



## Agave pulquero (*Agave salmiana*), socio-economic and agro-ecological importance and its development perspectives: a literature review

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**ABSTRACT:** *Historically, the agave pulquero (Agave spp.) has played an important ecological, economic, social, and cultural role in Mexico. Based on a systematic exploratory review of 125 scientific documents, four areas of knowledge associated with the study of agave pulquero were identified: i) biochemistry (46,4%), ii) socioeconomics (20%), iii) cultural studies (11,2%), and iv) agroecology (22,4%). Research converges on the need to value and preserve agaves since they can play an important role in rural development actions and the life quality of future societies, depending on the diversity of food, industrial, agro-ecological and cultural uses they provide. However, there is a fragmentary construction of the research problems that prevent a comprehensive vision of the producing territories as subjects of development. It is concluded that it is necessary to generate interdisciplinary perspectives for the valorization of the agave pulquero as an asset of rural development, based on inclusive innovation strategies, adapted to the specific needs of producers and consumers.*

**Key words:** *inclusive innovation, biotechnology, rural development, multidiscipline.*

## Agave pulquero (*Agave salmiana*), importância socioeconômica e agroecológica e suas perspectivas de desenvolvimento: uma revisão da literatura

**RESUMO:** *Historicamente, o agave pulquero (Agave spp.) tem desempenhado um importante papel ecológico, econômico, social e cultural no México. Com base em uma revisão exploratória sistemática de 125 documentos científicos, quatro áreas de conhecimento associadas ao estudo do agave pulquero foram identificadas: i) bioquímica (46,4%), ii) socioeconomia (20%), iii) estudos culturais (11, 2%) e iv) agroecologia (22,4%). A pesquisa converge para a necessidade de valorizar e preservar as agaves, uma vez que podem desempenhar um papel importante nas ações de desenvolvimento rural e na qualidade de vida das sociedades futuras, dependendo da diversidade de usos alimentícios, industriais, agroecológicos e culturais que proporcionam. No entanto, há uma construção fragmentária dos problemas de pesquisa que impedem uma visão abrangente dos territórios produtores como sujeitos de desenvolvimento. Conclui-se que é necessário gerar perspectivas interdisciplinares para a valorização do agave pulquero como um ativo de desenvolvimento rural, baseado em estratégias de inovação inclusivas, adaptadas às necessidades específicas de produtores e consumidores.*

**Palavras-chave:** *inovação inclusiva, biotecnologia, desenvolvimento rural, multidisciplinar.*

### INTRODUCTION

The traditional conception of rural development, until recently, focused on the productive reconversion of the territory aiming the production of *commodity* crops with high profitability in global markets (BERNSTEIN, 2010; PATEL, 2013). However, some more recent development perspectives have set their sights on the potential represented by native and endemic products, given their cultural and functional characteristics, which respond to specific

needs of contemporary society (AQUILANTI et al., 2020; GUERRERO et al. al., 2019).

Global food production faces challenges such as desertification, increased demand for healthy food, and competition for agricultural land (NICOLIA et al., 2014). The response to global crises requires low impact agrifood systems, hydraulic efficiency, crops resistant to climate change, independent of non-renewable resources, capable of generating energy inputs, but that do not compete for fertile soil for food production.

The maguey pulquero (*Agave* spp.), represented a resource of high economic, cultural, and nutritional importance in Mexico since pre-Hispanic times (HERNÁNDEZ, 1979). The main product derived from this plant is pulque, an alcoholic beverage with a whitish, viscous, slightly acidic, and low alcohol content (4-7 ° GL), resulting from the fermentation of the fresh sap (commonly called aguamiel) that is extracted from the base of the plant stem (ESCALANTE et al., 2016).

During the colonial era, it became an important agro-industry for the country's economy (LEAL & ROUNTREE, 2011). However, in the mid-19th century, the pulque agribusiness stagnated due to several factors, such as the introduction of the brewing industry, agrarian reform, anti-alcohol campaigns and drives to discredit pulque (RAMÍREZ, 2015; VALADEZ, 2014), due to the devaluation of the product and the loss of cultivated areas (AGUILAR et al., 2014). Recently, in the context of the revalorization of the biological and cultural heritage, development opportunities have been opened for the agave production chain.

Facing the global trend of consuming products of natural origin, it is considered appropriate to carry out a multidisciplinary analysis of scientific production on agave pulquero, to understand the changes that this natural resource faces.

Among the manuscripts reviewed is the special issue of *Fermented foods in health and disease prevention* (FRIAS et al., 2016); *The Science of Beverages* edited by GRUMEZESCU & HOLBAN, (2019), and the book *Beyond pulque and tepache: the indigenous non-distilled alcoholic beverages of Mexico* (GODOY et al., 2003). This international research provides innovative knowledge on fermented beverages and aim to consolidate high value-added agribusinesses based on functional and nutraceutical foods (FRIAS et al., 2016).

Although, scientific research seeks to contribute to each disciplinary field in addition to generating and promoting knowledge (CONTRERAS et al., 2015), most of them tend aim highly specialized audiences such as the agri-food industry or the scientific community. For this reason, it is necessary to increase its incidence in the producing communities, to support the weakest economic sectors, increase the capacity for innovation at the local level, make social use of knowledge and give greater legitimacy to scientific research (AROCENA & SUTZ, 2009; DEVAUX et al., 2018).

Therefore, it is necessary to promote the alliance between research and innovation with

inclusive processes capable of influencing social, economic, and technological development for the Mexican agricultural sector (HEEKS et al., 2014; AMARO & GORTARI, 2016).

In this sense, the question guiding this literature review is: What is the contribution of scientific research on agave pulquero, developed in the last 20 years, in terms of its possible impacts on rural development? To try to answer the question, various research approaches are assembled, from the social and economic sciences due to their sociocultural importance, to the agroecological and biochemical sciences that perceive their agro-industrial and economic potential.

The objective of this literature review is to reflect on the importance of scientific contributions about the study of the pulquero agave and its possible horizons of rural development in the producing territories.

## METHODOLOGY

To identify the areas of knowledge that have contributed to the study of the relationship between agave pulquero and rural development, a systematic exploratory review was carried out (LEVAC et al., 2010) of the literature available in the Elsevier, Scopus, Springer, WorldWideScience, and PubMed databases were performed between January 2019 and February 2020. An exploratory approach was chosen since a systematized body of knowledge on the problem studied was not identified. Furthermore, this first approach is the basis for the identification of knowledge gaps and the generation of new lines of research.

Those search engines that had a multilanguage real-time search platform were chosen, with various filters and ordering options for the results, thereby facilitating systematic access to publications from different fields of knowledge. Therefore, they are considered as sources of updated, stable, and reliable information to retrieve the relevant scientific records (ELLIS et al., 2018).

Only original research papers were selected. The search was carried out based on a semantic criterion, using the keywords: pulque, aguamiel, and *Agave salmiana*, this selection is based on the need to include those words that strictly refer to the most popular variety of agave pulquero (MORA-LÓPEZ et al., 2011; ÁLVAREZ-RÍOS et al., 2020c) and its derivatives.

The foregoing allows restricting the search for this variety since in Mexico there is a vast scientific production of other varieties of agave, particularly those intended for the production of distillates.

To generate a global panorama of the research on maguey pulquero (*Agave salmiana*), documents produced during the last 20 years were considered. While to understand the evolution of the studies, papers, and books written between 1950 and 1998 were reviewed. The information was organized using data tables, based on thematic axes. A total of 125 records were collected, compiled in pdf version (Table 1). They were classified according to the disciplinary fields in which they were developed. The data was ordered in a database in Excel version 2010.

Finally, a thematic analysis of the results was carried out (Table 2) (ARKSEY and O'MALLEY, 2005). It was reflected on the usefulness of scientific contributions to activate rural development dynamics, with innovations of high scientific and technological content capable of invigorating the agave pulquero production system, generating economically profitable productive innovations, improving the life quality of producers.

#### General aspects and uses of agaves

##### The maguey pulquero in Mexico

The maguey (common name for individuals of the *Agave* genus), originated about 12 million years ago in the arid regions of the current territory of northern Mexico and the southern United States of America (MONJA-MIO et al., 2019). They are perennial plants that maintain a crassulacean acid metabolism (CAM), a low demand for nutrients, and efficient use of water (GUZMÁN & CONTRERAS, 2018), they can survive in extreme conditions, including high altitude mountain places, they have a single event reproductive in their life, and contain a high concentration of fructans as reserve substances (CASTILLO et al., 2019).

In Mexico, the maguey has been used since pre-Hispanic times by its native peoples (GENTRY,

1982) to satisfy food, clothing, and construction needs (MACNEISH, 1964). Currently, 22 use categories have been reported for 107 agave taxa present in Mexico (COLUNGA-GARCÍA et al. 2007).

The maguey pulquero is considered an emblematic plant of the Mexican Central Highlands, which is used to obtain sap and produce pulque, a fermented drink associated with the food culture of various ethnic groups, valued in urban and rural contexts (ÁLVAREZ-RÍOS et al., 2020ab). Currently, there are more than 8 thousand hectares planted with maguey pulquero, distributed in the states of Guanajuato, Guerrero, Hidalgo, Michoacán, Puebla, Querétaro, San Luis Potosí, Tlaxcala, State of Mexico and Veracruz (Servicio de Información Agroalimentaria y Pesquera SIAP, 2018).

Among the different varieties of maguey that are most used to produce aguamiel and pulque are: *Agave macroculmis*, *A. mapisaga*, *A. mapisaga* var. *lisa*, *A. salmiana*, *A. angustifolia*, *A. ferox*, *A. salmiana* subsp. *crassispina* and *A. tecta* (COLUNGA-GARCÍA et al., 2007). Of which, the *Agave salmiana* var. *Salmiana* is the most suitable for pulque production due to its high acceptance among consumers (MORA-LÓPEZ et al., 2011; ÁLVAREZ-RÍOS et al., 2020c), for this reason, this review will focus exclusively on the research generated on this variety.

The maguey pulquero differs from other agaves used for the elaboration of alcoholic beverages, due to its fermentation characteristics that require low technification in its production processes, so that few changes have been experienced since the pre-Hispanic era (ESCALANTE et al., 2016; ROBERTSON & CABRERA-CORTÉS, 2017). In addition to social, political, and economic factors that, historically, have relegated it to the economic and social marginalization in which it is commercialized (BLAS-YAÑEZ et al.,

Table 1 - Classification of 125 scientific documents on maguey pulquero published between 2000 and 2020.

Knowledge area	Number of Publications	%*
Biochemistry	58	46.4
Agroecology	28	22.4
Socioeconomics	25	20.0
Cultural studies	14	11.2
Total	125	100

\*Percentage of total documents reviewed.

Source: own elaboration (2020).

Table 2 - Trends and research challenges on the maguey pulquero.

Discipline	Research topic	Trends	Challenges
Biochemistry	Chemical and microbiological studies	Functional foods development	Multidisciplinary Consumer niches Rural Agroindustry
	Biotechnology	Genetic improvement and micropropagation	Local germplasm banks Local management of biotechnology
	Development of industrial inputs	Development of biofuels, biological pesticides and biomaterials	Inclusive innovation and local technology for development
Agroecology	Ecological functions	Soil remediation and soil recovery	Public policies for the preservation and sustainable use of the agave pulquero
	Ecogeographical distribution of species	Variability and taxonomy	Decrease in cultivated area
Socioeconomics	Legal regulations	Laws for the promotion, conservation, and protection	Application of the legal framework Development of programs for the preservation and sustainable use of agave
	Competitiveness	Uses and applications of agave and its derivatives (industrial, food and recreational)	Productive diversification and innovation
Cultural studies	Sociocultural importance of agave production and consumption	Studies on cultural identities	Strategies for the sociocultural reproduction of the agave crop

Source: own elaboration (2020).

2018; 2019). This has caused that there are no precise statistical data on the production of maguey pulquero, agamiel, and pulque (AGUILAR et al., 2014).

The scientific community has indicated that agave has a high agro-ecological value, given its ability to retain soil, infiltrate moisture (TORRES-GARCÍA et al., 2019), and its potential to phytostabilize and remediate contaminated soils (PERALES et al., 2020). Also, the decrease in the cultivated area of maguey and the erosion of knowledge about its use (AGUILAR et al., 2014; ÁLVAREZ-DUARTE et al., 2018) lead to the loss of its genetic variability, which puts it in danger of extinction to various endemic species (MONJA-MIO et al., 2019) ecologically, economically and culturally relevant in rural areas of Mexico.

Given these concerns, in recent years various policies have been generated for the cultural revaluation of maguey and pulque as iconic elements of national gastronomy, this has been reflected with the rise of fairs, museums, tourist routes, urban pulque shops who seek to rescue the crop and claim its identity value (TORRES-NIETO, 2013; ROJAS-RIVAS et al., 2019).

Besides, biotechnological research has been generated on industrial (HOLTUM et al., 2011;

NAVA-CRUZ et al., 2015), agrifood (SANTOS-ZEA et al., 2016; ÁLVAREZ-RÍOS et al., 2020a), and the genetic potential of agave (MONJA-MIO et al., 2019; ÁLVAREZ-RÍOS et al., 2020b); however, the transfer of technology and applied science to enhance rural development has been minimal (ESCALANTE et al., 2016). Therefore, the pulque agribusiness is maintained with low technification, in a condition of informality, coupled with the poor application of public policies on the production, use, and marketing of pulque and other maguey products (BLAS-YAÑEZ et al., 2018).

#### *Socioeconomic studies on the maguey pulquero*

The first governmental interventions on the maguey pulquero were fiscal, sanitary and public order policies during the 19th century (VALADEZ, 2014; RAMÍREZ, 2015), in the first half of the 20th century, the agrarian reform, led to the dismantling of the pulque haciendas, the productive reconversion to annual crops such as barley and abandonment of replanting agave (GONÇALVES DE LIMA, 1956; RAMÍREZ, 2015) that led to the crisis of the pulque industry.

The disappearance of the maguey plantations and their negative effects on ecology



and economy was the starting point to address the problem of maguey in Mexico, from the perspective of agroecology and rural sociology, for the sake of thinking about comprehensive management of the crop.

The states of the central valley of the country have promoted various state laws for the promotion, conservation, and protection of the maguey. However, there are still no evaluations on the practical utility of such initiatives, to remedy the problems of the producers, such as the reduction of cultivated areas, the theft of plants and leaves, low technification, and limited commercial competitiveness.

Currently, the pulque that is marketed locally and regionally is maintained in small-scale production systems, generally developed for self-consumption and informal trade (ÁLVAREZ-RÍOS, 2020ab, BLAS-YAÑEZ et al., 2018).

From the social and economic perspective, the maguey pulquero is considered as an endogenous resource with the potential to promote rural development (NARVÁEZ-SUÁREZ et al., 2016), based on valorization strategies such as tourism (TORRES-NIETO, 2013) and the production and marketing of edible insects that grow and feed on this plant (ESPARZA-FRAUSTO et al., 2008; LLANDERAL-CÁZARES et al., 2010).

Producer typologies have been proposed, according to their production capacity and forms of commercialization (BLAS-YAÑEZ et al., 2019), as well as consumer studies to analyze the market niche represented by young consumers (ROJAS-RIVAS et al., 2019). From the anthropology of food, the consumption spaces of pulque and the social relationships that develop in them are analyzed (TONER, 2011; BLAS-YAÑEZ et al., 2018).

#### *Cultural studies on the maguey pulquero*

Some studies have analyzed the historical transformations of economic activities linked to the maguey pulquero (RAMÍREZ, 2015; VALADEZ, 2014; WRIGHT, 2009) and on the importance of agave for the establishment and survival of Mesoamerican civilizations (PARSONS & DARLING, 2000).

Other research focuses on the value of the maguey pulquero for pre-Columbian societies, considering its social and ceremonial importance (GONÇALVES DE LIMA, 1956; FOURNIER & BARRIOS, 2012; MAZZETTO & MORAGAS, 2015), as well as the evolution of the tools used for the extraction and fermentation of sap (ÁLVAREZ-PALMA et al., 2016; ROBERTSON & CABRERA-CORTÉS, 2017). The social systems that support the pulque production chain and its consumers

(NEMSER, 2011) and the symbolic representations of the maguey in the construction of national identity have also been analyzed (WRIGHT, 2009).

#### *Contributions of agroecology to the study of the maguey pulquero*

Agroecological studies focus on three main aspects: i) variability, taxonomy, and eco-geographical distribution of species (AGUILAR et al., 2014; TORRES et al., 2016), which describe the agaves used for pulque and mead production (ROJAS et al., 2007; COLUNGA-GARCÍA et al. 2007; REYES-AGÜERO et al., 2019); ii) ecological functions (MORENO-CALLES et al., 2013; TORRES-GARCÍA et al., 2019), with emphasis on genetic erosion and reduction of cultivated areas (FLORES-BENÍTEZ et al., 2007; ROJAS et al., 2007; REYES-AGÜERO et al., 2019) and iii) genetic improvement to improve productivity and conserve threatened wild species. The research by MONJA-MIO et al., (2019) and NAVA-CRUZ et al., (2015), highlights the importance of *in situ*, *in vivo*, and *in vitro* techniques for the conservation of germplasm. Biotechnological development is essential to optimize the production, diversification, and technology transfer of agave pulquero in the future (PUENTE-GARZA et al., 2015).

#### *Chemical and microbiological studies of agave*

Since the first decades of the 20th century, chemical and microbiological studies have been carried out on aguamiel and pulque (LOYOLA-MONTEMAYOR, 1956; SÁNCHEZ-MARROQUÍN, 1967). The first research (ANDERSON, 1946; SÁNCHEZ-MARROQUÍN and HOPE, 1953), emerged in an ideological and political context: hygienist, moralist, colonizer, and modernist (VARGAS, 2019).

The second wave of researches emerged in a context of hypermodernity (BECK, 2006), where the microbiological and nutraceutical potential of maguey pulquero and its derivatives is taken up, for use in biotechnological applications and bioprocesses (LAPPE-OLIVERAS et al., 2008; NAVA-CRUZ et al., 2015).

The biotechnological applications of maguey pulquero are divided into three strands: i) food biotechnology, based on the analysis of microbial behavior (VALADEZ-BLANCO et al., 2012; GUTIÉRREZ-URIBE et al., 2017) prebiotic content (CASTILLO et al., 2019; CASTRO-ZAVALA et al., 2015), probiotic content (LEAL-DÍAZ et al., 2015; CASTRO-ZAVALA et al., 2015; VILLARREAL-MORALES et al., 2019) and nutritional value

(ESCALANTE et al., 2004; 2016; TOVAR-ROBLES et al., 2011) to infer its usefulness in gastrointestinal disorders (VILLAREAL-MORALES et al., 2019; MIRAMONTES-CORONA et al., 2019), and develop functional foods (RIVERA et al., 2010; FRÍAS et al., 2016; GILES-GÓMEZ et al., 2016); ii) agricultural biotechnology for genetic improvement (MONJAMIO et al., 2019), *in vitro* micropropagation (SILOSEPINO et al., 2007) and obtaining active components of industrial interest (PUENTE-GARZA et al., 2015). iii) Energy biotechnology to obtain cellulose (NAVA-CRUZ et al., 2015), bioethanol (DAVIS et al., 2011; HOLTUM et al., 2011; LÁINEZ et al., 2019), biogas, and hydrogen (RIVERA-VARGAS et al., 2016), light biomaterials (NARVÁEZ-ZAPATA & SÁNCHEZ-TEYER, 2009) and as an adherent of composite polymers (HAQUE et al., 2016).

*Agave salmiana* can also contribute to remediating contaminated soils (PERALES et al., 2020) and the aguamiel can be used as a substrate in the production of nematodes for biocontrol of pests (ISLAS-LÓPEZ et al., 2005).

## DISCUSSION

Scientific publications on public health and microbiology on pulque in the 19th century served to demonstrate, criticize and address socio-cultural problems such as the non-responsible consumption of this drink, having repercussions in the conformation of regulatory frameworks that include public space, obligations tax, food safety, and production limits for agave pulquero.

This period of strong political and administrative restrictions also gave rise to new knowledge about the microbiological nature of pulque (LOYOLA-MONTEMAYOR, 1956; SÁNCHEZ-MARROQUÍN, 1967), providing new elements for its industrialization and conservation. However, these studies have generated incipient results due to their limited capacity to adapt to the socially constructed taste around this product, which is preferably consumed fresh and based on a social bond and trust with the producer. Pulque still faces adverse scenarios due to the implementation of global consumption patterns, which have spread the presence of cosmopolitan products such as wine and beer (LUTZ, 2012; RODRIGUES & PARR, 2019).

Nowadays, the findings from agroecology have drawn attention to the scarcity of plantations and the loss of endemic varieties of agave, where genetics and *in vitro* cultures raise efficiency in their application

for the massive regeneration and preservation of said varieties. However, the appropriation processes on these technologies are still limited and have been little studied from the economic, social, and technological perspectives to delineate the local development scenarios that exist, based on endogenous resources such as the agave pulquero.

Despite the fact that Mexico is a territory with a great diversity of agaves and its cultivation is rooted in culture, it has not gone beyond local consumption, nor traditional forms of consumption (BLAS-YAÑEZ et al., 2018). However, the trends in scientific research are oriented towards technological development linked to functional foods and biomaterials (GILES-GÓMEZ et al., 2016; LÁINEZ et al., 2019). This means that a comprehensive rural development strategy should be based on the socialization of technology and the integration of farmers within the value chains and business vision of new products.

The foregoing denotes the lack of specific studies to be able to base an opinion on the viability for the industrialization of derivatives of the agave pulquero applied in specific local contexts, to generate information that allows designing interventions to improve the productivity and sustainability of the crop, oriented to increase its benefits for the rural sector.

With the systematization of the evidence, it is possible to indicate that access to knowledge is limited since it only passes through scientific journals or specialized databases. Hence, the need to promote strategies to disseminate knowledge and transfer technological applications to producers who experience conditions of marginalization and poverty, but are the ones who have ultimately preserved the resources and their associated knowledge.

In this vein, it is necessary to study the socio-cultural and structural conditions that hinder the effective appropriation of knowledge, to understand the rupture between scientific production and its empirical application in specific productive contexts, this division being a limiting aspect to achieve the inclusive innovation (HEEKS et al., 2014; DEVAUX et al., 2018) so necessary for rural societies in peripheral countries.

Therefore, our review calls for dialogue between different areas and disciplines of knowledge to obtain a comprehensive view of the problem studied. One of the lessons that we have learned regarding how the lines of research on the agave pulquero have been constructed is the marked division between the biotechnological, socio-cultural, and economic-administrative aspects. This division must be overcome

to generate inclusive, culturally appropriate, and feasible innovation processes in the market.

In summary, the state of knowledge about the pulquero agave indicates the need to move from a basic research stage to an applied research stage, with a strong component of territorial innovation and rural extensionism.

## CONCLUSION

The reviewed scientific publications illustrate the growing interest of the sciences in the study of the maguey pulquero, given its biological characteristics and its great capacity for edaphoclimatic adaptation, it opens up various possibilities for development and innovation for local agave pulquero production systems, which face conditions of economic and environmental crisis.

The adoption of this potential implies the opening of new markets and the possibility of improving the quality of life of producers and consumers. However, it is necessary to have elements to determine its economic and social feasibility, as well as to overcome preconceptions regarding technological innovation as a restricted field for large companies, whose access is denied to rural producers.

However, there is a profound disarticulation between the academy, the industry, the State, and the social actors immersed in the preservation, production, and use of this plant. Therefore, the need to prosecute multidisciplinary projects that articulate economic, biotechnological, agri-food, and social aspects, to promote the full use of the maguey pulquero, as a resource that can influence the quality of life of future societies.

This literature review is expected to be useful in delineating research agendas in this area, based on a broad overview of the production, benefits, and conservation of this endogenous resource in rural communities.

Future research should propose empirical studies where the flow of scientific knowledge to rural communities is analyzed and the technology transfer for the production and transformation of the pulquero agave is evaluated.

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## DECLARATION OF CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest. The funding entities had no influence on the study design; nor in the collection, analysis or interpretation of the data; in the writing of the manuscript, nor in the decision to publish the results.

## AUTHORS' CONTRIBUTIONS

The authors contributed equally to the manuscript.

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