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Desarrollo de capacidades productivas para autoconsumo mediante agricultura protegida en comunidades rurales de Perote, Veracruz, México

Development of productive capacities for self-consumption through protected agriculture in rural communities of Perote, Veracruz, Mexico

Desenvolvimento de capacidades produtivas para autoconsumo por meio da agricultura protegida em comunidades rurais de Perote, Veracruz, México

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Resumen

La seguridad alimentaria como derecho humano está en riesgo en comunidades rurales de México con condiciones edafoclimáticas restrictivas como es el caso de la zona alta del municipio de Perote, Veracruz, a más de 3,000 metros sobre el nivel del mar (msnm), con clima semifrío semihúmedo. El cultivo más extendido por aspectos culturales y su resistencia climática es la papa, que es la base de su dieta a la que se integran tortillas, frijoles, chile y eventualmente carne. Con el objetivo de ofrecer alternativas productivas viables en la región, se implementó un proyecto financiado de agricultura protegida en túneles siguiendo metodologías participativas y un enfoque agroecológico para la producción de hortalizas. Se complementó con talleres experienciales para la adopción de prácticas agroecológicas como la elaboración de bioinsumos para mejorar el suelo, control de plagas y de enfermedades. Se instruyó sobre la importancia de emplear semillas criollas y se diseñaron talleres de cocina saludable para el rescate e innovación de recetas locales, incorporando a su dieta la producción lograda. Se establecieron 10 túneles atendidos por mujeres donde produjeron hortalizas para la alimentación suficiente, inocua, nutritiva y sostenida de sus familias con lo cual se impacta favorablemente a la comunidad. La evaluación participativa mostró que la agricultura protegida fue eficiente durante todo el año, aunque en invierno el número y rendimiento de los cultivos disminuyeron, no se detuvieron del todo.

Palabras clave: bioinsumos; hortalizas; mujeres; prácticas agroecológicas; túneles de cultivo.

Abstract

Food security as a human right is at risk in rural communities in Mexico with restrictive edaphoclimatic conditions, such as the highland area of the municipality of Perote, Veracruz, at over 3,000 meters above sea level, with a semi-cold, semi-humid climate. Due to cultural considerations and its climate resistance, the most widespread crop is the potato, which forms the basis of their diet, along with tortillas, beans, chili peppers, and occasionally meat. With the goal of offering viable productive alternatives in the region, a funded project of protected agriculture in growing tunnels was implemented using participatory methodologies and an agroecological approach to vegetable production. This was complemented by experiential workshops for the adoption of agroecological practices such as the production of bio-inputs to improve the soil, pest and disease control, and the use of heirloom seeds and healthy cooking workshops for the recovery and

innovation of local recipes, incorporating the resulting produce into their diet. Ten growing tunnels were established, managed by women, where they produce vegetables to sustain their families' food supplies, positively impacting the community. The participatory evaluation showed that protected agriculture was efficient throughout the year, although in winter the number and yield of crops decreased, they did not stop completely.

Keywords: bio-inputs; vegetables; women; agroecological practices; growing tunnels.

Resumo

A segurança alimentar como direito humano está em risco em comunidades rurais do México com condições climáticas e de solo restritivas, como as terras altas do município de Perote, Veracruz, localizadas a mais de 3.000 metros acima do nível do mar, com clima semi-frio e semi-úmido. A cultura mais difundida, devido a fatores culturais e à sua resiliência climática, é a batata, que constitui a base da dieta dessas comunidades, complementada por tortillas, feijão, pimenta e, ocasionalmente, carne. Para oferecer alternativas viáveis de produção na região, foi implementado um projeto financiado para agricultura protegida em estufas, seguindo metodologias participativas e uma abordagem agroecológica para a produção de hortaliças. Este projeto foi complementado por oficinas práticas para a adoção de práticas agroecológicas, como a produção de bioinsumos para melhorar o solo e controlar pragas e doenças. Os participantes foram instruídos sobre a importância do uso de sementes nativas e participaram de oficinas de culinária saudável para resgatar e inovar receitas locais, incorporando os produtos resultantes à sua alimentação. Dez estufas, cultivadas por mulheres, foram instaladas para a produção de hortaliças, garantindo alimento suficiente, seguro, nutritivo e sustentável para suas famílias e, consequentemente, impactando positivamente a comunidade. A avaliação participativa demonstrou que a agricultura protegida foi eficiente ao longo do ano, embora a quantidade e a produtividade das colheitas tenham diminuído no inverno; a produção não cessou completamente.

Palavras-chave: bioinsumos; hortaliças; mulheres; práticas agroecológicas; estufas de cultivo.

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Introduction

Climate change is a phenomenon that impacts all ecosystems, productive activities, and rural and urban communities. Recent examples include the various environmental events experienced in 2024, ranging from prolonged droughts and above-average temperatures in many parts of the world to diverse meteorological phenomena such as intense rainfall, cyclones, and hurricanes that caused flooding and severe damage (Boix-Cruz, 2021; Government of Mexico, 2024) . According to the forecast presented by Suastegui Cruz in 2021, the climatic trend of having the same precipitation as previous years but in shorter intervals was confirmed in 2024. This resulted in the leaching of soil nutrients in areas where they are unusable and longer periods of drought (Suastegui-Cruz, 2021).

In this scenario, there are sectors of the population that are more severely affected by the effects of this process, and one of them is the rural sector, since those who live in this sector depend on the climate to produce the food that we all consume and in the face of a disturbance they are unable to produce their own sustenance; unlike the population in the cities who, in this same situation, can access products from regions less affected by droughts or floods (State Network for Rural Development, 2020; Spanish Network for Sustainable Development, 2021) .

In 2009, Altieri and Nichols mentioned that climate change models predicted that the damage would be shared unequally by farmers in developing countries, especially those dependent on rainfall for production (Altieri and Nichols, 2009).

In recent years this prediction has materialized in many regions of Mexico and the world (Ahumada-Cervantes et al., 2020) ; as a response to this situation, the awareness work carried out in rural areas on the importance of protecting the natural environment allows the vulnerability perspective to be proactively assumed by farmers in various areas of Mexico, as is the case of inhabitants of the localities of Agua de los Pescados and El Conejo in the municipality of Perote, Veracruz, Mexico (Chamorro-Zárate et al., 2016; Narave-Flores et al., 2021) , where several projects have been developed on the importance of the preservation and/or restoration of the forests that predominate in the area, to consider them not only as a source of sustenance, but as areas of environmental importance.

The soil and climate conditions in these communities limits crop growth for most of the year. Only from March to July is there relatively sunny weather, but this coincides with the dry season. Therefore, the traditional open-field crop is potatoes, and to a lesser extent, forage crops such as barley or alfalfa. Given these climatic conditions, the population is forced to purchase almost all its food, whether fresh or processed.

Furthermore, the scarcity of economic resources limits their ability to purchase food to meet their nutritional needs, jeopardizing food security (Mundo-Rosas et al., 2023) and leading to what are known as *food deserts.* (Ramos-Truchero, 2015) because there is not enough fresh food in sufficient quantity and quality.

This article addresses the work carried out in these communities with the aim of strengthening capacities for food production in pursuit of food security and effectively addressing climate change, for which protected agriculture was used as a technical tool, an educational approach based on environmental education and participatory action research methods.

Materials and methods

The research was conducted using participatory action research methods to generate comprehensive solutions that duly considered the environment, people, and economy (Villasante, 2014) , ensuring they were appropriate to the context and perspective of the people involved, while also being adaptable to the conditions, interests, and vision of the target social groups. It was constructed using the experience narrative technique, which allows for the reconstruction of a given reality through reflective ethnographic dialogue, recovering anecdotal accounts and shared experiences of the people involved in a particular phenomenon or situation (Fontalvo-Buelvas et al., 2024). The process was configured following a systemic model in the following stages:

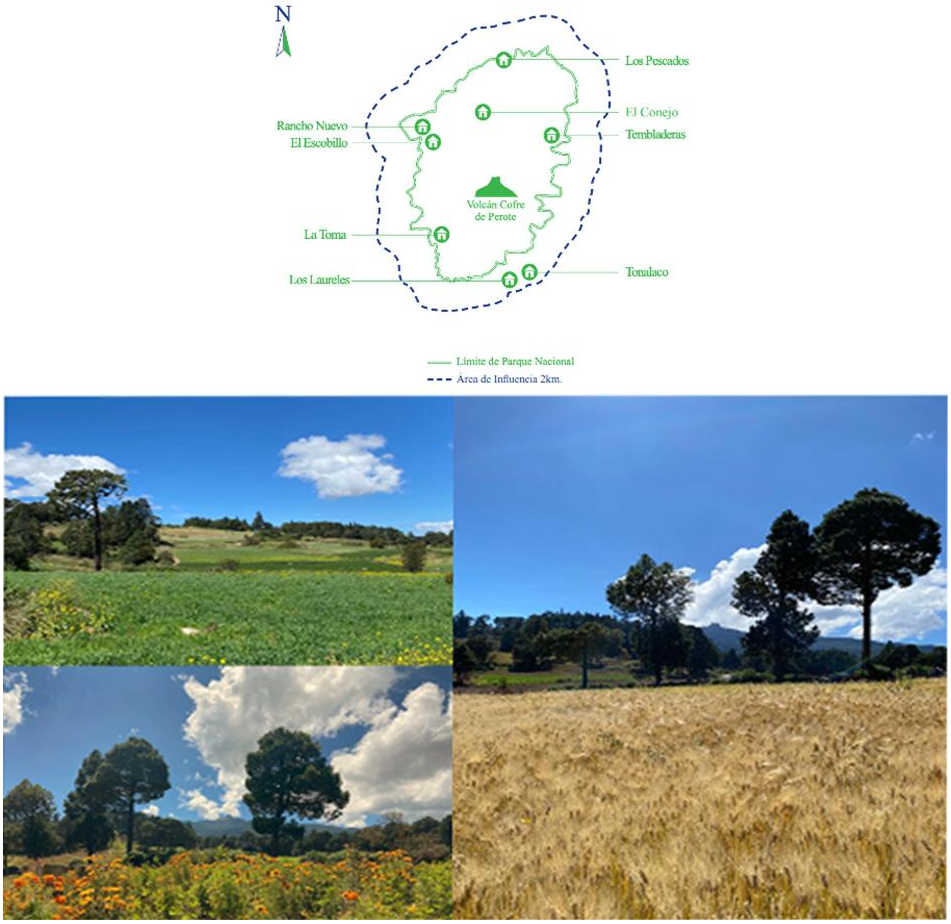
Context analysis

Since late 2023, the Academic Group for Research and Education for Sustainable Development (UV-362) of the Faculty of Biology at the Universidad Veracruzana, with funding from COVEICYDET, developed the project “Strengthening Capacities in the Face of Socio-Environmental Vulnerability and Climate Change in Agua de Los Pescados and El Conejo, Perote, Veracruz” (Project Code: 1111 1739/2023), which included the activity reported in this article. This group of academics has also carried out other projects for over a decade, and therefore has a formal track record of collaboration for community development work in the area.

Los Pescados and El Conejo, Perote, are two rural communities in the state of Veracruz, Mexico, located partially and entirely within the Cofre de Perote National Park, respectively, at an altitude of 3,000 meters above sea level, as shown in Figure 1. The communities have a semi-cold, sub-humid climate; the soil in the region is Andosol, and rainfall is 1,100 mm. The population, which is around 1,500 inhabitants per community,

experiences medium to high levels of poverty; their main economic activity is potato production *(Solanum tuberosum).*

Figure 1. Location of the rural communities of Los Pescados and El Conejo, municipality of Perote, Veracruz, Mexico.



Source: Narave -Flores and Chamorro-Zárate, 2012, *Let's get to know the Cofre de Perote National Park!, p. 50*

Socio-environmental diagnosis

A socio-environmental assessment was conducted with 10% of the families in both communities to gather information that would allow for the construction of a knowledge framework based on their opinions about their current situation in terms of infrastructure, services, education, employment, resources, and the environmental and social problems they face. Based on this assessment and the experience gained from previous projects, five family groups in each community were selected to participate, as they had the necessary space and willingness to engage in the required work.

Needs and resources analysis

The next stage of the process consisted of an analysis of food needs and preferences. Through open discussion, participation was encouraged to identify available local food resources and those acquired from external sources. In these areas, it is common for women to be responsible for acquiring and preparing food for their families, while husbands and older sons leave the community to work in other towns throughout the week and return on Saturdays and Sundays to tend to their own crops locally. Family units generally consist of five to seven people and include an elderly relative or have nephews or grandchildren in their care. Therefore, the production strategy focused on spaces that women could manage, with the support of children, in a consensual and informed manner.

Likewise, a diagnosis of the resources available to establish vegetable production systems through protected agriculture was carried out, with a focus on the materials available for the construction of tunnels, heirloom seeds and those necessary in the preparation of bio-inputs for plant nutrition and pest and disease control.

An important part was the discussion about their dietary preferences regarding vegetables to define the heirloom seeds to obtain and the appropriate sowing periods in each case.

Design

In this phase of the project, careful attention was paid to ensuring the active participation of women and collaborative decision-making regarding the size, location, and layout of the garden. They were the ones who decided what they could manage based on their available time. The basic design of the tunnel for vegetable production was developed collaboratively, adapting it to the specific needs of each family. It was decided to build the structure using local materials; the funded project provided resources for purchasing coverings and necessary tools such as hoses, shovels, hoes, gardening tools, watering cans, and more. The design included the creation of raised beds with walkways between them to facilitate access, as well as an agroecological model using intercropped species to prevent pests and diseases.

The design included soil analysis, substrate improvement, workshops on preparing bio-inputs such as biofertilizers and pesticides; in addition, for the first time in this type of project, healthy cooking workshops were incorporated to make the most of the projected vegetable production.

Implementation

The implementation phase involved organizing working groups, selecting locations for the tunnels, and establishing a schedule of activities from February to October 2024. This phase focused particularly on training and environmental education to help families recognize the importance of developing appropriate solutions to their food insecurity within their specific context. It also included the regular participation of project collaborators from the Universidad Veracruzana, including researchers and undergraduate biology students completing their community service requirement.

In this phase, each family built the tunnel structures using their own resources, assembled the covering, and prepared the planting beds. This activity was typically carried out by the men of the families. Some of the chosen vegetables were sown directly, while others were started in seedbeds. Throughout the entire process, necessary maintenance was performed, and the women of each participating family took part in this aspect. The university team was present, collaborating and guiding each phase.

Feedback

In any participatory process, feedback is essential to maintain horizontal and effective communication, so criteria were established to always maintain it, ensuring a dialogue of knowledge open to the knowledge and experiences of both the researchers and the community.

An important point in conducting participatory research is that work was done on forming a participatory action group (PAR), which must be people with a lot of motivation and ability to convene, open to collaboration so that at the end of the project, they could assume the role of community action managers in favor of strengthening local capacities (Martí, 2017).

Results

The process began in January 2024 with an initial outreach to authorities in both communities. In February 2024, the first meeting was held with those interested in participating, primarily homemakers. This meeting covered the advantages of the technique, the responsibilities of both parties, the work plan, the delivery of materials, and the workshop dates. Questions and concerns were addressed, and requests regarding specific aspects of tunnel management were received.

Socio-environmental diagnosis

The population of Agua de los Pescados is 1,694, with an average of 5.5 inhabitants per house, totaling 308 houses. El Conejo has a population of 1,230, with an average of 7.4 inhabitants per house, totaling 165 houses. Given the nature of the information to be collected, the sample of 10% of the families showed that the predominant occupations are agriculture (48%), followed by domestic work (39%), with 10% of the population being students and 3% engaged in commerce.

They have public services such as electricity, water, drainage, and roads, although the latter are not in good condition; they have schools from preschool through high school; they lack efficient health services, because they have a clinic, but it usually lacks medical personnel and medicines. They believe that problems with alcohol and drug addiction are becoming more frequent.

The environmental problems they face include climate change, with prolonged droughts and more extreme weather in both hot and cold seasons; they also perceive a decrease in soil quality due to the excessive use of agrochemicals, a reduction in forest areas, a decrease in wildlife, and are gradually beginning to observe a decrease in the amount of available water.

A particularly important problem is the inability to grow a variety of foods due to climatic conditions; as they indicated, they mainly grow potatoes, broad beans and some forage plants such as alfalfa, so they depend on acquiring the rest of their food from external sources.

At this point, it is important to compare this with the findings of Velasco-Torres and Cantellano-Rodríguez (2021) regarding the vulnerability of some rural areas in relation to their food security. The situation in the study area is like that reported by these authors in the Oaxaca region: residents depend on cultivating their own crops for food and selling surpluses to obtain what they don't grow. However, they face the constant worry that weather changes will prevent expected production, leaving them unable to support themselves. To overcome this situation, a family member must find employment outside the community to obtain a relatively secure income. In the Perote area, they work in concrete block factories or as wage earners in nearby cities, which provides them with some stability. However, in the medium term, this situation promotes the abandonment of rural areas, a significant problem facing the country.

It is noteworthy that in their discourse they assume responsibility for addressing and solving many of the problems they face, not delegating that responsibility solely to government entities. Although there is still a tendency to depend on government programs

to obtain benefits that allow them to meet their needs, their active and proactive role in generating solutions is evident.

Needs analysis

At the project's initial meeting, the advantages of protected agricultural production techniques were outlined; the responsibilities of both parties were defined, along with the work plan, the delivery of materials (Figure 2), and the dates for the workshops. Questions and concerns were addressed, and requests were received regarding specific training topics for tunnel management and the vegetable production process at each stage.

Figure 2. Working meeting with women for the delivery of materials, and tunnels installed in Los Pescados and El Conejo, Perote, Ver .

Source: Project archive.

Specifically, the proposal for vegetable production in tunnels was coordinated to meet the demand for healthy and sufficient plant-based foods for most of the year, as well as to integrate healthy cooking workshops to foster a sense of cultural ownership of their agricultural production. These tunnels have proven efficient in various locations with

climatic limitations (Adame-García et al., 2021, 2024; Murillo-Cuevas et al., 2020; Turcios-Herrera, 2022) , and even more so when complemented with agroecological practices such as the production and use of bio-inputs and organic amendments, crop rotation and intercropping, mulching, insect-repellent plants, etc. These production spaces were designed to be 5 m wide by 6 m deep and 2 m high, covered with greenhouse plastic and secured with wire embedded in tubing to prevent the wind from tearing them. They were located next to each of the five houses in each town, a total of 10 production units.

It was determined that the area had wood available for the construction of the planting tunnels, manure for the preparation of biofertilizers and compost, heirloom seeds adapted to the region, as well as suitable substrate for planting vegetables, water in sufficient quantity and quality, and the necessary labor.

The study also involved working with the women who took on the roles of caretaker for each tunnel, to determine the types of vegetables they typically consume and those they believe could be viable to grow in their tunnels. An open dialogue was fostered, building trust so they could express their genuine interests and avoid any bias in their opinions due to the researchers' involvement. They decided to cultivate vegetables such as chard, radish, carrot, zucchini, cilantro, beet, onion, garlic, lettuce, broccoli, and cabbage.

From a social perspective, it is noteworthy that the groups in each community actively participated in the project, assuming leadership roles with the support of the research team. This proved beneficial in achieving the project's objectives. However, it also presented a challenge with the rest of the community. Although the entire community was initially invited to participate, only a few families got involved, forming a core group of five families in each community. Furthermore, upon seeing the results of the construction and production, some people expressed dissatisfaction, feeling that the projects and their resources were not distributed equitably, but rather benefited only a select few.

This situation is commonly observed in projects of this nature due to the intrinsic dynamics of the communities, where groups form that assume a proactive stance and groups that react to relationships rather than processes; possibly this stems from the trend, driven for many years, of receiving government support without offering work or results, as reported by Medan (2014) where he analyzes how government programs are offered to different sectors without a commitment to fulfill the contract on which the support offered is based; moreover, when the beneficiary fails to comply with the contract, the

support continues to be offered unconditionally, which fosters the idea that it is not necessary to strive to meet the objectives of a project.

Implementation

Starting in March 2024, the five participants from each town were invited to choose the best location near their homes for the installation of a family tunnel, an activity carried out in conjunction with the training team. The work of preparing the site and constructing the tunnel was the responsibility of the family members. It is important to note that husbands and sons participated in the construction of the tunnels, while the women and their young children were responsible for managing the space. This was made possible thanks to the project's contribution of building materials, tools, and heirloom seeds from the region.

At this point, it is interesting to highlight the division of labor that naturally emerged at the beginning of the project. The men were assigned the heavier tasks of building the structure and assembling the beds, while the women took on the tasks of planting, watering, tending, harvesting, and cooking. According to Vivar Arenas (2020), men's work is traditionally given preferential status over women's, as it is considered crucial for successful production. However, through the work carried out in the project, specifically in the closing stages where vegetables were harvested and cooked, men showed a greater openness to the importance of the women's work and its impact on family nutrition and, of course, their finances. Obtaining fresh, healthy food for their own consumption and even for sale represented a significant benefit to their health and their economic well-being.

Figure 3 shows the tunnels installed in various phases, from the raising of the structure to the covering, the assembly of beds, and the covering to maintain the moisture of the substrate.

Figure 3. Installation of tunnels with local materials.

Source: Project Archive

During May and June, compost was made from available manure and plant waste, so the substrate preparation continued until the end of June. Meanwhile, the heirloom seeds that had been germinated grew and were ready for transplanting. Throughout these months, the technical support of the team was provided through workshops on the preparation of agricultural inputs, compost/vermicompost production, seedbed preparation, planting techniques, efficient use of irrigation water, and planting and harvesting cycles.

Efforts were made to empower the individuals responsible for each tunnel to assume a leadership role in their production processes, communicating their needs and development perspectives for each of their production spaces to the researchers. It was observed that those in charge of each tunnel proactively focused on producing their vegetables, which also allowed them to take conceptual and practical ownership of the spaces, processes, and tools used. This area, traditionally considered the domain of men (Vivar-Arenas, 2020) , began to be transformed through this process into a space for everyone, for the benefit of their families.

Once the workspaces were set up and the organic amendments prepared from local materials such as crop residues, kitchen scraps, and manure, the raised beds were prepared and arranged in the way the participating women considered most practical for their daily management. Seedlings of various vegetables were transplanted and watered to prevent dehydration during these early stages. The tunnels housed a variety of vegetables chosen for their consumption preferences, as well as herbs, as shown in Figure 4. The maintenance of the vegetable crops was carried out by the women responsible for each tunnel, with the support of their children, dedicating one to two hours daily to tasks such as watering, weeding, staking, hilling, and pest control using natural preparations.

Figure 4. Diversity of vegetable crops inside the tunnels managed by women in Los Pescados and El Conejo, Perote, Ver.

Source: Project archive.

During the planting-to-harvest phase, adverse weather conditions were not expected; however, the effects of the "La Niña" climate phenomenon that affected Mexico in 2024 caused a severe frost in the summer season (United Nations Office for Disaster Risk Reduction , 2024), which in turn caused damage to some of the vegetables in production that were planted at the limits of each tunnel and that are especially

susceptible, such as the case of zucchini that had problems adapting to the frost even with the protection of the tunnel, the farmers reported the perception of a loss of more than 40% in this vegetable.

These protected areas proved effective and productive in zones with extreme soil and climate conditions, such as the high, dry, and cold area of Cofre de Perote. In addition to providing healthy food for self-consumption (Cano-Contreras, 2015), they serve as spaces for learning and community building, acting as centers for daily learning and meeting points for women who gather to reinforce their existing knowledge and acquire new skills (Arcos-Severo et al., 2021). The incorporation of agroecological practices to replace agrochemicals proved successful, as the women understand the importance of healthy eating very well. Furthermore, these practices are easy to prepare, low-cost, efficient, easy to remember, and adaptable to the needs of each production tunnel. Moreover, the inputs are obtained locally or on the plot itself, thus avoiding the use of agrochemicals (Castellanos-Guzmán et al., 2024).

In September, October and November 2024, healthy cooking workshops were held in both communities, with the idea of promoting the appropriation of vegetables within their culinary culture and exploring the options that cultivated vegetables can provide for their daily diet.

As mentioned, potatoes are their staple crop because they are best suited to the region. However, many perceive their consumption as degrading, believing that only the poor eat them because they have no other means of sustenance. With this perspective, work was done to design alternative food dishes using potatoes and vegetables to promote a renewed appreciation for potatoes and their nutritional and culinary possibilities. Vegetables grown in the community garden were also incorporated, highlighting their nutritional value and versatility in the kitchen.

According to Wright, Maher, and Tanner (2015, as cited in Vásquez-Ruiz and Chávez-Arellano, 2023), the food that women provide for their families is not solely focused on its nutritional value, but rather a way of expressing meanings such as care, attention, and affection. Therefore, the aim is for the food to be enjoyable and well-received by those who consume it. For this reason, this project employed a collaborative and horizontal approach to understand what women like, how they value their food most, and how they prefer to consume it.

Recipes were designed to include the maximum number of vegetables and potatoes, incorporating the minimum of external resources to avoid the consumption of

processed or ultra-processed foods, thus maintaining a healthy and abundant diet to meet their nutritional needs, but also in accordance with their tastes and preferences.

The following recipes were prepared during the workshops:

- Pasta with vegetables
- Cabbage and onion tart with bacon
- Empanadas with chard filling
- Cabbage and carrot salad with sweet dressing
- Vegetable salad with tuna or cheese
- Cream of potato soup with bacon
- Roasted beetroot
- Mountain potatoes, which is a recipe created for the target group.

In addition, they were shown how to prepare bread on a griddle, mayonnaise, fresh pasta, and dough for wheat flour empanadas (Figure 5).

Figure 5. Healthy cooking workshops from the garden.

Source: Project archive.

In this part of the investigative process, observation, active listening, and the presentation of topics were used as basic tools to explore the properties of vegetables, their versatility, and their possibilities for complementing one's diet.

In both communities, the proposed recipes were very well received, as they helped broaden their range of options for feeding their families. Furthermore, they allowed participants to visualize ways to make the most of their harvested vegetables and develop their own creativity in creating other recipes using the same ingredients. Additionally, using potatoes in various dishes helped to diminish their negative perception of this food by redefining its potential in their diets. Some of the comments obtained after tasting the dishes prepared in the workshops are presented below with the participants' consent:

- *P1: "I didn't know you could eat not only the leaves but also the stems of chard, and that they tasted so good cooked that way."*
- *P2: "I used to not eat radish leaves because I thought they were spicy , but they taste really good in a salad."*
- *P3: "This potato soup is like restaurant food, it tastes really good, I like potatoes like this" (child's comment)*
- *P4: "Many people here don't want to eat potatoes because they say only poor people eat them, but with these recipes I can add them to food to have more options and make sure there's enough food for everyone, and they don't even realize they're eating potatoes."*
- *P5: "I didn't know it was so easy to make bread for lunch, it's so easy on the griddle, with that I have enough to make my expenses go further."*
- *P2: "Is it really that easy to make pasta for soup?"*
- *P5: "I like learning more recipes because that way I can make the most of the food I have for my children and my husband, and I take advantage of everything I harvest."*
- *P6: "When I started to see my vegetables grow I said, 'What am I going to do with so much chard and lettuce?' But now I've learned and I really liked the recipes."*
- *P7: "These kinds of workshops are good because sometimes you don't know what to do with vegetables and they aren't used to their full potential."*

The main purpose of these cooking workshops was to promote the intensive use of the resources provided by the garden. Previous experiences had involved growing vegetables, but the participants hadn't consumed them because they weren't used to eating

them, which diminished their nutritional value and discouraged them from growing vegetables and from participating in similar projects in general. For these reasons, holding cooking workshops in the garden was considered a good way to conclude the production and consumption cycle.

It is worth noting that not only did the women in charge of the gardens participate, but other women from the community, children, young people, and even some men actively participated, which generated a participatory environment and family and social integration.

An important point is that in these communities, as in those reported by Vázquez Ruiz and Chávez Arellano (2023) , women continue to fulfill the role of family caregiver and are responsible for food preparation and cultivation in small spaces. While men assume certain roles more involved in these processes and childcare, their participation is still considered "help" to women rather than their own responsibility. Through the project focused on tunnel cultivation and by interchanging traditionally assumed roles, greater consideration and respect for women's work was observed, along with greater involvement from men, especially when they were able to observe and enjoy the food produced and prepared entirely by the women.

Likewise, the management of the project allowed the natural formation of GAPs (participatory action groups) which ensure that the initiatives do not cease when the researchers' intervention ends, but rather the participants themselves become managers for the promotion of the project's initiatives in the short, medium and long term because there is already learning that helps them become active agents in generating solutions (Villasante, 2014) .

Discussion

As reported by Adame García et al. (2024) , this research showed that using protected agriculture in vegetable production is a viable alternative for families to have viable strategies to meet their food needs in rural contexts, favoring women to manage these spaces that are more manageable due to their size and the work involved; especially in this case, by using it in an area where the climate conditions are restrictive for several months of the year, vegetable production was achieved in the months where temperatures drop below 5º, which makes open-air production unfeasible.

However, a challenging condition is the reliance on inputs such as greenhouse plastic, which is frequently damaged by the strong winds that batter the region.

Furthermore, the protection offered by this infrastructure may not be sufficient to combat the low temperatures, causing vegetables to freeze. This exacerbates food shortages in both quality and quantity, and, as Ahumada et al. (2020) point out, this situation diminishes the capacity to cope with climate change. It is worth noting that, although low temperatures prevail in this area and are commonly managed, the climatic variations of recent years have caused unseasonal frosts, damaging vegetable production, as observed by the participants.

Promoting adequate nutrition is essential for people's health, as indicated by Mundo Rosas et al. (2023). The population most affected by food insecurity is that living in rural areas, as they lack sufficient variety and quality in their food (Urquía-Fernández, 2014). In this project, the target groups acquired a greater variety of healthy and fresh foods, which they were able to incorporate into their diets through healthy cooking workshops. The preparations were well-received, according to the participants' feedback, and it is hoped that what they learned will broaden their perspective on the possibilities and benefits of maintaining their own gardens. Previous vegetable production projects have been developed, but without adequately addressing the process of assimilating these foods into the diet, which has led to the abandonment of the gardens.

In this research, as reported by Castellanos Guzmán et al. (2024) , participatory action research (PAR) proved to be a relevant method for promoting the collaborative development of solutions related to the cultivation and use of the garden. This was due to the appropriation of cultivation techniques and methods, which strengthened knowledge about the application of agroecological techniques, such as the use of local resources to produce bio-inputs, thus avoiding the need to purchase synthetic products. These projects require financial and human resource investment, which can be covered, as in this case, through government funding and the active participation of academia.

Conclusions

Family gardens established using protected agriculture methods and managed agroecologically can produce fresh, healthy food for most of the year due to their semi-controlled internal conditions and the daily care provided by the participating women. Under these conditions, they can produce enough food for up to ten people, if planting is scheduled, the garden beds are fertilized using bio-inputs and organic amendments, and water is supplied and used efficiently. In winter, low external temperatures limit the production of certain crops; however, the incorporation of semi-mature compost can raise

the soil temperature (Jiménez et al., 2018) and promote the growth of crops such as chard, peas, onions, carrots, and broad beans, among others.

The development of this project continued throughout 2024, monitoring production activities, cooking workshops, and the evaluation of agricultural performance in terms of production volume. This also included outreach activities at fairs, in local schools, and participation in academic events.

This type of collective and community-based work project strengthens local capacities to produce healthy plant-based foods and fosters environmental awareness in communities, enabling them to share the benefits of actions like those reported in the research within their communities. Coordinated work between government, educational institutions, local authorities, and communities is essential to achieving significant progress for low-income rural families, helping them meet their basic food needs and exercise their right to consume safe and nutritious food, thereby strengthening food security.

Similarly, the project served to strengthen the communities socially by improving the bonds between participants and their collaborative networks through the GAP (Group Action Plans). This will allow the training they received to help them generate solutions to the problems they face as a community. It is essential to work on sharing knowledge and encouraging those who initially declined to participate, offering them a clear and tangible vision of the benefits achieved, to interest them in becoming involved in productive projects of this nature. This is projected to improve food security throughout the community.

Future lines of research

The results of the action research, combined with the openness and willingness of the people in the communities with whom we worked, opened the possibility of further strengthening the bond between the University and the communities. This is a key element for implementing future research on the processes of assimilating and appropriating theoretical and practical knowledge useful in their environment and conditions. Projects of this nature help these communities proactively address the effects of climate change, improving their ability to meet their food needs, and strengthening their role in conserving the ecosystem they inhabit, which significantly impacts life in that region and in nearby communities and cities. Action research is the methodology that can help document experiences, identify patterns, and simultaneously build viable food

production models for regions with similar conditions, thus contributing to food sovereignty in Mexico.

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