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Native Mexican aromatic flora and essential oils: Current research status, gaps in knowledge and agro-industrial potential

Luz María Calvo-Irabien

Centro de Investigación Científica de Yucatán, Unidad Recursos Naturales, Calle 43 #130 x 32 y 34, Col. Chuburná de Hidalgo, 97205 Mérida, Yucatán, Mexico

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ABSTRACT

Knowledge of the properties and industrial applications of aromatic plant essential oils is growing rapidly. Mexico harbours immense biological and cultural diversity, and is the source of numerous aromatic plants, many of which are endemic. Despite the country's vast natural and cultural capital, scant study has been done of the essential oils from native Mexican aromatic plants. Identifying agro-industrial applications based on aromatic plant cultivation and essential oil production requires greater knowledge and understanding of endemic aromatic plant species as well as development of technologies for industrial applications and essential oil-based products. As part of an effort to unlock the enormous potential of these plant resources, this review summarises the current state of research into essential oils from native Mexican aromatic plants, identifies gaps in knowledge and suggests areas for further research. A systematic literature search showed that the essential oils of 76 native species have been characterized, although this represents just 17% of the known aromatic flora in Mexico. Asteraceae is the family with the highest number of records. Research has focused on the evaluation of biological activity, dominated by antibacterial, antifungal, insecticidal and antioxidant properties. Interesting opportunities for essential oil-based products developed from native aromatic plants are highlighted. Progress in research on aromatic flora and their essential oils is limited by a general lack of knowledge, but also by an absence of robust collaborative processes. Mechanisms facilitating collaboration and multidisciplinary studies will promote faster growth in knowledge of native Mexican aromatic plants, their essential oils and any actual or potential industrial applications.

1. Introduction

Humans have been using aromatic plants for millennia, developing in the process an extremely broad and deep knowledge of their properties and myriad applications (Kubeczka, 2010). Aromatic plants contain essential oils (EO), each a complex blend of tens to hundreds of volatile molecules, including terpenes and terpenoids, and aliphatic and phenol-derived aromatic components (Bakkali et al., 2008; Franz and Novak, 2010). These natural products are extracted from different parts of the plant, including both above- and underground organs, usually using processes such as distillation or cold pressing.

Knowledge is a constantly growing on EO properties and their multiple industrial applications. Due mainly to their well-known antioxidant and antimicrobial activities, they are highly valued for their therapeutic properties in human, and more recently animal, health (Avila-Ramos et al., 2012; Bakkali et al., 2008). These same activities, in addition to their specific flavours and fragrances, also make them important in diverse food and cosmetics industries applications (Burt, 2004; Lubbe and Verpoorte, 2011). In other areas, ecological knowledge of EO's roles in plant–plant and plant-insect interactions has been fundamental in the development of bio-herbicides and pesticides (Amri et al., 2013; Isman, 2000; Regnault-Roger et al., 2012). The importance of EO to human health and well-being, and ecosystem functioning, is therefore quite well established.

One of the world's biodiversity hotspots, Mexico contains immense and vital natural capital. It is also home to enormous cultural capital, with approximately sixty different living cultures with ancient ethnobotanical knowledge of plant properties (Sarukhán et al., 2009). Many widely used aromatic plants are indigenous to Mexico, and in many cases were domesticated within its territory (Colunga-GarcíaMarín and Zizumbo-Villarreal, 2004; Dressler, 1953; Picó and Nuez, 2000). Perhaps most famous among them is *Vanilla planifolia*, for which Mexico is known to be the centre of origin and domestication. Before European contact the Aztec elite and merchant class esteemed vanilla for its flavour and rarity, although Mexico currently accounts for less than 1% of global vanilla production (Bory et al., 2008; Herrera-Cabrera et al., 2012; Lubinsky et al., 2008). Renowned for the scent of its flower, *Polianthes tuberose* was also widely used in pre-Contact Mexico.

E-mail address: lumali@cicy.mx.

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Tuberose roots were used as a soap substitute, other plant parts were used for medicinal purposes, and the flowers were valued for their intense perfume. Tuberose cultivation and management is so old that no reports exist of wild populations (Trueblood, 1973). The *Polianthes* genus is also endemic to Mexico, where twenty different species have been reported (Barba-Gonzalez et al., 2012). Another example is the genus *Tagetes*, now cultivated worldwide and known for its horticultural and essential oil-yielding species. Native to the New World, the principal *Tagetes* cultivars (*T. erecta* and *T. patula*) are generally accepted to have been domesticated in Mexico before European contact (Kaplan, 1960). Commonly referred to as Indian lavender, the *Bursera* genus, particularly *Bursera delpechiana*, is well known for its aromatic resin (Becerra and Noge, 2010). Less commercially important aromatic species that are also native to Mexico include *Pimenta dioica*, *Persea americana*, *Piper auritum*, *Hyptis suaveolens*, *Porophyllum ruderale*, and *Dysphania* (=*Chenopodium*) *ambrosioides* (Blanckaert et al., 2012; Dressler, 1953). Essential oils derived from these and other native Mexican species have many important potential industrial applications.

Despite this vast natural and cultural capital, the EO of native aromatic plants in Mexico have received surprisingly little attention. Of the approximately 23,000 native plant species described to date in Mexico (Villaseñor and Ortiz, 2014), about 450 have been reported as aromatics (Martínez, 1979). This meagre knowledge of Mexico's native aromatic flora, and their natural derivative products, may be one of the reasons for the country's low share (2.8%) in the world EO market (Bizzo et al., 2009; ITC, 2009). This share is dwarfed by those of other highly biologically diverse countries such as China, which has a five-fold larger share in terms of tons EO produced, India, with a four-fold greater production, and Brazil, with twice the production. In addition, EO exports from Mexico are largely non-native species; for example lime EO represents 95% of the country's EO export market. Mexico also produces small quantities of garlic EO, while lavender/lavendin and mint EO production is increasing. Vanilla and oregano are the only native species from which EOs are extracted for export (ITC, 2009). Mexico's overall trade in EOs has grown rapidly in recent years, with the main markets being the United States (54%) and Europe (35%) (Bizzo et al., 2009; ITC, 2009).

Mexico's status as the centre of origin and domestication of a wide variety of aromatic species provides it with invaluable plant germplasm, and a unique set of genotypes for improvement, management, cultivation and conservation programmes aimed at established cultivated species and related wild species. Expanding the country's aromatic plant cultivation and EO production requires greater knowledge and understanding of the vast diversity of native aromatic plant species, their traditional and current uses, and development of technologies for industrial applications and EO-based products. The present review is intended to analyse the current status of knowledge on EOs in Mexico, identify gaps in it and suggest promising areas for future research aimed at unlocking the enormous potential of aromatic plant resources in Mexico.

A comprehensive, systematic literature review was done in September 2016. A specialized search was run using the SCOPUS and Web of Science databases of peer-reviewed scientific articles based on the terms “essential oil” and “Mexico” in the fields of abstract, title and keywords. All duplicates were eliminated from the resulting citations list. The abstract of each citation was reviewed and the entire text read when warranted. Only those citations matching the following two criteria were selected for analysis:

1) Essential oil extracted from plant material collected in Mexico (wild or cultivated), including native or non-native species (e.g. citrus, rosemary, mint, lavender).
2) Plant extracts obtained by distillation or cold-press extraction (essential oil). Other types of plant extracts (organic, infusions, supercritical) were excluded.

Similar literature database searches were run using the term “essential oil”, to estimate the total number of citations on this subject, as well as “essential oil” and “Brazil” and “essential oil” and “India”, to generate country comparisons. The “essential oil” and “Mexico” search produced a total of 352 published articles which were then culled to 246 based on the selection criteria. The analysis and results for native aromatic flora in Mexico in this review are based on these 246 publications.

2. Current knowledge

The first study of native aromatic flora and EO in Mexico was published in 1969 (Lozano et al., 1969), and only fourteen additional articles were published in the following 25 years. This number had doubled to 21 by the year 2000 and has since grown rapidly to 352 in August 2016. Eighty percent of the articles in this total were published during the past six years (2010–2016), representing an annual average of 47 articles. However, this total represents less than 1% of EO-related articles published worldwide (40,500). It is also less than 15% of the total publications identified in the search for EO research from Brazil (3243) or India (2805), both countries with natural and cultural diversity comparable to that of Mexico.

Knowledge on EOs from native Mexican aromatic flora is highly disperse across research institutions in the country and among publication sources. Research has been developed in eighty different institutions, none of which concentrated more than 10% of the total published articles. In conjunction, the Universidad Nacional Autonoma de Mexico, Instituto Politecnico Nacional and Universidad Autonoma Chapingo contributed 30% of the total publications, while 24 institutions contributed just one article. Published information on aromatic plants and essential oils in Mexico can be found spread across approximately 140 scientific journals, none of which accounted for more than 5% of the total publications.

Most (45%) of the research has focused on evaluation of EO biological activity, concentrating primarily on potential benefits to human health. Biological activity assessments have been dominated by antibacterial, antifungal, insecticidal and antioxidant activities (Table 1). This is followed by studies of EO characterisation (25%), and EO applications in the food industry (10%). Much smaller proportions of the literature have addressed cultivation of aromatic plants (9%), EO extraction techniques (3%), and various topics such as genetics, plant physiology, chemotaxonomy and chemical synthesis.

Ample attention has been given to introduced species currently cultivated in Mexico (e.g. citrus, chamomile, oregano, cinnamon, rosemary, thyme and clove, among others) to characterise and screen them for an array of biological activities and industrial applications (Alvarez et al., 2014; Ayala-Zavala et al., 2008; del Toro-Sánchez et al., 2010; Hernández-Ceruelos et al., 2002; Hernández-Ochoa et al., 2014; Martinez et al., 2009; Murillo-Amador et al., 2013). This review, however, places special emphasis on research focused on native aromatic species (Table 1).

The literature search showed that the EO of 76 native species have been characterized. This accounts for just 17% of the approximately 450 species of known Mexican aromatic flora (Martínez, 1979). Asteraceae is the family with the highest number of records (27%), followed by Burseraceae, Lamiaceae and Laurace, each representing 11% of the total number of species. Most (*ca.* 40%) prior research has focused on Mexican oregano *Lippia graveolens* (=*Lippia berlandieri, Lippia palmeri;* O'Leary et al., 2012), by far the most thoroughly studied native species EO in Mexico.

3. Essential oil biological activities

Cytotoxicity is a vital property when addressing EO industrial applications. Their lipophilic nature allows EO to pass through the cell wall and cytoplasmic membrane of pathogenic organisms (e.g.