

Quantitative assays show that ethanolic and hydroalcoholic extracts contain substantial amounts of total phenolics and flavonoids, with compounds such as chlorogenic, caffeic, caffeoylmalic, and ferulic acids, as well as rutin and quercetin, consistently identified in LC-MS analyses. Earlier isolation work from aerial parts yielded a panel of flavonoids including apigenin, luteolin, kaempferol, quercetin, and myricetin, alongside simple phenolic acids such as gallic and syringic acids, many of which display strong free-radical-scavenging activity in DPPH assays (Qu et al., 2006). More recent metabolomic studies on *Leonurus* spp. confirm that phenylpropanoids-including rare caffeoylglucaric acids-and classical flavonoids are quantitatively dominant in the phenolic fraction, emphasizing their central contribution to the plant's antioxidant capacity (Olennikov and Chirikova, 2016).

These phenolic constituents are closely linked to activities relevant for gynecological health, especially anti-oxidative, anti-inflammatory, vascular-protective, and tissue-repair effects that accompany uterine and pelvic pathologies. Antioxidant testing consistently demonstrates that phenolic-rich partitions (e.g., ethyl acetate fractions) and individual flavonoids such as luteolin, kaempferol, and quercetin exhibit higher radical-scavenging power than reference antioxidants, supporting their role in limiting oxidative damage during menstrual pain or postpartum recovery (Qu et al., 2006). In a wound-healing model, hydroalcoholic extracts with higher flavonoid content accelerated inflammatory resolution, wound contraction, and collagen synthesis, suggesting that polyphenols from *L. japonicus* can facilitate repair of reproductive-tract and perineal injuries associated with childbirth or gynecological surgery. Phenolic acids such as chlorogenic and caffeic acid, together with rutin and related flavonoid glycosides, also correlate with anti-inflammatory, vasodilatory, and enzyme-inhibitory activities in *Leonurus* species, providing mechanistic support for their use in relieving pelvic congestion, dysmenorrhea, and microvascular complications associated with gynecological disorders (Angeloni et al., 2021).

3.3 Volatile oils and other bioactive compounds

Beyond alkaloids and phenolics, *L. japonicus* produces essential oils and a suite of terpenoid and minor constituents that add further pharmacological dimensions, particularly antimicrobial and anti-inflammatory effects relevant to gynecological infections and postpartum care. Hydrodistillation of the herb (Yimucao) and fruits (Chongweizi) reveals marked variation in essential-oil profiles between parts: herb oil is dominated by sesquiterpenes and diterpenes, with phytone, phytol, caryophyllene oxide, and β -caryophyllene as major components, whereas fruit oil is richer in aliphatic hydrocarbons and bornyl acetate. These compositional differences translate into distinct bioactivities; Yimucao oil shows broad-spectrum activity against Gram-positive bacteria, while Chongweizi oil is largely inactive, underscoring the herb's particular value for managing genital and puerperal infections in traditional practice (Xiong et al., 2013). The predominance of β -caryophyllene, a sesquiterpene with known anti-inflammatory and analgesic potential, further suggests synergism with uterotonic alkaloids and phenolics in alleviating pelvic pain and inflammatory gynecological conditions.

In addition to essential oils, numerous labdane-type diterpenoids, ionone derivatives, terpenoid acids, and triterpenes have been isolated from the aerial parts of *L. japonicus*, many of them newly characterized in the last decade (Zhong et al., 2015; Wei et al., 2023). Several labdane diterpenes, including novel epimeric pairs, significantly inhibit nitric oxide production and pro-inflammatory cytokine release in LPS-stimulated macrophages, partly by blocking NF- κ B signaling, thereby providing a non-alkaloid anti-inflammatory axis that may contribute to relief of uterine inflammation, endometritis, or pelvic inflammatory disease. Other terpenoids such as leojaponic acids A and B and triterpenes like ursolic acid exhibit enzyme-inhibitory and cytoprotective activities, which, together with minor phenylethanoid glycosides and iridoids documented in the genus, broaden the spectrum of biological actions relevant to women's health (Wu et al., 2016; Angeloni et al., 2021). Collectively, the volatile and terpenoid fractions complement the hormone-modulating and hemodynamic actions of alkaloids with antimicrobial, anti-inflammatory, and tissue-protective effects, forming a multi-target phytochemical ensemble well-suited to complex gynecological syndromes that involve infection, inflammation, pain, and impaired uterine involution.