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A Systematic Review of the Mysterious Caterpillar Fungus *Ophiocordyceps sinensis* in DongChongXiaCao (冬蟲夏草 Dōng Chóng Xià Cǎo) and Related Bioactive Ingredients

Hui-Chen Lo[1], Chienyan Hsieh[2], Fang-Yi Lin[3] and Tai-Hao Hsu[3]

[1]Department of Nutritional Science, Fu Jen Catholic University, Xinzhuang District, New Taipei City, Taiwan.
[2]Department of Biotechnology, National Kaohsiung Normal University, Yanchao Township, Kao-Hsiung County, Taiwan.
[3]Department of Medicinal Botanicals and Healthcare and Department of Bioindustry Technology, Da-Yeh University, Changhua, Taiwan.

ABSTRACT

The caterpillar fungus *Ophiocordyceps sinensis* (syn.[†] *Cordyceps sinensis*), which was originally used in traditional Tibetan and Chinese medicine, is called either "yartsa gunbu" or "DongChongXiaCao (冬蟲夏草 Dōng Chóng Xià Cǎo)" ("winter worm-summer grass"), respectively. The extremely high price of DongChongXiaCao, approximately USD $20,000 to 40,000 per kg, has led to it being regarded as "soft gold" in China. The multi-fungi hypothesis has been proposed for DongChongXiaCao; however, *Hirsutella sinensis* is the anamorph of *O. sinensis*. In Chinese, the meaning of "DongChongXiaCao" is different for *O. sinensis*, *Cordyceps* spp.,[‡] and *Cordyceps* sp[ƒ]. Over 30 bioactivities, such as immunomodulatory, antitumor, anti-inflammatory, and antioxidant activities, have been reported for wild DongChongXiaCao and for the mycelia and culture supernatants of *O. sinensis*. These bioactivities derive from over 20 bioactive ingredients, mainly extracellular polysaccharides, intracellular polysaccharides, cordycepin, adenosine, mannitol, and sterols. Other bioactive components have been found as well, including two peptides (cordymin and myriocin), melanin, lovastatin, γ-aminobutyric acid, and cordysinins. Recently, the bioactivities of *O. sinensis* were described, and they include antiarteriosclerosis, antidepression, and antiosteoporosis activities, photoprotection, prevention and treatment of bowel injury, promotion of endurance capacity, and learning-memory improvement. *H. sinensis* has the ability to accelerate leukocyte recovery, stimulate lymphocyte proliferation, antidiabetes, and improve kidney injury. Starting January 1st, 2013, regulation will dictate that one fungus can only have one name, which will end the system of using separate names for anamorphs. The anamorph name "*H. sinensis*" has changed by the *International Code of Nomenclature for algae, fungi, and plants* to *O. sinensis*.

Key words: Bioactive Ingredients, *Cordyceps sinensis*, DongChongXiaCao, *Hirsutella sinensis*, *Ophiocordyceps sinensis*

Notification
[†]The term *"Cordyceps sinensis"* has been renamed to its synonym *"Ophiocordyceps sinensis"* by Sung *et al.* in 2007. In the discussion, *"Cordyceps sinensis"* is still used to represent *"Ophiocordyceps sinensis"* out of respect to the original authors of the articles that we cited.
[‡]*Cordyceps* spp. indicates any species that belongs to the genus *Cordyceps*.
[ƒ]*Cordyceps* sp. indicates the unidentified species that belong to the genus *Cordyceps*

Correspondence to:
Prof. Tai-Hao Hsu, Department of Medicinal Botanicals and Healthcare and Department of Bioindustry Technology, Da-Yeh University, Datsuen, Changhua, 51591, Taiwan. Tel: +886-4-28511888-2288; E-mail: th4420@gmail.com

INTRODUCTION

The caterpillar fungus *Ophiocordyceps sinensis* (syn. *Cordyceps sinensis*) is one of the entomogenous Ascomycetes and parasitizes the larvae of Lepidoptera to form the well-known traditional Tibetan medicine "yartsa gunbu" or, in traditional Chinese medicine, "DongChongXiaCao (冬蟲夏草 Dōng Chóng Xià Cǎo)"("winter worm-summer grass," [Figure 1]). DongChongXiaCao is a well-described remedy that has been used in traditional Chinese medicine for over 700 years.[1] The wild fungus, which possesses a plant-like fruiting body and originates from dead caterpillar that fill with mycelia [Figure 2], has generally been called *C. sinensis* or *Cordyceps* spp. ("ChongCao" in Chinese) due to its insect-shape appearance. *O. sinensis* (previously named *C. sinensis*) is a slow-growing fungus and needs to be grown at a comparatively low temperature, i.e., below 21ºC. Both temperature and growth rate are crucial factors that identify *O. sinensis* from other similar fungi.[2] In recent decades, curative and health-care products derived from the so-called "Cordyceps" are extremely popular in China in various forms such as capsules, oral liquids, and drinks.[3] Most of these products, derived from submerged mycelial *O. sinensis* cultures [Figure 3], are the popular merchandise items on the market.

It has been shown that *O. sinensis* can be used to treat conditions such as hyposexuality, night sweats, hyperglycemia, hyperlipidemia, asthenia, arrhythmias, and other heart, respiratory, renal and liver diseases.[3] Although "natural *O. sinensis* specimens" have significant pharmaceutical effects, the commercial cultivation of this fungus on larvae of moth to produce fruiting body has not yet been successful.[4] Therefore, the biology of *O. sinensis* remains a secret, and its commercial cultivation is still a dream.[5]

In the past years, several new names have been proposed for *O. sinensis*-like species from alpine regions, such as *O. gansuënsis*, *O. crassispora*, *O. kangdingensis*, *O. multiaxialis, O. nepalensis*, and others, but there is not sufficient to distinguish these species from *O. sinensis*.[6] Fungi other than *O. sinensis* originating

Figure 1. Wild DongChongXiaCao (black part: the fruiting body; brown part: the caterpillar corpus)

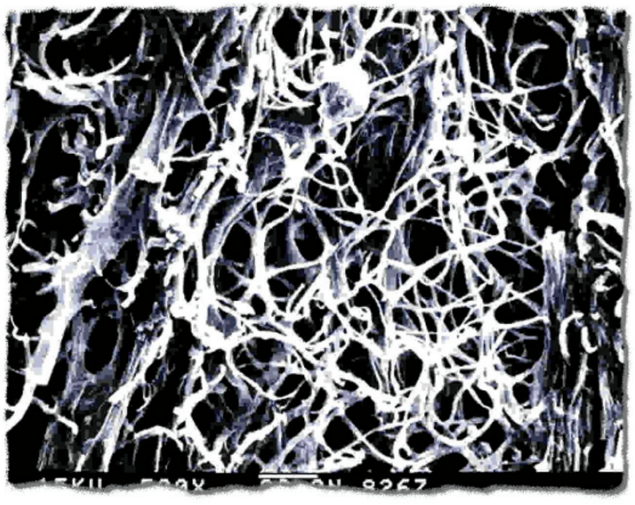

Figure 2. Scanning electron micrograph of mycelia filling the inside of a fruiting body of wild DongChongXiaCao

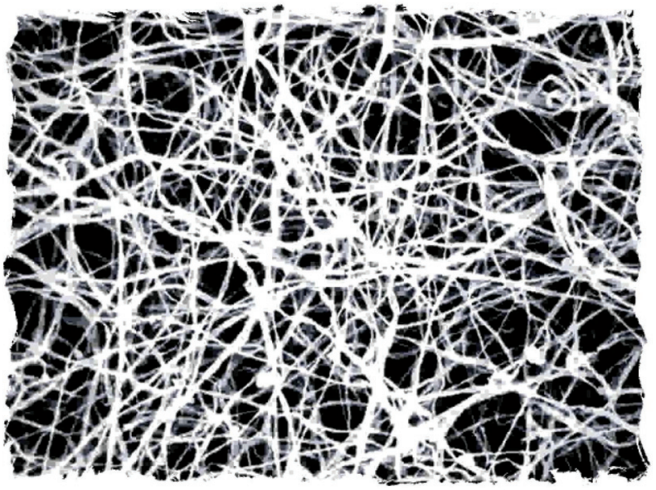

Figure 3. Scanning electron micrograph of mycelia from the medium of a submerged culture of *Ophiocordyceps sinensis*

Figure 4. Label showing the precious price (CNY ¥698 per gram) of wild DongChongXiaCao sold in August, 2012 in Beijing, China