

PRELIMINARY SURVEY OF THE DIVERSITY OF THE GENUS *AGARICUS* IN MEXICO

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ABSTRACT

Mushroom cultivation was introduced to Mexico around 1930 and since then mushroom production has been increasing, setting the country as the principal mushroom producer in Latin America. Despite of its commercial importance, the diversity of the genus *Agaricus* in Mexico has been little studied; only one study has been conducted in Mexico which recorded 13 species; although there have been several studies, mainly floristic, that include some species of the genus. The aim of this study is to produce a preliminary *Agaricus* checklist based on the collections of four main Mexican herbaria (ENCB, IBUG, MEXU, XAL), and at the same time gather information on poor explored regions and places with potential presence of *Agaricus* species. At present, 204 specimens have been revised and, after checking the synonyms, 32 species taxonomically valid are recognized, which has been collected in 27 of the 32 states of the Mexican Republic. The most common and wide spread species are *A. campestris* (present in 18 states), *A. placomyces* (present in 12), *A. augustus* (present in 9) and *A. arvensis* (present in 8). Undoubtedly, the revision of the genus *Agaricus* in Mexico will allow to add new records to the Mexican fungal flora, and also to describe new species to science (especially from subtropical and tropical regions, so far poorly explored). These studies must rely primarily on the molecular analysis of the species and it would be desirable to perform, at the same time, genetic studies of productivity in the most popular edible species.

Keywords: Mushroom biodiversity; Herbaria revision; Taxonomy; Species distribution.

INTRODUCTION

The consumption of edible fungi in Mexico represents a culinary tradition that descends from pre-Hispanic times. Popular markets offer during the rainy season a wide variety of edible species estimated at more than 200 species [1-3], many of these fungi have their names in Indian languages and some of them are consumed almost exclusively in the central region of Mexico, as is the case of the "huitlacoche" (corn smut), a species prized for its delicate flavor.

Some species of the genus *Agaricus* L., are traditionally eaten in Mexico and received several popular names: "sanjuanero", "llanero", among others [4]. Different publications have emphasized the ethnomycological importance of this fungi genus among indigenous people [5-10]. *A. bisporus* (J.E. Lange) Imbach is the most cultivated and consumed species in Mexico and it is popularly called "champiñon", a word derived from the French term to designate all fungi: champignon. The cultivation of *A. bisporus* was introduced in Mexico in the 1930s [11] and since then its production has been increasing. Mexico is currently the largest producer of mushrooms in Latin America with more than 43 000 tons of fresh mushrooms per year [12].

Although it is difficult to estimate the number of species of the genus *Agaricus* extant [13], it is considered that Europe alone has more than 130 species [14] of the 200 species mentioned at world level [15]. Taking into account that one third of the species analyzed by Kerrigan et al. [16] resulted to be new species to science from the best known mycological regions (Europe and North America), one could predict that the number of *Agaricus* species in subtropical and tropical regions must be substantial.

Paradoxically, the genus *Agaricus* has been little studied in Mexico with only one published work that specifically described 13 species of this genus collected in Mexico [17], although several studies, especially floristic, cite species of the genus. Martínez-Carrera et al. [11] reported the production of 10 wild Mexican *Agaricus* species, but this study was focused on basidiomes production, the authors indicating that the identification of the species cultivated was tentative. By the end of the 1980s it was assumed that all specimens of *A. bisporus* used for the isolation of strains for mushroom cultivation, were exclusively European. However, upon finding wild specimens of this species in the Californian desert, in the United States [18], the concept of distribution has changed. During 2001, one of the authors of the present work and P. Callac (INRA, France) made some excursions in Mexican territory and found wild *Agaricus* specimens with basidia typically bisporic [19]. Recently two new Mexican species have been described, one belonging to the section Xanthodermatei, *Agaricus tollocanensis* [20] and another to section Duploannulati, *A. tlaxcalensis* [21].

The objective of the present work was to compile a list of *Agaricus* species deposited in the major herbaria of Mexico, in addition to documenting species previously mentioned in the literature, in order to identify some scarcely explored regions that could potentially host species of *Agaricus* in this country.

MATERIALS AND METHODS

A review of the *Agaricus* genus specimens deposited in the 4 major herbaria of Mexico was made: ENCB (Instituto Politécnico Nacional), IBUG (Universidad of Guadalajara), MEXU (Universidad Autónoma de México) and XAL (Instituto de Ecología, A.C.). It took data from the locality, collector and species from specimens found in good condition. A bibliographic review of papers published in Mexico relating to the *Agaricus* genus was carrying out. At the same time the valid names for the species mentioned in the Index fungorum were reviewed (<http://www.indexfungorum.org/names/names>) in order to determine the synonyms in the studied species. Some *Agaricus* specimens were microscopically reviewed to corroborate their identifications. The microscopic study of the specimens was riding hand from various parts of the basidioma temporary cuts made preparations to observe structures, which were revised in a compound microscope (Carl Zeiss Stemi 2000 model), using KOH to 5%, phloxine, Congo red and solution of Melzer.

RESULTS AND DISCUSSION

Two hundred and four specimens from herbaria were reviewed; this material was ascribed to 32 taxonomically valid species after confirming the possible synonyms (Table 1). The specimens were collected in 25 of the 32 States of Mexico, the most common and widely distributed species were: *A. campestris* (collected in 18 states), *A. placomyces* (present in 12), *A. augustus* (present in 9) and *A. arvensis* (present in 8). The states with the largest number of species are Veracruz, Mexico and Tlaxcala, each one with 9 species. The State of Aguascalientes has a single registered species and the territories with no records of *Agaricus* are: Campeche, Coahuila, Colima, Nayarit, Sinaloa, Tamaulipas and Yucatan. In general the majority of the collections

were made from central regions of the country, while in tropical and subtropical zones of South and Southeast and temperate zones of the North, expeditions have been scarce.

Table 1. Species of *Agaricus* genus that have been recorded in the major herbaria of Mexico (ENCB, IBUG, MEXU and XAL)

Species	States in which it has collected	*
<i>Agaricus altipes</i> (F.H. Møller) F.H. Møller	14	
<i>A. arvensis</i> Schaeff	6, 8, 11, 12, 14, 17, 23	[22, 24, 30, 31, 32]
<i>A. augustus</i> Fr.	4, 5, 6, 8, 11, 12, 14, 17, 23	[11, 22, 24, 32, 35]
<i>A. benesii</i> Pilát, A	14	[17]
<i>A. benzodorus</i> Heinem. & Gooss	19	[23]
<i>A. bisporus</i> (J.E. Lange) Imbach	1. 6, 7, 8, 12, 22, 23, 24	[22, 30, 32, 33]
<i>A. bitorquis</i> Saccardo, P.A.	6, 11, 14, 17	[22, 32]
<i>A. californicus</i> Peck, C.H.	3, 23, 24	
<i>A. campestris</i> L.	3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 21, 23, 24, 25	[22, 24, 30-34, 36-37, 39-40]
<i>A. cretaceus</i> Bull.	6	
<i>A. crocodilinus</i> Murrill, W.A	6, 18	[23, 32]
<i>A. endoxantus</i> Berkeley, M.J.; Broome, C.E.,	19	[23]
<i>A. lividonitidus</i> Møller, F.H.	20	
<i>A. moelleri</i> Wasser	6, 24	[17]
<i>A. nivescens</i> Møller, F.H.	14	
<i>A. osecanus</i> Pilát, A.	17	[23]
<i>A. placomyces</i> Peck, C.H	6, 7, 8, 9, 11, 12, 13, 14, 16, 17, 23, 24	[22, 24-25, 30, 32, 34-35]
<i>A. porosporus</i> Heinem	19	[23]
<i>A. porphyrocephalus</i> F.H. Møller	12	[23, 30]
<i>A. purpurellus</i> (F.H. Møller) F.H. Møller	19	
<i>A. silvaticus</i> Schaeff.	4, 5, 12, 17, 18, 23, 24	[22, 31-32, 35-37]
<i>A. silvicola</i> (Vittad.) Peck	2, 8, 12, 24	[22, 31-33, 35-37]
<i>A. singeri</i> Heinemann, P. (19	[23]
<i>A. solidipes</i> Peck	5	
<i>A. subperonatus</i> (J.E. Lange) Singer	12	[17, 23, 30, 32]
<i>A. subrufescens</i> Peck	6, 8	[11]
<i>A. subrutilescens</i> (Kauffman) Hotson & D.E. Stuntz	6, 13, 14	[22]
<i>A. tlaxcalensis</i> Callac & G. Mata	23	[21]
<i>A. tollocanensis</i> Callac & G. Mata	8, 23	[20]
<i>A. trinitatisensis</i> R.E.D. Baker & W.T. Dale	19	[23]
<i>A. volvatulus</i> Heinem. & Gooss.-Font.	24	[38]
<i>A. xanthodermus</i> Genev.	5, 6, 8, 12, 13, 17, 24	[17, 22, 24, 30, 32]

States in which the species has been registered: 1. Aguascalientes, 2. Baja California Sur, 3. Baja California, 4. Chiapas, 5. Chihuahua, 6. Distrito Federal, 7. Durango, 8. Estado de Mexico, 9. Guanajuato, 10. Guerrero, 11. Hidalgo, 12. Jalisco, 13. Michoacan, 14. Morelos, 15. Nuevo Leon, 16. Oaxaca, 17. Puebla, 18. Queretaro, 19. Quintana Roo, 20. San Luis Potosi, 21. Sonora, 22. Tabasco, 23. Tlaxcala, 24. Veracruz, 25. Zacatecas.

* Species cited in the Mexican literature. Numbers in brackets correspond to bibliographic references that were cited.

Although only one published work exists that focused on this genus in Mexico [17], other studies have included collections of this species, but a full taxonomic description of the specimens is lacking (Table 1). Although some reports did not specify if the specimens are deposited in a herbarium or this material is preserved in herbaria that were not reviewed in this paper, the literature recorded 17 species more than reported in Table 1. These species are: *A. albolutescens* [11], *A. bambusigenus* [22], *A. bernardii* [23, 24], *A. comtulus* [17], *A. denisii* [23], *A. dulcidulus* [23], *A. fuscofibrillosus* [17], *A. impudicus* [17], *A. pampeanus* [10], *A. phaeolepidotus* [17], *A. porphyrizon* [25], *A. robustissimus* [11], *A. semotus* [17], *A. volvatus* [23], *A. xantholepis* [17], *A. xuchilensis* [26] and *A. yucatanensis* [26]. This means that 49 species of the *Agaricus* genus had been registered from Mexico, representing 25% of the diversity reported by Kirk et al. [15]. However, most of this material has been identified mainly using European and American keys so that the identification of many specimens is probably wrong. The articles of Guzmán [27, 28] and Gutierrez Ruiz and Cifuentes [17] contain keys to the identification of the species collected in Mexico. The maintenance of the majority of specimens deposited in the herbaria is poor, as well as the lack of data of fresh material, particularly chemical reactions; hinder the corroboration of the identifications.

According to Guzman [29], the case of *Agaricus* as and other genera in Mexico must be revised and monographed and this work aims to achieve this goal. Undoubtedly the study of *Agaricus* genus in Mexico will allow, in addition adding new records to the national microflora, the description of new species to science especially those that inhabit rarely visited places in the tropic and subtropics. Studies should be primarily based on molecular analysis of the species and it would be desirable that they be made in parallel with genetic and yield researches of the most prized edible species.

ACKNOWLEDGMENTS

The authors are grateful to the authorities of Instituto de Ecología A.C. and Instituto de Investigaciones Forestales (Universidad Veracruzana), and Dr. Samuel Cruz Sanchez, research director of last institution, their important support for the implementation of this project. The biologists Ranulfo Castillo and Marcelo Camacho help in various activities. This work is part of research funded by a bilateral cooperation between Mexico (project 115790 CONACYT) and France (ANR-09-BLAN-0391-01) in the “AgaSub” project: “Biology of the gourmet and medicinal mushroom *Agaricus subrufescens*, development of its cultivation and of new products of therapeutic interest or for diseases prevention”.

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