

Cordyceps Militaris: The Medicinal Mushroom

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Abstract: *Cordyceps militaris* is a highly sought after medicinal mushroom known for its bright orange, club shaped fruiting bodies. It is widely used in traditional Asian entomedicine as an adaptogenic and tonic agent and wellness supplements to potentially boost cellular energy, support immune function, reduce inflammation and enhance athletic performance. *Cordyceps militaris* produce potent bioactive compounds and polysaccharides including two peptides, (cordymin and myriocin) and melanin, lovastatin, γ -aminobutylic acid, ergothioneine and cordysinin. Over 30 bioactivities suggest immunomodulatory, anti-tumour, anti-inflammatory, and anti-oxidant activities; have been reported for wild DongChongXiaCao and for the mycelia and culture supernatants of *O. sinensis* were described, and they include antiarteriosclerosis, anti-depression and anti-osteoporosis activities, photoprotection, prevention and treatment of bowel injury, promotion of endurance capacity and learning memory improvement.

Keywords: Cordiceps militaris, Corycepin, Bioactive compounds, DongChongXiaCao, immunomodulatory, medicinal mushroom, polysaccharides, ergothioneine and therapeutic effects

I. INTRODUCTION

Cordyceps militaris, commonly known as the caterpillar fungus or scarlet caterpillar club, is a parasitic fungus in the family of Cordycipitaceae. [1] It was originally described by Carl Linnaeus in 1753 as *Clavaria militaris* and forms bright orange/red club-shaped fruiting bodies 1–8 cm high. [2] The fungus parasitizes underground insect pupae (mainly moths) and is the type of species of the *Cordyceps* genus containing hundreds of species. [3]

C. militaris contains bioactive principles acting as antioxidant/anti-aging, anti-tumor/anti-cancer, immunomodulatory, anti-inflammatory, neuroprotective, and anti-diabetic agents. [4] It is considered a potential harbour of bio-metabolites for herbal drugs and is now used extensively in modern systems of medicine. [5] The mushroom is popular among sportsmen and fitness enthusiasts for boosting stamina, athletic performance, and improving oxygen utilization. [6] There are over 400 wild *Cordyceps* species; similar species include *C. sobolifera*, *Elaphocordyceps capitata*, and *E. ophioglossoides*. [7] Of at least a dozen *Cordyceps* species recorded in the British Isles, *C. militaris* (scarlet caterpillar club) is the most common. [8] The genus includes species attacking ants, other insects, and even fungi like puffballs or false truffles. [9]

Main bioactive compounds include adenosine, cordycepin (3' -dehydroadenosine), polysaccharides, mannitol, superoxide dismutase (SOD), and carotenoids. [10] Cordycepin is the highest in fruiting bodies on pupae and is the most important bioactive compound in *C. militaris*. [11] The bioactive constituents also include cordycepic acid, mannitol, alkaloids, vitamins B1/B2 along with polysaccharides. [12]

Common names across different cultures [13]

- English: Scarlet caterpillar club, caterpillar fungus, orange cordyceps
- Chinese: DongChongXiaCao
- Hindi: Keedajari
- Japanese: Tama-Chotaku
- Korean: Yeongchi-myeon



Unlike its rare and expensive counterpart *Ophiocordyceps sinensis* (which grows only at high altitudes in the Himalayas on specific caterpillars), *C. militaris* has several advantages like therapeutic effects, pharmacological properties, sustainable cultivation, market growth (USD 3.34 billion by 2033 with a CAGR of 10.9%) and approved as a novel food in China and increasingly used in pharmaceutical, dietary supplements and functional foods. Species of *Ophiocordyceps* are entomopathogenic on a range of insects. [14] The host of species of *Ophiocordyceps* are the larvae of coleopteran and Lepidoptera as well as the adults of araneae, diptera, hemiptera, hymenoptera, odonata and orthoptera. [15] Although *Ophiocordyceps* has worldwide distribution, the tropics and sub tropics are where the highest number of species is recorded. Moreover, it is considered that there is an underestimation of the number of *Ophiocordyceps* species. [16] The biodiversity of Vietnam, both flora and fauna due to the tropical monsoon climate with high temperature and rainfall is a favorable environment for the development of entomopathogenic fungi. Lang Biang biosphere reserve is in Lam Dong province and comprises a vast primitive jungle with the Lang Biang Mountain at its core, one of Vietnam's four biodiversity centers. [17]

In this study, we introduce this specimen as a new species of *Ophiocordyceps* that parasitizes the larva of cleoptera. [18] We present a morphological description and phylogenetic analysis based on the phylogenetic construction of the nuclear large ribosomal subunit (nrLSU), nuclear small ribosomal subunit (nrSSU) and RNA polymerase II subunit B1 (rpb 1) of species of *Ophiocordyceps* including this new species. [19]

Classification of *Cordyceps militaris*: [20]

Taxonomic Rank	Classification
Domain	Eukaryota
Kingdom	Fungi
Division	Ascomycota
Class	Sordariomycetes
Order	Hypocreales
Family	Cordycipitaceae
Genus	<i>Cordyceps</i> Fr. (1818)

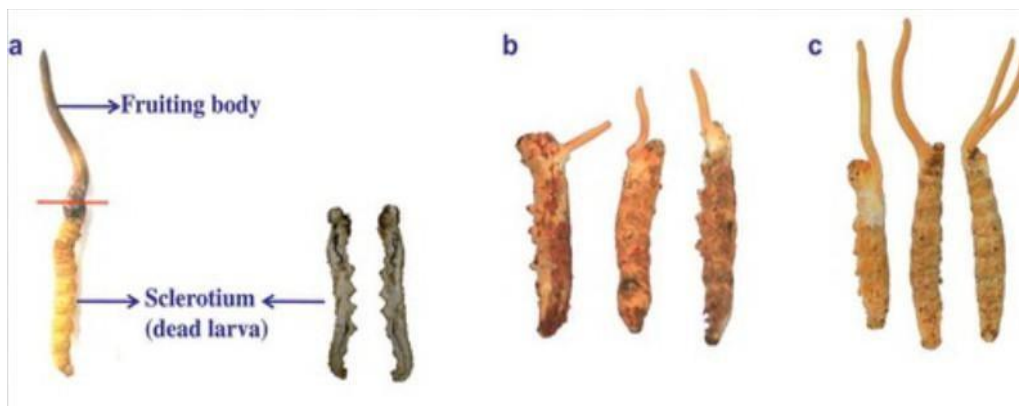
Detailed Morphology of *Cordyceps militaris* [21]

Produces distinctive, easily recognizable fruiting bodies that are remarkable for their bright orange to scarlet, orange coloration and club shaped morphology. The fungus produces both sexual (teleomorph) and asexual (anamorph) stages, each with unique morphological characteristics.

Macroscopic Morphology (Fruiting Body/Stroma) [22]

FEATURE	DESCRIPTION	MEASUREMENT S
Overall height	Club-shaped orange/red fruiting body	1-8 cm (½-3 ¼ inches)
Emergence Pattern	Grows out of dead underground Pupae	Often curved at base
Surface Texture	Roughly punctured Appearance	Perithecia visible as raised dots
Internal Tissue	Whitish to pale orange when cut	Firm, brittle when Dry





Detailed morphological regions: [23]

1. Fertile Head (Capitulum/Upper portion) [24]

- Length: 0.5-4cm
- Diameter: 2-4mm
- Colour: bright orange or scarlet orange (most intense colour)
- Surface: granular with visible raised pores (Perithecia embedded in stroma)
- Shape: club shaped, slightly rounded at apex
- Function: produces sexual spores (ascospores)
- Texture: rough, pimply feeling due to Perithecia.

1. Sterile stem/stipe (lower portion) [25]

- Length: 1-3cm
- Diameter 1-1.5mm (narrow than fertile head)
- Colour: paler orange (lighter than fertile head)
- Surface: smooth, wavy, non granular
- Shape: tapering towards the base, narrowing at attachment point
- Texture: smooth compared to rough fertile head
- Function: supports fertile head, emerges from pupa

2. Base/attachment point [26]

- Emerging from mummified insect pupa
- Frequently curved or bent at emergence
- May show white mycelia masses around parasitized insect

Colour Characteristics [27]

PART	FRESH COLOUR	DRIED COLOUR
Fertile Head	Bright orange to scarlet orange	Darker orange, may fade
Stem	Paler orange	Pale orange to yellowish
Internal Tissues	Whitish to pale orange	Whitish
Myceliu M	White (when fresh)	White to cream

The characteristic bright orange color comes from carotenoid pigments produced by the fungus, which are induced by light exposure during cultivation. [28]



MICROSCOPIC MORPHOLOGY [29]

Sexual stage (Teleomorph) Spores (Ascospores) [30]

CHARACTERISTIC	DESCRIPTION
SHAPE	Long-filiform (thread-like), slightly curved
SURFACE	Smooth (non-ornamented)
COLOUR	Hyaline (transparent/colourless)
SEPTATION	Often septate (divided into segments)
SIZE	3-7 micrometer x 1-1.2 micrometer
DISPERSAL	Released from asci into perithecia
GERMINATION	Unidirectional germination in sterile water

Asci: [31]

CHARACTERISTIC	DESCRIPTION
SHAPE	Long and cylindrical
SIZE	300-500 um long x 3.5-5um diameter
CONTENTS	8 ascospores each

Perithecia: [32]

CHARACTERISTIC	DESCRIPTION
SHAPE	Flask-like, spherical
ARRANGEMENT	Embedded in stroma surface
VISIBILITY	Visible as raised dots on a fertile head
FUNCTION	Contain asci and produce ascospores
OPENING	Small ostiole for spore release

STROMA: [33]

- COMPOSITION: compact mass of fungal hyphae
- FUNCTION: contains Perithecia in its tissue
- COLOUR: bright orange throughout
- TEXTURE: firm, somewhat fleshy when fresh

ASEXUAL STAGE (ANAMORPH) [34]

Cordyceps militaris sometimes produces an anamorphic state identified as *Isaria*.



CONIDIAL DEVELOPMENT [35]

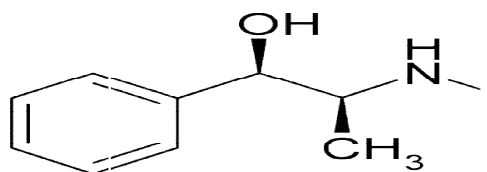
FEATURE	DESCRIPTION
CONIDIOGENESIS	Conidia develop from germinating ascospores and vegetative hyphae
MICROCYCLI CONIDATION	Most ascospores germinate unidirectionally, conidia develop directly from hyphal tips within 36 hours
FIRST-FORMED CONIDIA	Cylindrical or clavate
SUBSEQUENT CONIDIA	Globose (spherical) and ellipsoidal shapes
CONIDIA TYPES	Two distinct types: elongated pyriform or cylindrical globose
CONIDIAL ARRANGEMENT	Slimy heads on phialides
CONIDIAL SIZE	Polymorphic
NUCLEAR STATUS	Uninucleate
PHIALIDES	Conidiogenous cells more slender than vegetative hyphae with attenuated tips
PHIALIDE ARRANGEMENT	Solitary, opposite or whorled type

PHYTOCHEMISTRY [36]

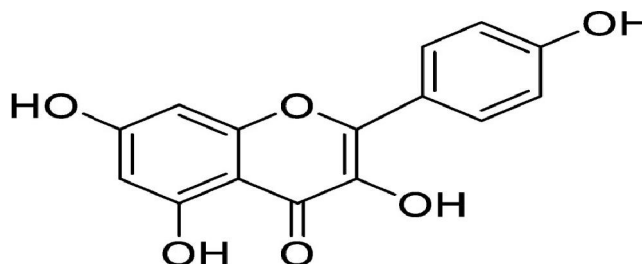
Cordyceps militaris contains a diverse array of bioactive compounds responsible for its extensive pharmacological activities. [37] The mushroom photochemical profiles include nucleosides, polysaccharides, amino acids, proteins, sterols, pigments, and various secondary metabolites. [38] Phytochemical screening is carried out to identify the major bioactive compounds present in *Cordyceps sinensis* (also known as *ophiocordyceps sinensis*). [39] Although it is a fungus rather than a plant, the term phytochemical screening is commonly used in natural products research. [40]

MAJOR BIOACTIVE COMPOUNDS DETECTED: [41]

1. ALKALOIDS: [42]



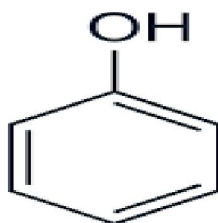
- Present in moderate amounts and contribute to neurological and pharmacological activities



1. FLAVONOIDS: [43]

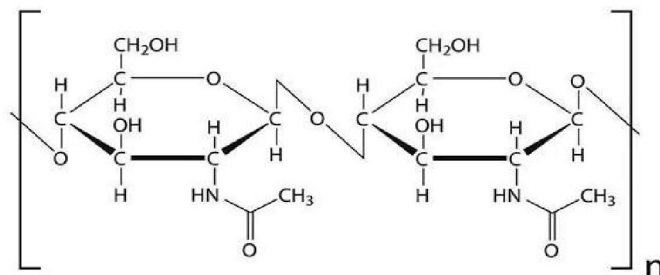
- Strong antioxidant properties
- Help in scavenging free radicals

2. PHENOLIC COMPOUNDS: [44]



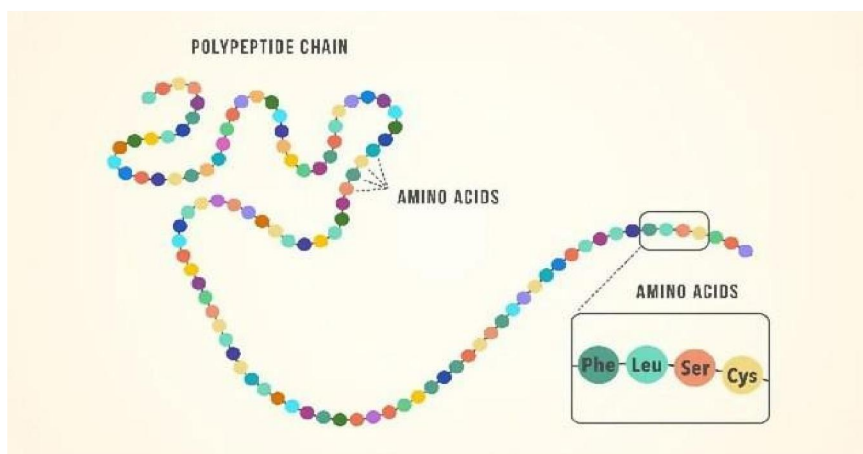
Responsible for anti-oxidant and anti-inflammatory effects.

3. POLYSACCHARIDES: [45]



- One of the most important constituents
- Immune-modulatory and anti-tumour activities

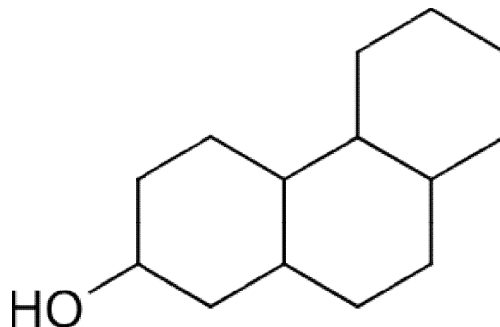
4. Includes b-glucans and amino acids: [46]



- Essential amino acids are present which contribute to nutritional and therapeutic value

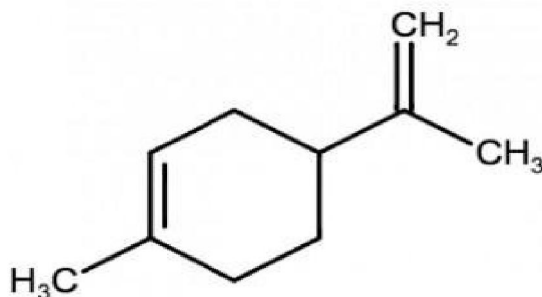
5. **PROTEIN:** [47]

6. **STEROLS:** [48]



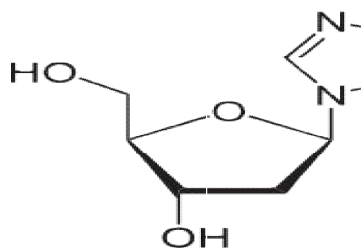
- Ergosterols is commonly detected which is a precursor of vitamin D2

7. **TERPENOIDS:** [49]



- Possesses anti microbial and anti-inflammatory properties

8. **NUCLEOSIDES:** [50]



- Cordycepin and adenosine are major compounds
- Important for anti-cancer and energy metabolism activities



STANDARD PRELIMINARY PHYTOCHEMICAL TEST: [51]

SOLVENT	MAJOR COMPOUNDS EXTRACTED
METHANOL	Phenolics, flavanoids, cordycepin
ETHANOL	Alkaloids, sterols, terpenoids
WATER	Polysaccharides and Proteins
CHLOROFORM	Lipophilic compounds and sterols
ETHYL ACETATE	Phenolics and secondary metabolites

MARKER COMPOUNDS COMMONLY USED FOR [52]

COMPOUND GROUP	TEST USED	POSITIVE INDICATION
ALKALOIDS	Dragendorff's/ Mayer's test	Cream or orange precipitate
FLAVONOIDS	Shinoda test	Pink/red colour
PHENOL	Ferric chloride test	Blue-green coloration
SAPONINS	Foam test	Persistent froth

MAJOR MEDICINAL VALUES: [53]

1. IMMUNITY ENHANCEMENT: [54]

- Contains bioactive compounds such as polysaccharides, cordycepin, adenosine, and sterols.
- Helps stimulate immune cells like macrophages and natural killer cells.
- Also it is often studied for immunomodulatory activities.

2. ANTIOXIDANT ACTIVITIES: [55]

- Reduces oxidative stress by scavenging free radicals
- May help delay cellular ageing and tissue damage

3. ANTI-INFLAMMATORY EFFECTS [56]

- Can reduce production of inflammatory mediators
- Traditionally used in respiratory and inflammatory disorders

4. ANTI-FATIGUE AND ENERGY BOOSTING [57]

- Cordyceps is believed to improve ATP production and oxygen utilisation.
- It is used traditionally to enhance stamina and physical performance.

CULTIVATION:

The cultivation of cordyceps militaris the artificial growing and propagation of this medicinal fungus under controlled environment conditions using suitable nutrient substrates, temperature, humidity, light and sterile techniques to produce its mycelium and fruiting bodies for medicinal, research and commercial purposes. [58]

REQUIREMENTS FOR CULTIVATION: [59]

- 1. Pure culture:** a healthy and contamination free culture of cordyceps militaris is essential. The culture is generally obtained from a microbial culture laboratory and maintained on potato dextrosagar PDA medium. [60]
- 2. Substrate:** the fungus grows well on nutrient rich substrate. [61]



COMMONLY USED SUBSTRATE: [62]

- Brown rice
- White rice
- Silk worm pupae powder
- Wheat grains
- Millet and nutrient supplements like glucose, peptone, and yeast extract.

3. Environmental conditions: Optimal growth conditions include:

- Temperature – 18-22 celsius
- Relative humidity- 70-90%
- Light- mild fluorescent light for fruiting
- Ph- 6-6.5
- Proper air exchange and ventilation [63]

METHOD OF CULTIVATION

STEP 1: PREPARATION OF SUBSTRATE

Rice is washed properly and soaked in water for several hours. [64] The soaked rice is mixed with nutrient supplements and transferred into glass jars or polypropylene bottles. [65] Adequate moisture is maintained because excess water can lead to contamination. [66]

STEP 2: STERILISATION

The filled containers are sterilised in an autoclave at 121 degree celsius for about 20-30 mins. sterilisation prevents the growth of unwanted microorganisms such as bacteria and molds. [67]

STEP 3: INNOCULATION

After cooling, the sterilised substrate is inoculated with the fungal culture under aseptic conditions inside a laminar air flow chamber. [68] Small pieces of actively growing mycelium are transferred into the substrate containers. [69]

STEP 4: INCUBATION

The inoculated containers are incubated in darkness at around 20 degree celsius for 10-15 days. [70] During this period, white mycelium spreads throughout the substrate. [71]

STEP 5: FRUITING STAGE

After complete colonization, the containers are exposed to light and high humidity. [72] Fruiting bodies begin to appear within 1-2 weeks. [73] Orange coloured club-shaped stomata are produced which are the characteristic of *cordyceps militaris*. [74]

STEP 6: HARVESTING

The fruiting bodies are harvested when they reach full size and bright orange colour. [75] Harvesting is done carefully to avoid damage. [76] The mushrooms are then dried at low temperature for storage and medicinal use. [77]

PRECAUTIONS DURING CULTIVATION:

- maintain strict sterile conditions
- avoid excess moisture to prevent contamination
- ensure proper ventilation during fruiting
- monitor temperature and humidity regularly
- use high-quality spawn and substrate [78]



Artificial cultivation also reduces dependence on wild harvesting and helps conserve natural populations. [79]
The cultivation of cordyceps militaris is an important biotechnological process with high medicinal and economic value. [80] With proper substrate preparation, sterilization and environmental control, high-quality fruiting bodies can be produced commercially, its growing demand in the pharmaceutical and health sectors makes it a promising medicinal mushroom for future research and cultivation industries. [81]

MARKET FORMULATION OF CORDYCEPS MILITARIS

Market formulation refers to the different commercial forms in which cordyceps militaris is processed, packaged, and sold for medicinal, nutritional and health related uses. [82]

COMMON MARKET FORMULATIONS:

1. CAPSULES AND TABLETS [83]

Dried cordyceps powder is packed into capsules or compressed into tablets for easy consumption.

2. POWDER FORM: [84]

The dried or fruiting body or mycelium is finely powdered and used in health drinks, smoothies and supplements.

3. EXTRACTS: [85]

Concentrated extracts containing cordycepin and polysaccharides are prepared using water and alcohol extraction methods.

4. TEA AND BEVERAGES: [86]

Cordyceps is added to herbal teas, coffee blends, and energy drinks.

5. TINCTURES AND SYRUPS: [87]

Liquid formulations are produced for medicinal and therapeutic purposes.

6. FUNCTIONAL FOODS [88]

It is incorporated into chocolates, soups, protein bars, and nutraceutical foods.

7. COSMETIC PRODUCTS [89]

Cordyceps extracts are used in skincare products due to their anti-oxidant properties.

IMPORTANCE OF MARKET FORMULATION:

- Increases shelf life
- Improves consumer convenience
- Enhances medicinal value and bioavailability
- Expands commercial and pharmaceutical applications
- Provides value-added products for the health industry [90]

II. CONCLUSION

Cordyceps militaris is an important medicinal fungus known for its nutritional and therapeutic properties. [91] Its artificial cultivation under controlled conditions helps in the large-scale production of high-quality fruiting bodies while reducing dependence on wild sources. [92] Proper cultivation techniques, including suitable substrates, sterilisation and environmental control ensure successful growth and higher yield. [93] Due to the presence of valuable bioactive compounds such as cordycepin and polysaccharides, cordyceps militaris has gained significant importance in pharmaceutical, nutraceutical and healthcare industries. Various market formulations such as capsules, powders,



extracts, beverages and cosmetic products have further increased its commercial demand. [94] Therefore, the cultivation and commercialisation of cordyceps militaris offer great potential in medicine, biotechnology and the health supplement industry. [95]

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