

# Algae and Fungi: use in Pre-Hispanic Mexico

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The use of microorganisms in Mexico began before the Spanish conquest. Grains and fruit were fermented for thousands of years around the world, and Mexico was no exception. Many beverages are still prepared nowadays using an assortment of different microorganisms. These beverages use several yeasts, including *Saccharomyces* and non-*Saccharomyces* species. Although not conclusive, it has been suggested (and strong evidence points towards it) that pre-Hispanic cultures not only fermented beverages, but also distilled them.

Keywords: algae ; bioactive compounds ; fungi ; Mexico ; microorganisms ; pre-Hispanic ; biotechnology

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## 1. Introduction

Fermented Mexican beverages include “tejuino”, “pulque”, “pozol”, “tepache”, and bitter “atole”. These beverages have shown microbiological properties, such as probiotic capabilities, antibacterial, and fungicidal activities <sup>[1][2]</sup>. Several properties of fermented beverages in Mexico have been previously discussed <sup>[1][3]</sup>. One of the main examples is pulque, which is a fermented beverage from some agave species consumed in pre-Hispanic (and present) times in Mexico. Pulque includes probiotic organisms and was even adapted to be used as an enema to replenish the intestinal microbiota <sup>[4][5]</sup>. Another example, “pozol” is a non-alcoholic fermented beverage from native and mestizo cultures in Mexico. This beverage is produced from a form of processed maize called “nixtamal”. During fermentation, “nixtamal” changes the microbiota of the dough <sup>[6]</sup>. Empirically, this is evidence of pre-Hispanic cultures using microorganisms for their nutrition, health, and religious and ludic activities, among other purposes.

## 2. Algae

One of the most conspicuous groups of microorganisms used in pre-Hispanic Mexico was algae. Most information about algae use in native communities in Mexico comes from Mayan and Nahuatl communities (including the Aztecs) <sup>[7][8]</sup>. These cultures used micro-algae, mainly as dietary supplements. For example, the Aztecs of Texcoco used “tecuitlatl” (*Arthrospira platensis*), known today as spirulina, as a complement to maize <sup>[9]</sup>. Aztecs have consumed the blue–green algae since at least the 13th century <sup>[10]</sup>.

Other algae commonly consumed in pre-Hispanic times include “cuculito”. “Cuculito” consists primarily of two algae: *Phormidium tenue* and *Chroococcus turgidus* <sup>[10]</sup>. “Cuculito” was used as a food supplement, which provided calcium and iron <sup>[11]</sup>.

Aztecs also used “tizatl”, which consisted of diatoms from the Bacillariophyceae family. “Tizatl” was normally transformed as a white powder and commonly used for medicinal purposes <sup>[11]</sup>. Additionally, “tizatl” was frequently used as a white ornamental coloring for sacrificial war captives <sup>[12]</sup>.

## 3. Fungi

The biological and cultural richness of fungi in Mexico is vast, but risks disappearing due to erosion of human cultures <sup>[13]</sup>. Several indigenous groups still use fungi in rituals, food, or medicine. The Mazatec, Nahuatl, Purepecha, Raramuris, and Zapotec are ancient Mesoamericans who were knowledgeable about the application of hallucinogenic fungi <sup>[14]</sup>. The most important hallucinogenic fungi belong to the genera *Psilocybe*, *Panaeolus*, and *Stropharia* <sup>[15]</sup>. Moreover, 3-[2-(dimethylamino)ethyl]-1H-indol-4-yl dihydrogen phosphate (psilocybin) is pharmacologically responsible for the hallucinogenic properties of *Psilocybe* spp., in which, once ingested, is converted to 4-hydroxy-N,N-dimethyltryptamine (psilocin), a potent hallucinogenic substance <sup>[16]</sup>.

Consumption of hallucinogens in ceremonies and religious rituals spread from the valley of Mexico to all of Central America approximately 3500 years ago. The Mayas consumed a fungus known as “k’aizalaj okox” (*Psilocybe cubensis*),

which was also known to the Aztecs, who named it “teonanacatl” <sup>[15]</sup>. This type of fungus was also consumed by the Huasteca, Totonac, Mazatec, and Mixtec. In Teotenango, one of their customs was to grind mushrooms with water on specialized stone plates of temples that were being constructed. Similar evidence was found in temples in other parts of Mexico and Guatemala, Honduras, and El Salvador <sup>[15]</sup>. The Mixtec God “Yya Sahuaco”, also known as the “Lord of Seven Flowers” is often represented with a pair of mushrooms in his hands. The mural of Tepantitla of Teotihuacán, dated to be created around AD 450, shows, below raindrops created by the Aztec rain god Tlaloc, the appearance of priests carrying (hallucinogenic) fungi. Furthermore, these fungi were employed at the coronation ceremonies of various Aztec emperors, including Tizoc, Ahuizotl, and Moctezuma II, who was ruler when Hernán Cortés arrived in 1519 on the east coast of the Aztec empire <sup>[15]</sup>.

Fortunately, the traditional knowledge of indigenous people from different regions has been preserved, to a certain extent <sup>[17]</sup>. One of the intensely studied ethnicities are the Mixtec. The Mixtec use at least 26 fungal species for hallucinogenic, ludic, and medicinal applications <sup>[13]</sup>. In the Central Valleys of Oaxaca, there are twenty species of edible fungi being commercialized. These mushrooms are exported, have medicinal and nutritional value, and help as inoculants for forestry crops, such as prickly pear, *Opuntia* spp. <sup>[18][19]</sup>. Collectively, the use of mushrooms has been reported in 15 of the 68 indigenous groups and, in addition, in mestizo communities from rural areas <sup>[20][21]</sup>.

Recently, the cultural importance of mushrooms among an indigenous group from the northern region of Jalisco, the Wixaritari, has been studied in detail <sup>[21]</sup>. In general, several mushroom species are highly valued as food, with low acceptance being very uncommon. Among the favored species are *Amanita basii* and *A. laurae*, *Volvariella bombycina*, *Pleurotus djamor*, and *P. opuntiae*. Galls from the smut *Ustilago maydis* are also appreciated as a source of food <sup>[21]</sup>. A few species serve ludic uses, e.g., fruiting bodies from *Calvatia cyathiformis* and *Pisolithus* spp. being used as projectiles by children when on mushroom collection trips with their parents <sup>[21]</sup>. In addition, several mushroom species (e.g., *Ganoderma oerstedii* and *Pycnoporus sanguineus*) have important medical applications. An unidentified bolete mushroom is used for the treatment of heart and joint problems, while *G. oerstedii* and *P. sanguineus* extracts are a medication against skin ailments as well as fever. A drink made from *G. oerstedii* is used as medicine against stomach pain, diarrhea, and kidney complications <sup>[21]</sup>. In general, the Wixaritari are an example of an indigenous Mexican people who still possess profound knowledge on many aspects of mushroom utilization, which began thousands of years ago in pre-Hispanic times.

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