EDIBLE, FUNCTIONAL AND MEDICINAL MUSHROOMS: A BIOTECHNOLOGICAL ALTERNATIVE TO THE SOCIAL, ECONOMIC AND ECOLOGICAL PROBLEM OF SARGASSUM IN THE MEXICAN CARIBBEAN

Introduction

Climate change is progressing inexorably, bringing enormous challenges for human societies and strong selection pressure on agroecosystems and natural ecosystems. Food production is a notably vulnerable activity and requires special attention. In addition to promoting and strengthening the production of staple foods in a changing environment while reducing our ecological footprint, it is essential we diversify our food sources, and incorporate increasing numbers of kingdoms and species from nature (Martínez-Carrera & Larqué-Saavedra, 2019). This is possible in a country like Mexico, where there is great cultural, biological and environmental diversity. In this sense, the degradation of organic matter through the efficient multi-enzymatic system of the fungi kingdom is a good example, as it allows not only its accelerated bio recycling in ecosystems, but also the possibility of producing food fast, such as various edible mushrooms (Martínez-Carrera et al., 2016).

Algae are important organisms in the aquatic ecosystems of our planet. Some species, such as Sargassum muticum, are considered a traditional food in Korea or a traditional medicine in China (Milledge et al., 2016). Pelagic Sargassum (Sargassum) is a brown macroalga (Phaeophyceae) that floats freely in the seas and oceans, forming a natural habitat that benefits a wide range of species. In the Mexican Caribbean, experts have identified two species that are found annually: S. natans and S. fluitans (Rodríguez-Martínez et al., 2016). There are few studies on their biology, distribution, use and potential value. Recently, the massive invasion of Pelagic Sargassum has been observed and documented on the Mexican Caribbean coast. The phenomenon is growing, as are its social, economic and ecological consequences for tourism, given that the state of Quintana Roo alone received 16.9 million visitors in 2017, with economic benefits exceeding 8,810 million US$ (SEDETUR, 2018).

In this report, we propose to use biotechnology to produce edible, functional and medicinal mushrooms, and to take advantage of the annual accumulation of Sargassum on the coasts of the Mexican Caribbean as a growing medium, biodegrading it and promoting its accelerated recycling in nature.

Edible mushrooms contain various bioactive compounds with health benefits (anticancer, antibiotic, antioxidant, anti-inflammatory, cholesterol and hypertension reducer, antithrombotic, antidiabetic; Chang & Miles, 2004), and are culturally accepted by a large part of the population and international tourism.

Problematic

The proliferation and invasion of algae on the coasts of many countries is an increasingly frequent phenomenon with a growing impact. Although its specific causes are unknown, it has been proven that the phenomenon is linked to the eutrophication of the sea (Smetacek & Zingone, 2013) and possibly to the increase in ocean temperature and therefore to climate change, which modifies the configuration of winds and ocean currents. Satellite images show that the Sargassum affecting the Mexican Caribbean comes from the central-eastern Atlantic Ocean (USF- NASA, 2018).

In the Mexican Caribbean, the sudden invasion of Pelagic Sargassum on the coasts, mainly in the state of Quintana Roo, first occurred with isolated strandings, some months in small quantities. Then, between 2011 and 2018, the proliferation and invasions of Pelagic Sargassum increased alarmingly (Schell et al., 2015). The largest beach stranding of Sargassum occurred in 2018, as can be seen in Figure 1, and its presence continued for most of the year. As the large quantities of Sargassum biomass reach the coast, they become completely heterogeneous within a few hours or days. The accumulation of Sargassum on a daily basis forms clogged piles, which promote the unpleasant smelling fermentation process and initiate the degradation of organic matter (Figure 2). The tide and waves throw some of the fermented Sargassum back into the sea and contaminate it, while cyclically mixing it with fresh Sargassum. The optical properties of water change when masses of Sargassum cover the sea, forming a layer up to 20 cm thick that blocks sunlight and disrupts the energy balance of primary producers in the reef system, such as seagrass beds. The delicate trophic balance of an eminently oligotrophic system, which under normal circumstances lacks suspended particulate matter, is also disrupted. Over time, the heterogeneous and dehydrated piles of partially degraded Sargassum are gradually blown away and deposited on coastal dunes, forming a vegetation cover and reducing wind and tidal erosion (Figure 3). During its long journey from sea to dunes, Sargassum often mixes with sand and other residues of human activity, mainly plastic. This great heterogeneity of Sargassum accumulated on the coasts strongly hinders its potential use, as most industrial processes require homogeneous raw material.

The massive influx, accumulation and slow natural recycling of Sargassum has enormous negative social implications on the Mexican Caribbean coast, mainly in the state of Quintana Roo, since the main economic activities depend on tourism, especially international tourism. The presence of Sargassum deteriorates the landscape, and the polluted sea can cause irritation or illness (GCFI, 2018). Sargassum that has travelled long distances at sea before reaching the coast can also carry invasive species that have a negative ecological impact locally. Removing Pelagic Sargassum from the sea or heterogeneous piles of Sargassum accumulated on the coast is difficult to manage, either manually or mechanically, as the quantities are huge and the processes have economic costs. The machines available on the market are expensive, rather rudimentary and have been designed for small quantities. Their use is therefore limited and must be carried out by trained operators. Sargassum collection can also have serious ecological implications, such as manual or mechanical erosion of sand and nutrients; sand compaction; geomorphological modification of beaches; damage to the dune system; increased wind erosion; degradation of reefs, seagrass beds and coral gardens; negative impact on sea turtle nesting and egg-laying, as well as the return of hatchlings to the sea; degradation of coastal vegetation; contamination of soil and groundwater due to the storage of seaweed in licensed and monitored sites.

In 2019, the Pelagic Sargassum invasion is expected to match or exceed that of 2018 with the El Niño phenomenon likely to increase ocean temperatures and intensify winds and ocean currents. Unfortunately, there is a high probability that the Sargassum problem will continue to grow out of control in the future. Therefore, Mexico must invest now in basic, applied and socio-economic scientific research to manage or counteract these adverse effects. This will fill the current knowledge gap on a problem that has completely caught all levels of government organisation off guard. Not only is the response time slow, but there is also organisational confusion about levels of responsibility and about how the problem is to be solved, which has resulted in wasted resources. In 2018 alone, we estimate that an investment of more than 240 million Mexican pesos was made in the state of Quintana Roo, to test a barrier that contains the offshore seaweed beds, and to manually collect more than 250,000 m3 of Sargassum from the beaches (Rebolledo-Vieyra, 2018).