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Research paper

Ethnomycological survey of traditional usage and indigenous knowledge on desert truffles among the native Sahara Desert people of Algeria

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ABSTRACT

Ethnopharmacological relevance: Desert truffles are edible hypogeous fungi, highly appreciated by the inhabitants of hot-desert settlements. Native Saharan people use truffles for food, promoting tourism, increasing fertility, and treatment of eye diseases and fatigue.
Aim of the study: This study consists of a cross-sectional survey focusing on the knowledge, use and ethnomycological practices of desert truffles among the native people of the Algerian Northern Sahara.
Materials and methods: The study was conducted through direct interviews with 60 truffle-hunters in the regions of Ouargla and Ghardaia.
Results: Three species were harvested and consumed by the surveyed subjects: *Terfezia claveryi* was the most appreciated and most expensive species, followed by *Terfezia areanaria* moderately preferred, then *Tirmania nivea* the least appreciated and least expensive. Among the 60 interviewees, 90% rely on the abundance of symbiotic plants (*Helianthemum lippii*) to harvest truffles, 65% begin harvesting from mid-February to March, after rains of the autumn (38%) and winter (36%), particularly in the Wadi beds (37%) and Daya landscapes (32%). Interviewees harvested truffles mainly for home consumption; however 26.7% sell any harvest surplus, and of those only 15% generate significant revenue from this source, and 73% considered the sale of desert truffles to have low financial value. Desert truffles are used in traditional medicine, especially against eye infections (22%), weakness (19%) and to promote male fertility (19%). In the case of desert truffles for consumption, the surveyed population preferred to prepare the truffles with couscous and meat, or in porridge. Respondents used price as the main criterion for deciding whether to purchase desert truffles.
Conclusions: The surveyed trufflers use the knowledge passed from one generation to the next to help ensure a good harvest of truffles during each foray into the desert. Our findings highlight the various uses of truffles in the Sahara Desert, and how these relate to the lifestyle of local people.

1. Introduction

Desert truffles are the fruiting bodies of some edible fungi belonging to the phylum Ascomycota and the class Ascomyceta. They were long related to the order of Pezizales (Trappe, 1979) and it is only in modern classification they have been grouped under the order of Tuberales, which is classified into two families: Tuberaceae and Terfeziaceae that are represented by many genera, such as *Terfezia*, *Tirmania*, *Delastria*, *Balsamia*, *Mattirolomyces*, *Picoa*, *Phaeangium*, *Leucangium*, *Delastreopsis* and some species of *Tuber* (Ammarellou and Trappe, 2007; Kagan-Zur et al., 2014).

Desert truffles grow in arid and semi-arid lands, particularly in countries around the Mediterranean, especially in countries of Southern Europe including Spain, Portugal, Italy, France, Hungary and Turkey (Janex-Favre et al., 1988; El-Kholy, 1989; Gücin and Dülger, 1997; Ławrynowicz et al., 1997; Moreno et al., 2000), North Africa that extends from Mauritania to Egypt (Malençon, 1973; Bokhary, 1987; Khabar et al., 2001; Slama et al., 2006; Fortas, 2009), and the Middle East (Alsheikh and Trappe, 1983; Al-Ruqaie, 2002; Mandeel and Al-Laith, 2007). However, some species of desert truffles were also found in Botswana, South Africa (Marasas and Trappe, 1973; Trappe et al., 2008a; Kagan-Zur et al., 2014) and in North America (Trappe and Sundberg, 1977; Kagan-Zur et al., 2014).

Desert truffles live in mycorrhizal association with Cistaceae plants, especially of the genus Helianthemum and Cistus (Khanaqa, 2006). Their development in hot deserts occurs after the fall of rains

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heralding the end of winter and the beginning of the hot season, with a specific temporal distribution of rainfall amounts along the year (Bradai et al., 2015), but also depending on the type of soil and climate, and abundance of host plants (Kagan-Zur and Roth-Bejerano, 2008; Kagan-Zur et al., 2014). In general, the distribution of truffle species is closely linked to climatic and edaphic conditions (Kagan-Zur and Roth-Bejerano, 2008; Bradai et al., 2014, 2015). In Algeria, desert truffles mainly colonize habitats of the Steppe and the Sahara Desert (Fortas, 2009), and are represented by three genera *Terfezia*, *Tirmania* and *Picoa* (Zitouni, 2010). Moreover, their taxonomy, ethnomycology and ecology are very little studied, not only in Algeria but at North African scale (Volpato et al., 2013).

With regard to their nutritional value, the desert truffles are rich in various chemical compounds, including carbohydrates, proteins, amino acids, fiber, vitamins, minerals, sterols, terpenes and fatty acids, which embue them with a unique musky flavor that makes them taste very different from truffles of the genus of *Tuber* (Bokhary and Parvez, 1993; Omer et al., 1994; Hussain and Al-Ruqaie, 1999; Dabbour and Takruri, 2002a; Murcia et al., 2002). Desert truffles are highly appreciated by people of North Africa, Middle East and Gulf countries; they are even eaten raw in some areas. In Europe, several recipes, based on or having desert truffles as major constituent, are presented in high-class restaurants (Fortas and Chevalier, 1992; Slama et al., 2006; Fortas, 2009; Bradai et al., 2013).

In addition, desert truffles are an untapped source of therapeutic compounds with anti-inflammatory, immunosuppressants, anti-mutagenic and anti-carcinogenic characteristics (Hannan et al., 1989; Kagan-Zur et al., 2014). Besides, they have been proven to contain compounds with antioxidant and antiradical activities (Al-Laith, 2010).

Their popularity is not only due to their specific taste and nutritional value, but also to their therapeutic properties (Mandeel and Al-Laith, 2007; Kagan-Zur and Roth-Bejerano, 2008; Slama et al., 2010; Wang and Marcone, 2011; Kagan-Zur et al., 2014). Indeed, their chemical composition has been the subject of numerous studies that have demonstrated their richness in proteins, amino acids, fiber, fatty acids, minerals and carbohydrates (Ahmed et al., 1982; Alsheikh and Trappe, 1983; Bokhary et al., 1989; Bokhary and Parvez, 1993; Murcia et al., 2003). Truffles are also used as food sources to survive in arid regions where food is scarce (Harris and Mohammed, 2003; Boa, 2004; Benucci et al., 2012), since they contribute to the incomes of populations after sale or simple exchanges against other products (De Roman, 2010; Benucci et al., 2012).

At Northern Sahara of Algeria, three species of desert truffles have been identified: *Tirmania nivea* (Desf.) Trappe 1971, *Terfezia arenaria* (Moris 1829) Trappe 1971 and *Terfezia claveryi* Chatin 1892 (Bradai et al., 2014). In this region, local settlements consider desert truffles, regardless of the species, as the most highly appreciated hypogeous fungi due to traditional knowledge that is transmitted from one generation to another (Bradai, 2006). Moreover, Bedouins of the region rely on a wide range of natural products, mostly medicinal plants, in traditional medicine (Bensizerara et al., 2013). Through this investigative approach, we will try to qualitatively analyze the ethnological knowledge of desert truffles among the Aboriginal people of the Algerian Sahara Desert, through the emphasis of aspects related to practices of researching and harvesting desert truffles, their economic importance and their valorization in traditional pharmacopoeia.

2. Materials and methods

2.1. Study area

The present study was conducted in the Northern Sahara Desert of Algerian, including the regions of Mzab (Ghardaia) and Oued Mya (Ouargla) (Fig. 1). Both areas are subjected to extreme severe edaphic and climatic conditions of the Sahara. The main types of Saharan landscapes include expanses of sand dunes and desert pavements "Hamada and Reg". Habitats with alluvial soils and soil crusting are local phenomena (Ozenda, 1991).

The climate of the study area is hot hyperarid (desertic). It is characterized by low and erratic rainfall chiefly occurring in winter with annual isohyets that range between 50 and 100 mm. Average annual temperatures are high (~30 °C), with absolute maxima exceeding 50 °C in July–August and minimum temperatures in January ranging from 2 to 9 °C (Bradai et al., 2013, 2015).

The people have multiple ethnical origins: Berber, Arab, African and mestizos from mixed marriages. The main activity of the population typically is oasis agriculture, which is mainly based on the cultivation of date palm (*Phoenix dactylifera*) associated with underlying crops, and the extensive livestock farming of camel in the large Saharan pastoral areas.

In both regions, a pilot-community was chosen to conduct the survey: (i) the locality of Metlili (32°16′N, 03°37′E) lies approximately at in the center of the Algerian Sahara, at 40 km south-east of the province Ghardaia, and (ii) the location of Rouisset (31°26′N, 05°40′E) lies about 12 km south of the capital of the province of Ouargla.

2.2. Data collection

2.2.1. Description of species of desert truffles

The three species of truffles: *Terfezia claveryi* (Chatin), *Terfezia arenaria* (Morris. Trappe) (Terfeziaceae) and *Timania nivea* Desf. Trappe (Pezizaceae) are common in the Northern Sahara. Their main characteristics are shown in Table 1. According Bradai et al. (2014), these three species live in symbiosis with *Helianthemum lippii* (Cistaceae) in sandy soils of the Northern Sahara where ascocarps appear from early February until mid-April. Most ascocarps were produced at soil depths less than 60 mm. *Tirmania nivea* is the most common species in different sites producing desert truffles, while *Terfezia arenaria* and *Terfezia claveryi* are considered rare (Table 1).

2.2.2. Survey and questionnaire

A preliminary investigation lasting two weeks (from late February to early March 2014) was carried out to test the questionnaire prepared to that effect. The collection of specimens and

Fig. 1. Location of the study sites (Ouargla and Ghardaia) in the Sahara Desert of Algeria.

Table 1
Principal characteristics of the truffle species identified during ethnomycological study in the Northern Sahara of Algeria (Adapted according to Bradai et al. (2014)).

Characteristics	Species of desert truffles		
	Tirmania nivea (Desf. Trappe)	*Terfezia areanaria* (Morris. Trappe)	*Terfezia claveryi* (Chatin)
Local name	*Terfesse Labyadh*	*Terfesse Lahmar*	*Terfesse Lak'hal*
Color	White	Brown	Black
Size (mm)	40 × 105	50 × 120	45 × 100
Average weight (g)	59.29 ± 17.09	64.67 ± 16.30	62.93 ± 12.01
Soil depth of ascocarps (mm)	49.2 ± 12.1	50.4 ± 09.3	54.6 ± 07.6
Onset period (ascocarps fruiting)	Early February	Early February	Early February
Abundance	Very common	Uncommon	Rare
Symbiotic plants	*Helianthemum lippii* (locally called El-Reguigue)		

ethnomycological data gathered all information about desert truffles of the Northern Sahara of Algeria, namely: truffle species, their characteristics, their ecology, harvesting methods, storage and preservation, feeding, sale, and forms of usage in traditional medicine.

The ethnomycological survey was conducted among the native people of Northern Sahara, who have carried out at least three annual fieldtrips to search for desert truffles during the past five years. Direct interviews were conducted with 60 experts and truffle researchers "truffle hunters", after obtaining prior informed consent, during the period of collection and sale of desert truffles (March–April 2014) in the study area. These people were equally distributed over the two study regions of Ghardaia and Ouargla (Fig. 1).

This cross-sectional survey aimed to seek information about the importance of truffles in the diet of people and their different uses, and to try to guage their level of knowledge about these fungi. In fact, the study mainly targeted males of different ages, education levels and with different lifestyles. In addition, the questionnaire was designed to collect data on various aspects related to the usage of desert truffles. It included these topics:

- time and duration of the search for truffles;
- number of annual fieldtrips conducted to search for truffles;
- selection criteria of truffle grounds, namely geomorphology or landscape type, the abundance of host plants, and indices used by other trufflers;
- weight and number of ascocarps harvested and amount of truffles harvested by fieldtrip;
- methods of truffle storage (preservation);
- usage of harvested truffles: consumption or sale and economic benefit; and
- feeding habits and therapeutic uses of harvested truffles in the traditional pharmacopoeia.

2.3. Data analysis

The frequency of responses was computed as the percentage of respondents rounded to the total of surveyed people. Pearson's Chi-squared test (χ^2) was performed to test the statistical significance of differences between groups of each surveyed variable. All statistical tests were carried out using the statistical software R (R Development Core Team, 2014).

3. Results and discussion

3.1. Characteristics of the interviewed subjects

The analysis of socio-demographic data of the subjects by the χ^2 test showed that the respondent groups significantly differed between age classes ($\chi^2=16.27$, $P=0.023$), educational levels ($\chi^2=11.8$, $P=0.038$), functions ($\chi^2=31.93$, $P<0.001$), and lifestyles ($\chi^2=45.07$, $P<0.001$). The search of truffles was mainly done by respondents aged between 25 and 45 years (66.7%) and also the 50–55 age class (20%), but only 8.8% of respondents were above 55 years of age. It is obvious that exploring remote desert areas for tens of days whilst searching for desert truffles represents a difficult task for elderly subjects, even in the presence of transportation adapted to desert terrain. As for the education level of respondents, the high school category prevailed with 26.7%, followed by students of Koranic school with 23.3%, then primary school level (18.3%), middle school level (16.7%), and university graduates with 10% and 5% were illiterate. The respondents who sought most desert truffles in the Northern Sahara were land-farmers (28.3%), employees (26.7%) and traders (21.7%). Stock-farmers and entrepreneurs accounted for 10% while civil servants and retirees participated only with 1.7%. Additionally, the majority of the questioned truffle-hunters had a sedentary lifestyle (93%), while the semi-nomadic subjects represented only 7% (Table 2).

3.2. Level of knowledge about desert truffles

Information relating to the level of knowledge about desert truffles in the studied populations are summarized in Table 3. At first glance, based on the parameters chosen for this study, there was a highly significant difference in the information provided by interviewed subjects.

The Chi-square test revealed that the distribution of subjects according to season duration of searching for truffles differed significantly ($\chi^2=28.30$, $P<0.001$), with 65% of respondents opting for an average searching period from mid-February to March, and 23.3% for long period (late January–March), and 11.6% for the short period lasting from late February to March (Table 3A). As for the time of searching for desert truffle during each fieldtrip, 68.3% of the studied subjects spent less than one week in the desert, 25% spent a period of 1–2 weeks and only 6.7% of respondents stated that they spend more than two weeks in the field. The number of respondents differed significantly ($\chi^2=36.10$, $P<0.001$) between these three periods (Table 3B). The same applies to the number of harvests conducted per truffle season ($\chi^2=36.33$, $P<0.001$), where the majority of surveyed subjects (41.7%) opted for two harvests per year, whereas 33% carried out one harvest and 18% of subjects performed three harvests per truffle season. Few people conduct four (5%) or five (1%) harvests per year (Table 3C).

Compared to Bahraini people, the truffle-harvesting season usually occurs during January–February in 50% of trufflers (Mandeel and Al-Laith, 2007). This period lasts for about 2–3 weeks, mainly in early spring (Bokhary, 1987). While Volpato et al. (2013) reported that Sahrawi refugees and nomads harvest truffles in Western Sahara during a broad season that ranges between November and April, with a peak from January to March.

Among the criteria, related to the type of landscapes, used by trufflers for selecting truffle-harvesting sites in the Northern Sahara,

Table 2
Demographic characteristics of the surveyed truffle-hunters living in the Algerian Sahara Desert.

Parameters	Number	%	χ^2	*P*-value
Age (Years)	*N*=60		16.27	0.023
25–30	9	15.0		
30–35	12	20.0		
35–40	10	16.7		
40–45	9	15.0		
45–50	3	5.0		
50–55	12	20.0		
55–60	2	3.3		
60–65	3	5.0		
Education	*N*=60		11.8	0.038
Illiterate	3	5.0		
Quran school	14	23.3		
Primary school	11	18.3		
Secondary school	10	16.7		
High school	16	26.7		
University graduate	6	10.0		
Function	*N*=60		31.93	<0.001
Land-farmer	17	28.3		
Stock-farmer	6	10.0		
Employee	16	26.7		
Trader	13	21.7		
Entrepreneur	6	10.0		
Civil servant	1	1.7		
Retired	1	1.7		
Lifestyle	*N*=60		45.07	<0.001
Sedentary	56	93.3		
Semi-sedentary	4	6.7		

37% of respondents distinguished Wadi beds, followed by Dayas (32%), Ergs (16%), and only 4% for Regs (Table 3D), with a significant difference between these types of desert landscapes ($\chi^2=86.69$, $P<0.001$), whereas 7% of the surveyed subjects had not submitted a specific preference about landscapes of truffle sites.

According Mandeel and Al-Laith (2007), sites where desert truffles grow need to be far from anthropogenic activities and disturbances, and have a topography that allows the accumulation of rainwater. This is in accordance with landscape preferences of native people of Northern Sahara, where truffles are abundant in Dayas and Wadi beds. In contrast, desert truffles are not commonly observed in heavy clay soils and rocky plateaus as Hammada. This specific choice of truffle sites reflects trufflers' traditional knowledge with regard to edaphic characteristics of habitats producing desert truffles abundantly (Kagan-Zur and Roth-Bejerano, 2008; Bradai et al., 2014).

Furthermore, our results show that 90% of subjects do their truffle searching where host plants (*Helianthemum* spp.) abound, while only 10% do not take this criterion into account (Table 3E) The Chi² test revealed a significant difference between groups of respondents about using of symbiotic plants in searching for desert truffle ($\chi^2=38.40$, $P<0.001$). Moreover, the majority of respondents (88%) used indications of other truffle collectors to ride towards truffle sites, whereas 12% of subjects select harvesting sites based on their own information and knowledge ($\chi^2=33.38$, $P<0.001$, Table 3F). Obviously most trufflers (85%) returned to almost the same sites where they had a good harvest the previous year ($\chi^2=29.40$, $P<0.001$, Table 3G). This finding proves a good knowledge of the geography of the Algerian Sahara while searching of desert truffles. Indeed, similar results were observed with Sahrawi refugees in the Western Sahara (Volpato et al., 2013). Once the Bedouins discover a site of desert truffles, they mark it for future regular visits. Because they know that truffles, once installed in a favorable habitat, will regenerate spontaneously after rainfall.

This is obvious because elderly and experienced people have always played a crucial role in preserving traditional knowledge and socio-cultural information by passing them to younger generations, despite the media that abound in our modern life. This finding related to transfer of knowledge, experience and expertise on the truffles was reported among the indigenous population of Cameroon (Yongabi et al., 2004), Nigeria (Osagualekhor and Okhuoya, 2005) and Bahrain (Mandeel and Al-Laith, 2007).

The number of harvested truffles differed significantly between groups of respondents ($\chi^2=76.86$, $P<0.001$) where it was limited to a single ascocarps per symbiotic plant among 86.7% of the subjects surveyed, while 8.3% stated that they usually harvest 1–2 ascocarps per host plant and 5% of respondents harvested 1–3 truffles (Table 3H).

The weight of the harvested desert truffle ascocarps raged between 250–500 g among 53% of respondents, while it is less than 250 g in 31%, and only 15% of subjects harvested ascocarps with a weight greater than 500 g ($\chi^2=13.30$, $P<0.001$, Table 3I). According to 74% of interviewees, a good harvest of truffles is expected following the storms and rains of autumn and winter, whereas it is due to the density of the host plant (*Helianthemum* spp.) in 17% of respondents, and average temperatures of spring in 2% of responses, while 7% of surveyed subjects related good truffle-harvest to the involvement of all the four factors (Table 3J). Percentages of respondents significantly differed between categories of good harvest indicators ($\chi^2=73.19$, $P<0.001$).

In addition, the amount of harvested truffles per harvest-trip varied between 5 and 10 kg in 37% of questionnaires. It was below 5 kg in 28% of subjects, and lay around 10–30 kg among 20% of respondents, while 15% stated they obtained an amount greater than 30 kg for each harvest-trip. No difference was observed between the distribution of subjects according to classes of quantity of harvested truffles ($\chi^2=6.53$, $P<0.088$, Table 3K). This demonstrates that the surveyed people are good truffle harvesters in desert environments where they use their experience and exert an effort to ensure as much as possible a good and constant harvest whatever the conditions are, knowing that the desert truffle production across habitats of the Northern Sahara varies from one year to another. It is all dependent on the climatic conditions, especially the autumnal rains (Bradai et al., 2015).

In agreement with the Bedouins of Bahrain (Mandeel and Al-Laith, 2007), the occurrence of thunder influences the number and size of desert truffles. Indeed, it seems that the use of nitrates by these fungi is high during the rainy season compared to the dry season, which contributes to the increasing quality and yield of truffles (Bokhary, 1987; Bencivenga and Urbani, 1996). According Awameh and Al-Sheik (1980), it is well known that thunder coupled with rain can generate enough electric power to induce the precipitation of nitrogen compounds (oxides), thus triggering germination or breaking seed dormancy of many plants and fungal spores.

Besides, according to El Enshasy et al. (2013), the growth of desert truffles requires an annual rainfall ranging between 50 and 380 mm, although in Northern Africa, good truffle yields are recorded with rainfalls ranging between 70 and 120 mm. Among Saharawi refugees (Volpato et al., 2013), it is known that “After three rains, the desert has a present for us!”, thus indicating that two or three heavy rains distributed over one to three months are necessary for desert truffle fruiting. The same finding was given by Bradai et al. (2014) with an emphasis on the importance of temporal distribution of rains for both germination and growth of the two symbionts (fungus and host plant).

According to the study Bradai et al. (2014), the three desert truffle species (*Tirmania nivea*, *Terfezia arenaria*, *Terfezia claveryi*) of Northern Sahara differ in frequency along truffle-producing sites. Indeed, our investigations revealed that the food quality of these species is differently appreciated by the indigenous population, and this following ascending order of species rarity: *Tirmania nivea* (very common) was appreciated by the local population, *Terfezia*

Table 3
Main parameters of the ethnomycological study investigating native people's knowledge about desert truffles in the Algerian Northern Sahara.

Variables	Subjects	%	χ^2	*P*
A. Period of searching for desert truffles	*N*=60		28.30	<0.001
Long period (late January–late March)	14	23.3		
Mid period (mid-February–late March)	39	65.0		
Short period (late February–late March)	7	11.7		
B. Time spent searching for truffles per trip	*N*=60		36.10	<0.001
<1 week	41	68.3		
1–2 weeks	15	25.0		
>2 weeks	4	6.7		
C. Number of harvests per truffle season	*N*=60		36.33	<0.001
Once/year	20	33.3		
Twice/year	25	41.7		
Three times/year	11	18.3		
Four times/year	3	5.0		
Five times/year	1	1.7		
D. Landscape types of truffle collecting sites	*N*=110		86.69	<0.001
Reg	4	3.6		
Erg	18	16.4		
Hamada	0	0		
Daya	39	31.8		
Wadi beds	41	37.3		
Do not know	8	7.3		
E. Using of symbiotic plants in searching for truffle	*N*=60		38.40	<0.001
Presence of symbiotic plants is irrelevant	6	10.0		
High density of symbiotic plants does matter	54	90.0		
F. Using of indications of other truffle collectors	*N*=58		33.38	<0.001
No indication from trufflers	7	12.1		
As indicated by other trufflers	51	87.9		
G. Using previous experience for harvesting site choice	*N*=60		29.40	<0.001
Explore new areas	9	15.0		
Explore the same sites of the past year	51	85.0		
H. Number of harvested truffles per host plant seedling	*N*=60		76.90	<0.001
1 Ascocarp	52	86.7		
1–2 Ascocarps	5	8.3		
1–3 Ascocarps	3	5.0		
I. Average weights of desert truffle ascocarps (g)	*N*=60		13.30	0.001
<250	19	31.7		
250–500	32	53.3		
>500	9	15.0		
J. Indicators of good truffle-harvest	*N*=135		73.19	<0.001
Storms and rains of autumn	51	37.8		
Favorable rainfall in winter	49	36.3		
Average temperatures of spring	3	2.2		
High density of *Helianthemum* spp.	23	17.0		
All the above factors involved	9	6.7		
K. Amount of harvested truffles (kg)	*N*=60		6.53	0.088
<5	17	28.3		
5–10	22	36.7		
10–30	12	20.0		
>30	9	15.0		
L. Onsite methods of truffle preservation	*N*=84		42.00	<0.001
Covering truffles with green desert plants	46	54.7		
Kept in the shade	28	33.3		
None	10	12.0		
M. Destination of harvested desert truffles	*N*=60		49.60	<0.001
Home consumption only	44	73.3		
Sale only	0	0		
Home consumption and selling surplus	16	26.7		
N. Financial income from truffle post-sale	*N*=60		43.30	<0.001
Low	44	73.3		
Average	7	11.7		
High	9	15.0		
O. Purchase preferences based on truffle provenances	*N*=60		60.00	<0.001
Steppic origin	0	0		
Saharan origin	60	100		
Indifferent	0	0		
P. Symptoms and diseases treated	*N*=104		13.02	0.011
Eye infections and diseases	23	22.2		

Table 3 (*continued*)

Variables	Subjects	%	χ^2	*P*
Anemia	9	8.6		
Increase fertility	20	19.2		
Weakness and fatigue	20	19.2		
No special therapy	33	31.7		
Q. Mode of therapeutic use	*N*=68		18.10	<0.001
Only truffles (ascocarps or extracts thereof)	27	39.7		
Truffles mixed with honey, olive oil etc.	8	11.8		
No therapeutic usage (only for feeding)	33	48.5		

arenaria (rare) was very appreciated, while *Terfezia claveryi* (very rare) was very highly appreciated. Therefore, the selling price of species is determined by their rarity as well. Thus, the selling price of 1 kg of *Tirmania nivea* varied between USD 6.31 and 32.81/kg in local markets, that of *Terfezia arenaria* ranged from USD 7.57 to 33.44/kg, whereas the price of *Terfezia claveryi* can reach up to USD 37.86/kg. However, these prices show large annual fluctuations, according to the availability of truffles and the quantity produced, which is based on rainfall (Bradai et al., 2015). Moreover, the amount of truffle harvested by collectors, even during a good season, may influence the selling price (law of Supply and Demand). Therefore, the disproportionate abundance between commercialized truffle species would be behind the difference in the degree of appreciation among the local population, and consequently their prices. Volpato et al. (2013) indicate that the selling price of truffles can multiply ten times along the commercialization process from the Sahara Desert towards the north of the country or even abroad (Europe and/or the Middle East), following the sale chain: harvesters > Local collectors > traders at different scales regional/national/international > consumers.

Since truffles spoil very quickly, they deteriorate within one week after harvest notably when exposed to sunlight and/or heat (Bokhary et al., 1990); hence their preservation is required soon after their harvest in a shaded and well-ventilated room (Feeney, 2002). The surveyed people use simple techniques to temporarily store truffles before consumption and/or selling: they store the truffles up to three weeks by burying them in the sand protected from the sun, but ascocarps can withstand up to two weeks if they are only covered by green desert plants. In addition, truffles can be trimmed into strips and dried or also steamed or boiled in water and then stored in the freezer. Bedouins of the Middle East rather keep truffles in vinegar and salt (3–6%) (Mandeel and Al-Laith, 2007). Nigerians often dry truffles in the sun and preserve them in salt solutions (Akpaja et al., 2003). However, as the methods of preservation often modify the organoleptic qualities of truffles and their nutritional value; Al-Ruqaie (2002) proposes a remedy to this by putting them in a salt solution of boiling sodium chloride for four minutes. In the Algerian Sahara, our survey revealed that 54.7% of people temporarily preserve the fresh truffles covered by desert plants before consumption; 33.3% keep them in the shade covered with salt to prevent spoilage, and the rest (12%) offer no type of preservation ($\chi^2=42$, $P<0.001$, Table 3?). It is noteworthy that very few store truffles beyond the harvest season. The most widely used medium in this case is the sun drying.

The sale of desert truffles is not yet as regulated as that of *Tuber* because their production is still natural and the overall harvested amount is not well known in the producing countries, such as North Africa and the Middle East (Fortas, 2009). In the current survey, trufflers collected truffles mainly for home consumption, but 27% of them sell the surplus. The study found that none of the questioned subjects collected truffles for purely commercial purposes. Le χ^2 test showed a significant difference between the number of surveyed subjects according to different uses of truffles after harvest ($\chi^2=49.60$, $P<0.001$, Table 3M).

In Algeria, the total domestic production of desert truffles is unknown, although it may reach at southwestern Algeria about 4 million quintals during years of good production. Truffles are usually sold in the souks or exported to Europe and the Middle East (Fortas, 2009). However, in some countries such as Saudi Arabia and Kuwait the business of desert truffles is more developed. In fact, during the season, markets for truffles are held daily near the small towns where truffles are sold directly by the Bedouins or indirectly by truffle brokers (Mandeel and Al-Laith, 2007). That being said, the sale of truffles brings a low income according to 73% of respondents, against 15% stating that truffle sale provided them high income and 11% of respondents stating average income ($\chi^2=43.30$, $P<0.001$, Table 3N). It is also noteworthy that the entire study population preferred buying truffles of Saharan origin against truffles harvested from steppe borderlands located just north of the study area ($\chi^2=60$, $P<0.001$, Table 3O).

Truffles are an untapped source of therapeutic compounds having anti-inflammatory, immunosuppressant, anti-mutagenic and anti-carcinogenic characteristics (Hannan et al., 1989). Their therapeutic properties, especially against eye aches and pains, have been described in Islamic religious texts for over 14 centuries. Indeed, the Arabs used a diluted extract in traditional medicine against certain eye diseases and alopecia areata (Haloubi, 1988). Despite these medical and therapeutic features, the results of our study noted that 31.7% of the population did not use desert truffles in traditional medicines. However, 22% reported having used truffles as a remedy against eye infections; 19% had used truffles against symptoms of weakness and fatigue; 19% had used to improve fertility in men and 8% used truffles in anemia cases ($\chi^2=13.02$, $P<0.011$, Table 3P). As regards the mode of therapeutic use, 39% of respondents used ascocarps of desert truffles or extracts thereof (pure or diluted) alone. Only 11% of responses stated that truffles were mixed with honey, olive oil and sometimes with pollen of the date palm (*Phoenix dactylifera*) then used for therapeutic purpose, mainly to increase fertility ($\chi^2=18.10$, $P<0.001$, Table 3Q).

In addition, those surveyed did not distinguish specific therapeutic properties between the three desert truffle species of Northern Sahara during the treatment of diseases or symptoms. All truffles species are equitably used and this therapeutic knowledge seems common in countries accustomed to desert truffles. However, some species are specifically used in traditional medicine. For example *Terfezia claveryi* is used in the treatment of certain eye diseases such as trachoma or pain of the eye associated with desert storms (Al-Marzooky, 1981); it is used too against the increase of blood cholesterol and to calm muscle and joint pain (Khanaqa, 2006), moreover even antibiotics were extracted from desert truffles (Janakat et al., 2004).

Regarding criteria of consumption preferences of truffles, *Terfezia claveryi* was the most appreciated (68.3%) species among interviewed subjects in the Algerian Sahara. As second choice, *Terfezia arenaria* dominates with 65%, then *Tirmania nivea* dominates as third choice with 54.7% (Fig. 2A). The χ^2 test revealed a highly significant difference between the percentages of species of truffles and ranking choice criteria ($\chi^2=77.10$, $P<0.001$). In Bahrain, it is the white truffle (*Tirmania nivea*), commonly called "Zubeidi", which is highly preferred by Bahraini and Non-Bahraini people (Mandeel and Al-Laith, 2007).

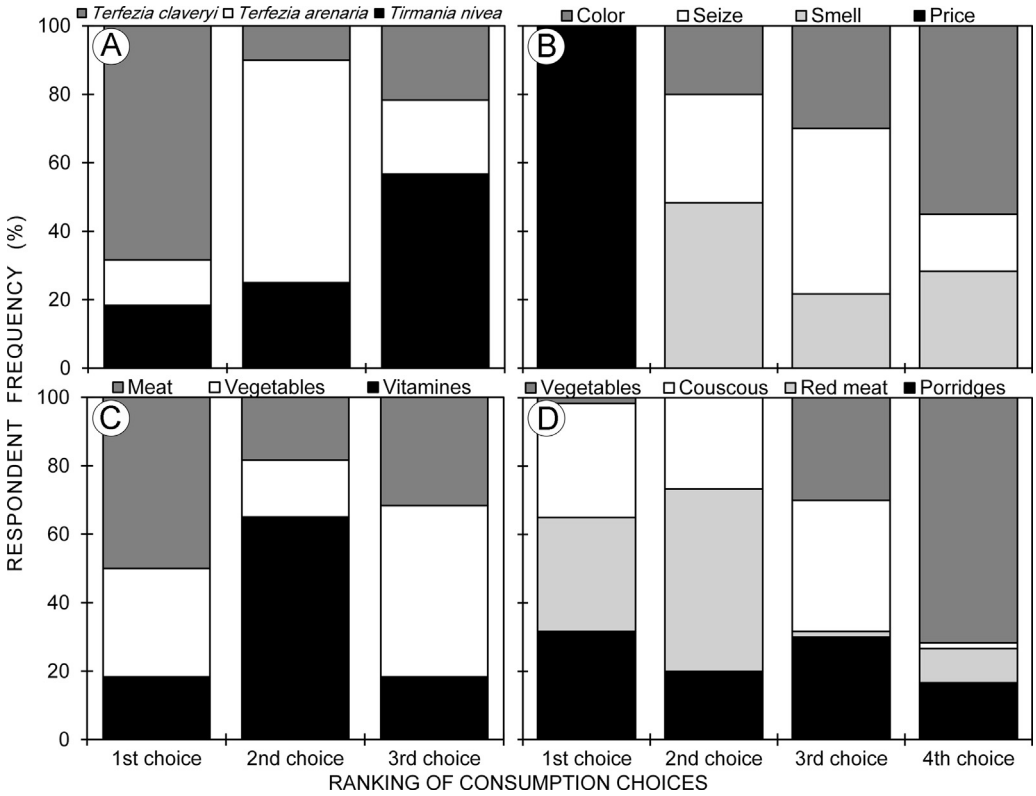

Fig. 2. Ranking consumption choices and dietary habits of desert truffles among people of the Algeria Sahara Desert according to truffle species (A), purchasing criteria (B), gastronomic appreciation (C), and cooking method (D).

Concerning buying criteria of truffles in local markets, all interviewed subjects (100%) take truffle price as the first choice of purchasing criteria. As a second choice, the smell dominates with 48.3% of respondents; whereas the size of ascocarps prevail as third choice with 48.3%, and at the end color with 55% as the last selected criterion (Fig. 2B). The Chi-square test revealed a significant deference between the percentages of buying criteria and ranking of choice ($\chi^2 = 276.72$, $P < 0.001$). In fact, the selling price of a kilogram of desert truffles in Algeria varies with harvesting years and locations of collection and sales. In general, the price is lower in regions where truffles grow and more expensive in markets of big cities especially in early season (Volpato et al., 2013). On this point, a similar response indicates that 64% of Bahraini respondents (Mandeel and Al-Laith, 2007) and even the Mexican people (Ruán-Soto et al., 2006) expressed their unwillingness to buy truffles due to the relatively high price of desert truffles.

Regarding their edible value, the desert truffles do not have the same flavor as European truffles of the genus *Tuber*; in addition to that, they have a unique musky flavor. Their popularity is due to their unique taste and nutritional value. Their chemical composition has been the subject of numerous studies that have demonstrated their richness with proteins (20–27%), amino acids, fiber (7–13%), fatty acids (3–7.5%), ascorbic acid (2–5%), diverse mineral content (Si, K, Na, Ca, Mg, Mn, Fe, Al, Cu, Zn), carbohydrates (60%), with sterols and terpene compounds (Al-Delaimy, 1977; Bokhary et al., 1989; Ahmed et al., 1982; Bokhary and Parvez, 1993; Dabbour and Takruri, 2002b; El Enshasy et al., 2013). In the present investigation, the desert truffles are most popular than meat in 50% of the subjects surveyed, secondarily as a source of vitamins at 65%. Thirdly, truffles are considered better than vegetables in 50% of the questioned population (Fig. 2C). The distribution of percentages of gastronomical appreciations according to preference choices differed significantly ($\chi^2 = 46.20$, $P < 0.001$). In Niger, for example, Akpaja et al. (2003) reported that 95% of Igbo people consume these fungi for their taste and 86% as a substitute for meat, while others make thick soups for therapeutic purposes.

The present study showed that truffles are preferred equally with red meat (33.3%), with couscous (33.3%) and porridges (31.7%), as first choice. In addition, respondents of the Algerian Sahara prefer truffles as second choice with red meat (53.3%) and as third choice with couscous, vegetables and porridges, and as last choice with vegetables with 71.7% (Fig. 2D). The Chi-square test showed that the four cooking methods differed significantly with regard to ranking choices of preference ($\chi^2 = 141.36$, $P < 0.001$). For a long time, desert truffles are consumed by indigenous peoples of hot desert regions (Trappe et al., 2008a, 2008b), including those of North Africa and the Middle East. Their culinary preparation is specific to each country, which indeed varies according to social and religious traditions. In Morocco, for example, they are incorporated into tagines; and in Kuwait, they are boiled in camel or cow's milk or roasted in ghee. The western gourmets also prepare desert truffles as dessert cream (Feeney, 2002).

4. Conclusion

The present study shows that desert truffles represent great interest as food, economic and therapeutic values among native people of the Algerian Northern Sahara. The subjects surveyed in this region have extensive experience of searching for and collecting desert truffles. This is the result of wide know-how on truffles derived from the preservation of traditional knowledge and socio-cultural information transmitted from one generation to another. It would be very useful to develop the traditional knowledge in relation to deeper scientific research to make better use of it.

The exploitation of such data about edible desert truffles and their different ethnomycological uses for various social and religious purposes allows to develop the scientific knowledge about artificial culture of these truffles the one hand; and to better understand their autoecology on the other hand. Deepening and development of basic and applied knowledge on desert truffles would also

consider their introduction in such hostile desert environments to exploit lands that hitherto were considered unproductive. For this purpose, it is preferable to orient research towards the establishment of truffle cultivation proper to hot arid regions in order to produce foods rich in protein, minerals and vitamins and having at the same time considerable therapeutic value.

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