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STUDIES ON THE TRADITIONAL MANAGEMENT, AND PROCESSING OF MATSUTAKE MUSHROOMS IN OAXACA, MEXICO*

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ABSTRACT

In central Mexico, matsutake mushrooms [*Tricholoma magnivelare* (Peck)Redhead] are gathered commercially by differing rural communities since the middle of the 1980's. We describe the way rural communities (indigenous Zapotecs and peasants) from the State of Oaxaca are organized to make use of matsutake from their communal forest. Mexican exports of matsutake, however, have decreased significantly during the period 1996-2000. Long-term management of matsutake mushrooms will be mainly based on the social, economic, and land tenure systems associated to traditional mushroom gathering in every community or region. In general, the traditional use, management, and conservation of wild edible mushrooms by rural communities follow different strategies from the ecosystem management philosophy carried out in other regions. Fresh matsutake mushrooms gathered by peasants were also processed (freeze-drying, freezing, drying, and canning) in order to explore potential alternatives for developing marketing strategies by rural communities. Advantages and disadvantages of methods studied are discussed.

Key words: Matsutake mushrooms, processing, non-timber forest products, traditional management, traditional organization, Zapotecs, Oaxaca, Mexico.

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INTRODUCTION

Wild edible mushrooms, such as matsutake, morels, boletes, and chanterelles, are exploited on a large or small scale, and marketed worldwide. Their economic value has been reported to be in excess of several billion dollars [19]. In Japan, the "matsutake" mushroom [*Tricholoma matsutake* (S. Ito & Imai)Sing.] is considered a delicacy, which is highly prized by its strong aromatic flavour. The market value of this mushroom can be as high as USD $ 1,250.00 per kilogram. Fruit bodies are large, fleshy, and the cap's surface is covered with tawny brown to russet, flattened scales. This species is known from China, Korea, and Japan [10]. *T. magnivelare* (Peck) Redhead is a closely related species found in North America (U.S.A., Canada, Mexico), where it is known as the "white matsutake" or "pine mushroom". In this case, fruit bodies have a paler cap, bearing smaller, yellowish brown to reddish brown, fibrous scales on a white background [10, 18].

In central Mexico, there is a long cultural tradition in rural communities for the consumption and marketing of wild mushrooms during the rainy season [17]. Matsutake mushrooms, identified by conventional taxonomy as *T. magnivelare* [18], are gathered commercially by peasants and/or indigenous people since the middle of the 1980's, mainly in the States of Durango, Hidalgo, Mexico, Michoacan, Oaxaca, Puebla, and Veracruz (**Fig. 1**). The matsutake mushroom is known locally as "hongo blanco" (white mushroom), "hongo de rayo" (ray mushroom), "hongo de ocote" (torch-pine mushroom), and "hongo de venado" (deer mushroom). The Mexican matsutake normally grows following ring or semi-ring patterns during June to November, and associated to *Pinus* (*P. teocote* Schl. et Cham., *P. douglasiana* Martínez), *Quercus* (*Q. scytophylla* Liebm., *Q. crassifolia* Née, *Q. conzattii* Martínez), and *Arbutus* spp. These conditions are found in temperate forest regions having elevation ranges from 2000-3250 m, and slopes from 12-70%. The long fruiting pattern is interesting, as matsutake mushrooms appear around July to September in China, around September to November in Japan [10], and around August to January in North America [12]. In Mexico, fruiting has been reported to occur in climates classified as subhumid (semi-warm, temperate) with summer rains, showing an average annual temperature from 10-18 C, and an average annual precipitation from 600-2500 mm. Main edaphic conditions described are: stony soils (cambisol, eutric regosol, humic andosol, lithosol, luvisol), medium texture, pH 5.0-7.2, 12-25% organic matter, and 2-10 cm humus layer. The natural productivity of fresh Mexican matsutake ranges from 2.5-5.0 kg/ha/year at about 2,300 m [4].

Prices of matsutake mushrooms vary according to each region, natural production, stage of the season, and fruit-body quality. The Mexican matsutake is seldom consumed traditionally in rural areas, although

Fig. 1. Main States of Mexico where matsutake mushrooms (*Tricholoma magnivelare*) are gathered commercially by rural communities.

it has recently been found in popular markets from Oaxaca city. It is normally sold to private companies to be exported to Japan. For this reason, matsutake has become one of the main non-timber commercial products for rural communities [2, 4, 6, 16, 18, 21, 22].

Information from official databases (**Table 1**) show the amount of matsutake mushrooms exported to Japan, and its economic importance. During the last 15 years, three main periods can be identified:

1) A slow initial phase (*ca*. 1985-1989) in which private companies made a strong promotion for gathering matsutake amongst rural communities. In this phase, mushrooms were bought to rural gatherers (peasants and/or indigenous people) at low prices (USD $ 2.30-17.30 per kg), and national exports in 1989 reached 15 tonnes having an economic value of USD $ 147,000.

2) A mature phase (1993-1995) characterized by rapid growth of matsutake gathering in many forest regions. Mushrooms were bought to rural gatherers at a higher average price (USD $ 22.44-38.07 per kg). Exports increased from 15 to 55.512 tonnes/year in 1995, and reached their highest economic value of USD $ 2,113,692.

3) A declining phase (1996-2000) in which exports have decreased from 42.318 to 4.435 tonnes in 2000. This dramatic reduction is associated with higher average prices paid to rural gatherers (USD $ 32.11-55.21 per kg) by private companies.

In total, 230.31 tonnes of matsutake mushrooms have been exported during the period 1989-2000, whose economic value was USD $ 7,620,916. These facts may indicate that the natural production of matsutake mushrooms is decreasing, and that it is perhaps being overexploited, despite strong official regulations (Law: LGEEPA; specific regulations: NOM-059-ECOL-1994, NOM-010-RECNAT-1996) [2]. However, it may also be due to unusually dry years, and even to forest logging, succession, or diseases. A similar case happened in Japan, where the domestic production and marketing of matsutake decreased from 6,448 metric tons in 1950, to 180 metric tons in 1984 [14]. This decline in Japanese production has been attributed to insect pests and forest succession to non-pine species [5].

Table 1. Estimated production, average local prices, and exports of matsutake mushrooms in Mexico.

Year	Local price (USD/kg)	Exports[a] (Tonnes)	Value of exports (USD)
Initial phase:			
1989	$ 2.30-17.30	15.000	$ 147,000[b]
Mature phase:			
1993	$ 30.40	25.875	$ 786,771
1994	$ 22.44	34.681	$ 778,473
1995	$ 38.07	55.512	$ 2,113,692
Declining phase:			
1996	$ 32.11	42.318	$ 1,359,223
1997	$ 55.21	13.820	$ 763,077
1998	$ 39.19	24.220	$ 949,193
1999	$ 34.92	14.449	$ 504,570
2000	$ 49.36	4.435	$ 218,917

[a] Database from the Mexican Government.

[b] Estimated value based on the national production reported by Villarreal and Pérez-Moreno [18].

The situation described opens up the possibility to carry out interdisciplinary research work for promoting the sustainable use of matsutake mushrooms in Mexico. At present, most research work has been focused on conventional taxonomy and ecology [4, 9, 17, 18, 21]. Considerable less attention has been given to socio-economic research, as well as to the potential application of processing

technologies to improve mushroom quality and marketing. In this study, we describe how rural communities (indigenous Zapotecs and peasants) from Oaxaca, Mexico, are organized to make use of matsutake mushrooms from their communal forest. Fresh mushrooms gathered in these communities were also processed (freeze-drying, freezing, drying, canning) in order to explore potential alternatives for developing marketing strategies by rural communities not only to export to other regions, but also to promote masutake consumption at a national or regional level.

MATERIALS AND METHODS

Social organization

To understand the context in which mushroom gathering is carried out in a rural community of indigenous people and/or peasants having a specific idiosyncrasy, we used the rural household system (RHS) model [1, 11]. The RHS is a concept developed by the authors to assess the rural household unit and its affairs regarded as a system. This model of analysis shows how Mexican rural communities associated to primary activities within forest regions are basically formed by diverse RHSs. An interview protocol was developed containing variables studied within open-ended, short-answer open-ended, and closed items, as well items with adjectival and adverb responses. Appropriate measurement scales were assigned to each variable. The interview protocol was applied individually by formal interviews (**Fig. 2**), followed by an observation protocol [15]. Several variables were assessed through participant observation: family organization, the process of mushroom gathering, household activities, and arrangements with private trade companies.

Mushroom processing

Fresh matsutake mushrooms were gathered by peasants and indigenous Zapotecs in two communal forests from "Yuvila" and "El Punto", Municipality of Ixtepeji, Oaxaca, Mexico. They were placed within ice-bag containers, transported overnight to the laboratory in Puebla (*ca*. 6 h). Food characterization is fundamental for developing any processing technology. The pH is one of the most important properties associated with food chemistry and with microbiological food spoilage. The pH from fresh and blanched matsutake fruit bodies was recorded, and the initial mushroom quality was assessed (residual soil or plant debris, larval damage or insects, appearance). After characterization, mushrooms were further cleaned, washed, and prepared for processing. Additional data obtained from mushrooms included: weight losses (initial weight - final weight); percentage of weight losses [(initial fresh weight - final fresh weight) / initial fresh weight x 100]; moisture content [(initial fresh weight - final dry weight) / initial fresh weight x 100]; final

Fig. 2. Interview about matsutake mushrooms (*Tricholoma magnivelare*) within a rural household system (RHS) from Oaxaca, Mexico (Photo: H. León).

weight before processing (FW^b= initial weight - total weight loss); final weight after processing (FW^a); and percentage of final weight as a proportion of the initial weight (%IW).

Clean fruit bodies were freeze-dried following standard procedures for 45 h (Labconco 4.5 L freeze dry system 77500, Kansas, U.S.A.). After washing and blanching, fruit bodies were also frozen at -20 C (Revco freezer ULT-1340-3, Asheville, U.S.A.). Other fruit bodies were cleaned, cut (slices), and dried in an oven. Canning was carried out using an acidified (pickled) Mexican recipe ("Hongos silvestres en escabeche"), which is popular. Fruit bodies were blanched, cooked, and canned in glass containers [3, 8].

Overall data from this section provide information for basic and comparative financial/technical planning by rural organizations or companies interested in marketing processed mushrooms [3, 8].

RESULTS AND DISCUSSION

Mushroom gathering

Rural communities (indigenous Zapotecs and peasants) of 4 Municipalities (Lachatao, Amatlán, Yavesia, Ixtepeji) from the State of Oaxaca are traditionally organized for the use, management, and conservation of the communal forest. This traditional organization is called "Pueblos Mancomunados" (Community of towns). Several communities have been there for centuries, indicating that the use of their forest has already been reasonably sustainable. This has recently been certified by foreign companies, which allow communities to export their forest products. Since 1994, before the rainy season, private trade companies have approached the community of towns to make a formal offer about matsutake regional use and prices. Representatives from each community select the highest bidder, and make a legal arrangement for the season.

Fresh matsutake mushrooms are gathered early in the morning within the communal forest, by one or more members (older than 16 years) from every RHS participating in the journey. All members should be formally recorded within the traditional organization. Initially (1994-1995), there were many RHSs (*ca*. 40) carrying out daily this activity; however, nowadays the amount of RHSs involved has reduced by 70%. In the perception of mushroom gatherers, this can be due to a reduced rainy season affecting forest and mushroom productivity. There has been accordingly a higher competition between RHSs and a stronger effort to gather matsutake mushrooms.

A dealer from the company normally called at the community in the afternoon. Mushrooms are brought to every community for being slightly cleaned with a brush, selected, classified, and weighed by a dealer from the foreign private company (**Fig. 3A**). Fruit-body spoilage due to improper handling and transportation is avoided. During weighing, a representative (indigenous Zapotec or peasant) from the community recorded the amount and type of matsutake gathered by members from every RHS (**Fig. 3B**). There are three main classes: 1) Top quality (young fruit bodies having closed caps and lamellae covered by the veil); 2) Second class (mature fruit bodies with partially opened caps); and 3) Third class (mature fruit bodies with completely opened caps). Mushrooms are then sorted out onto an absorbent cloth within polystyrene boxes closed with a lid; normally two layers, separated by a paper (**Fig. 4A**). Fruit bodies are arranged in such a way that overlapping and excessive damage is avoided (**Fig. 4B-C**).

Fig. 3A-B. Traditional marketing of matsutake mushrooms (*Tricholoma magnivelare*) in Oaxaca, Mexico. A: Gatherers (indigenous Zapotecs and/or peasants) take fresh mushrooms to the community for being cleaned, selected, classified, and weighed by a dealer from the foreign private company. B: During weighing, the amount of mushrooms picked by each gatherer is recorded by a representative from the community (Photos: H. León).

All these activities are normally carried out in the same day. Finally, private companies take selected and packed Mexican matsutake mushrooms out of the community. Later, they make a further packing and cooling for selling matsutake at high prices in the international markets (mainly Japan).

The representative from the community of towns, after dealing with the foreign private company, is also in charge to pay to all RHSs involved a few days later, according to the amount of mushrooms gathered initially. Every member from a RHS pays about 10-12.5% of his total incomes to the representative for "derecho de monte" (the right to use the communal forest). This payment is later used for satisfying diverse community needs. A kilogram of top quality matsutake varies from USD $ 45.00-50.00, while second class ranges from USD $ 20.00- 25.00, and third class from USD $ 10.00-15.00.

In the case of those mushrooms which cannot be sold due to its lower quality, the trade company advises the RHSs to keep them in brine (**Fig. 5**). These companies normally come back to the community out of season, in order to buy matsutake in brine. Other RHSs use matsutake mushrooms of lower

Fig. 4A-C. Traditional marketing of matsutake mushrooms (*Tricholoma magnivelare*) in Oaxaca, Mexico. A: Classified mushrooms are carefully placed into polystyrene boxes. B-C: Top quality matsutake consists of young fruit bodies having closed caps and lamellae covered by the veil. All boxes containing classified mushrooms are directly sold to the dealer (Photos: H. León).

Fig. 5. Rural processing of lower quality matsutake mushrooms preserved in brine (*Tricholoma magnivelare*) in Oaxaca, Mexico (Photo: H. León).

quality for own consumption, although their main objective is to get incomes.

Mushrooms and the community

In Oaxaca, most RHSs have developed subsistence strategies to cope with their own daily living under conditions of poverty (**Fig. 6**). These sustainable strategies are complex processes involving social, ecological, and economical factors determined by community, regional, or global systems with which the RHS interacts directly or indirectly. Those RHSs that gather matsutake from the communal forest are normally integrated by three main subsystems, as follows: 1) Family members (organization, life circumstances); 2) Conventional agricultural activities (crop plants, livestock); and 3) Extra-agricultural activities [utilization of the forest (firewood, timber products), gathering of wild edible mushrooms, the making of produces (coal, bricks), trading, labouring]. Thus, one or several family members from most RHSs gather matsutake mushrooms as an extra-agricultural activity for obtaining monetary (money provided by the main RHS activities), complementary (money provided by supplementary RHS activities), or potential (not monetary but satisfy RHS needs, such as food crops cultivated for own consumption) incomes to satisfy their basic household needs [11]. In fact, at present, matsutake mushrooms are the non-timber product gathered in the forest with the highest commercial value. There are several RHSs, whose economic situation is better and, accordingly, they gather matsutake exclusively for obtaining monetary incomes. Communities are organized for, as far as possible, promoting social equity amongst RHSs, for avoiding internal competition between RHSs, for controlling over-exploitation, and for dealing with private traders. In this way, matsutake mushrooms reach profitably the global markets.

A flexible social organization allows communities to react swiftly to a new non-timber product of high commercial value. RHSs have assimilated the gathering of matsutake for obtaining different sorts of incomes. Although this activity has social and economic benefits for the RHS, its ecological impact remains to be assessed thoroughly as population density increases in the region, and matsutake mushrooms may fetch higher prices becoming more attractive for gathering.

Mushroom processing

After gathering and packing, 3.430 kg of fresh matsutake mushrooms were taken to the laboratory. Fruit bodies had different stages of development, their pileus diameter varied from 1.5-11 cm (**Fig. 7A-B**). Weight loss during transportation by car (*ca*. 6 h)

was only 0.4% (14.5 g). Main characteristics of fruit bodies are shown in **Table 2**. The presence of residual soil or plant debris (2.6-5.6%), as well as larval damage (0.1%), was low in comparison with other wild mushroom species commonly sold in popular markets [8]. The moisture content of fruit bodies was 87.7%. Their pH was 6.4, the same as that from *Amanita caesarea* and within the range (5.7-6.8) reported for other wild and cultivated mushrooms. This pH raises up to 7.1 after blanching, although most wild mushrooms show a pH range from 6.2-6.8 (**Table 3**).

Main changes of matsutake mushrooms

Table 2. Characteristics of the matsutake mushrooms gathered in Oaxaca, Mexico.

Stage of development	N	W (kg)	A (%) S	A (%) L
Button	5	0.107	2.6	0.0
Young (closed cap)	20	1.342	5.6	0.1
Mature	11	1.966	4.6	0.0

N= Number of fruit bodies studied. W= Fresh weight. S= Residual soil or plant debris. L= Larval damage or insects. A= Appearance.

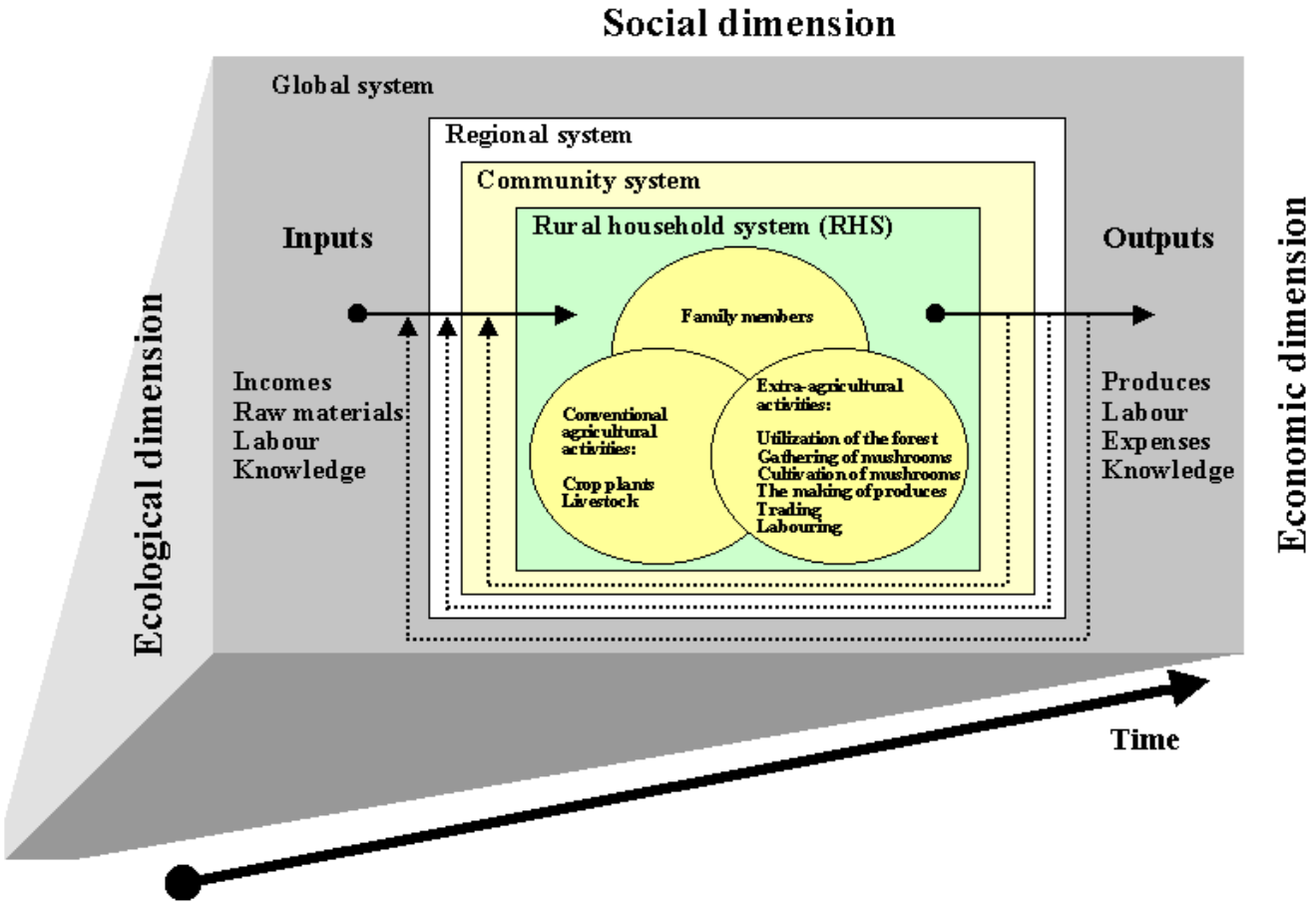


Fig. 6. Mushroom gathering as an extra-agricultural activity integrated within rural household systems (RHSs) from communities of Oaxaca, Mexico.

processed by different methods are shown in **Table 4** and **Fig. 8A-C**. Freeze-dried matsutake, represented 8.8% from the initial weight. Their morphological appearance was very good, but their aroma is practically lost. The experimental production of 1 kg of freeze-dried matsutake requires about 11.3 kg of fresh mushrooms.

During the process of freezing, mushrooms lost 8.1% of their initial weight, after handling, preselection, and blanching (4.66 h). It took 1.17 h for fruit bodies (919 g) to reach 0 C, and additional 7.42 h to reach -27 C (**Fig. 9A**). This temperature was maintained for 24 h, and then stabilized at -20 C for 214 days. After

Fig. 7A-B. Fruit bodies of Mexican matsutake mushrooms (*Tricholoma magnivelare*) from Oaxaca, Mexico. A: Main stages of development. B: Longitudinal section.

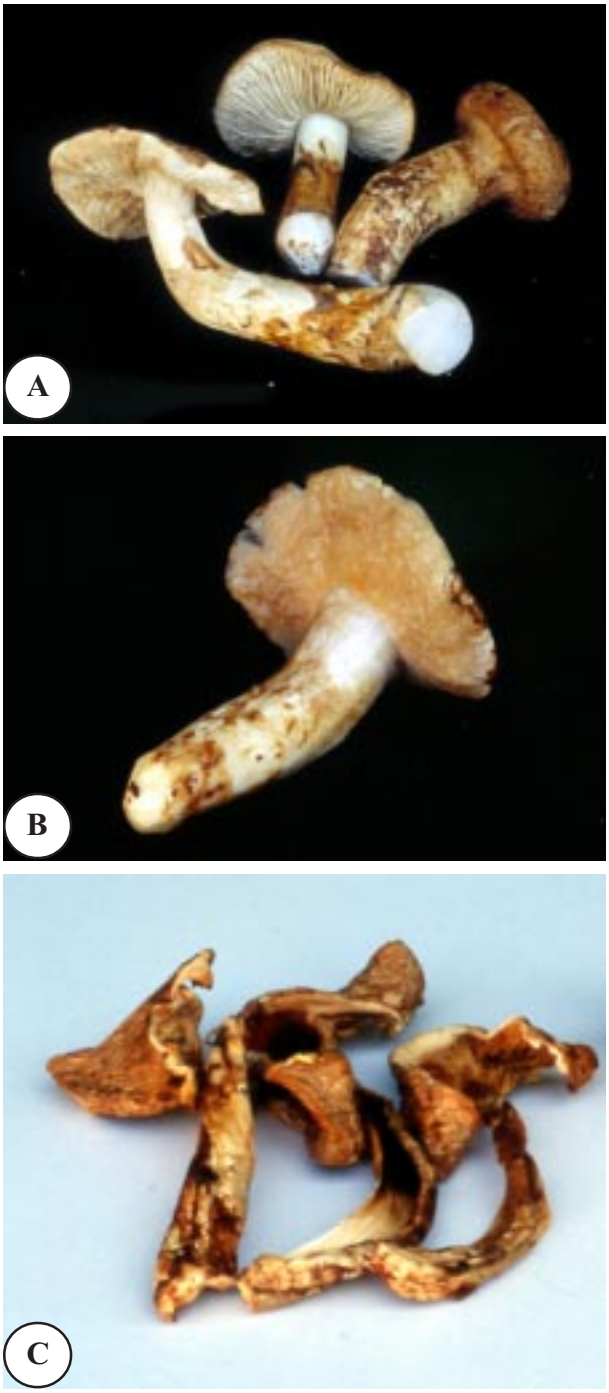


Fig. 8A-C. Fruit bodies of matsutake mushrooms (*Tricholoma magnivelare*) from Oaxaca, Mexico, processed by different methods. A: Freeze-drying. B: Freezing (after 7 months). C: Drying.

this period, frozen mushrooms weighed 824.5 g, indicating a weight loss of 10.3%. This change can be due to a loss of fruit-body exudates during freezing. Unfreezing was carried out at room temperature (25.5-27 C), taking 0.2 h for the fruit bodies to reach 0 C, and additional 6.13 h to reach 22 C (final weight: 516.2 g) [**Fig. 9B**]. After about seven months of freezing (214 days), fruit bodies kept a pleasant aroma, the pH varied from 7.1 (fresh) to 6.2, although there was a loss of texture, and a total weight loss of 48.4% (*i.e.*, about 1.9 kg of fresh mushrooms are needed to obtain 1 kg of frozen matsutake).

Fruit bodies processed by drying only lost 3.7% of weight after handling and preselection. These fruit bodies were sliced up and dried following an initial drying period (45 C for 3 h), a main drying period (50 C for 12 h), a final drying period (55 C for 3 h), and a finishing drying period (60 C for 2 h). Dry slices (30 C) were placed into polypropylene plastic bags, and sealed. Total weight loss was of 95.5% (*i.e.*, about 22.2 kg of fresh mushrooms are needed to obtain 1 kg of dry matsutake), and there was also a loss of the original aroma (**Fig. 10**).

In the case of canning, fresh and unfrozen mushrooms were used. Fresh mushrooms lost 9.7% of their initial weight due to handling,

Table 3. Average pH from the Mexican matsutake in comparison with those from other wild or cultivated edible mushrooms, either fresh or after blanching.

Species	Fresh mushrooms		Mushrooms blanched	
	Sample (g) + H_2O (ml)[c]	pH[a]	Sample (g)	pH[b]
Tricholoma magnivelare	30	6.4	30	7.1[a]
Amanita caesarea[8]	29 + 5	6.4	27	6.6
Amanita rubescens[8]	28	5.7	25	6.4
Boletus edulis[8]	29 + 10	6.2	27	6.3
Laccaria laccata[8]	29 + 15	6.8	27	7.1
Lactarius indigo[8]	27	6.2	26	6.5
Lyophyllum decastes[8]	40	6.6	32	6.6
Ramaria flava[8]	28	6.1	31	6.2
Russula brevipes[8]	28 + 20	6.3	27	6.3
R. brevipes attacked by *Hypomyces lactifluorum*[8]	28 + 10	6.5	29	6.8
Pleurotus ostreatus	30	6.2	30	6.6

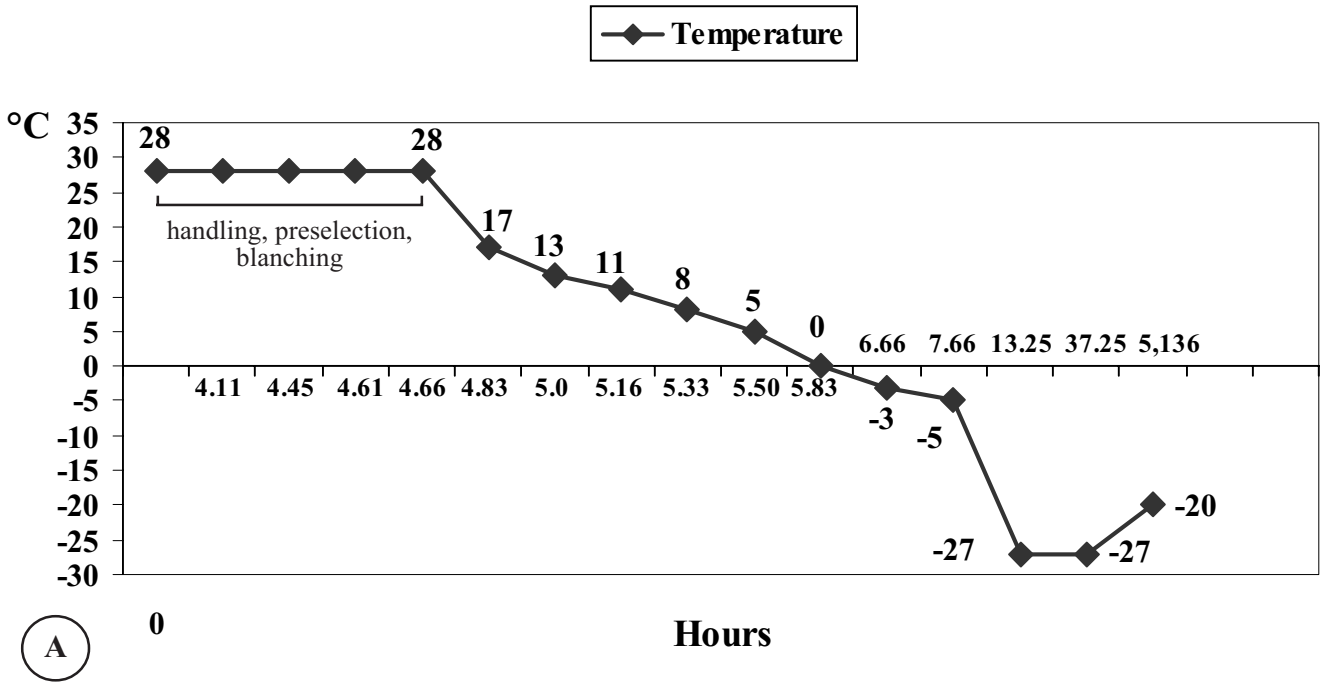
[a] Average from three replicates.
[b] Average from two replicates.
[c] Distilled water was added.
8 Source: Martínez-Carrera *et al*.

preselection, and blanching. This is a small loss in comparison with other wild edible mushrooms, which vary significantly from 24-60%. After blanching, matsutake mushrooms were cooked and sterilized along with other ingredients to make the recipe: "jalapeño" peppers (*Capsicum*), vinegar, carrots (*Daucus*), onions (*Allium cepa*), vegetable oil, garlic (*A. sativum*), salt, oregano (*Origanum*), olive oil, laurel (*Laurus*), thyme (*Thymus*), black pepper (*Piper*), and water. A cost-benefit analysis indicated a production cost of USD $ 15.44 per jar, with an estimated market value of USD $ 30.88 (**Table 5**). Although the value added to fresh matsutake mushrooms reached 184%, these prices are higher in comparison with other wild and cultivated mushrooms whose production costs range from USD $ 0.62-1.00 per jar. Likewise, after food stabilization, the final pH was 3.9 for the canned product, which is similar to that recorded for other wild and cultivated

Table 4. Weight losses during the processing of Mexican matsutake, in comparison with those from other wild edible mushrooms used for canning.

Mushroom species	IW	IP	Weight losses (kg)			FW		FP
	(kg)	(USD/kg)	Ps	B	T	kg	%IW	(USD/kg)
Freeze-drying:								
Tricholoma magnivelare	0.136	$ 50.0	0.006	-	0.006	0.012	8.8[a]	568.1
Freezing:								
Tricholoma magnivelare	1.0	$ 50.0	0.036	0.045	0.081	0.516	51.6[a]	96.8
Drying:								
Tricholoma magnivelare	1.0	$ 50.0	0.037	-	0.037	0.045	4.5[a]	1,111
Canning:								
Tricholoma magnivelare (fresh)	0.885	$ 50.0	0.068	0.017	0.085	0.800	90.3[b]	55.4
Amanita caesarea[8]	5.930	$ 3.0	0.622	1.246	1.868	4.062	68.4[b]	3.96
Amanita rubescens[8]	1.923	$ 1.0	0.294	0.176	0.470	1.453	75.5[b]	1.24
Boletus edulis[8]	2.050	$ 3.0	0.775	0.187	0.962	1.088	53.0[b]	4.41
Laccaria laccata[8]	0.550	$ 1.0	0.157	0.059	0.216	0.334	60.7[b]	1.39
Lactarius indigo[8]	0.360	$ 1.0	0.088	0.019	0.107	0.253	70.2[b]	1.30
Lyophyllum decastes[8]	4.060	$ 1.0	1.210	0.931	2.141	1.919	47.2[b]	1.53
Ramaria flava[8]	1.280	$ 1.0	0.470	0.293	0.763	0.517	40.3[b]	1.60
Russula brevipes[8]	7.190	$ 1.4	4.204	0.050	4.254	2.936	40.8[b]	2.23
Russula brevipes attacked by *Hypomyces lactifluorum*[8]	0.840	$ 1.4	0.102	0.169	0.271	0.569	67.7[b]	1.85

IW= Initial weight. IP= Initial price in the community or a popular market. FW= Final weight. FP= Final price (USD/kg), before or after mushroom processing. Ps= After handling and preselection of mushrooms suitable for processing. B= After blanching. T= Total weight loss. %IW= Percentage of mushrooms as a proportion of the initial weight. **8** Source: Martínez-Carrera *et al*. [a] = After mushroom processing. [b] = Before mushroom processing.



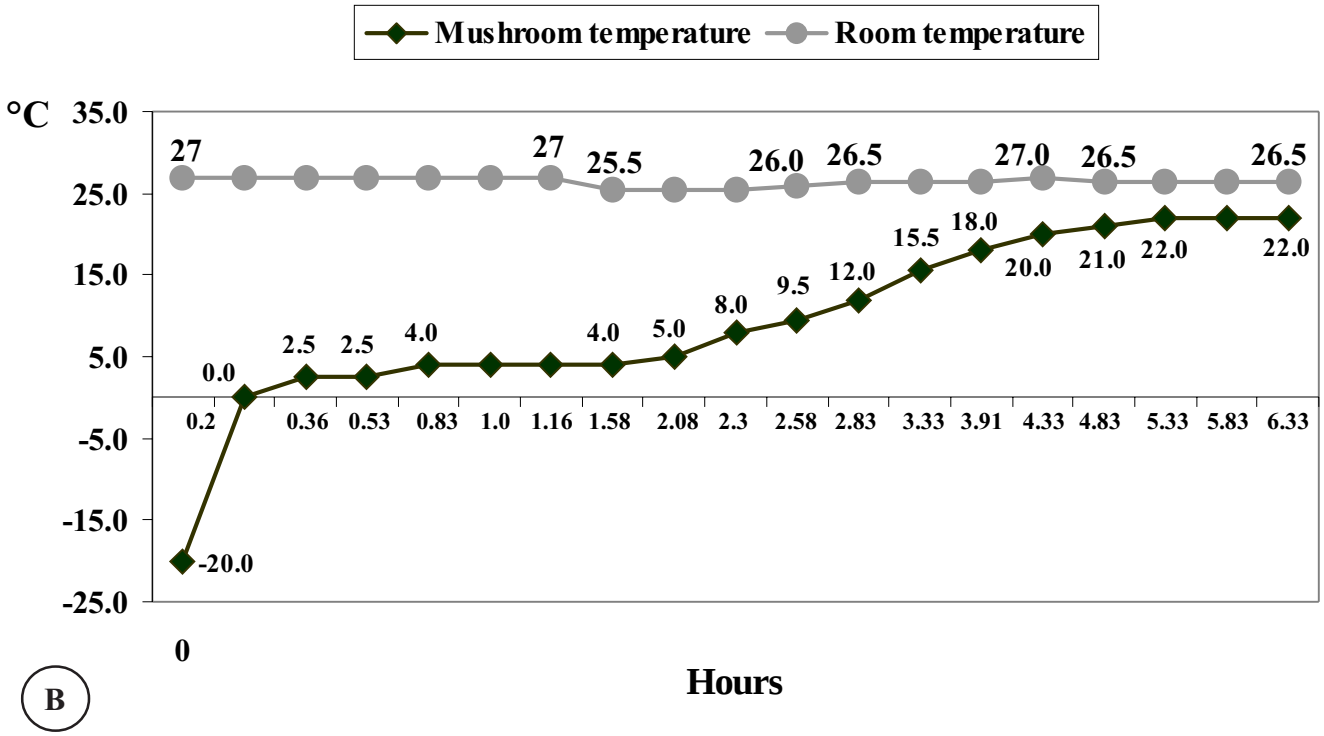


Fig. 9A-B. Temperatures reached by fruit bodies from Mexican matsutake mushrooms (*Tricholoma magnivelare*) which were frozen using a selected freezing level. A: Freezing. B: Unfreezing.

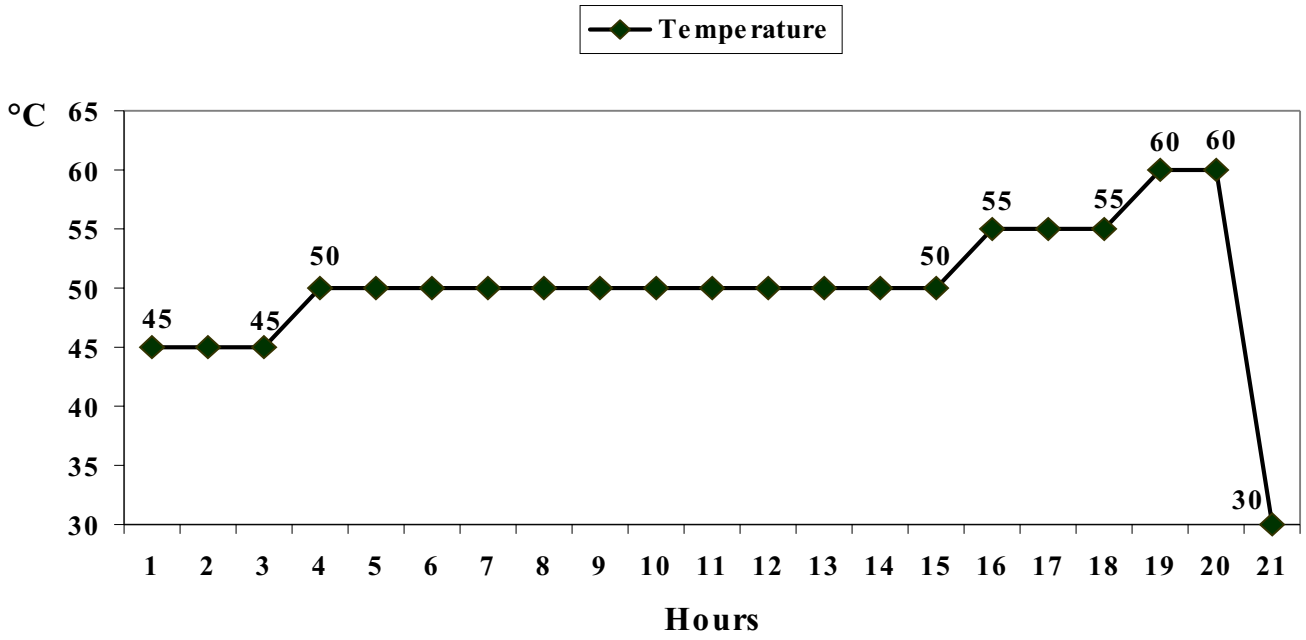


Fig. 10. Temperatures used to dry fruit bodies from Mexican matsutake mushrooms (*Tricholoma magnivelare*), using selected drying periods.

mushrooms (**Table 6**). This acidity standard showed that unfrozen matsutake mushrooms can also be used as raw material for canning, generating a product which is microbiologically stable and safe (**Fig. 11**).

The comparative nutrition facts of the recipe studied are shown in **Table 7**, indicating a low content of calories, and good content of proteins (1 g), carbohydrates (6 g), vitamins A and C, and dietary fiber (0.5 g).

In general, the processing methods studied provide useful information for developing alternative commercial products based on matsutake mushrooms, or other wild mushrooms. Some methods, such as canning, can be developed in rural communities according to standard regulations [11]. Studies on other technologies are in progress, such as modified atmosphere packaging. Although several methods can be used to process matsutake mushrooms to make them available throughout the year, their natural aroma, taste, and texture are diminished or even lost. In this case, mushrooms must be marketed differently promoting consumption in other regions, as Japanese people value matsutake fresh because of the odour. Other preservation methods, conversely, may highlight certain culinary properties. Diverse alternatives can be made available in due course for new consumers worldwide.

Remarks and prospects

In general, the traditional use, management, and conservation of wild edible mushrooms by Mexican rural communities follow different strategies from the ecosystem management philosophy carried out in the U.S.A. Several social and economic aspects of mushroom gathering between both regions are contrasted in **Table 8** [7, 11, 13]. Traditional gatherers in Mexico belong to a local culture, normally represented by indig-

enous people and/or peasants (around 60 ethnic groups distributed all over the country). They make use of remote communal forest regions lacking good facilities and infrastructure. Community organization permits the use and management of timber and non-timber forest products by RHSs. In the U.S.A., gatherers are multi-cultural (native Americans, European settlers, Latin American and Asian immigrants), who make use of public (federal, state) and private lands having camping and sanitation facilities, traffic safety, roads, bridges, and trails. The use and management of this land is determined by forest managers, government regulations and permits.

Traditional gatherers actually live within forest regions, and their knowledge is passed from one generation to another. They are mainly devoted to primary activities (agricultural and extra-agricultural), and there is a division of labour within the RHS. Men and their sons are normally involved in mushroom gathering, while women are usually devoted to household activities, such as choosing, cleaning, cooking, and marketing of wild mushrooms. This condition, however, appears to have recently been changing, as most adult men in rural communities are moving or emigrating towards urban areas or foreign countries, looking for better opportunities. Women are thus getting more involved in agricultural and extra-agricultural activities (*e.g.*, mushroom gathering) performed outside their house.

Gatherers (commercial harvesters,

Table 5. Cost-benefit analysis (USD) from canning the Mexican matsutake in comparison with those from other wild and cultivated edible mushrooms using the recipe "hongos silvestres en escabeche" (HSE). This analysis was carried out considering the minimum cost-benefit ratio of 2.0 [8].

Mushroom species	N	Production cost per jar	Market value	Gross incomes	Profits	Value added (%)
Tricholoma magnivelare (fresh)	45	15.44	30.88	1,389.6	694.8	184.6
Amanita caesarea[8]	45	0.96	1.92	86.40	43.20	197.1
Amanita rubescens[8]	45	0.62	1.24	55.80	27.90	406.7
Boletus edulis[8]	45	1.00	2.00	90.00	45.00	184.4
Laccaria laccata[8]	45	0.64	1.28	57.60	28.80	374.5
Lactarius indigo[8]	45	0.62	1.24	55.80	27.90	388.0
Lyophyllum decastes[8]	45	0.66	1.32	59.40	29.70	351.0
Ramaria flava[8]	45	0.67	1.34	60.30	30.15	340.6
Russula brevipes[8]	45	0.74	1.48	66.60	33.30	269.8
R. brevipes attacked by *Hypomyces lactifluorum*[8]	45	0.70	1.40	63.00	31.50	307.6
Pleurotus ostreatus[8]	45	0.67	1.34	60.30	30.15	340.6

N= Number of jars. [8] Source: Martínez-Carrera *et al*.

Table 6. Average pH from the Mexican matsutake canned in glass containers using the recipe "Hongos silvestres en escabeche" (HSE), in comparison with those from other wild and cultivated edible mushrooms.

Species	pH[a]
Tricholoma magnivelare (fresh, unfrozen)	3.9
Amanita caesarea[8]	3.8
Amanita rubescens[8]	3.8
Boletus edulis[8]	3.8
Laccaria laccata[8]	3.7
Lactarius indigo[8]	3.6
Lyophyllum decastes[8]	3.9
Ramaria flava[8]	3.7
Russula brevipes[8]	3.8
R. brevipes attacked by *Hypomyces lactifluorum*[8]	3.9
Pleurotus ostreatus	3.8

[a] Average from three replicates, data taken 45-91 days after canning.
[8] Source: Martínez-Carrera *et al*.

Fig. 11. Fruit bodies from Mexican matsutake mushrooms (*Tricholoma magnivelare*) processed by canning following a Mexican recipe.

recreationalists, unemployed workers, immigrants, individuals working in the forest and timber industry, native people, eco-tourists) from the U.S.A. are devoted to diverse rural and urban activities, and generally live in nearby towns or cities. For this reason, their knowledge system about wild mushrooms may be fragile as people drop out. Men (65%) and women (35%) do participate in mushroom gathering, basically as an individual activity following ethnic patterns.

Mushroom gathering in Mexican rural communities is mainly carried out as an extra-agricultural activity, associated to other gathering activities (*e.g.*, firewood, medicinal plants, various timber and non-timber products), as an overall subsistence strategy within the RHS. In fact, rural communities traditionally make use of more than 112 species of wild mushrooms from their communal assets during the rainy season. The average period devoted to mushroom gathering by RHSs is 31.5 days per year. An adult peasant can pick about 6.3 kg of wild mushrooms in a typical journey (8 h; 21-26 km in a day, on foot). Accordingly, RHSs can obtain monetary, complementary, or potential incomes to

Table 7. Nutrition facts from the Mexican recipe named "Hongos silvestres en escabeche" (HSE). Estimated composition of the wild edible mushroom studied was based on FDA values[20].

Composition	Content [a]		HDR
	HSE[b]	FDA	
Total calories	50	15	
Calories from fat	25	10	
Total fat	3 g	0.9 g	< 65 g
Saturated fat	0.5 g	0.5 g	< 20 g
Cholesterol	0 mg	0 mg	< 300 mg
Sodium	490 mg	147 mg	< 2,400 mg
Total carbohydrate	6 g	1.8 g	300 g
Dietary fiber	0.5 g	< 0.5 g	25 g
Sugars	5 g	2 g	
Proteins	1 g	0 g	50 g[c]
Vitamin A	15%[d]	4%	5,000 IU
Vitamin C	30%[d]	10%	60 mg
Calcium	1.8%[d]	< 2%	1 g
Iron	6%[d]	2%	18 mg

[a] Calories per gram: fat, 9; carbohydrates, 4; protein, 4.
[b] Content in 100 g.
[c] Daily reference value for adults, and children (4 years old or more).
[d] Percent daily values are based on a 2,000 calorie diet.
HDR= Human daily requirements (2,000 calorie diet).
FDA= According to Food and Drug Administration labelling regulations in the U.S.A., considering a serving size of 30 g for HSE. IU= International unit.

satisfy their basic household needs. It has been estimated that mushroom gathering represents up to 19.2% from overall incomes obtained from agricultural and extra-agricultural activities.

By contrast, in the U.S.A., mushroom gathering has a strong recreational and commercial orientation, in which monetary incomes are predominately involved. Gatherers are mainly focused on harvesting more than 20 mushroom species, devoting 25.8 days per year to this activity. A gatherer can pick about 6.7 kg of wild mushrooms per day (6.3 h; vehicles used).

It is interesting to show that the amount of mushrooms gathered in both countries are similar, despite gatherer's strategies, as well as social and economic circumstances, are completely different. These data indicate that the ecological impact of mushroom gathering would appear to be equivalent in other regions of the world. Mushroom gathering is also highly heterogeneous, as Mexican gatherers traditionally visit 2-10 different places in a day, picking around 0.5-6.0 kg at each site when mushrooms are found [11].

Social, economic, and land tenure systems prevent rural communities and government authorities from establishing conventional measures for mushroom conservation (*e.g.*, to define forest reserves, to close forest regions to the public, the control of picking, and the legal protection of edible species gathered). Rural communities will, accordingly, determine main trends of mushroom gathering by developing sustainable strategies on the traditional management, processing, and marketing of wild edible mushrooms. They have flexible social organizations, which have remained within forest regions for a long time.

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Table 8. Comparison of main social and economic factors associated to mushroom gathering between Mexico (developing country) and the U.S.A. (developed country).

Factor	Mexico [11]	U.S.A. [7, 13]
Social:		
Gatherer	Local culture (peasant and indigenous groups)	Multi-cultural (native Americans, European settlers, Latin American and Asian immigrants)
	Rural gatherers having traditional knowledge	Commercial harvesters, recreationalists, unemployed workers, immigrants, individuals working in the forest and timber industry, native people, eco-tourists. Local harvester knowledge is dynamic and may be fragile
	Men and boys (*ca*. 100%)	Men (65%), women (35%)
Mushroom gathering	Community organization	Forest managers, harvesters, regulations/permits
	Local household activity, division of labour	Mainly individual activity, ethnic patterns, local, commuter, and circuit harvesters
	Extra-agricultural activity normally associated to other gathering activities (firewood, timber, coal, medicinal plants), as an overall subsistence strategy within RHSs	Basically recreational and commercial
Average period devoted to gathering	31.5 days/year	25.8 days/year (chanterelles)
Hours spent gathering	8 h/day, on foot	6.3 h/day (chanterelles), vehicles used
Number of edible species usually gathered	>112	>20
Amount gathered	6.3 kg/day	6.7 kg/day (chanterelles)
Incomes	Monetary, complementary, potential (household consumption)	Monetary (commercial harvesters), personal use (recreational harvesters)
	Proportion from total RHS incomes: 0.2-19.2%	-
Economic:		
Land	Communal forest	Public (federal, state), private
Facilites, infrastructure	Weak, absent	Strong

RHS= Rural household system.

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