Socioeconomic characteristics of the production system of the Apaxtleco chili (*Capsicum annuum* L.)

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ABSTRACT

Objective: To analyze the socioeconomic characteristics of the producers and the production system of the Apaxtleco chili in Apaxtla, Guerrero, Mexico.

Design/Methodology/Approach: A structured questionnaire comprising both open- and closed-ended questions was administered, encompassing pre-production, production, post-harvest handling, and marketing components, in accordance with the methodology for evaluating agri-food chains to identify problems and propose projects. Additionally, the questionnaire assessed the social, economic, and productive attributes of the producers. For the evaluation of the production system, the Natural Resource Management Systems Evaluation Framework was applied.

Results: The producers are predominantly older adults; 84% possess only basic education. They rely mainly on family labor, with 92% cultivating the Apaxtleco chili primarily for self-consumption, selling only the surplus, which results in minimal participation in the local market. The cultivated area ranges from 0.02 to 7.0 hectares. The production system remains traditional and is transmitted intergenerationally, forming part of the biocultural heritage of Apaxtla de Castrejón, Guerrero.

Limitations of the Study/Implications: Due to regional insecurity, it was not feasible to interview all producers. Nonetheless, significant productive, social, and economic challenges among the surveyed producers were identified.

Findings/Conclusions: The main constraints on the profitability of Apaxtleco chili cultivation in Apaxtla, Guerrero, include the advanced age and low educational attainment of producers, limited technology transfer, and insufficient government support. Furthermore, climatic challenges particularly droughts along with pest and disease control issues, the absence of a comprehensive technological package, marketing difficulties, and persistent insecurity and political instability in the region, collectively hinder development.

Keywords: production, marketing, agronomic management.

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INTRODUCTION

Chili pepper (*Capsicum annuum* L.) is one of the most important crops worldwide and a staple in the Mexican diet. It is consumed fresh, dried, cooked, or industrially processed (Aguirre & Muñoz, 2015). Additionally, it serves as raw material in the production of colorants, resins, and is used medicinally for respiratory ailments, as an analgesic, laxative, and digestive aid. In 2023 alone, Mexico produced 3,681,061.47 tons of chili peppers, with the highest production concentrated in the states of Chihuahua, Sinaloa, Zacatecas, San Luis Potosí, Jalisco, and Sonora (SIAP, 2023). Prominent varieties include Jalapeño, Ancho, Guajillo, Pasilla, Serrano, de Árbol, and Piquín (López-López & Pérez-Bennetts, 2015). In the same year, Guerrero cultivated 1,412.58 hectares and produced 9,606.16 tons of chili peppers of various morphotypes and native varieties, each characteristic of specific regions where they are well recognized and commonly used in traditional dishes across Guerrero and broader Mexico (SIAP, 2023; Aguilar & Esparza, 2010; Aguilar-Rincón *et al*., 2010; Mena *et al*., 2007). One such case is the Apaxtleco chili, an endemic crop specific to Apaxtla de Castrejón, located in the northern region of Guerrero, Mexico (Sabino-López *et al*., 2021). This traditional crop is cultivated on small plots (Mena *et al*., 2007; Guzmán-Olea *et al*., 2024), using primarily family labor, and represents a vital source of income for local producers (Vázquez-Casarrubias *et al*., 2011). However, these endemic chili varieties face extinction risks due to climatic factors (Narez *et al*., 2014), particularly drought, as they are rainfed crops (Luna-Ruíz *et al*., 2018). Additional challenges include low technological input due to extensive-traditional production methods (Aguilar-Rincón *et al*., 2010; López-López *et al*., 2016), pest and disease incidence, lack of capital, high production costs, absence of value addition, and weak producer organization (Aguilar & Esparza, 2010; Monsalvo *et al*., 2020). These issues constrain productivity and hinder commercialization. Nevertheless, such agricultural systems play a crucial role in the management, conservation, and utilization of native seeds, grounded in the traditional knowledge and perspective of the producers (SAGARPA, 2016). Therefore, the objective of this study was to examine the socioeconomic characteristics of the producers and the production system of the Apaxtleco chili in Apaxtla, Guerrero, Mexico.

MATERIALS AND METHODS

The study was conducted in the municipality of Apaxtla de Castrejón, Guerrero, Mexico, located between 17° 56’ 12” and 18° 14’ 26” N latitude, and 99° 51’ 24” and 100° 07’ 13” W longitude, at an elevation of 1,200 meters above sea level. The area spans 857.1 km^2 and features a warm sub-humid to semi-warm sub-humid climate, with an average annual temperature of 26 °C (Gaceta del Gobierno del Estado de Guerrero, 2020). Twenty-five participating producers were interviewed between June 2021 and February 2022, out of a total of 35, as adverse conditions in the region hindered broader data collection. The questionnaire included both open- and closed-ended questions to gather information across four stages of the agri-food chain: pre-production, production, post-harvest management, and marketing (La Gra *et al*., 2016), in addition to social, economic, and productive characteristics of the producers (Quecedo & Castaño, 2002). Data were organized in Excel spreadsheets (version 2010) for subsequent descriptive analysis and quantitative assessment of production costs. To evaluate the Apaxtleco chili production system, the Natural Resource Management Systems Evaluation Framework (MESMIS) was adapted, as recommended by Monsalvo *et al.* (2020) and originally proposed by Masera *et al.* (1999).

RESULTS AND DISCUSSION

Socioeconomic characteristics of the producers

All Apaxtleco chili producers interviewed were men, with an average age of 64.48 years significantly above the national average (54.6 to 55 years) for individuals engaged in agriculture (FAO-SAGARPA, 2014). Notably, 75% were elderly, representing a critical threat to the continuity of this crop and its potential extinction in the medium term, given that the average life expectancy in Mexico is 75 years (INEGI, 2021).

The average household size was 4.28 members, surpassing the national average of 3.9 (CONEVAL, 2010). Of these households, 28% consisted of two members (the producer and their spouse), 4% had more than 12 members, and 68% ranged from three to eleven individuals many of whom contribute labor or act as economic agents within the production system (Sánchez-Galván *et al.*, 2020). In terms of education, 68% of producers had completed primary school, 16% secondary school, 8% high school, and 2% held a university degree, with an average of 6.58 years of schooling below the national average of 8.6 years (CONEVAL, 2010), though comparable to tomato producers (Martínez *et al.*, 2014). This educational gap hampers the development of technical, productive, and entrepreneurial capacities, thus limiting income-generating potential (FAO-SAGARPA, 2012; IICA-PRODAR-FAO, 2006), as these competencies directly impact productivity and household income (Vásquez *et al.*, 2019). Regarding income, 64% of producers reported monthly earnings between $5,000 and $10,000 MXN, which is below the estimated $13,529 MXN required to sustain a household (INEGI, 2019). Although 36% did not disclose specific income levels, they stated that their earnings covered both their basic needs and chili production costs. Notably, 92% of producers grow Apaxtleco chili primarily for self-consumption, with only surplus production entering the local market albeit with marginal participation (Aguilar-Rincón *et al.*, 2010). Approximately 68% of producers allocate less than 1.0 hectare to chili cultivation (Figure 1), with individual plots ranging from 0.02 to 7 hectares. This pattern is consistent with endemic chili varieties typically grown in open fields on small-scale plots between 0.5 and 2.0 hectares per producer, rarely exceeding 10 hectares in total (López-López *et al.*, 2016). Such scale enables cultural practices to be performed by family labor, which is unpaid and consequently helps reduce production costs (Vázquez-Casarrubias *et al.*, 2011; González *et al.*, 2019).

Cultural importance and uses of the apaxtleco chili

The Apaxtleco chili is an integral part of the biocultural heritage of Apaxtla de Castrejón, Guerrero hence its name. Both its fresh and dried forms serve as the primary ingredient in regional cuisine, particularly in the preparation of various traditional dishes (Aguilar-Rincón *et al.*, 2010). These dishes are prominently featured in local social and religious celebrations, mirroring the role of other local genotypes of *Capsicum annuum* in various regions of Mexico (López-López & Pérez-Bennetts, 2015; García-Gaytán *et al.*, 2017). In fact, the first Sunday of every February marks the annual Apaxtleco Chili Fair, an event where the finest fruits from the previous production cycle are showcased, and tasting events are held highlighting traditional dishes such as mole, the region's signature preparation. However, from 2016 to 2020, the number of Apaxtleco chili producers declined by 50.72% (Figure 2). Beyond the culinary use of green and dried fruits, the plant stems are utilized as livestock fodder, and crop residues are either incorporated into the soil or burned; the resulting ashes are used as a nutrient source to enhance soil fertility.

Regarding cultivation duration, 60% of producers maintain the crop for four months, 28% for three months, 8% for seven months, and 4% for five months. Among the different morphotypes of Apaxtleco chili, ancho liso occupies the largest cultivation area (38%), while mulato is grown on the smallest area (2%) (Figure 3). The most widely recognized types include ancho chino, ancho liso, and carricillo (Aguilar-Rincón *et al.*, 2010).

Field Production process of the apaxtleco chili

The cultivation of Apaxtleco chili is carried out using traditional methods, in alignment with the findings of Aguilar-Rincón *et al.* (2010). The production cycle begins between May and June with land preparation and concludes between September and November with harvesting. Producers utilize seeds from fruits harvested during

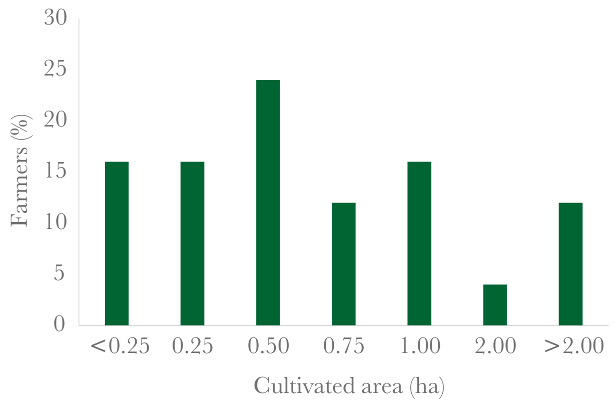

Figure 1. Area of Apaxtleco chili cultivated per producer during the 2019 -2020 cycle.

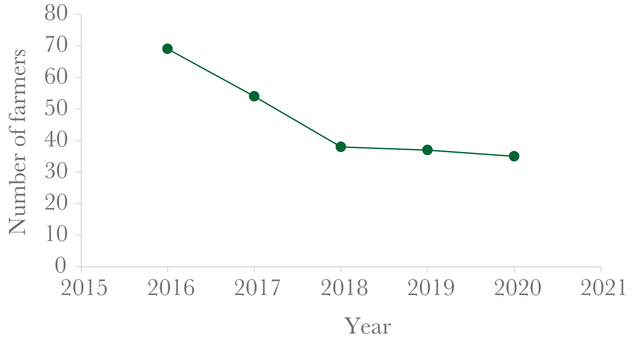

Figure 2. Number of producers of Apaxtleco chili in Apaxtla, Guerrero.

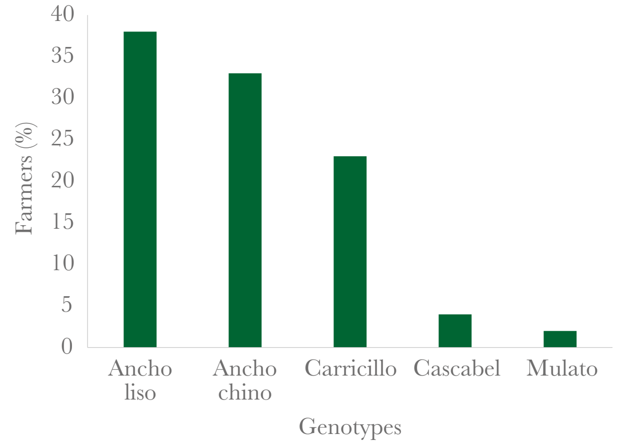

Figure 3. Genotypes of Apaxtleco chili cultivated in Apaxtla, Guerrero.

the previous cycle, selected based on their own criteria and experience, considering attributes such as size, shape, and color consistent with the observations of López-López *et al.* (2016) and San Juan *et al.* (2019). However, the sanitary quality of the fruits is not guaranteed due to the absence of a standardized seed selection and storage system, which negatively affects the fruits' physical and organoleptic characteristics (Vázquez-Casarrubias *et al.*, 2011). Yields of Apaxtleco chili in open-field conditions range from 0.60 to 0.75 t ha^{-1} of dehydrated fruit. This limited productivity is largely attributed to the lack of locally adapted technologies (Bahena *et al.*, 2012; Monsalvo *et al.*, 2020). Nevertheless, these figures are comparable to the field yield of 1 t ha^{-1} reported by Mena (2007). In greenhouse conditions, yields range from 0.24 to 1.15 t ha^{-1} of dry fruit, depending on planting density and transplant age (Vázquez-Casarrubias *et al.*, 2011). Therefore, cultivation under optimized environmental and agronomic conditions could significantly enhance productivity (Guzmán-Olea *et al.*, 2024). Despite this potential, water scarcity remains the principal constraint to productivity (Monsalvo *et al.*, 2020), often resulting in significant economic losses. The crop is typically rainfed, occasionally supplemented with manual irrigation, grown in monoculture, and cultivated on sloped terrains (Aguilar-Rincón *et al.*, 2010; Ramírez-Meraz *et al.*, 2015). Production costs exceed $42,100.00 MXN per cycle (Table 1), with the main cost components distributed as follows: seedling production, transplanting, and post-transplant management account

Table 1. Production costs for Apaxtleco chili cultivation during the 2019 spring-fall cycle.

Activity	Period	Cost (MXN $)
Land preparation	May	5,900.00
Seedling production and transplanting	May -June	8,500.00
Cultural practices	June -September	7,000.00
Irrigation and fertilization	June -September	7,000.00
Pest and disease control	June -September	6,900.00
Harvesting and storage	September -November	6,800.00
Total		42,100.00

for 20.2% of total costs; cultural practices, irrigation, and fertilization each represent 16.6%; pest and disease control, harvesting, and storage comprise 16.2%; while land preparation accounts for 14%. These costs are lower than those reported for other native chili varieties, where labor constitutes up to 40% of operational expenses (López-López *et al.*, 2016). In this case, the use of unpaid family labor substantially reduces overall production costs. In contrast, for crops such as tomato and habanero chili, fertilization typically represents the largest expenditure, especially when soil analysis is not conducted (Perrilla *et al.*, 2011; Marina *et al.*, 2020).

Harvest and marketing

A total of 92% of producers harvest the fruits at commercial maturity, 4% base their timing on prevailing market prices, and the remaining do so early to prevent theft. Once the fruits turn red, they are harvested and sun-dried for up to 20 days on rooftops or patios. During drying, the fruits are periodically turned to ensure uniform dehydration, as reported by Aguilar-Rincón *et al.* (2010) and López-López *et al.* (2016). Afterwards, the chilis are selected and stored in burlap, henequen, or ixtle sacks, which are kept inside homes or storage sheds (estrojas) for periods ranging from one month to a year, depending on the availability of buyers or favorable market conditions.

Producers do not apply post-harvest treatments for pest or disease prevention and lack specialized structures for drying or storage. Furthermore, they receive no training in the selection, preservation, handling, or transportation of the harvested product. Apaxtleco chili is marketed primarily in the local market (Table 2), where fresh fruit sells for $35.00 MXN per kilogram, and between $30.00 and $35.00 MXN per cuartillo (a local volume measure). Dehydrated fruit is sold exclusively by the cuartillo (weighing 180-190 grams) at prices ranging from $25.00 to $50.00 MXN, depending on perceived quality, particularly the pungency and color of the fruits criteria consistent with García-Gaytán *et al.* (2017). The average price of $35.00 MXN per kilogram has remained stable in the local market for several years, yielding a benefit-cost ratio of 1.5 (Mena *et al.*, 2007). This variety is also marketed in regional markets, other states in Mexico, and even the United States, where it sells for $10.00 to $45.00 USD per cuartillo, depending on fruit quality. However, this export channel is primarily utilized by producers with relatives living in the U.S., who assist in marketing the product abroad. In this context, Ordoñez (2018) notes that 80% of small producers primarily market their products in local and national markets. Nonetheless, exportation represents a promising alternative for scaling up production and expanding commercialization into new market niches (García-Gaytán *et al.*, 2017).

Table 2. Marketing locations for Apaxtleco chili.

Sales Location	Sales (%)
Local market (Apaxtla de Castrejón, Guerrero)	64
Regional market (Teloloapan) and state-level market (Cuernavaca)	32
United States of America	4

Challenges in the apaxtleco chili production chain

Six major challenges were identified in the Apaxtleco chili production chain (Figure 4): (1) climatic factors, (2) pests and diseases, (3) commercialization, (4) lack of government institutional support, (5) absence of a technological package, and (6) insecurity and political instability. Regarding climatic factors, all cultivated areas for Apaxtleco chili are rainfed. Approximately 25% of producers reported that irregular rainfall adversely affects production an issue also observed in other rainfed crops (Sánchez *et al.*, 2015; Barajas-Rodríguez *et al.*, 2020). This occurs despite the proximity of the Balsas River and the Carlos Ramírez Ulloa hydroelectric dam. However, the lack of irrigation infrastructure and the rugged topography characterized by slopes ranging from 5% to 30% (Aguilar-Rincón *et al.*, 2010) make irrigation implementation difficult. Concerning pests and diseases, 22% of producers identified whitefly (*Bemisia tabaci*) as the most detrimental pest affecting the crop, followed by grasshoppers (*Caelifera* sp.) at 18%, and fruit borer (*Anthonomus eugenii* C.) at 11%. The most commonly reported diseases include damping-off (*Pythium* spp.) at 20% and viral infections at 10%. These pest and disease pressures are consistent with those reported in Huacle chili (López-López *et al.*, 2016). An additional 22% of producers mentioned other, less frequent but potentially devastating pests and diseases. These issues are difficult to manage, often requiring chemical control as a short-term solution an approach that increases production costs (Monsalvo *et al.*, 2020).

Per capita annual consumption of dehydrated Apaxtleco chili ranges from 0.5 to 4.0 kg. However, 21% of producers reported marketing challenges, which largely confine sales to the local market. Furthermore, the market becomes oversaturated between October and January, often pushing sale prices to levels equal to or below production costs. The commercialization model is semi-structured and traditional, involving direct sales between producers and consumers or through short marketing circuits involving intermediaries (Sánchez-Galván *et al.*, 2020). Producers have not diversified the product through industrial processing. Only a few transform it into chili paste for mole, primarily due to a lack of training in alternative uses, derived products, and by-products such as capsaicin, oleoresins, pharmaceuticals, pepper spray, essential oils, pigments, purees, sauces, and processed powders (Aguirre & Muñoz, 2015; Ruíz *et al.*, 2011; García-Gaytán *et*

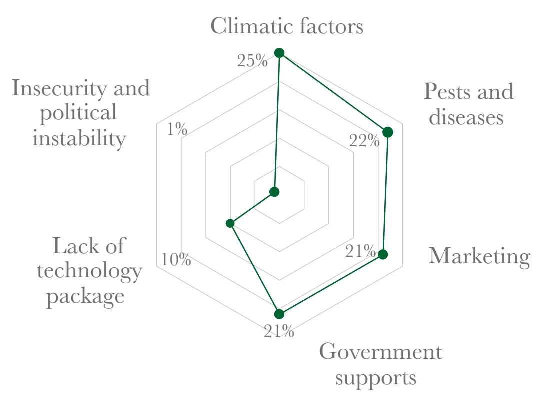

Figure 4. Constraints in the Apaxtleco chili production chain.

al., 2017). Therefore, organizing producers for collective marketing and industrialization could be a viable alternative to improve profitability (Aguilar & Esparza, 2010; Martínez *et al.*, 2014; Monsalvo *et al.*, 2020), while simultaneously promoting domestic markets for equitable and sustainable growth (De Grammont, 2010). Regarding institutional support, 21% of producers highlighted the lack of government assistance programs, attributing it to a weak institutional framework characterized by bureaucracy, poor interagency coordination, unclear regulations, and programs misaligned with community realities. This hinders both productivity and income generation (FAO-SAGARPA, 2012). In contrast, regions like the Comarca Lagunera reported 97.75% of producers benefiting from government support programs (Espinoza-Arellano *et al.*, 2024), and CONEVAL (2018) documented 98.35% coverage under the PROAGRO program. Additionally, 10% of producers noted that low yields are the result of the absence of a defined technological package for this crop. Production practices remain traditional, based on generational knowledge, and the introduction of new technologies has been minimal. Training and technical assistance in agronomic and postharvest management are scarce (Monsalvo *et al.*, 2020). The only guidance producers typically receive comes from the commercial suppliers of agricultural inputs. Developing a comprehensive technological package could enhance both productivity and market reach (García-Gaytán *et al.*, 2017). However, the absence of government support is also tied to regional insecurity and political instability, which hinders diagnostic efforts aimed at identifying community and production system needs. These challenges have led to significant economic losses (124.3 billion MXN in 2023) and social costs, including livestock loss, damage to family assets, and forced displacement (La Jornada, 2024). Most of the issues identified in this study were previously reported in the production of dried chili in Zacatecas (Galindo *et al.*, 2000; Aguilar & Esparza, 2010) and in native chili cultivation in Guerrero, Mexico (Mena *et al.*, 2007).

CONCLUSIONS

Apaxtleco chili is a traditional crop cultivated primarily by elderly producers. It represents a vital cultural asset in the region's gastronomy and holds market potential at the local, national, and international levels, both in the food and industrial sectors. The factors limiting the profitability of Apaxtleco chili production in Apaxtla, Guerrero, include the advanced age and limited education of producers, lack of technology transfer, insufficient government support, climatic challenges especially drought productive limitations such as inadequate pest and disease control, the absence of a defined technological package, marketing difficulties, and regional insecurity and political instability. Producers acknowledge the need for collective organization and training to identify viable solutions and develop strategies to ensure the preservation and continuity of this crop, which constitutes a crucial source of family income.

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