Distribution of *Agave* species used for distilled and non-distilled beverage in Queretaro, Mexico †

[Distribución de especies de *Agave*, utilizadas para bebidas destiladas y no destiladas en el estado de Querétaro, México]

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SUMMARY

Background. Agaves (genus *Agave*) represent a significant component of Mexico's biocultural heritage, with over 40 documented specific uses across 22 use categories. These include food, distilled and fermented beverages, traditional medicine (human and veterinary), construction materials, living fences, soil retention, and ornamental applications. The use of agaves for beverage production, such as aguamiel and pulque, dates back to pre-Hispanic times. The state of Queretaro lies within one of the country's most active regions for pulque agave cultivation. **Objectives.** (1) identify the regions of *Agave* production for mezcal and pulque in Queretaro; (2) determine the species and varieties of Agave used for these purposes; and (3) document the cultivation systems involved. **Methodology.** Fieldwork was conducted in 17 of the 18 municipalities of Queretaro during 2022. A total of 105 sites were surveyed to collect data on geographical location, *Agave* species utilized, and associated cultivation systems. **Results.** Based on *Agave* use and distribution, Queretaro was categorized into three main zones: (1) the "mezcal zone" in the Sierra Madre Oriental region; (2) the "pulque zone" covering the southern and central areas, the largest in extent; and (3) the wild "agave zone" located in the eastern part of the state. **Implications.** Although Queretaro lacks a Designation of Origin (DO) for mezcal or tequila, the state cultivates mezcal-producing species such as *Agave rhodacantha* and *A. angustifolia*, as well as *A. tequilana*, which is traditionally used for tequila in other regions but is cultivated locally for inulin extraction. **Conclusions.** Agave cultivation in Queretaro encompasses both monoculture and agroecological systems, reflecting a diversity of practices linked to local knowledge and environmental conditions.

Key words: mezcal; pulque; Queretaro; Agave; cultivation systems.

RESUMEN

Antecedentes. Las plantas del género *Agave*, presentan una alta diversidad biocultural en México. Se han documentado 40 usos específicos y 22 categorías de uso, destacando aplicaciones como consumo alimenticio, bebidas destiladas, bebidas fermentadas, medicina humana y veterinaria, materiales de construcción, cercas vivas, retención de suelos y fines ornamentales, entre otros. En México, el uso de magueyes para producir bebidas como aguamiel y pulque data

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de tiempos prehispánicos. Querétaro se sitúa en la zona con mayor intensidad de cultivo de agave para la producción de pulque. **Objetivos.** 1) reconocer las regiones o zonas de producción de agaves mezcaleros y pulqueros en el Estado de Querétaro; 2) identificar las especies y variedades de *Agave* que se usan para tales fines; y 3) registrar sus sistemas de cultivo. **Metodología.** Se realizaron recorridos de campo en 17 de los 18 municipios de Querétaro durante 2022. Se obtuvo información de ubicación geográfica, especies de *Agave* usadas y sistemas de producción en 105 sitios. **Resultados.** De acuerdo con los resultados obtenidos, se llevó a cabo la zonificación del estado de Querétaro, en 3 regiones principales: 1) región de la Sierra Madre Oriental, denominada como "zona mezcalera"; 2) la región ubicada en el sur y centro del estado, la cual es la más extensa, denominada como "zona pulquera"; y 3) la región Este del estado, denominada como "zona de parientes silvestres". **Implicaciones.** El estado de Querétaro no tiene Denominación de Origen (DO) para la producción de mezcal y tequila, sin embargo, se registra la producción de especies mezcaleras como *Agave rhodacantha* y *A.angustifolia*, así como la producción de *A. tequilana*, la cual es usada para la producción de tequila en otros estados, en Querétaro está siendo producida para la obtención de inulina. **Conclusiones.** En cuanto a los sistemas de cultivo, se observa que los agaves se producen tanto en sistemas de monocultivo, como en sistemas agroecológicos.
Palabras clave: mezcal; pulque; Querétaro; Agave; sistemas de cultivo.

INTRODUCTION

Plants of the genus *Agave*, commonly known as "magueyes" or "agaves", exhibit high biocultural diversity in Mexico (Trejo *et al.*, 2018). That is, there is a high diversity of species alongside a wide range of traditional uses (Colunga-GarcíaMarín *et al.*, 2017; Pérez *et al.*, 2016). Evidence of this species diversity shows that the genus *Agave* contains 200 species, 79% of which are distributed in Mexico, with 59% endemic (García-Mendoza, 2011). Furthermore, 40 specific uses and 22 categories of use have been documented, highlighting applications such as food consumption, distilled beverages, fermented beverages, human and veterinary medicine, construction materials, living fences, soil retention, and ornamental purposes, among other uses (Colunga-GarcíaMarín *et al.*, 2017; Torres-García *et al.*, 2019).

In Mexico, the use of magueys to produce beverages like aguamiel and pulque dates to pre-Hispanic times (Gentry, 1982; Figueredo-Urbina *et al.*, 2024). Aguamiel is derived from the base of the floral peduncle of various *Agave* species (Moreno-Terrazas *et al.*, 2017). To collect it, magueys must show signs of initiating inflorescence development, at which point the plants are "castrated" (the floral bud is cut) to extract the sweet sap known as aguamiel. Pulque is an alcoholic beverage derived from the fermentation of aguamiel and is considered the oldest and most traditional Mexican alcoholic beverage (Moreno-Terrazas *et al.*, 2017). Thus, non-distilled beverages include both aguamiel (unfermented) and pulque (fermented), while distilled beverages are often broadly referred to as "mezcals", encompassing regionally specific products such as tuxca, raicilla, bacanora, and "tequila" (Colunga-GarcíaMarín *et al.*, 2017).

The origin of mezcal production in Mexico—that is, the distillation of beverages from magueys—has been widely debated. Some authors propose a colonial origin for agave-based distilled beverages, linked to external influences, particularly Filipino techniques adapted in New Spain (Zizumbo-Villarreal and Colunga-GarcíaMarín, 2008). In contrast, experimental and archaeological evidence suggests that distillation may have been known in Mesoamerica prior to European contact. In particular, reconstructed Capacha-phase ceramic vessels from western Mexico (ca. 1500-1000 BCE) have been shown to function as rudimentary distillation systems, capable of condensing alcohol vapors from fermented agave (Zizumbo-Villarreal *et al.*, 2009). These findings raise the possibility that distilled beverages could have been produced for ceremonial purposes before the arrival of the Spanish. However, biomolecular archaeological analyses have not yet provided direct chemical evidence to confirm this hypothesis, indicating that pre-Hispanic distillation remains plausible but unproven (McGovern *et al.*, 2019). This ongoing debate has important implications for how agave-based traditions are understood and recognized.

Regardless of this debate, the cultivation of agaves for both distilled and non-distilled beverages likely spans thousands of years in Mexico, representing a traditional practice in many regions of the country. In this context, the Denomination of Origin of Mezcal (DOM) is a legal instrument that does not fully reflect the biocultural diversity of magueys in Mexico, partly because it excludes regions where mezcal has been traditionally produced (Colunga-GarcíaMarín *et al.*, 2017; López, 2018). Such is the case for the state of Queretaro, located in the region termed the "wine-mezcal region" by Colunga-GarcíaMarín *et al.* (2017), where there is evidence that may indicate the production of distilled beverages in pre-Hispanic times. Additionally, Queretaro is situated in the area

with the highest intensity of agave cultivation for pulque production (Gentry, 1982).

The species most used to produce pulque are *Agave americana*, *A. mapisaga*, and *A. salmiana*, which are widely distributed in Mexico, especially in arid and semi-arid regions (Moreno-Terrazas *et al.*, 2017). Distilled beverages known as mezcals are obtained from various maguey species depending on the region. The most common species include *Agave americana*, *A. angustifolia*, *A. asperrima*, *A. cupreata*, *A. durangensis*, *A. karwinskii*, *A. inaequidens*, *A. marmorata*, *A. potatorum*, *A. rhodacantha*, *A. salmiana*, *A. seemanniana*, and *A. tequilana*. Notably, the plants used for producing both distilled and non-distilled beverages are sourced from cultivated fields as well as wild populations (Arellano-Plaza *et al.*, 2022; Moreno-Terrazas *et al.*, 2017).

Regarding mezcal, the growing commercial demand—which has increased from 1 million to 8 million liters over the past 10 years (Arellano-Plaza *et al.*, 2022)—has led to the overexploitation of *Agave* species used for this purpose, especially those harvested from wild populations (Arellano-Plaza *et al.*, 2022). Mezcal production not only involves extracting *Agave* plants from the wild but also the use of firewood for distillation and the clearing of natural vegetation to establish monocultures. This production system results in the loss of genetic diversity and soil fertility, as well as the excessive use of agrochemicals for pest control, among other negative ecological impacts (Valiente-Banuet, 2023). Valiente-Banuet (2023, p. 310) emphasizes that the high commercial demand for mezcal is causing "extinction debts" in ecosystems, which entail the loss of species, ecological interactions, and cultural aspects, including the possible disappearance of thousands of traditional producers, occurring due to the various social and environmental dimensions of mezcal production.

Considering these concerns, a diagnostic study of the production of distilled and non-distilled beverages in the state of Queretaro was undertaken. The specific objectives were: (1) to identify the regions or zones of mezcal and pulque agave production in Queretaro; (2) to identify the *Agave* species and varieties used for these purposes; and (3) to document their cultivation systems.

METHODS

Regions producing mezcal and pulque agaves

Communication was established with producers' associations, governmental agencies, individual producers, indigenous communities, and common lands to define the study sites and to gather information on the cultivation systems of agaves used for distilled and non-distilled beverages in the state of Queretaro. For the purposes of this study, a site was defined as a location where either cultivated agave plots or natural populations of agaves used for beverage production were found.

Field surveys were conducted between February and December 2022 in 17 of the 18 municipalities of Queretaro, excluding only the municipality of Corregidora due to safety concerns. A total of 105 sites were visited, selected based on preliminary consultations and exploratory research. At each site, data were recorded on the municipality, locality name, geographic coordinates, altitude, and the *Agave* species present. In the case of wild populations, the type of surrounding vegetation was documented. In cultivated plots, the cultivation system was characterized, distinguishing between monocultures and agroecological systems. In this context, agroecological systems refer to maguey fields where natural vegetation and plant diversity are preserved or promoted, without intensive land clearing, fertilizers, or pesticide use, allowing spontaneous vegetation to coexist with the *Agave* crop (Nicholls *et al.*, 2017).

In additions to field observations, open-ended interviews were conducted with local maguey producers and residents who were identified as knowledgeable about local *Agave* use and cultivation. These interviews were carried out in person during the field visits and were used to gather complementary information on species use, cultivation areas, and commercialization practices, including sale prices.

When mezcal or pulque *Agave* species were present, specimens were collected and deposited at the herbarium of the Universidad Autónoma de Querétaro (QMEX). In cases where wild species used for mezcal production in other Mexican regions were identified, the site was documented and sampled in the same way.

Identification of *Agave* species and varieties used for distilled and non-distilled beverages

The *Agave* specimens collected during the fieldwork were pressed, preserved, and identified taxonomically using specialized botanical keys and relevant scientific literature (Gentry, 1982; Magallán-Hernández, 1998; Villarreal, 1996). Each specimen was properly labeled and mounted for inclusion in the scientific collection of the herbarium of the University Autonomous of Queretaro (QMEX).

Database and cartographic information

All information gathered during the field surveys was compiled into a structured database. This dataset was subsequently used to generate a distribution map of *Agave* species in Queretaro through the Geographic Information System software QGIS (version 3.28.1, desktop edition).

RESULTS AND DISCUSSION

Field surveys were conducted in 17 out of the 18 municipalities of Queretaro, excluding only the municipality of Corregidora due to safety concerns. Information on geographical location and *Agave* species was obtained from 105 sites. The state of Queretaro was zoned according to the study objectives. Three main regions were identified (Figure 1): the northeastern region of Queretaro situated in the Sierra Gorda, part of the Sierra Madre Oriental, is labeled as the “mezcal zone”, with two mezcal-producing *Agave* species present: *Agave rhodacantha*, commonly known as "mezcal," and *Agave angustifolia*, known as "mezcalillo." The largest region, located in the south and center of the state, is labeled the "pulque zone," where three main species are distributed: *Agave mapisaga*, *A. salmiana*, and *A. weberi*. The eastern region of the state, labeled as the "wild agaves zone," is home to four wild species: *Agave applanata* (Cházaro and Narave-Flores, 2018), *A. asperrima* (Reyes *et al.*, 2023), *A. gentryi*, and *A. montana* (Treviño-Carreon *et al.*, 2007), which are used to produce mezcal in other regions of Mexico. It is worth noting that two areas with *Agave tequilana* (blue agave) crops were identified, though these were isolated in the municipalities of Amealco and Jalpan, so they are not depicted as a distinct “zone” on the map (Figure 1).

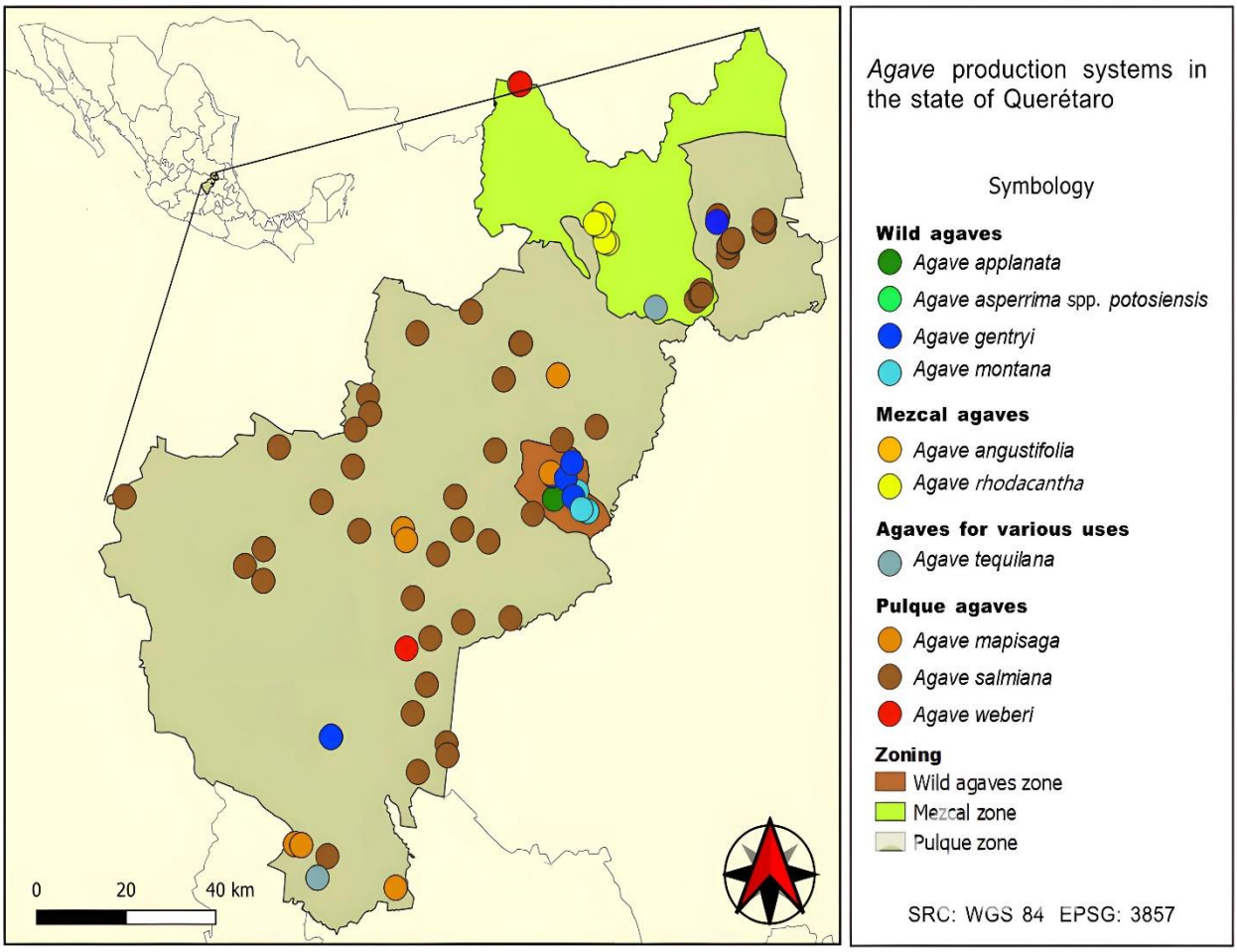

Figure 1. Zoning of the state of Queretaro according to the distribution of Agave species used to produce nondistilled and distilled beverages, as well as the distribution of wild agaves that are used for mezcal production in other regions of Mexico.

In the region referred to as the “mezcal zone,” non-common land, owned by small-scale farmers, is used for the cultivation of *Agave rhodacantha,* known as “mezcal”, which is refer to as “mezcal”. This species is grown using traditional production methods, meaning it is not part of a technified monoculture system. Instead, other plant species are allowed to grow freely around the agaves, with no land clearing or the use of fertilizers or pesticides. In some areas, species from the Fabaceae, Lamiaceae, and Asteraceae families were observed around the agave plants, as well as up to six different agave varieties, some used for pulque production, such as *Agave salmiana*, *A. mapisaga*, and *A. weberi* (Moreno-Terrazas *et al.*, 2017). The total area under *Agave rhodacantha* cultivation in Queretaro was found to be 52,379 m², though this figure is likely underestimated as it was not possible to sample all the lands in the region. Nevertheless, it is notable that the area is quite limited.

According to information provided by local producers, people from the neighboring states of Jalisco and Guanajuato occasionally visit the area to specifically purchase *A. rhodacantha*. These buyers usually arrive in pick-up trucks, allowing them access to remote areas. They negotiate plant prices, which can range from $100 to $500 Mexican pesos per "piña" (maguey heart), depending on size, with the most common price being $400 per piña. These buyers have specialized tools and experience in harvesting agaves, including the process of “jima *in situ*” (removing the leaves). Once the piñas are ready, they are transported in pick-up trucks to a location where all purchased piñas are gathered, then loaded onto 3-ton trucks or trailers. Producers in Queretaro noted that there is no regularity in the purchase of piñas, though the frequency of transactions has increased.

The state of Queretaro does not have municipalities with Designation of Origin for mezcal (DOM) (Arellano-Plaza *et al.*, 2022), though it is surrounded by states that do. This may explain the presence of buyers, possibly due to the scarcity of maguey resources in neighboring states. This system of commercialization is very convenient for producers in the Sierra Gorda of Queretaro, as it involves minimal agricultural management costs, and no expenses for transportation or marketing. A drawback is the unpredictability of when buyers will arrive. *Agave angustifolia* is cultivated much less frequently, as it was only recorded in one of the surveyed areas.

On the other hand, the pulque zone covers nearly the entire state of Queretaro, with several maguey species present, predominantly *Agave mapisaga*, *A. salmiana*, and *A. weberi*. It is important to note that *A. salmiana* and *A. weberi* are used for mezcal production in other regions of Mexico (Colunga-GarcíaMarín *et al.*, 2017). Although *A. americana* is present in Queretaro (Magallán-Hernández and Hernández-Sandoval, 2000), it was not recorded in this study. However, this species is used for mezcal production in other areas.

The presence of *Agave tequilana* crops was also noted in some plots in Amealco and Huimilpan (southwest of Queretaro). It was not possible to contact the producers to determine the destination of the production. In these municipalities, *Agave tequilana* is grown in monoculture systems. It is likely that the crop is intended to produce distilled beverages, given the proximity to the states of Michoacan and Guanajuato, which have DOM for tequila.

Additionally, in the Sierra Madre Oriental, there is an association called the "Consejo Agavero de la Sierra Gorda", with cultivated *Agave tequilana* plots in the municipalities of Jalpan, Landa de Matamoros, Arroyo Seco, and Pinal de Amoles. According to its leader, the crops are intended to produce inulin, not tequila. The association operates a monoculture, technified production system, with approximately 75 hectares dedicated to the species.

Lastly, the region referred to as the “wild agaves zone” is composed of two areas: 1) part of the Queretaro-Hidalgo semi-desert in the municipality of Toliman, and 2) the Sierra El Doctor in the municipality of Cadereyta. In this zone, three wild *Agave* species are found, which are used to produce mezcal in other regions of Mexico. In the semi-desert region, *Agave asperrima* ssp. *potosiensis* is relatively abundant in the municipality of Toliman, though it is not used for beverage production in this region. In the Sierra El Doctor, *Agave montana* and *A. gentryi* are found (Figure 2), both of which are used for mezcal production in northern Mexico. It is noteworthy that *A. montana* has only been recorded in this region of Queretaro. Although its conservation status has not been specifically assessed, it is considered a threatened species (personal observations), as community members collect its flowers and inflorescences, preventing sexual reproduction and reducing genetic diversity.

In this context, as part of this research, we propose the implementation of agroecological management plots for this species to promote its conservation while also serving as a genetic reservoir for future issues in the mezcal production system. The other species, *Agave gentryi*, known in the community as "maguey verde de cerro" (green maguey of hill) or "maguey verde" (green maguey), is very common in the Sierra El Doctor, and is associated with the *Juniperus-Quercus* forests of the area. Community members indicated that

more than 50 years ago, artisanal mezcal was produced in the region, and they can still locate the sites where the ovens and an old distillation structure were located (Figure 3). The species used for mezcal production at the time was the "maguey verde," i.e., *Agave gentryi*.

Figure 2. *Agave montana* (left) and *A. gentryi* (right) growing wild in a location in the Sierra El Doctor. Both species are used for mezcal production in other regions of Mexico, and in the Sierra El Doctor, they are used for pulque production.

Figure 3. Old mezcal distillery in the Sierra El Doctor region, Cadereyta, Queretaro.

CONCLUSIONS

The state of Queretaro does not currently face the challenges seen in other parts of the country regarding the mezcal boom, primarily because it lacks a Designation of Origin (DOM), meaning there are virtually no locations where mezcal is produced. However, several species of *Agave* used for mezcal production in other regions do exist in Queretaro, and there has been a recent commercial demand for *Agave* plants from the Sierra Gorda region for mezcal production. Pulque production is widespread across Queretaro, with three of the cultivated species also used for mezcal production in other regions. The Sierra El Doctor is a highly important region for the conservation of the genetic and cultural diversity of wild mezcal *Agave* species, and it is proposed as a conservation and management zone to produce *Agave montana* and *A. gentryi*.

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Mancilla-Benítez – Data curation, Formal analysis, Software.

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