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Assessing sustainability in Puebla's artisanal mezcal production: Insights from a composite indicator approach

Jaramillo-Villanueva, José Luis[1*]; García-Benítez, Erika[1]

[1] Colegio de Postgraduados, Campus Puebla. Boulevard Forjadores de Puebla No. 205, Santiago Momoxpan, C.P. 72760. San Pedro Cholula, Puebla. México.
* Correspondence: jaramillo@colpos.mx

ABSTRACT

Objective: To assess the sustainability of the artisanal mezcal production system in the state of Puebla using composite indicators.

Methodology: A sample of 42 producers and their artisanal mezcal production facilities, known as palenques were selected using the snowball sampling method. Data were analyzed using variance analysis (ANOVA), multivariate analysis, and regression analysis. The SAFA framework (Sustainability Assessment of Food and Agriculture) guided the selection of 17 indicators grouped into the economic, social, and environmental dimensions, to derive a Composite Sustainability Index (CSI) of each mezcal production unit. Analysis was conducted for the entire sample and clusters generated through cluster analysis.

Result: The average CSI for artisanal mezcal production (and its standard deviation) was 0.45 (0.2033), comprising economic (0.596, 0.2366), social (0.398, 0.2161), and environmental (0.437, 0.196) dimensions. ANOVA revealed significant differences in CSI between groups. The highest value of the CSI was obtained in the group of high-scale producers (0.539), followed by medium-scale (0.427), and low scale producers (0.393).

Conclusions: Artisanal production systems demonstrate low sustainability levels, impacted by limited training, excessive agave usage, and minimal recycling practices for inputs.

Keywords: agave, sustainability index, mezcal.

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INTRODUCTION

The production of artisanal beverages has gained significance in response to new market trends, as informed consumers increasingly seek sustainable products with a strong connection to their place of origin [1]. In this context, mezcal production is socioeconomically and culturally intertwined with the natural landscapes where it is crafted [2]. In Puebla, mezcal production reached nearly half a million liters in 2022, growing from an annual rate of 0.1% in 2014, and 2.5% in 2022, with an increasing share of 2.19%. This positive outlook is encouraging for the mezcal industry in Puebla, aiming to boost production to one million liters [3].

While these figures are economically promising, they also imply increasing environmental pressure on biodiversity, soil, and water resources. For this reasons, the mezcal industry has begun to consider actions to enhance the sustainability of agave and mezcal production [4]. There is a broad agreement that assessing the sustainability of agri-food systems must include social, environmental, and economic dimension [5].

Sustainability assessment

Unlike other methods focused solely on environmental and productive aspects, the SAFA framework offers a comprehensive approach that spans the entire production chain, from the agricultural production unit to the final consumers [6]. It adapts to diverse contexts and farm operation sizes. SAFA is based on three pillars —environmental integrity, economic resilience, and social well-being— that together form a unified definition of sustainability, structured into themes and subthemes for each pillar. Goals are established for each theme, with objectives defined for the subthemes. Within each subtheme, indicators are identified to set measurable criteria for sustainable performance. These indicators, applicable across various company size, types and contexts, provide standardized metrics to guide future sustainability assessments. For a detailed explanation of SAFA, refer to FAO (2014). IN SAFA, sustainability measurements rely on selecting indicator to form a composite index [7]. The rising demand for artisanal mezcal in Mexico and abroad, coupled with the mezcal industry's expansion plans, underscores the need to analyze the sustainability of mezcal production in Puebla. Therefore, this study aimed to evaluate artisanal mezcal production systems using synthetic indicators to create and index reflecting their sustainability levels.

MATERIALS AND METHODS

The research was conducted in rural communities in the state of Puebla, identified by key informants as significant centers of artisanal mezcal production. These communities included Cuautinchán, Tecali de Herrera, San Diego la Mesa Tochimiltzingo, Huehuetlán el Grande, and Tepeojuma.

Data were collected through in-depth interviews with key informants, guided by a structured questionnaire administered to a sample of 42 producers selected using the snowball sampling method. The questionnaire covered the following aspects: i) sociodemographic characteristics: age, sex, education, indigenous language, economic dependents, household members, generational succession, organization, off-farm activities, training, and technical assistance. ii) productive characteristics: production unit size, type of labor, land tenure, cultivation area, agricultural practices, agave varieties, income, and costs. iii) marketing: liters produced, price, marketing channels, and consumption characteristics; and iv) subsidies and support programs: input costs, water and energy used in the production process, as well as challenges and outlooks for mezcal production.

Stages in the construction of the composite indicator

The logical sequence proposed by Gómez-Limón *et al.* [9] was followed to construct the composite indicator, including the following stages:

1. Indicator selection. Seventeen indicators were selected to construct the Composite Sustainability Index (CSI) for the artisanal mezcal production units, integrating the three sustainability dimensions: economic, social, and environmental.
2. SAFA based selection criteria: indicator selection was based on SAFA principles, encompassing social well-being, economic resilience, and environmental integrity, as extensively described by the authors [6; 10; 11].
3. Multivariate analysis: Multivariate analysis was conducted to ensure no significant correlation existed between selected indicators and to identify groups of indicators for similar production units, facilitating result interpretation. Principal Component Analysis and Cluster Analysis were conducted using STATA 18 software.
4. Normalization: "Min-max" normalization was applied to standardize indicators into comparable units, with normalized values ranging from 0-1 [12]. For all indicators, zero indicates lack of sustainability, while higher values represent greater sustainability. Table 1 describes the selected indicator and each sustainability pillars.

Economic indicators

The following economic indicators were considered:

1. Profitability, represented by the benefit-cost ratio.
2. Sales contract, represents security in production sales, with a value of 1 assigned when the producer has a sales contract for their production.

Table 1. CSI indicators in mezcal production.

Index	Indicators	Minimum	Maximum	Media	Std. Dev.
Economic	1. Profit	0.5	2.7	1.78	1.089
	2. Revenue	−236.4	420.9	135.51	109.738
	3. Contracts	0	1	0.45	0.504
	4. Subsidy	0	1	0.64	0.485
	5. Certificated	0	1	0.46	0.447
Social	6. Employment	0	0.9	0.27	0.157
	7. Fam production	0.33	1	0.62	0.229
	8. Intergenerational	0	1	0.57	0.501
	9. Organizational	0	1	0.67	0.437
	10. Training	0	1	0.19	0.283
	11. Security	0	1	0.24	0.431
Environmental	12. Bio-fertilizers	0	1	0.38	0.492
	13. Water	2	50	18.75	9.153
	14. Wildlife	0	0.7	0.2	0.182
	15. Reciclyng	0	1	0.21	0.334
	16. Conservation	0.33	1	0.56	0.231
	17. Energy	0.33	1	0.48	0.279

Source: developed by the authors.

3. Subsidies, indicate the dependency of mezcal production on government supports, with a value of 1 assigned when the production unit does not receive subsidies.
4. Certification, reflects mezcal quality and ensures a better price. A score of 1 is given if the production holds and official certification.

Social indicators

The following social indicators were considered:

1. Family production, represents the degree of family labor used in the production process, measured by the number of family members participating in each stage.
2. Employment, represents job creation resulting from the production and marketing of mezcal; a higher number of family wages per liter produced suggests greater social sustainability.
3. Transgeneration, reflects the likelihood of preserving artisanal knowledge for future generations. If the master mezcalero is actively teaching the process, this indicator is rated highly.
4. Capabilities, represents the development level of the producer's skills in branding, production process, and marketing.
5. Work safety, indicates the likelihood of avoiding workplace accidents. If the palenque has a safety protocol in place along with essential equipment for handling emergencies (*e.g.*, fire extinguisher and first aid kit), this indicator is assigned a value of 1.

Environmental indicators

The following items were used as environmental indicators:

1. Conservation, assesses whether the producer engages in practices for soil conservation, water, and use of organic fertilizers.
2. Use of wild agave, reflects the levels of dependency on wild agave. If the production process does not rely or uses only a minimal amount of wild agave, this indicator receives a high value.
3. Recycling, considers whether the producer implements water recycling, rainwater harvesting, and waste treatment.
4. Energy sources, represents the type of energy sources used, classified by environmental impact level: zero (manual), low (animal or electric), or high (gasoline/diesel).

Production unit stratification

To enhance the analysis, a cluster analysis was conducted to categorize the *palenques*, resulting in three distinct groups.

RESULTS AND DISCUSSION

The results indicate that 93% of those responsible for the *palenques* are male, while 7% female. However, women participate in one or more stages of the production process,

representing 50% of labor in tasks, such as collecting firewood, filling the oven, and performing distillation and fermentation activities. On average, 60% of those involved in the entire maguey-mezcal chain are men and 30% are women [13]. This distribution helps explain the presence of a mezcal women's organization in the study region. Additionally, 9.5% of the *palenque* leaders reported speaking an indigenous language.

The average education level was 9.0 years, which is similar to the state average of Puebla, of 9.2 years [14]. The study region also demonstrated a higher education level compared to the mezcal-producing regions in Oaxaca, where most palenque owners have only basic education [15]. This difference may be due to the higher marginalization in Oaxacan municipalities.

Mezcal production is predominantly artisanal, with 91% of mezcaleros following traditional practices. Among mezcal types, young mezcal is the most common (92%), though aged (3%) and ancestral mezcal (5%) varieties were also observed mezcal production relies on a mix of family and hired labor: 48% of production units combines both, 19% rely solely on family labor, and 33% exclusively on hired labor. On average, 248 workdays are required to produce 3,117 liters per year, with an average benefit-cost ratio (B/C) of 1.78. In comparison, a study of mezcal producers in Caltepec, Puebla, reported an IRR (internal rate of return) of 91.98% and a B/C ratio of 1.27 [16], with lower profitability attributed mainly to lower sales price.

Production unit stratification

The multivariate analysis identified three distinct strata of artisanal mezcal producers (Table 2): i) High production producers (PEA), ii) Medium production producers (PMP), and iii) Low production producers (PBP). These groups align with the typology established in previous studies [17]. All three groups share common characteristics, being artisanal producer with traditional production systems.

The PEA group has an average age of 56±13 years, with a maximum of 70. Their education level is above secondary school (9.8 years on average). They produce an average of 6,615 liters of mezcal per year, achieving higher profitability in mezcal sales (B/C of 2.7) compared to the PMP and PBP groups. Family labor represents 10% of their workforce, and this group has a higher training rate than the other two. They use 8.5 liters of water per liter of mezcal produced, with 30% of the agave being wild.

The PMP group has an average age of 47±9 years and education level averaging 8.2 years. They produce 2,514 liters of artisanal mezcal per year, with a B/C ration of 1.9. This group uses 20% wild agave and consumes 15.4 liters of water per liter of mezcal.

The PBP group produces 650 liters annually, with losses (−$128.91 per liter) and a B/C ration less than one, indicating lower profitability relative to the PEA and PMP groups. They use 30.8 liters of water per liter of mezcal, making them the least efficient stratum in this regard. The estimated CSI value for this group was 45.01, composted of economic (59.6), social (39.8), and environmental (43.7) dimensions. The PEA group showed a significantly higher average CSI compared to the PMPM and the PBP strata, which belong to the same group.

Table 2. Descriptive statistics of the stratification variables.

Variable	Estrata	Media	Std. Dev.	Minimum	Maximum
Rate of B/C	PEA	2.7	0.629	1.60	3.70
	PBP	0.8	0.480	0.10	1.40
	PMP	1.9	1.039	0.50	3.50
Profits ($/lt.)	PEA	200	104.95	62.6	420.9
	PBP	−129	229.77	−736.4	61.3
	PMP	59	113.66	−192.6	213.0
Labour use (%)	PEA	0.1	0.044	0.00	0.10
	PBP	0.3	0.206	0.10	0.90
	PMP	0.2	0.102	0.00	0.40
Experience (years)	PEA	26.7	17.951	2.00	56.00
	PBP	13.0	9.739	1.00	30.00
	PMP	33.0	17.236	2.00	55.00
Training index	PEA	0.4	0.348	0.00	1.00
	PBP	0.1	0.204	0.00	0.75
	PMP	0.1	0.137	0.00	0.33
Production volumen (lts)	PEA	6615	6979.59	2000.0	24000
	PBP	650	481.441	100.00	1800
	PMP	2514	1600.412	500.0	5000
Water use (Lt/mezcal lt)	PEA	8.5	5.298	2.0	18.7
	PBP	30.8	26.560	4.0	100.0
	PMP	15.4	9.408	3.5	37.5
Wild agave (%)	PEA	30.0	21.8	20.0	70.0
	PBP	50.0	13.1	30.0	70.0
	PMP	20.0	11.3	10.0	50.0

Source: developed by the authors using data from interviews, 2022.

The sustainability of the study units (*palenques*)

This study reveals substantial variability in sustainability indicators among artisanal mezcal producers. Three distinct strata were identified, differing in production volume, profitability, education, experience, and skills. Similarly, three production systems were identified in Miahuatlán Oaxaca, including subsistence, medium-scale, and low-scale producers, with significant differences observed [18].

The Composite Sustainability Index (CSI) is displayed in Figure 1. Among the dimensions, the economic indicator was significant ($p<0.01$), confirming that the mezcal production is profitable. Regarding the social index, producers' experience —reflected in their knowledge of artisanal mezcal production— showed significant differences in the PBP stratum, with an average subindex of 37.1 ± 18.5, higher in the PEA and PMP group. This resulted in highly significant differences in the overall index among the three groups ($p<0.01$). The environmental dimension also displayed notable differences, with the PMP group showing the highest significance (46.4 ± 23.64). The PEA group achieved

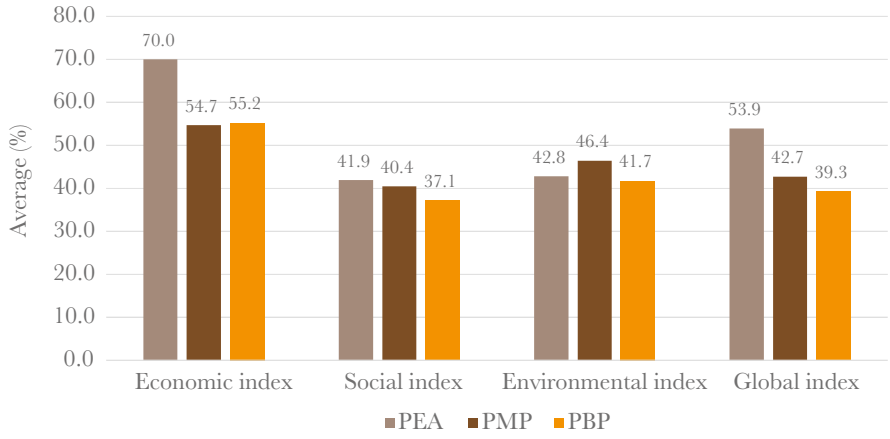

Figure 1. Sustainability index by strata and general (CSI).

the highest general index score (53.9), with a minimum sustainability level of 32.12 and maximum of 82.90.

CONCLUSIONS

Artisanal mezcal production was classified into distinct strata, with significant differences observed in terms of age, education, profitability, production process, and agave type. This diversity among mezcal producers is essential for designing targeted public strategies. The sustainability levels across the three pillars evaluated in this study was found to be low. Several aspects of the production process need substantial improvement, including reducing the reliance on wild agave, adopting more sustainable energy sources, and decreasing water use or implementing recycling processes.

The PEA group was distinguished by its extensive experience, higher profit per liter of mezcal, and lower water usage; however, it showed similar dependency on wild agave as the PMP and PBP groups. The PBP stratum, although producing a lower volume, demonstrated greater returns on investment compared to the PMP group, and utilized more labor in the production process than the PEA and PMP strata. Regarding the overall sustainability index, the PEA stratum scored higher than the PMP and PBP groups. Thus, the production system is in a transitional phase toward improved sustainability.

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