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ESTABLISHMENT OF A FAMILY PRODUCTION UNIT OF *Pleurotus* spp. IN A RURAL COMMUNITY OF OAXACA, MEXICO

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ABSTRACT

Family Production Units (FPUs) are a strategy in low-cost food production for the rural population, as a system of associativity that allows the involvement of its members. The study's objective was to establish a mushroom (*Pleurotus* spp.) FPU in the community of San Juan Yatzona, Oaxaca, as an alternative to contribute to food security. The participative action research methodology was followed for the integration, organization, and construction of the FPU. *Pleurotus pulmonarius* and *P. ostreatus* were grown in wheat straw (S) and straw with corn stubble (SS 1:1) under rustic conditions. The productivity was evaluated, the cost analysis of the project, and social evaluation through the logical framework methodology were carried out. The FPU was established on a surface of 56 m^2, subdivided into zones to carry out the total process. The highest productivity of *P. pulmonarius* was found in wheat straw, while for *P. ostreatus,* it was in straw with corn stubble 1:1, with a biological efficiency of 72.52% and 47.46%, respectively. In general, the most productive species was *P. pulmonarius*, statistically different from *P. ostreatus*, while there were no significant differences between the substrates. The total investment cost for this FPU was $11,156 MX, regarded as affordable for the members involved. The training and development of abilities in women from the community for mushroom production allowed the establishment of the FPU as an alternative to contribute to food security.

Keywords: food security, mushrooms, self-management, socio-productive project, solidarity.

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INTRODUCTION

Fungi have become a food with high demand in the market due to their sensorial characteristics and nutritional value, especially mushrooms which have a high content of amino acids and vitamin C, are low fat, among others, and are important in the daily intake for human beings (Barros *et al.,* 2008). Technological advancements have made mushroom production possible, which globally represents around 85% of the following species: *Lentinula edodes* (22%), *Pleurotus* (19%), *Auricularia* (18%), *Agaricus bisporus* (15%), and *Flammulina* (11%) (Royse and Sánchez, 2017).

The cultivation and consumption of *Pleurotus* spp. in Mexico began in the 1970s. Since then, interest in its propagation has increased (Gaitán-Hernández, 2007). Traditional techniques have been adapted and changed to reduce the production cost of mushrooms, through the evaluation of various agricultural residues for their cultivation (Gaitán-Hernández *et al.*, 2006). In 2019, Mexico produced 31'212,167.5 tons of corn (white and yellow), and 702,054.9 tons of wheat, which generated lignocellulosic residues that can be used (Instituto Nacional de Estadística y Geografía-INEGI, 2019) for their incorporation in the circular economy and to reduce the environmental challenge of their waste (Pilafidis *et al*., 2022).

Therefore, mushroom cultivation represents an alternative for the use of these residues. On the other hand, Family Production Units (FPUs) are a strategy for low-cost food production for the rural population (Ramírez-García *et al*., 2015), as a system of associativity that allows the involvement of its members.

In particular, San Juan Yatzona, Oaxaca, is a community with tradition and culture in the consumption of wild mushrooms, and occasionally, they consume those cultivated commercially by external suppliers. However, the amount of mushrooms collected has decreased in recent years, according to local people, which makes it necessary to offer alternatives for the production and consumption of cultivated species. The study had the objective of establishing a mushroom (*Pleurotus* spp.) family production unit (FPU) as an alternative to contribute to the food security of that community.

THEORETICAL FRAMEWORK

Food security intends, at all time, to have physical, social, and economic access to sufficient, innocuous and nutritional foods; it is composed of four dimensions: availability of foods, access, consumption, and stability (Organización de las Naciones Unidas para la Alimentación y la Agricultura-FAO, 2018). However, different factors impact food security negatively, particularly in rural communities, which are affected by an increase in prices of basic foods, low income, higher presence of processed foods, loss of some wild foods, and a decrease in farmland activities due to lack of investment, counseling, among others (Lemos *et al*., 2018).

Changes in temperature and rainfall, together with a greater impact of droughts, floods, and heat, affect agricultural productivity by reducing soil moisture, increasing evaporation, and creating conditions for pests to accelerate infestations. Therefore, it is important to prioritize family agriculture, through the development of projects that foster the availability and access to sufficient, innocuous, and nutritional foods, with the strengthening of rural and commercial production.

The availability of foods depends on production systems, which is why techniques to obtain foods sustainably must be sought, through the promotion of family agriculture, inclusion of small-scale producers in local markets, tax measures on highly processed foods, and regulation and control of food elaboration, among others (FAO, 2018).

In addition, food production should be sustainable, since it stands for responsible consumption and also the rational use of resources, production that prevents contamination and environmental impact, promotion of environmental education, as well as the disposition of an equitable proportion between the population and its practices (Carta de Principios de la Economía Solidaria, 2011). This production system can be implemented through social organizations, made up of people from communities in free and voluntary associations, aware of the production of goods and service provision and self-realization of the members (Orrego and Arboleda, 2006).

Family production units (FPUs) are within this type of organization since they are part of the voluntary associations aimed at pursuing a benefit for the family, which can extend to a social benefit. A FPU is an organization where members come together to implement socio-productive projects, to provide sustenance to a family, thus achieving a satisfactory standard of living, in addition to providing work to its members and developing a technique that can be useful in its region (Ramírez-García *et al.,* 2015).

The proposal is to promote the cultivation of edible mushrooms, due to their various advantages for production, nutritional value, and commercialization (Martínez-Carrera *et al.*, 2000). The *Pleurotus* mushroom is known commercially as "seta" (wild mushroom) and it has two main commercial species in Mexico, *Pleurotus ostreatus* (Jacq.: Fr) Kumm. and *P. pulmonarius* (Fr.) Quél. These fungi can degrade cellulose and lignin, which are found in straws and stubbles, and also agro-industrial wastes, such as bagasse from sugarcane, tequila maguey, coffee pulp, and forestry. All these substrates are available in rural communities, so using them for cultivation is affordable (Gaitán-Hernández *et al.*, 2006) and, with this, they are incorporated into the circular economy and the environmental challenge from their waste decreases (Pilafidis *et al.*, 2022). It is important to highlight that, for mushroom production, the initial investment is low since it is an alternative activity to the family economy (Gaitán-Hernández, 2007).

In this study, mechanisms for the integration and training of women in an indigenous community were established, to form a family production unit for edible mushrooms production, to contribute to the food security of the community of San Juan Yatzona, in the Sierra Norte of Oaxaca, Mexico. It is assumed that this FPU will function as a social alternative for economically viable food production.

METHODOLOGY

The project was conducted in the community of San Juan Yatzona, Oaxaca, Mexico, located at 1,300 masl (Figure 1). The climate is cold-humid, with temperatures that vary from 11 to 31 °C. Agricultural activities are based on the production of corn, bean, and coffee, and the community has a situation of high marginalization (Plan municipal de San Juan Yatzona, 2014).

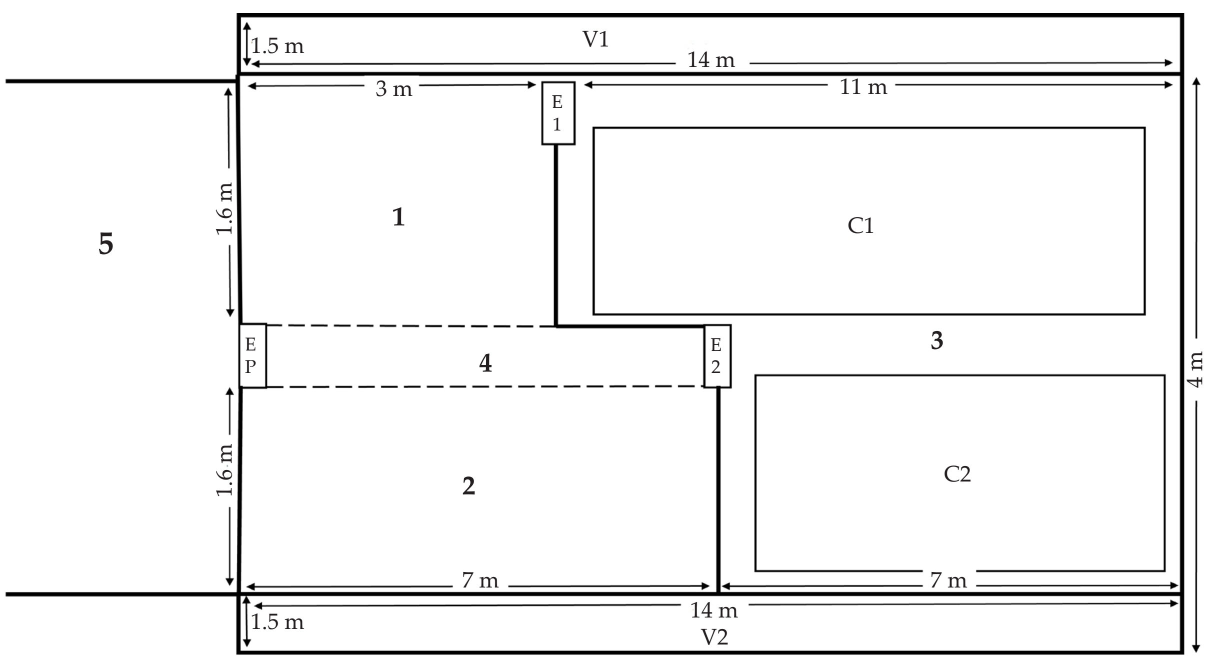
Integration of the FPU

The integration was carried out through the participative development tool by Geilfus (2002), with women from the community interested in mushroom production, who participated in the formulation (action plan matrix), training (development of abilities and workshops regarding mushroom production), production and evaluation of the project; this implied the iterative participation of teaching-learning processes.

Source: https://www.cerebriti.com/juegos-de-geografia/estados-de-la-republica-mexicana, https://www.pinterest.com.mx/pin/861313497461581613/ y http://oaxaca.orgfree.com/regionsierranorte.html) [9-10].
Figure 1. Location of San Juan Yatzona.

Establishment of the FPU

It was established in a space of 56 m^2, with a cement floor, galvanized metal sheet roof, windows covered with sacks and fabrics, to prevent light entry, and anti-aphid mesh to avoid pest entry. The place was divided into five spaces: input warehouse (1), sowing (2), incubation and fructification (3), hallway (4), and exterior area for substrate treatment (5) (Figure 2).



1: warehouse; 2: sowing; 3: incubation and production; 4: hallway; 5: exterior area for substrate treatment, C1 and C2: beds for bag placement.
Source: prepared by the authors.
Figure 2. Floorplan of mushroom family production unit (FPU).

Preparation of the substrate and sowing

For the cultivation of *Pleurotus*, the methodology described by Gaitán-Hernández *et al*. (2006) was followed. The substrates used for the cultivation were corn stubble (obtained in the community) and wheat straw (acquired from a commercial supplier), fragmented to a particle size of approximately 5 cm, which were deposited in burlap sacks, thermally treated by water immersion at 65 °C for 60 min. The inoculum of *P. pulmonarius* (IE-115) was donated by the Instituto de Ecología (INECOL, Xalapa, Mexico), and of *P. ostreatus* it was obtained from a commercial supplier. Two treatments were used: wheat straw (S) and straw with corn stubble in 1:1 proportion (SS 1:1). For each treatment, 4 kg (b.h.) of substrate were placed in new polyethylene bags and sown with 5% of inoculum from each of the variants. The bags were closed and labeled and 12 perforations were made with a disinfected sharp knife, and then the bags were transported to the incubation area.

Incubation and production

The incubation was carried out with a cycle of 12 hours of light and dark, at an average room temperature of 21 °C, and the production conditions were at an average temperature of 23 °C with the same light and dark conditions mentioned before. The mushrooms were harvested manually in their adult stage when the pileus was compact, turgid, and non-flaccid.

Productivity

To evaluate productivity, the following were considered: biological efficiency (BE), production rate (PR), yield (Y), and number of harvests (Gaitán-Hernández *et al.* (2006).

Experimental design

The experimental design was completely random with four treatments (2 substrates and 2 strains), with seven repetitions. ANOVA was applied to the values obtained, and the differences between the means of the samples were analyzed through Tukey's HDS test ($p<0.05$).

Cost analysis for the establishment of the FPU

The materials used to outfit the production area were considered (mesh, fabric and plastic); and the purchase of inputs to implement the FPU (work table, digital scale, thermometer, digital hygrometer, containers, hygiene and sanitizing materials, inoculum and substrates).

Socioeconomic evaluation of the intervention

From the economic point of view, a study was made by determining the production costs and the utility margin per kilogram of fresh mushroom harvested, taking as a basis the production of 25 bags, with 4 kg of moist substrate. For the calculation of the production cost, inputs such as firewood and corn stubble were not contemplated, due to the availability in the community; the workforce was also not included, since it was offset by members of the FPU. To calculate the net real utility, all the inputs were considered and the direct and indirect labor too. The social evaluation was carried out through a matrix of Geilfus (2002) indicators, adapted to the principles of solidary economy such as participation in training workshops, cooperation, trust, teamwork, and sense of belonging to the group, through a questionnaire applied to the members.

RESULTS

Participation and outfitting of the FPU

The group was made up of four women from the community, who assisted and participated in the action plan to achieve the establishment of the FPU, which involved: training, cleaning the place, arrangement of fabric on windows, division of spaces, construction, arrangement of beds for the bags, and purchase of materials and inputs for the production of mushrooms (Figure 3).

Wild mushroom production in the FPU

The mean temperature recorded in the FPU in the months of November-January, from incubation to fructification, was 18-24 °C and relative humidity of 73-94%, based on the appearance of the primordia; irrigation was applied to the bags daily to keep the moisture high. For both species, the incubation period was 19 days and the production period was 21 days. *P. pulmonarius* in SS 1:1 had a lower production than the one recorded in wheat straw (Figure 4). For its part, *P. ostreatus* attained higher production in SS 1:1 than in S. In SS both strains achieved three harvests and in S only two.

Source: prepared by the authors.
Figure 3. Family production unit (FPU) outfitted in the community. A: sowing area and B: incubation and fructification area.

Source: prepared by authors.
Figure 4. Harvest of basidiomes of *Pleurotus pulmonarius* in substrate of straw with corn stubble (SS 1:1) in the family production unit installed.

Productivity

The biological efficiency (BE) was significantly affected by the strain (F=50.52, p=0.0000), but not by the substrate (F=0.0101, p=0.9212), although it was by its interactions (F=13.222, p=0.0022). Table 1 shows that the BE of *P. pulmonarius* in SS 1:1 was lower than in S and significantly different between these substrates ($p<0.05$), while *P. ostreatus* also showed significant differences between the substrates tested, although with higher production in SS 1:1.

In general, a higher BE was observed in *P. pulmonarius* than in *P. ostreatus*, although there were no significant differences between substrates, regardless of the species cultivated

Table 1. Biological efficiency (BE%) obtained for Pleurotus in each of the substrates evaluated.

Species	Substrate		Means
	S	SS 1:1	
Pleorotus pulmonarius	$72.52±12.76^d$	$59.53±5.52^c$	$66.03±11.52^b$
P.ostreatus	$35.17±4.19^a$	$47.46±5.52^b$	$41.32±7.96^a$
Means	$53.85±21.62^a$	$53.50±8.22^a$	-----

Source: prepared by the authors.

(Table 1). Therefore, both substrates can be an option for *Pleurotus* production under the conditions evaluated.

The results are expressed as means ± standard deviation of the measurements taken by species and by substrate. The different letters in the superindex in the same column or line indicate significant difference ($p \leq 0.05$, Tukey HDS). S: wheat straw, SS: straw with corn stubble, BE: biological efficiency.

The species evaluated in the FPU showed an average BE of 66.03% for *P. pulmonarius* and 41.32% for *P. ostreatus*, so it is considered a profitable crop for the first of them.

When it comes to the production rate (PR), it was significantly affected by the strain (F=50.52, p=0.0000), but not by the substrate (F=0.0101, p=0.9212) although it was by its interactions (F=13.22, p=0.0022). The study shows that *P. pulmonarius* reached values of 1.65 ± 0.28 which was significantly higher than what was achieved by *P. ostreatus* (Table 2). Regarding the substrate, no significant difference was found between them, which indicates that both substrates favor the growth and fructification of *Pleurotus* similarly.

The results are expressed as means ± standard deviation of the measurements taken by species and by substrate. The different letters in the superindex in the same column or line indicate significant difference ($p \leq 0.05$, Tukey HDS). S: wheat straw, SS: straw with corn stubble, PR: production rate.

Table 3 shows the yield (Y) obtained for both species in the substrates evaluated. The Y differed significantly from the effect of the strain (F=50.41, p=0.0000), but not from the substrate (F=0.0086, p=0.9271), and it did from its interactions (F=13.25, p=0.0022). In general, the yield was 16.50% ±2.88 in *P. pulmonarius,* significantly different from *P. ostreatus,* where R of 10.33% ±1.99 was found; similar to other variables, it did not present a significant difference in the R of the substrates.

The results are expressed as means ± standard deviation of the measurements taken by species and by substrate. The different letters in the superindex in the same column or line indicate significant difference (Tukey HDS). S: wheat straw, SS: straw with corn stubble, Y: yield.

As presented in Tables 1, 2, and 3, the values of BE, PR and Y, in the substrates evaluated, did not show significant differences, which indicates that both substrates favored the growth and fructification of *Pleurotus*.

Table 2. Production rate (%) of *Pleurotus* in the substrates evaluated.

Species	Substrate		Means
	S	SS 1:1	
Pleurotus pulmonarius	1.81 ± 0.31^{d}	1.48 ± 0.13^{c}	1.65 ± 0.28^{b}
P.ostreatus	0.87 ± 0.10^{a}	1.86 ± 0.13^{b}	1.03 ± 0.19^{a}
Means	1.34 ± 0.54^{a}	1.33 ± 0.20^{a}	----

Source: prepared by the authors.

Table 3. Yield (%) obtained by *Pleurotus* in wheat straw and mixture of straw with stubble.

Species	Substrate		Means
	S	SS 1:1	
Pleurotus pulmonarius	18.13 ± 3.19[d]	14.88 ± 1.38[c]	16.5 ± 2.88[b]
P.ostreatus	8.79 ± 1.04[a]	11.87 ± 1.38[b]	10.33 ± 1.99[a]
Means	13.46 ± 5.4[a]	13.38 ± 2.05[a]	-----

Source: prepared by the authors.

Costs

In this study, it was determined that the cost of outfitting the area of the FPU was $5,952.00, and $5,204.01 was required for its operation; that is, a total investment of $11,156.01. It should be highlighted that part of the materials used were compensated by the project's recipients, and this allowed the initial investment costs to be reduced. This FPU represents a food source for subsistence and extra income from a nutritional and healthy product sale, which benefits those involved in the project, their families, and the community.

Estimation of the production costs

The production cost of 24 bags with 4 kg of humid substrate each which yielded 22 kg of fresh mushrooms, was $1,670.00 MX pesos (Table 4). With this cost and the current price for the sale of one kg of mushrooms in the regional market of Sierra Norte de Oaxaca, a sale price was determined for mushrooms produced in the FPU of $140.00 MX pesos per kg, which represented a profit margin of 46.03% per kg. This profit is high since payment for labor is not considered in the process, for it was an activity carried out by those involved without any payment. Based on this, the profit per kilogram of

Table 4. Production cost and determination of the sale price per kg of mushroom produced.

Materials	Amount	Cost ($)
Wheat straw	24 kg	1,275.00
Seed of *P.ostreatus*	4 kg	320.00
Sowing seed (40×60cm)	25 pieces	75.00
Total		$1,670.00
Unit cost (kg)		$75.91
Sale price		$140.00
Total sales		$3,080.00
Gross profit		$1,417.84
Gross profit margin		46.03%

Source: prepared by the authors.

mushrooms sold was $64.00 MX pesos. Considering a production projection of 80 kg of fresh mushrooms in two months, and a half and under the conditions of the FPU, contemplating total inputs and direct and indirect expenditures on labor, a profit margin of 16.97% is obtained.

Social evaluation

The results from the questionnaire applied showed that the members of the FPU developed abilities and skills from the training received and participation in the production of mushrooms in the unit.

On the other hand, the activities developed for the construction of the FPU fostered teamwork, cooperation, trust, and a sense of belonging, in addition to the responsibilities involved in belonging to a social organization.

DISCUSSION

The results obtained in this study show that production of mushrooms under rustic conditions, such as climatological conditions, yield, productivity, and social integration, was reached during the intervention period in the community. This is because values of temperature and relative moisture found in the community were similar to those reported by Gaitán-Hernández and Silva (2016) for the production of *Pleurotus* spp., who recorded incubation temperatures of 15 to 20 °C and relative humidity of 72 to 81%. For the same mushroom, Jaramillo and Albertó (2019) and Salmones *et al.* (2020) cited incubation temperatures of 25±1 °C and 26±3 °C and relative humidity of 80 to 90%, although under controlled conditions.

The incubation periods were found within the interval, compared to those reported by Gaitán-Hernández and Silva (2016), with an incubation of 22 days for *P. pulmonarius* and 25 days for *P. ostreatus*, cultivated under rustic conditions in a mixture of corn and oats straw, in the region of Cofre de Perote, Veracruz; the authors obtained three harvests, in a period of 45 to 65 days.

The BE values obtained in the FPU were lower than those reported by Gaitán-Hernández and Silva (2016), who attained a BE of 110.8% for *P. pulmonarius* grown in corn stubble. These authors cultivated *P. ostreatus* in the same substrate, where they obtained a BE of 103.9%, with cultivation conditions that were also rustic.

Cruz-Montes *et al.* (2018), Valencia *et al*. (2018), Portilla *et al.* (2019), and Morán *et al.* (2020), have described higher BE than those in this study; nevertheless, in controlled conditions of moisture, temperature, light, and air circulation. The BE reported by the authors cited before, has ranged from 64.68% to 136.20%, with *P. ostreatus* cultivated in corn stubble and 85% to 141.29%, cultivated in wheat straw.

According to what was suggested by Ríos *et al.* (2010), a BE higher than 50% can be considered acceptable, although it should be mentioned that other factors intervene to achieve the profitability of a product. The difference in the productivity of both species can be due to a better adaptation of *P. pulmonarius* to the environmental conditions, of substrate and rustic cultivation.

Gaitán-Hernández and Silva (2016) reported these same cultivated species in corn stubble presented similar values of PR, 1.4 and 1.3 for *P. pulmonarius* and *P. ostreatus,* respectively. Meanwhile, Cruz-Montes *et al.* (2018) and Morán *et al.* (2020) reported PR values higher than 2.0 in *P. ostreatus* cultivated in corn stubble and wheat straw, under controlled conditions.

The yield values obtained in this study were lower than those reported by Gaitán-Hernández and Silva (2016), since for *P. pulmonarius* they obtained a Y of 23.3% and for *P. ostreatus* a Y of 21.8%, species cultivated in corn stubble under rustic conditions in the region of Cofre de Perote, Veracruz. The values cited, in contrast to those obtained in this study, are because of the substrates used, the environmental conditions, and in general, the different production processes in each of the trials.

Regarding the substrates, it is reported that their mixture helps to develop the primordia and that the formation of adult mushrooms is favored in up to 95% in substrates rich in protein (Amuneke *et al.*, 2011; Romero-Arenas *et al.*, 2018). For the substrates used in this study, wheat straw and corn stubble, values of protein content of 3.34% and 4.9%, respectively, have been reported (Romero-Arenas *et al.,* 2018). However, these values of protein can vary according to the origin of the substrate, due to factors such as variety, degree of maturity, management, soil fertility, and time of sowing, among others, which influence the general development of the plants and therefore the nutrient content (Romero *et al.,* 2010).

According to the results of social evaluation, the family production of mushrooms, as reported by Borunda *et al.* (2021), is an activity that represents an alternative to contribute to family sustenance, due to the roles already established by society and the household, which allow them to explore their potentialities and to put into practice their knowledge. In this production unit, the principles of solidarity were characteristic of a social organization, since as mentioned by Orrego *et al.* (2006), the essence of these organizations is directed toward the social base and have the aim of actions that imply improving community life, social integration and local development. Based on the results, it can be said that the members assumed a responsibility in common. In addition, they are aware that mushrooms cover a need for food for subsistence, as well as for the community; therefore, the FPU means having an alternative for development in the region for their productive viability.

Valdespino (2020) indicated that this production not only involves the producer and the consumer but also strengthens the production chain since it is food with nutritional sources and economic resources for vulnerable zones. When they know wild mushroom production, confidence is generated in the community to acquire them and consume them, contributing to food security in the region. The members of the FPU understand that fungi contribute benefits to health, that mushrooms are natural products, of good flavor, and nutritional, and accepted in the community for their consumption.

CONCLUSIONS

Despite the rustic conditions of production and the environmental parameters that prevailed in the FPU of San Juan Yatzona, the generation of food that contributes to food security in the community was achieved. The substrates evaluated favored the fructification of *Pleurotus*. The use of corn stubble stood out since it was obtained from the main primary activity in the community. This represents an alternative to recycling agricultural waste, in an alternative productive process.

This study contributes to strengthening the capacities of women in the community, through training, both in Spanish and in their native language. This develops skills to produce cultivated edible mushrooms and decreases the dependency on wild seasonal species. During the production process of mushrooms, principles of the solidary economy were promoted, which allowed the success of a family production unit; this suggests an alternative socioeconomic activity to increase the availability of mushrooms for subsistence and sale.

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