Amaranth (*Amaranthus* spp.) value chain in Mexico

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ABSTRACT

Objective: To analyze the value chain of amaranth (*Amaranthus* spp.) in Mexico, considering the actors, their relationships and functions, as well as the factors influencing its performance.

Design/methodology/approach: The value chain map was obtained through targeted surveys and working panels with various stakeholders.

Results: The results highlight that small producers face greater difficulties, such as the lack of adequate technology. Additionally, a disconnection between producers, researchers, and the government was evidenced.

Limitations on study/implications: Obstacles in processing and marketing were identified, with relationships being purely commercial with collectors, as well as limited commercial promotion. Despite this, opportunities are perceived to improve marketing, especially at the national level, through awareness campaigns and marketing strategies. The importance of association among producers and institutional support to overcome challenges is emphasized.

Findings/conclusions: The study concludes with the need for a robust public policy to promote the consumption of amaranth, highlighting its nutritional and cultural properties. The study offers insight into the amaranth value chain in Mexico, highlighting its problems and proposing solutions for its strengthening.

Keywords: Production, Collection, Processing, Marketing, Consumption.

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INTRODUCTION

Amaranth (*Amaranthus* spp.) is a high-yield and versatile seed capable of thriving under adverse conditions. Its high nutritional value, both in quantity and quality, highlights it as a healthy food source for rural communities and as a viable crop alternative to address issues of malnutrition, public health, and climate change that affect society. In the international context, it has gained prominence in recent years due to its nutritional importance. Annually, approximately 201,000 t of the cereal are imported worldwide (Fierro *et al.*, 2020). The United States has emerged as the main importer of amaranth from Mexico, driven by its growing demand for organic, healthy, and nutritious products (Agri Food and Fisheries Information Service [SIAP], 2023).

At the national level, amaranth is primarily found in rainfed cultivation regions characterized by low levels of mechanization, family labor, and predominantly conventional systems. The cultivated area ranges from average plots of 0.5 to 3 ha to producers managing up to 200 ha, reflecting the diversity of scales and production methods in the sector (Ayala *et al.*, 2014). By 2022, the leading states in the production of this grain in Mexico, in terms of volume, were Puebla, Tlaxcala, and the State of Mexico, mainly concentrated in the central region of the country. Although Puebla is the main producer state in terms of volume, with 2,857.52 t, Tlaxcala surpasses it in production value (SIAP-Agri-Food Information System for Consultation [SIACON], 2022).

Contrary to its importance, the amaranth value chain in Mexico faces significant challenges due to the lack of resources and financing in the rural communities where it is cultivated (De la O *et al.*, 2012; Ayala *et al.*, 2012).

The lack of integration and organization among producers, combined with competition from more mechanizable crops and low selling prices, has resulted in reduced incomes for producers, amounting to only $7,075.56 per ha (Ayala *et al.*, 2014). The creation of alliances and better management of distribution and marketing could enhance the competitiveness of the chain (Peña *et al.*, 2008). Identifying and addressing these limitations is crucial for improving producers' incomes and overall competitiveness. The objective of this study was to analyze the amaranth value chain, considering the actors, their relationships and functions, as well as the factors affecting the chain's competitiveness, to establish alternatives that can help overcome the limitations and improve producers' incomes.

MATERIALES Y METODOS

The value chain refers to how a set of actors interacts with a product to increase its value throughout the different links (Acosta, 2006).

Variables

Innovatión. To determine the degree of influence of various factors, performance, and innovation were analyzed as indicators of the growth in amaranth production. The Venezian and Gamble (1969) equation, modified by Contreras (1999), was used (Equation 1), and data were taken from SIAP-SIACON (2022).

$$P_t = Y_0\left(A_t - A_0\right) + A_0\left(Y_t - Y_0\right) + \left(A_t - A_0\right)\left(Y_t - Y_0\right) \qquad \text{Equation 1}$$

Where: Pt = Total increase in production for the analysis period; $Y_0\left(A_t - A_0\right)$ =Quantifies the contribution of the area; $A_0\left(Y_t - Y_0\right)$ =Quantifies the contribution of yield; $\left(A_t - A_0\right)\left(Y_t - Y_0\right)$ =Quantifies the combined effect of area and yield; A_0=Initial average harvested area (1982=435 ha); A_t=Final average harvested area (2022=3,211.45 ha); Y_0=Initial national average yield (1982=0.51 t ha^{-1}); Y_t=Final average yield (2022=1.78 t ha^{-1}).

To assess whether growth has been intensive or extensive, one can determine the proportion of each factor in the total increase in production (growth from 1982 to

2022=100%). Extensive growth involves an increase in harvested area, while intensive growth is related to an increase in yield. Additionally, combined growth implies an increase in both area and yield equally (Zarazúa *et al.*, 2009).

Value chain

Working panels

To characterize the amaranth value chain, producer panels were employed using the Delphi technique, aiming to obtain reliable and consensus-based responses from a group of experts (Franco *et al.*, 2018). These panels included representatives from Hidalgo, Tlaxcala, State of Mexico, Puebla, Morelos, and Mexico City.

In the first working session, participants received guidance on the fundamentals of value chain methodology and established initial guidelines for the analysis of the chain and competitiveness. A dialogue was initiated with experts in each panel to gather information related to production, technical parameters, and marketing systems for a baseline year. Feedback was received and strategies and recommendations were formulated. Validation of the results was conducted through a consensus process with the original panelists to verify the integrity and accuracy of the information. This process is crucial to ensure the validity and representativeness of the data obtained (Zavala *et al.*, 2012). The Amaranth value chain was modeled based on information provided by experts in two panels.

Attendees included input suppliers, producers from different regions, processors, academic and governmental institutions, NGOs, as well as stakeholders interested in the subject matter.

Field surveys

Surveys in the aforementioned states involved 96 producers, 8 processors, 12 experts, 6 traders, and 40 consumers. The surveys, consisting of qualitative questions, were transformed into quantitative data for detailed analysis. A group of producers was convened through non-probabilistic sampling (Pimienta, 2000). Efforts were made to ensure that producers had similar production systems and technological levels, as well as knowledge and information on technical parameters and production costs. The activity took place between June and December 2023.

Conceptual map of the amaranth value chain

To obtain the conceptual map of the amaranth value chain, different levels were analyzed, including actors and their roles, horizontal relationships, the domestic market, critical support services, technical assistance, quality management, logistics, and storage.

RESULTADOS Y DISCUSIÓN

National production of amaranth in the national context

The growth of amaranth production is determined by the combined interaction between the increase in planted area and the yield improvement of the crop by 64% (Factor Decomposition, Table 1). This implies an increase in both area and yield in a combined manner, suggesting that innovation adoption in amaranth is not high. The crop grows primarily based on an expanded cultivation area.

Table 1. Growth of amaranth production in the national context.

Item	Surface	Yield	Surface–yield interaction	Total
Value obtained	1416	552	3526	5494
Value (%)	26	10	64	100

Author's elaboration with data from SIAP-SIACON, 2023.

According to Ayala *et al.* (2016) productivity increase is dependent on the adoption of technological innovations, which are recommended based on the characteristics of production zones (Estrada *et al.*, 2006). Muñoz *et al.* (2007) state that the adoption of technologies involves multiple factors, with one of the most critical being the involvement of trained extensionists who are knowledgeable about innovations. The low yield growth (Table 2) reflects the limited adoption of technologies.

Between 2000 and 2021, the yield per ha increased at an annual average growth rate (CAGR) of 1.94%, while production increased at 2.21%. The lower productivity increase compared to production is attributed to the low adoption of technological packages, as corroborated by fieldwork. The lack of continuous training and inadequate technical guidance also contribute to this stagnation.

Value chain and involved actors

Amaranth value chain map in Mexico

The amaranth value chain map (Figure 1) consists of six links. It includes input and information suppliers, followed by primary production, collectors, processors, marketing, and consumers. On the far right, there are stakeholders; however, some of these (the dotted ones) are not yet formally integrated.

Relationships among producers

Ayala *et al.* (2014) mentioned that in 2014, the links amongst producers were weak. However, due to their own initiative, they are currently organized into small informal groups. These associations are composed of proactive producers seeking to improve their production conditions through continuous learning. 21% of producers have organized themselves into groups driven by initiatives such as the field schools of the Secretariat of Welfare, which have been present since 2021 in Tlaxcala, Puebla, and Hidalgo, and will continue until 2024 in the State of Mexico.

While mechanization has facilitated land preparation and agricultural tasks, there are still some producers (24%) who use traditional methods such as the yoke. The National Institute of Forestry, Agricultural, and Livestock Research (INIFAP) has designed seeders and harvesters to optimize primary production, but access to these is not universal. Thus,

Table 2. Growth of amaranth production in the national context.

Concept	Harvested area (%)	Production (%)	Yield (%)
CAGR	1.04	2.21	1.94

Author's elaboration with data from SIAP-SIACON, 2023.

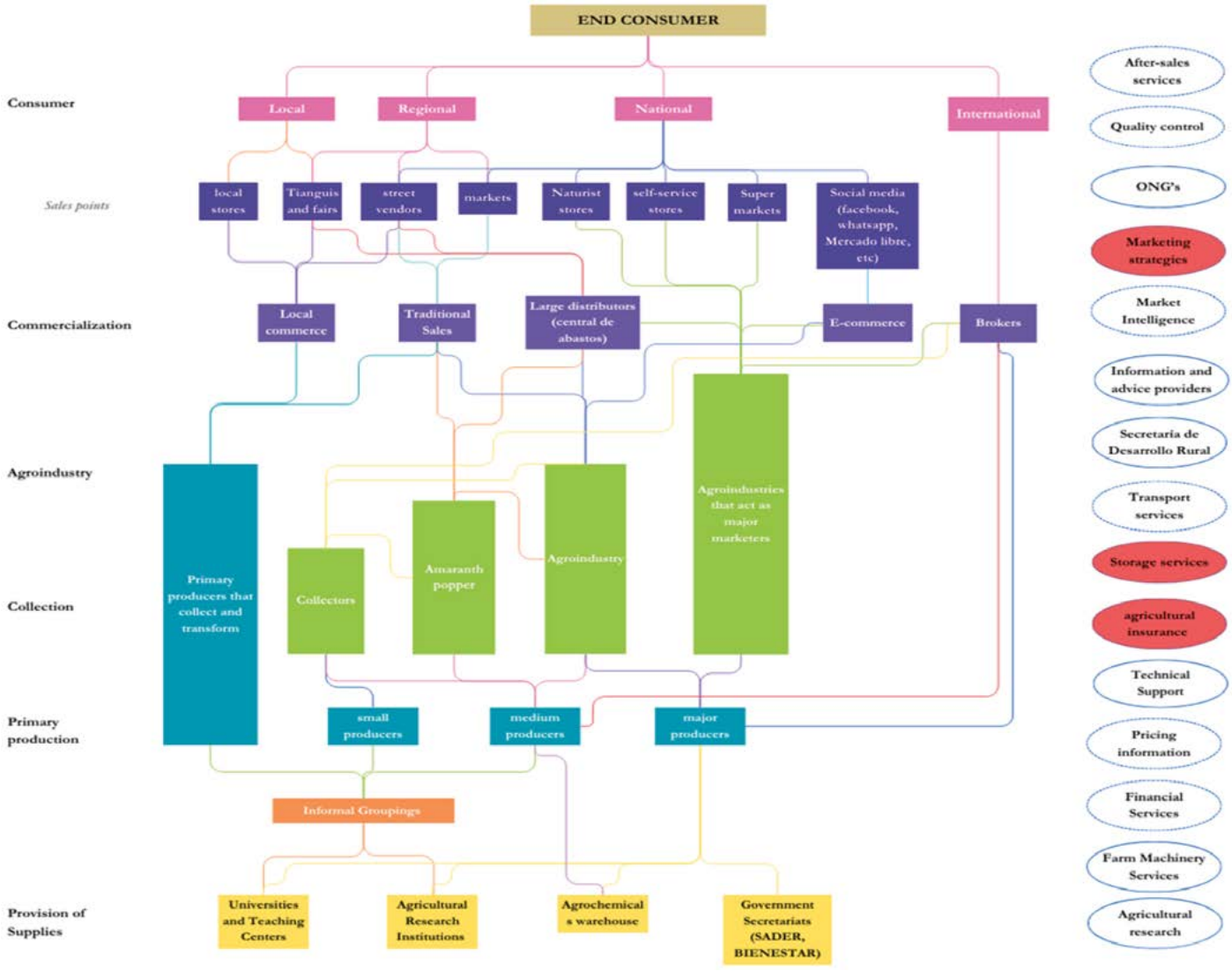

Figure 1. Linkages and relationships in the amaranth value chain in Mexico.

large producers with conditioned machinery rent it to their peers. Harvesting remains a challenge due to the high demand for labor (an average of 49 workdays) and the difficulty in finding workers due to low wages.

The field study also revealed that 89% of the producers do not own more than 10 ha. These small producers supply raw materials to the agro-industry. In contrast, producers with more than 10 ha sell their production directly to the processing industry. It is important to note that the percentage of producers involved in processing is minimal. Only 13% of those with up to 10 ha and 9% of those with more than 10 ha process their production or have small agro-industries. This represents a total of 23% of the surveyed producers. This is considered a low percentage, indicating an opportunity for more producers to integrate into this link (Figure 2).

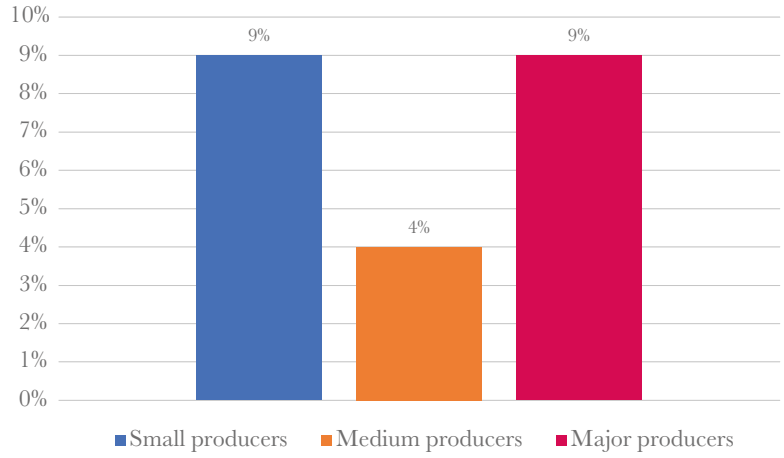

Figure 2. Classification of producers participating in processing.

Identified issue: Weaknesses were detected in the linkage between producers, researchers, and the government, along with deficient technical assistance and indiscriminate use of agrochemicals in production, mainly due to a lack of knowledge about technological packages. Climate changes also affect the crop and drive the search for more profitable alternatives, such as sorghum, which has displaced amaranth cultivation in Morelos. Inadequate agricultural practices and the lack of agricultural insurance or financial resources exacerbate the situation.

Collection

The commercialization of amaranth is characterized by a regional market (86%), although it has also managed to enter the national and international markets. The latter is to a lesser extent (5.26%), concentrated in Puebla and the State of Mexico. Some local collectors act as intermediaries and large collectors, who set the price and quality of the grain, often without knowledge of current regulations or process standardization.

Identified issue and alternatives: The collectors establish horizontal links with their peers, limiting the participation of producers in the value chain. It is necessary to develop effective marketing strategies that ensure proper quality management. To achieve this, efforts are focused on diversifying markets and establishing collection organizations that strengthen the negotiating position of producers.

Transformation

The transformation of amaranth is characterized by diverse relationships between processors and producers, supporting large-scale producers and selling to major industries. Institutions such as the College of Postgraduates (COLPOS) and the Meritorious Autonomous University of Puebla (BUAP) have promoted innovation and the development of technologies that facilitate amaranth processing. In Puebla, producer organizations like Amaranteo, Productores del Volcán Popocatépetl de Amaranto, Tochialegria, and Delice stand out for their efforts in amaranth transformation. Opportunities are identified to foster collaboration, promote research, support organizations, and diversify product offerings.

Identified issue: Existing equipment for grain popping is inadequate and affects the quality of the grain, thereby limiting its nutritional value. Additionally, most of the transformed products (90%) have high sugar content, highlighting the need for further research to develop amaranth-based foods with enhanced nutritional value.

Quality

In Mexico, the regulatory framework for amaranth intended for human consumption is established through two standards: Mexican Standard NMX-FF-114-SCFI-2009, which defines the quality specifications of the grain in terms of its physical, physicochemical, and microbiological characteristics, and Standard NMX-116-SCFI-2010, which complements the former by establishing necessary precautions to prevent contamination of popped grain during threshing, bagging, and storage stages (Secretaria de Economia [SE], 2009; 2010). Despite the existence of these standards, the study revealed that only 52% of producers establish criteria to ensure grain quality (Figure 3). These criteria are based on physical characteristics such as the presence of ferrous material, foreign matter, metallic particles, or black grain; physicochemical parameters such as moisture, ether extract, ashes, crude fiber, density, peroxide index, and heavy metals; and microbiological specifications including presence of molds and yeasts, aerobic mesophiles, total coliforms, *Salmonella* spp., *Staphylococcus aureus*, and aflatoxins (SE, 2009; 2010).

For processors, 74% are aware of the quality and safety requirements that must be met regarding raw materials and inputs, while 52% establish quality and safety criteria for their amaranth suppliers (Figure 4).

In NMX-FF-116-SCFI-2010, popped amaranth grain is classified into three quality grades: Category I, II, and III (Table 3), depending on its physical and physicochemical characteristics (SE, 2010).

Producers who establish quality criteria classify it into these three categories. Meanwhile, processors mentioned that the popped grain they use for their processes falls within categories III and II (Figure 5).

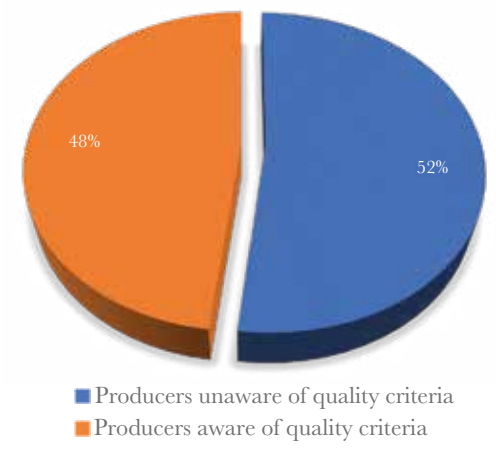

Figure 3. Awareness of Quality Criteria Compliance (Establishes quality criteria according to NMX-FF-116-SCFI-2010).

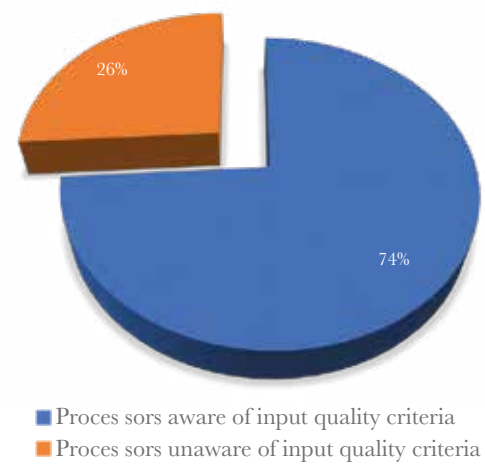

Figure 4. Knowledge of quality criteria that inputs must meet.

Table 3. Classification of grain according to NMX-FF-116-SCFI-2010.

Criteria	Category I	Category II	Category III
Grain popping (% of retention in 16mm screen)	100 - 96	95,9 - 90	Less than 90
Rresence of ferrous material (%)	<0,05	0,051 - 0,20	
Foreign matter	See 6.6		
Metalic particles	Absent		
Black grain (%)	≤0,5		
Brunt grain	Absent	Not applicable	

NMX-FF-116-SCFI-2010. (2010)

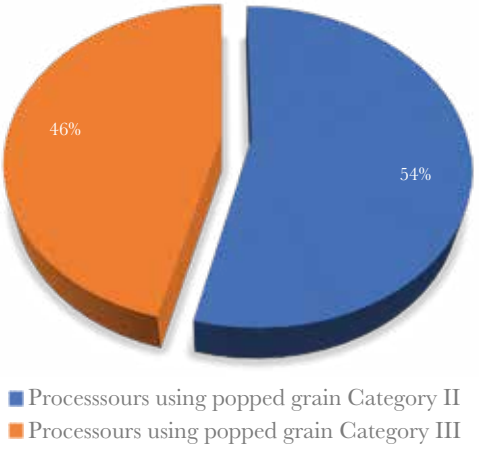

Figure 5. Classification of grain according to NMX-FF-116-SCFI-2010.

Although Mexican standards establish guidelines for the quality of amaranth, their non-mandatory nature and the lack of quinquennial reviews create gaps in regulation. The study reveals variations in the quality and safety of amaranth-based products, especially in the artisanal sector, highlighting the need for more robust regulation. Surveys and work

sessions indicate that 62% of the stakeholders involved in the value chain perceive low to moderate compliance with quality standards, indicating a lack of standardization in grain processing processes.

Commercialization

There are industries dedicated to large-scale marketing of processed amaranth such as Grupo San Miguel de Proyectos Agropecuarios, and Biogramin, among others. The Federal Government, through the National System for Integral Family Development (DIF) and Mexican Food Security (SEGALMEX), also provides another option for trade.

Identified issue: Small-scale marketing of amaranth represents one of the weakest points in the chain. Eighty percent of the production is controlled by intermediaries who unilaterally set prices, limiting market alternatives for small producers. In addition to this, there is a lack of policies regulating the traceability of products derived from amaranth, which fosters informal trade, especially in products like "alegría."

Uses and Forms of Consumption

Despite the various applications of amaranth, its traditional use is primarily focused on making 'alegría', a sweet treat combining popped grains with honey, sugar, or piloncillo, among other ingredients. According to fieldwork conducted, 74% of the producers process amaranth into flour, sweets, and dietary supplements, while baking; and the production of healthy foods are 22% (Figure 6).

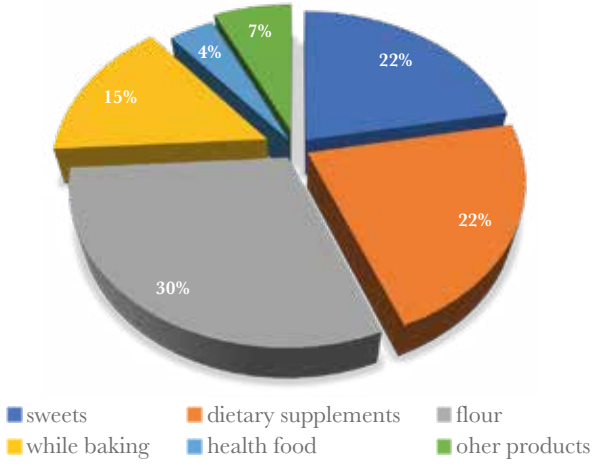

Figure 6. Types of products processed.

Table 4. Grains *per capita* consumption (kg) 2020-2023.

Year	2020	2021	2022	2023
Amaranth	0.043	0.043	0.047	0.044
Corn	335.800	331.900	346.400	335.200
Rice	9.000	10.100	9.100	10.100
Beans	7.700	9.000	11.000	7.600

SADER-SIAP (2023).

Amaranth can be transformed into various products, satisfying different consumer needs and tastes. From traditional sweets like "alegrías," "palanquetas," "obleas," and "mazapanes," to granola, whole grain flours, extruded foods (snacks), oils, baby porridge, dietary supplements, bread products (bread and cookies), tamale flours, and nutritional foods. According to fieldwork studies, processors agree that, in addition to traditional "alegrías," the most popular sweets in the market are simple or chocolate-combined bars, "palanquetas," and cookies. Therefore, their productive activity focuses on these products.

Amaranth ranks 32nd in the basic basket and is categorized as a "treat" rather than recognized as a food, grouping it with other products like peanuts (Secretaría de Agricultura y Desarrollo Rural [SADER], 2023). In Mexico, its consumption is relatively low, with official figures indicating an average of 44.25 grams per capita consumption during the period from 2020 to 2023 (Table 4).

In the same period, the average per capita consumption was 330 kilograms for corn, 9.5 kg for rice, and 8.8 kg for beans (SADER-SIAP, 2023).

There is an absence of a state policy promoting amaranth consumption as a food, despite its importance for marginalized rural communities or children with nutritional issues. According to Espitia *et al.* (2021), the limitations of low amaranth consumption depend on political will where its consumption has not been popularized. It is noteworthy that only 34% of the interviewed producers consume it, and of these only 1% of their production is used for consumption.

Consumer Characterization

Consumer Profile

According to the field study, consumers of amaranth range in age from 20 to 65 years old, with an equal distribution between men and women. 76.2% of amaranth consumers have a bachelor's degree level of education. In terms of occupation, 69% are employees, followed by students (14.3%) and homemakers (9.5%). Most consumers fall within an income range of 1 to 3 daily minimum wages.

Consumption habits

Consumption of amaranth varies among consumers. The majority (31%) consume it monthly or weekly (19%), while a smaller percentage (15%) consume it daily or annually. The main forms of consuming amaranth are through "alegrías" (a traditional sweet made with popped amaranth), cookies, and churros. However, it is also consumed in flour, baked goods, cereals, and dietary supplements, although to a lesser extent.

Regarding taste, 72.5% of consumers find it pleasant. However, a significant percentage is unaware of the nutritional value (45%) and properties of amaranth (55%). Despite this, it is believed that if consumers were informed about these attributes, they would be willing to consume or try amaranth more frequently. The willingness to purchase amaranth is high, as most consumers (50%) believe that if someone were to promote the qualities of amaranth, they would consider buying this product more often.

Challenges and opportunities

Education and research institutions

Within the value chain, various actors are involved at the same level such as input suppliers, education, and research institutions. In this regard, the crucial role played by research institutions such as INIFAP, COLPOS, and some universities stands out. These institutions not only conduct research but also provide advisory services to producers to help them adopt best practices in their crops. They have also developed improved varieties, with some seeds being cultivated by the producers. In the National Catalog of Plant Varieties of the National Seed Inspection and Certification Service (Snics, in Spanish), there are 14 registered varieties. However, there are still some varieties pending registration (it is estimated that there are 18 varieties in total).

Government support (since 2022)

There are government programs that provide support to amaranth producers, such as the "Production for Well-being Program", which provides economic support to small and medium-sized ejido producers. The Ministry of Welfare offers guidance for an agroecological transition to producers. Since 2023, the "Fertilizers for Well-being" program has been implemented, which provides direct support with fertilizers. However, some producers (21%) also receive guidance for an agroecological transition, which contradicts the policy of fertilizer supply.

Although there are various current government supports, there are no specific supports for amaranth producers nor technological packages adapted to each region. Field schools are places where knowledge and experiences on agroecological production techniques are exchanged. Additionally, the Technical Accompaniment Strategy (EAT in Spanish) implements productive activities aimed at transitioning to glyphosate-free and transgenic seed-free production.

Vertical relationships and linkages

In the supply chain of input providers, there are informal traders who sell their products without adding value to the chain. Agrochemical stores only supply fertilizers, insecticides, and herbicides without access issues, maintaining solely a commercial relationship. Research institutions play a crucial role in technology generation, although they duplicate efforts and do not collaborate effectively. Government institutions provide training and participate in the process, benefiting producers. Companies offering credit, financing, or agricultural insurance are scarce. Buyers determine prices and maintain purely commercial relationships, except for Company San Miguel, which has a serious social commitment and seeks to improve the quality of life of its members (Ayala *et al.*, 2017).

Horizontal linkages

A culture of associativity among producers has been identified, allowing them to enhance their negotiation skills and modify power relations. The producers have established informal links that provide them with productive benefits. At the industrial level, there are horizontal linkages mainly among large producers. In the states of Morelos, Tlaxcala, and

Mexico City, stakeholders are represented in a planning committee of the Product System. On the other hand, in Puebla, integration into the National Product System is sought. According to surveys, there is low member participation in decision-making and a low level of cooperation among stakeholders. Only 24% of producers are formally organized, while the rest are informally grouped or participate in producer groups. Organization is crucial for generating economies of scale and facilitating negotiations and power relations in the value chain. Lack of organization can limit value generation in the chain.

Critical support services

Financial services

There is a lack of financing and agricultural insurance for production processes from primary production to agribusiness. Such support is necessary to improve technology and infrastructure in the agribusiness sector. Only 11% of respondents have access to credit due to high capital costs.

Technical assistance services

Technical assistance is also limited. In 2022-2023, only 21% of producers had the opportunity to participate in field schools.

Quality management services

Few key stakeholders are aware of Mexican standards for amaranth, and they are generally not used or referenced for compliance by producers, collectors, and marketers. In contrast, 74% of processors are aware of the quality and safety requirements for raw materials and inputs, and 52% establish quality and safety criteria for their amaranth suppliers. However, this is not the case for artisanal agribusinesses.

Following the modifications introduced in the Mexican Official Standard NOM-051-SCFI/SSA1-2010 in 2020, processors noted a decrease in the commercialization of their products, particularly those with high levels of sugars, sodium, and fats. Prior to these regulations, products made from amaranth were often considered healthy, but the presence of warning labels led consumers to reconsider their purchases. While consumption of these products initially decreased upon implementation of the regulation, once adapted to these changes, consumption stabilized without further growth. These Mexican standards, which are not mandatory, are not updated or reviewed on a five-year basis.

There is evidence of low compliance with quality and safety standards for many amaranth-based products, especially those produced at the artisanal level, highlighting the need for regulation. Stakeholders in the chain are aware of the low to medium compliance with quality standards.

Commercial intelligence

Changes in state governments have reduced market opportunities for the industries. In previous years, contracts were established with government institutions. There is an absence of policies that regulate the traceability of products derived from amaranth. Another issue is trademark registration, which for many has been a process fraught with

obstacles that hinder completion due to lack of knowledge or interest. Additionally, there is a lack of marketing strategies.

Social relationships influence the discovery of new marketing networks, which have been proven to lead to export opportunities. It is proposed to generate specialized content distributed through commonly used communication channels such as blogs and social media. Collaborations between recognized brands for the development of quality products should be pursued. Adopting and promoting a cause such as fair trade and consumption of domestic products is recommended. The introduction of the product and its derivatives by producer organizations into commercial chains should also be considered.

All the above considerations are based on the premise that the marketing link is not regulated. There is limited commercial promotion of amaranth-derived products in international markets. According to Ayala *et al.* (2014), this link is one of the most vulnerable in the chain.

Logistics and storage

Regarding logistics and storage services, no actors were identified as providing these services, which remains the same situation as in 2014 (Ayala *et al.*, 2017).

CONCLUSIONES

Amaranth production in Mexico faces several challenges and opportunities. Despite growth in production and crop yield, driven mainly by an increase in cultivated area, there is a low adoption of technological innovations that could further improve productivity. The lack of continuous training and technical assistance limits yield growth. Moreover, there is a disconnect between producers, researchers, and the government, hindering access to necessary resources and knowledge. The Amaranth value chain exhibits unequal distribution of benefits, with smaller producers primarily selling on a local level and having limited access to processing and commercialization opportunities. Lack of financing, adequate technical assistance, and quality management services exacerbate the challenges. However, there are opportunities to improve commercialization, especially in the domestic market, through awareness campaigns about the nutritional benefits of amaranth and targeted marketing strategies. Associativity among producers and support from research institutions and the government are key to overcoming obstacles and strengthening the amaranth value chain in Mexico. A public policy is needed to address the lack of consumer culture, as not all of the population is familiar with amaranth. This policy should promote a culture of quality consumption, highlighting its nutritional properties and cultural identity as a food.

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