ligulate capitula. Stage 6 of the radiate capitulum has both disc and ray floret primordia, stage 6 of the discoid capitulum only has disc floret primordia, and stage 6 of the ligulate capitulum only has ray floret primordia. RF, ray florets; DF, disc florets; FP, foliage primordia; Br, bract; DFP, disc floret primordia; and RFP, ray floret primordia (Adopted from Wen et al., 2022)

Wen et al. (2022) The figure and research detail the expression patterns of *NAM/CUC* and *LOB30* homologous genes across ten Asteraceae species during different capitulum developmental stages. The study focuses on radiate, discoid, and ligulate capitula types, examining gene expression at stages 1 and 6. *NAM* and *LOB30* genes show high expression in radiate capitula, crucial for differentiating disc and ray florets. *CUC2* and *CUC3* exhibit varied expression in discoid and ligulate capitula, suggesting roles in different capitulum types' development. The research highlights the hub roles of *NAM*, *CUC2/3*, and *LOB30* genes in capitulum development, particularly in floret differentiation. The findings underscore the genetic complexity and evolutionary significance of these genes in the diverse floral structures within the Asteraceae family, offering insights into plant developmental biology and potential applications in horticultural breeding programs.

2.2 Cultivation and harvesting

Chrysanthemum morifolium is cultivated extensively for both ornamental and medicinal purposes. The plant thrives in well-drained soil with a pH range of 6.0 to 7.0 and requires full sun to partial shade for optimal growth. It is typically propagated through cuttings, division, or tissue culture to maintain the genetic consistency of cultivars. The cultivation process involves regular watering, fertilization, and pest management to ensure healthy growth. Harvesting of the flowers is usually done in the autumn when they are in full bloom. The flowers are then dried and processed for use in traditional Chinese medicine and as a tea ingredient (Guan et al., 2021; Cai et al., 2022; Hao et al., 2022).

2.3 Varieties and distribution

Chrysanthemum morifolium has a rich diversity of cultivars, each with unique morphological and chemical characteristics. Notable cultivars include 'Hangju', 'Boju', 'Gongju', 'Chuju', 'Huaiju', 'Jiju', 'Chuanju', and 'Qiju', which differ in their geographical origins and processing methods. These cultivars are widely distributed across China, Korea, and Japan, where they are cultivated for their ornamental and medicinal properties. The genetic diversity among these cultivars is a result of various hybridizations between multiple wild species, contributing to their wide range of bioactive compounds such as flavonoids, phenolic acids, and volatile oils (Chen et al., 2020; Eeckhaut et al., 2020; Zou et al., 2021; Hao et al., 2022).

3 Chemical Composition

3.1 Major constituents

3.1.1 Flavonoids

Flavonoids are a significant class of compounds found in *Chrysanthemum morifolium*. In a study analyzing the chemical compositions of chrysanthemum teas, various flavonoids such as 6,8-C,C-diglucosylapigenin and eriodicyol-7-O-glucoside were identified. These compounds contribute to the antioxidant and anti-inflammatory properties of the plant (Li et al., 2019b).

3.1.2 Terpenoids

Terpenoids are another major group of constituents in *Chrysanthemum morifolium*. The essential oils of this plant have been found to contain significant amounts of camphor, which accounts for 14.56% of the oil composition. This terpenoid is known for its antimicrobial and antiviral activities, making it a valuable component in natural preservative formulations (Youssef et al., 2020).

3.1.3 Essential oils

The essential oils of *Chrysanthemum morifolium* are rich in various bioactive compounds. Gas Chromatography/Mass Spectrometry (GC/MS) analysis has revealed that camphor is a predominant component. These essential oils exhibit notable antioxidant potential, with IC50 values of 2.59 mg/mL, and possess antimicrobial properties against various pathogens (Youssef et al., 2020).

3.2 Minor constituents

3.2.1 Phenolic acids

Phenolic acids are present in smaller quantities in *Chrysanthemum morifolium*. These compounds contribute to the overall antioxidant activity of the plant. The phenolic content in chrysanthemum teas has been quantified, with the hot-H_2O extract of Kunlunmiju 1 showing a total phenolic content of 12.72 mg gallic acid equivalents/g (Li et al., 2019b).

3.2.2 Carotenoids

Carotenoids, although not as abundant as other constituents, are still present in *Chrysanthemum morifolium*. These compounds are known for their antioxidant properties and contribute to the health benefits associated with the consumption of chrysanthemum teas (Li et al., 2019b).

3.2.3 Other phytochemicals

In addition to the major and minor constituents mentioned above, *Chrysanthemum morifolium* contains various other phytochemicals. For instance, acetylmarein has been detected in different varieties of chrysanthemum, including HangJu, GongJu, and HuaiJu. These phytochemicals play a role in the plant's bioactivity, including its anti-inflammatory and radical scavenging activities (Li et al., 2019b).

By understanding the chemical composition of *Chrysanthemum morifolium*, we can better appreciate its potential applications in food and pharmaceutical industries as a natural preservative with significant bioactive properties.

4 Analytical Methods for Chemical Characterization

4.1 Extraction techniques

4.1.1 Solvent extraction

Solvent extraction is a widely used method for isolating bioactive compounds from plant materials. In the study by (Chen et al., 2021), various solvents such as 95% ethanol, ethyl acetate, n-hexane, and distilled water were employed to extract different components from *Chrysanthemum morifolium* Ramat. The ethanolic extract demonstrated the highest levels of total flavonoids, polyphenols, and chlorogenic acids, indicating its efficacy in extracting these bioactive compounds. Similarly (Li et al., 2019b), utilized hot water and 75% methanol for extracting chemical compositions from commercial chrysanthemum teas, highlighting the versatility of solvent extraction in different solvent systems.

4.1.2 Supercritical fluid extraction

Supercritical fluid extraction (SFE) is an advanced technique that uses supercritical fluids, typically CO_2, to extract bioactive compounds. Although specific studies on SFE for *Chrysanthemum morifolium* were not provided in the data, this method is known for its efficiency and environmental friendliness. SFE can selectively extract compounds based on their solubility in supercritical CO_2, which can be fine-tuned by adjusting temperature and pressure.

4.2 Chromatographic methods

4.2.1 High-performance liquid chromatography (HPLC)

High-Performance Liquid Chromatography (HPLC) is a powerful analytical technique used to separate, identify, and quantify components in a mixture. In the research by Chen et al. (2020), HPLC was employed to construct a spectral tag library for identifying and quantifying various bioactive compounds in *Chrysanthemum morifolium* flowers. This method allowed for the precise determination of flavonoids, caffeoylquinic acids, and other compounds, demonstrating its utility in chemical characterization.

4.2.2 Gas chromatography-mass spectrometry (GC-MS)

Gas Chromatography-Mass Spectrometry (GC-MS) combines the features of gas chromatography and mass spectrometry to identify different substances within a test sample. The study by (Youssef et al., 2020) utilized GC-MS to analyze the essential oils of *Chrysanthemum morifolium*, identifying camphor as a major constituent. Additionally (Sayed, 2023), employed GC-MS to discover bioactive substances such as lupeol and α-amyrin in the acetone extracts of *Chrysanthemum morifolium*, showcasing the method's capability in detailed chemical profiling.

4.3 Spectroscopic methods

4.3.1 Nuclear magnetic resonance (NMR)

Nuclear Magnetic Resonance (NMR) spectroscopy is a technique used to determine the structure of organic compounds by observing the behavior of nuclei in a magnetic field. In the study by (Loh et al., 2021), a proton NMR-based metabolomics approach was used to characterize xanthine oxidase inhibitors in *Chrysanthemum morifolium*. This method provided detailed insights into the metabolite profile and helped identify key compounds responsible for the observed bioactivity.

4.3.2 Infrared (IR) spectroscopy

Infrared (IR) spectroscopy is used to identify and study chemicals through their infrared spectra. Although specific studies on IR spectroscopy for *Chrysanthemum morifolium* were not provided in the data, this technique is commonly used to identify functional groups and characterize molecular structures in plant extracts. IR spectroscopy can complement other analytical methods by providing additional information on the chemical composition of the extracts.

In summary, a combination of solvent extraction, chromatographic, and spectroscopic methods provides a comprehensive approach to the chemical characterization of *Chrysanthemum morifolium*. These techniques enable the detailed analysis of bioactive compounds, contributing to the understanding of their potential health benefits and applications in various industries.

5 Bioactivity of *Chrysanthemum morifolium*

5.1 Antioxidant properties

5.1.1 Mechanisms of action

Chrysanthemum morifolium exhibits significant antioxidant properties primarily due to its high phenolic and flavonoid content. The antioxidant mechanisms involve scavenging free radicals and enhancing the activity of antioxidant enzymes such as superoxide dismutase (SOD) and catalase. The presence of compounds like acacetin-7-O-rutinoside, luteolin-7-O-glucoside, and chlorogenic acid contributes to these effects by neutralizing reactive oxygen species (ROS) and reducing oxidative stress (Zhang et al., 2019; Li et al., 2019a; 2019b).

5.1.2 *In vitro* studies

In vitro studies have demonstrated the potent antioxidant activity of *Chrysanthemum morifolium* extracts. For instance, the hot-water extract of *Chrysanthemum morifolium* cv. *Fubaiju* showed significant free radical scavenging activities in ABTS, DPPH, and FRAP assays (Li et al., 2019a). Additionally, the cellular antioxidant activity (CAA) assay indicated that a combination of *Chrysanthemum morifolium* and wolfberry exhibited synergistic antioxidant effects (Zhang et al., 2019).

5.1.3 *In vivo* studies

In vivo studies have further confirmed the antioxidant potential of *Chrysanthemum morifolium*. For example, the flower extract was shown to reduce oxidative damage in ARPE-19 cells by activating the PI3K/Akt-mediated Nrf2/HO-1 signaling pathway, which enhances the expression of antioxidant enzymes (Hao et al., 2021). Moreover, *Chrysanthemum morifolium* extract ameliorated obesity-induced oxidative stress in rats by increasing muscle mitochondrial content and activity (Lee et al., 2021).

5.2 Anti-inflammatory effects

5.2.1 Molecular targets

The anti-inflammatory effects of *Chrysanthemum morifolium* are mediated through the inhibition of key inflammatory pathways. The extract targets molecules such as nuclear factor-kappa B (NF-κB), mitogen-activated protein kinases (MAPKs), and pro-inflammatory cytokines like TNF-α, IL-1β, and IL-6 (Zhang et al., 2019; Lee et al., 2021; Li et al., 2019b).

5.2.2 Experimental evidence

Experimental evidence supports the anti-inflammatory properties of *Chrysanthemum morifolium*. In vitro studies showed that the extract significantly reduced lipopolysaccharide (LPS)-induced nitric oxide production and inhibited the expression of inflammatory mediators in RAW 264.7 macrophages (Zhang et al., 2019). In vivo, the extract alleviated obesity-induced inflammation in rats by modulating the expression of genes involved in inflammation and adipogenesis (Lee et al., 2021).

5.3 Antimicrobial activity

5.3.1 Spectrum of activity

Chrysanthemum morifolium exhibits a broad spectrum of antimicrobial activity against various pathogens, including bacteria, viruses, and fungi. The essential oils from the flower have shown effectiveness against Streptococcus agalactiae, Helicobacter pylori, and several viruses such as herpes simplex virus type-1 (HSV-1) and vesicular stomatitis virus (VSV) (Youssef et al., 2020).

5.3.2 Clinical relevance

The antimicrobial properties of *Chrysanthemum morifolium* suggest its potential use as a natural preservative in food and pharmaceutical products. Its ability to inhibit the growth of pathogenic microorganisms and its antioxidant properties make it a valuable ingredient for enhancing food safety and shelf life (Youssef et al., 2020).

5.4 Cardiovascular benefits

5.4.1 Mechanisms of action

The cardiovascular benefits of *Chrysanthemum morifolium* are attributed to its ability to modulate lipid metabolism, reduce oxidative stress, and improve endothelial function. The extract enhances the activity of adenosine monophosphate-activated protein kinase (AMPK) and sirtuin 1 (SIRT1), which play crucial roles in regulating energy balance and mitochondrial function (Lee et al., 2021).

5.4.2 Experimental evidence

Experimental studies have shown that *Chrysanthemum morifolium* extract can significantly reduce dyslipidemia, hepatic fat accumulation, and systemic inflammation in high-fat diet-induced obese rats. The extract also increased energy expenditure and improved mitochondrial biogenesis and function in skeletal muscle (Lee et al., 2021).

5.5 Neuroprotective effects

5.5.1 Mechanisms of action

Chrysanthemum morifolium exerts neuroprotective effects through its antioxidant and anti-inflammatory properties. The extract modulates neurotransmitter levels and protects against oxidative damage by enhancing the activity of antioxidant enzymes and reducing the expression of pro-apoptotic proteins (Hao et al., 2021; Liu et al., 2020).

5.5.2 Experimental evidence

In experimental models, *Chrysanthemum morifolium* extract has been shown to protect against oxidative damage in neuronal cells by activating the Nrf2/HO-1 signaling pathway (Hao et al., 2021). Additionally, the extract demonstrated anti-depressive effects in corticosterone-induced depression models by modulating metabolic pathways related to neurotransmitter synthesis and energy metabolism (Liu et al., 2020) (Figure 2).

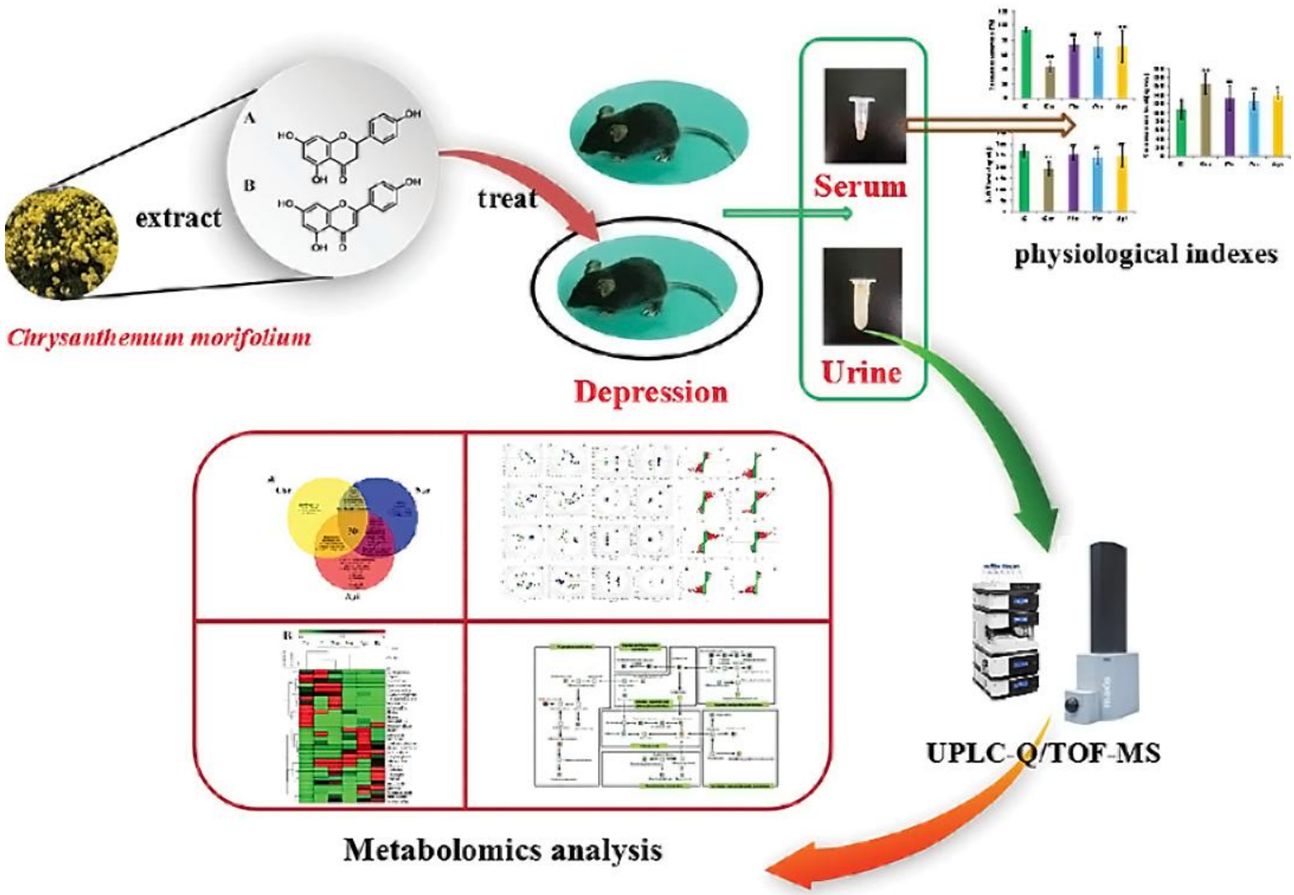

Figure 2 Metabolomics analysis of *Chrysanthemum morifolium* extract in ameliorating depression (Adapted from Liu et al., 2020)

Liu et al. (2020) illustrates the study's workflow analyzing the antidepressant effects of *Chrysanthemum morifolium* (Chr) and its major components, naringenin (Nar) and apigenin (Api), on a corticosterone-induced depression model. The process involves treating depressed animals with Chr/Nar/Api, followed by the collection of serum and urine samples for physiological index evaluation. Metabolomics analysis using UPLC-Q/TOF-MS is performed to identify biomarkers and related metabolic pathways. The study finds that Chr/Nar/Api influence various metabolic pathways, including tryptophan metabolism, arginine and proline metabolism, and the citrate cycle, among others. The results suggest that Nar and Api have significant antidepressant effects, potentially offering alternative treatments to traditional medicine. This integrative approach effectively elucidates the biochemical mechanisms underlying the therapeutic effects of TCM components on depression.

6 Clinical Applications and Efficacy

6.1 Traditional uses

6.1.1 Historical context

Chrysanthemum morifolium, commonly known as pot mums, has been a staple in traditional Chinese medicine (TCM) for centuries. Historically, it has been utilized to treat a variety of ailments, including allergies, cardiovascular diseases, severe flu, hypertension, and sore throat. The plant's rich content of volatile oils and flavonoids has been attributed to its therapeutic properties (Ojha et al., 2023).

6.1.2 Ethnopharmacology

Ethnopharmacological studies have highlighted the diverse applications of *Chrysanthemum morifolium* in traditional medicine. The plant is known for its anti-inflammatory, antibacterial, aromatic, demulcent, febrifuge, hepatic, hypotensive, and refrigerant properties. These characteristics have justified its widespread use in various traditional remedies across different cultures (Ojha et al., 2023).

6.2 Modern therapeutic applications

6.2.1 Evidence from clinical trials

Recent studies have provided substantial evidence supporting the therapeutic potential of *Chrysanthemum morifolium*. For instance, its flower extract has been shown to ameliorate obesity-induced inflammation and enhance muscle mitochondrial content and AMPK/SIRT1 activities in obese rats. This suggests its potential in managing obesity and related metabolic dysfunctions (Lee et al., 2021). Additionally, the essential oils of *Chrysanthemum morifolium* have demonstrated significant antimicrobial and antioxidant activities, further supporting its use as a natural preservative in food and pharmaceutical products (Youssef et al., 2020).

6.2.2 Potential for integrative medicine

The bioactive compounds in *Chrysanthemum morifolium*, such as flavonoids and caffeoylquinic acids, have shown promising results in various therapeutic applications. For example, the plant's extract has been found to enhance sleep quality in rodent models by modulating the GABAA receptor and Cl-channel activation, indicating its potential use in treating insomnia (Kim et al., 2023) (Figure 3). Moreover, its anti-depressive effects have been linked to the modulation of multiple metabolic pathways, suggesting its potential as an alternative or complementary treatment for depression (Liu et al., 2020). These findings highlight the potential of *Chrysanthemum morifolium* in integrative medicine, combining traditional knowledge with modern scientific research to develop effective therapeutic strategies.

Kim et al. (2023) illustrates the impact of *Chrysanthemum morifolium* extract (Chry) on sleep quality in rats, using the AccuSleep algorithm for EEG and EMG analysis. The administration of Chry (100 and 200 mg/kg) significantly increased total sleep duration (d) and non-rapid eye movement sleep (NREMS) time (f) while reducing wakefulness (c) and sleep-wake cycles (g), compared to the control group. Rapid eye movement sleep (REMS) duration was unaffected (e). This study demonstrates that Chry extract improves sleep quality by enhancing NREMS and overall sleep duration, suggesting its potential as a natural sleep aid. These findings highlight the therapeutic promise of *Chrysanthemum morifolium* for sleep disorders, warranting further investigation into its mechanisms and long-term effects.

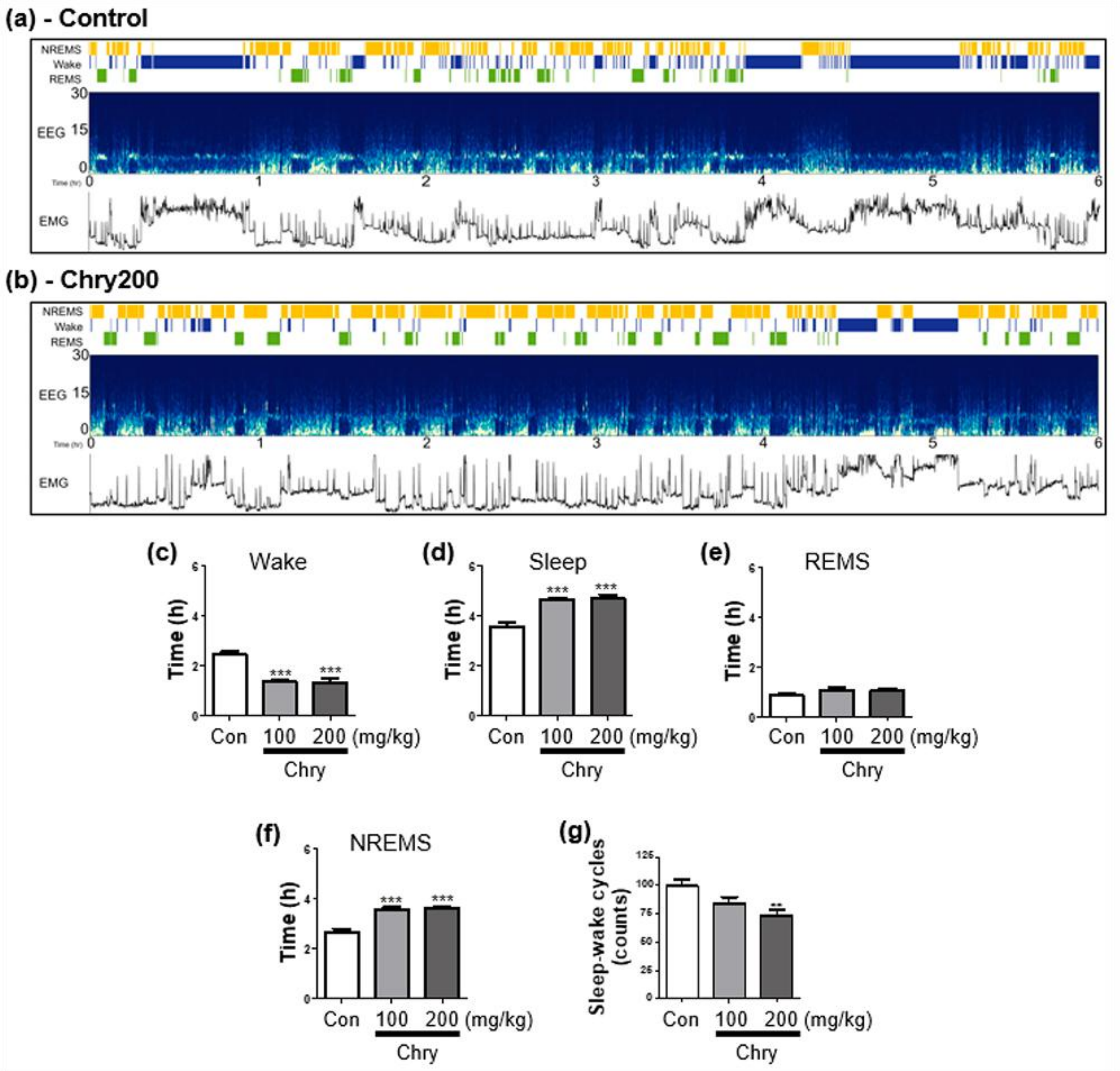

Figure 3 Sleep analysis of rats through automated sleep scoring by AccuSleep algorithm in MATLAB (Adopted from Kim et al., 2023)

Image caption: After the administration of Chry ext (100 and 200 mg/kg, p.o.) once a day for 7 days, EEG and EMG recorded for 6 h (10:00-16:00) at the last administration were used. The representative examples of AccuSleep interface including the sleep stages, EEG spectrogram, and EMG power in control and Chry200 are displayed (a,b). Wake and sleep time analysis (c,d), duration of REMS and NREMS time (e,f), and sleep-wake cycles (g) were determined. Data are expressed as mean ± SEM. ** $p < 0.01$, and *** $p < 0.001$, compared with the control group. Chry, *Chrysanthemum morifolium* extract; EEG, electroencephalogram; EMG, electromyogram; REMS, rapid eye movement sleep; NREMS, non-REMS; Wake, wakefulness (Adopted from Kim et al., 2023)

7 Safety and Toxicity

7.1 Acute and chronic toxicity studies

Chrysanthemum morifolium has been extensively studied for its bioactive compounds and their potential health benefits. However, the safety and toxicity profiles of these compounds are equally important. Acute and chronic toxicity studies are essential to determine the safe dosage and potential side effects of *Chrysanthemum morifolium* extracts. For instance, the study by Lee et al. (2021) demonstrated that *Chrysanthemum morifolium* flower extract (CE) was administered to rats over a 13-week period, showing no adverse effects at doses of 0.2% and 0.4% CE in their diet. This suggests a favorable safety profile for long-term consumption. Additionally, the study by (Kim et al., 2023) indicated that *Chrysanthemum morifolium* extract improved sleep quality in rodent models without any reported toxicity, further supporting its safety in traditional medicinal use.

7.2 Safety in traditional use

Chrysanthemum morifolium has a long history of use in traditional medicine, particularly in East Asia, where it is commonly consumed as tea or used in herbal remedies. The traditional use of *Chrysanthemum morifolium* is generally considered safe, as evidenced by its widespread consumption over centuries. The study by (Li et al., 2019b) highlighted the anti-inflammatory and antioxidant properties of *Chrysanthemum morifolium* teas, which are consumed daily by many people. This long-term traditional use without significant adverse effects supports the safety of *Chrysanthemum morifolium* in its conventional forms.

7.3 Regulatory status and quality control

The regulatory status of *Chrysanthemum morifolium* varies by region, but it is generally recognized as safe when used in food and traditional medicine. Quality control measures are crucial to ensure the safety and efficacy of *Chrysanthemum morifolium* products. The study by (Chen et al., 2020) utilized liquid chromatography mass spectrometry to identify and quantify the chemical compounds in various cultivars of *Chrysanthemum morifolium*, providing a basis for standardizing and ensuring the quality of these products. Additionally, the study by (Youssef et al., 2020) compared the chemical composition and biological activities of essential oils from *Chrysanthemum morifolium*, emphasizing the importance of rigorous quality control to maintain the safety and therapeutic potential of these products.

In conclusion, the available studies indicate that *Chrysanthemum morifolium* is generally safe for both acute and chronic use, supported by its long history in traditional medicine and current regulatory standards. However, ongoing research and stringent quality control are essential to ensure its continued safety and efficacy.

8 Future Directions and Research Opportunities

8.1 Unexplored bioactivities

Despite the extensive research on the chemical composition and known bioactivities of *Chrysanthemum morifolium*, there remain numerous unexplored bioactivities that warrant further investigation. For instance, while the antiviral, antimicrobial, and antioxidant properties have been well-documented (Youssef et al., 2020), other potential bioactivities such as anti-inflammatory, anti-cancer, and neuroprotective effects have not been thoroughly examined. Future studies should focus on these areas to fully elucidate the therapeutic potential of *C. morifolium*.

8.2 Advanced analytical techniques

The application of advanced analytical techniques can significantly enhance our understanding of the chemical characteristics of *C. morifolium*. Techniques such as high-resolution mass spectrometry, nuclear magnetic resonance (NMR) spectroscopy, and advanced chromatographic methods can provide more detailed and accurate profiles of the bioactive compounds present in *C. morifolium* (Chen et al., 2020). These techniques can also help in identifying novel compounds that may contribute to the plant's bioactivity.

8.3 Integrative approaches in therapy

Integrative approaches that combine the use of *C. morifolium* with other therapeutic modalities could offer synergistic benefits. For example, combining *C. morifolium* extracts with conventional antimicrobial agents may enhance their efficacy and reduce the risk of resistance development. Additionally, the incorporation of *C. morifolium* in dietary supplements and functional foods could provide a holistic approach to health and wellness, leveraging its rich content of flavonoids and caffeoylquinic acids (Chen et al., 2020).

8.4 Sustainable cultivation and harvesting

Sustainable cultivation and harvesting practices are crucial for ensuring the long-term availability of *C. morifolium*. Research should focus on developing eco-friendly agricultural practices that minimize environmental impact while maximizing yield and quality. This includes exploring organic farming methods, optimizing harvest times, and implementing sustainable pest management strategies. Additionally, understanding the relationship between cultivation conditions and the chemical composition of *C. morifolium* can help in producing high-quality plants with consistent bioactive profiles (Chen et al., 2020).

By addressing these future directions and research opportunities, we can unlock the full potential of *Chrysanthemum morifolium* and enhance its applications in various fields, from medicine to food science.

9 Concluding Remarks

The comprehensive study on the chemical characteristics and bioactivity of *Chrysanthemum morifolium* has revealed several significant findings. The essential oils of *C. morifolium* contain a variety of bioactive compounds, with camphor being a major constituent, which contributes to its notable antimicrobial and antioxidant activities. The flower extract of *C. morifolium* has shown potential in ameliorating obesity-induced inflammation and enhancing muscle mitochondrial content and AMPK/SIRT1 activities in obese rats, indicating its role in metabolic health. Additionally, *C. morifolium* is rich in flavonoids and caffeoylquinic acids, which are associated with its antioxidant properties and potential use as a natural preservative. The flower extract also exhibits significant anti-inflammatory and free radical scavenging activities, which can modulate gut microbiota and improve overall health. Furthermore, the neuroprotective effects of certain compounds isolated from *C. morifolium* highlight its potential in treating neurodegenerative diseases. The extract has also demonstrated efficacy in reducing lipid and protein oxidation in meat products, suggesting its application as a natural antioxidant in the food industry.

The findings from this study open several avenues for future research. Firstly, further investigation into the specific mechanisms underlying the bioactive effects of *C. morifolium*, particularly its anti-inflammatory and antioxidant properties, is warranted. This could involve exploring the molecular pathways and identifying additional bioactive compounds responsible for these effects. Secondly, the potential of *C. morifolium* in treating metabolic disorders, such as obesity and hyperuricemia, should be explored in more detail, including clinical trials to validate its efficacy and safety in humans. Additionally, the neuroprotective properties of *C. morifolium* warrant further research to develop potential therapeutic agents for neurodegenerative diseases. Lastly, the application of *C. morifolium* as a natural preservative in the food industry should be expanded, with studies focusing on its effectiveness in various food products and its impact on sensory qualities.

In conclusion, *Chrysanthemum morifolium* exhibits a wide range of bioactivities, including antimicrobial, antioxidant, anti-inflammatory, and neuroprotective effects. These properties make it a promising candidate for various applications in the fields of medicine, food preservation, and functional foods. The rich chemical composition of *C. morifolium*, particularly its flavonoids and caffeoylquinic acids, underpins its health benefits and potential therapeutic uses. Future research should aim to further elucidate the mechanisms of action, optimize extraction methods, and conduct clinical trials to fully harness the potential of this versatile plant. The integration of *C. morifolium* into health-promoting products could significantly contribute to improving public health and well-being.

Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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