Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 16 February 2024
DOI 10.3389/fsufs.2024.1329532

Check for updates

OPEN ACCESS

EDITED BY
Fernando Casanoves,
Centro Agronomico Tropical De Investigacion Y Ensenanza Catie, Costa Rica

REVIEWED BY
Héctor Eduardo Hernández Núñez,
University of the Amazon, Colombia
Alondra Flores,
University of Guadalajara, Mexico

*CORRESPONDENCE
José Espinoza-Pérez
✉ jep.espinozajose@gmail.com

RECEIVED 29 October 2023
ACCEPTED 05 February 2024
PUBLISHED 16 February 2024

CITATION
Espinoza-Pérez J, Cortina-Villar S, Perales H, Méndez-Flores OG and Soto-Pinto L (2024) Edible plants as a complement to the diet of peasant farmers: a case study of the Totonacapan region of Puebla, Mexico. *Front. Sustain. Food Syst.* 8:1329532. doi: 10.3389/fsufs.2024.1329532

Edible plants as a complement to the diet of peasant farmers: a case study of the Totonacapan region of Puebla, Mexico

José Espinoza-Pérez[1]*, Sergio Cortina-Villar[1], Hugo Perales[1], Orquidia G. Méndez-Flores[2] and Lorena Soto-Pinto[1]

[1]El Colegio de la Frontera Sur (ECOSUR), Carretera Panamericana y Periférico Sur S.N., San Cristóbal de las Casas, Mexico, [2]Universidad Juárez Autónoma de Tabasco (UJAT), Col. Tamulte de las Barrancas, Villahermosa, Tabasco, Mexico

Peasant societies have traditionally produced food for themselves and for the market based on a diversity of plants that they grow and cultivate in their agroecosystems; however, these societies are modifying their agriculture, their consumption, the structure and composition of their plots and abandoning the consumption of these species, which are gradually ceasing to be part of their diets. This research aimed to analyze the contribution of local crop diversity to the peasant diet of the Totonacapan region of Puebla, Mexico. During 2020, 270 dietary surveys were applied, and in 2022, the richness of edible species in 146 peasant plots was recorded and 69 semi-structured interviews were conducted to document ethnobotanical information on edible species. A total of 102 edible species were identified in the plots; 65 are native and 37 are introduced. The milpas and the family garden are the main areas where food for self-consumption is grown: corn, beans, and some grean leaves (*quelites*). Meanwhile, coffee plantations and horticultural areas mainly contain food for sale; coffee, fat pepper, bananas, oranges, and chili peppers stand out. Half of the plants inventoried (53%) were not recorded in the diet surveys. Absent foods were fruit trees, roots and tubers, spices, *quelites*, and local vegetables. On the other hand, most of the 48 species recorded in the plots and the dietary surveys had a very low frequency of consumption. The limited consumption of this group of species is largely because they are no longer suitable for consumption, are difficult to cook, or require much time for collection and preparation. The reason villagers conserve these plants may be because they are emergency foods. After all, they consume them eventually or in times of scarcity, hence the importance of keeping them in the plots. Even though a great wealth of edible plants is grown in the campesino plots, it does not mean they have a relevant presence in the diets.

KEYWORDS

agrodiversity, farmer plots, self-consumption, Totonacs, traditional food

Introduction

Small-scale and peasant agriculture can contribute to an improvement in the nutrition of the population in underdeveloped countries, characterized by high agricultural diversity with the potential to solve malnutrition problems (Frison et al., 2006; Lachat et al., 2018). In some regions, such as in several African countries, it is well recognized that agrodiversity, including wild and cultivated plants, is indispensable for achieving food security and food sovereignty in indigenous smallholder communities (Hassen, 2021; Koukou et al., 2022). Access to agrodiverse foods can have a positive impact on the nutritional quality of the population's diet: the inclusion of fruits, flowers, leaves, stems and tubers (among others) of diverse species facilitates the acquisition of micronutrients, such as vitamins, minerals and essential oils, quality macronutrients (unrefined carbohydrates, containing dietary fiber and water) in addition to facilitating a functional diet (Aragaw et al., 2021) by increasing the consumption of foods containing elements that are known to possess preventive or regulatory properties against various illnesses (Grivetti and Ogle, 2000). Despite this importance, there is little knowledge of the consumption of these plant species whose diverse natural wealth and autochthonous knowledge are safeguarded by a plethora of rural and indigenous communities.

Many ethnobotanical studies discuss the richness of edible species in rural and peasant farming regions, but few study the frequency of their consumption. In Mexico, the cultural, economic, and ecological importance of approximately 2,168 edible plant species found predominantly in indigenous and rural areas has been documented (Mapes and Basurto, 2016); however, there are no records regarding their use (Neupane et al., 2022). Therefore, there is a need for more studies that evaluate the extent to which local agrobiodiversity on smallholdings complements peasant diets, given that a high richness of edible species on farm plots does not necessarily imply that they are being consumed frequently (Soto-Pinto et al., 2022). Many wild or fostered edible plant species are generally considered as emergency food sources, consumed in times of scarcity or when there is a chronic shortage of staple foods such as maize (Mapes and Basurto, 2016; Rivera-Núñez et al., 2022); however, their consumption when staple foods (mainly cereals) are sufficient is not known. Furthermore, several studies report that in some rural regions, the consumption of fruits and vegetables is limited as the vast majority are sold to supplement household income; therefore, they are no longer an integral component of household self-subsistence (Miller et al., 2016; Mehraban and Ickowitz, 2021). In the case of *quelites* (edible wild herbs or greens), many species are reported (Bye and Linares, 2000); however, only 50% form part of the diet of peasant families (Basurto-Peña, 2011).

Knowledge of the extent to which local agricultural diversity is exploited and what limits its use among communities, particularly native peoples, would enable us to provide guidelines and focus efforts on promoting edible plants, as many people and institutions propose. The prevailing idea at the international and national level is that plants that are underutilized should be promoted to improve the nutrition of the world population (Knez et al., 2023); however, there is a lack of data that would assist us in the decision-making process regarding the form and process such promotion would take and on which food groups efforts should be concentrated. This concept occurs within the recent context of dietary changes as a result of increased rural–urban migration, urbanization, the widespread incorporation of industrialized foods into the diets of a large part of the population, changing tastes of new generations, and the increased perception that local foods are consumed only by poor families (Kuhnlein and Receveur, 1996; Duguma, 2020; Soto-Pinto et al., 2022).

This study provides data on the frequency of consumption of locally produced foods in the diets of an indigenous group that knows the consumption of such plants, both currently and historically (Basurto-Peña et al., 1998; García-Vazquez et al., 2022). The research was conducted in the Totonacapan region, situated in the northeastern part of the state of Puebla. The area is inhabited by the Totonac people, who speak one of the 68 native languages of Mexico [INALI (Instituto Nacional de Lenguas Indígenas), 2010] and descend from an ancient Mesoamerican people (González-Bonilla, 1942). Before colonization, the Totonaca population based their diet on the use of a great diversity of plants. Many of them were also important in ceremonies, rituals, and traditional medicine, and some had their domestication center in Totonacapan, which is the emblematic case of vanilla (Bruman, 1948; Kelly and Palerm, 1952). Several ethnobotanical studies have reported that the Totonacs recognize about 200 species of edible plants (Martínez-Alfaro et al., 1995, 2007; Basurto-Peña et al., 1998, 2003), including herbs, greens, seeds, fruits, vegetables, tubers, and roots. However, although many edible plants are grown on the plots, families rely more on the market to feed themselves (Espinoza-Pérez et al., 2023). As the region is predominantly mountainous, the agricultural landscape of the Totonacapan region consists of steep slopes (>30%) and valleys. It is characterized by a mosaic of agricultural areas and *acahuales* (fallow land colonized by secondary vegetation). Agricultural areas are recognized according to the preeminence of certain crops: maize, coffee, beans, chili, and sugarcane. Against this background, this study aims to analyze the use of the diversity of edible plants that are found on smallholder farms and as an integral part of the peasant farmer diet, grounded on the following research question: To what extent is the richness of edible plants consumed by farming families who know their use and the floristic resource in their region?

Materials and methods

Study background

Based on 270 surveys carried out in 2020, a study was published on the diet of peasant farmers in the poblano Totonacapan region in which it was reported that the diet of these families included around 159 food items, comprising 104 edible plants, of which 63 originated from the family plots, and 41 were purchased externally. As mentioned, we only worked with peasant families and did not include families that were dedicated to other activities, for example, livestock farmers or had other occupations such as carpenters, construction workers, and chauffeurs. All the families interviewed follow a Mesoamerican diet; that is, they continue to consume corn, beans, chili pepper, *quelites*, *chayotes* (*Sechium edule*), squash, and other local vegetables. Differences in diets between families were reported, with some consuming more self-subsistence foods and others relying more on the market. According to the statistical tests performed in the previous study, factors such as income and environment did not influence food availability. From the previously mentioned research, four dietary profiles were identified and grouped according to the frequency of consumption and the origin of the food (A, B, C, and D) (Espinoza-Pérez et al., 2023). Households in groups A and D consumed more frequently self-produced and locally produced foods (corn, beans, chili pepper, local vegetables) were named regional food groups. In addition, families in group D included complementary foods such as *quelites* and other additional species of beans in their diet. In the field, we observed that these families spend more time cultivating their plots and place greater value on the consumption of local plants and crops. In contrast, the regional transition food group (groups B and C) consumed more externally sourced foods, including corn, beans, chili peppers, and other vegetables. The difference between the two groups was that the families in group C consumed tortillas from *tortillerías* (tortilla shops) and no longer homemade tortillas, as in group B, although with purchased corn. Because of this situation, these families had low consumption of local food, which includes own-produced food and food produced at the local or community level (Espinoza-Pérez et al., 2023).

Records of edible species

From the 270 surveys mentioned above, two families were randomly selected from each dietary profile in nine localities distributed over seven municipalities within the Poblano Totonacapan region (Table 1), giving us a total of 69 families. In each selected household, we produced an inventory of the richness of edible species in each agroecosystem (milpa, coffee plantation, home garden, horticulture, and *acahual*). These agroecosystems are different in structure and floristic composition and differ in management. A total of 146 plots were sampled: 63 milpas (cornfields), 47 coffee plantations, 27 home gardens, seven horticulture plots, and two sites that were *acahual* (fallow land). In Mexico, we call milpa the traditional agricultural system made up of a polyculture, its main species is corn, accompanied by various species of beans, pumpkins, chili peppers, tomatoes, and many other edible plants. The surface area devoted to cultivation was recorded in each plot. The "walk in the agroecosystems" technique (Phillips and Gentry, 1993), which consists of walking throughout the plots with the owner and recording herbs, vines, shrubs, and trees, was used. To ensure that most of the edible plants were recorded, the visits were conducted during the period between sowing and harvest. For example, the milpa agroecosystem was surveyed between January and June while the horticultural areas from May to July and from September to October, corresponding to the growing periods; the remaining agroecosystems (coffee plantation, home garden, *acahual*) were visited throughout the year as there is no specific period when these are managed and cultivated.

TABLE 1 Number of families surveyed and type of climate for each locality.

Municipality	Locality	NF	Climate
Atlequizayan	Ignacio Allende	8	A(f)
Zapotitlán de Méndez	Tuxtla	8	A(f)
	Nanacatlán	8	A(f)
Olintla	Vicente Guerrero	8	A(f)
	Dimas López	8	A(f)
Jonotla	Ecatlán	8	A(f)
Camocuautla	Tapayula	7	(A)C(fm)
Amixtlán	Cuautotola	8	(A)C(fm)
Huehuetla	Ozeloanacaxtla	6	(A)C(fm)

A(f): warm wet climate; (A)C (fm): warm subhumid climate; NF: number of families in each locality that participated in the study.

For each edible plant identified, the name in Totonac and Spanish was recorded, as well as parts of the plant used, management, and destination of the edible products (self-consumption, sale, or both) (Soto-Pinto et al., 2022). In addition, the reasons for occasional consumption or abandonment of plant consumption in the diet were explored through semi-structured interviews with the participating families who owned the inventoried plots. Information on the origin and life cycle of the plants was reviewed in the literature. Each plant was recorded in a database and classified into cereals, herbs and leafy greens, fruits, vegetables, legumes, roots and tubers, spices, beverages, and seeds (Kennedy et al., 2013; Figure 1).

Data analysis

A database was generated in Excel 2013® and then transferred to the statistical program SPSS 21.0 to determine the frequency of species for each household, origin, food group, management type, and agroecosystem. The relative frequency of each plant species was also calculated for each household. From the diet surveys applied in 2020, the consumption frequency per week (F) of the plants recorded in the plots was calculated using the following formula:

$$F = \left(Q^{*}S\right) / E.$$

where F = consumption frequency per week.
Q = total consumption frequency reported by food or component.
S = number of days consumed per week.
E = number of survey days.

Finally, a Kruskal–Wallis test was performed on the edible species richness data to identify possible significant differences in the use and consumption of edible plants between food profiles and by agroecosystem, using the SPSS 21.0 statistical program.

Results

Richness and distribution of edible plant species

At the regional level, 102 edible species were identified of which 65 were native species and 37 introduced species, belonging to nine food groups. According to the level of human intervention, 57 species were cultivated, 31 enhanced, and 13 collected. These plants are distributed in five agroecosystems (milpa coffee plantations, home gardens, horticultural areas, and *acahuales*) that provide food for peasant households (Table 2). The coffee plantations contained 71 edible plants, home gardens 66, milpa 57, horticulture plots 13, and *acahuales* 8. The food groups with the highest number of species were fruit trees (32), herbs and leafy greens (26), and local vegetables (20) (Table 3). Agroecosystems are different in their composition and floristic structure. In milpas and horticulture it is common to observe an association of herbaceous plants, some shrub species, and very few tree species. On the contrary, a tree stratum predominates in coffee plantations and *acahuales*. On the other hand, the home garden is a space where all types of plants are associated, from

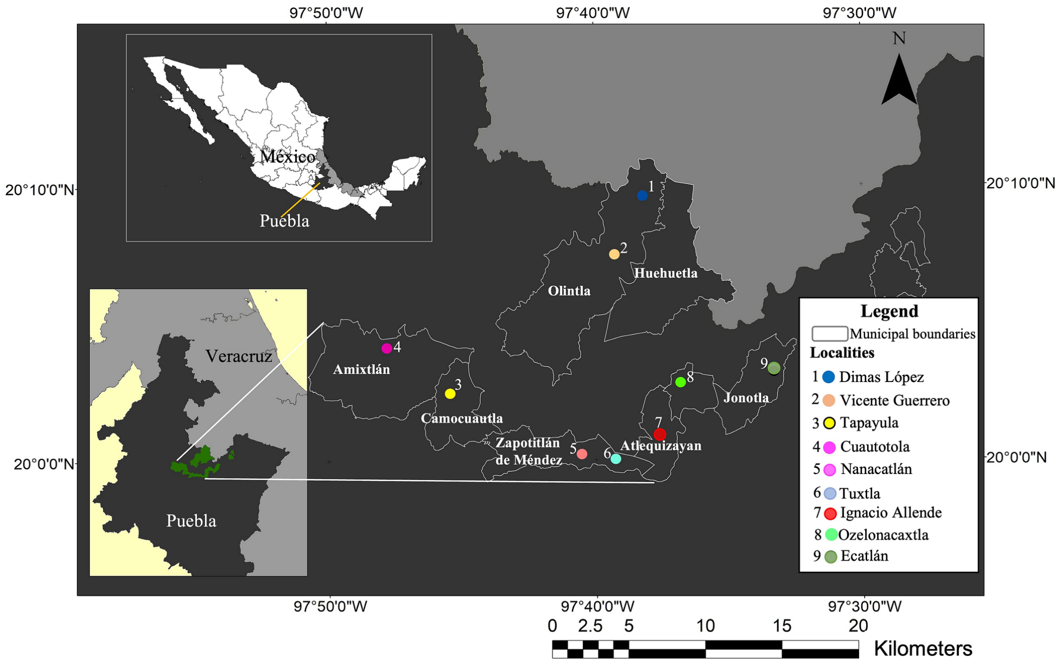

FIGURE 1
Geographical location and distribution of study sites in the Totonacapan region of Puebla, Mexico.

herbaceous, shrub and tree species, and it is a space managed mainly by women.

Edible species by food group and agroecosystem

Edible species richness data showed differences between families, food profiles, and agroecosystems. A mean of 13.8 ± 7.05 edible species per family was recorded at the regional level. Families in profile groups A and D (16.05 ± 6.01; 19.29 ± 9.22) presented a significantly higher richness of edible plants than those in groups B and C (9.81 ± 2.68; 10.16 ± 3.46). Homegardens and coffee plantations presented a higher mean plant richness (8.25 ± 4.95; 7.7 ± 5.7) than the other agroecosystems. This high richness is because both agroecosystems are cultivated most of the year. On the other hand, milpa and horticulture are cultivated seasonally, and the richness of plants that can be found varies from year to year. *Acahual* is a partially abandoned system, only edible plants are harvested, and it does not receive intensive management like the other agroecosystems. As can be observed, almost all families cultivated milpa (63 families out of a total of 69), and the majority cultivated coffee (47 families out of 69). Slightly less than half of the families possessed an orchard (27 out of 69), and a small number possessed a horticultural area or *acahual* (Table 4).

Consumption of edible species present in the farm plots

Of 102 edible species recorded, 37 were used exclusively for self-consumption, 52 for self-consumption and sale, and 13 for sale only. In addition, 54 species were not recorded in the diet surveys, while 48 were recorded. According to those interviewed, of the 54 species absent from the diet survey, 28 are used for self-consumption, 17 for self-consumption and sale, and a few are exclusively for sale (9 species). The majority were fruit species (25 species), 11 species of leafy greens, eight species of local vegetables, and four species belonging to the tubers and roots group. Most of the species were cultivated and encouraged, 25 and 20 species, respectively, (Table 5).

Regarding the edible plant species recorded in the dietary surveys and farm plots, in addition to the staple food crop maize and six species of beans, there were seven species of fruits, 11 species of vegetables, and 17 species of *quelites*. Of these, 33 were cultivated, 11 encouraged. As for their destination, 35 species were used for self-consumption and four were exclusively for sale: coffee, allspice, bananas, and oranges (Table 5). Coffee and allspice are agricultural products that are marketed outside the region. At the same time, bananas and oranges are sold in the same communities.

The distribution of edible plants recorded in dietary surveys differs greatly from those not recorded. Most plants recorded in the diet survey were more abundant than unrecorded species in the corresponding farm plots; however, some unrecorded species, such as *chalahuite*, *mamey sapote*, *capulin*, peach, mango, and *tequelite*, were common in the plots. Of the plants recorded in the diet survey, 40 out of 48 species were present in more than five plots, and only three species were found in two or fewer plots (Figure 2B); in contrast, unrecorded species presented a very low frequency in the plots, with only six out of 54 species present in five or more plots and a large number found in only two or less (Figure 2A). The most frequent crops recorded in the plots were maize and coffee, followed by bananas, oranges, *majayan* beans, *chayote*, chili, *huaxi*, allspice, *xkijit* (*Renealmia alpinia*), and some *quelites* such as elephant ear and citrus

TABLE 2 List of edible species present in the plots of peasant families in the Totonacapan region of Puebla.

Food group	Scientific name	Common name		Relative frequency (%)	Consumption frequency (Times per week)	Life cycle	Origin	Part of plant used	Agroecosystem	Management
	Species	Spanish name	Totonac							
Beverages	*Coffea arabica* L.	Café	Kapen	6.2	7	2	2	5	1,2	1
	Coffea canephora L.	Café de árbol	Kapen	0.1	0	2	2	5	2	1
	Cymbopogon citratus (DC) Stapf.	Zacate limón	Sekget'kapen	0.2	0.5	3	2	3	3	1
Cereal	*Zea mays* L.	Maíz	Kuxi	6.6	12	2	1	5	1	1
Spices	*Pimenta dioica* (L.) Merr.	Pimienta gorda	Ukum	2.8	0.5	1	1	5,3	2,3	1
	Sesamum indicum L.	Ajonjolí	Talhtsinkiw	0.1	0.5	3	2	6	4	1
	Vanilla planifolia (Jacks.)	Vainilla	Sumixanat	0.2	0	3	1	5,7	2	1
	Vanilla insignis Ames	Vainilla	Sumixanat	0.2	0	3	1	5	2	1
	Vanilla pompona Schiede.	Vainilla	Sumixanat	0.2	0	3	1	5,7	2	1
Fruit	*Ananas comosus* (L.) Merr.	Piña	Akaxka´	0.1	0	3	2	5	3	1
	Annona cherimola Mill.	Chirimoya	Akchitkiwi'	0.3	0	1	2	5	2	1
	Annona muricata L.	Guanábana	ND	0.1	0	1	1	5	2	1
	Artocarpus heterophyllus Lam.	Yaca	ND	0.1	0	1	2	5	2,3	1
	Carica papaya L.	Papaya	Papaya	0.6	0.5	2	1	5	2,3	1
	Citrus ×latifolia (Yu. Tanaka) Tanaka	Limón persa	Xukut	0.1	0	2	2	5	2	1
	Citrus ×sinensis (L.) Osbeck	Naranja	Laxux	4.2	0.5	1	2	5	2,3	1
	Citrullus lanatus (Thunb.) Matsum. & Nakai	Sandía melón	ND	0.1	0	3	2	5	2	1
	Citrus x aurantifolia (Christm.) Swingle	Lima	Tsikit'lima	0.1	0	1	2	5	3	1
	Citrus reticulata Blanco	Mandarina	Mandarina	1.7	0.5	1	2	5	2,3	1
	Citrus ×limon (L.) Burm. f.	Limón	Limón	1.0	0.5	1	2	5	1,2	1
	Conostegia xalapensis (Bonpl.) D. Don ex DC.	Capulin	Mujut	1.3	0	2	1	5	1,5	2
	Couepia polyandra (Kunth) Rose	Olopillo	Pija	0.1	0	1	1	5	3,5	3
	Diospyros nigra (J. F. Gmel.) Perr.	Zapote negro	Suwalh	0.5	0	1	1	5	1,2	2
	Inga vera Willd.	Chalahuite	Kalama	2.8	0	1	1	5	2	2
	Licania platypus Hemsl.	Zapote cabello	Akgchixitjaka'	0.5	0	1	1	5	2,5	3
	Litchi chinensis Sonn.	Lichi	Lichi	0.2	0	1	2	5	2	1
	Macadamia spp.	Macadamia	Macadamia	0.3	0	2	2	5	2	1
	Mangifera indica L.	Mango	SD	1.1	0	1	2	5	2,5	2
	Musa spp.	Plátano	Seekgna'	6.4	0.5	2	2	5	1,2,3	1

(Continued)

10.3389/fsufs.2024.1329532

TABLE 2 (Continued)

Food group	Scientific name: Species	Common name: Spanish name	Common name: Totonac	Relative frequency (%)	Consumption frequency (Times per week)	Life cycle	Origin	Part of plant used	Agroecosystem	Management
	Parathesis psychotrioides L.	Capulin	Akgtalaawat	0.4	0	2	1	5	1,5	2
	Parmentiera aculeata (Kunth).	Chote	Puxni	0.1	0	1	1	5	3	2
	Passiflora edulis Sims	Maracuya	Maracuya	0.1	0	3	2	5	2,3	1
	Pouteria sapota (Jacq.) H. E. Moore & Stearn	Zapote mamey	Jaka	2.2	0	1	1	5	3,5	3
	Prunus persica (L.) Batsch	Durazno	Tarazno	1.4	0	1	2	5	1,3	1
	Psidium guajava L.	Guayaba	Asiwit	1.3	0.5	1	1	5	2, 3	1
	Punica granatum L.	Granada	SD	0.1	0	1	2	5	3	1
	Saccharum officinarum L.	Caña	Chankat	1.3	0.5	2	2	2	1,2,3,6	1
	Selenicerius sp.	Pitahaya	Chach	0.3	0	3	1	5	2,3,5	3
	Spondias mombin L.	Jobo	Xiipa	0.1	0	1	1	5	2,5	3
	Syzygium jambos (L.) Alston	Pomarosa	Pumarrosa	0.1	0	1	2	5	2,5	2
	Theobroma cacao L.	Cacao	Cacao	0.1	0	1	1	5	2	1
Leguminous plants	*Arachis hypogaea* L.	Cacahuate	Cacawatl	0.4	0	3	2	1	4	1
	Cajanus cajan (L.) Huth	Frijol de árbol	Kiwi'stapu	0.1	0	3	2	5	1	2
	Leucaena leucocephala L.	Huaxi	Lilekg	2.9	0.2	1	1	5,6	1,2,3	1
	Phaseolus coccineus L.	Frijol ayocote	Tlanka'stapu	0.5	0.2	3	1	5,6	1,3	1
	Phaseolus dumosus Macfad.	Frijol xoyoma	Xuymit	0.8	0.2	3	1	5,6	1,3	1
	Vicia faba L.	Haba	Aux	0.6	0.2	3	2	5,6	1	1
	Vigna unguiculata L.	Frijol torito	Lukut'stapu	1.3	0.2	3	2	5,6	1,3	1
	Phaseolus vulgaris L.	Frijol enredadera	Majayan	3.8	1	3	1	5,6	1,3,4	1
Quelites/ herbs and leafy greens	*Amaranthus hybridus* L.	Quintonil blanco	Kgalhtunit	0.1	0.12	3	1	3	3,4	1
	Amaranthus hypochondriacus L.	Quintonil rojo	Kgalhtunit	1.8	0.12	3	1	3	3, 4	1
	Arthrostemma ciliatum Pav. ex D. Don	Agrio cuadrado	Xalhtakaka'xkutna'	0.2	0.12	3	1	3	1,2,3,5	3
	Allium neapolitanum Cirillo	Cebollina	Kgatsasna	2.1	0.12	3	2	3	1,3	1
	Begonia heracleifolia Cham.	Agrio rayada	Xalpilili'xuktna'	2.1	0.12	3	1	2	1,2,3,5	3
	Begonia nelumbiifolia Cham. Et	Agrio	Sturonkgot	0.9	0.12	3	1	2,3	1,2,3,5	3
	Cyclanthera langaei Cong.	Cincoquelites	Tatsilum/Akgawa'	2.1	0.12	3	1	3	1,2,3	2
	Cyclanthera ribiflora (Schltdl.) Cogn.	Quelite torito	Xkulum	0.6	0.12	3	1	3	1,2,3	2
	Coriandrum sativum L.	Cilantro	Kulanto	1.0	0.12	3	2	3	4	1

(Continued)

10.3389/fsufs.2024.1329532

TABLE 2 (Continued)

Food group	Scientific name	Common name		Relative frequency (%)	Consumption frequency (Times per week)	Life cycle	Origin	Part of plant used	Agroecosystem	Management
	Species	Spanish name	Totonac							
	Erythrina caribaea Krukoff & Barneby	Gásparo	Lalhni'	1.1	0.12	1	1	3,4	1,2,3,5	2
	Ipomoea dumosa (Benth.) L. O. Williams	Manto blanco	Siiyu'	0.1	0.12	3	1	3	2,3	2
	Mentha spicata L.	Hierba buena	Kuxlalhkgejna'	0.5	0.12	3	2	3	3	1
	Porophyllum ruderale (Jacq.) Cass	Papaloquelite	Puksnankak	1.0	0.12	3	1	3	3,4	1
	Rumex crispus L.	Lengua de vaca	Skgota	0.7	0.12	3	2	3	3	2
	Solanum americanum Mill.	Hierba mora	Mustulut	3.7	0.12	3	1	3	1,2,3,4	2
	Xanthosoma robustum Schott	Barabarón	Pa'xnikak	2.2	0.12	3	1	3	1,2,5	2
	Yucca aloifolia L.	Equizote	Akalukut	1.3	0.12	2	1	4	5	3
	Begonia incarnata Link & Otto	Ala de ángel	Xuktna'	0.1	0	3	1	2	3	3
	Begonia thiemei C. DC.	Agrio extranjero	Extranjero	0.1	0	3	1	2,3	1,2,3,5	3
	Cnidoscolus multilobus (Pax) I. M. Johnston	Mala mujer	Kgajni	0.2	0	2	1	4,6	5	3
	Eryngium foetidum L.	Cilantro extranjero	Lhtukuni'kulanto	0.1	0	3	1	3	2,3	2
	Dysphania ambrosioides (L.) Mosyakin & Clemants	Epazote	Lhkgejna	0.3	0	3	1	3	3	1
	Jaltomata procumbens (Cav.) J. L. Gentry	Quelite cimarrona	ND	0.1	0	3	1	3	3	3
	Peperomia maculosa (L.) Hook.	Tequelite	Kuksasan	0.6	0	3	1	3	1,2,3	1
	Peperomia peltilimba C.DC.	Tequelite chiquito	Laktsu kuksasan	0.2	0	3	1	3	2,3	1
	Physalis gracilis (Miers)	Tomatillo	Chapululh	0.1	0	3	1	3	1,2,3	2
	Smilax laurifolia L.	Cozol	Kgentsililh	0.3	0	3	1	2	2,4	3
	Tinantia erecta (Jacq.) Schltdl.	Pata de gallo	Kitxtak	0.3	0	3	1	3	2,3	2
Seeds	*Jatropha curcas* L.	Piñon	Chuu'ta	0.8	0.5	2	1	6	2,3	1
Tubers/ Roots	*Dioscorea alata* L.	Ñame	Tlitlee'kglh	0.1	0	3	1	1	2,3,5	2
	Dioscorea bulbifera L.	Papa voladora	Pabs	0.4	0	3	1	1	1,2	3
	Ipomoea batatas (L.) Lam.	Camote	Manta	0.1	0	3	1	1	1,2,3	2
	Manihot esculenta Crantz	Yuca	Koxkgew	0.4	0	2	2	1	2,3	1
	Xanthosoma sagittifolium (L.) Schott	Mafafa	Pisis	0.2	0.5	3	1	1	1,2	2

(Continued)

10.3389/fsufs.2024.1329532

TABLE 2 (Continued)

Food group	Scientific name	Common name		Relative frequency (%)	Consumption frequency (Times per week)	Life cycle	Origin	Part of plant used	Agroecosystem	Management
	Species	Spanish name	Totonac							
Local vegetables	*Allium cepa* L.	Cebolla morada	ND	0.1	0	3	2	1	4	1
	Beilschmiedia anay (S.F.Blake)	Anaya	Aniya	0.1	0	1	1	5	2,5	3
	Brassica oleracea var. *capitata* for. Alba subv. Conica	Col de hoja	Kulx	0.1	0	3	2	3	4	1
	Capsicum annuum spp.	Chile de árbol, serrano, bolita	Stilampin	3.1	1.5	3	1	5,6	1,2,3,4	1
	Capsicum annuum var. glabriusculum	Chiltepin	Laktsuupi'n	2.2	1.5	3	1	5,6	2,3	1
	Cucurbita sp.	Calabaza	Nipxi	1.9	0.3	3	1	4,5	1,2,3	1
	Cucurbita ficifolia Bouché	Chilacayote	ND	0.2	0.3	3	2	5	1	1
	Lycopersicon esculentum P. Mill.	Jitomate riñon	Xtili'pakglhcha	1.1	0.3	3	2	5	1,3,4	1
	Lycopersicon lycopersicum (L.) H. Karst.	Jitomate silvestre	Staku'pakglhcha	0.4	0.3	3	2	5	1,3	1
	Persea americana Mill.	Aguacate criollo	Kukuta	0.8	0.3	1	1	5	2,3	2
	Persea schiedeana Nees.	Pahua	Lhpuj	1.3	0.3	1	1	5	3,5	2
	Physalis ixocarpa Brot. ex. Horn.	Tomate de cáscara	Tamat	0.4	0.3	3	1	5	4	1
	Renealmia alpinia (Rottb.) Maas	Jengibre de jardín	Xkijit	2.6	0.3	2	1	3,5	2	2
	Sechium edule (Jacq.) Sw.	Chayotes	Maklhtukun	3.3	0.3	3	1	1,3,5	1,2,3	1
	Cucurbita argyrosperma C. Huber	Pipian	Talhtsi	0.1	0	3	1	4,5	1	1
	Opuntia cochenillifera (L.) Mill.	Nopal	Axilh	0.4	0	2	1	2	2,3	2
	Persea americana var. *americana*	Aguacate	Kukutlitli	0.1	0	1	1	5	3	2
	Renealmia mexicana Klotzsch ex. Petersen	Xkijit	Sikulna xkjit	0.1	0	2	1	3,5	2	2
	Solanum suaveolens Kunth & C.D. Bouché	Tomate de monte	Sipi'tomat	0.2	0	3	2	5	2,3	3

Plant type: (1) tree, (2) bush, (3) herbaceous; Origen: (1) native, (2) introduced; Part of plant used: (1) root, tuber, rhizome, (2) stems, (3) leaves, (4) flowers or inflorescence, (5) fruit, (6) seeds, (7) sap; Agroecosystem: (1) milpa, (2) coffee plantation, (3) homegarden, (4) horticulture, (5) acahual; Management: (1) cultivated; (2) fomented; (3) collected/wild; ND = No data.

10.3389/fsufs.2024.1329532

TABLE 3 Edible species richness by food group and agroecosystem.

Food group	Milpa	Coffee plantation	Homegarden	Horticulture	*Acahual*	Species richness (unique)
Beverages	2	2	2	0	1	3
Cereals	1	0	1	0	0	1
Spices	3	3	5	1	0	5
Fruit	14	25	23	1	2	32
Leguminous plants	7	3	5	2	0	8
Herbs and leafy greens	14	21	16	5	3	28
Seeds	1	1	1	0	0	1
Tubers/Roots	3	5	2	0	0	5
Vegetables	12	11	11	4	2	19
Number of Species	57	71	66	13	8	102

TABLE 4 Richness of recorded edible plants between families, dietary profiles, and by agroecosystem.

	Edible plant richness	
	Mean	Standard deviation
Household ($n = 69$)	13.8	±7.1
Profiles*		
A ($n = 18$)	16.1[b]	±6.1
B ($n = 16$)	9.8[a]	±2.6
C ($n = 18$)	10.1[a]	±3.4
D ($n = 17$)	19.2[b]	±9.2
*Agroecosystem***		
Milpa ($n = 63$)	5.2[ab]	±2.8
Coffee plantation ($n = 47$)	7.7[b]	±5.7
Homegarden ($n = 27$)	8.2[b]	±4.9
Horticulture ($n = 7$)	3.8[a]	±2.4
Acahual ($n = 2$)	4.5[a]	±0.7

*Kruskal–Wallis test gl: 3, $p \leq 0.01$. **Kruskal–Wallis test, gl: 4, $p \leq 0.01$. ab = means with the same letters between profiles (A–D) and agroecosystem are not statistically different ($p \leq 0.01$).

TABLE 5 Number of edible plants present in the farm plots that were recorded or unrecorded in the diet surveys.

Food group	Recorded in the diet surveys		
	No	Yes	Total
Cereals	0	1	1
Beverages	1	2	3
Fruit	25	7	32
Spices	3	2	5
Leguminous plants	2	6	8
Quelites (herbs and leafy greens)	11	17	28
Roots and tubers	4	1	5
Seeds	0	1	1
Local vegetables	8	11	19
Management			
Collected	9	4	13
Encouraged	20	11	31
Cultivated	25	33	58
Destination			
Self-consumption	28	9	37
Self-consumption and sale	17	35	52
Sale	9	4	13

fruit. The remaining species in Figure 3B were reported in less than 15 of the 69 households.

Differentiated consumption of edible plants

Among the four dietary profiles, there were significant differences in the species richness recorded in the agricultural plots. To differentiate between them, we will call them groups A, B, C, and D. In this case, groups A and D had more edible species than groups B and C (Figure 3). Thus, the families that followed a diet in which there was a high consumption frequency of self-produced and local/regional food (groups A and D) showed a higher richness of edible species in their plots compared to families that demonstrated a higher consumption frequency of purchased food (groups B and C). The families of profiles A, B, and C had a high proportion of plants inventoried in the agroecosystems and not documented in the diets. Among the same groups of families, no significant differences were observed in the consumption of edible plants from the plots and those recorded in the diet surveys. In families of profile D, 50% of the edible plants found in their agroecosystems were included in their diets, maintaining a more diversified diet with food from their plots than the other three groups (Figure 3).

Low consumption frequency of local edible species

When asked about the reasons for the low consumption frequency of edible species, respondents stated that it was due to the loss of

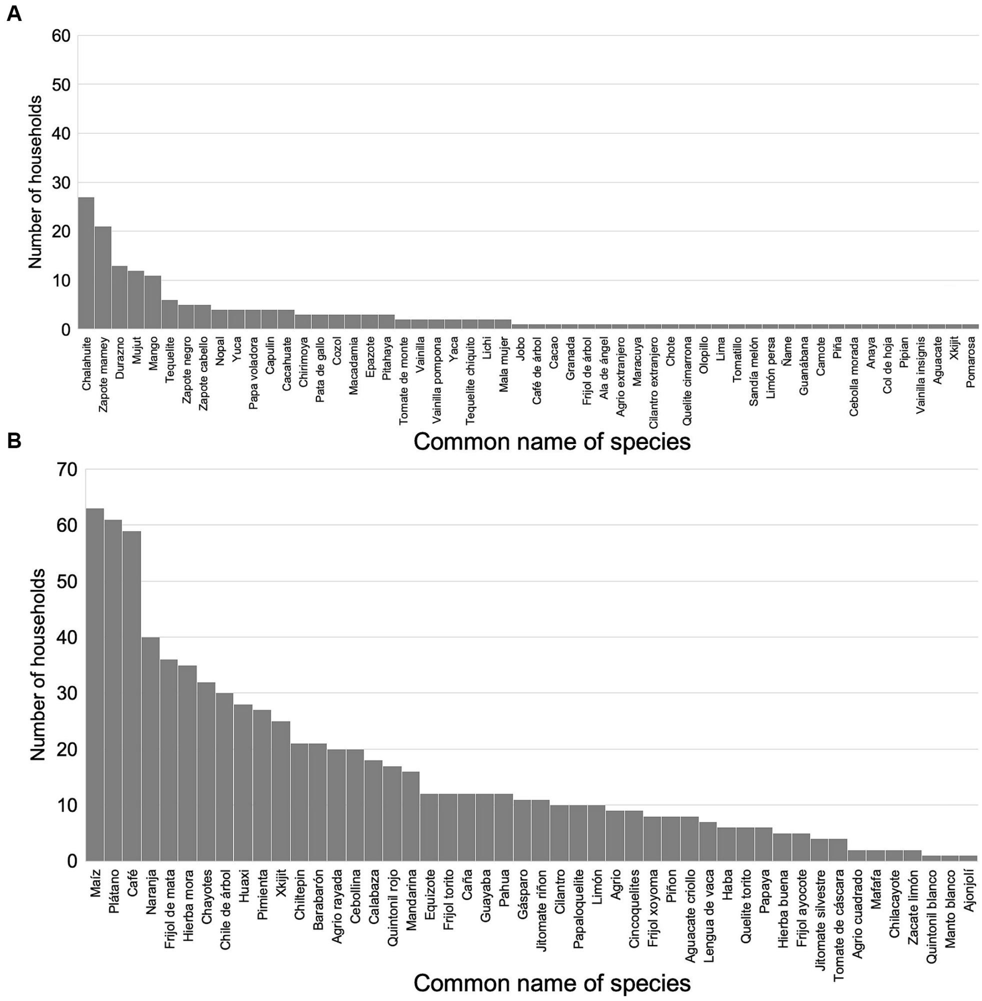

FIGURE 2
(A) Frequency of edible species present in the plots but unrecorded in the diet surveys. **(B)** Frequency of edible species present in the plots and recorded in the diet surveys.

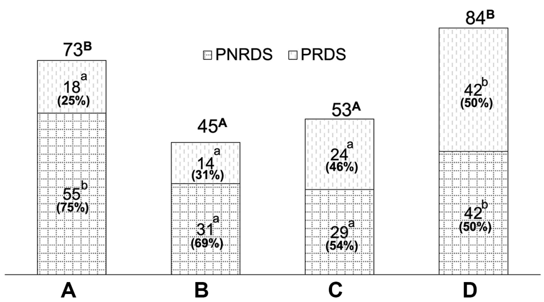

FIGURE 3
Richness of edible plants recorded in the agroecosystems but not in dietary surveys (PNRDS), and edible plants recorded in both agroecosystems and dietary surveys (PRDS) by dietary profile. **Kruskal–Wallis test, gl: 3, $p \leq 0.01$. ab = means with the same letters within groups **(A–D)** are not statistically different. AB = means with the same capital letters among groups are not statistically different.

traditional autochthonous knowledge related to the cultivation and use of edible plants. Furthermore, they indicated that some plants are difficult to cook, are not popular in diets, receive little promotion, and are rarely cultivated. In addition, they emphasized that new generations are more disconnected from their natural surroundings and agroecosystems than previous generations, which is reflected in the decreasing consumption of locally produced food (Figure 4). Respondents also mentioned that the collection of some herbs and *quelites* is time-consuming, time that most families cannot afford, thus impeding their consumption and cultivation. Such plants include *quelites*: *Cyclanthera langaei*, *Cyclanthera ribiflora*, *Ipomoea dumosa*, and the flowers of the *Cnidoscolus multilobus*. A quarter of the 69 families surveyed commented that their children no longer want to consume *quelites*, as some plants have a bitter taste and burn the tongue; such is the case of *Xanthosoma robustum*, *Solanum americanum*, and *Physalis gracilis*. In addition, 20% of the families surveyed stressed that many *quelites* are no longer being promoted or cultivated and are currently difficult to find in the local market or in the areas where they used to collect them. Respondents also commented that the collection and preparation of *Dioscorea alata* and *Manihot esculenta* is also time-consuming. In contrast, fruits do not require much preparation; however, many species are not encouraged or cultivated. This is the case *Acanthocereus tetragonus*, *Annona muricata*, *Spodias mombin*, *Moquilea platypus*, *Pouteria sapota*, and *Syzygium jambos*, which were present in five or fewer plots out of the

10.3389/fsufs.2024.1329532

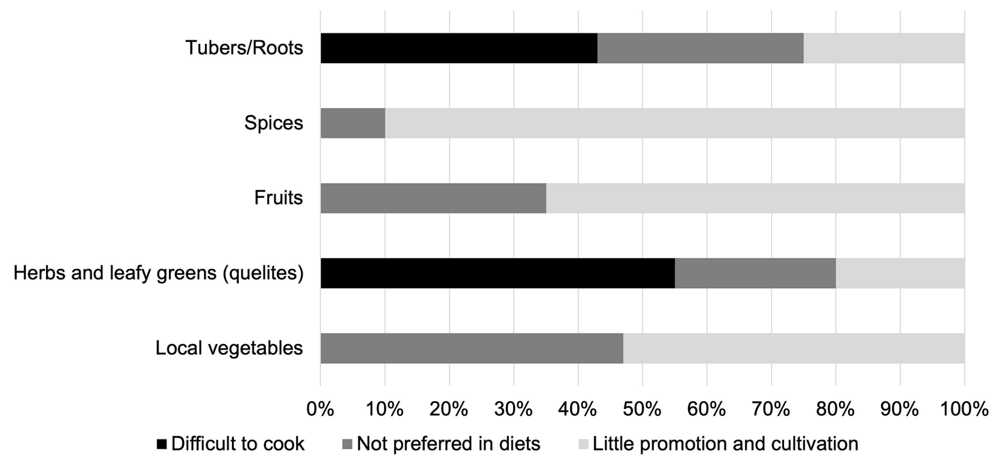

FIGURE 4
Reasons given by households for the low consumption frequency of several food groups. For the analysis, the vegetable group did not include chili, tomato, and squash. n: 69.

146 inventoried. Regarding local vegetables and spices, respondents added that as these are seasonal foods, they are often in short supply, which explains their low consumption frequency, exemplified by vanilla, locally grown avocados, and *Persea schiedeana*.

On the other hand, the villagers commented that some edible plants grown are no longer adapted and have low production compared to other years. They attributed this situation mainly to the lack of rainfall and the continued presence of strong winds and hurricanes. According to the villagers, these changes in the weather cause low production of corn, coffee, beans, tomatoes, and chili peppers.

Discussion

Our results show that a high number of edible species are still maintained at the regional level, comparable to other regional ethnobotanical studies that have inventoried between 80 and 153 species in the smallholdings of the Totonac families of the Sierra Norte de Puebla (Del Ángel Pérez and Mendoza, 2004; Martínez-Alfaro et al., 2007). This number of edible species is higher than in other regions of Mexico, where less than 100 edible plants have been recorded (Solís and Casas, 2023). Moreover, if we consider the mean number of edible species grown per household (13.8 ± 7.05), this richness is high compared to other studies in rural peasant regions. For example, a study in Ghanaian farm households reported that some households grew up to eight edible plants, with a mean of 3.2 species per household (Bellon et al., 2020). A study in Kenya reports that the mean edible plant richness per household was 9.9 ± 4.3 (Oduor et al., 2019). Meanwhile, a study conducted in Mayan communities in Guatemala reported that households cultivate a mean of 15 ± 8 edible plants per household (Luna-González and Sorensen, 2018), which is very similar to our findings. However, the presence of these plant species in the plots was very low; out of a total of 101 species, 54 species were present in less than five plots, and most of these were either unrecorded or presented a very low frequency in the diet surveys. Fifty-three percent of the edible plant species inventoried in the farmer's plots was not recorded in the diet surveys conducted in the same communities, reflecting the apparent scarcity of these species. Therefore, they do not constitute a regular part of the diet and are likely to be used only when staple foods are scarce or in times of crisis, as noted by Mapes and Basurto (2016). The food groups with the highest proportion of such species include *quelites*, local vegetables, tubers, and fruit trees, which is consistent with the findings of Rivera-Núñez et al. (2022). An alternative explanation for this discrepancy between the species recorded in the farmer's plots and those mentioned in the diet surveys is that many of these plants are not consumed because family members, especially children, do not like their taste; consequently, even if the plants are present in the plots, they may not form part of the household's diet, as documented by other authors (Benítez et al., 2020).

The inhabitants of the Totonacapan region consider that the enhancement and cultivation of edible plants that complement their staple diet will continue to decline, primarily because many tubers, roots and local vegetables are difficult to cook. Furthermore, their collection and preparation are very time-consuming. Nuani et al. (2022) noted that some tubers and roots, such as *Manihot esculenta* and *Dioscorea alata* L., were rarely consumed because of several factors: their low presence in farmer's plots, unattractive taste and a lack of time required to prepare traditional meals using these plants as ingredients. A low volume of plants harvested and their complementary role in meals may also be a factor in the absence of many plant species in the dietary surveys. Some studies report that households do not mention food that only accompany meals, such as spices and some leafy greens (Duguma, 2020).

Among the 48species recorded in the plots and diet surveys, maize, one species of bean, one species of chili, squash, and local *chayotes*, all cataloged as traditional ingredients in the Mesoamerican peasant diet (Zizumbo-Villarreal et al., 2012), were common in the plots and presented the highest consumption frequency. Apart from *Citrus × sinensis* and *Musa* spp., whose fruits are mainly sold and not used for self-consumption, the remaining edible plants demonstrated a low consumption frequency and corresponded to those species that were least recorded in the plots. Edible plants such as tomatoes and other varieties of chilies and beans, considered staples in the peasant diet, showed a high consumption frequency in contrast to their low presence in the farm plots, which could be related to the fact that local and regional markets are selling foods from outside the region that are replacing those grown on the plots (Espinoza-Pérez et al., 2023). It is not clear whether the decrease in local production is because products can be bought in the markets or whether families buy in the market due to the decrease in local production. However, the dependence on the market for food varied between households, and even though we are referring to the same cultural and environmental area, species richness and consumption of edible plants differed considerably between families in the region. The families that consumed more self-produced and locally or regionally produced food maintained a greater richness of edible plants in their plots (groups A and D) compared to the families that depended predominantly on the market for food (groups B and C). Although several families in Group A owned plots rich in edible plant species, they consumed a low proportion of edible plant species. These results suggest that the more families depend on self-consumption to subsist, the greater the diversity of edible species in their farm plots; this finding supports the argument that crop diversification in farmers' agroecosystems increases the capacity for self-consumption in the diets of rural families (Bellon et al., 2020). Apart from staple crops such as maize and beans, there is another group of edible plants used in peasant diets that is not consumed by some families, even though they are present in their plots, we refer to *quelites*, fruit trees, and some local vegetables. This finding confirms that a large number of edible species in the plots of peasant farmers does not automatically imply that they are consumed frequently (Soto-Pinto et al., 2022).

This study reveals that, in some households, using available agricultural diversity can complement and diversify diets. This coincides with other studies that argue a positive association between edible plant richness and the nutritional quality of peasant household diets (Lachat et al., 2018; Benítez et al., 2020). However, there were families whose plots presented high species richness but exhibited the same consumption pattern as families from group A that consumed more food purchased from the market.

These results show that the contribution of agricultural diversity to farmer's diets appears to have diverse effects. As shown by other studies that have analyzed the relationship between crop and diet diversification, our results are mixed and depend on the context of the populations studied (Powell et al., 2015; Sibhatu and Qaim, 2018). Sibhatu et al. (2015) reported positive and significant associations between production and dietary diversity in Indonesia and Malawi, but not in Ethiopia and Kenya. To these findings, we would add that the household use of edible plants may differentiate within the same cultural and ecological region.

Study limitations

The discrepancy between the richness of plants in the plots and those consumed could be because the surveys only recorded food eaten at home, and many edible plants were consumed outside the household or not as part of regular meals, such as in the case of fruits that are often consumed in the plots where the fruit trees grow. A further consideration, particularly in the case of fruit, is that food availability is seasonal. Thus, some edible plants may not have been recorded as the surveys were conducted during nine months of the year. Another factor that may have contributed to the under-recording of plants in the diet surveys is that these were carried out in 2020, and edible species in plots were recorded in 2022.

Conclusion

Our study reveals that many plants found in the plots are marginal in the peasant farmer's diet, largely because of their low presence in the plots. This is reflected in the fact that more than half of the species inventoried in the plots were not mentioned in the diet surveys. The main reasons for the limited consumption of edible plants are that many people, especially children, no longer like their taste, they are difficult to cook, and that collection and preparation are time-consuming. Notwithstanding, farmers continue to tolerate and enhance these plant species in their plots, possibly as they are useful during food shortages or crises, given that ethnobotanical information showed that 83% of these species are used for self-consumption and occasionally for sale.

Although regional agricultural diversity is high, with 101 edible plants recorded, not all farm plots and family diets presented a substantial diversity of edible plants, and their relative use demonstrated a differential pattern among households. The families that relied more on self-consumption for subsistence maintained a greater richness of edible plants in their plots. For other families, a high richness of edible plants in their plots did not signify a diversified diet, while a large proportion of households maintained plots with few species of edible plants as their diet consisted predominantly of food purchased from the market.

The results of this research provide evidence of several factors that limit and contribute to the use of edible plants in peasant farming regions, such as the low presence of edible plants in plots, the importance placed by farmers on self-consumption, as well as preferences and tastes for local food. These are aspects that should be considered by researchers, farmers, nutritionists, and public policymakers in order to promote plants that are considered ignored and underutilized but have the potential to improve the nutrition of rural populations at the local, regional, and global levels.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Studies with human participants were reviewed and approved by the Ethics Committee of El Colegio de la Frontera Sur. Consent was obtained from the local authorities of the study communities and parents where the study was conducted. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JE-P: Conceptualization, Writing – original draft. SC-V: Conceptualization, Supervision, Validation, Writing – review & editing. HP: Formal analysis, Methodology, Supervision, Writing – review & editing. OM-F: Methodology, Supervision, Validation, Writing – review & editing. LS-P: Formal analysis, Supervision, Validation, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. Mexico's National Council of Humanities, Science, and Technology (CONAHCYT) provided a scholarship to JEP for her doctoral studies (587494).

Acknowledgments

The authors thank the peasant families of the Northeastern Sierra of Puebla for their support in this research.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Aragaw, H. S., Nohr, D., and Callo-Concha, D. (2021). Nutritional potential of underutilized edible plant species in coffee agroforestry systems of Yayu, southwestern Ethiopia. *Agrofor. Syst.* 95, 1047–1059. doi: 10.1007/s10457-021-00626-6

Basurto-Peña, F. (2011). "Los quelites de México: especies de uso actual" in *Especies vegetales poco valoradas: una alternativa para la seguridad alimentaria*. eds. D. Castro-Lara, L. M. Mera-Ovando and R. Bye (México, D.F.: UNAM-SNICS-SINAREFI), 213.

Basurto-Peña, F., Castro, D., and Martínez-Alfaro, M. A. (2003). Edible begonias from the north of Puebla Mexico. *Econ. Bot.* 57, 48–53. doi: 10.1663/0013-0001

Basurto-Peña, F., Martínez-Alfaro, M. A., and Villalobos-Contreras, G. (1998). The Quelites (edible greens) in the sierra Norte de Puebla, Mexico: inventory and methods of preparation. *Bot. Sci.* 62, 49–62. doi: 10.17129/botsci.1550

Bellon, M. R., Hundie, K. B., Azzarri, C., and Caracciolo, F. (2020). To diversify or not to diversify, that is the question. Pursuing agricultural development for smallholder farmers in marginal areas of Ghana. *World Dev.* 125:104682. doi: 10.1016/j.worlddev.2019.104682

Benítez, K. M., Soto-Pinto, L., Estrada-Lugo, E., and Pat-Fernández, L. (2020). Huertos familiares y alimentación de grupos domésticos cafetaleros en la Sierra Madre de Chiapas. *Revista Agricultura, Sociedad y Desarrollo.* 17, 27–56. doi: 10.22231/asyd.v17i1.1321

Bruman, H. (1948). The culture history of Mexican vanilla. *Hisp. Am. Hist. Rev.* 28, 360–376. doi: 10.1215/00182168-28.3.360

Bye, R., and Linares, E. (2000). Los quelites, plantas comestibles de México. *Una reflexión sobre intercambio cultural. Biodiversitas.* 31, 11–14.

Del Ángel Pérez, A. L., and Mendoza, M. A. (2004). Totonac homegardens and natural resources in Veracruz Mexico. *Agric. Hum. Val.* 21, 329–346. doi: 10.1007/s10460-004-1219-9

Duguma, H. T. (2020). Wild edible plant nutritional contribution and consumer perception in Ethiopia. *Int. J. Food Sci.* 2020, 1–16. doi: 10.1155/2020/2958623

Espinoza-Pérez, J., Cortina-Villar, S., Perales, H., Soto-Pinto, L., and Méndez-Flores, O. G. (2023). Autoabasto en la dieta campesina del Totonacapan poblano (México): implicaciones para la agrodiversidad. *Región y Sociedad.* 35:e1717. doi: 10.22198/rys2023/35/1717

Frison, E. A., Smith, I. F., Johns, T., Cherfas, J., and Eyzaguirre, P. B. (2006). Agricultural biodiversity, nutrition, and health: making a difference to hunger and nutrition in the developing world. *Food Nutr. Bull.* 27, 167–179. doi: 10.1177/156482650602700208

García-Vazquez, R., López-Santiago, M. A., Valdivia-Alcalá, R., and Sánchez-Toledano, B. I. (2022). Use of traditional food and proposal for the dish of good eating for the Totonac region: totonaco plate of good eating. *AgroProductividad.* 1. doi: 10.32854/agrop.v15i1.2057

González-Bonilla, L. A. (1942). "Los Totonacas". Instituto de Investigaciones de la UNAM. *Repositorio Universitario Digital.* 4, 81–101.

Grivetti, L. E., and Ogle, B. M. (2000). Value of traditional foods in meeting macro- and Micro-nutrient needs: the wild plant connection. *Nutr. Res. Rev.* 13, 31–46. doi: 10.1079/095442200108728990

Hassen, A. (2021). Diversity and potential contribution of wild edible plants to sustainable food security in north Wollo, Ethiopia. *Biodiversitas* 22, 2501–2510. doi: 10.13057/biodiv/d220660

INALI (Instituto Nacional de Lenguas Indígenas). (2010). CatÁlogo de las Lenguas Indígenas Nacionales: Variantes Lingüísticas de México con sus autodenominaciones y referencias geoestadísticas. Available at: https://site.inali.gob.mx/pdf/catalogo_lenguas_indigenas.pdf

Kelly, I., and Palerm, A. (1952). *The Tajín Totonac, part I*. Washington: Smithsonian Institution. 359.

Kennedy, G., Ballard, T., and Dop, M. (2013). *Guía para medir la diversidad alimentaria a nivel individual y del hogar*. Roma: Organización de las Naciones Unidas.

Knez, M., Ranic, M., Gurinovic, M., Glibetic, M., Savic, J., Mattas, K., et al. (2023). Causes and conditions for reduced cultivation and consumption of underutilized crops: is there a solution? *Sustain. For.* 15:3076. doi: 10.3390/su15043076

Koukou, E., Amoussa-Hounkpatin, W., Sognigbé, N., Sounouke, C. V. D. P., Ntandou-Bouzitou, G., and Termote, C. (2022). Local knowledge of agricultural biodiversity and food uses of edible plant species in two agroecological zones of southern Benin. *Ethnobot. Res. Appl.* 23, 1–22.

Kuhnlein, H. V., and Receveur, O. (1996). Dietary change and traditional food systems of indigenous peoples. *Annu. Rev. Nutr.* 16, 417–442. doi: 10.1146/annurev.nu.16.070196.002221

Lachat, C., Raneri, J. E., Smith, K. W., Kolsteren, P., Van Damme, P., Verzelen, K., et al. (2018). Dietary species richness as a measure of food biodiversity and nutritional quality of diets, in *Proceedings of the national academy of sciences*. 115, 127–132. doi: 10.1073/pnas.1709194115

Luna-González, D. V., and Sorensen, M. (2018). Higher agrobiodiversity is associated with improved dietary diversity, but not child anthropometric status, of Mayan Achí people of Guatemala. *Public Health Nutr.* 21, 2128–2141. doi: 10.1017/S1368980018000617

Mapes, C., and Basurto, F. (2016). "Biodiversity and edible plants of Mexico in Mexican Ethnobotaby" in *Interactions of People and Plants in Mesoamerica*. eds. R. Lira, A. Casas and J. Blancas. 83–132. Available at: https://link.springer.com/chapter/10.1007/978-1-4614-6669-7_5

Martínez-Alfaro, M. A., Evangelista, V., Basurto, F., Mendoza, M., and Cruz-Rivas, A. (2007). Flora útil de la Sierra Norte de Puebla, México. *Revista Mexicana de Biodiversidad.* 78, 15–40. doi: 10.22201/ib.20078706e.2007.001.457

Martínez-Alfaro, M.A., Evangelista, V., Mendoza, M., Morales, G., Toledo, G., and Wong, A. (1995). *Catálogo de plantas útiles de la Sierra Norte de Puebla México Cuadernos del Instituto de Biología*, México. Universidad Nacional Autónoma de México.

Mehraban, N., and Ickowitz, A. (2021). Dietary diversity of rural Indonesian households declines over time with agricultural production diversity even as incomes rise. *Glob. Food Sec.* 28:100502. doi: 10.1016/j.gfs.2021.100502

Miller, V., Yusuf, S., Chow, C. K., Dehghan, M., Corsi, D. J., Lock, K., et al. (2016). Availability, affordability, and consumption of fruits and vegetables in 18 countries across income levels: findings from the prospective urban rural epidemiology (PURE) study. *Lancet Glob. Health* 4, e695–e703. doi: 10.1016/S2214-109X(16)30186-3

Neupane, N. P., Yadav, E., and Verma, A. (2022). "Cultural, practical, and socio-economic importance of edible medicinal plants native to Central India" in *Edible plants in health and diseases*. eds. M. H. Masoodi and M. U. Rehman (Singapore: Springer)

Nuani, F. O., Gido, E. O., Ayuya, O. I., and Musyoka, M. P. (2022). Demand analysis for selected roots and tubers among urban households of Nakuru County Kenya. *Cog. Food Agric.* 8:1. doi: 10.1080/23311932.2022.2093047

Oduor, F. O., Boedecker, J., Kennedy, G., and Termote, C. (2019). Exploring agrobiodiversity for nutrition: household on-farm agrobiodiversity is associated with improved quality of diet of young children in Vihiga Kenya. *PLoS ONE.* 14:e0219680. doi: 10.1371/journal

Phillips, O., and Gentry, A. H. (1993). The useful plants of Tambopata, Perú: I. Statistical hypotheses test with a new quantitative technique. *Econ. Bot.* 47, 15–32. doi: 10.1007/BF02862203

Powell, B., Thilsted, S. H., Ickowitz, A., Termote, C., Sunderland, T., and Herforth, A. (2015). Improving diets with wild and cultivated biodiversity from across the landscape. *Food Secur.* 7, 535–554. doi: 10.1007/s12571-015-0466-5

Rivera-Núñez, T., García-Barrios, L., Benítez, M., Rosell, J. A., García-Herrera, R., and Estrada-Lugo, E. (2022). Unravelling the paradoxical seasonal food scarcity in a peasant microregion of Mexico. *Sustain. For.* 14:6751. doi: 10.3390/su14116751

Sibhatu, K. T., and Qaim, M. (2018). Review: Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households. *Food Policy* 77, 1–18. doi: 10.1016/j.foodpol.2018.04.013

Sibhatu, K. T., Krishna, V. V., and Qaim, M. (2015). Production diversity and dietary diversity in smallholder farm households. *Proc. Natl. Acad. Sci. U. S. A.* 112, 10657–10662. doi: 10.1073/pnas.1510982112

Solís, L., and Casas, A. (2023). "Cuicatec ethnobotany: plants and subsistence in San Lorenzo pa´ Palo, Oaxaca" in *Ethnobotany of the mountain regions of Mexico, ethnobotany of mountain regions*. eds. A. Casas and J. Blancas. 517–553.

Soto-Pinto, L., Escobar, C. S., Benítez, K. M., López, C. A., Estrada, L. E., Herrera, H. B., et al. (2022). Contributions of agroforestry systems to food provisioning of peasant households: conflicts and synergies in Chiapas Mexico. *Front. Sustain. Food Syst.* 5:756611. doi: 10.3389/fsufs.2021.756611

Zizumbo-Villarreal, D., Flores-Silva, A., and Colunga-García, P. M. (2012). The archaic diet in Mesoamerica: incentive for milpa development and species domestication. *Econ. Bot.* 66, 328–343. doi: 10.1007/s12231-012-9212-5