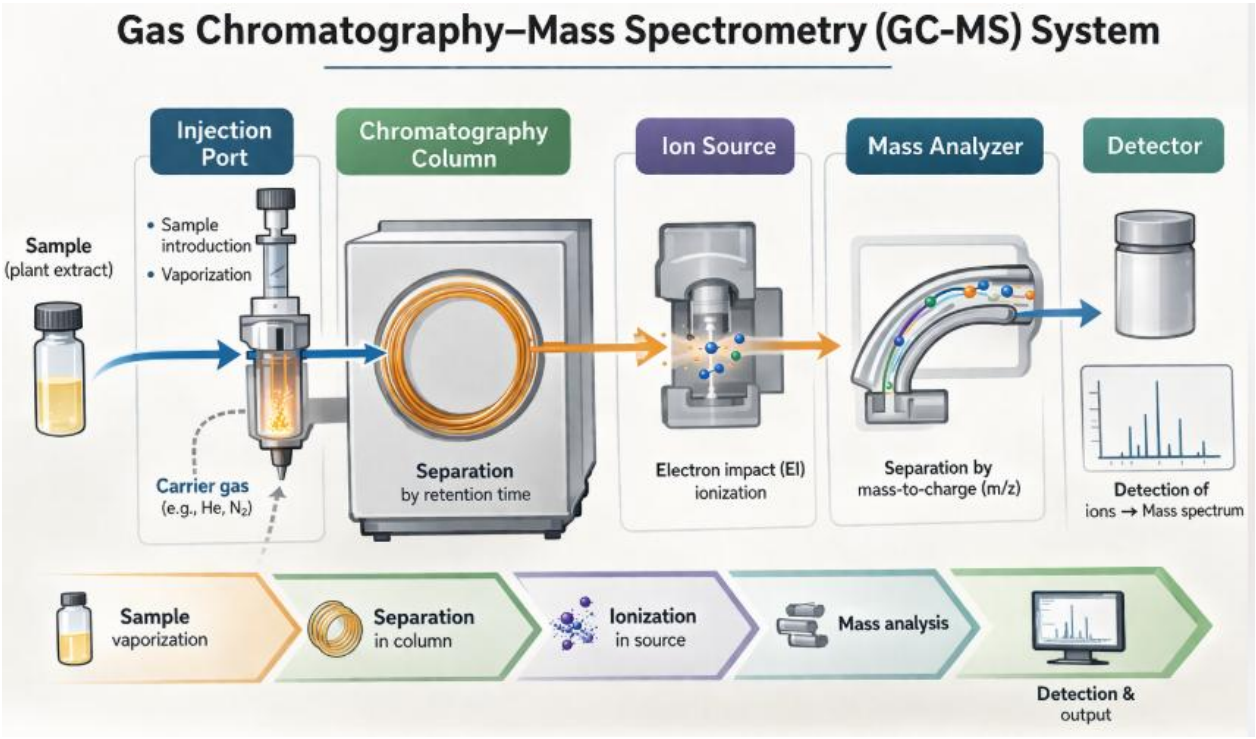

Figure 2 Schematic diagram of the gas chromatography-mass spectrometry (GC-MS) system illustrating sample injection, chromatographic separation, and mass spectral detection. Adapted from general analytical instrumentation principles

3.3 Quantitative analysis of major active compounds

Quantitative determination of key bioactive constituents is essential to standardize plant extracts and evaluate dose-dependent effects on mosquito populations. Techniques such as calibration curve-based HPLC quantification allow accurate measurement of major phenolic acids, flavonoids, or terpenoids known for insecticidal or repellent activities. This quantitative data supports reproducibility in bioassays and facilitates comparisons between different plant species or extraction methods (Dhanaraj et al., 2025; Hodoșan et al., 2025).

Furthermore, advanced mass spectrometry methods including high-resolution MS enable precise quantification even in complex mixtures at low concentrations. Such analyses help identify marker compounds that can serve as quality control indicators during extract production. Understanding the concentration ranges of active components also informs formulation strategies to optimize efficacy while minimizing potential toxicity to non-target organisms or the environment (Heinrich et al., 2022; Kapadia et al., 2022).

4 Larvicidal Activity of Plant Extracts against *Anopheles gambiae*

4.1 Mortality rates under different concentration treatments

The larvicidal efficacy of various plant extracts against *Anopheles gambiae* larvae generally exhibits a clear dose-dependent relationship, with higher concentrations producing increased mortality rates. For instance, methanol crude extracts of *Croton macrostachyus* achieved 100% mortality at 400 ppm, while lower concentrations showed proportionally reduced effects, demonstrating strong larvicidal potential (Tadesse et al., 2025). Similarly, ethanol leaf extracts from *Azadirachta indica*, *Carica papaya*, and *Annona muricata* caused significant larval mortality, with complete mortality observed at concentrations above 10% for *A. indica* and *C. papaya* and above 5% for *A. muricata* (Ekpo et al., 2025).

Other studies confirm this trend across different plant species and extraction methods; for example, methanol leaf extracts of *Ocimum gratissimum* and *Cymbopogon citratus* showed high larvicidal activity with mortality rates reaching up to 100% at the highest tested concentrations (1 000 ppm) after 72 hours exposure (Opoggen et al., 2019). These findings underscore the importance of optimizing extract concentration to maximize larvicidal effects while considering practical application limits in vector control programs (Okbatinsae and Haile, 2017).