

Caterpillar Fungus in the Himalaya

Current Understanding
and Future Possibilities



G.B. Pant National Institute of Himalayan Environment
Kosi-Katarmal, Almora 263 643, Uttarakhand, India

© G.B. Pant National Institute of Himalayan Environment, 2020

Citation

Vikram S. Negi, Suresh K. Rana, Lalit Giri, Ranbeer S. Rawal (2020). Caterpillar Fungus in the Himalaya, Current Understanding and Future Possibilities. G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora , Uttarakhand, India

Acknowledgements

This work is largely based on published literature on caterpillar fungus in Himalaya. We have freely used this information; authors of all such literature used in this book are gratefully acknowledged. Our sincere thanks are due to local people of Chipla Kedar and Chaudas area of Pithoragarh districts in Uttarakhand for sharing information and related photographs on collection of caterpillar fungus. Mr. Narendra Parihar (GBP-NIHE) and Mr. Naveen Bisht, Dharchula, Pithoragarh helped in collection of photographs from local inhabitants. We also thank Dr. I.D. Bhatt (Scientist, GBP-NIHE) for providing inputs on the marketing of caterpillar fungus. The help received from Dr. Shashi Upadhyay and Dr. Dalbeer Pharswan (GBP-NIHE) in compiling information is gratefully acknowledged.

We sincerely thank Dr. C.S. Negi, MBPG College Haldwani (Uttarakhand), and Dr. Gajendra Rawat, Uttarakhand Space Application Centre (USAC), Dehradun for providing inputs and independent views on status and future prospects of caterpillar fungus.

Dr. Gopal S. Rawat, former Dean Wildlife Institute of India, and Dr. Rajendra Dobhal, Director General UCOST, in their individual expert capacity, reviewed the draft document and provided valuable inputs for improvement. We gratefully acknowledge the help rendered by them.

The encouragement and support received from the Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India, is sincerely acknowledged. The partial financial support received from GBP-NIHE and KSLCDI-ICIMOD for this work is gratefully acknowledged.

Disclaimer:

The views and interpretations in this publication are those of the authors (s). They are not attributable to GBP-NIHE and do not imply the expression of any opinion concerning the legal status of any country, territory, province.

This publication may be produced in whole or in part and in any form for educational or non-profit purposes without permission from the copy right holders, provided acknowledgement of this source is made.

GBP-NIHE will appreciate copy of any such publication that uses this publication as a source.

Photo credits: Vikram S. Negi; Narendra Parihar; Naveen Bisht

ISBN Number: 978-93-5416-900-7



Caterpillar Fungus in the Himalaya

Current Understanding and Future Possibilities

•••••
Vikram S. Negi

Suresh K. Rana

Lalit Giri

Ranbeer S. Rawal



Table of contents

<i>Foreword</i>	5
<i>Preface</i>	7
1. Introduction	9
1.1 The species-caterpillar association	10
1.2 Production, collection and trade	11
1.3 Caterpillar fungus in Indian Himalaya	12
2. The review	15
2.1 Literature survey	15
2.2 Geographical distribution and habitat association	15
2.3 Caterpillar fungus-life cycle	17
2.4 Biochemical and pharmacological studies	18
2.5 The research & development investments	24
3. Collection, grading and market	29
3.1 Camping and collection	29
3.2 Grading of material	32
4. Caterpillar fungus and socio-economic development	35
4.1 Contribution to rural economy	35
4.2 Socio-economic transformation	36
5. Evolving trade and marketing	39
6. Ecological consequences and sustainability	45
6.1 Sustainability of habitats	45
6.2 Unregulated harvesting in conservation areas	48
6.3 Overexploitation leading to population decline	48
6.4 Caterpillar fungus under changing climate	48
6.5 Addressing issues of sustainability	50
7. Governance issues - social & ecological implications	53
8. Way forward	57
<i>Bibliography</i>	60



Foreword



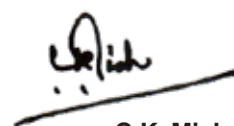
The Indian Himalayan Region (IHR) is known for richness of wild bio-resources, which are intricately linked with livelihoods of local indigenous communities. A large proportion of rural poor, especially among ethnic groups, depend on these

resources as sources of food, nutrition, medicine, and other useful materials. Further, collection and marketing of selected bio-resources has traditionally been a major source of rural income and revenue to the government. Among others, Himalayan medicinal plants, all through the history, have served the people in remote localities as an effective means of curing diseases. In recent times, with an upsurge of global interest on herbal drugs, several Himalayan plants have become globally popular. More recently one particular species, *Ophiocordyceps sinensis* (Caterpillar fungus; locally known as Keera-jari), from higher altitudes of the Himalaya, has attracted special attention with fast increasing market demand.

With its distribution confined to larger part of higher Himalaya, in Bhutan, Tibetan Autonomous Region of China, India and Nepal, this caterpillar fungus has become globally popular as Himalayan Herbal Viagra and resulted in multifold increase in its price within a small period of time. The increased market demand has resulted in a significant increase in collection by scores of collectors thereby posing severe pressure on its natural populations and habitats in sensitive alpine ecosystems.

Reports indicate, availability of the resource has declined, and harvesting has become difficult. This calls for attention with respect to sustainability of its habitats. The emergence of caterpillar fungus as game changer, both in socio-economic and ecological domain, brings issues pertaining to governance of this common's resource on forefront. Effective guidelines and mechanism for harvesting, marketing and trade are mostly lacking. While China has made good progresses in research fields and product development of caterpillar fungus Bhutan, India and Nepal remain way behind.

I am extremely happy to note that a team of researchers at G.B. Pant National Institute of Himalayan Environment (NIHE) has comprehensively analyzed and synthesized available knowledge on this important resource. The synthesis, as presented in this book, will serve diverse groups of stakeholders. More importantly, extensive bibliography appended with this document, will prove a good source material for future researchers. The team of authors deserve appreciation. I hope, readers will enjoy contents of this book and provide their feedback to the Institute.



C.K. Mishra
Secretary Government of India
Ministry of Environment, Forest and Climate Change
6th May 2020



Preface

During last three decades or so, interest on caterpillar fungus (*Ophiocordyceps sinensis*) from the high altitude areas of the Himalaya has grown across the globe. Fast growing global market demand and year by year increasing price at international markets have made this fungus very lucrative to local indigenous communities inhabiting higher Himalayan villages, which has transformed their socio-economic status. Such collection and marketing of this fungus has emerged as an important source of income in parts of Bhutan, China, India and Nepal. However, increasing popularity and growing demand of caterpillar fungus has also become a curse to the unique alpine ecosystems. Hundreds of people camp in high alpine areas for the collection of this fungus every year, and stay there for one-two months (i.e., during May and June). During this prolonged stay, collectors damage the local biodiversity and ecosystem in several ways, including illegal poaching of high altitude animals and harvesting of other medicinal plants. All this affects the pristine alpine habitats severely. While the fungus has been in use for long in Chinese traditional medicine system, it became globally famous with its recognition as Himalayan Herbal Viagra in recent decades. The species is enriched with over 30 bioactive compounds, which are having various pharmacological activities like anti cancer, aphrodisiac, immunomodulatory, anti-inflammatory, antioxidant, etc.

The major occurrence of caterpillar fungus in India has been reported from alpine ranges of Sikkim and Uttarakhand. However, alpine areas of Pithoragarh and Chamoli districts of Uttarakhand are specifically

important, where local indigenous communities of high altitude villages are intensively engaged with its collection. Despite such an importance, the research based information on this species is surprisingly meagre from the Indian Himalayan Region. The present effort, therefore, targets to review the available global studies on this fungus to provide more authentic details of its status, contribution in local livelihoods, marketing problems, and future prospects. Review has clearly indicated that conservation of this species to sustain livelihoods in long run is very important. Further, the communities dependent on this resource have become highly vulnerable in the wake of decreasing production of caterpillar fungus due to changing climate and over harvesting. This calls for immediate attention to make appropriate interventions so as to build resilience of vulnerable communities under changing circumstances.

The book contains chapters on collection, grading and market; caterpillar fungus linked socio-economic development; evolving trade and marketing; and ecological consequences of fungus collection. Also, an attempt has been made to touch upon governance issues, and provide a way forward. Extensive bibliography at the end brings all available researches on target species at one place. We sincerely believe the book will be of immense value for the diverse stakeholders, ranging from local communities to researcher, from practitioners to policy people.

Authors
May 2020





I. Introduction

All through the human history, wild bioresources have played a key role in sustenance of a large portion of human population across the world. However, in recent times, issues pertaining to elimination of hunger and ensuring food and health security have necessitated new ways for collection, consumption and trade in wild resources (Negi et al. 2011; SDG 2019). Estimates suggest about 1.6 billion people, including 60 million indigenous ethnic people across the globe depend directly on forest based products for their livelihoods and food security (FAO 2011; Vedeld et al. 2007). Indigenous forest dwelling communities depend on wild resources not only for their livelihoods, but also to generate a substantial amount of income. It is reported, forests contribute 22-28% of household income in developing countries (Angeles et al. 2014), and over 90% of extremely poor people depend on forests for all or part of their livelihoods (OECD, 2009; Pouliotv and Treue 2013). Among various forest products, collection of non-timber forest produce (NTFPs) and medicinal plants from wild habitats form an important activity in the mountains regions, including the Himalaya (Dhar et al. 2000, 2002; Rawat 2006; Negi et al. 2018a).

The Himalaya, which forms one of the Global Biodiversity Hotspot, is well recognized for richness, uniqueness of its biodiversity, and numerous goods and services (Rawal et al 2013). Local and indigenous ethnic communities in the region have rich traditions of use of bioresources for food shelter and medicine. The Himalaya is also diverse in indigenous ethnic communities who inherit rich traditional knowledge on the use of medicinal plants and health practices (Rawat 2006; Negi et al. 2018a). In different parts of the Himalaya people follow different folk systems of medicine in addition to the codified medicine systems like Ayurveda, Amchi, Unani, Sidha, etc. In India, 1178 species of medicinal plants are under trade largely for use in several systems of medicine (Goraya and Ved 2017), many of these have their natural habitats in the high altitude regions of the Himalaya. In general, alone in Indian Himalaya over 1700 plant species have been documented as species of medicinal use; some of these species have very high market value.

Demand of a particular species in trade varies with time following the requirement in the industries. Depending upon the growing demand, a particular species emerges as high value and its natural populations begin to face heavy pressure. One such example, in recent decades, has been reported in the form of collection of *Ophiocordyceps sinensis* (Caterpillar fungus) from the high altitude habitats of the Himalaya including Tibetan plateau. In last three decades collection of high-value, low-volume caterpillar fungus has become an important livelihood activities and source of income in the mountainous parts of Bhutan (Wangchuk et al., 2012), China (Winkler 2008, 2009), India (Kuniyal and Sundriyal 2013; Negi et al. 2014) and Nepal (Shrestha and Bawa 2014a).

1.1 The species-caterpillar association

Ophiocordyceps sinensis (Berk.) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora (earlier known as *Cordyceps sinensis*) is a high altitude Himalayan fungus-caterpillar association found in alpine meadows of Bhutan, China, India and Nepal. It belongs to Ophiocordycipitaceae family of Division Ascomycetes, which parasitizes on underground dwelling larva of moths belonging to the family Hepialidae (Lepidoptera), particularly on the species of *Thitarodes* (Wang and Yao 2011; Jang et al. 2016; Zhong et al. 2016). The body of the insect host is used by the fungus as substrate to form the mycelium, which is finally converted into a sclerotium covered by the intact exoskeleton of the insect to withstand the winter (Wang and Yao 2011; Li et al. 2011).

The stroma (fruiting body) of the fungus grows from the sclerotium and emerges above the ground with the advent of snow melt during the following spring and early summer (Pegler et al. 1994). It is collected with the sclerotium as a whole for medicinal use and the traded product is thus a fungus – caterpillar complex (Wang and Yao 2011). This species has been in use in the Traditional Chinese Medicine (TCM) system for over 2000 years (Pegler et al. 1994; Zhang et al. 2009; Li et al. 2011). Its demand has grown substantially during last 2-3 decades and collection from the alpine areas of Bhutan, China, India and Nepal has become a common practice. On account of its ever increasing demand and rapid decline in natural populations, the species has been listed in the endangered category by China (Wang and Yao 2011).

The common name of species varies from place to place. For instance, it is popularly known as *Dong Chong Xia Cao*, in China, *Yartsa Gunbu* in Tibet, *Tockukaso* in Japan, *Yarsagumba* in Nepal, *Keerajadi* in India and the Chinese caterpillar fungus in English (Belwal et al. 2019). Species is confined to high altitude habitats and flourishes well in subalpine and alpine grasslands or meadows as well as on open dwarf scrublands around the potential timberline and along gentle mountain slopes of the Tibetan Plateau and high Himalaya (Baral et al. 2015).



Un-mature stroma of caterpillar fungus: it is harvested at this stage





The species is used for the treatment of many ailments like diarrhea, headache, cough, rheumatism, asthma, pulmonary diseases, cardiovascular disorder, sexual dysfunction, renal and liver disease for centuries in Chinese traditional medicine and Bhutanese indigenous medicine (Jiang and Yao 2002; Chakraborty et al. 2014; Belwal et al. 2019). Zhang et al. (2009) reported over 30 bioactivities of caterpillar fungus including immunomodulatory, antitumor, anticancer, anti-inflammatory and antioxidant. The species has been officially classified as a drug in the Chinese Pharmacopoeia since 1964. More recently, use as an aphrodisiac and a tonic has been highlighted (Zhou et al. 2009). The product named as *Himalayan Herbal Viagra* with its widely popularized aphrodisiac properties has resulted in multifold increase in price of caterpillar fungus within a small period of time. The reports indicate value range from USD \$20,000 to USD \$40,000 per kg in the international market (Winkler 2008, 2009; Negi et al. 2014).

1.2 Production, collection and trade

In the past 20-25 years, in all countries with its occurrence, caterpillar fungus has become a major source of cash income for rural people. It is collected and sold by thousands of people in Bhutan, China, India and Nepal and plays a significant role in socio-economic development of high altitude rural areas in the Himalaya (Negi et al. 2015; Pant et al., 2017; Shrestha et al. 2017). The collection camps are established by individual families or small groups of closely related individuals comprising men, women and children. They stay in tented temporary camps around the habitat of this species and collection activity generally starts in the spring when the snow melts and lasts for one to two months. The reported production of the caterpillar fungus ranges between 84.2 tons/year to 182.5 tons/year globally, which varies considerably in Tibetan Plateau and other parts of the Himalaya (Belwal et al. 2019). Winkler (2009) reported highest production of the caterpillar fungus from Tibetan plateau (80–175 tons/year) followed by Nepal (1.0–3.2 tons/year), India (1.7–2.8 tons/year) and Bhutan (0.5–1.5 tons/year).

after 1993 World Athletic Championships in Stuttgart, Germany, when Chinese athletes reportedly trained with dietary supplements of caterpillar fungus and turtle blood, set multiple records in distance running (Winkler 2009). The present prices of caterpillar fungus are very high and its regional trade forms an annual multibillion dollar business (Pouliot et al. 2018).

A single unit of caterpillar mushroom if neatly dried and cleaned may fetch upto US\$ 50/- in China (Yeh and Lama 2013).

The increasing trade and high demand of this fungus is often attributed to its hyped fame as *Himalayan Herbal Viagra* all over the world (Shrestha and Bawa 2013). In the context of Himalaya, the caterpillar fungus is mainly traded directly from Katmandu to China's mega-cities. The local traders make advance payments in cash or in the form of ration to the collectors directly or via agents based on oral agreement to facilitate value creation. Market networks are operated through informal trust-based relationships (buyer and seller negotiating prices) enabling the marketing of this resource from remote areas to urban centers (Pouliot et al. 2018).

1.3 Caterpillar fungus in Indian Himalaya

In India caterpillar mushroom mostly grows in the alpine region of Uttarakhand, Sikkim and Arunachal Pradesh. Of these, Uttarakhand has the highest volume of trade owing to its proximity and accessibility to market in Nepal and Tibetan Autonomous Region (TAR) in China. As such, the use of this species in traditional system in the region is not very strong and evident. Likewise, the scientific information in the form of research is very limited from India. Research gaps on various facets of *O. sinensis* i.e. ecological, life cycle, factors affecting the distribution and abundance of mushroom, sustainable harvesting practices, etc., are evident.

Review of the literature on caterpillar fungus shows that largest volume of research has been conducted in China followed by Taiwan, Japan and least by India. China dominates the research in all aspects of the studies including medicine, biochemistry, immunology and ecology. This book is an attempt to review the current status of research on caterpillar fungus especially in light of Indian scenario to identify the research priorities and opportunities on the species in the Indian Himalayan region. This attempt would be of much use to natural resource managers and researchers in the Himalayan region to find the gaps and opportunities for conducting research work on the caterpillar fungus.









2. The Review

2.1 Literature survey

An exhaustive literature survey on the Web of Science (<https://login.webofknowledge.com>) and Scopus (<https://www.scopus.com>) databases was performed to systematically identify peer-reviewed journal and book articles. To filter the literature we used combination of the keywords *Ophiocordyceps sinensis* OR *Cordyceps sinensis* OR caterpillar fungus for article titles search in these databases. Articles were searched for all periods and in all languages irrespective of the number of citations. We excluded the papers published in non-peer reviewed journals and conference proceedings. For each selected publication, the following information was retrieved: author name(s), title, year of publication, journal title, and article language, country of the first author, funding country, funding agency and research discipline. Based on the information available in the keywords we classified the articles into five research discipline i.e. Medicine, Biochemistry, Molecular biology, Ecology and Immunology.

We found a total of 770 peer reviewed papers and articles (759 journal articles and 11 book chapter). Among these, 623 (81%) articles have been published in English language, 140 (18%) in Chinese and 7 (1%) in other languages with translated abstracts in English that is available in Scopus database. Based on the spatial, temporal and thematic information available for the research articles a trend analysis for the research on caterpillar fungus was conducted. Towards developing a comprehensive understanding on caterpillar fungus, available literature was analysed and the outcomes are documented under various aspects such as geographical distribution, habitat association, life cycle, molecular composition, medicinal properties, economic uses, conservation status, policy issues, etc.

2.2 Geographical distribution and habitat association

The caterpillar fungus is a restricted range species confined to Tibetan Plateau and high altitude areas of the Himalaya. Tibet is called as Xizang in Chinese (This is also spelt as Xinjiang, Zheijiang, Zijhiang). Hence, it has to be carefully matched under localities in China (Li et al. 2011; Nakamura et al. 2015; Jang et al. 2016) given in Table 2.1. The species is widely distributed in the alpine and sub-alpine areas of Bhutan, Nepal and Indian states of Arunachal Pradesh, Sikkim and Uttarakhand (Negi et al. 2006, 2014; Kuniyal and Sundriyal 2013).

The general distribution of *O. sinensis* in China is from Central Yunnan Plateau to the Qilian Mountains in Qinghai Province, and from Mount Daloushan in Guizhou Province to the wide areas of the Himalaya has been reported by Zang (1979). The habitat association of this fungus, however, appears limited due to its strict host-specificity on moth insects and limited geographical distribution. The altitudinal range of caterpillar fungus is reported between 2200-5000 m in China, between 4200-5200 m in Bhutan, between 3500-5050 m in Nepal and between 3200-4800 m in India. In India, caterpillar fungus was first reported during late 1990s (Negi et al. 2006). The species has been documented from alpine meadows of some protected area like Kanchendzonga Biosphere Reserve in Sikkim, Dehang-Debang Biosphere Reserve in Arunachal Pradesh, Nanda Devi Biosphere Reserve and Askot Wildlife Sanctuary in Uttarakhand.

Although, the species is reported from three states in Indian Himalaya but most of the product for trade is reported from Uttarakhand along the border lines with Nepal and China (Negi et al. 2014). The information available from the region suggests the reported locations are mostly in Uttarakhand (Table 2.1). However, authentic reports of collection and trade of the product are lacking.



Table 2.1: Reported locations in four countries having distribution range of caterpillar fungus

Country	Reported regions of occurrence	Altitudinal range (m asl)	References
Bhutan	Namna (North Western Bhutan), Bumthang Valley (North Central Bhutan), and Bumdeling Wildlife Sanctuary	4200-5200	Balfour-Browne (1955), Kobayasi (1980), Cannon et al. (2009)
China	Xinjiang, Yunan, Jilin, Shanxi, Shaanxi, Hubei, Zhejiang, Jiangxi, Guizhou, Taiwan, Guangdong, Guangxi, Sichuan and Hainan Province, and Lhasa and Shannan in Tibet	2260-5000	Winkler (2009), Li et al. (2011)
India	Uttarakhand (Darma valley, Choudans valley, Ralamdhura, Panchachuli base, Moist alpine areas of Dharchula and Munsyari Blocks especially, Pindari catchment in Bageshwar district, Niti valley, Nanda Devi Biosphere Reserve, Sutol, Kanol in chamoli district, Sikkim (North and East Sikkim i.e. Luchung, Khangchendzonga national Park and Wildlife Sanctuary, etc. and Arunachal Pradesh	3200-4800	Negi (2003), Negi et al. (2006, 2009, 2014), Kuniyal and Sundriyal (2013), Sharma (2004), Pradhan (2016)
Nepal	Dolpa, Darchula, Jumla, Bajura, Kalikot, Mugu, Humla, Rukum, Bajhang, Manang, Mustang, Gorkha, Lamjung, Dhading, Rasuwa, Dolakha, Sindhupalchowk, Solukhumbu, Sankhuwasabha, and Taplejung districts	3540-5050	Shrestha and Sung (2005), Adhikari (2008), Devkota (2008, 2010)



Natural habitat of caterpillar fungus in Chipla Kedar, Pithoragarh

Alpine and sub alpine grasslands and shrub lands that receive a minimum of 350 mm average annual precipitation form the typical habitat of caterpillar fungus (Winkler 2009). It grows optimally between altitudinal range of 3000-5000 m asl but upper altitude limit however may reach the snowline areas above 5000 m asl (Jang et al. 2016). Major classes of alpine vegetation where Chinese caterpillar fungus grows in higher abundance are: (i) Mixed Herbaceous Formations (i.e. *Bistorta affinis*, *B. vivipara*, *Potentilla* spp., *Ranunculus* spp., *Anemone* spp., *Iris kumaonesis*, *Geranium* spp., *Geum elatum*, *Allium* spp., *Carum carvi*) dominated by short forbs, (ii) Kobresia sedge meadows and (iii) Edges and gaps of moist alpine scrub. Caterpillar fungus mainly grows in association with herbaceous species of genera like *Saussurea*, *Ranunculus*, *Delphinium*, *Aconitum*, *Potentilla*, *Euphorbia*, *Saxifraga*, *Primula*, *Corydalis*, *Cremathodium*, *Anemone*, *Epilobium*, *Nardostachys*, *Bistorta*, *Geum*, etc.

2.3 Caterpillar fungus-Life cycle

Caterpillar fungus grows on larvae of host insects, which remain underground for their entire larval stage of three

to four years or longer. These larvae feed on roots and caudexes of alpine plants, and usually die once infected by the fungus in the winter (Fig. 2.1). With the rise of outside temperature at the beginning of the spring, the endosclerotium starts germinating and extrudes through the head part of the larva and ultimately protrudes through the soil usually known as stroma (fruiting bodies). Its head contains mature perithecia full of thread-like ascospores. On maturity, the fruiting body of the fungus releases thousands of ascospores in the surrounding environment (primarily soil) and when the freshly hatched Caterpillars come in contact they get infested (Chakraborty et al. 2014; Li et al. 2018). Most likely the infestation occurs at first instar stage, as their hatching period overlaps with the discharge and dispersal of the ascospores (Cannon et al. 2009). The fungus enters the hemocoel of the larvae, fragments into fusiform hyphae, and multiplies. The fungal cells spread inside the body through the circulatory system, and consume all the internal organs of the larva except its exoskeleton. The infected larva moves to 2–5 cm below the surface of the soil and dies with its head facing upward. Subsequently following a period of dormancy, a yeast-like stage

develops that spreads throughout the haemocoel and concentrates within the caterpillar's lipid reserves (Cannon et al. 2009). Growth of the fungus therefore results in depletion of host's internal nutrient supply, which causes effective death of Caterpillar due to starvation.

Following the death of Caterpillar, the fungus changes to a mycelial growth phase which spread inside the body through the circulatory system and consume all the internal tissues of the larvae except its exoskeleton (Xing and Guo 2008). A small stroma bud usually emerges from the head of the sclerotium (host larvae) before the soil freezes. It is a dormant stage in the life cycle which can resist unfavorable snow cold conditions. Hyphae of *O. sinensis* can grow at about 2°C with the optimum temperature between 15-18°C temperatures. The hyphal growth is checked when temperature reaches 25°C, and stops below 0°C (Liu 1988; Dong and Yao 2010).

2.4 Biochemical and pharmacological studies

2.4.1 Active Bio compounds

Use of caterpillar fungus is known from ancient time for curing multiple disorders and diseases, including kidney, respiratory, liver, cardiovascular diseases, sexual impotency, diarrhea, headache, cough, rheumatism, asthma, allergic rhinitis, irregular menstruation, etc. (Zhou et al. 1990; Wang and Shiao 2000), and extensively utilized by people in Asian countries. It has been designated as nutraceutical or medicinal mushroom

(Smith et al. 2000), owing to its novel biologically active compounds (Table 2.2) and especially those associated with various pharmacological activities (Table 2.3). Some of the known bio-active constituents of caterpillar fungus are discussed below:

(i) Nucleosides

Various nitrogenous compounds, like nucleosides, are known to be the active components in caterpillar fungus. More than ten nucleosides and their related compounds, including adenine, adenosine, inosine, cordycepin, cytidine, cytosine, guanine, uridine, thymidine, uracil, hypoxanthine, and guanosine, have been isolated from caterpillar fungus. Reports indicate almost all of the nucleotides and nucleosides in caterpillar fungus can be transformed reciprocally (Yang et al. 2010). Among the nucleosides, thymine, adenosine and cordycepin are found to be major compounds in a range from 138.5–174.2, 79.6–186.5 and 31.3–91.2 µg/g, respectively (Xie et al. 2010). The other known important compound is cordycepic acid, an isomer of quinic acid, is one of the main active medicinal components in a range of 7-29% which varies across growth stages (Jiang 1987). High content of Adenosine in caterpillar fungus plays a key role in the pharmacological applications and helps in maintaining coronary and cerebral circulation (Toda et al. 1982), prevention of cardiac arrhythmias (Pelleg and Porter 1990), control of blood flow (Berne 1980; Berne 1983) and nerve tissue function such as the inhibition of neurotransmitter release and the modulation of adenylate cyclase activity (Ribeiro 1995).

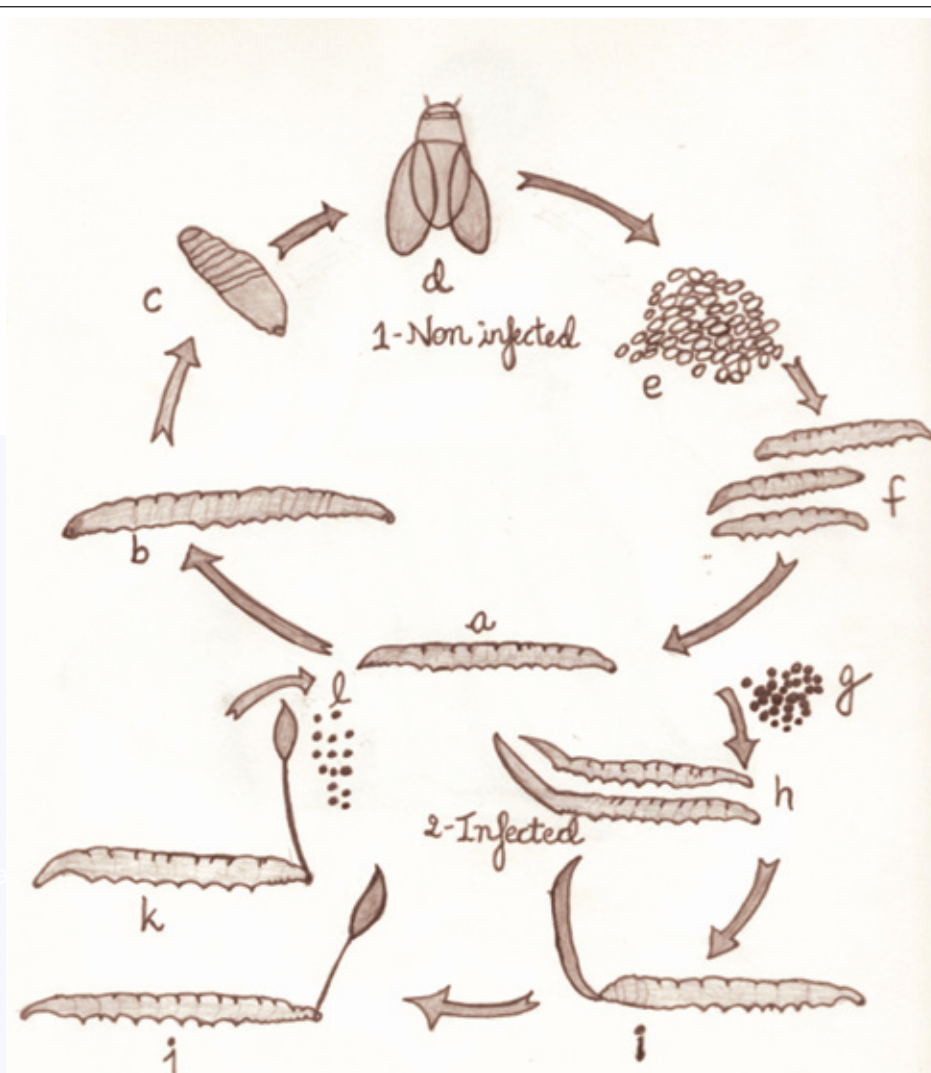


Figure 2.1. Life cycle of caterpillar fungus; 1. Stage - Non Infected (a-Normal larva stage; b- 5 year larva; c-Pupa; d-Insect ; e- egg; f-larva) and 2. stage –Infected (g –spores; h-germination, i- k-mature OS and l-spore spread (Based on Chakraborty et al. 2014)



(ii) Sterols

The available information suggest caterpillar fungus contain 21 type of sterol compounds. Among these, ergosterol is considered as an important source of vitamin D₂. This is present in two forms, free and esterified ergosterol having different physiological functions (Yuan et al. 2007).

(iii) Proteins: Amino acid and Polypeptides

A number of crude proteins are present in caterpillar fungus ranging between 29-33% (Hsu et al. 2002). Following hydrolysis of crude proteins, and 18 amino acid have been reported with glutamate, arginine and aspartic acid having highest content (Ji et al. 1999).

(iv) Fatty acids and other organic acids

Caterpillar fungus contains both unsaturated and saturated fatty acids like palmitic acid, lauric acid, myristic acid, linoleic acid, etc. The maximum unsaturated fatty acids (e.g., linoleic acid) are reported in the fruiting body, which comprises of about 70% of the total fatty acids (Hyun 2008).

(v) Polysaccharides

Polysaccharides which form the medicinally active compound are found in large availability between 3–8% of the total weight of caterpillar fungus (Zhou et al. 1990; Li et al. 2002). Cordyceps polysaccharides mainly include extracellular polysaccharide and intracellular polysaccharide. Guan et al. (2010) has determined 10 monosaccharides (rhamnose, ribose, arabinose, xylose, mannose, glucose, galactose, mannitol, fructose and sorbose) from caterpillar fungus.

2.4.2 Pharmacology

Wide ranges of biological activities have been reported from caterpillar fungus which include anti-inflammatory, antioxidant, anti-tumor, anti-metastatic, immunomodulatory etc. As several bio-active compounds can be responsible for a particular pharmacological activity, attempt has been made to summarize pharmacological activities of major effective compounds that have been reported for caterpillar fungus (Table 2.3).

(i) Anti-tumor/anticancer activity

The extract of caterpillar fungus is used in the treatment of cancer or tumor cells (He and Zhang 2006). Nitrogenous compounds (Adenosine, Cordycepin, Cordyceamides A, Cordyceamides B and Cordycedipeptide A), sterols (Ergosterol peroxide; 5 α ,8 α -epidioxy-22-E-ergosta-6,9(11); 22-trien-3 β -ol,5 α ,8 α -epidioxy-24(R)-methylcholesta-6,22-dien-3 β -D-glucopyranoside; Ergosta-4,6,8(14), 22-tetraen-3-one; β -sitosterol) and polysaccharide [Cordysinocan (Glc:Man:Gal = 2.4:2.1)] are the major bioactive compounds in *O. sinensis* that have anticancer activity (Jia et al. 2005, Zhang et al. 2005, Ji et al. 2009, Matsuda et al. 2009) (Kobori et al., 2007; Zhao et al., 2011; Awad et al., 2009; Cheung et al., 2009).

(ii) Aphrodisiac activities

In TCM caterpillar fungus has been in use for centuries to treat sexual troubles. Human clinical trials have also demonstrated the effectiveness of caterpillar fungus in combating decreased sex drive and virility (Guo, 1986). Therefore owing to this it has also been named as 'Himalayan Herbal Viagra'. Cordycepin (Leu et al., 2011), β -sitosterol (Zhang et al. 2011) and D-mannitol (Ohkuma et al. 1998) are the important chemical constituents which are responsible for aphrodisiac activities of caterpillar fungus.

(iii) Anti-oxidant activity

The extracts of caterpillar fungus possess high antioxidant activities. Water extracts using three different assays, the xanthine oxidase assay, the induction of hemolysis assay and the lipid peroxide assay has been used to analyze antioxidant activity of caterpillar fungus (Nakamura et al. 1999). The results showed that extract possess a strong antioxidant activity. Among the compounds, polysaccharides of caterpillar fungus have showed maximum antioxidant activity (Table 2.3).

(iv) Hepatoprotection

Use of caterpillar fungus has been reported to increase the efficient functioning of liver and protects against various disease like hepatitis A, chronic hepatitis B, chronic hepatitis c, hepatitis fibrosis, etc. (Liu and Shen



2003). The polysaccharides [CS-F10 (Gal:Glc:Man = 43:33:24); CSP-1 (Glc:Man:Gal = 1:0.6:0.75)] of caterpillar fungus are reported for hepatoprotection activity (Kiho et al. 1996; Le et al. 2006).

(v) Hypoglycemia activity

Caterpillar fungus has an antidepressant-like activity which prevents the diabetes induced higher blood glucose concentrations. Evaluation of anti-diabetic effect of caterpillar fungus has revealed that extracts of caterpillar fungus inhibits the diabetes in rats (Shi et al. 2009). Cordycepin and polysaccharides [CS-F10 (Gal:Glc:Man = 43:33:24) and CSP-1 (Glc:Man:Gal = 1:0.6:0.75)] are the main compounds which showed hypoglycemia activity (Kiho et al. 1996; Le et al. 2006).

(vi) Immunomodulatory activity

Caterpillar fungus extracts are known for both immune suppressive and immune stimulating functions. The extracts of caterpillar fungus activate the immune cells, such as lymph proliferation response, natural kill cell activity and phytohaemagglutinin stimulated interleukin-2 and tumor necrosis factor (Kuo et al., 1996). Studies have shown that following bioactive compounds work in immunosuppression [Cordycepin \downarrow , sterols (Ergosta-5-8(14),22-trien-7-one, 3β -ol (H1-A) \downarrow , immunostimulation \uparrow , β -sitosterol \uparrow], and polysaccharides [Cordysinocan (Glc:Man:Gal = 2.4:2.1) \uparrow and CS-PS (Man:Rhm:Ara:Xyl:Glc:Gal = 38.37:2.51:2.21:5.22:27.44:24.45) \uparrow] (Yang et al. 2003, Zhou et al. 2008, Zhang et al. 2011; Fraile et al. 2012; Cheung et al. 2009).

(vii) Improving physical stamina

Caterpillar fungus is well known for improving the physical stamina among the athletes by increasing the production of ATPs (Dai et al. 2001). Caterpillar fungus extract has been found effective in enhancing aerobic exercise capability, endurance exercise performance and exercise metabolism and alleviating fatigue in healthy humans. The presence of adenosine, cordycepin, cordycepic acid, d-manitol, polysaccharide, vitamins and trace elements can be attributed for such effects.

Table 2.2: Major bioactive compounds reported from caterpillar fungus

Compounds	References
Nitrogenous compounds (27 Nos.)	
Uracil; adenine; guanine; hypoxanthine; adenosine; cordycepin; dideoxyadenosine; N6-(2-hydroxyethyl) adenosine; inosine; guanosine; thymine; , thymidine; uridine; dideoxyuridine; cordyceamides A; cordyceamides B; aurantiamide acetate; cordysin A; cordysin B; cordysin C; cordysin D; cordysin E; cordycedipeptide A (3-acetamino-6-isobutyl-2,5-dioxopiperazine); 3-isopropyl-6-isobutyl-2,5- Dioxopiperazine; 3,6-di(4-hydroxy)benzyl-2,5-dioxopiperazine; caffeine; N-(2'-hydroxy-tetracosanoyl)-2-amino-1,3,4-trihydroxy-octadec-8E-ene (tetracosanamide), 2-nicotinic acid	Huang et al. (2003); Li et al. (2003); Jia et al. (2005); Li et al. (2006); Holliday and Cleaver (2008); Jia et al. (2009); Liu et al. (2010); Yang et al. (2011)
Sterols (21 Nos.)	
Ergosterol, ergosteryl-3-O- β -D-glucopyranoside; ergosterol peroxide; 5 α ,8 α -epidioxy-24(R)-methylcholesta-6,22-dien-3 α - D-glucopyranoside; (24R)-ergosta-7,22-diene-3 α ,5 α ,6 α -triol (cerevisterol); ergosta-4,6,8(14); 22-tetraen-3-one, 4,4-dimethyl-5 α -ergosta-8,24(28)-dien-3 α -ol, 3-O-ferulylcycloartenol; 5 α ,6 α -epoxy-24(R)-methylcholesta-7,22-dien-3 α -ol; ergosta-5-8(14),22-trien-7-one; 3 β -ol [H1-A], 22,23-dihydroergosteryl-3-O- α -D- glucopyranoside; β -sitosterol; β -sitosterol 3-O-acetate;daucoesterol; stigmasterol; stigmasterol 3-O-acetate; cholesterol; campesterol; dihydrobrassicasterol [D5-ergosterol]; fungisterol [D7-ergosterol]; (17R)-17-methylincisterol	Kadota et al. (1986); Bok et al. (1999); Lin et al. (1999); Li et al. (2003); Yang et al. (2011)
Proteins: nucleic acids, amino acids and polyamines- (20 Nos.)	
Cyclo-(Gly-Pro); cyclo-(Leu-Pro); cyclo-(Val-Pro); cyclo-(Ala-Leu); cyclo-(Ala-Val); cyclo-(Thr-Leu) 1,3-diamino propane, cadaverine, spermidine, spermine putrescine, flazin, perlolyrine, 1-methylpyrimidine-2,4-dione, 1-acetyl- α -carboline, 1-(5-hydroxymethyl-2-furyl)- β -carboline (perlolyrine), cyclo(L-Pro3-L-Val), cyclo(L-Phe-L-Pro), cyclo(L-Pro-L-Tyr), cordymin, L-tryptophan	Zhang et al. (1991); Holliday and Cleaver (2008), Yang et al. (2011); Qian (2012).
Fatty acids and other organic acids (11 Nos.)	
palmitic acid; lauric acid; myristic acid; pentadecanoic acid; palmitoleic acid; linoleic acid; oleic acid ; stearic acid; docosanoic acid; lignoceric acid; succinic acid	Li et al. (2003); Yang et al. (2009); Yang et al. (2011)
Phenolics and acids (15 Nos.)	
p-hydroxybenzoic acid; vanillic acid; syringicaci; p-methoxybenzoic acid; p-hydroxyphenylacetic acid; 3,4-dihydroxyacetophenone; 4 hydroxyacetophenone;	
protocatechuic acid; 3, p-methoxyphenol; acetovanillone; salicylic acid; 3-hydroxy-2-methyl-4-pyrone; methyl p-hydroxyphenylacetate; 2-deoxy-D-ribo-1,4-lactone; furancarboxylic acid	Yang et al. (2011)
Isoflavones (4 Nos.)	
32,42,7-trihydroxyisoflavone; glycitein; daidzein orobol;, genistein	Yang et al. (2011)
Polysaccharide and sugar derivatives (12 Nos.)	
CS-F30 [Gal:Glc:Man = 62:28:10]; CS-F10 [Gal:Glc:Man = 43:33:24]; CT-4N [Man:Gal =3:5]; CS-81002 [Man:Gal:Glc = 10.3:3.6:6.1]; SCP-I [D-glucan]; CSP-1 [Glc:Man:Gal = 1:0.6:0.75]; CPS1[Glc:Man:Gal = 2.8:2.9:1]; cordysinocan [Glc:Man:Gal = 2.4:2.1]; PS-A [Glc:Gal:Man = 2:1:1]; CS-PS [Man:Rhm:Ara:Xyl:Glc:Gal=38.37:2.51:2.21:5.22:27.44:24.45]; mannoglucan [Man:Glc = 1:9]; D mannitol	Kihoet al. (1986); Gong et al. (1990); Kiho et al. (1993); Kiho et al. (1999); Li et al. (2003); Wu et al. (2006); Wu et al. (2007); Cheung et al. (2009); Wang et al. (2009); Kim (2010); Zhang et al. (2011); Yang et al. (2011)
Vitamins (5 Nos.)	
B1, B2, B12, E, and K	Zhu et al. (1998a)
Inorganics (19 Nos.)	
K, Na, Ca, Mg, Fe, Cu, Mn, Zn, Pi, Se, Al, Si, Ni, Sr, Ti, Cr, Ga, V, and Z	Zhu et al. (1998a)

Table 2.3: Pharmacological activity of selected bio-active compounds of caterpillar fungus

S.N.	Compounds*	Pharmacological Activities							
		Anti-cancer ^A	Aphrodisiac ^B	Anti-inflammation ^C	Antioxidant ^D	Hepatoprotection ^E	Hypoglycemic ^F	Anti-asthemia ^G	Hypolipidemic ^H
Nitrogenous Compounds									
1.	Adenosine	+			+		+		
2.	Cordycepin	+	+	+	+		+	+	+
3.	Cordyceamides A	+							
4.	Cordyceamides B	+							
5.	Cordycedipeptide A	+							
Sterols									
6.	Ergosterol peroxide	+		+					
7.	5 α ,8 α -epidioxy-22-E-ergosa-6,9(11), 22-trien-3 β -ol	+							
8.	Ergosteryl-3-O- β -D-glucopyranoside			+	+				
9.	5 α ,8 α -epidioxy-24(R)-methylcholesta-6,22-dien-3 β -Dglucopyranoside	+							
10.	(3 β ,5 α ,6 β ,22E)-ergosta-7,22diene-3,5,6 triol (cerevisterol)							+	
11.	Ergosta-4,6,8(14),22-tetraen-3-one	+							
12.	Ergosta-5-8(14),22-trien-7-one, 3 β -ol (H1-A)					+			+
13.	β -sitosterol	+	+						+
14.	Stigmasterol			+					
Proteins									
15.	1-(5-hydroxymethyl-2-furyl)- β -carboline (perlolyrine)			+	+				
16.	Cordymin			+	+				
Isoflavones									
17.	3',4',7-trihydroxyisoflavone				+				
Polysaccharide and sugar derivatives									
18.	CS-F10 (Gal:Glc:Man = 43:33:24)					+	+		
19.	CS-F30 (Gal:Glc:Man = 62:28:10)					+			
20.	CSP-1 (Glc:Man:Gal = 1:0.6:0.75)				+		+		
21.	Cordysinocan (Glc:Man:Gal = 2.4:2.1)	+			+				+
22.	CPS1 (Glc:Man:Gal = 2.8:2.9:1)				+				
23.	PS-A (Glc:Gal:Man = 2:1:1)				+				
24.	CS-PS (Man:Rhm:Ara:Xyl:Glc:Gal = 38.37:2.51:2.21:5.22:27.44:24.45)				+				+
25.	D-mannitol		+					+	
Phenolic Compounds									
26.	Butylated hydroxytoluene				+				+

*Each compound number is followed by reference and pharmacological activities A-I: (1) Nakamura et al. (2006)^A, Maggirwar et al. (1994)^D, Yue et al. (2008)^G; (2) Matsuda et al. (2009)^A, Holliday and Cleaver (2008)^A, Leu et al. (2011)^B, Kim et al. (2006)^C, Yang et al. (2011)^C, Xiao et al. (2012)^D, Yun et al. (2003)^E, Yue et al. (2008)^G, Zhou et al. (2008)^I, (3) Jia et al. (2005, 2009)^A, (4) Jia et al. (2005, 2009)^A, (5) Jia et al. (2005)^A; (6) Kobori et al. (2007)^{A and C}, (7) Matsuda et al. (2009)^A, (8) Yang et al. (2011)^{C and D}, (9) Matsuda et al. (2009)^A, Bok et al. (1999)^A, (10) Lin et al. (2004)^G, (11) Zhao et al. (2011)^A, (12) Lin et al. (1999)^E, Yang et al. (2003)^I, (13) Awad et al. (2009)^A, Zhang et al. (2011a)^B, Fraile et al. (2012)^I, (14) Gabay et al. (2010)^C, (15) Yang et al. (2011)^{C and D}, (16) Wang et al. (2012)^{C and D}, (17) Yang et al. (2011)^D, (18) Chen et al. (2009)^A, (19) Kiho et al. (1996)^E, (20) Li et al. (2006b)^{D and F}, (21) Cheung et al. (2009)^{A and D}, (22) Wang et al. (2009)^D, (23) Kim (2010)^D, (24) Zhang et al. (2011b)^{D and I}, (25) Ohkuma et al. (1998)^B, Ilowite et al. (2008)^G (26) Babu and Wu (2008)^D, Jilal and Devraj (1996)^H

2.5 The Research & Development Investments

A large number of workers in the field of medicine, entomology, mycology and TCM have undertaken in depth studies on various aspects of caterpillar fungus. Detailed review of literature reveals that highest numbers of papers on this species have been published by Chinese authors. Among others authors from Taiwan, Japan and India are most prominent which have published on caterpillar fungus (Fig. 2.2). However, their contribution in each case remains less than 15% of research publications by China. From India 43 research articles have appeared that is only 8.5% of China. Besides in English language, China has also published 140 research papers in Chinese which forms nearly 30% contribution to the literature published from the country. Further analysis of publications reveal largest volume of research has been conducted in the field of Medicine followed by Biochemistry, Molecular biology, Ecology and Immunology (Fig. 2.3). Along temporal ranges an abrupt increase in the research on caterpillar fungus is evident around the year 2000 with recorded higher growth in publication under Medicine, Biochemistry and Molecular biology (Fig. 2.4). Numbers of ecological researches have shown a gradual rise till 2005 and an upsurge is evident thereafter. Studies related to Immunology have however remained more or less consistent over the years.

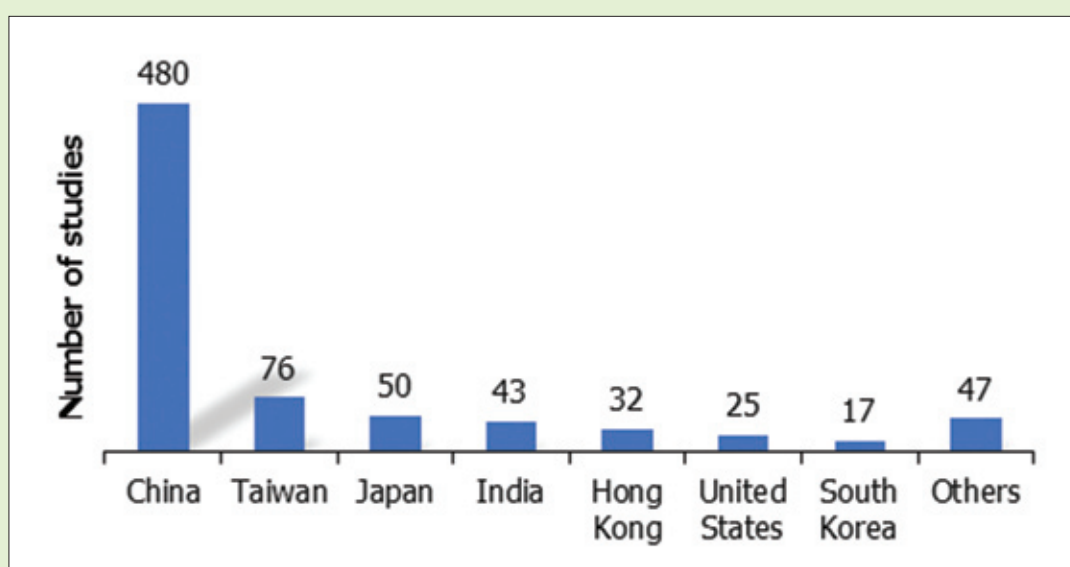


Figure 2.2: Top contributing countries for research publications on caterpillar fungus

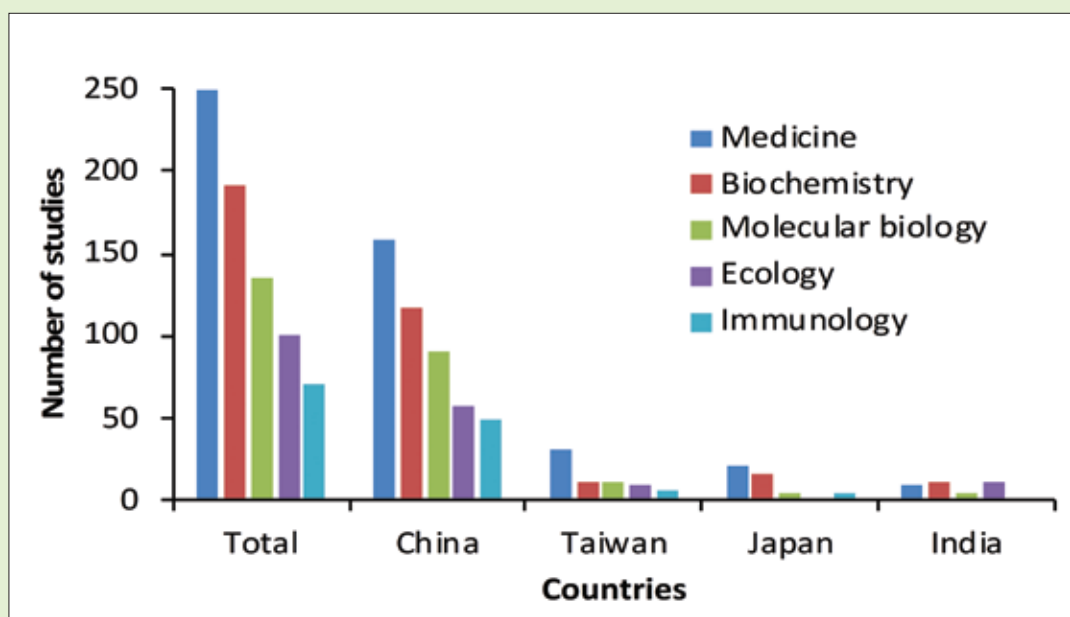


Figure 2.3: Publications across disciplines of research from different countries.

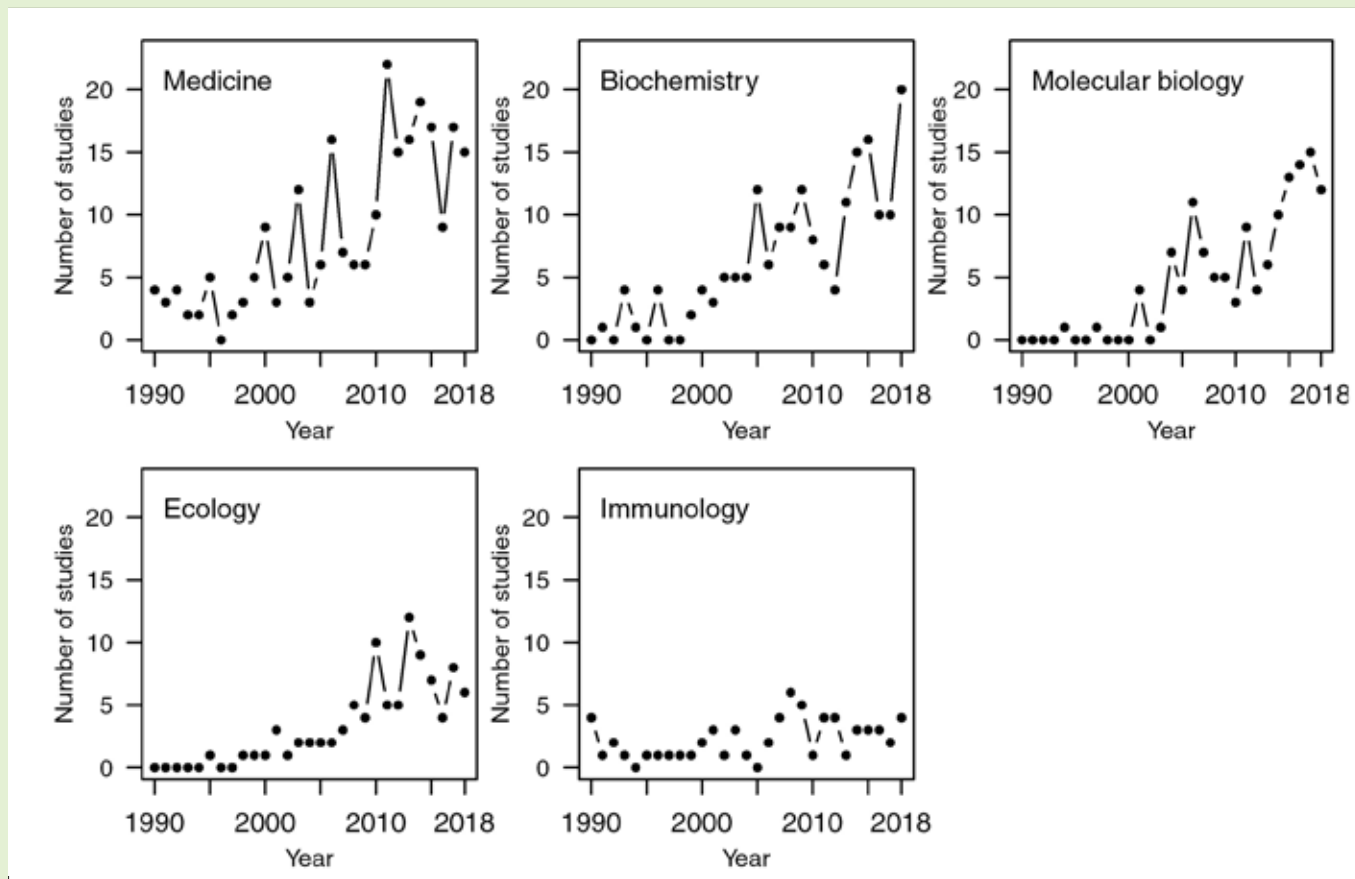


Figure 2.4: Temporal trends in publications on caterpillar fungus across research disciplines

China with 61% share of total studies that have been funded for research and development on caterpillar fungus occupies the top rank. Taiwan and Hong Kong, with 17% and 5% contribution respectively, are other countries which have invested on R&D of caterpillar fungus whereas India and Japan each contribute only 2% to the R&D funding on this species (Fig. 2.5). In terms of research funding across disciplines, Medicine receives highest investment in all the countries; except Hong Kong, which has funded more on Biochemical studies on caterpillar fungus, while other countries have shown very less interest on research in these fields. China had also funded equally for the research on Biochemical and molecular studies in these fields (Fig. 2.6).

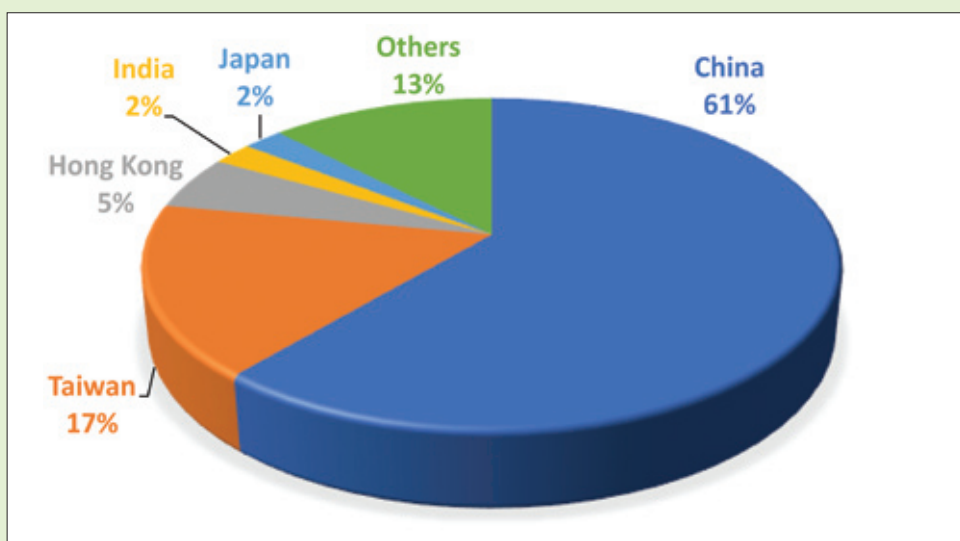


Figure 2.5: Proportional distribution of studies funded by countries for research on Caterpillar fungus

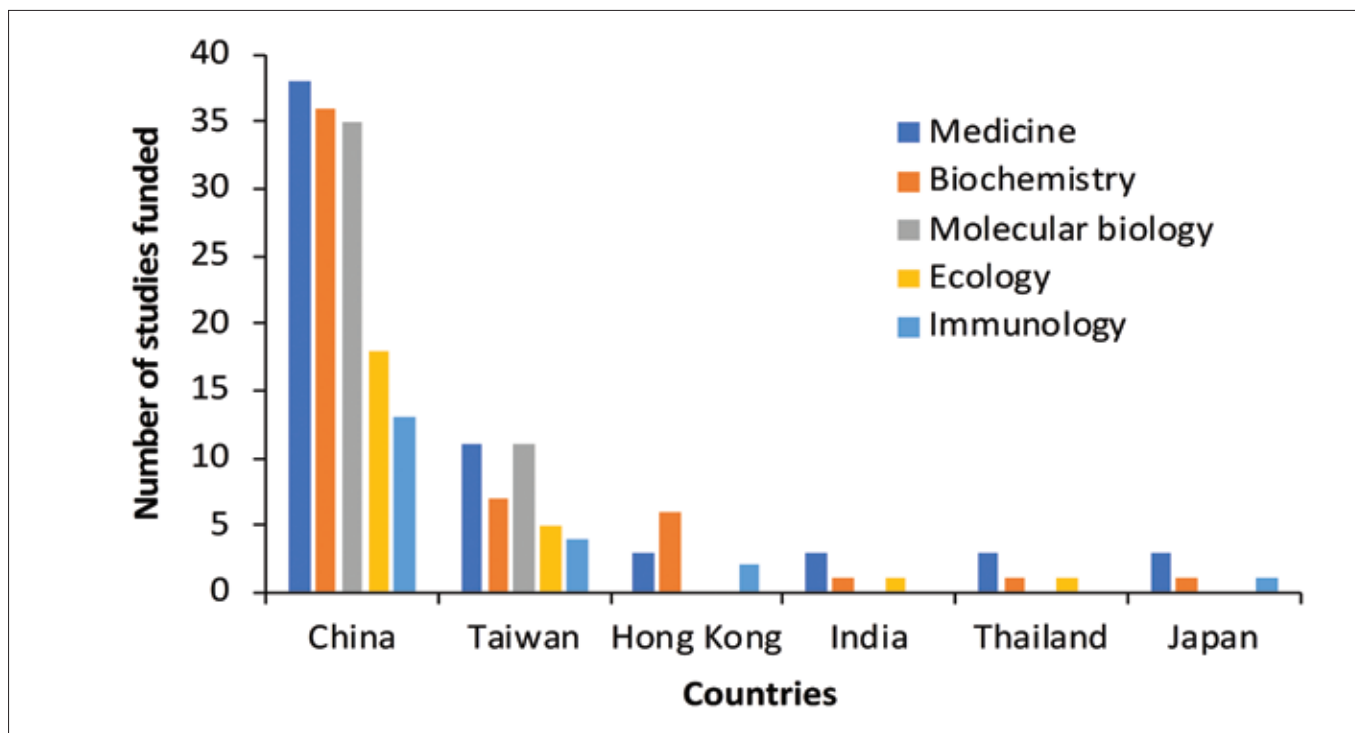


Figure 2.6: Studies funded across disciplines in different countries

All the top funding agencies for research on caterpillar fungus are from China. National Natural Science Foundation of China has funded highest number of 86 studies followed by Chinese Academy of Science and Technology (20 studies) and Chinese Ministry of Science and Technology (16 studies). National Science Council, Taiwan is the top most funding agency outside China which has provided financial support to 13 studies (Fig. 2.7). In terms of journals, maximum (32) researches on caterpillar fungus have appeared in Chinese journal Zhongguozhongyaozazhi (English meaning: China Journal of Chinese Materia Medica). International Journal of Medicinal Mushrooms ranked number two (26), followed by FASEB journal (20; Fig. 2.8).

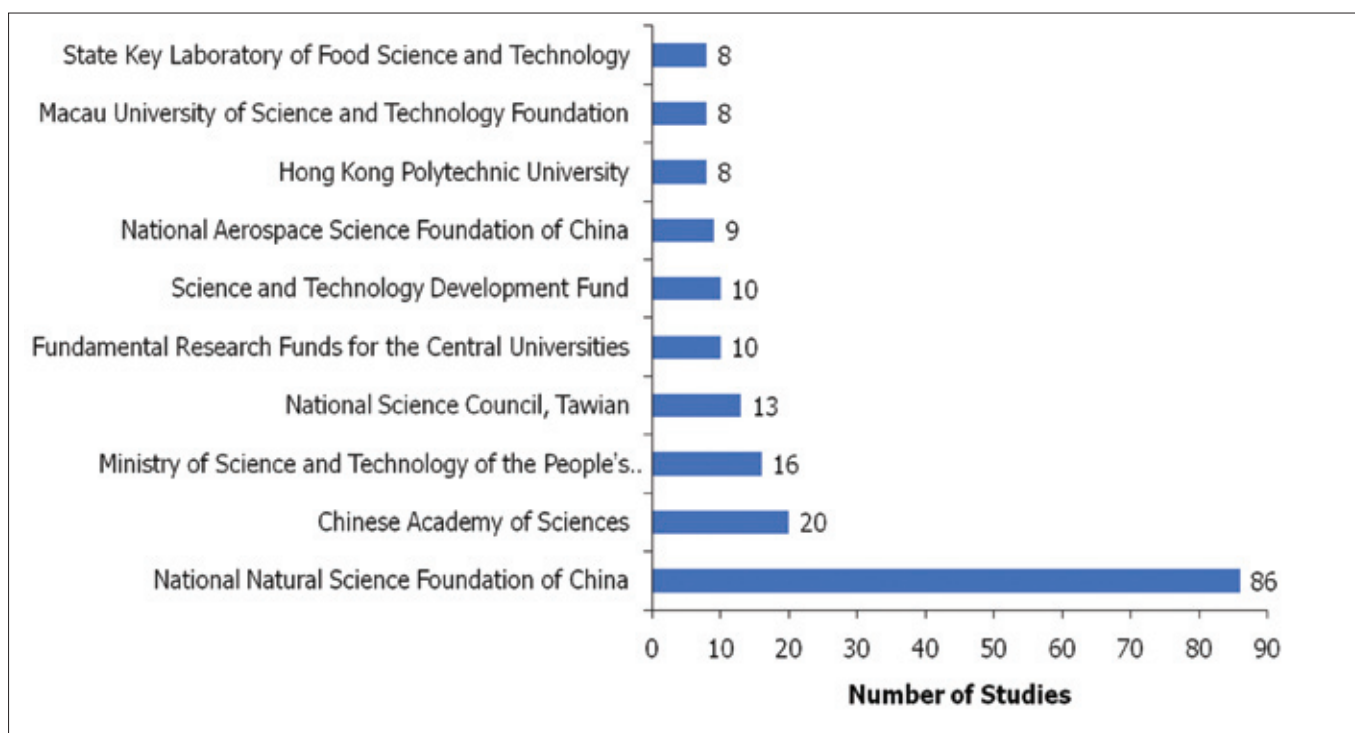


Figure 2.7: Top funding agencies for research on caterpillar fungus

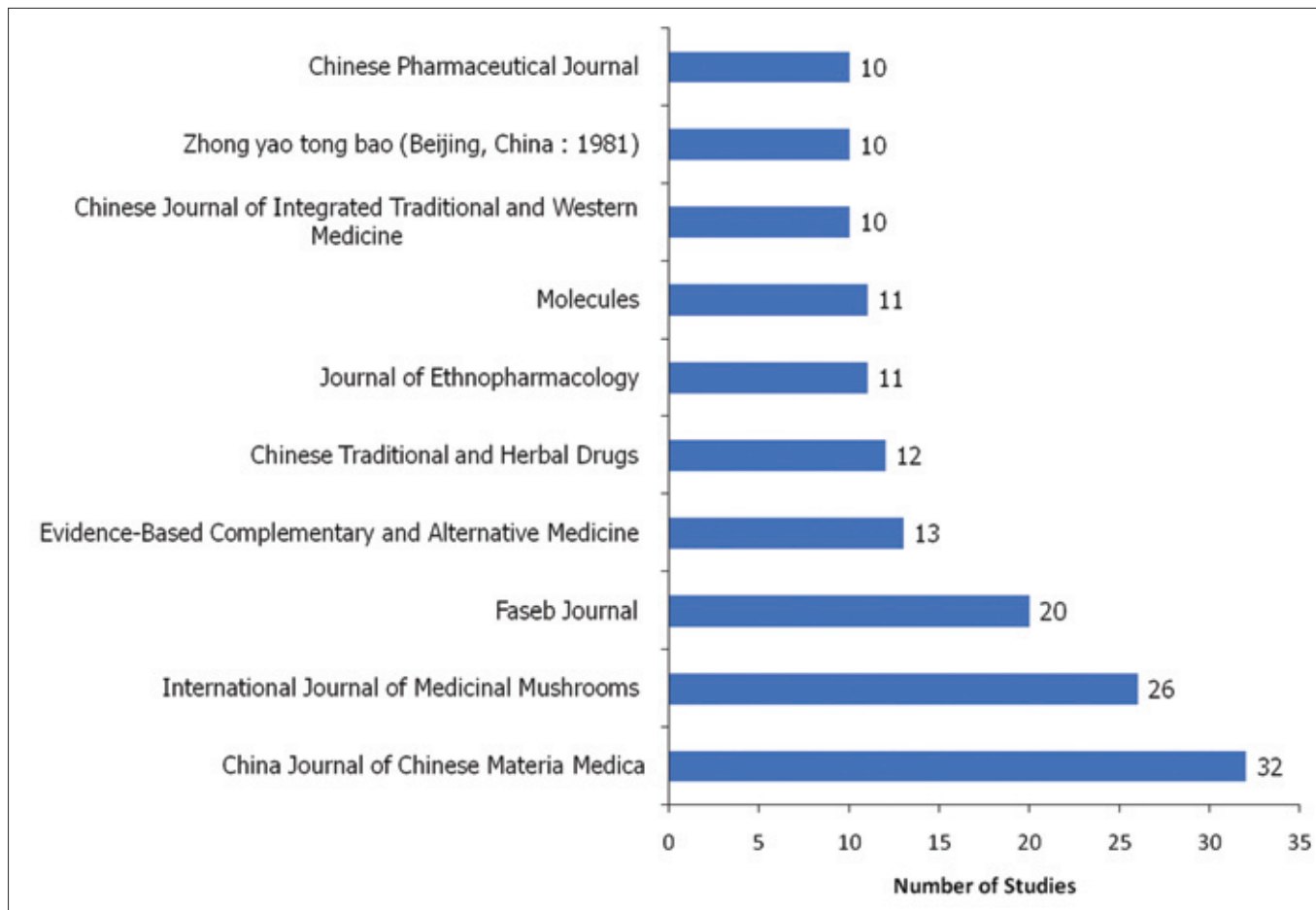


Figure 2.7: Top funding agencies for research on caterpillar fungus





3. Collection, Grading and Market

3.1 Camping and collection

The collection season begins in the early May and goes up to the end of June (Box 3.1). However, it varies considerably depending on two main factors i.e. the local weather and amount of snow in the collection area (Negi et al. 2014). The collection generally begins when the snow melts off and the meadows are sufficiently exposed to sun which allows for the growth of the caterpillar fungus. The end of the season often correlates with the emergence of the monsoon rains. There are broad similarities in collection and trade of the caterpillar fungus across its distribution range (Cannon et al., 2009; Weckerle et al., 2010; Woodhouse et al., 2013; Shrestha and Bawa 2014; Negi et al. 2014).



Experiences from Indian Himalaya especially in Uttarakhand suggest that meadows shared by two or more villages have mutually agreed upon camp locations for each village. Camping by collectors is generally made near the large boulders which provide shelter (Caplins and Halvorson 2017).

Until a few years ago, women were not allowed to enter the alpine meadows (considered sacred), which obviously restricted the number of harvesters. However, with increase in the price of the commodity, now women are actually encouraged to go for collection (Negi et al. 2014). Harvesting of few medicinal plants is also carried out along with the collection of caterpillar fungus.

The collectors remain careful for selecting camping site on flat land having availability of water and fuelwood. Collectors from individual family usually work in two groups i.e. cooking and collection group, otherwise big families cook and tent separately. Collection groups set out in the field early in the morning and collect till mid-day.

Searching involves careful scanning of the ground for the fruiting body of the fungus (Caplins and Halvorson 2017; Negi et al. 2014). Fungus searching is very intense and often done while standing, kneeling or crawling. Collection groups usually return from the meadows to the villages after 20-30 days depending on the availability of food and weather conditions.



Box 3.1 Preparation for collection

Collectors make adequate preparations before they hike to alpine meadows. The major content of preparation include (i) weather assessment (ii) discussions over snow and trail conditions, (iii) identification of pastures for collection, (iv) selection of group members and review of their preparedness, (iv) purchase and packing of food and other essential items including tent, sleeping bags/mattress, blankets and personal apparel. Food supplies vary across groups but most commonly it contains a mix of easy to prepare foods and traditional cuisine. The preparations also draws from experiences shared by others and lessons learnt in previous years.



Fresh collected caterpillar fungus



3.2 Grading of material

The main criteria defining the quality of the produce, in order of preference are: lower water content (completely dried samples), the state of processing (cleaned), and the size (Box 3.2). The degree of dryness of caterpillar fungus is an important factor that controls weight – a price determining factor (Negi et al. 2014). Collectors and traders generally put the material in 4 grades of quality.

(i) Superior quality: the caterpillar is golden yellowish, undamaged, completely dried with stroma a bit shorter than the larva. Traders purchase such material at highest prices even superior individuals are priced individually.

(ii) Good quality: the caterpillar is golden yellowish, undamaged and having good size (completely dried samples are preferred over the fresh ones). Traders purchase these at good prices.

(iii) Broken (damaged): the caterpillar is broken and the fungus fruiting body may be entirely missing; Traders purchase these at lower prices.

(iv) Fused: Improperly dried, infected, and black coloured caterpillars. traders do not usually purchase such material.

Thus, while setting prices, the degree of dryness of caterpillar fungus becomes an important factor that controls the weight. Flexibility of fungus is considered for assessing the moisture content. The ratio of size of the stroma versus the size of the insect larva forms another important criterion for quality determination. Highest value is given to the material where stroma is a bit shorter than the larva (Pouliot et al. 2019; Negi et al. 2014).



Broken (damaged) caterpillar fungus



Fused caterpillar fungus



Superior quality dried caterpillar fungus



Good quality dried caterpillar fungus

Box 3.2 Post collection processing and storing

Once the collection is brought back to the camp or the village in case of bad weather, the material is then processed and stored for sale. The cleaning process involves brushing to remove soil particles and the outer thin blackish skin with a soft toothbrush. Further processing is limited to air-drying at camp site or back in the villages and storing in soft muslin cloth till the product is sold. More aware collectors for example Bhotia families in Uttarakhand, adopt different means to keep the caterpillar fungus in good condition even during bad weather including (i) wrapping every individual in tissue paper, (ii) wrapping all material together in fabrics, and (iii) placing the caterpillar fungus loose in boxes without any wrappings. During sunny days in monsoon many families place stored material in the sun for further drying.

Information based on Caplins and Halvorson (2017; Pouliot et al. 2018)



4. Caterpillar fungus and socio-economic development

4.1 Contribution to rural economy

A number of studies have analyzed the economic importance of caterpillar fungus to rural economy in Bhutan (Cannon et al. 2009), China (Yeh and Lama 2013), India (Kuniyal and Sundriyal 2013; Caplins and Halvorson 2017), and Nepal (Shrestha and Bawa 2013, 2014b; Childs and Choedup 2014). An estimate made by Shrestha and Bawa (2013) suggests of the total global production of caterpillar fungus; the largest producer is China that share 95-96% production. Nepal contributes 1.2-1.8% , India 1.5–2.0%, and Bhutan 0.6–0.8% of total global production. Contribute to rural economy in different parts is as below.

The boom of caterpillar fungus has facilitated integration of rural Tibetan households into regional, national and international economic cycles. The enormous price increase in recent years has turned this fungus into the most important source of cash income in contemporary rural Tibet (Winkler 2008). Per capita income from caterpillar fungus collection at rural and small town level (i.e., 93% of the Tibetan plateau population) accounts between 50-80% of overall rural income. Over 300,000 Chinese individuals in respective local regions depend on collection and sale of this resource (Winkler 2009).

In Nepal, this species makes relatively high contribution to income for the rural poor, and thereby playing a significant role in education and food security (Shrestha and Bawa 2013). Income from caterpillar fungus accounted for >65% of the total household cash income, on average, and its contribution was highest in case of poorest households in many villages of Nepal (Shrestha et al., 2014). In Bhutan, caterpillar fungus harvest provides a far greater income compared to their traditional activities for most of the yak herders. One individual earns more than US \$2500, which is almost the annual salary of a graduate teacher in Bhutan (Cannon et al. 2009).

In India, it has emerged as an important contributor to the economy in many high altitude villages especially for those who were traditionally engaged in pastoral activities. For instance, Bhotiya, the main high land ethnic group in Uttarakhand state, have been practicing a form of seasonal migration (i.e., transhumance) for decades . They migrate to higher altitude settlements during summer.

A study has reveal approximately 110 villages (2511 harvesters) are engaged and dependent on the collection of caterpillar fungus in the



Pithoragarh district of Uttarakhand (Negi et al. 2014). The collection of caterpillar fungus has also emerged as an important source of income in Sikkim and Arunachal Pradesh. Available information indicates that the collection of caterpillar fungus per family averages between 150 and 300 specimens, which means an earning between Rs. 1-3 lakhs per annum in the Kumaon part of Uttarakhand (Negi et al. 2014). The estimated annual income contribution of caterpillar fungus in Munyari block of Uttarakhand between 2004 and 2009 was reported around US \$972–1485 per collector (Pant and Tewari 2014). A more recent study from Gori valley in Kumaon Himalaya (Laha et al. 2018) has reported that the earnings from caterpillar fungus contribute 60–78% to the annual household income. Ever increasing interest in its collection have resulted in congestion in collection areas and triggered conflicts among collectors (Box 4.1).

4.2 Socio-economic transformation

The fast changing rural economy of the inhabitants engaged in collection of caterpillar fungus in the Himalayan and Tibetan villages has resulted in socio-economic transformation. The quick flow of cash income to rural communities from collection and trade of this fungus has caused far-reaching impact on the social and economic conditions of rural communities (Winkler 2009; Shrestha and Bawa 2013). For example, trade in caterpillar fungus has facilitated the integration of rural Tibetan households even into international economic cycles. The income derived from its trade has led to an empowerment of marginal communities living in extremely harsh climates of high altitude. These communities, otherwise, were used to secure their survival through agro-pastoral activities (Winkler 2009; Pant et al., 2017; Shrestha et al. 2017). Studies from Nepal (Shrestha et al. 2013, 2014), India (Kuniyal and Sundriyal 2013; Negi et al. 2014; Pant et al., 2017) and various parts of Tibet Autonomous Region, China (Winkler 2008, 2009; Woodhouse et al. 2013; He et al. 2018) exhibit that soaring prices of caterpillar fungus have led to remarkable increase in annual cash income of the engaged households. This income thus contributes for better educational opportunities, health care and management of basic daily needs like food, clothes, etc. in areas of harsh climate, like the Tibetan Plateau. The availability of cash also allows for the outsourcing of

services in construction work and agriculture activities in these areas.

In India, engagement in collection and trade of caterpillar fungus has significantly contributed for uplift of the socio-economic condition in the high altitude villages particularly in Pithoragarh and Chamoli districts of Uttarakhand (Negi et al. 2006, 2014; Kuniyal and Sundriyal 2013). This income has resulted in better living standards, improved houses and education in the remotely located high altitude villages. Increasing incidences of in-migration for the collection of caterpillar fungus have been reported during recent decades. However, this quick flow of money has also brought several negative impacts, which includes declining interest of villagers in agricultural and pastoral activities (Negi et al. 2006, 2014). Such change may have long term implications for food and nutrient security in remote high altitude villages. Also, it will affect the diversity of genetic resources being maintained by villages in remote high altitudes. Available literature reveals the big income earned from trade of this species are often not only a blessing, but also has become a challenge (Shrestha and Bawa, 2014; Pant et al., 2017; Shrestha et al. 2017).

Families in high altitude villages have grown in subsistence based economy through agriculture and animal husbandry system. Therefore, they are not so mature in managing big and quick amounts (Shrestha and Bawa, 2014; Shrestha et al. 2017). This lack of management often results some families running out of funds at some point during the year and thereby forcing them to borrow money. Yet another looming challenge associated with the annually guaranteed access to substantial cash income, generated in a relatively short period, is in the form of disinterest of young people about learning a trade or getting into a profession.

A study by Negi et al (2015) indicates that with the passage of time there has been an increase in income, efforts of collection, and number of collectors of caterpillar fungus, but the yield has remained constant or declined. Furthermore, we may expect significant impact of global warming on overall production of this species, hence the dependent people becoming more vulnerable. For example, Negi et al. (2015) reported a comparatively higher increase in the income than the yield of caterpillar fungus from the Pithoragarh district of Uttarakhand in India (Fig. 4.1).

Box 4.1 Access to Caterpillar fungus- Cause of dispute

With caterpillar fungus collection becoming a major source of livelihood and income to most of the pastoral and other communities in higher altitude region of Bhutan, China, India and Nepal there have been increasing incidences of disputes. Ever increasing interest in its collection have resulted in congestion in collection areas and triggered conflicts among collectors. Historically in Himalayan high altitudes, community disputes were mostly reported over grazing rights. However, in recent times access to caterpillar fungus resources of particular regions have emerged as major cause of conflict. Since the prices of caterpillar fungus have been increasing continuously, a large number of people from lowlands and neighboring areas have also become interested in the collection of this species to earn quick money. However, inhabitants of caterpillar fungus growing areas do not want such outsiders to enter in the area hence resulting in severity of conflicts. Incidents have been frequently reported in recent years, with some conflicts resulting in physical assault, accidental death, and even in reported murder. All these have increasingly made Caterpillar fungus collection an intense cause of conflict within and among communities.

Information based on Winkler (2010); Shrestha and Bawa (2014); Negi et al. (2014)

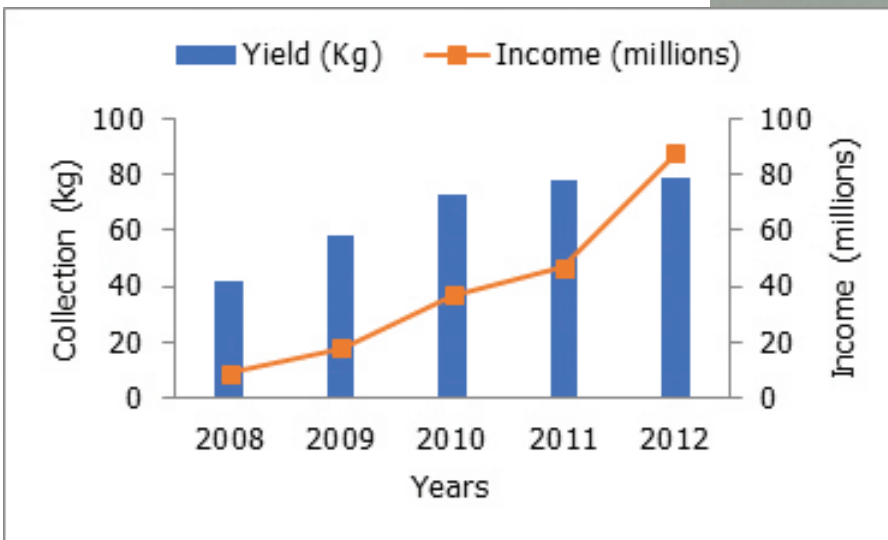
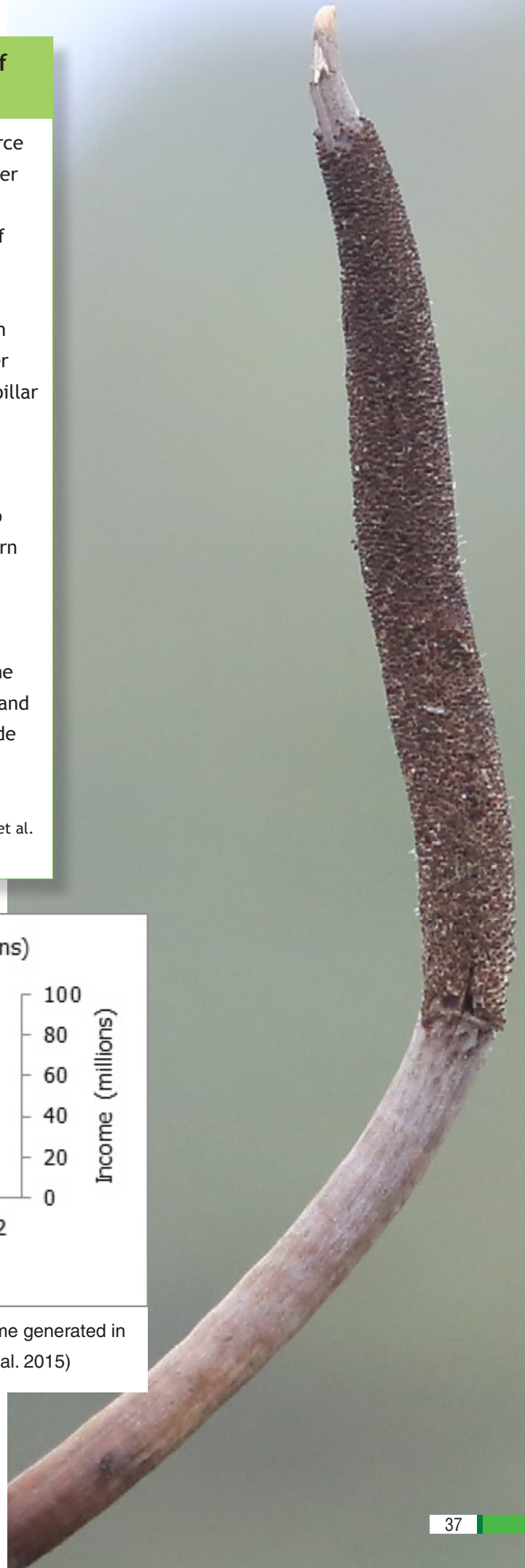


Figure 4.1: Total collections of caterpillar fungus and income generated in Pithoragarh district, Uttarakhand (Based on Negi et al. 2015)





5. Evolving trade and marketing

One can find traces of the trade of caterpillar fungus from 17th century in the Tibetan Plateau, when Tibetan people bartered it for tea and silk with China (Winkler 2008). With time, the trade of this species has grown significantly in China. Harvesting of caterpillar fungus was considered illegal until 2004 in Bhutan; thereafter, restricted harvesting was introduced in an effort to deter poaching and encourage stewardship by villagers (Cannon et al 2009). In Nepal, its trade began around 1987 and was legalized in 2001 (Shrestha and Bawa 2013). In India, caterpillar fungus harvesting began in the early 1990s, and was rapidly popularized during 1995-2000. Negi et al (2006) reported a 1256% increase in the price of caterpillar fungus locally in Kumaon between 1999 and 2004. The global trade is estimated at about US \$5-11 billion annually (Shrestha 2012). By weight, the prices of caterpillar fungus are more expensive than gold. The high-quality products cost as much as US \$60,000 per kilogram (Lei et al. 2015). Many products based on caterpillar fungus are now sold in the global markets as well as by online shopping websites. A list of products available from online shopping websites is given along with the prices of the products (Table 5.1).



Table 5.1: Commercially available products containing caterpillar fungus as an active ingredient

S. No	Product name	Approximate price (\$)	Uses	Manufacturing company
1	Yarsagumba	\$28571.43/Kg	Clinical	Aditya Agni Trading Co., India
2	A Grade IC PRO <i>Cordyceps sinensis</i>	\$12857.14/Kg	Clinical	IC Pro, India
3	Cordyceps Extract	\$22.85/g	Clinical	Herbal creative, India
4	<i>Cordyceps sinensis</i> Extract (200 g)	\$138.34/200 g	Supplement	G & E Nutrition
5	IRISS HERBALS <i>Cordyceps sinensis</i> Yarsagumba Capsules	\$85.71/60 capsules (500 mg each)	Boosts immunity	Iriss Herbals, India
6	Mystique Hills Organic <i>Cordyceps sinensis</i> Powder (Caterpillar Fungus)	\$34.28/100 g	Beneficial for the heart, lungs, reproductive organs	Mystique Hills- Organic Living
7	Urban Platter Cordyceps Mushroom Extract Powder	\$10/50 g (50g/ 1.76oz)	Boost energy level	Urban Platter
8	<i>Cordyceps Sinensis</i> Capsules -SGS and cGMP Certified, 99.6% rDNA Proven -60 Per Bottle	\$78.87/350 mg	Boost energy level	Tonicology, LLC
9	Organo Gold Red Tea	\$ 33/box	Revitalizing drink	Organo Gold Enterprises Inc., Canada
10	CordyMax CS-4	\$ 53.30/120 capsules	Dietary supplement for stamina and vitality	Pharmanex, Inc., USA
11	Le'JOYva Gourmet Arabica Black Instant Healthy Coffee	\$ 29.99/pack	Revitalizing drink	Le'JOYva Inc., USA
12	Cordyceps Soap	\$ 9.79/unit	Skin nourishment	Full and Fill Bio, Thailand
13	Cordyceps organic mushroom	\$ 3/unit	Sexual tonic, lowers blood glucose and cholesterol levels	Full and Fill Bio, Thailand
14	Mountain Fresh Organic Cordyceps Homeopathic Cream	\$ 108.92/unit	Helps to brighten and whiten the face	Mountain Fresh, UK
15	YanWo drink with rose bud and Cordyceps extract	\$ 60.22/unit	Revitalizing drink, antiaging, smooth skin	QiYun B.V, UK
16	New China Cordyceps <i>sinensis</i> whitening cream	\$ 17.65/unit	Removes dark spots	Smile, China
17	Cordyceps Mushroom Extract Powder	\$ 0.50/gram	Dietary supplement	Real Mushrooms, Canada
18	Cordyceps Capsules	\$ 44.96/pack (120 capsules)	Dietary supplement	Host Defense Inc., USA
19	Now Foods Cordyceps	\$ 12.34/750 mg	Dietary supplement	Now Foods Inc., USA
20	Mdrive Elite performance	\$ 79.99/box (90 capsules)	Dietary supplement	Dream Brands, Inc., USA
21	Kala health Cordyceps	\$ 97.95/ box (600 capsules)	Dietary supplement	Kala Health Inc., USA
22	Cordyceps Capsules - 650mg - Cordyceps sinensis - Vegan	\$20.679/120 capsules (17.30/100 gm)	Dietary supplement	Fair & Pure

Source: amazon.in, amazon.com, amazon.co.uk, alibaba.com, aliexpress.com, indiamart.com



Value added as well as sustainable use of caterpillar fungus, Temi Tea Estate in South Sikkim, Government of Sikkim has launched a new product 'Sikkim Cordyceps Green Tea' on the occasion of World Entrepreneur's Day on 21st August, 2018. NP Establishing and understanding trade route is one of the most important aspects of the trade and marketing. High price index of caterpillar fungus has remained uncertain and unpredictable among global market as trade of the product involve multiple channels (Fig. 5.1). The payment varies at different levels of trade routes, which starts from the collector households in the field to brokers and their agents who collect the caterpillar fungus at various locations. China, being the major market for the produce, account for the most of trade. The caterpillar fungus is mainly traded directly from Katmandu, Nepal to China's mega-cities particularly Guangzhou (He et al. 2018). In most cases, Chinese regional wholesalers travel to Katmandu to buy the product directly from central wholesalers. A small volume of this valuable fungus is also traded at the traditional border markets, mostly directly to local retailers or transported to Lhasa for sale to tourists. Trade by local traders (intermediaries) who are well familiar with local communities and villagers is the most common practice in all the countries (i.e., Nepal, China, India, Bhutan). These intermediaries usually remain in contact with central wholesalers in Katmandu. The central wholesalers in Katmandu send it in China through Lhasa or Shigatse via Gyilong and Zhangmu (He et al. 2018).

Over the years, the market for caterpillar fungus has evolved considerably. According to the Winkler (2009), the price for average grade caterpillar fungus may go up to US \$9000 to US \$10000/Kg and for good quality grade it may rise to US \$500000 per kg. In Nepal, market price of caterpillar fungus has increased up to 2300% from 2001 to 2011 (Shrestha and Bawa 2013). However, in India the price increased six folds (US \$ 3333/kg to US \$20,000/kg) between 2008-2012 (Negi et al. 2014). As per the existing information, in 2001, the resource was sold at INR 80,000 (US \$ 1677.43) per Kg, while its price went up to INR 1,25,000-1,30,00 per KG in 2002 and INR 400000 to 500000 per Kg in 2012 (Rana 2004; Sharma 2004; Bhandari et al., 2012). Negi et al. (2014) reported that approximately 400-500 Kg of caterpillar fungus trafficked annually to Nepal from Dharchula, Pithoragarh (Uttarakhand) in India. According to Lo et al. (2013),

the price in international market has increased from US \$ 20,000 to 40,000/Kg. Study by Winkler (2008) and Weckerle et al. (2010), revealed that 40 to 90% of the collectors depend on caterpillar fungus for the cash income. Shestha and Bawa (2014) reported that this is the second largest source of income for collector households in Nepal. Similar trend was reported from Bhutan (Cannon 2009, Wu et al. 2016) and from India (Negi et al. 2015, Caplins and Halvorson 2017). Temporal changes in economic contribution by trade of caterpillar fungus is given in Table 5.2.

Market networks of caterpillar fungus operate through informal trust-based relationships (buyer and seller negotiating prices); enabling the marketing of this resource from remote areas to urban centers (Pouliot et al. 2019). In most areas, local traders provide pre-collection advance payments to the collectors directly or via local agents based on oral agreement to create an environment of confidence.

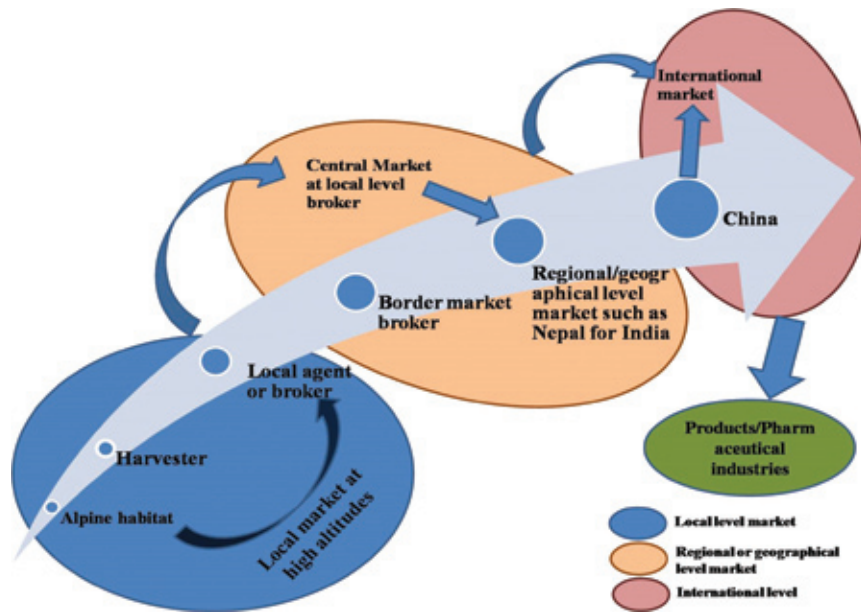


Figure 5.1: Different levels of caterpillar fungus trading from highlands to international market



Grading and marketing of caterpillar fungus: in the workshop at Bhutan



'Sikkim Cordyceps Green Tea'

Table 5.2: Economic contribution through trade in caterpillar fungus

Country	Place	Remark regarding economy (year)	Reference
China	China	\$140,000/kg (2011)	Shrestha and Bawa (2014)
	Tibet	\$225 million/50,000Kg (2004)	Winkler (2008)
	Tibet (Chamdo and Nagchu)	70-90% households benefitted by selling caterpillar fungus	Winkler (2009)
	Domkhok Township, Qinghai	\$26,600/kg/household	Sulek (2012)
	Tibet, Yunnan province, Diqing and Shangri-La	\$6-10/piece, 157 households	He et al. (2018)
	Baima Xueshan Nature Reserve	\$1560.72, 54 households, five villages	Weckerle et al. (2010)
Nepal	Dolpa district, Majphal village development committee (five villages)	\$130,000/kg (2011), 203 harvesters	Shrestha and Bawa (2013)
	Jumla district, Garjyangkot village development committee	\$2,287.2/year, Caterpillar fungus accounted for 65% of the total household cash income	Shrestha et al. (2017)
	Darchula district	\$10,070/kg (2015-2016) \$16,110/kg (2014-2015) \$16,110/kg (2013-2014)	Pouliot et al. (2018)
	Nubri and Tsum	\$4,700/household (2014)	Childs and Chodup (2014)
	Dolpa district	\$1843.66/household (second biggest contributor in income generation)	Shrestha and Bawa (2014)
	Dhorpatan hunting reserve	\$1.5-3/piece	Thapa et al. (2014)
India	Dharchula	19 villages, 80% population, \$1333/kg	Negi et al. (2006)
	Chamoli district	\$850-1000/kg	Singh et al. (2010)
	Pithoragarh district; Byans, Johar, Darma, Gori Paar, Chaudas, Metali, Ranthi and Jumma landscapes	\$142857.143 in 2008; followed by \$257142.857 (2009); \$5000000 (2010); \$7571428.57 (2011); \$13571428.6 (2012)	Negi et al. (2015)
	Chamoli district (Garhwal Himalaya)	\$3,500/year/household, 88 collector groups of 13 villages	Caplins and Halvorson (2017)
Bhutan	Bhutan; Lingshi, Gasa, Thimphu	\$38 to \$2,541/season / household	Cannon et al. (2009)



© K. Sambhav

6. Ecological consequences and sustainability

6.1 Sustainability of habitats

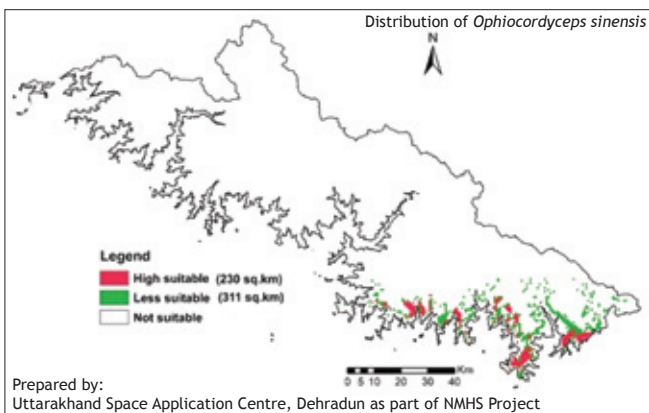
The increased prices and market demands have obviously led to significant increase in the number of collectors of caterpillar fungus. This in turn has posed severe pressure on its natural populations and alpine ecosystems (Box 6.1). Reports indicate, the availability of the resource has declined, and harvesting has become difficult in recent years in the Tibetan Plateau, areas of Nepal, Bhutan and India. This calls for attention with respect to sustainability of its habitat in particular and alpine meadows in general. For example, in the valley of Gori Ganga in Pithoragarh district of Uttarakhand (India) alone, the number of fungus gatherers at alpine habitats has increased fourfold since the year 2000 (Negi et al. 2014). This study also exhibits that the yield of caterpillar fungus has remained more or less steady over the years, however, the price of the commodity has increased manifold. The Box 6.1 reflects views of one of the researcher engaged with field studies of caterpillar fungus during last two decades in Uttarakhand.





Box 6.1 Yartsa Gunbu: sustainability is in question

In Uttarakhand (India) Yartsa Gunbu came into the limelight in the year 1996-97. It occurs in about 230 sq.km area between 3500-4800 m in *Kobresia* dominated sedge meadows. Every year, over 10,000 people representing nearly 200 households venture this area in search of Yartsa Gunbu for almost two months (May-June). The hotspot of this resource in the state is Chiplakedar area. Sumdum, Philam, Bon, Baling, Dugtu and Daantu in Darma valley, Ralam Dhura, Panchachuli base, Nagnidhura and Namik in Dharchula-Munsyari region of Pithoragarh district are other important collection areas. Few areas surrounding Pindari, Kafni and Sundardhunga catchments in district of Bageshwar, Kunwaripass, Khrion valley, Manpai areas of Chamoli District are also known for its availability. On an average, each family earns between 1-3 lacs per season (150-300 pieces). My understanding, based on field studies as well as evidences available from other studies, is that given the growing demand and destructive collection trends it would be difficult to ensure sustainability of resource in the region. However, if the local communities and management authorities establish coordination for: (i) limiting the number of people visiting and days they spend in alpine meadows, (ii) developing sustainable harvest strategies, (ii) establishing transparent mechanism for marketing and trade, and (iv) encouraging youths to work on traditional agriculture practices, there is a possibility that this resource continues to benefit communities for long.



Yartsa Gunbu collection in the Chiplakedar area (@ ID Rai)



Dr. Gajendra Singh
Uttarakhand Space Application Centre, Dehradun



The ecological impacts of caterpillar fungus harvesting include loss of pastures as a result of trampling, soil compaction, deforestation and dumping of solid wastes in the pastures. All these pose severe threats to alpine meadows and the unique biodiversity elements in these vulnerable habitats (Negi et al. 2014; Shrestha et al., 2014). Huge aggregations of people for nearly one month in the remote pastures is bound to affect the pristine nature of these ecosystems, which not only support many endemic and threatened species (Negi et al. 2014; Shrestha et al. 2014; Yadav et al. 2016) but also contribute for sustained flow of services to downstream areas (Negi et al. 2018b).

The studies have shown that the caterpillar fungus populations and its per-capita harvest is declining (Shrestha and Bawa 2013; Negi et al. 2014; Shrestha et al. 2014; Shrestha et al. 2017). Recently Shrestha et al. (2017) reported a mean annual decline of 25 pieces in the per capita harvest of caterpillar fungus in Nepal during 2010-2014, which can be attributed to the steady increase in the number of collectors every year. The major reasons for decline in availability and per capita harvest include: (i) unregulated and rampant harvesting of the resource (Shrestha et al. 2014; Negi et al. 2014; Pouliot et al. 2018), (ii) premature harvesting (Shrestha et al., 2014; Negi et al. 2014; Shrestha et al. 2017), (iii) decrease in moth and larval populations due to changing climatic conditions (Shrestha & Bawa 2013), (iv) modification of the soil microhabitats congenial to fungal spores by the harvesters (Shrestha et al. 2014), and (v) increased grazing intensity and climate change (Shrestha & Bawa 2013).

The study by Winkler (2005) explains, how in want of higher value fungus specimens are collected before sporulation and therefore minimizing chances of spore dispersal for future larvae infection. Conversely, when the caterpillar fungus is harvested very late in its lifecycle towards the end of the collection season, sporulation takes place, which has utmost ecological importance to sustain the caterpillar fungus population. However, at this stage it fetches fewer returns. Lesser the availability of mature sporocarp, lesser would be the chances that reproductive spores would find the likely host insect—the obligate out-crosser (Thitarode larva), to complete its life cycle.

It has been frequently reported that (i) exploitation of herbaceous plants as well as woody vegetation on whose roots and flowers the host larva thrives, (ii) trampling by harvesters and livestock, and (iii) prolonged stays of collectors in its habitat areas have resulted in degradation of both the habitats and the host insect in its range of distribution (Shrestha et al 2014; Negi et al. 2015). Extensive cutting of alpine shrubs particularly *Rhododendron campanulatum*, *Juniperus* spp., and tree species like *Betula utilis* for fuelwood and tent preparations, is further causing pressure on these species at climate sensitive timberline. Furthermore, dumping of large amount of trash in alpine pastures and open defecation has also become a challenge, especially to protect water the sources from contamination. Currently there exists no management practice to mitigate or reduce generated garbage during stay of harvesters.

6.2 Unregulated Harvesting in Conservation Areas

More importantly, unregulated harvesting of caterpillar fungus in biodiversity rich conservation sites has increasingly become a challenge. Even in India, many alpine habitats of caterpillar fungus fall in designated conservation areas such as Nanda Devi Biosphere Reserve, Gangotri National Park, Govind National Park, Askot Wild Life Sanctuary and Kedarnath Wild Life Sanctuary in Uttarakhand; Kanchendzanga Biosphere Reserve in Sikkim and Dehang-Debang Biosphere Reserve in Arunachal Pradesh. The collection of caterpillar fungus continues unabated from these sites and thereby impeding the ecological integrity of these conserved systems and their unique plants particularly high value medicinal plants. The efficacy of departmental system to monitor such vast areas in difficult terrain is always questionable, particularly in view of the limited resources available with government departments.

6.3 Overexploitation leading to population decline

With overexploitation of caterpillar fungus its own survival is also in dilemma (Box 6.2). It is well established that harvesting, which lead to mortality of the target plant

species that makes the populations more vulnerable (Cunningham 2001). In this context, caterpillar fungus with a single reproductive cycle is likely to be more vulnerable. Therefore, there is a need to leave enough individuals un-harvested during collection to ensure adequate reproduction. Unfortunately this level of understanding is missing among most of the collectors. It is reported that the harvested lot often consists of 70–80% immature samples. Therefore, inadequate number of spores dispersed by the smaller surviving population of mature individuals further increases the vulnerability of the species (Negi et al. 2015). This study also concludes, declining population of caterpillar fungus would result in resurgence of the population of the host insect (Thitarode), which in turn would affect ecology of the above-ground vegetation.

6.4 Caterpillar fungus under changing climate

Impact of climate change on this important resource has surprisingly remained less investigated area. Box 6.3 compiles some of such studies, largely from China. However, a more comprehensive study by Hopping et al. (2018), which cover its entire range of occurrence in the Himalaya, reveals that winter temperature is the key factor for both distribution and production of caterpillar fungus. The species distribution models detected upper and lower winter temperature thresholds beyond which sustainable habitats are limited. Study reports within the temperature range production decreases with increase in winter temperature. Therefore, the significant winter warming as reported throughout its distribution range in India, Bhutan and Nepal may have caused the production decline in respective countries. This study by Hopping et al. (2018) further indicates significant winter warming in exceptionally cold northeastern Tibetan Plateau may have shifted new area above the low-temperature threshold, thereby promoting the increased production there.

Box 6.2 We are hell bent on killing the goose laying the golden eggs

The caterpillar fungus (Yartsa Gunbu) offers an example of the phenomenon, where a resource of immense economic value runs into the risk of being over-exploited. Study by my team covered 110 villages in District Pithoragarh (Uttarakhand), which are engaged in its harvesting reveal: (i) there is a perceptible decline in the yield of Yartsa Gunbu over the years (Fig. 1), and (ii) a significant, 14.81% decline in the population of the host insect too within the span of 5 years (Fig. 2). Harvesting of immature specimen remains the prime factor for yield decline. Healing power of Yartsa Gunbu is believed to be concentrated in the caterpillar, filled with *Ophiocordyceps* mycelium, and not the size of the fruiting body. The harvesters are thus forced to make collections early in the season. In fact, 70 to 80% of the harvested lot consists of immature specimens. Such collection impacts negatively on reproduction and its future availability in wild. Therefore, increasing demand in international markets and ever growing price of niche commodity is likely to result in more extensive and prolonged duration of harvesting season with resultant greater degradation of the habitat, and concomitant loss of vegetation cover, upon which the host larva thrives. Given this scenario, and realizing the low level of awareness among stakeholders, my suggestion would be to regularly organize workshops, awareness programmes across the landscape. Stakeholders need to be made convinced that the present mode of exploitation invariably relates with declining yield. One sound strategy would be to make their stay 2-3 kms away from the alpine meadows, in the forest fringes, so that duration of harvest per day in the habitat sites gets reduced.

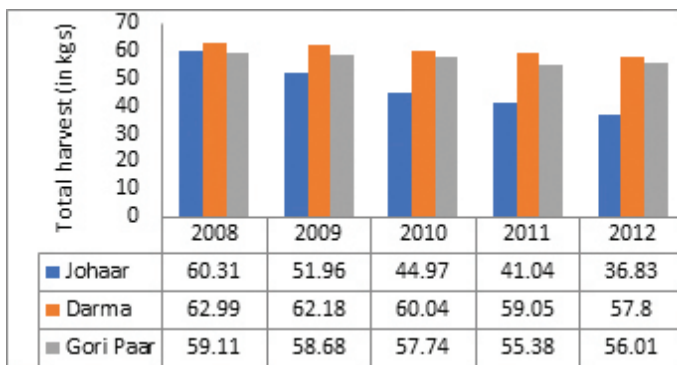


Figure 1: Decline in total harvest of Yartsa Gunbu over the five years (2008-12) in Pithoragarh district of Uttarakhand - a rough estimate of the total yield as per the informants (n=1370)

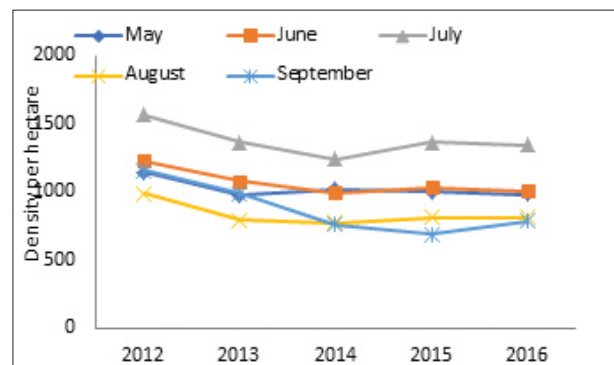


Figure 2: Perceptible decline in the population size of the host caterpillar host - Thitarode

Dr. C.S. Negi,
MBPG College Haldwani (Uttarakhand)

Box 6.3 Climate change and Caterpillar fungus

The Himalaya is warming much faster than the global average. Therefore, impacts are more apparent. Evidences reveal, climate change in the Himalaya has impacted hydrology, agriculture, ecosystems, and resulted in altitudinal shifts of vegetation communities. Several studies have shown that climate change has altered mushroom fruiting phenology (e.g., Kausrud et al., 2008, 2012), but there are very few studies concerning range shifts of fungi in response to climate change (Yang 2008; Shrestha and Bawa, 2014). According to Yang (2010), the altitudinal limits of the prime caterpillar fungus habitat have been pushed up by around 200-500m between 3900 to 4400 m in Tibetan Plateau. A recent study by Yan et al. (2017) from Tibetan Plateau, predicted net habitat loss of 19% by years 2050 and 2070 under Representative Concentration Pathways-RCP 2.6, and of 8% and 4% under RCP 8.5 for the years 2050 and 2070, respectively. The study also argues that if a non-dispersal scenario was considered, 36-39% of the current habitats would be lost in the future. A study on model based projection by Shrestha and Bawa (2014) from Nepal revealed that across all future climate change trajectories over three different time periods, the area of predicted suitable habitat of caterpillar fungus would expand, with 0.11-4.87% expansion over current suitable habitat. Climatic conditions suitable for caterpillar fungus growth would seriously undermine overall habitat availability. However, so far there is no baseline research that would allow comparing past habitat to suggested current habitats of caterpillar fungus. Therefore, in want of evidences it is difficult to say how caterpillar fungus will perform under changed condition. However, being an association of the caterpillar larvae and the fungus, any differences in response towards changing climate by either of these constituents would be influencing the overall availability of caterpillar fungus in the Himalaya.

6.5 Addressing issues of sustainability

Towards ensuring the sustainability of resource, cyclic regulation for fungus collection by the villagers or through concerned government department seems a viable option. This may help achieving conservation as well as sustainable harvesting of caterpillar fungus in long run. In the context of India, Negi et al. (2014) have suggested urgent need to educate the villagers on following (i) sustainable harvesting methods; (ii) regulating the number of harvesters per household, (iii) reducing the length of stay of collectors in the alpine meadows, (iv) garbage management in the alpine, and (v) minimizing degradation of the habitats, primarily on account of fuelwood collection.

Further, recognizing the huge market demand accompanied by limited availability in nature and realizing increasing socio-economic relevance and looming threats under changing climate, there is a definite need for finding alternative ways to meet the demand. Therefore, artificial cultivation becomes a possible solution. As a result several researchers are getting attracted towards its artificial cultivation (Box 6.4).

Box 6.4 In Vitro culture of Caterpillar fungus

Laboratory cultivation of *O. sinensis* is difficult, while the cultivation of other species of *Ophiocordyceps* such as *O. militaris* has been tremendously successful (Sung et al., 1999; Baral and Maharjan 2012, Kang et al., 2014). Available literature suggests that *Ophiocordyceps* can be cultured on potato dextrose agar plates for 96 h at 28°C temperature (Han and Liu, 2009; Liu et al., 2010). However, the success of cultivation on large-scale has not been achieved. Low survival rate of the host, low rate of infection, and the induction of primordium are the primary technical difficulties in achieving the breakthroughs in artificial cultivation. Sunshine Lake Pharma Co. Ltd. (Guangdong, China) has claimed to optimize the method on artificial cultivation of *O. sinensis*. At the Institute of Microbiology, Chinese Academy of Sciences, the cultivated samples under artificial conditions were examined for many years, and the fungus and the hosts have been identified as *O. sinensis* and *Hepialus xiaojinensis* by both morphological and molecular methods (Zhang et al., 2018). The annual yield of the company is increasing year by year like 2.5, 5, and 10 tons in 2014, 2015, and 2016, respectively, which accounts for nearly 5% of the total natural resource annually. With further refinement and scaling up of cultivation would certainly benefit the survival of natural population.







7. Governance issues – Social & Ecological implications

The emergence of caterpillar fungus as game changer, both in socio-economic and ecological domain, brings issues pertaining to governance of this common's resource on fore front. As this fungus has transformed into a highly valuable resource within a short time frame (Winkler 2019; Cannon et al. 2009; Corrina et al. 2019), the specific governance system has not evolved to the extent desired. The existing systems vary considerably within and across countries.

In Nepal, the harvest of caterpillar fungus was banned till 2000 under the Forest Act 1993 and Forest Regulations 1995. However, the collection and trade were going on illegally and secretly making the ban ineffective. Realizing this, the ban was lifted in 2001 with the provision of revenue of NRs 20,000 per kg and later that revenue was reduced to NRs 10,000 per kg in 2006 (Devkota, 2010). After legalization of trade of caterpillar fungus in 2001, earnings from the harvest have gradually increased due to the increase in market prices. Now in Nepal, caterpillar fungus collection and sale in all community forests and conservation areas is legal (MoFSC 2017), but the conflicts regarding access between villagers and distant collectors are common (ICIMOD 2015; Pant et al. 2017). A study by Corrina et al. (2019) reveals that the National policies in Nepal legalize collection and sale of NTFP, including caterpillar fungus. However, for a protected area (e.g. Api Nampa Conservation Area-ANCA) quantities of its collection are defined by the Department of National Parks and Wildlife conservation (DNPWC). ANCA authorities collect royalty for collection @ 25,000 NR per Kg. It receives revenue to the extent US\$173,000 per year from collection of caterpillar fungus. The vertical integration between local and national actors and institutions remains weak. There has been a situation of governmental Institutions override customary rights and practices (Corrina et al. 2019).

In Bhutan, caterpillar fungus was placed in Schedule 1 list of the Forest and Nature Conservation Act 1995 and its harvest remained illegal until 2004, when a limited collection regime was introduced (Cannon et al. 2009). Many of the harvest sites in Bhutan are close to the border with Tibet (China), which is difficult to patrol by law enforcement agencies and hence cross-border illegal trade continues in caterpillar fungus. The law was changed in 2004 to allow limited collection of caterpillar fungus by the yak herders whose herds traditionally graze in the pastures. Various measures were put in place to restrict the overall harvest, including a ban on collection

except during the month of June, and a stipulation that only one member of each household allowed to collect (Cannon et al. 2009). Rationale behind the regulation on harvest dates (in the month of June) was to lessen the collection of immature specimens. Realizing the success of these measures they have been maintained with some modifications.

In state of Uttarakhand (India), the sale of caterpillar fungus was not regulated by law, until the recent state government guidelines, which led to smuggling/illegal trade of the caterpillar fungus to Nepal and China. In order to address the problems associated with unregulated trade, the State Government of Uttarakhand, by declaring the species as an NTFP on the basis of the Indian Forest Act, 1927, has issued certain guidelines on the collection and trade of caterpillar fungus from reserve forests through village level forest councils (Van Panchayat), while commercial exploitation from wildlife sanctuaries and national parks is completely prohibited (Yadav et al. 2016). Thus, the commercial collection of caterpillar fungus is legal only in community forests managed by van panchayats (village forest councils) with the approval of the State Forest Department. However, collectors harvest caterpillar fungus wherever possible – within state forests or protected areas – regardless of rights and legal status (Negi et al. 2016). Illegal collection and trade across the border to China and Nepal is well known but the extent of the illegal harvest and trade has never been estimated so far. Dharchula (District Pithoragarh) serves as a porous border between India and Nepal which is also used as a transit location for other forms of trade between the two countries. This situation of illegal trade has emerged largely due to low profitability in legal marketing through Governmental Institution, and also on account of the absence of a formalized institutional setup.

In Sikkim State of India, Government framed the rules and regulation for collecting the caterpillar fungus known as Collection and Selling rules-2009 implemented on July 2, 2009. As per the rule, no caterpillar fungus is allowed to be collected in the State of Sikkim unless permission is obtained from the Range Officer who shall issue permission after field verification and with approval of the Principal Chief Conservator of Forest (PCCF). However, no collection is permitted in the Wildlife Sanctuary and

National Parks. If a Joint Forest Management Committee or Eco Development Committee members desire to collect caterpillar fungus from their territory they shall apply to DFO concerned. The committee needs to provide a rough sketch map along with approximate quantity of collection, which shall not be more than 33% of that total stock of the area. These rules were not much effective for sustainable harvesting of the caterpillar fungus because rule is not sufficient on its own as it did not include the most important aspect i.e. the Access and Benefit Sharing (ABS) provision defined in the Indian Biological Diversity Act 2002. Therefore in 2016, Sikkim government drafted a new guidelines “*Ophiocordyceps sinensis* (Yartsa Gunbu) Auctioning and Harvesting Guidelines 2016”. The new guidelines restricts the collection period for one month and issue of the specific number of permits, strictly to the local community. On the basis of new notification, government issued 101 collection permits (free of cost) to the highlanders and facilitated open auction for its sales. However, there were negligible participation from both buyers and sellers on caterpillar fungus auction. So, the efforts of the Sikkim Government could not succeed due to various issues among State Government, buyers and sellers (Pradhan et al., 2019).

The government order (Forest Department 1790/18.01.2002) of Uttaranchal authorized van panchayats in Johar valley of District Pithoragarh with supreme powers vested on the sarpanch and that a committee of van panchayats is formed to monitor the harvesting. This arrangement also could not succeed and several conflict situations emerged. Remoteness and inaccessibility of collection sites accompanied by limitations of human and financial resources of state forest Department constraints execution of existing system of governance (Corinna et al. 2019). On October 08, 2018, the government of Uttarakhand has issued a guideline regarding collection and marketing of caterpillar fungus. Under this guideline caterpillar fungus is now considered as Non-timber Forest Products (NTFP). The collection is allowed through license system. In general, the government led governance systems in the high alpine areas have struggled to overcome the disturbances, and to set up and enforce management mechanisms for sustainable collection of caterpillar fungus (Cannon et al. 2009; Negi et al. 2015; Pant et al.

2017). Study by Corrina et al. (2019), in the context of India and Nepal, concluded that neither government nor communities alone can ensure effective governance in remote mountain areas when resource values rapidly increase. This requires a complex and complementary resource governance system consisting of both government institutions and community management arrangements.

With the recent inclusion of species in Red List of IUCN (Box 7.1) as 'Vulnerable' brings a new dimension to whole issue of governance. The respective governments are expected to respond to it in a way to strike balance between increasing conservation needs and high dependence of local communities on this resource.

Box 7.1 World's most expensive fungus threatened

International Union for Conservation of Nature (IUCN) has entered caterpillar fungus in Red List as 'Vulnerable'. The fungus is highly valued in Traditional Chinese Medicine, where it has been used for over 2,000 years to treat many diseases. Demand for the fungus has risen sharply since the 1990s. In the last two decades, the fungus has become the main source of livelihoods for thousands of indigenous people where it occurs. According to IUCN, 'caterpillar fungus populations have declined by at least 30% over the past 15 years as a result of overharvesting'.

Prof Gregory Mueller, Chair of the IUCN SSC Fungal Conservation Committee mentioned "This is one of the few documented cases of a fungus being threatened by overharvesting". Therefore, there exists an urgent need to ensure sustainable harvest of this species so as to address issues of (i) natural population decline, and (ii) long-term income/ livelihoods of dependent communities.

Based on: IUCN 2020 (IUCN.Org)







8. Way forward

Undoubtedly in recent decades, caterpillar fungus has emerged as an important resource for local communities in Himalaya, especially the local indigenous communities living in the high altitudes villages where livelihood opportunities are very limited. Increasing dependency of these inhabitants on caterpillar fungus collection and trade will leave these communities vulnerable, if the production and per capita availability continues to decline as reported in many studies. The studies on ecological status of caterpillar fungus have frequently reported that wild material gatherers extract natural resources without considering its sustainability and often use destructive harvesting methods. Given the ever-increasing demand in the international markets and the price of the commodity, populations of the species, its host as well as the associated communities and habitats become severely vulnerable to degradation. The current scenario of caterpillar fungus extraction indicates immense future impacts both on the species as well as its habitat which also might result in loss or local extinction of other rare and geographically restricted species in the pristine alpine habitats of the Himalaya. Furthermore, these high altitude habitats of the Himalaya have been predicted to be affected by the climate change, which in turn will have an enhanced negative impact on caterpillar fungus and its associated species. In view of this there exists a need for timely implementation of conservation and sustainable management strategy across the caterpillar fungus distribution range for conservation of the species, its associated communities and habitat. National and International level collaboration and conservation forums can play an important role by way of evolving a common holistic conservation policy that integrated effective conservation and harvesting strategy.

Trade of caterpillar fungus from India is largely conducted through Nepal to China in an illegal manner but in very high intensity owing to its higher profitability. Effective guidelines and mechanism for extraction, marketing and trade of caterpillar fungus are still lacking in India. Therefore, uniform methods and guidelines needs to be developed for its sustainable harvesting and trade. Moreover, awareness of local communities regarding the problems associated with commercial exploitation is of utmost importance. Management issues need trans-disciplinary and trans-sectoral supports, including science-based research, technology development, rangeland ecosystem management, climate change adaptation, collection specification, fair and honest trade, value-added products and marketing, export and import rule, etc. Further, as be the availability the frontline staff and the local community institution such as JFMCs/





EDCs/BMCs along with the military, para military forces and local police need to be engaged on regular patrolling and monitoring the activities of the collators in the habitat areas during the harvesting seasons for controlling the habitat degradation, illegal collection, purchase and trans-boundary trade.

The fluctuation in the price of caterpillar fungus varies within the IHR states annually, which is totally controlled by the middleman largely due to least market awareness and lack of coordination between local communities and the government agencies. Therefore, there is an urgent need to have provision of market information system for caterpillar fungus in which the local community can explore possibilities of gaining maximum benefits. There exists a great opportunity to explore possibilities of the value addition in caterpillar fungus in the form of supplementary food as well as medicinal products for promoting the livelihood opportunity to the local community in the IHR states.

Much progress has been made in China where various aspects of caterpillar fungus research, like habitat management, reproduction of insect and fungus, development of new technologies and new products etc. have been investigated. However, the status of caterpillar fungus research in India is lagging far behind in all the aspects. Very few efforts have been made in India for laboratory based research to discover the medicinal potential of the caterpillar fungus. Similarly, limited number of studies have been conducted on the ecological and conservation status of the caterpillar fungus and its habitats in the Indian Himalayan region. Therefore, more focused efforts are required from scientific community for investigation on various aspects of the caterpillar fungus. Further, studies are needed for unbiased and rational investigation on the trade-off between the impact of caterpillar fungus collection on the rural economy and habitat degradation due to its extraction from the pristine alpine habitats. Thus, for a better understanding on the medicinal potential, economic values, ecology and conservation of the caterpillar fungus increased financial supports must flow in for both basic and applied research across the caterpillar fungus range.

Most importantly, in view of declining production due to overharvesting as well as changing climate, and likely implications of this decline for dependent community, there is an urgent need to find alternative livelihood options for communities associated with its harvesting. Vulnerability of these otherwise marginalized communities is therefore has increased considerably with production decline and/or availability limitations. Appropriate attention on such communities is needed immediately.

Bibliography

- Adhikari, M. K. 2008. The diversity of Cordycepioid fungi (Ascomycotina : Clavicipitales) reported from Nepal. *Bulletin of the Department of Plant Resources* 30:1–8.
- Ahmed, A. F., N. N. El-Maraghy, R. H. A. Ghaney, and S. M. Elshazly. 2012. Therapeutic Effect of Captopril, Pentoxifylline, and *Cordyceps Sinensis* in Pre-Hepatic Portal Hypertensive Rats. *Saudi Journal of Gastroenterology* 18:182–187.
- Akaki, J., Y. Matsui, H. Kojima, S. Nakajima, K. Kamei, and M. Tamesada. 2009. Structural analysis of monocyte activation constituents in cultured mycelia of *Cordyceps sinensis*. *Fitoterapia* 80:182–187.
- Angelsen, A., P. Jagger, R. Babigumira, B. Belcher, N. J. Hogarth, S. Bauch, J. Börner, C. Smith-Hall, and S. Wunder. 2014. Environmental Income and Rural Livelihoods: A Global-Comparative Analysis. *World Development* 64:S12–S28.
- Anonymous. 2003. *Cordyceps sinensis* and *Ganoderma lucidum* amongst top “herbal” medicines. *Mycological Research* 107:259–259.
- Au, D., L. Wang, D. Yang, D. K. Mok, A. S. Chan, and H. Xu. 2011. Application of microscopy in authentication of valuable Chinese medicine I-*Cordyceps sinensis*, its counterfeits, and related products. *Microscopy Research and Technique* 75:54–64.
- Avtonomova, A. V., L. M. Krasnopolskaya, M. I. Shuktueva, E. B. Isakova, and V. M. Bukhman. 2015. Assessment of Antitumor Effect of Submerged Culture of *Ophiocordyceps sinensis* and *Cordyceps militaris*. *Antibiotiki i khimioterapiia = Antibiotics and chemotherapy [sic] / Ministerstvo meditsinskoi mikrobiologicheskoi promyshlennosti SSSR* 60:14–17.
- Awad, A. B., K. C. Chan, A. C. Downie, and C. S. Fink. 2000. Peanuts as a source of beta-sitosterol, a sterol with anticancer properties. *Nutrition and Cancer* 36:238–241.
- Babu, B., and J.-T. Wu. 2008. Production of natural butylated hydroxytoluene as an antioxidant by freshwater phytoplankton. *Journal of Phycology* 44:1447–1454.
- Bai, J.-X., J. Han, L. Dai, H. Xu, B.-D. Shen, R.-L. Yin, and H.-L. Yuan. 2013. Studies on grinding degree of *Cordyceps sinensis* based on in vitro dissolution and pharmacodynamics of anti-hepatic fibrosis. *Chinese Traditional and Herbal Drugs* 44:2823–2827.
- Bai, X.-L., S.-X. Yang, Y. Shan, W.-J. Li, J. Li, Y. Xiao, X.-F. Hu, and L. Cao. 2018. Effects of cultivated *Cordyceps sinensis* on proliferation and apoptosis of human leukemia K562 cells. *Zhongguo Zhongyao Zazhi* 43:2134–2139.
- Balfour-Browne, F. 1955. Some Himalayan fungi. *Bulletin of the British Museum Natural History* 1:189–218.
- Balon, T. W., A. P. Jasman, and J. S. Zhu. 2002. A fermentation product of *Cordyceps sinensis* increases whole-body insulin sensitivity in rats. *Journal of Alternative and Complementary Medicine* 8:315–323.
- Bao, T. T., G. F. Wang, and J. L. Yang. 1988. Pharmacological actions of *Cordyceps sinensis*. *Zhong xi yi jie he za zhi = Chinese journal of modern developments in traditional medicine / Zhongguo Zhong xi yi jie he yan jiu hui (chou), Zhong yi yan jiu yuan, zhu ban* 8:352–354, 325.
- Bao, Z. D., Z. G. Wu, and F. Zheng. 1994. Amelioration of aminoglycoside nephrotoxicity by *Cordyceps sinensis* in old patients. *Zhongguo Zhong xi yi jie he za zhi Zhongguo Zhongxiyi jiehe zazhi = Chinese journal of integrated traditional and Western medicine / Zhongguo Zhong xi yi jie he xue hui, Zhongguo Zhong yi yan jiu yuan zhu ban* 14:271–273, 259.

- Baral, B. 2017. Entomopathogenicity and Biological Attributes of Himalayan Treasured Fungus *Ophiocordyceps sinensis* (Yarsagumba). *Journal of Fungi* 3:UNSP 4.
- Baral, B., B. Shrestha, and J. Silva. 2015. A review of Chinese Cordyceps with special reference to Nepal, focusing on conservation. *Environmental and Experimental Biology* 13:61–73.
- Barseghyan, G. S., J. C. Holliday, T. C. Price, L. M. Madison, and S. P. Wassert. 2011. Growth and Cultural-Morphological Characteristics of Vegetative Mycelia of Medicinal Caterpillar Fungus *Ophiocordyceps sinensis* GH Sung et al. (Ascomycetes) Isolates from Tibetan Plateau (PR China). *International Journal of Medicinal Mushrooms* 13:565–581.
- Belwal, T., I. D. Bhatt, D. Kashyap, K. Sak, H. S. Tuli, R. Pathak, R. S. Rawal, and S. M. Ghatnur. 2019. *Ophiocordyceps sinensis*. Pages 527–537 *Nonvitamin and Nonmineral Nutritional Supplements*. Elsevier.
- Berne, R. M. 1980. The role of adenosine in the regulation of coronary blood flow. *Circulation Research* 47:807–813.
- Bhandari, A. K., J. S. Negi, V. K. Bisht, N. Singh, and R. C. Sundriyal. 2012. *Cordyceps sinensis*: fungus inhabiting the Himalayas and a source of income. *Current Science* 103:876–876.
- Bhatt, V. P., V. Negi, and V. K. Purohit. 2009. *Cordyceps sinensis* (Berk) Sacc. Keera-Jari: A life-chip from alpine meadows of Garhwal Himalaya. *National Academy Science Letters-India* 32:345–350.
- Bi, B., X. Wang, H. Wu, and Q. Wei. 2011. Purification and characterisation of a novel protease from *Cordyceps sinensis* and determination of the cleavage site motifs using oriented peptide library mixtures. *Food Chemistry* 126:46–53.
- Bok, J. W., L. Lermer, J. Chilton, H. G. Klingeman, and G. H. N. Towers. 1999. Antitumor sterols from the mycelia of *Cordyceps sinensis*. *Phytochemistry* 51:891–898.
- Brewster, J. F., and C. L. Alsberg. 1917. Note on the physiological action of *cordyceps sinensis*. *Journal of Pharmacology and Experimental Therapeutics* 10:277–280.
- Buenz, E. J., B. A. Bauer, T. W. Osmundson, and T. J. Motley. 2005. The traditional Chinese medicine *Cordyceps sinensis* and its effects on apoptotic homeostasis. *Journal of Ethnopharmacology* 96:19–29.
- Buenz, E. J., J. G. Weaver, B. A. Bauer, S. D. Chalpin, and A. D. Badley. 2004. *Cordyceps sinensis* extracts do not prevent Fas-receptor and hydrogen peroxide-induced T-cell apoptosis. *Journal of Ethnopharmacology* 90:57–62.
- Bukumirovic, N., and D. Segan. 2011. Influence of seven-day treatment with fungus *cordyceps sinensis* on rat's organism. *European Journal of Medical Research* 16:146–146.
- Bushley, K. E., Y. Li, W.-J. Wang, X.-L. Wang, L. Jiao, J. W. Spatafora, and Y.-J. Yao. 2013. Isolation of the MAT1-1 mating type idiomorph and evidence for selfing in the Chinese medicinal fungus *Ophiocordyceps sinensis*. *Fungal Biology* 117:599–610.
- Cai, H., J. Li, B. Gu, Y. Xiao, R. Chen, X. Liu, X. Xie, and L. Cao. 2018. Extracts of *Cordyceps sinensis* inhibit breast cancer cell metastasis via down-regulation of metastasis-related cytokines expression. *Journal of Ethnopharmacology* 214:106–112.
- Canney, S. 2006. *Cordyceps sinensis* animal, vegetable or both? *Journal of Chinese Medicine*:43–49.
- Cannon, P. F., N. L. Hywel-Jones, N. Maczey, L. Norbu, Tshitila, T. Samdup, and P. Lhendup. 2009. Steps towards sustainable harvest of *Ophiocordyceps sinensis* in Bhutan. *Biodiversity and Conservation* 18:2263–2281.

- Cannon, P. F., N. L. Hywel-Jones, N. Maczey, L. Norbu, Tshitila, T. Samdup, and P. Lhendup. 2009. Steps towards sustainable harvest of *Ophiocordyceps sinensis* in Bhutan. *Biodiversity and Conservation* 18:2263–2281.
- Cao, L., Y. Ye, and R. Han. 2015. Fruiting Body Production of the Medicinal Chinese Caterpillar Mushroom, *Ophiocordyceps sinensis* (Ascomycetes), in Artificial Medium. *International Journal of Medicinal Mushrooms* 17:1107–1112.
- Caplins, L., and S. J. Halvorson. 2017. Collecting *Ophiocordyceps sinensis*: an emerging livelihood strategy in the Garhwal, Indian Himalaya. *Journal of Mountain Science* 14:390–402.
- Caplins, L., and S. J. Halvorson. 2017. Collecting *Ophiocordyceps sinensis*: an emerging livelihood strategy in the Garhwal, Indian Himalaya. *Journal of Mountain Science* 14:390–402.
- Caterpillar fungus: The emperor's mighty brother. 2015. *Economist* (United Kingdom) 411.
- Cha, S. H., J. C. Kim, J. S. Lim, C. S. Yoon, J. H. Koh, H. I. Chang, and S. W. Kim. 2006. Morphological characteristics of *Cordyceps sinensis* 16 and production of mycelia and exo-biopolymer from molasses in submerged culture. *Journal of Industrial and Engineering Chemistry* 12:115–120.
- Cha, S. H., J. S. Lim, C. S. Yoon, J. H. Koh, H. I. Chang, and S. W. Kim. 2007. Production of mycelia and exo-biopolymer from molasses by *Cordyceps sinensis* 16 in submerged culture. *Bioresource Technology* 98:165–168.
- Chakraborty, S., S. Chowdhury, and G. Nandi. 2014. Review on yarsagumba (*Cordyceps sinensis*) - An exotic medicinal mushroom. *International Journal of Pharmacognosy and Phytochemical Research* 6:339–346.
- Chakraborty, S., S. Chowdhury, and G. Nandi. 2014. Review on Yarsagumba (*Cordyceps sinensis*) - An Exotic Medicinal Mushroom. *International Journal of Pharmacognosy and Phytochemical Research* 6:8.
- Chan, R. C. H., S. S. W. Lam, F. L. Y. Fong, D. T. W. Chan, F. W. F. Lee, and E. T. P. Sze. 2018. Optimization of protein extraction and two-dimensional gel electrophoresis profiles for the identification of *Cordyceps sinensis* and other similar species. *Plos One* 13:e0202779.
- Chan, S., B. Liu, Z. Zhao, M. Lam, K. Law, and H. Chen. 2011. Studies on macroscopic and microscopic identification of *Cordyceps sinensis* and its counterfeits. *Zhongguo Zhongyao Zazhi* 36:1141–1144.
- Chan, T. P., K. W. Ma, and F. T. Chau. 2000. Analyses of valued Chinese medicines, *Ganoderma* and *Cordyceps sinensis*: Comparison of both qualitative and quantitative results from high performance liquid chromatography (HPLC) and thin layer chromatography (TLC) studies. *Abstracts of Papers of the American Chemical Society* 220:U80–U80.
- Chang, Y., W.-H. Hsu, W.-J. Lu, T. Jayakumar, J.-C. Liao, M.-J. Lin, S.-H. Wang, P. Geraldine, K.-H. Lin, and J.-R. Sheu. 2015. Inhibitory Mechanisms of CME-1, a Novel Polysaccharide from the Mycelia of *Cordyceps sinensis*, in Platelet Activation. *Current Pharmaceutical Biotechnology* 16:451–461.
- Chatterjee, R., K. S. Srinivasan, and P. C. Maiti. 1957. *Cordyceps sinensis* (Berkeley) Saccardo: Structure of Cordycepic Acid. *Journal of the American Pharmaceutical Association (Scientific ed.)* 46:114–118.
- Chen, C.-C., L.-L. Cheng, K.-N. Chen, and C.-H. Kuo. 2010a. Effects Of *Rhodiola Crenulata* And *Cordyceps Sinensis* Based Supplementation On Endurance Performance And Physiological Stress In Altitude Trained Subjects. *Medicine and Science in Sports and Exercise* 42:450–451.
- Chen, C.-S., C.-T. Huang, and R.-S. Hseu. 2009a. Identification of *Cordyceps sinensis* by 18S nrDNA Sequencing and Characterization of Fermented Products in Taiwan. *Food Biotechnology* 23:191–199.
- Chen, C.-S., C.-T. Huang, and R.-S. Hseu. 2017a. Evidence for two types of nrDNA existing in Chinese medicinal fungus *Ophiocordyceps sinensis*. *Aims Genetics* 4:192–201.
- Chen, C.-Y., C.-H. Lin, Y.-H. Liao, T.-C. Hung, C.-W. Hou, C.-C. Chen, and L.-L. Cheng. 2013a. *Rhodiola Crenulata* And *Cordyceps Sinensis* Based Supplementation Enhance The Aerobic Exercise Performance After 2-week Altitude Training. *Medicine and Science in Sports and Exercise* 45:566–566.

- Chen, C.-Y., C.-W. Hou, J. R. Bernard, C.-C. Chen, T.-C. Hung, L.-L. Cheng, Y.-H. Liao, and C.-H. Kuo. 2014. *Rhodiola crenulata*- and *Cordyceps sinensis*-Based Supplement Boosts Aerobic Exercise Performance after Short-Term High Altitude Training. *High Altitude Medicine & Biology* 15:371–379.
- Chen, D. M. 1985. The effect of natural *Cordyceps sinensis* and its cultured mycelia on murine immuno-organs and function of the mononuclear macrophage system. *Zhong xi yi jie he za zhi = Chinese journal of modern developments in traditional medicine / Zhongguo Zhong xi yi jie he yan jiu hui (chou), Zhong yi yan jiu yuan, zhu ban* 5:42–44, 5.
- Chen, D. M. 1987. Platelet hemopoiesis and ultrastructure observations in mice treated with natural *Cordyceps sinensis* and its cultured mycelia. *Zhong yao tong bao (Beijing, China : 1981)* 12:47–49.
- Chen, G., G. Chen, G. C. Sun Tsieh, and J. M. Henshall. 1991. Effects of *cordyceps sinensis* on murine T lymphocyte subsets. *Chinese Medical Journal* 104:4–8.
- Chen, J. P., W. Y. Zhang, T. T. Lu, J. Li, Y. Zheng, and L. D. Kong. 2006. Morphological and genetic characterization of a cultivated *Cordyceps sinensis* fungus and its polysaccharide component possessing antioxidant property in H22 tumor-bearing mice. *Life Sciences* 78:2742–2748.
- Chen, J., S. Lee, Y. Cao, Y. Peng, D. Winkler, and D. Yang. 2010b. Ethnomycological Use of Medicinal Chinese Caterpillar Fungus, *Ophiocordyceps sinensis* (Berk.) G. H. Sung et al. (Ascomycetes) in Northern Yunnan Province, SW China. *International Journal of Medicinal Mushrooms* 12:427–434.
- Chen, J.-L., Y.-C. Chen, S.-H. Yang, Y.-F. Ko, and S.-Y. Chen. 2009b. Immunological alterations in lupus-prone autoimmune (NZB/NZW) F1 mice by mycelia Chinese medicinal fungus *Cordyceps sinensis*-induced redistributions of peripheral mononuclear T lymphocytes. *Clinical and Experimental Medicine* 9:277–284.
- Chen, L., Y. Liu, Q. Guo, Q. Zheng, and W. Zhang. 2018a. Metabolomic comparison between wild *Ophiocordyceps sinensis* and artificial cultured *Cordyceps militaris*. *Biomedical Chromatography* 32:e4279.
- Chen, L., Y. Wu, Y. Guan, C. Jin, W. Zhu, and M. Yang. 2018b. Analysis of the High-Performance Liquid Chromatography Fingerprints and Quantitative Analysis of Multicomponents by Single Marker of Products of Fermented *Cordyceps sinensis*. *Journal of Analytical Methods in Chemistry*:5943914.
- Chen, P. X., S. Wang, S. Nie, and M. Marcone. 2013b. Properties of *Cordyceps Sinensis*: A review. *Journal of Functional Foods* 5:550–569.
- Chen, S. J., D. H. Yin, L. Li, X. L. Zhou, and X. Za. 2001a. Studies on anamorph of *Cordyceps sinensis* (Berk) from Naqu Tibet. *Zhongguo Zhong yao za zhi = Zhongguo zhongyao zazhi = China journal of Chinese materia medica* 26:453–454.
- Chen, S., D. Yin, L. Li, X. Zha, J. Shuen, and C. Zhama. 2000. Resources and distribution of *Cordyceps sinensis* in Naqu Tibet. *Zhong yao cai = Zhongyao cai = Journal of Chinese medicinal materials* 23:673–675.
- Chen, S., J. Wang, Q. Fang, N. Dong, and S. Nie. 2019. Polysaccharide from natural *Cordyceps sinensis* ameliorated intestinal injury and enhanced antioxidant activity in immunosuppressed mice. *Food Hydrocolloids* 89:661–667.
- Chen, S., Z. Li, R. Krochmal, M. Abrazado, W. Kim, and C. B. Cooper. 2010c. Effect of Cs-4 (R) (*Cordyceps sinensis*) on Exercise Performance in Healthy Older Subjects: A Double-Blind, Placebo-Controlled Trial. *Journal of Alternative and Complementary Medicine* 16:585–590.
- Chen, S.-D., S.-Y. Lin, Y.-S. Lai, and Y.-H. Cheng. 2008. Effect of *Cordyceps sinensis* adlay fermentative products on antioxidant activities and macrophage functions. *Taiwanese Journal of Agricultural Chemistry and Food Science* 46:223–233.
- Chen, S.-J., D.-H. Yin, G.-Y. Zhong, and T.-F. Huang. 2002. Study on the biology of adults parasite of *cordyceps sinensis*, *Hepialus biruensis*. *Zhongguo Zhongyao Zazhi* 27:895.
- Chen, W., F. Yuan, K. Wang, D. Song, and W. Zhang. 2012. Modulatory effects of the acid polysaccharide fraction from one of anamorph of *Cordyceps sinensis* on Ana-1 cells. *Journal of Ethnopharmacology* 142:739–745.

- Chen, W., W. Zhang, W. Shen, and K. Wang. 2010d. Effects of the acid polysaccharide fraction isolated from a cultivated *Cordyceps sinensis* on macrophages in vitro. *Cellular Immunology* 262:69–74.
- Chen, X., J. Wu, and X. Gui. 2016. Production and characterization of exopolysaccharides in mycelial culture of *Cordyceps sinensis* fungus Cs-HK1 with different carbon sources. *Chinese Journal of Chemical Engineering* 24:158–162.
- Chen, Y. C., Y. L. Huang, and B. M. Huang. 2003. *Cordyceps sinensis* activates PKA and PKC signal pathways to stimulate steroidogenesis in MA-10 mouse Leydig tumor cells. *Biology of Reproduction* 68:360–361.
- Chen, Y. C., Y. L. Huang, and B. M. Huang. 2005. *Cordyceps sinensis* mycelium activates PKA and PKC signal pathways to stimulate steroidogenesis in MA-10 mouse Leydig tumor cells. *International Journal of Biochemistry & Cell Biology* 37:214–223.
- Chen, Y. P. 1983. Studies on immunological actions of *Cordyceps sinensis*. I. Effect on cellular immunity. *Zhong yao tong bao* (Beijing, China : 1981) 8:33–35.
- Chen, Y. Q., B. Hu, F. Xu, W. M. Zhang, H. Zhou, and L. H. Qu. 2004. Genetic variation of *Cordyceps sinensis*, a fruit-body-producing entomopathogenic species from different geographical regions in China. *Fems Microbiology Letters* 230:153–158.
- Chen, Y. Q., N. Wang, L. H. Qu, T. H. Li, and W. M. Zhang. 2001b. Determination of the anamorph of *Cordyceps sinensis* inferred from the analysis of the ribosomal DNA internal transcribed spacers and 5.8S rDNA. *Biochemical Systematics and Ecology* 29:597–607.
- Chen, Y., H. Guo, Z. Du, X.-Z. Liu, Y. Che, and X. Ye. 2009. Ecology-based screen identifies new metabolites from a *Cordyceps*-colonizing fungus as cancer cell proliferation inhibitors and apoptosis inducers. *Cell Proliferation* 42:838–847.
- Chen, Y., L. Fu, M. Han, M. Jin, J. Wu, L. Tan, Z. Chen, and X. Zhang. 2018c. The Prophylactic and Therapeutic Effects of Fermented *Cordyceps sinensis* Powder, Cs-C-Q80, on Subcortical Ischemic Vascular Dementia in Mice. *Evidence-Based Complementary and Alternative Medicine*:4362715.
- Chen, Y., W. Wang, Y. Yang, B. Su, Y. Zhang, L. Xiong, Z. He, C. Shu, and D. Yang. 1997a. Genetic divergence of *Cordyceps sinensis* as estimated by random amplified polymorphic DNA analysis. *Acta Genetica Sinica* 24:415–416.
- Chen, Y., Y.-P. Zhang, Y. Yang, and D. Yang. 1999. Genetic diversity and taxonomic implication of *Cordyceps sinensis* as revealed by RAPD markers. *Biochemical Genetics* 37:201–213.
- Chen, Y.-C., and B.-M. Huang. 2010. Regulatory Mechanisms of *Cordyceps sinensis* on Steroidogenesis in MA-10 Mouse Leydig Tumor Cells. *Bioscience Biotechnology and Biochemistry* 74:1855–1859.
- Chen, Y.-C., Y.-H. Chen, B.-S. Pan, M.-M. Chang, and B.-M. Huang. 2017b. Functional study of *Cordyceps sinensis* and cordycepin in male reproduction: A review. *Journal of Food and Drug Analysis* 25:197–205.
- Chen, Y.-J., M.-S. Shiao, S.-S. Lee, and S.-Y. Wang. 1997b. Effect of *Cordyceps sinensis* on the proliferation and differentiation of human leukemic U937 cells. *Life Sciences* 60:2349–2359.
- Cheng, Q. 1992. Effect of *cordyceps sinensis* on cellular immunity in rats with chronic renal insufficiency. *Zhonghua yi xue za zhi* 72:27–29, 63.
- Cheng, R.-L., Y.-X. Yu, L.-X. Liu, C.-X. Zhang, and C.-X. Fang. 2016. A draft genome of the ghost moth, *Thitarodes* (*Hepialus*) sp., a medicinal caterpillar fungus. *Insect Science* 23:326–329.
- Cheng, W., X. Zhang, Q. Song, W. Lu, T. Wu, Q. Zhang, and C. Li. 2017. Determination and comparative analysis of 13 nucleosides and nucleobases in natural fruiting body of *Ophiocordyceps sinensis* and its substitutes. *Mycology* 8:318–326.
- Cheng, W.-Y., X.-Q. Wei, K.-C. Siu, A.-X. Song, and J.-Y. Wu. 2018. Cosmetic and Skincare Benefits of Cultivated Mycelia from the Chinese Caterpillar Mushroom, *Ophiocordyceps sinensis* (Ascomycetes). *International Journal of Medicinal Mushrooms* 20:623–636.

- Cheng, Y.-J., S.-M. Cheng, Y.-H. Teng, W.-C. Shyu, H.-L. Chen, and S.-D. Lee. 2014a. Cordyceps sinensis Prevents Apoptosis in Mouse Liver with D-Galactosamine/Lipopolysaccharide-Induced Fulminant Hepatic Failure. *American Journal of Chinese Medicine* 42:427–441.
- Cheng, Y.-J., W.-C. Shyu, Y.-H. Teng, Y.-H. Lan, and S.-D. Lee. 2014b. Antagonistic Interaction Between Cordyceps sinensis and Exercise on Protection in Fulminant Hepatic Failure. *American Journal of Chinese Medicine* 42:1199–1213.
- Cheong, K.-L., L.-Y. Wang, D.-T. Wu, D.-J. Hu, J. Zhao, and S.-P. Li. 2016b. Microwave-Assisted Extraction, Chemical Structures, and Chain Conformation of Polysaccharides from a Novel Cordyceps Sinensis Fungus UM01. *Journal of Food Science* 81:C2167–C2174.
- Cheong, K.-L., L.-Z. Meng, X.-Q. Chen, L.-Y. Wang, D.-T. Wu, J. Zhao, and S.-P. Li. 2016a. Structural elucidation, chain conformation and immuno-modulatory activity of glucogalactomannan from cultured Cordyceps sinensis fungus UM01. *Journal of Functional Foods* 25:174–185.
- Cheung, J. K. H., J. Li, A. W. H. Cheung, Y. Zhu, K. Y. Z. Zheng, C. W. C. Bi, R. Duan, R. C. Y. Choi, D. T. W. Lau, T. T. X. Dong, B. W. C. Lau, and K. W. K. Tsim. 2009. Cordysinocan, a polysaccharide isolated from cultured Cordyceps, activates immune responses in cultured T-lymphocytes and macrophages: signaling cascade and induction of cytokines. *Journal of Ethnopharmacology* 124:61–68.
- Chiang, C.-S., W.-L. Chuang, H.-L. Huang, W.-C. Liu, and J.-H. Hong. 2006. Cordyceps sinensis enhances the anti-tumor effects of taxol by promoting the recovery of taxol-caused leukopenia and immunosuppression. *Cancer Research* 66.
- Chiang, H. M., Y. C. Hou, S. Y. Tsai, S. Y. Yang, P. D. L. Chao, S. L. Hsiu, and K. C. Wen. 2005. Marked decrease of cyclosporin absorption caused by coadministration of Cordyceps sinensis in rats. *Journal of Food and Drug Analysis* 13:239–243.
- Childs, G., and N. Choedup. 2014. Indigenous management strategies and socioeconomic impacts of Yartsa gunbu (*Ophiocordyceps sinensis*) harvesting in Nubri and Tsum, Nepal. *Himalaya* 34:8–22.
- Chiou, W.-F., P.-C. Chang, C.-J. Chou, and C.-F. Chen. 2000. Protein constituent contributes to the hypotensive and vasorelaxant activities of cordyceps sinensis. *Life Sciences* 66:1369–1376.
- Chiou, Y.-L., and C.-Y. Lin. 2012. The Extract of Cordyceps sinensis Inhibited Airway Inflammation by Blocking NF-kappa B Activity. *Inflammation* 35:985–993.
- Chiu, J.-H., C.-H. Ju, L.-H. Wu, W.-Y. Lui, C.-W. Wu, M.-S. Shiao, and C.-Y. Hong. 1998. Cordyceps sinensis Increases the Expression of Major Histocompatibility Complex Class II Antigens on Human Hepatoma Cell Line HA22T/VGH Cells. *The American Journal of Chinese Medicine* 26:159–170.
- Choi, G.-S., Y. S. Shin, J. E. Kim, Y.-M. Ye, and H.-S. Park. 2010a. Five cases of food allergy to vegetable worm (*Cordyceps sinensis*) showing cross-reactivity with silkworm pupae. *Allergy* 65:1196–1197.
- Choi, J. W., K. S. Ra, S. Y. Kim, T. J. Yoon, K.-W. Yu, K.-S. Shin, S. P. Lee, and H. J. Suh. 2010b. Enhancement of anti-complementary and radical scavenging activities in the submerged culture of Cordyceps sinensis by addition of citrus peel. *Bioresource Technology* 101:6028–6034.
- Chutvirasakul, B., W. Jongmeesuk, P. Tirasomboonsiri, N. Sansandee, and S. Tadtong. 2017. Stability indicating method to determine bioactive nucleosides in crude drugs, extracts, and products from cordyceps sinensis and cordyceps militaris. *Thai Journal of Pharmaceutical Sciences* 41:52–60.
- Colson, S. N., F. B. Wyatt, D. L. Johnston, L. D. Autrey, Y. L. FitzGerald, and C. P. Earnest. 2005. Cordyceps sinensis- and Rhodiola rosea-based supplementation in male cyclists and its effect on muscle tissue oxygen saturation. *Journal of Strength and Conditioning Research* 19:358–363.
- Cunningham, A. B. 2014. *Applied Ethnobotany : People, Wild Plant Use and Conservation*. Routledge.

- Dai, D. L., W. Sheng, and X. Q. Guan. 2005. Effect of *Cordyceps sinensis* on rats with nonalcoholic fatty livers. *Zhonghua gan zang bing za zhi = Zhonghua ganzangbing zazhi = Chinese journal of hepatology* 13:464–465.
- Dai, D.-L., W. Shen, H.-F. Yu, X.-Q. Guan, and Y.-F. Yi. 2006. Effect of *cordyceps sinensis* on uncoupling protein 2 in experimental rats with nonalcoholic fatty liver. *Journal of Health Science* 52:390–396.
- Dai, G., T. Bao, C. Xu, R. Cooper, and J. S. Zhu. 2001. CordyMax Cs-4 improves steady-state bioenergy status in mouse liver. *Journal of Alternative and Complementary Medicine (New York, N.Y.)* 7:231–240.
- Dai, Y., C. Wu, Y. Wang, Y. Wang, L. Huang, X. Dang, X. Mo, P. Zeng, Z. Yang, D. Yang, C. Zhang, P. Lemetti, and H. Yu. 2019. Phylogeographic structures of the host insects of *Ophiocordyceps sinensis*. *Zoology* 134:27–37.
- Dai, Z., and H. Dai. 2017. Medicinal Herb *Cordyceps Sinensis* Promotes Long-Term Allograft Survival by Tipping the Balance Between CD4+FoxP3+Tregs and CD8+Tcm Cells. *American Journal of Transplantation* 17:456–456.
- Damodar, G. 2019. Resource Assessment and Marketing of Caterpillar Fungus (*Ophiocordyceps sinensis*) in the Buffer Zone of Makalu Barun National Park, Nepal. *Journal of Natural & Ayurvedic Medicine* 3:194.
- Deng, B., Z. P. Wang, W. J. Tao, W. F. Li, C. Wang, M. Q. Wang, S. S. Ye, Y. J. Du, X. X. Wu, and D. Wu. 2015. Effects of polysaccharides from mycelia of *Cordyceps sinensis* on growth performance, immunity and antioxidant indicators of the white shrimp *Litopenaeus vannamei*. *Aquaculture Nutrition* 21:173–179.
- Devkota, S. 2006. Yarsagumba *Cordyceps sinensis* (Berk.) Sacc.; Traditional Utilization in Dolpa District, Western Nepal. *Our Nature* 4:48–52.
- Devkota, S. 2008. Distribution and Status of Highland Mushrooms: A Study from Dolpa, Nepal. *Journal of Natural History Museum* 23:51–59.
- Devkota, S. 2010. *Ophicordyceps sinensis* (Yarsagumba) from Nepal Himalaya: status, threats and management strategies. Pages 91–108 *Cordyceps Resources and Environment*. Grassland Supervision Center by the Ministry of Agriculture, People's Republic of China.
- Dhar, U., R. S. Rawal, and J. Upreti. 2000. Setting priorities for conservation of medicinal plants — a case study in the Indian Himalaya. *Biological Conservation* 95:57–65.
- Dhar, U., S. Manjkhola, M. Joshi, A. Bhatt, A. K. Bisht, and M. Joshi. 2002. Current status and future strategy for development of medicinal plants sector in Uttaranchal, India. *Current Science* 83:956–964.
- Di, C., Y. JianPing, X. ShiPing, Z. XiaoGang, Z. Yan, X. XiaoMing, Z. ZhiWen, Z. GuRen, and W. JiangHai. 2009. Stable carbon isotope evidence for tracing the diet of the host *Hepialus* larva of *Cordyceps sinensis* in the Tibetan Plateau. *Science in China Series D-Earth Sciences* 52:655–659.
- Ding, C. G., P. X. Tian, and Z. K. Jin. 2009. Clinical application and exploration on mechanism of action of *Cordyceps sinensis* mycelia preparation for renal transplantation recipients. *Zhongguo Zhong xi yi jie he za zhi Zhongguo Zhongxiyi jiehe zazhi = Chinese journal of integrated traditional and Western medicine / Zhongguo Zhong xi yi jie he xue hui, Zhongguo Zhong yi yan jiu yuan zhu ban* 29:975–978.
- Ding, C., P.-X. Tian, W. Xue, X. Ding, H. Yan, X. Pan, X. Feng, H. Xiang, J. Hou, and X. Tian. 2011. Efficacy of *Cordyceps sinensis* in long term treatment of renal transplant patients. *Frontiers in Bioscience - Elite 3 E*:301–307.
- Dong, C. H., and Y. J. Yao. 2005. Nutritional requirements of mycelial growth of *Cordyceps sinensis* in submerged culture. *Journal of Applied Microbiology* 99:483–492.
- Dong, C., and Y. Yao. 2012. Isolation, characterization of melanin derived from *Ophiocordyceps sinensis*, an entomogenous fungus endemic to the Tibetan Plateau. *Journal of Bioscience and Bioengineering* 113:474–479.

- Dong, C.-H., and Y. J. Yao. 2008. In vitro evaluation of antioxidant activities of aqueous extracts from natural and cultured mycelia of *Cordyceps sinensis*. *Lwt-Food Science and Technology* 41:669–677.
- Dong, C.-H., and Y.-J. Yao. 2010. Comparison of Some Metabolites Among Cultured Mycelia of Medicinal Fungus, *Ophiocordyceps sinensis* (Ascomycetes) from Different Geographical Regions. *International Journal of Medicinal Mushrooms* 12:287–297.
- Dong, C.-H., and Y.-J. Yao. 2011. On the reliability of fungal materials used in studies on *Ophiocordyceps sinensis*. *Journal of Industrial Microbiology & Biotechnology* 38:1027–1035.
- Dong, C.-H., X.-Q. Xie, X.-L. Wang, Y. Zhan, and Y.-J. Yao. 2009. Application of Box-Behnken design in optimisation for polysaccharides extraction from cultured mycelium of *Cordyceps sinensis*. *Food and Bioproducts Processing* 87:139–144.
- Dong, K.-Z., S.-W. Fu, L. Sheng, Y.-J. Mi, and L. Su. 2014a. Effect of *cordyceps sinensis* mycelium on serum vasoactive intestinal peptide and substance P in mice with intestinal dysbacteriosis. *Medical Journal of Chinese People's Liberation Army* 39:873–876.
- Dong, K.-Z., Y.-S. Gao, X.-H. Wang, Y.-Q. Ma, and L. Su. 2016. Protective effect of mycelial polysaccharides from *cordyceps sinensis* on immunological liver injury in mice. *Medical Journal of Chinese People's Liberation Army* 41:284–288.
- Dong, Y., J. Yang, Y. Zhang, C. Zhao, Z. Wu, N. Tan, J. Lu, M. Bartlett, and J. Zhu. 2014b. *Cordyceps sinensis* Cs-5 improves memory and learning abilities in a dysmnesia model. *Faseb Journal* 28.
- Dong, Y.-Z., L.-J. Zhang, Z.-M. Wu, L. Gao, Y.-S. Yao, N.-Z. Tan, J.-Y. Wu, L. Ni, and J.-S. Zhu. 2014c. Altered Proteomic Polymorphisms in the Caterpillar Body and Stroma of Natural *Cordyceps sinensis* during Maturation. *Plos One* 9:e109083.
- dos Santos, L. F., R. Rubel, S. J. Ribeiro Bonatto, A. A. Yamaguchi, M. F. Torres, V. T. Soccol, A. L. Lopes da Silva, and C. R. Soccol. 2018. Effects of *Cordyceps sinensis* on macrophage function in high-fat diet fed rats and its anti-proliferative effects on IMR-32 human neuroblastoma cells. *Pakistan Journal of Pharmaceutical Sciences* 31:1–8.
- dos Santos, L. F., R. Rubel, S. J. Ribeiro Bonatto, A. L. Zanatta, J. Aikawa, A. A. Yamaguchi, M. F. Torres, V. T. Soccol, S. Habu, K. B. Prado, and C. R. Soccol. 2012. *Cordyceps Sinensis* Biomass Produced by Submerged Fermentation in High-Fat Diet Feed Rats Normalizes the Blood Lipid and the Low Testosterone Induced by Diet. *Excli Journal* 11:767–775.
- Dou, J.-F., and X.-G. Weng. 2006. Effects of zymoyic fungal powder of *cordyceps sinensis* on renal structure in diabetic rats. *Chinese Journal of Clinical Rehabilitation* 10:105–107.
- Du, C., J. Zhou, and J. Liu. 2017. Identification of Chinese medicinal fungus *Cordyceps sinensis* by depth-profiling mid-infrared photoacoustic spectroscopy. *Spectrochimica Acta Part a-Molecular and Biomolecular Spectroscopy* 173:489–494.
- Du, D. J. 1986. Antitumor activity of *Cordyceps sinensis* and cultured *Cordyceps* mycelia. *Zhong yao tong bao (Beijing, China : 1981)* 11:51–54.
- Du, F., S. Li, T. Wang, H.-Y. Zhang, Z.-H. Zong, Z.-X. Du, D.-T. Li, H.-Q. Wang, B. Liu, J.-N. Miao, and X.-H. Bian. 2015. *Cordyceps sinensis* attenuates renal fbrosis and suppresses BAG3 induction in obstructed rat kidney. *American Journal of Translational Research* 7:932–940.
- Duh, P.-D. 2007. Rebuttal on comparison of protective effects between cultured *Cordyceps militaris* and natural *Cordyceps sinensis* against oxidative damage - Response. *Journal of Agricultural and Food Chemistry* 55:7215–7216.
- Ebizuka, Y., K. Nishimura, M. Hoshino, and M. Shibuya. 2007. Composition and antioxidant activities of polysaccharides from mycelial culture of a medicinal fungus *Cordyceps sinensis* Cs-HK1. *Drugs of the Future* 32:19–20.
- El Ashry, F. E. Z. Z., M. F. Mahmoud, N. N. El Maraghy, and A. F. Ahmed. 2012. Effect of *Cordyceps sinensis* and taurine either alone or in combination on streptozotocin induced diabetes. *Food and Chemical Toxicology* 50:1159–1165.

- Esteban, C. I. 2007. *Cordyceps sinensis*, a fungi used in the Chinese traditional medicine [Cordyceps sinensis, un hongo usado en la medicina tradicional China]. *Revista Iberoamericana de Micología* 24:259–262.
- Fan, S., X. Huang, S. Wang, C. Li, Z. Zhang, M. Xie, and S. Nie. 2018a. Combinatorial usage of fungal polysaccharides from *Cordyceps sinensis* and *Ganoderma atrum* ameliorate drug-induced liver injury in mice. *Food and Chemical Toxicology* 119:66–72.
- Fan, S.-T., S.-P. Nie, X.-J. Huang, S. Wang, J.-L. Hu, J.-H. Xie, Q.-X. Nie, and M.-Y. Xie. 2018b. Protective properties of combined fungal polysaccharides from *Cordyceps sinensis* and *Ganoderma atrum* on colon immune dysfunction. *International Journal of Biological Macromolecules* 114:1049–1055.
- FAO. (n.d.). *State of the World's Forests 2014. Enhancing the Socioeconomic Benefits from Forests | Policy Support and Governance*. Food and Agriculture Organization of the United Nations.
- Feng, K., F.-Q. Yang, and S.-P. Li. 2008. *Rengongchongcao (Cultured Cordyceps sinensis)*. Pages 157–178 *Pharmacological Activity-Based Quality Control of Chinese Herbs*. Nova Science Publishers, Inc.
- Feng, K., L.-Y. Wang, D.-J. Liao, X.-P. Lu, D.-J. Hu, X. Liang, J. Zhao, Z.-Y. Mo, and S.-P. Li. 2017. Potential molecular mechanisms for fruiting body formation of *Cordyceps* illustrated in the case of *Cordyceps sinensis*. *Mycology* 8:231–258.
- Feng, K., S. Wang, D. J. Hu, F. Q. Yang, H. X. Wang, and S. P. Li. 2009. Random amplified polymorphic DNA (RAPD) analysis and the nucleosides assessment of fungal strains isolated from natural *Cordyceps sinensis*. *Journal of Pharmaceutical and Biomedical Analysis* 50:522–526.
- Feng, M. G., Q. G. Zhou, and G. H. Feng. 1987. Vasodilating effect of cultured *Cordyceps sinensis* (Berk) Sacc. mycelia in anesthetized dogs. *Zhong yao tong bao (Beijing, China : 1981)* 12:41–45, 60.
- Feng, X., J. Wang, Y. Zou, Z. Chu, and Z. Zhang. 2018. Determination of nucleosides contents in *Cordyceps sinensis* from different origins and its counterfeit products. *Pharmaceutical Care and Research* 18:304–307.
- Fraile, L., E. Crisci, L. Córdoba, M. A. Navarro, J. Osada, and M. Montoya. 2012. Immunomodulatory properties of beta-sitosterol in pig immune responses. *International Immunopharmacology* 13:316–321.
- Fu, T., and J. Lin. 2001. Effect of *Cordyceps sinensis* on inhibiting systemic lupus erythematosus in MRL 1pr/1pr mice (correction of rats). *Zhong yao cai = Zhongyaocai = Journal of Chinese medicinal materials* 24:658–659.
- Fung, S. Y., P. C. H. Cheong, N. H. Tan, S. T. Ng, and C. S. Tan. 2018. Nutrient and Chemical Analysis of Fruiting Bodies of a Cultivar of the Chinese Caterpillar Mushroom, *Ophiocordyceps sinensis* (Ascomycetes). *International Journal of Medicinal Mushrooms* 20:459–469.
- Fung, S. Y., S. S. Lee, N. H. Tan, and J. Pailoor. 2017. Safety assessment of cultivated fruiting body of *Ophiocordyceps sinensis* evaluated through subacute toxicity in rats. *Journal of Ethnopharmacology* 206:236–244.
- Gabay, O., C. Sanchez, C. Salvat, F. Chevy, M. Breton, G. Nourissat, C. Wolf, C. Jacques, and F. Berenbaum. 2010. Stigmasterol: a phytosterol with potential anti-osteoarthritic properties. *Osteoarthritis and Cartilage* 18:106–116.
- Gamage, S., and S. Ohga. 2018. Effects of different electric field on mycelial growth of isolated strain of wild *Ophiocordyceps sinensis*. *Journal of the Faculty of Agriculture Kyushu University* 63:223–229.
- Gao, B., J. Yang, J. Huang, X. Cui, S. Chen, H. Den, and G. Xiang. 2010. *Cordyceps sinensis* extract suppresses hypoxia-induced proliferation of rat pulmonary artery smooth muscle cells. *Saudi Medical Journal* 31:974–979.
- Gao, L., X. H. Li, J. Q. Zhao, J. H. Lu, and J. S. Zhu. 2011. Detection of multiple *Ophiocordyceps sinensis* mutants in premature stroma of *Cordyceps sinensis* by MassARRAY SNP MALDI-TOF mass spectrum genotyping. *Beijing da xue xue bao. Yi xue ban = Journal of Peking University. Health sciences* 43:259–266.

- Gao, L., X. H. Li, J. Q. Zhao, J. H. Lu, J. G. Zhao, and J. S. Zhu. 2012. Maturation of *Cordyceps sinensis* associates with alterations of fungal expressions of multiple *Ophiocordyceps sinensis* mutants in stroma of *Cordyceps sinensis*. *Beijing da xue xue bao. Yi xue ban = Journal of Peking University. Health sciences* 44:454–463.
- Gao, L., Y. Zhang, C. Zhao, J. Yang, Y. Zhou, N. Tan, and J.-S. Zhu. 2008. A fermented *Cordyceps sinensis* product Cordymax-6 improves sexual functions via PDE-5 Inhibition and central pathways. *Faseb Journal* 22.
- Gao, Q., G. Wu, and D. He. 2000. Effect of *Cordyceps sinensis* on the Th1/Th2 cytokines in patients with Condyloma Acuminatum. *Zhong yao cai = Zhongyao cai = Journal of Chinese medicinal materials* 23:402–404.
- Garbyal, S. S. 2001. Occurrence of *Cordyceps sinensis* in upper Himalaya, Dharchula sub-division, Pithoragarh district, Uttaranchal, India. *Indian Forester* 127:1229–1231.
- Ghatnur, S. M., G. Parvatam, and M. Balaraman. 2015. Culture Conditions for Production of Biomass, Adenosine, and Cordycepin from *Cordyceps sinensis* CS1197: Optimization by Desirability Function Method. *Pharmacognosy Magazine* 11:S448–S456.
- Gong, F., Y. Peng, H. Cui, Y. Liang, A. K. M. Leung, and F.-T. Chau. 1999a. Hyphenated chromatography applied to multicomponent determination of *Cordyceps sinensis*. *Yaoxue Xuebao* 34:214–217.
- Gong, F., Y.-G. Peng, H. Cui, Y.-Z. Liang, A. K. M. Leung, and F.-T. Chau. 1999b. HELP Applied to Traditional Chinese Medicine Analysis - Determination of Components of *Cordyceps Sinensis*. *Kao Teng Hsueh Hsiao Hua Heush Hsueh Pao/ Chemical Journal of Chinese Universities* 20:203.
- Gong, H. Y., K. Q. Wang, and S. G. Tang. 2000. Effects of *cordyceps sinensis* on T lymphocyte subsets and hepatofibrosis in patients with chronic hepatitis B. *Hunan yi ke da xue xue bao = Hunan yike daxue xuebao = Bulletin of Hunan Medical University* 25:248–250.
- Gong, M. F., J. P. Xu, Z. Y. Chu, and J. Luan. 2011. Effect of *Cordyceps sinensis* sporocarp on learning-memory in mice. *Zhong yao cai = Zhongyao cai = Journal of Chinese medicinal materials* 34:1403–1405.
- Goraya, G.S. and D. K. Vend. 2017. Medicinal Plants in India: An assessment of their demand and supply. National Medicinal Plants Board. Ministry of AYUSH, Govt. of India. New Delhi & ICFRE, Dehradun. 395 pp.
- Gruschke, A. 2011. Nomads and their market relations in Eastern Tibet's Yushu region: The impact of caterpillar fungus. Pages 211–229 *Economic Spaces of Pastoral Production and Commodity Systems: Markets and Livelihoods*.
- Gu, G.-S., J.-A. Ren, G.-W. Li, Y.-J. Yuan, N. Li, and J.-S. Li. 2015a. *Cordyceps sinensis* preserves intestinal mucosal barrier and may be an adjunct therapy in endotoxin-induced sepsis rat model: a pilot study. *International Journal of Clinical and Experimental Medicine* 8:7333–7341.
- Gu, Y., H. Wang, S. Wang, H. Gao, and M. Qiu. 2015b. Effects of *Cordyceps sinensis* on the Expressions of NF-kappa B and TGF-beta 1 in Myocardium of Diabetic Rats. *Evidence-Based Complementary and Alternative Medicine*:369631.
- Guan, J., F.-Q. Yang, and S.-P. Li. 2010. Evaluation of carbohydrates in natural and cultured *Cordyceps* by pressurized liquid extraction and gas chromatography coupled with mass spectrometry. *Molecules (Basel, Switzerland)* 15:4227–4241.
- Guo, D.-L., L. Qiu, D. Feng, X. He, X.-H. Li, Z.-X. Cao, Y.-C. Gu, L. Mei, F. Deng, and Y. Deng. 2018b. Three new -pyrone derivatives induced by chemical epigenetic manipulation of *Penicillium herquei*, an endophytic fungus isolated from *Cordyceps sinensis*. *Natural Product Research*.
- Guo, D.-L., X.-H. Li, D. Feng, M.-Y. Jin, Y.-M. Cao, Z.-X. Cao, Y.-C. Gu, Z. Geng, F. Deng, and Y. Deng. 2018a. Novel polyketides produced by the endophytic fungus *Aspergillus fumigatus* from *cordyceps sinensis*. *Molecules* 23:1709.

- Guo, F. Q., A. Li, L. F. Huang, Y. Z. Liang, and B. M. Chen. 2006. Identification and determination of nucleosides in *Cordyceps sinensis* and its substitutes by high performance liquid chromatography with mass spectrometric detection. *Journal of Pharmaceutical and Biomedical Analysis* 40:623–630.
- Guo, J., C. Li, J. Wang, Y. Liu, and J. Zhang. 2011. Vanadium-Enriched *Cordyceps sinensis*, a Contemporary Treatment Approach to Both Diabetes and Depression in Rats. *Evidence-Based Complementary and Alternative Medicine*:1–6.
- Guo, J., F. Jiang, J. Yi, X. Liu, and G. Zhang. 2016. Transcriptome characterization and gene expression analysis related to sexual dimorphism in the ghost moth, *Thitarodes pui*, a host of *Ophiocordyceps sinensis*. *Gene* 588:134–140.
- Guo, J.-Y., C.-C. Han, and Y.-M. Liu. 2010. A Contemporary Treatment Approach to Both Diabetes and Depression by *Cordyceps sinensis*, Rich in Vanadium. *Evidence-Based Complementary and Alternative Medicine* 7:387–389.
- Guo, L.-X., G.-W. Zhang, J.-T. Wang, Y.-P. Zhong, and Z.-G. Huang. 2018c. Determination of Arsenic Species in *Ophiocordyceps sinensis* from Major Habitats in China by HPLC-ICP-MS and the Edible Hazard Assessment. *Molecules* 23:1012.
- Guo, L.-X., X.-M. Xu, C.-F. Wu, L. Lin, S.-C. Zou, T.-G. Luan, J.-P. Yuan, and J.-H. Wang. 2012a. Fatty acid composition of lipids in wild *Cordyceps sinensis* from major habitats in China. *Biomedicine and Preventive Nutrition* 2:42–50.
- Guo, L.-X., X.-M. Xu, F.-R. Liang, J.-P. Yuan, J. Peng, C.-F. Wu, and J.-H. Wang. 2015. Morphological Observations and Fatty Acid Composition of Indoor-Cultivated *Cordyceps sinensis* at a High-Altitude Laboratory on Sejila Mountain, Tibet. *Plos One* 10:e0126095.
- Guo, L.-X., X.-M. Xu, Y.-H. Hong, Y. Li, and J.-H. Wang. 2017b. Stable Carbon Isotope Composition of the Lipids in Natural *Ophiocordyceps sinensis* from Major Habitats in China and Its Substitutes. *Molecules* 22:1567.
- Guo, L.-X., Y.-H. Hong, Q.-Z. Zhou, Q. Zhu, X.-M. Xu, and J.-H. Wang. 2017a. Fungus-larva relation in the formation of *Cordyceps sinensis* as revealed by stable carbon isotope analysis. *Scientific Reports* 7:7789.
- Guo, M., Y. Gao, Y. Zheng, P. Wang, F. Xia, and X. Zhou. 2017c. Screening of liquid fermentation media of an endophytic fungus NS2-B1 isolated from *Ophiocordyceps sinensis*. *Chinese Journal of Applied and Environmental Biology* 23:939–944.
- Guo, M.-Y., Y. Liu, Y.-H. Gao, T. Jin, H.-B. Zhang, and X.-W. Zhou. 2017d. Identification and Bioactive Potential of Endogenetic Fungi Isolated from Medicinal Caterpillar Fungus *Ophiocordyceps sinensis* from Tibetan Plateau. *International Journal of Agriculture and Biology* 19:307–313.
- Guo, S.-M., F. Zhong, Q. Zhou, Y. Lu, X. Hao, W.-M. Wang, and N. Chen. 2012b. Renal protective effect of *Cordyceps sinensis* on 5/6 nephrectomy-induced renal fibrosis in rats. *Journal of Shanghai Jiaotong University (Medical Science)* 32:1-8+31.
- Guo, Y. 1986. Medicinal chemistry, pharmacology and clinical applications of fermented mycelia of *Cordyceps sinensis* and JinShuBao capsule. *Journal of Modern Diagnostics Therapeutics* 1:60–65.
- Guo, Y. L., and J. Zhu. 2005. Existence of multiple fungi in *Cordyceps sinensis*: Simultaneous isolation of *Hirsutella sinensis* and *Paecilomyces hepiali*. *Faseb Journal* 19:A1033–A1033.
- Guo, Y. W. 1985. Preliminary study of *Cordyceps barnesii*—comparison of the chemical constituents of *Cordyceps barnesii* and *Cordyceps sinensis*. *Zhong yao tong bao (Beijing, China : 1981)* 10:33–35.
- Hamburger, M. 2007. Comment on comparison of protective effects between cultured *Cordyceps militaris* and natural *Cordyceps sinensis* against oxidative damage. *Journal of Agricultural and Food Chemistry* 55:7213–7214.
- Hammerschmidt, D. E. 2003a. Fruiting body of *Cordyceps sinensis*. *Journal of Laboratory and Clinical Medicine* 141:84.
- Hammerschmidt, D. E. 2003b. About the cover illustration: Fruiting body of *Cordyceps sinensis*. *Journal of Laboratory and Clinical Medicine* 141:84–86.

- Hao, J.-J., Z. Cheng, H.-H. Liang, X.-L. Yang, S. Li, T.-S. Zhou, W.-J. Zhang, and J.-K. Chen. 2009. Genetic differentiation and distributing pattern of *Cordyceps sinensis* in China revealed by rDNA ITS sequences. *Chinese Traditional and Herbal Drugs* 40:112–116.
- Hao, L., M. S. Pan, and Y. Zheng. 2012a. Effects of *Cordyceps sinensis* and *tipterygium wilfordii* polyglycosidium on the podocytes in rats with diabetic nephropathy. *Zhongguo Zhong xi yi jie he za zhi Zhongguo Zhongxiyi jiehe zazhi = Chinese journal of integrated traditional and Western medicine / Zhongguo Zhong xi yi jie he xue hui, Zhongguo Zhong yi yan jiu yuan zhu ban* 32:261–265.
- Hao, L., M.-S. Pan, Y. Zheng, and R.-F. Wang. 2014. Effect of *Cordyceps sinensis* and *Tripterygium wilfordii* polyglycosidium on podocytes in rats with diabetic nephropathy. *Experimental and Therapeutic Medicine* 7:1465–1470.
- Hao, L., Q. Wang, M. Kobayashi, M. Tamesada, and H.-J. Wang. 2008. Effectiveness of *Cordyceps Sinensis* alone or in combination with chemotherapy in patients with non-small cell lung cancer. *Biotherapy* 22:345–349.
- Hao, T., J. J. Li, Z. Y. Du, C. M. Duan, Y. M. Wang, C. Y. Wang, J. P. Song, L. J. Wang, Y. H. Li, and Y. Wang. 2012b. [*Cordyceps sinensis* enhances lymphocyte proliferation and CD markers expression in simulated microgravity environment]. *Zhongguo shi yan xue ye xue za zhi / Zhongguo bing li sheng li xue hui = Journal of experimental hematology / Chinese Association of Pathophysiology* 20:1212–1215.
- Hatton, M. N., K. Desai, D. Le, and A. Vu. 2018. Excessive postextraction bleeding associated with *Cordyceps sinensis*: a case report and review of select traditional medicines used by Vietnamese people living in the United States. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology* 126:494–500.
- He, J. 2018. Harvest and trade of caterpillar mushroom (*Ophiocordyceps sinensis*) and the implications for sustainable use in the Tibet Region of Southwest China. *Journal of Ethnopharmacology* 221:86–90.
- He, L., B.-R. Ma, J.-S. Zhang, Y.-R. Jin, H.-S. Gu, G.-H. Yuan, J.-L. Li, M.-Y. Liang, and D. Chen. 1993. Chemical study of *Cordyceps militaris* and *C. sinensis*. *Chinese Pharmaceutical Journal* 28:279–280.
- He, X.-G., C. Johnson, and J. Seleen. 2006. Simultaneous separation and identification of nucleosides in cultured *Cordyceps sinensis* (Berk.) Sacc. (Ascomycetes) mycelia by using the HPLC-DAD-MS technique. *International Journal of Medicinal Mushrooms* 8:343–349.
- Holliday, J., and M. P. Cleaver. 2008. Medicinal value of the Caterpillar fungi species of the genus *Cordyceps* (fr.) link (Ascomycetes). a review. *International Journal of Medicinal Mushrooms* 10.
- Hong, T., M. Zhang, and J. Fan. 2015. *Cordyceps sinensis* (a traditional Chinese medicine) for kidney transplant recipients. *Cochrane Database of Systematic Reviews*:CD009698.
- Hopping, K. A., S. M. Chignell, and E. F. Lambin. 2018. The demise of caterpillar fungus in the Himalayan region due to climate change and overharvesting. *Proceedings of the National Academy of Sciences of the United States of America* 115:11489–11494.
- Hou, F.-X., J. Cao, S.-S. Wang, X. Wang, Y. Yuan, C. Peng, D.-G. Wan, and J.-L. Guo. 2017. Development and evaluation of a rapid PCR detection kit for *Ophiocordyceps sinensis*. *Zhongguo Zhongyao Zazhi* 42:1125–1129.
- Hou, X.-R., L.-J. Luan, and Y.-Y. Cheng. 2005. Quantitative analysis of the nucleosides in *Cordyceps sinensis* with capillary zone electrophoresis. *Zhongguo Zhongyao Zazhi* 30:447–449.
- Hsiao, K. Y., M. H. Wu, B. M. Huang, P. C. Chuang, and S. J. Tsai. 2002. Regulations of steroidogenic enzymes and ovarian steroids in human granulosa-lutein cells by *Cordyceps sinensis*. *Biology of Reproduction* 66:287–287.
- Hsieh, C. Y., M. J. Tsai, T. H. Hsu, D. M. Chang, and C. T. Lo. 2005. Medium optimization for polysaccharide production of *Cordyceps sinensis*. *Applied Biochemistry and Biotechnology* 120:145–157.

- Hsu, C. C., S. J. Tsai, Y. L. Huang, and B. M. Huang. 2002a. The mechanism of *Cordyceps sinensis* on steroidogenesis in normal mouse Leydig cells. *Biology of Reproduction* 66:142–142.
- Hsu, C. C., S. J. Tsai, Y. L. Huang, and B. M. Huang. 2003b. Regulatory mechanism of *Cordyceps sinensis* mycelium on mouse Leydig cell steroidogenesis. *Febs Letters* 543:140–143.
- Hsu, C. C., Y. A. Lin, B. Su, J. H. Li, H. Y. Huang, and M. C. Hsu. 2011. No Effect of *Cordyceps Sinensis* Supplementation on Testosterone Level and Muscle Strength in Healthy Young Adults for Resistance Training. *Biology of Sport* 28:107–110.
- Hsu, C. C., Y. L. Huang, S. J. Tsai, C. C. Sheu, and B. M. Huang. 2003a. In vivo and in vitro stimulatory effects of *Cordyceps sinensis* on testosterone production in mouse Leydig cells. *Life Sciences* 73:2127–2136.
- Hsu, T. H., L. H. Shiao, C. Y. Hsieh, and D. M. Chang. 2002b. A comparison of the chemical composition and bioactive ingredients of the Chinese medicinal mushroom *DongChongXiaCao*, its counterfeit and mimic, and fermented mycelium of *Cordyceps sinensis*. *Food Chemistry* 78:463–469.
- Hu, H., L. Xiao, B. Zheng, X. Wei, A. Ellis, and Y.-M. Liu. 2015. Identification of chemical markers in *Cordyceps sinensis* by HPLC-MS/MS. *Analytical and Bioanalytical Chemistry* 407:8059–8066.
- Hu, S. 2019. Boundary-Crossing Species: Making the Realities of the Caterpillar Fungus. *Science as Culture*.
- Hu, T., C. Jiang, Q. Huang, and F. Sun. 2016. A comb-like branched beta-D-glucan produced by a *Cordyceps sinensis* fungus and its protective effect against cyclophosphamide-induced immunosuppression in mice. *Carbohydrate Polymers* 142:259–267.
- Hu, X., Y. J. Zhang, G. H. Xiao, P. Zheng, Y. L. Xia, X. Y. Zhang, R. J. St Leger, X. Z. Liu, and C. S. Wang. 2013. Genome survey uncovers the secrets of sex and lifestyle in caterpillar fungus. *Chinese Science Bulletin* 58:2846–2854.
- Hu, Y., T. Kang, and Z. Zhao. 2003. Studies on Microscopic Identification of Animal Drugs' Remnant Hair (1) Identification of *Cordyceps sinensis* and Its Counterfeits. *Natural Medicines* 57:163–171.
- Hu, Z., M. Ye, L. Xia, W. Tu, L. Li, and G. Zou. 2006. Purification and characterization of an antibacterial protein from the cultured mycelia of *Cordyceps sinensis*. *Wuhan University Journal of Natural Sciences* 11:709–714.
- Huang, B. M., C. C. Hsu, S. J. Tsai, C. C. Sheu, and S. F. Leu. 2001a. Effects of *Cordyceps sinensis* on testosterone production in normal mouse Leydig cells. *Life Sciences* 69:2593–2602.
- Huang, B. M., K. Y. Hsiao, P. C. Chuang, M. H. Wu, H. A. Pan, and S. J. Tsai. 2004a. Upregulation of steroidogenic enzymes and ovarian 17 beta-estradiol in human granulosa-lutein cells by *Cordyceps sinensis* mycelium. *Biology of Reproduction* 70:1358–1364.
- Huang, B. M., S. Y. Ju, C. S. Wu, W. J. Chuang, C. C. Sheu, and S. F. Leu. 2001b. *Cordyceps sinensis* and its fractions stimulate MA-10 mouse Leydig tumor cell steroidogenesis. *Journal of Andrology* 22:831–837.
- Huang, B. M., Y. M. Chuang, C. F. Chen, and S. F. Leu. 2000. Effects of extracted *Cordyceps sinensis* on steroidogenesis in MA-10 mouse Leydig tumor cells. *Biological & Pharmaceutical Bulletin* 23:1532–1535.
- Huang, B., Y.-L. Cheng, X.-J. Cao, Y. Li, R. Chen, J. Cao, C. Peng, D.-G. Wan, C.-H. Shen, and J.-L. Guo. 2017a. HPLC fingerprint of *Cordyceps sinensis* and its confused species and identification of common composition. *Chinese Traditional and Herbal Drugs* 48:991–996.
- Huang, B.-M. 2005. Stimulatory effects of *Cordyceps sinensis* mycelium on mouse Leydig cell steroidogenesis. *Abstracts of Papers of the American Chemical Society* 230:U77–U77.
- Huang, D., S. Meran, S.-P. Nie, A. Midgley, J. Wang, S. W. Cui, M. Xie, G. O. Phillips, and A. O. Phillips. 2018. *Cordyceps sinensis*: Anti-fibrotic and inflammatory effects of a cultured polysaccharide extract. *Bioactive Carbohydrates and Dietary Fibre* 14:2–8.

- Huang, J., D. Song, A. Yang, H. Yin, and W. Zhang. 2011a. Differentiation and maturation of human dendritic cells modulated by an exopolysaccharide from an anamorph of *Cordyceps sinensis*. *Biomedicine and Preventive Nutrition* 1:126–131.
- Huang, L. F., M. J. Wu, X. J. Sun, F. Q. Guo, Y. Z. Liang, and X. R. Li. 2004b. Simultaneous determination of adenine, uridine and adenosine in *cordyceps sinensis* and its substitutes by LC/ESI-MS. *Journal of Central South University of Technology* 11:295–299.
- Huang, L. F., Y. Z. Liang, F. Q. Guo, Z. F. Zhou, and B. M. Cheng. 2003. Simultaneous separation and determination of active components in *Cordyceps sinensis* and *Cordyceps militaris* by LC/ESI-MS. *Journal of Pharmaceutical and Biomedical Analysis* 33:1155–1162.
- Huang, L.-F., F.-Q. Guo, Y.-Z. Liang, and B.-M. Chen. 2004c. Determination of adenosine and cordycepin in *Cordyceps sinensis* and *C. militaris* with HPLC-ESI-MS. *Zhongguo Zhongyao Zazhi* 29:764.
- Huang, Q.-L., K.-C. Siu, W.-Q. Wang, Y.-C. Cheung, and J.-Y. Wu. 2013. Fractionation, characterization and antioxidant activity of exopolysaccharides from fermentation broth of a *Cordyceps sinensis* fungus. *Process Biochemistry* 48:380–386.
- Huang, Y. L., L. M. Huang, Y. K. Wang, C. S. Wu, and B. M. Huang. 2001c. The effects of *Cordyceps sinensis* on apoptosis in MA-10 mouse Leydig tumor cells. *Biology of Reproduction* 64:259–259.
- Huang, Y. L., S. F. Leu, B. C. Liu, C. C. Sheu, and B. M. Huang. 2004d. In vivo stimulatory effect of *Cordyceps sinensis* mycelium and its fractions on reproductive functions in male mouse. *Life Sciences* 75:1051–1062.
- Huang, Y.-Q., X.-X. Tong, X. Tao, Y.-X. Wang, C. Peng, S.-H. Wang, and J.-L. Guo. 2017b. Study on bio-synthesis of cordycepin in *Ophiocordyceps sinensis* based on RNA-seq []. *Chinese Traditional and Herbal Drugs* 48:4044–4050.
- Huang, Z., J. Jin, X. Tong, Q. Yang, B. Gu, J. Wang, Yuedi-shen, and J. Xie. 2011b. The immunomodulatory effects of *Cordyceps sinensis* on dendritic cells derived from chronic myelogenous leukemia (CML). *Journal of Medicinal Plants Research* 5:5925–5932.
- Huang, Z.-J., H. Ji, P. Li, L. Xie, and X.-C. Zhao. 2002. Hypoglycemic effect and mechanism of polysaccharides from cultured mycelium of *Cordyceps sinensis*. *Journal of China Pharmaceutical University* 33:51–54.
- Huo, X., C. Liu, X. Bai, W. Li, J. Li, X. Hu, and L. Cao. 2017. Aqueous extract of *Cordyceps sinensis* potentiates the antitumor effect of DDP and attenuates therapy-associated toxicity in non-small cell lung cancer via I kappa B alpha/NF kappa B and AKT/MMP2/MMP9 pathways. *Rsc Advances* 7:37743–37754.
- Ilowite, J., P. Spiegler, and S. Chawla. 2008. Bronchiectasis: new findings in the pathogenesis and treatment of this disease. *Current Opinion in Infectious Diseases* 21:163–167.
- Jang, S.-H., J. Park, S.-H. Jang, S.-W. Chae, S.-J. Jung, B.-O. So, K.-C. Ha, H.-S. Sin, and Y.-S. Jang. 2016. In vitro Stimulation of NK Cells and Lymphocytes Using an Extract Prepared from Mycelial Culture of *Ophiocordyceps sinensis*. *Immune Network* 16:140–145.
- Jang, S.-H., S.-H. Kim, H.-Y. Lee, S.-H. Jang, H. Jang, S.-W. Chae, S.-J. Jung, B.-O. So, K.-C. Ha, H.-S. Sin, and Y.-S. Jang. 2015. Immune-Modulating Activity of Extract Prepared from Mycelial Culture of Chinese Caterpillar Mushroom, *Ophiocordyceps sinensis* (Ascomycetes). *International Journal of Medicinal Mushrooms* 17:1189–1199.
- Jayakumar, T., C.-C. Chiu, S.-H. Wang, D.-S. Chou, Y.-K. Huang, and J.-R. Sheu. 2014. Anti-cancer Effects of CME-1, a Novel Polysaccharide, Purified from the Mycelia of *Cordyceps sinensis* against B16-F10 Melanoma Cells. *Journal of Cancer Research and Therapeutics* 10:43–49.
- Ji, D.-B., J. Ye, C.-L. Li, Y.-H. Wang, J. Zhao, and S.-Q. Cai. 2009. Antiaging Effect of *Cordyceps sinensis* Extract. *Phytotherapy Research* 23:116–122.

- Ji, H., H.-H. Tu, N.-S. Li, and G.-Q. Liu. 1993. Study on hypoglycemic activity of alkaline extract from cultural mycelium of *Cordyceps sinensis*. *Chinese Pharmacological Bulletin* 9:386–389.
- Ji, J., J. Liu, H. Liu, and Y. Wang. 2014. Effects of fermented mushroom of *Cordyceps sinensis*, rich in selenium, on uterine cervix cancer. *Evidence-Based Complementary and Alternative Medicine*:173180.
- Ji, N.-F., L.-S. Yao, Y. Li, W. He, K.-S. Yi, and M. Huang. 2011. Polysaccharide of *Cordyceps sinensis* Enhances Cisplatin Cytotoxicity in Non-Small Cell Lung Cancer H157 Cell Line. *Integrative Cancer Therapies* 10:359–367.
- Ji, Y. B. 1999. Pharmacological actions and applications of anticancer traditional Chinese medicines (150. *Cordyceps sinensis* (Berk) Sacc). Heilongjiang Science and Technology Press.
- Ji, Y.-B., X.-L. Bai, X.-W. Huo, W.-J. Li, J. Li, Y. Xiao, X.-F. Hu, and L. Cao. 2018. Effects of cultivated *Cordyceps sinensis* on proliferation and migration of B16 melanoma cells [B16]. *Chinese Traditional and Herbal Drugs* 49:368–373.
- Jia, J. M., X. C. Ma, C. F. Wu, L. J. Wu, and G. S. Hu. 2005. Cordycedipeptide A, a new cyclodipeptide from the culture liquid of *Cordyceps sinensis* (BERK.) sacc. *Chemical & Pharmaceutical Bulletin* 53:582–583.
- Jia, J.-M., H.-H. Tao, and B.-M. Feng. 2009. Cordyceamides A and B from the Culture Liquid of *Cordyceps sinensis* (BERK.) SACC. *Chemical & Pharmaceutical Bulletin* 57:99–101.
- Jia, J.-M., H.-H. Tao, and B.-M. Feng. 2009. Cordyceamides A and B from the Culture Liquid of *Cordyceps sinensis* (BERK.) SACC. *Chemical & Pharmaceutical Bulletin* 57:99–101.
- Jia, J.-M., X.-C. Ma, C.-F. Wu, L.-J. Wu, and G. Hu. 2005. Cordycedipeptide A, a new cyclodipeptide from the culture liquid of *Cordyceps sinensis* (Berk.) Sacc. *Chemical & Pharmaceutical Bulletin* 53:582–583.
- Jia, T., and B. H. S. Lau. 1997. The immuno-enhancing effect of Chinese herbal medicine *Cordyceps sinensis* on macrophage J774. *Chinese Pharmaceutical Journal* 32:142–144.
- Jialal, I., and S. Devaraj. 1996. Low-density lipoprotein oxidation, antioxidants, and atherosclerosis: a clinical biochemistry perspective. *Clinical Chemistry* 42:498–506.
- Jiang, P. 1987. Pharmacology constituent and function of *Cordyceps sinensis*. *Journal of Westnorthern Medicine* 2:43–44.
- Jiang, Y., and Y. J. Yao. 2002. Names related to *Cordyceps sinensis* anamorph. *Mycotaxon* 84:245–254.
- Jiemei, Z., H. Jianjun, G. Jie, H. Benhong, and H. Hao. 2011. Effects of fistular onion stalk extract on the level of NO and expression of endothelial NO synthase (eNOS) in human umbilical vein endothelium cells. *African Journal of Biotechnology* 10:2536-2540–2540.
- Jin, G.-S., X.-L. Wang, Y. Li, W.-J. Wang, R.-H. Yang, S.-Y. Ren, and Y.-J. Yao. 2013. Development of conventional and nested PCR assays for the detection of *Ophiocordyceps sinensis*. *Journal of Basic Microbiology* 53:340–347.
- Jin, Y., B. Xu, X. Yang, Z. Qin, M. Gao, H. Lu, and L. Zhu. 2010. The spatial distribution of *Cordyceps sinensis* in Nakchu Prefecture of Tibetan Plateau. *Shengtai Xuebao/ Acta Ecologica Sinica* 30:1532–1538.
- Jiraungkoorskul, K., and W. Jiraungkoorskul. 2016. Review of naturopathy of medical mushroom, *ophiocordyceps sinensis*, in sexual dysfunction. *Pharmacognosy Reviews* 10:1–5.
- Jordan, J. L., A. M. Sullivan, and T. D. G. Lee. 2008. Immune activation by a sterile aqueous extract of *Cordyceps sinensis*: Mechanism of action. *Immunopharmacology and Immunotoxicology* 30:53–70.
- Joshi, R., A. Sharma, K. Thakur, D. Kumar, and G. Nadda. 2018. Metabolite analysis and nucleoside determination using reproducible UHPLC-Q-ToF-IMS in *Ophiocordyceps sinensis*. *Journal of Liquid Chromatography & Related Technologies* 41:927–936.
- Ju, Y. S., L. M. Huang, C. S. Wu, and B. M. Huang. 2000. The effects of *Cordyceps sinensis* on steroidogenesis in rodent Leydig cells. *Biology of Reproduction* 62:236–237.

- Jung, S. H., Y. S. Lee, S. S. Lim, Y. S. Kim, S. Lee, and K. H. Shin. 2009. Hepatoprotective and Antioxidant Capacities of *Paecilomyces japonica* and *Cordyceps sinensis* in Rats with CCl₄-Induced Hepatic Injury. *Korean Journal of Horticultural Science & Technology* 27:668–672.
- Kadota, S., T. Shima, and T. Kikuchi. 1986. Steroidal components of “I-Tiam-Hong” and *Cordyceps sinensis*. Separation and identification by high-performance liquid chromatography. *Yakugaku Zasshi* 106:1092–1097.
- Kai, Z., G. Sheng, L. Yongjian, Z. Boya, L. Yu, J. Zhe, and Z. Kai. 2014. Preventive effects of *cordyceps sinensis* against contrast induced nephropathy in type 2 diabetics with renal insufficiency undergoing coronary angiography. *Journal of the American College of Cardiology* 64:C138–C138.
- Kai, Z., L. Yongjian, and Zhaokai. 2013. Role of *Cordyceps Sinensis* in Preventing Contrast Induced Nephropathy in Stable Angina Pectoris Patients. *Heart* 99:E178–E179.
- Kakuda, M., N. Yoshikawa, Y. Takahashi, Y. Kimoto, A. Sato, A. Nishiuchi, M. Kunitomo, S. Kagota, K. Sinozuka, and K. Nakamura. 2011. The anti-tumor effect of *Cordyceps sinensis* on human HT1080 fibrosarcoma cells via a reduction of c-MYC expression. *Journal of Pharmacological Sciences* 115:121P-121P.
- Kan, W.-C., H.-Y. Wang, C.-C. Chien, S.-L. Li, Y.-C. Chen, L.-H. Chang, C.-H. Cheng, W.-C. Tsai, J.-C. Hwang, S.-B. Su, L.-H. Huang, and J.-J. Chuu. 2012. Effects of extract from solid-state fermented *Cordyceps sinensis* on type 2 diabetes mellitus. *Evidence-Based Complementary and Alternative Medicine*:743107.
- Kang, C., Wen, T. C., Kang, J. C., Meng, Z. B., Li, G. R., and Hyde, K. D. 2014. Optimization of large-scale culture conditions for the production of cordycepin with *Cordyceps militaris* by liquid static culture. *The scientific world journal*
- Kang, S., J. Zhang, and R.-C. Lin. 2013. Macroscopic and microscopic characteristics of Chinese Caterpillar Fungus. *Yaoxue Xuebao* 48:428–434.
- Kang, X., L. Hu, P. Shen, R. Li, and D. Liu. 2017a. SMRT Sequencing Revealed Mitogenome Characteristics and Mitogenome-Wide DNA Modification Pattern in *Ophiocordyceps sinensis*. *Frontiers in Microbiology* 8:1422.
- Kang, X., Y. Hu, J. Hu, L. Hu, F. Wang, and D. Liu. 2017b. The mitochondrial genome of the lepidopteran host cadaver (*Thitarodes* sp.) of *Ophiocordyceps sinensis* and related phylogenetic analysis. *Gene* 598:32–42.
- Kausrud, H. avard, E. Heegaard, U. Büntgen, R. Halvorsen, S. Egli, B. I. Senn-Irlet, I. Krisai-Greilhuber, W. Dämon, M. mihorski, J. Nordén, K. Høiland, P. H. S. Kirk, M. Semenov, L. M. Boddy, and N. C. Stenseth. 2012. Warming-induced shift in European mushroom fruiting phenology. *Proceedings of the National Academy of Sciences of the United States of America* 109:14488–14493.
- Kausrud, H., L. C. Stige, J. O. Vik, R. H. Økland, K. Høiland, and N. C. Stenseth. 2008. Mushroom fruiting and climate change. *Proceedings of the National Academy of Sciences* 105:3811–3814.
- Khan, M. S., R. Parveen, K. Mishra, R. Tulsawani, and S. Ahmad. 2015b. Determination of nucleosides in *Cordyceps sinensis* and *Ganoderma lucidum* by high performance liquid chromatography method. *Journal of Pharmacy and Bioallied Sciences* 7:264–266.
- Khan, M. S., W. Khan, M. Manickam, R. K. Tulsawani, K. S. Misra, P. S. Negi, and S. Ahmad. 2015a. Quantification of Flavonoids and Nucleoside by UPLC-MS in Indian *Cordyceps sinensis* and its In-vitro Cultures. *Indian Journal of Pharmaceutical Education and Research* 49:353–361.
- Kiho, T., A. Yamane, J. Hui, S. Usui, and S. Ukai. 1996. Polysaccharides in fungi .36. Hypoglycemic activity of a polysaccharide (CS-F30) from the cultural mycelium of *Cordyceps sinensis* and its effect on glucose metabolism in mouse liver. *Biological & Pharmaceutical Bulletin* 19:294–296.
- Kiho, T., A. Yamane, J. Hui, S. Usui, and S. Ukai. 1996. Polysaccharides in fungi. XXXVI. Hypoglycemic activity of a polysaccharide (CS-F30) from the cultural mycelium of *Cordyceps sinensis* and its effect on glucose metabolism in mouse liver. *Biological & Pharmaceutical Bulletin* 19:294–296.

- Kiho, T., H. Tabata, S. Ukai, and C. Hara. 1986. A minor, protein-containing galactomannan from a sodium carbonate extract of *Cordyceps sinensis*. *Carbohydrate Research* 156:189–197.
- Kiho, T., J. Hui, A. Yamane, and S. Ukai. 1993. Polysaccharides in Fungi .32. Hypoglycemic Activity and Chemical-Properties of a Polysaccharide from the Cultural Mycelium of *Cordyceps-Sinensis*. *Biological & Pharmaceutical Bulletin* 16:1291–1293.
- Kiho, T., K. Ookubo, S. Usui, S. Ukai, and K. Hirano. 1999. Structural features and hypoglycemic activity of a polysaccharide (CS-F10) from the cultured mycelium of *Cordyceps sinensis*. *Biological & Pharmaceutical Bulletin* 22:966–970.
- Kim, H. G., B. Shrestha, S. Y. Lim, D. H. Yoon, W. C. Chang, D.-J. Shin, S. K. Han, S. M. Park, J. H. Park, H. I. Park, J.-M. Sung, Y. Jang, N. Chung, K.-C. Hwang, and T. W. Kim. 2006. Cordycepin inhibits lipopolysaccharide-induced inflammation by the suppression of NF-kappaB through Akt and p38 inhibition in RAW 264.7 macrophage cells. *European Journal of Pharmacology* 545:192–199.
- Kim, H. O., and J. W. Yun. 2005. A comparative study on the production of exopolysaccharides between two entomopathogenic fungi *Cordyceps militaris* and *Cordyceps sinensis* in submerged mycelial cultures. *Journal of Applied Microbiology* 99:728–738.
- Kim, S. D. 2010. Isolation, Structure and Cholesterol Esterase Inhibitory Activity of a Polysaccharide, PS-A, from *Cordyceps sinensis*. *Journal of the Korean Society for Applied Biological Chemistry* 53:784–789.
- Kim, S. D. 2010. Isolation, structure and cholesterol esterase inhibitory activity of a polysaccharide, PS-A, from *Cordyceps sinensis*. *Journal of the Korean Society for Applied Biological Chemistry* 53:784–789.
- Kinjo, N., and M. Zang. 2001. Morphological and phylogenetic studies on *Cordyceps sinensis* distributed in southwestern China. *Mycoscience* 42:567–574.
- Kobayasi, Y. 1980. Miscellaneous notes on the genus *Cordyceps* and its allies. *Journal of Japanese Botany* 55:181–188.
- Kobori, M., M. Yoshida, M. Ohnishi-Kameyama, and H. Shinmoto. 2007. Ergosterol peroxide from an edible mushroom suppresses inflammatory responses in RAW264.7 macrophages and growth of HT29 colon adenocarcinoma cells. *British Journal of Pharmacology* 150:209–219.
- Koh, J. H., H. J. Suh, and T. S. Ahn. 2003c. Hot-water extract from mycelia of *Cordyceps sinensis* as a substitute for antibiotic growth promoters. *Biotechnology Letters* 25:585–590.
- Koh, J. H., J. M. Kim, U. J. Chang, and H. J. Suh. 2003a. Hypocholesterolemic effect of hot-water extract from mycelia of *Cordyceps sinensis*. *Biological & Pharmaceutical Bulletin* 26:84–87.
- Koh, J. H., K. M. Kim, J. M. Kim, J. C. Song, and H. J. Suh. 2003b. Antifatigue and antistress effect of the hot-water fraction from mycelia of *Cordyceps sinensis*. *Biological & Pharmaceutical Bulletin* 26:691–694.
- Koh, J. H., K. W. Yu, H. J. Suh, Y. M. Choi, and T. S. Ahn. 2002. Activation of macrophages and the intestinal immune system by an orally administered decoction from cultured mycelia of *Cordyceps sinensis*. *Bioscience Biotechnology and Biochemistry* 66:407–411.
- Kong, R., Y. Zhang, S. Zhang, M. Liu, W. Sun, Y. Xing, Y. Guan, C. Han, and Z. Liu. 2015. Protective Effect of Ethanol Extracts of the Chinese Caterpillar Mushroom, *Ophiocordyceps sinensis* (Ascomycetes), on the Experimental Middle Cerebral Artery Occlusion/Reperfusion (MCAO/R) Model. *International Journal of Medicinal Mushrooms* 17:997–1003.
- Konoha, K., K. Nakamura, Y. Yamaguchi, S. Kagota, K. Shinozuka, and M. Kunitomo. 2003. Combined effects of *Cordyceps sinensis* and dacarbazine on spontaneous metastatic tumor model mice. *Journal of Pharmacological Sciences* 91:282P–282P.
- Kubo, E., A. Sato, N. Yoshikawa, S. Kagota, K. Shinozuka, and K. Nakamura. 2012. Effect of *Cordyceps sinensis* on TIMP-1 secretion from mouse melanoma cell. *Central European Journal of Biology* 7:167–171.

- Kubo, E., N. Yoshikawa, M. Kunitomo, S. Kagota, K. Shinozuka, and K. Nakamura. 2010. Inhibitory Effect of *Cordyceps sinensis* on Experimental Hepatic Metastasis of Melanoma by Suppressing Tumor Cell Invasion. *Anticancer Research* 30:3429–3433.
- Kubo, E., N. Yoshikawa, Y. Takahashi, S. Kagota, K. Shinozuka, M. Kunitomo, and K. Nakamura. 2009. Effect of water extract of *Cordyceps sinensis* on hepatocyte growth factor-accelerated invasion of B16-mouse melanoma cells. *Journal of Pharmacological Sciences* 109:290P–290P.
- Kumar, R., P. S. Negi, B. Singh, G. Ilavazhagan, K. Bhargava, and N. K. Sethy. 2011. *Cordyceps sinensis* promotes exercise endurance capacity of rats by activating skeletal muscle metabolic regulators. *Journal of Ethnopharmacology* 136:260–266.
- Kuniyal, C. P., and R. C. Sundriyal. 2013. Conservation salvage of *Cordyceps sinensis* collection in the Himalayan mountains is neglected. *Ecosystem Services* 3:E40–E43.
- Kuo, C. F., C. C. Chen, Y. H. Luo, R. Y. Huang, W. J. Chuang, C. C. Sheu, and Y. S. Lin. 2005a. *Cordyceps sinensis* mycelium protects mice from group A streptococcal infection. *Journal of Medical Microbiology* 54:795–802.
- Kuo, C.-F., C.-C. Chen, C.-F. Lin, M.-S. Jan, R. Y. Huang, Y.-H. Luo, W.-J. Chuang, C.-C. Sheu, and Y.-S. Lin. 2007a. Abrogation of streptococcal pyrogenic exotoxin B-mediated suppression of phagocytosis in U937 cells by *Cordyceps sinensis* mycelium via production of cytokines. *Food and Chemical Toxicology* 45:278–285.
- Kuo, H. C., Y. L. Su, H. L. Yang, and T. Y. Chen. 2005b. Identification of Chinese medicinal fungus *Cordyceps sinensis* by PCR-single-stranded conformation polymorphism and phylogenetic relationship. *Journal of Agricultural and Food Chemistry* 53:3963–3968.
- Kuo, H.-C., Y.-L. Su, H.-L. Yang, I.-C. Huang, and T.-Y. Chen. 2006. Differentiation of *Cordyceps sinensis* by a PCR-single-stranded conformation polymorphism-based method and characterization of the fermented products in Taiwan. *Food Biotechnology* 20:161–170.
- Kuo, M.-C., C.-Y. Chang, T.-L. Cheng, and M.-J. Wu. 2007b. Immunomodulatory effect of exo-polysaccharides from submerged cultured *Cordyceps sinensis*: enhancement of cytokine synthesis, CD11b expression, and phagocytosis. *Applied Microbiology and Biotechnology* 75:769–775.
- Kuo, Y. C., W. J. Tsai, J. Y. Wang, S. C. Chang, C. Y. Lin, and M. S. Shiao. 2001. Regulation of bronchoalveolar lavage fluids cell function by the immunomodulatory agents from *Cordyceps sinensis*. *Life Sciences* 68:1067–1082.
- Kuo, Y. C., W. J. Tsai, M. S. Shiao, C. F. Chen, and C. Y. Lin. 1996. *Cordyceps sinensis* as an immunomodulatory agent. *The American Journal of Chinese Medicine* 24:111–125.
- Kuo, Y.-C., C.-Y. Lin, W.-J. Tsai, C.-L. Wu, C.-F. Chen, and M.-S. Shiao. 1994. Growth Inhibitors Against Tumor Cells in *Cordyceps sinensis* Other than Cordycepin and Polysaccharides. *Cancer Investigation* 12:611–615.
- Laha, A., R. Badola, and S. A. Hussain. 2018a. Earning a livelihood from Himalayan caterpillar fungus in Kumaon Himalaya: Opportunities, uncertainties, and implications. *Mountain Research and Development* 38:323–331.
- Laha, A., R. Badola, and S. A. Hussain. 2018b. Earning a Livelihood from Himalayan Caterpillar Fungus in Kumaon Himalaya: Opportunities, Uncertainties, and Implications. *Mountain Research and Development* 38:323–331.
- Lai, Y. H., G. P. Ruan, Y. L. Xie, and H. A. Chen. 2008. Study on HPLC fingerprint characteristic analysis of *Cordyceps sinensis* and its similar products. *Zhong yao cai = Zhongyao cai = Journal of Chinese medicinal materials* 31:1142–1145.
- Lam, K. Y. C., G. K. L. Chan, G.-Z. Xin, H. Xu, C.-F. Ku, J.-P. Chen, P. Yao, H.-Q. Lin, T. T. X. Dong, and K. W. K. Tsim. 2015. Authentication of *Cordyceps sinensis* by DNA Analyses: Comparison of ITS Sequence Analysis and RAPD-Derived Molecular Markers. *Molecules* 20:22454–22462.

- Le, J., J. Liu, Z. Bo, X. Feng, Y. Kexue, and W. Fujiang. 2006. The effect of Zn on the Zn accumulation and biosynthesis of amino acids in mycelia of *Cordyceps sinensis*. *Biological Trace Element Research* 113:45–51.
- Lee, E.-J., K.-H. Jang, S.-Y. Im, Y.-K. Lee, M. Farooq, R. Farhoudi, and D.-J. Lee. 2015. Physico-chemical properties and cytotoxic potential of *Cordyceps sinensis* metabolites. *Natural Product Research* 29:455–459.
- Lei, J., J. Chen, and C. Guo. 1992. Pharmacological study on *Cordyceps sinensis* (Berk.) Sacc. and *ze-e Cordyceps*. *Zhongguo Zhong yao za zhi = Zhongguo zhongyao zazhi = China journal of Chinese materia medica* 17:364–366, 384.
- Lei, N., S.-S. Du, X.-M. Ni, W.-S. Zhang, E.-R. Guo, and Q. Li. 2006. Determination of nucleosides in natural *Cordyceps sinensis* and cultured *Cordyceps* by RP-HPLC. *Chinese Pharmaceutical Journal* 41:948–951.
- Lei, W., G. Zhang, G. Wu, and X. Liu. 2016. Cytological Characterization of Anamorphic Fungus *Lecanicillium pui* and Its Relationship with Chinese Caterpillar Mushroom, *Ophiocordyceps sinensis* (Ascomycetes). *International Journal of Medicinal Mushrooms* 18:75–81.
- Lei, W., G. Zhang, Q. Peng, and X. Liu. 2015b. Development of *Ophiocordyceps sinensis* through Plant-Mediated Interkingdom Host Colonization. *International Journal of Molecular Sciences* 16:17482–17493.
- Lei, W., H. Chen, G. Zhang, S. Li, Q. Peng, X. Zhong, and X. Liu. 2011. Molecular identification and food source inference of constructive plants, native to the *Ophiocordyceps sinensis* habitat. *African Journal of Biotechnology* 10:159–167.
- Lei, W., S. Li, Q. Peng, G. Zhang, and X. Liu. 2013. A Real-Time qPCR Assay to Quantify *Ophiocordyceps sinensis* Biomass in *Thitarodes* Larvae. *Journal of Microbiology* 51:229–233.
- Lei, W., X. Shui, G. Zhang, and X. Liu. 2015a. The latent infection pathways of *Ophiocordyceps sinensis* in *Thitarodes* larvae. *Research Journal of Biotechnology* 10:105–109.
- Leu, R., M. Sun, and H. Zhou. 1990. Clinical analysis of therapeutic efficacy of *Cordyceps Sinensis*(Berk)Sacc in premature beats. *Bulletin of Hunan Medical University* 15:384–386.
- Leu, S. F., C. H. Chien, C. Y. Tseng, Y. M. Kuo, and B. M. Huang. 2005. The in vivo effect of *Cordyceps sinensis* mycelium on plasma corticosterone level in male mouse. *Biological & Pharmaceutical Bulletin* 28:1722–1725.
- Leu, S.-F., S. L. Poon, H.-Y. Pao, and B.-M. Huang. 2011. The in vivo and in vitro stimulatory effects of cordycepin on mouse leydig cell steroidogenesis. *Bioscience, Biotechnology, and Biochemistry* 75:723–731.
- Leung, A. K.-M., F. Gong, Y.-Z. Liang, and F.-T. Chau. 2000. Analysis of the water soluble constituents of *Cordyceps sinensis* with heuristic evolving latent projections. *Analytical Letters* 33:3195–3211.
- Leung, P. H., and J. Y. Wu. 2006. BIOT 267-Ammonium feeding enhances the production of bioactive metabolites (cordycepin and exopolysaccharides) in mycelium culture of a *Cordyceps sinensis* fungus. *Abstracts of Papers of the American Chemical Society* 232.
- Leung, P. H., and J. Y. Wu. 2008. Structural characterization and anti-oxidant activity of an exo-polysaccharide from the cultured *Cordyceps sinensis* fungus, Cs-HK1. *Febs Journal* 275:411–411.
- Leung, P. H., Q. X. Zhang, and J. Y. Wu. 2006. Mycelium cultivation, chemical composition and antitumour activity of a *Tolyptocladium* sp fungus isolated from wild *Cordyceps sinensis*. *Journal of Applied Microbiology* 101:275–283.
- Leung, P. H., S. Zhao, K. P. Ho, and J. Y. Wu. 2009. Chemical properties and antioxidant activity of exopolysaccharides from mycelial culture of *Cordyceps sinensis* fungus Cs-HK1. *Food Chemistry* 114:1251–1256.
- Leung, P.-H., and J.-Y. Wu. 2007. Effects of ammonium feeding on the production of bioactive metabolites (cordycepin and exopolysaccharides) in mycelial culture of a *Cordyceps sinensis* fungus. *Journal of Applied Microbiology* 103:1942–1949.
- Li, C., Z. Li, M. Fan, W. Cheng, Y. Long, T. Ding, and L. Ming. 2006a. The composition of *Hirsutella sinensis*, anamorph of *Cordyceps sinensis*. *Journal of Food Composition and Analysis* 19:800–805.

- Li, C.-H., H.-L. Zuo, Q. Zhang, F.-Q. Wang, Y.-J. Hu, Z.-M. Qian, W.-J. Li, Z.-N. Xia, and F.-Q. Yang. 2017a. Analysis of Soluble Proteins in Natural *Cordyceps sinensis* from Different Producing Areas by Sodium Dodecyl Sulfate Polyacrylamide Gel Electrophoresis and Two-dimensional Electrophoresis. *Pharmacognosy Research* 9:34–38.
- Li, C.-Y., C.-S. Chiang, M.-L. Tsai, R.-S. Hseu, W.-Y. Shu, C.-Y. Chuang, Y.-C. Sun, Y.-S. Chang, J.-G. Lin, C.-S. Chen, C.-L. Huang, and I. C. Hsu. 2009a. Two-sided effect of *Cordyceps sinensis* on dendritic cells in different physiological stages. *Journal of Leukocyte Biology* 85:987–995.
- Li, C.-Y., C.-S. Chiang, W.-C. Cheng, S.-C. Wang, H.-T. Cheng, C.-R. Chen, W.-Y. Shu, M.-L. Tsai, R.-S. Hseu, C.-W. Chang, C.-Y. Huang, S.-H. Fang, and I. C. Hsu. 2012. Gene Expression Profiling of Dendritic Cells in Different Physiological Stages under *Cordyceps sinensis* Treatment. *Plos One* 7:e40824.
- Li, D. G., and Z. X. Ren. 2017. *Cordyceps sinensis* promotes immune regulation and enhances bacteriostatic activity of PA-824 via IL-10 in *Mycobacterium tuberculosis* disease. *Brazilian Journal of Medical and Biological Research* 50:e6188.
- Li, F., X. Y. Gao, B. F. Rao, L. Liu, B. Dong, and L. Q. Cui. 2006b. Effects of *cordyceps sinensis* alcohol extractive on serum interferon-gamma level and splenic T lymphocyte subset in mice with viral myocarditis. *Xi bao yu fen zi mian yi xue za zhi = Chinese journal of cellular and molecular immunology* 22:321–323.
- Li, F., Z. Wu, C. Xu, Y. Xu, and L. Zhang. 2014. The spatial distribution of *Ophiocordyceps sinensis* suitability in Sanjiangyuan Region. *Shengtai Xuebao/ Acta Ecologica Sinica* 34:1318–1325.
- Li, F.-H., P. Liu, W.-G. Xiong, and G.-F. Xu. 2006c. Effects of *Cordyceps sinensis* on dimethylnitrosamine-induced liver fibrosis in rats. *Journal of Chinese Integrative Medicine* 4:514–517.
- Li, H., Z. Hu, J. Yuan, H. Fan, W. Chen, S. Wang, S. Zheng, Z. Zheng, and G. Zou. 2007. A novel extracellular protease with fibrinolytic activity from the culture supernatant of *Cordyceps sinensis*: Purification and characterization. *Phytotherapy Research* 21:1234–1241.
- Li, J., C.-Q. Feng, X.-M. Ni, and W.-S. Zhang. 2008a. Determination of nucleosides of natural *Cordyceps sinensis* in Qinghai Province by capillary electrophoresis. *Chinese Pharmaceutical Journal* 43:1105+1106-1107.
- Li, J., G. Chen, Y. Jin, G. Chen, and Q. Pan. 1989. Effect of *cordyceps sinensis* on proliferation of CFU-GM in mice. *Bulletin of Hunan Medical University* 14:147–149.
- Li, J.-X., J. Li, L.-Z. Xu, S.-L. Yang, and Z.-M. Zou. 2003a. Studies on chemical constituents of *Cordyceps sinensis* (Berk) Sacc. *Chinese Pharmaceutical Journal* 38:499–501.
- Li, K., Q. Li, Y. Yuan, J.-Y. Chen, L.-Q. Huang, and Z.-G. Liu. 2011a. Identification and detection of *Cordyceps sinensis* with LAMP. *Chinese Traditional and Herbal Drugs* 42:1605–1608.
- Li, L. S., F. Zheng, and Z. H. Liu. 1996. Experimental study on effect of *Cordyceps sinensis* in ameliorating aminoglycoside induced nephrotoxicity. *Zhongguo Zhong xi yi jie he za zhi Zhongguo Zhongxiyi jiehe zazhi = Chinese journal of integrated traditional and Western medicine / Zhongguo Zhong xi yi jie he xue hui, Zhongguo Zhong yi yan jiu yuan zhu ban* 16:733–737.
- Li, L., D. H. Yin, C. H. Tang, and S. Q. Fu. 1993a. Relationship between illumination and growth of the stroma of *Cordyceps sinensis* (Berk.) Sacc. *Zhongguo Zhong yao za zhi = Zhongguo zhongyao zazhi = China journal of Chinese materia medica* 18:80–82, 124–125.
- Li, L., D. Yin, S. Chen, X. Zha, J. Sun, and Z. Xiao. 2000. The ejection of ascopora of *Cordyceps sinensis*. *Zhong yao cai = Zhongyao cai = Journal of Chinese medicinal materials* 23:515–517.
- Li, P. Z., W. G. Li, Q. Z. Jian, H. S. Yang, and W. W. Jian. 2008b. Antioxidant activity of aqueous extract of a *Tolyposcladium* sp. fungus isolated from wild *Cordyceps sinensis*. *African Journal of Biotechnology* 7:3004–3010.

- Li, Q., W. Zeng, D. Yin, and T. Huang. 1998. A preliminary study on alternation of generations of *Cordyceps sinensis* (Berkey) Sacc. *Zhongguo Zhong yao za zhi = Zhongguo zhongyao zazhi = China journal of Chinese materia medica* 23:210–212, 254.
- Li, R., Y. Zhao, and X. Jiang. 2011b. Chemical composition of *Hirsutella beakdumountainsis*, a potential substitute for *Cordyceps sinensis*. *African Journal of Biotechnology* 10:16286–16292.
- Li, S. P., F. Q. Yang, and K. W. K. Tsim. 2006d. Quality control of *Cordyceps sinensis*, a valued traditional Chinese medicine. *Journal of Pharmaceutical and Biomedical Analysis* 41:1571–1584.
- Li, S. P., G. H. Zhang, Q. Zeng, Z. G. Huang, Y. T. Wang, T. T. X. Dong, and K. W. K. Tsim. 2006. Hypoglycemic activity of polysaccharide, with antioxidation, isolated from cultured *Cordyceps mycelia*. *Phytomedicine: International Journal of Phytotherapy and Phytopharmacology* 13:428–433.
- Li, S. P., K. J. Zhao, Z. N. Ji, Z. H. Song, T. T. X. Dong, C. K. Lo, J. K. H. Cheung, S. Q. Zhu, and K. W. K. Tsim. 2003b. A polysaccharide isolated from *Cordyceps sinensis*, a traditional Chinese medicine, protects PC12 cells against hydrogen peroxide-induced injury. *Life Sciences* 73:2503–2513.
- Li, S. P., P. Li, T. T. X. Dong, and K. W. K. Tsim. 2001a. Determination of nucleosides in natural *Cordyceps sinensis* and cultured *Cordyceps mycelia* by capillary electrophoresis. *Electrophoresis* 22:144–150.
- Li, S. P., P. Li, T. T. X. Dong, and K. W. K. Tsim. 2001b. Anti-oxidation activity of different types of natural *Cordyceps sinensis* and cultured *Cordyceps mycelia*. *Phytomedicine* 8:207–212.
- Li, S. P., Z. R. Su, T. T. X. Dong, and K. W. K. Tsim. 2002. The fruiting body and its caterpillar host of *Cordyceps sinensis* show close resemblance in main constituents and anti-oxidation activity. *Phytomedicine* 9:319–324.
- Li, S., F. Zheng, S. Xiao, and B. Tan. 1995a. Effects of *Cordyceps-Sinensis* (cs) in Renal Damage of Hemorrhagic-Fever with Renal Syndrome (hfrs). *Journal of the American Society of Nephrology* 6:469–469.
- Li, S., X. Zhong, X. Kan, L. Gu, H. Sun, G. Zhang, and X. Liu. 2016a. De novo transcriptome analysis of *Thitarodes jiachaensis* before and after infection by the caterpillar fungus, *Ophiocordyceps sinensis*. *Gene* 580:96–103.
- Li, S.-P., and F.-Q. Yang. 2008. *Dongchongxiacao (Cordyceps sinensis)*. Page Pharmacological Activity-Based Quality Control of Chinese Herbs. Nova Science Publishers, Inc.
- Li, S.-P., P. Li, H. Ji, P. Zhang, T. T. X. Dong, and K. W. K. Tsim. 2001c. The contents and their change of nucleosides from natural *Cordyceps sinensis* and cultured *Cordyceps mycelia*. *Yaoxue Xuebao* 36:436–439.
- Li, T., B. Song, C.-Q. Wang, and T.-H. Li. 2013a. Analysis on soil fungal community structures in propagation of *Cordyceps sinensis* by denaturing gradient gel electrophoresis. *Chinese Traditional and Herbal Drugs* 44:478–481.
- Li, X., and D. Li. 2013. Enhancing antioxidant activity of soluble polysaccharide from the submerged fermentation product of *cordyceps sinensis* by using cellulase. *Advanced Materials Research* 641–642:975–978.
- Li, X., Q. Liu, W. Li, Q. Li, Z. Qian, X. Liu, and C. Dong. 2019. A breakthrough in the artificial cultivation of Chinese cordyceps on a large-scale and its impact on science, the economy, and industry. *Critical Reviews in Biotechnology* 39:181–191.
- Li, X.-H., X.-H. Han, L.-L. Qin, J.-L. He, Z.-X. Cao, Y.-C. Gu, D.-L. Guo, and Y. Deng. 2018. Isochromanes from *Aspergillus fumigatus*, an endophytic fungus from *Cordyceps sinensis*. *Natural Product Research*:1–6.
- Li, Y. H., and X. L. Li. 1991. Determination of ergosterol in *Cordyceps sinensis* and *Cordyceps black-bone chicken capsules* by HPLC. *Yao xue xue bao = Acta pharmaceutica Sinica* 26:768–771.
- Li, Y., G. Chen, and D. Jiang. 1993b. Combined Traditional Chinese and Western Medicine - Effect of *Cordyceps-Sinensis* on Erythropoiesis in Mouse Bone-Marrow. *Chinese Medical Journal* 106:313–316.

- Li, Y., L. Jiao, and Y.-J. Yao. 2013b. Non-concerted ITS evolution in fungi, as revealed from the important medicinal fungus *Ophiocordyceps sinensis*. *Molecular Phylogenetics and Evolution* 68:373–379.
- Li, Y., L.-X. Guo, Q.-Z. Zhou, D. Chen, J.-Z. Liu, X.-M. Xu, and J.-H. Wang. 2019a. Characterization of Humic Substances in the Soils of *Ophiocordyceps sinensis* Habitats in the Sejila Mountain, Tibet: Implication for the Food Source of *Thitarodes* Larvae. *Molecules* 24:246.
- Li, Y., T. Hsiang, R.-H. Yang, X.-D. Hu, K. Wang, W.-J. Wang, X.-L. Wang, L. Jiao, and Y.-J. Yao. 2016b. Comparison of different sequencing and assembly strategies for a repeat-rich fungal genome, *Ophiocordyceps sinensis*. *Journal of Microbiological Methods* 128:1–6.
- Li, Y., W.-J. Xue, P.-X. Tian, X.-M. Ding, H. Yan, X.-M. Pan, and X.-S. Feng. 2009b. Clinical Application of *Cordyceps sinensis* on Immunosuppressive Therapy in Renal Transplantation. *Transplantation Proceedings* 41:1565–1569.
- Li, Y., X.-D. Hu, R.-H. Yang, T. Hsiang, K. Wang, D.-Q. Liang, F. Liang, D.-M. Cao, F. Zhou, G. Wen, and Y.-J. Yao. 2015. Complete mitochondrial genome of the medicinal fungus *Ophiocordyceps sinensis*. *Scientific Reports* 5:13892.
- Li, Y., X.-L. Wang, L. Jiao, Y. Jiang, H. Li, S.-P. Jiang, N. Lhosumtseiring, S.-Z. Fu, C.-H. Dong, Y. Zhan, and Y.-J. Yao. 2011c. A survey of the geographic distribution of *Ophiocordyceps sinensis*. *Journal of Microbiology* 49:913–919.
- Li, Y., Y.-H. Wang, K. Wang, R.-H. Yang, and Y.-J. Yao. 2019b. Response to “The multiple genotypes of *Ophiocordyceps sinensis* and the ITS pseudogene hypothesis.” *Molecular Phylogenetics and Evolution* 139.
- Li, Z., A. Chen, Z. Li, M. Qu, H. Chen, B. Yang, and Y. Wang. 2017b. A novel and environmentally friendly bioprocess for separation and partial purification of polysaccharides from *Cordyceps sinensis* mycelia by an aqueous two-phase system. *Rsc Advances* 7:37659–37665.
- Li, Z., X. Zhou, and Q. Ren. 1995b. Effects of Interference by *Cordyceps Sinensis* (berk) Since on Passive Heymann Nephritis. *Kidney International* 48:601–602.
- Li, Z.-P., S. Noriaki, and S.-Q. Sun. 2016c. TOF-SIMS study of mannitol and cordycepin in *cordyceps sinensis*. *Guang Pu Xue Yu Guang Pu Fen Xi/Spectroscopy and Spectral Analysis* 36:1230–1234.
- Liang, H.-H., Z. Cheng, X.-L. Yang, S. Li, Z.-Q. Ding, T.-S. Zhou, W.-J. Zhang, and J.-K. Chen. 2008. Genetic Diversity and Structure of *Cordyceps sinensis* Populations from Extensive Geographical Regions in China as Revealed by Inter-Simple Sequence Repeat Markers. *Journal of Microbiology* 46:549–556.
- Liang, S. 2018. Missing pieces in the story of a caterpillar fungus - *Ophiocordyceps sinensis*. *Ima Fungus* 9:75–77.
- Liang, Y. L., Y. Liu, J. W. Yang, and X. C. Liu. 1997. Studies on pharmacological activities of cultivated *Cordyceps sinensis*. *Phytotherapy Research* 11:237–239.
- Lin, C. Y., F. M. Ku, Y. C. Kuo, C. F. Chen, W. P. Chen, A. Chen, and M. S. Shiao. 1999. Inhibition of activated human mesangial cell proliferation by the natural product of *Cordyceps sinensis* (H1-A): an implication for treatment of IgA mesangial nephropathy. *The Journal of Laboratory and Clinical Medicine* 133:55–63.
- Lin, C.-C., W. Pumsanguan, M. M.-O. Koo, H.-B. Huang, and M.-S. Lee. 2007. Radiation protective effects of *cordyceps sinensis* in blood cells. *Tzu Chi Medical Journal* 19:226–232.
- Lin, C.-Y., F.-M. Ku, Y.-C. Kuo, C.-F. Chen, W.-P. Chen, A. Chen, and M.-S. Shiao. 1999. Inhibition of activated human mesangial cell proliferation by the natural product of *Cordyceps sinensis* (H1-A): An implication for treatment of IgA mesangial nephropathy. *Journal of Laboratory and Clinical Medicine* 133:55–63.
- Lin, S., Z.-Q. Liu, P. J. Baker, M. Yi, H. Wu, F. Xu, Y. Teng, and Y.-G. Zheng. 2016. Enhancement of *cordyceps* polysaccharide production via biosynthetic pathway analysis in *Hirsutella sinensis*. *International Journal of Biological Macromolecules* 92:872–880.

- Linke, J. 2016. Re-shaping “soft gold”: Fungal agency and the bioeconomy in the caterpillar fungus market assemblage. Pages 51–66 *Biological Economies: Experimentation and the Politics of Agri-Food Frontiers*.
- Liu, A., J. Wu, A. Li, W. Bi, T. Liu, L. Cao, Y. Liu, and L. Dong. 2016a. The inhibitory mechanism of *Cordyceps sinensis* on cigarette smoke extract-induced senescence in human bronchial epithelial cells. *International Journal of Chronic Obstructive Pulmonary Disease* 11:1721–1731.
- Liu, B.-H., W.-M. He, Y.-G. Wan, K. Gao, Y. Tu, W. Wu, J.-Y. Tao, J.-J. Zhu, Y.-D. Lu, and W. Sun. 2019. Molecular mechanisms of mycelium of *Cordyceps sinensis* ameliorating renal tubular epithelial cells aging induced by D-galactose via inhibiting autophagy-related AMPK/ULK1 signaling activation. *Zhongguo Zhong yao za zhi = Zhongguo zhongyao zazhi = China journal of Chinese materia medica* 44:1258–1265.
- Liu, C., S. Lu, and M. R. Ji. 1992. Effects of *Cordyceps sinensis* (CS) on in vitro natural killer cells. *Zhongguo Zhong xi yi jie he za zhi Zhongguo Zhongxiyi jiehe zazhi = Chinese journal of integrated traditional and Western medicine / Zhongguo Zhong xi yi jie he xue hui, Zhongguo Zhong yi yan jiu yuan zhu ban* 12:267–269, 259.
- Liu, C., S. Lu, M. R. Ji, and Y. Xie. 1995. Study of effects of *Cordyceps sinensis* on natural killer cells in leukemia. *Chinese Journal of Integrated Traditional and Western Medicine* 1:108–110.
- Liu, F., D. Zhang, W. Zeng, L. Li, Q. Luo, Y. Tu, S. Chen, and D. Yin. 2015a. Effect of wound to growth of larva of host to *Ophiocordyceps sinensis* during artificial breeding. *Zhongguo Zhong yao za zhi = Zhongguo zhongyao zazhi = China journal of Chinese materia medica* 40:210–212.
- Liu, F., X.-L. Wu, S.-J. Chen, D.-H. Yin, W. Zeng, and G.-Y. Zhong. 2007. Advances in studies on artificial culture of *Cordyceps sinensis*. *Chinese Traditional and Herbal Drugs* 38:302–305.
- Liu, F., X.-L. Wu, Y. Liu, D.-X. Chen, D.-L. Zhang, and D.-J. Yang. 2016b. Progress on molecular biology of *Isaria farinosa*, pathogen of host of *Ophiocordyceps sinensis* during the artificial culture. *Zhongguo Zhong yao za zhi = Zhongguo zhongyao zazhi = China journal of Chinese materia medica* 41:403–409.
- Liu, F., X.-L. Wu, Z. Wei, D.-L. Zhang, S.-J. Chen, and D.-H. Yin. 2008a. Effects of integrated pest control techniques to growth of host larvae *Cordyceps sinensis*. *Zhongguo Zhongyao Zazhi* 33:2741–2744.
- Liu, G. T., and R. L. Xu. 1985. Immuno-pharmacologic activity of *Cordyceps sinensis* (Berk) Sacc. *Zhong xi yi jie he za zhi = Chinese journal of modern developments in traditional medicine / Zhongguo Zhong xi yi jie he yan jiu hui (chou), Zhong yi yan jiu yuan, zhu ban* 5:622–624, 581.
- Liu, H., D. Cao, H. Liu, X. Liu, W. Mai, H. Lan, W. Huo, and Q. Zheng. 2016c. The herbal medicine *Cordyceps sinensis* protects pancreatic beta cells from streptozotocin-induced endoplasmic reticulum stress. *Canadian Journal of Diabetes* 40:329–335.
- Liu, P., J. Zhu, Y. Huang, and C. Liu. 1996. Influence of *Cordyceps sinensis* (Berk.) Sacc. and rat serum containing same medicine on IL-1, IFN and TNF produced by rat Kupffer cells. *Zhongguo Zhong yao za zhi = Zhongguo zhongyao zazhi = China journal of Chinese materia medica* 21:367–369, 384.
- Liu, Q., W. Zhang, H. Cui, and Y. Ying. 2014a. Study on effect of *cordyceps sinensis* on early-stage silicotic pulmonary fibrosis in rabbits. *Zhonghua lao dong wei sheng zhi ye bing za zhi = Zhonghua laodong weisheng zhiyebing zazhi = Chinese journal of industrial hygiene and occupational diseases* 32:530–532.
- Liu, W.-C., S.-C. Wang, M.-L. Tsai, M.-C. Chen, Y.-C. Wang, J.-H. Hong, W. H. McBride, and C.-S. Chiang. 2006. Protection against radiation-induced bone marrow and intestinal injuries by *Cordyceps sinensis*, a Chinese herbal medicine. *Radiation Research* 166:900–907.
- Liu, W.-C., W.-L. Chuang, M.-L. Tsai, J.-H. Hong, W. H. McBride, and C.-S. Chiang. 2008b. *Cordyceps sinensis* health supplement enhances recovery from taxol-induced Leukopenia. *Experimental Biology and Medicine* 233:447–455.
- Liu, X. P. 1988. Influence of *Cordyceps sinensis* (Berk.) Sacc. and its cultured mycelia on murine platelets and immune organs after irradiation with ⁶⁰Co gamma-rays. *Zhong yao tong bao (Beijing, China : 1981)* 13:44–46, 64.

- Liu, X., F. Zhong, X. Tang, F. Lian, Q. Zhou, S. Guo, J. Liu, P. Sun, X. Hao, Y. Lu, W. Wang, N. Chen, and N. Zhang. 2014b. *Cordyceps sinensis* protects against liver and heart injuries in a rat model of chronic kidney disease: a metabolomic analysis. *Acta Pharmacologica Sinica* 35:697–706.
- Liu, X.-Y., and X.-T. Liang. 2013. Theoretical studies of two-dimensional IR spectroscopy for traditional Chinese medicine *cordyceps sinensis*. *Guangzi Xuebao/Acta Photonica Sinica* 42:64–68.
- Liu, Y. K., and W. Shen. 2003. Inhibitive effect of *cordyceps sinensis* on experimental hepatic fibrosis and its possible mechanism. *World Journal of Gastroenterology* 9:529–533.
- Liu, Y., J. Wang, W. Wang, H. Zhang, X. Zhang, and C. Han. 2015b. The Chemical Constituents and Pharmacological Actions of *Cordyceps sinensis*. *Evidence-Based Complementary and Alternative Medicine*:575063.
- Liu, Y., X.-Y. Wang, Z.-T. Gao, J.-P. Han, and L. Xiang. 2017. Detection of *Ophiocordyceps sinensis* and Its Common Adulterates Using Species-Specific Primers. *Frontiers in Microbiology* 8:1179.
- Liu, Y.-K., and W. Shen. 2002. Effect of *Cordyceps sinensis* on hepatocytic proliferation of experimental hepatic fibrosis in rats. *World Chinese Journal of Digestology* 10:388–391.
- Liu, Y.-S., P.-H. Leung, and J.-Y. Wu. 2008c. Exopolysaccharide production in batch and semi-continuous fermentation of *Cordyceps sinensis*. *Journal of Biotechnology* 136:S301–S302.
- Liu, Z. Y., Y. J. Yao, Z. Q. Liang, A. Y. Liu, D. N. Pegler, and M. W. Chase. 2001. Molecular evidence for the anamorph-teleomorph connection in *Cordyceps sinensis*. *Mycological Research* 105:827–832.
- Liu, Z., P. Li, D. Zhao, H. Tang, and J. Guo. 2010. Protective effect of extract of *Cordyceps sinensis* in middle cerebral artery occlusion-induced focal cerebral ischemia in rats. *Behavioral and Brain Functions* 6:61.
- Liu, Z., P. Li, D. Zhao, H. Tang, and J. Guo. 2011. Anti-inflammation Effects of *Cordyceps sinensis* Mycelium in Focal Cerebral Ischemic Injury Rats. *Inflammation* 34:639–644.
- Liu, Z.-Q., S. Lin, P. J. Baker, L.-F. Wu, X.-R. Wang, H. Wu, F. Xu, H.-Y. Wang, M. E. Brathwaite, and Y.-G. Zheng. 2015c. Transcriptome sequencing and analysis of the entomopathogenic fungus *Hirsutella sinensis* isolated from *Ophiocordyceps sinensis*. *Bmc Genomics* 16:106.
- Lo, H.-C., C. Hsieh, F.-Y. Lin, and T.-H. Hsu. 2013. A systematic review of the mysterious caterpillar fungus *Ophiocordyceps sinensis* in Dong-ChongXiaCao (D ng Chóng Xià C o) and related bioactive ingredients. *Journal of Traditional and Complementary Medicine* 3:16–32.
- Lo, H.-C., T.-H. Hsu, S.-T. Tu, and K.-C. Lin. 2006. Anti-hyperglycemic activity of natural and fermented *Cordyceps sinensis* in rats with diabetes induced by nicotinamide and streptozotocin. *American Journal of Chinese Medicine* 34:819–832.
- Lohwag, H. 1923. Beobachtungen an *Cordyceps sinensis* (Berk.) Sacc. und verwandten Pilzen. *Österreichische Botanische Zeitschrift* 72:294–302.
- Lu, D. 2017. Transnational Travels of the Caterpillar Fungus in the Fifteenth through Nineteenth Centuries. *Asian Medicine* 12:7–55.
- Lu, L. 2002. Study on effect of *Cordyceps sinensis* and artemisinin in preventing recurrence of lupus nephritis. *Zhongguo Zhong xi yi jie he za zhi Zhongguo Zhongxiyi jiehe zazhi = Chinese journal of integrated traditional and Western medicine / Zhongguo Zhong xi yi jie he xue hui, Zhongguo Zhong xi yan jiu yuan zhu ban* 22:169–171.
- Lu, W.-J., N.-C. Chang, T. Jayakumar, J.-C. Liao, M.-J. Lin, S.-H. Wang, D.-S. Chou, P. A. Thomas, and J.-R. Sheu. 2014. Ex vivo and in vivo studies of CME-1, a novel polysaccharide purified from the mycelia of *Cordyceps sinensis* that inhibits human platelet activation by activating adenylate cyclase/cyclic AMP. *Thrombosis Research* 134:1301–1310.

- Lu, Z., P. Shi, Y. He, D. Zhang, Z. He, S. Chen, Y. Tu, L. Li, F. Liu, and W. Zeng. 2015. Review on Natural Enemies and Diseases in the Artificial Cultivation of Chinese Caterpillar Mushroom, *Ophiocordyceps sinensis* (Ascomycetes). *International Journal of Medicinal Mushrooms* 17:693–700.
- Luo, Y., S.-K. Yang, X. Zhou, M. Wang, D. Tang, F. Liu, L. Sun, and L. Xiao. 2015. Use of *Ophiocordyceps sinensis* (syn. *Cordyceps sinensis*) combined with angiotensin-converting enzyme inhibitors (ACEI)/angiotensin receptor blockers (ARB) versus ACEI/ARB alone in the treatment of diabetic kidney disease: a meta-analysis. *Renal Failure* 37:614–634.
- Ma, K. W., and F. T. Chau. 2001. Qualitative and quantitative analyses of *Cordyceps sinensis* by using reversed-phase High Performance Liquid Chromatography. *Abstracts of Papers of the American Chemical Society* 221:U87–U87.
- Ma, K. W., and F. T. Chau. 2002. Qualitative and quantitative analyses of *cordyceps sinensis* by using reversed-phase high performance liquid chromatography (RP-HPLC). *Abstracts of Papers of the American Chemical Society* 223:U82–U82.
- Ma, K. W., F. T. Chau, and J. Y. Wu. 2004. Analysis of the nucleoside content of *Cordyceps sinensis* using the stepwise gradient elution technique of thin-layer chromatography. *Chinese Journal of Chemistry* 22:85–91.
- Ma, M., X. Gao, H. Yu, X. Qi, S. Sun, and D. Wang. 2018a. *Cordyceps sinensis* Promotes the Growth of Prostate Cancer Cells. *Nutrition and Cancer-an International Journal* 70:1166–1172.
- Ma, M., X. Gao, X. Qi, H. Yu, S. Sun, and D. Wang. 2015. *Cordyceps Sinensis* Significantly Decreases the Radiosensitivity of Prostate Cancer Cells. *International Journal of Radiation Oncology Biology Physics* 93:E511–E512.
- Ma, S., Y.-K. Lee, A. Zhang, and X. Li. 2018b. Label-free detection of *Cordyceps sinensis* using dual-gate nanoribbon-based ion-sensitive field-effect transistor biosensor. *Sensors and Actuators B-Chemical* 264:344–352.
- Ma, X., X. Jiao, J. Wu, J. Zhao, Y. Xu, T. Liu, J. Xu, L. Yang, and L. Dong. 2018c. The Function of *Ophiocordyceps sinensis* in Airway Epithelial Cell Senescence in a Rat COPD Model. *Canadian Respiratory Journal*:6080348.
- Maczey, N., K. Dhendup, P. Cannon, N. Hywel-Jones, and T. B. Rai. 2010. *Thitarodes namnai* sp nov and *T. caligophilus* sp nov (Lepidoptera: Hepialidae), hosts of the economically important entomopathogenic fungus *Ophiocordyceps sinensis* in Bhutan. *Zootaxa*:42–52.
- Maggiwar, S. B., D. N. Dhanraj, S. M. Somani, and V. Ramkumar. 1994. Adenosine acts as an endogenous activator of the cellular antioxidant defense system. *Biochemical and Biophysical Research Communications* 201:508–515.
- Ma u ká, L. U., Z. Bedlovi ová, and J. Harvanová. 2017. *Cordyceps Sinensis*: Medicinal fungus of Chinese medicine [*Cordyceps Sinensis*: Lie ivá huba ínskej medicíny]. *Chemicke Listy* 111:35–40.
- Mamta, S. Mehrotra, Amitabh, V. Kirar, P. Vats, S. P. Nandi, P. S. Negi, and K. Misra. 2015. Phytochemical and antimicrobial activities of Himalayan *Cordyceps sinensis* (Berk.) Sacc. *Indian Journal of Experimental Biology* 53:36–43.
- Manabe, N., M. Sugimoto, Y. Azuma, N. Taketomo, A. Yamashita, H. Tsuboi, A. Tsunoo, N. Kinjo, H. Nian-Lai, and H. Miyamoto. 1996. Effects of the Mycelial Extract of Cultured *Cordyceps Sinensis* on In Vivo Hepatic Energy Metabolism in the Mouse. *The Japanese Journal of Pharmacology* 70:85–88.
- Manabe, N., Y. Azuma, M. Sugimoto, K. Uchio, M. Miyamoto, N. Taketomo, H. Tsuchita, and H. Miyamoto. 2000. Effects of the mycelial extract of cultured *Cordyceps sinensis* on in vivo hepatic energy metabolism and blood flow in dietary hypoferric anaemic mice. *British Journal of Nutrition* 83:197–204.
- Mang, C.-Y., C.-P. Liu, G.-M. Liu, B. Jiang, H. Lan, K.-C. Wu, Y. Yan, H.-F. Li, M.-H. Yang, and Y. Zhao. 2015. Theoretical searches and spectral computations of preferred conformations of various absolute configurations for a cyclodipeptide, cordycedipeptide A from the culture liquid of *Cordyceps sinensis*. *Spectrochimica Acta Part a-Molecular and Biomolecular Spectroscopy* 136:1401–1408.

- Marchbank, T., E. Ojobo, C. J. Playford, and R. J. Playford. 2011. Reparative properties of the traditional Chinese medicine *Cordyceps sinensis* (Chinese caterpillar mushroom) using HT29 cell culture and rat gastric damage models of injury. *British Journal of Nutrition* 105:1303–1310.
- Martel, J., Y.-F. Ko, J.-C. Liau, C.-S. Lee, D. M. Ojcius, H.-C. Lai, and J. D. Young. 2017. Myths and Realities Surrounding the Mysterious Caterpillar Fungus. *Trends in Biotechnology* 35:1017–1021.
- Matsuda, H., J. Akaki, S. Nakamura, Y. Okazaki, H. Kojima, M. Tamesada, and M. Yoshikawa. 2009. Apoptosis-Inducing Effects of Sterols from the Dried Powder of Cultured Mycelium of *Cordyceps sinensis*. *Chemical & Pharmaceutical Bulletin* 57:411–414.
- Matsuda, H., J. Akaki, S. Nakamura, Y. Okazaki, H. Kojima, M. Tamesada, and M. Yoshikawa. 2009. Apoptosis-inducing effects of sterols from the dried powder of cultured mycelium of *Cordyceps sinensis*. *Chemical & Pharmaceutical Bulletin* 57:411–414.
- Meena, H., K. P. Singh, P. S. Negi, and M. Nasim. 2014. Anti-stress and muscular endurance effects of natural specimens and laboratory cultured mycelia of *Ophiocordyceps sinensis* (Berk.) G.H. Sung, J.M. Sung on rats and mice. *Indian Journal of Natural Products and Resources* 5:228–236.
- Meena, H., K. P. Singh, P. S. Negi, and Z. Ahmed. 2013. Sub-acute toxicity of cultured mycelia of Himalayan entomogenous fungus *Cordyceps sinensis* (Berk.) Sacc. in rats. *Indian Journal of Experimental Biology* 51:381–387.
- Meena, H., M. Mohsin, H. K. Pandey, P. S. Negi, and Z. Ahmed. 2010. Estimation of cordycepin by improved HPLC method in the natural and cultured mycelia of high medicinal value Himalayan entomogenous fungus *Cordyceps sinensis*. *Electronic Journal of Environmental, Agricultural and Food Chemistry* 9:1598–1603.
- Mei, Q. B., J. Y. Tao, S. B. Gao, G. C. Xu, L. M. Chen, and J. K. Su. 1989. Antiarrhythmic effects of *Cordyceps sinensis* (Berk.) Sacc. *Zhongguo zhong yao za zhi = Zhongguo zhongyao zazhi = China journal of Chinese materia medica* 14:616–618, 640.
- Mei, Y., W. Yang, P. Zhu, N. Peng, H. Zhu, and Y. Liang. 2014. Isolation, Characterization, and Antitumor Activity of a Novel Heteroglycan from Cultured Mycelia of *Cordyceps sinensis*. *Planta Medica* 80:1107–1112.
- Meng, L.-Z., B.-Q. Lin, B. Wang, K. Feng, D.-J. Hu, L.-Y. Wang, K.-L. Cheong, J. Zhao, and S.-P. Li. 2013. Mycelia extracts of fungal strains isolated from *Cordyceps sinensis* differently enhance the function of RAW 264.7 macrophages. *Journal of Ethnopharmacology* 148:818–825.
- Meng, L.-Z., K. Feng, L.-Y. Wang, K.-L. Cheong, H. Nie, J. Zhao, and S.-P. Li. 2014. Activation of mouse macrophages and dendritic cells induced by polysaccharides from a novel *Cordyceps sinensis* fungus UM01. *Journal of Functional Foods* 9:242–253.
- Meng, Q., H.-Y. Yu, H. Zhang, W. Zhu, M.-L. Wang, J.-H. Zhang, G.-L. Zhou, X. Li, Q.-L. Qin, S.-N. Hu, and Z. Zou. 2015. Transcriptomic insight into the immune defenses in the ghost moth, *Hepialus xiaojinensis*, during an *Ophiocordyceps sinensis* fungal infection. *Insect Biochemistry and Molecular Biology* 64:1–15.
- Min, Q., S. Cheng, J. Xi, J. Ma, T. Xin, B. Xia, and Z. Zou. 2016. Expression Patterns of Three Genes Under Short and Long Term Cold Exposure in *Thitarodes Pui* (Lepidoptera: Hepialidae), a Host of *Ophiocordyceps Sinensis*. *Cryoletters* 37:432–439.
- Mishra, J., R. Rajput, K. Singh, A. Bansal, and K. Misra. 2019. Antioxidant-Rich Peptide Fractions Derived from High-Altitude Chinese Caterpillar Medicinal Mushroom *Ophiocordyceps sinensis* (Ascomycetes) Inhibit Bacterial Pathogens. *International Journal of Medicinal Mushrooms* 21:155–168.
- Miyazaki, T., N. Oikawa, and H. Yamada. 1977. Studies on Fungal Polysaccharides .20. Galactomannan of *Cordyceps-Sinensis*. *Chemical & Pharmaceutical Bulletin* 25:3324–3328.

- Mizuha, Y., H. Yamamoto, T. Sato, M. Tsuji, M. Masuda, M. Uchida, K. Sakai, Y. Taketani, K. Yasutomo, H. Sasaki, and E. Takeda. 2007. Water extract of *Cordyceps sinensis* (WECS) inhibits the RANKL-induced osteoclast differentiation. *Biofactors* 30:105–116.
- Mu, W., Y.-L. Song, S. Zhang, L. Zhang, M. Fu, and H.-C. Shang. 2013. *Cordyceps sinensis* for chronic obstructive pulmonary diseases: A systematic review. *Chinese Journal of Evidence-Based Medicine* 13:1373–1381.
- Nagata, A., T. Tajima, and M. Uchida. 2006. Supplemental anti-fatigue effects of *Cordyceps sinensis* (Tochu-Kaso) extract powder during three stepwise exercise of human. *Japanese Journal of Physical Fitness and Sports Medicine* 55:145–151.
- Nakajima, R., N. Matsumoto, M. Matsumoto, A. Morita, M. Takamura, H. Tsunoo, M. Arita, M. Uchida, and Y. Kudo. 2002. The protective effects of *Cordyceps sinensis* extract on ischemia-induced brain edema. *Japanese Journal of Pharmacology* 88:96P-96P.
- Nakamiya, K., S. Hashimoto, H. Ito, J. S. Edmonds, A. Yasuhara, and M. Morita. 2005. Degradation of dioxins by cyclic ether degrading fungus, *Cordyceps sinensis*. *Fems Microbiology Letters* 248:17–22.
- Nakamura, K., K. Konoha, Y. Yamaguchi, S. Kagota, K. Shinozuka, and M. Kunitomo. 2003. Combined effects of *Cordyceps sinensis* and methotrexate on hematogenic lung metastasis in mice. *Receptors and Channels* 9:329–334.
- Nakamura, K., K. Shinozuka, and N. Yoshikawa. 2015. Anticancer and antimetastatic effects of cordycepin, an active component of *Cordyceps sinensis*. *Journal of Pharmacological Sciences* 127:53–56.
- Nakamura, K., Y. Yamaguchi, S. Kagota, K. Shinozuka, and M. Kunitomo. 1999b. Activation of In Vivo Kupffer Cell Function by Oral Administration of *Cordyceps sinensis* in Rats. *The Japanese Journal of Pharmacology* 79:505–508.
- Nakamura, K., Y. Yamaguchi, S. Kagota, Y. M. Kwon, K. Shinozuka, and M. Kunitomo. 1999a. Inhibitory Effect of *Cordyceps sinensis* on Spontaneous Liver Metastasis of Lewis Lung Carcinoma and B16 Melanoma Cells in Syngeneic Mice. *The Japanese Journal of Pharmacology* 79:335–341.
- Negi, C. S. 2009. Habitat ecology, biochemical analysis and pharmacological tests of crude extracts of Yar tsa Gumba (*Cordyceps sinensis* Berk.). *The Botanica* 57:71–79.
- Negi, C. S., M. Pant, P. Joshi, and S. Bohra. 2014. Yar tsa Gunbu [*Ophiocordyceps sinensis* (Berk.) G.H. Sung et al.]: The issue of its sustainability. *Current Science* 107:882–887.
- Negi, C. S., M. Pant, P. Joshi, and S. Bohra. 2014. Yar tsa Gunbu [*Ophiocordyceps sinensis* (Berk.) G.H. Sung et al.]: the issue of its sustainability. *Current Science* 107:882–887.
- Negi, C. S., P. Joshi, and S. Bohra. 2015. Rapid Vulnerability Assessment of Yartsa Gunbu (*Ophiocordyceps sinensis* [Berk.] GH Sung et al) in Pithoragarh District, Uttarakhand State, India. *Mountain Research and Development* 35:382–391.
- Negi, C. S., P. R. Koranga, and H. S. Ghinga. 2006. Yar tsa Gumba (*Cordyceps sinensis*): A call for its sustainable exploitation. *International Journal of Sustainable Development and World Ecology* 13:165–172.
- Negi, V. S., B.C. Joshi, R. Pathak, R. S. Rawal, and K. C. Sekar. 2018b. Assessment of fuelwood diversity and consumption patterns in cold desert part of Indian Himalaya: Implication for conservation and quality of life. *Journal of Cleaner Production* 196:23–31.
- Negi, V. S., P. Kewlani, R. Pathak, D. Bhatt, I. D. Bhatt, R. S. Rawal, R. C. Sundriyal, and S. K. Nandi. 2018a. Criteria and indicators for promoting cultivation and conservation of Medicinal and Aromatic Plants in Western Himalaya, India. *Ecological Indicators* 93:434–446.
- Negi, V. S., R. K. Maikhuri, and L. S. Rawat. 2011. Non-timber forest products (NTFPs): a viable option for biodiversity conservation and livelihood enhancement in central Himalaya. *Biodiversity and Conservation* 20:545–559.

- Ng, T. B., J. H. Wong, and E. F. Fang. 2013. Recent Research on Pharmacological Activities of the Medicinal Fungus *Cordyceps sinensis*. Pages 303–314 *Antitumor Potential and Other Emerging Medicinal Properties of Natural Compounds*. Springer, Netherlands.
- Nie, S., S. W. Cui, M. Xie, A. O. Phillips, and G. O. Phillips. 2013. Bioactive polysaccharides from *Cordyceps sinensis*: Isolation, structure features and bioactivities. *Bioactive Carbohydrates and Dietary Fibre* 1:38–52.
- Nie, S.P., S. W. Cui, A. O. Phillips, M.Y. Xie, G. O. Phillips, S. Al-Assaf, and X.L. Zhang. 2011. Elucidation of the structure of a bioactive hydrophilic polysaccharide from *Cordyceps sinensis* by methylation analysis and NMR spectroscopy. *Carbohydrate Polymers* 84:894–899.
- Nishizawa, K., K. Torii, A. Kawasaki, M. Katada, M. Ito, K. Terashita, S. Aiso, and M. Matsuoka. 2007. Antidepressant-like effect of *cordyceps sinensis* in the mouse tail suspension test. *Biological & Pharmaceutical Bulletin* 30:1758–1762.
- Niwa, Y., H. Matsuura, M. Murakami, J. Sato, K. Hirai, and H. Sumi. 2013. Evidence That Naturopathic Therapy Including *Cordyceps sinensis* Prolongs Survival of Patients With Hepatocellular Carcinoma. *Integrative Cancer Therapies* 12:50–68.
- Ohkuma, S., M. Katsura, Y. Hibino, A. Hara, K. Shirotani, E. Ishikawa, and K. Kuriyama. 1998. Mechanisms for facilitation of nitric oxide-evoked [3H]GABA release by removal of hydroxyl radical. *Journal of Neurochemistry* 71:1501–1510.
- Ong, B. Y., and Z. Aziz. 2017. Efficacy of *Cordyceps sinensis* as an adjunctive treatment in kidney transplant patients: A systematic-review and meta-analysis. *Complementary Therapies in Medicine* 30:84–92.
- Ong, B.Y. and Z. Aziz. 2019. Efficacy of *Cordyceps sinensis* as an adjunctive treatment in hemodialysis patients: a systematic review and Meta-analysis. *Journal of Traditional Chinese Medicine* 39:1–14.
- Osathanunkul, M., K. Osathanunkul, S. Wongwanakul, R. Osathanunkul, and P. Madesis. 2018. Multiuse of Bar-HRM for *Ophiocordyceps sinensis* identification and authentication. *Scientific Reports* 8:12770.
- Pal, M., A. Bhardwaj, M. Manickam, R. Tulsawani, M. Srivastava, R. Sugadev, and K. Misra. 2015. Protective Efficacy of the Caterpillar Mushroom, *Ophiocordyceps sinensis* (Ascomycetes), from India in Neuronal Hippocampal Cells against Hypoxia. *International Journal of Medicinal Mushrooms* 17:829–840.
- Pan, J., Y. Zhao, L. Fan, A. Zhang, Z. Zhang, and T. Bao. 1989. Inhibitory Effect of *Cordyceps Sinensis* on Aggregation of Human-Platelets. *Thrombosis and Haemostasis* 62:555–555.
- Pan, M.M., M.H. Zhang, H.F. Ni, J.F. Chen, M. Xu, A. O. Phillips and B.C. Liu. 2013b. Inhibition of TGF-beta 1/Smad signal pathway is involved in the effect of *Cordyceps sinensis* against renal fibrosis in 5/6 nephrectomy rats. *Food and Chemical Toxicology* 58:487–494.
- Pan, M.M., M.H. Zhang, H.F. Ni, J.F. Chen, M. Xu, and B.C. Liu. 2013a. The Effects of *Cordyceps Sinensis* on Renal Fibrosis in 5/6 Subtotal Nephrectomy Rats and Its Possible Mechanisms. *Nephrology Dialysis Transplantation* 28:106–107.
- Panda, A. K., and K. C. Swain. 2011. Traditional uses and medicinal potential of *Cordyceps sinensis* of Sikkim. *Journal of Ayurveda and Integrative Medicine* 2:9–13.
- Pant, B., R. Rai, C. Wallrapp, R. Ghate, U. Shrestha, and A. Ram. 2017. Horizontal integration of multiple institutions: solutions for Yarshagumba related conflict in the Himalayan region of Nepal? *International Journal of the Commons* 11:464–486.
- Pant, G. C., and A. Tewari. 2014. Contribution of *Ophiocordyceps Sinensis* (Berk.) Sung et Al. (*Yarsa Gumba*) in the Livelihood of Rural Communities in Kumaun Himalaya: Management and Conservation Issues. *Indian Forester* 140:384-388–388.
- Parcell, A. C., J. M. Smith, S. S. Schulthies, J. W. Myrer, and G. Fellingham. 2004. *Cordyceps sinensis* (CordyMax Cs-4) supplementation does not improve endurance exercise performance. *International Journal of Sport Nutrition and Exercise Metabolism* 14:236–242.

- Park, D. K., W. S. Choi, P.-J. Park, E. K. Kim, Y. J. Jeong, S. Y. Choi, K. Yamada, J. D. Kim, and B. O. Lim. 2008. Immunoglobulin and Cytokine Production from Mesenteric Lymph Node Lymphocytes Is Regulated by Extracts of *Cordyceps sinensis* in C57B1/6N Mice. *Journal of Medicinal Food* 11:784–788.
- Pegler, D. N., Y.-J. Yao, and Y. Li. 1994. The Chinese ‘Caterpillar Fungus.’ *Mycologist* 8:3–5.
- Pelleg, A., and R. S. Porter. 1990. The Pharmacology of Adenosine. *Pharmacotherapy: The Journal of Human Pharmacology and Drug Therapy* 10:157–174.
- Peng, J., X. Li, Q. Feng, L. Chen, L. Xu, and Y. Hu. 2013a. Anti-fibrotic effect of *Cordyceps sinensis* polysaccharide: Inhibiting HSC activation, TGF-beta 1/Smad signalling, MMPs and TIMPs. *Experimental Biology and Medicine* 238:668–677.
- Peng, Q., X. Zhong, W. Lei, G. Zhang, and X. Liu. 2013b. Detection of *Ophiocordyceps sinensis* in soil by quantitative real-time PCR. *Canadian Journal of Microbiology* 59:204–209.
- Peng, Y., K. Huang, L. Shen, Y. Tao, and C. Liu. 2016. Cultured Mycelium *Cordyceps sinensis* alleviates CCl4-induced liver inflammation and fibrosis in mice by activating hepatic natural killer cells. *Acta Pharmacologica Sinica* 37:204–216.
- Peng, Y., Q. Chen, T. Yang, Y. Tao, X. Lu, and C. Liu. 2014a. Cultured mycelium *Cordyceps sinensis* protects liver sinusoidal endothelial cells in acute liver injured mice. *Molecular Biology Reports* 41:1815–1827.
- Peng, Y., Y. Tao, Q. Wang, L. Shen, T. Yang, Z. Liu, and C. Liu. 2014b. Ergosterol Is the Active Compound of Cultured Mycelium *Cordyceps sinensis* on Antiliver Fibrosis. *Evidence-Based Complementary and Alternative Medicine*:537234.
- Pouliot, M., and T. Treue. 2013. Rural People’s Reliance on Forests and the Non-Forest Environment in West Africa: Evidence from Ghana and Burkina Faso. *World Development* 43:180–193.
- Pouliot, M., D. Pyakurel, and C. Smith-Hall. 2018. High altitude organic gold: The production network for *Ophiocordyceps sinensis* from far-western Nepal. *Journal of Ethnopharmacology* 218:59–68.
- Pouliot, M., D. Pyakurel, and C. Smith-Hall. 2018. High altitude organic gold: The production network for *Ophiocordyceps sinensis* from far-western Nepal. *Journal of Ethnopharmacology* 218:59–68.
- Pradhan, B. K. 2016. Caterpillar mushroom, *Ophiocordyceps sinensis* (ascomycetes): a potential bioresource for commercialization in sikkim himalaya, india. *International Journal of Medicinal Mushrooms* 18:337–346.
- Pradhan, B. K. 2016. Caterpillar mushroom, *Ophiocordyceps sinensis* (Ascomycetes): a potential bioresource for commercialization in Sikkim Himalaya, India. *International journal of medicinal mushrooms*, 18(4).
- Qi, W., P. Wang, W. Guo, Y. Yan, Y. Zhang, and W. Lei. 2011a. The Mechanism of *Cordyceps sinensis* and Strontium in Prevention of Osteoporosis in Rats. *Biological Trace Element Research* 143:302–309.
- Qi, W., Y. Yan, P. Wang, and W. Lei. 2011b. The Co-effect of *Cordyceps sinensis* and Strontium on Osteoporosis in Ovariectomized Osteopenic Rats. *Biological Trace Element Research* 141:216–223.
- Qi, W., Y. Zhang, Y. Yan, W. Lei, Z. Wu, N. Liu, S. Liu, L. Shi, and Y. Fan. 2013. The Protective Effect of Cordymin, a Peptide Purified from the Medicinal Mushroom *Cordyceps sinensis*, on Diabetic Osteopenia in Alloxan-Induced Diabetic Rats. *Evidence-Based Complementary and Alternative Medicine*:985636.
- Qi, W., Y.-B. Yan, W. Lei, Z.-X. Wu, Y. Zhang, D. Liu, L. Shi, P.-C. Cao, and N. Liu. 2012. Prevention of disuse osteoporosis in rats by *Cordyceps sinensis* extract. *Osteoporosis International* 23:2347–2357.
- Qian, G., G.-F. Pan, and J.-Y. Guo. 2012. Anti-inflammatory and antinociceptive effects of cordymin, a peptide purified from the medicinal mushroom *Cordyceps sinensis*. *Natural Product Research* 26:2358–2362.
- Qian, Z.-M., M.-T. Sun, Z. Ai, N. Liao, M.-X. Zhou, W.-J. Li, and W.-Q. Li. 2015. Simultaneous determination of three nucleosides in *Cordyceps sinensis* by QAMS. *Chinese Pharmaceutical Journal* 50:1297–1300.

- Qiao, X. Z., and Y. W. Jian. 2007. Cordyceps sinensis mycelium extract induces human premyelocytic leukemia cell apoptosis through mitochondrion pathway. *Experimental Biology and Medicine* 232:52–57.
- Qi-Qing, C., C. Chun-Song, O. Yue, L. Chi-Chou, C. Hao, X. Yu, J. Zhi-Hong, L. Wen-Jia, and Z. Hua. 2018. Discovery of differential sequences for improving breeding and yield of cultivated *Ophiocordyceps sinensis* through ITS sequencing and phylogenetic analysis. *Chinese Journal of Natural Medicines* 16:749–755.
- Quan, Q.-M., L.-L. Chen, X. Wang, S. Li, X.-L. Yang, Y.-G. Zhu, M. Wang, and Z. Cheng. 2014a. Genetic Diversity and Distribution Patterns of Host Insects of Caterpillar Fungus *Ophiocordyceps sinensis* in the Qinghai-Tibet Plateau. *Plos One* 9:e92293.
- Quan, Q.-M., Q.-X. Wang, X.-L. Zhou, S. Li, X.-L. Yang, Y.-G. Zhu, and Z. Cheng. 2014b. Comparative Phylogenetic Relationships and Genetic Structure of the Caterpillar Fungus *Ophiocordyceps sinensis* and Its Host Insects Inferred from Multiple Gene Sequences. *Journal of Microbiology* 52:99–105.
- Rao, Y. K., S.-H. Fang, and Y.-M. Tzeng. 2007. Evaluation of the anti-inflammatory and anti-proliferation tumoral cells activities of *Antrodia camphorata*, *Cordyceps sinensis*, and *Cinnamomum osmophloeum* bark extracts. *Journal of Ethnopharmacology* 114:78–85.
- Rathor, R., K. R. Mishra, M. Pal, Amitabh, P. Vats, V. Kirar, P. S. Negi, and K. Misra. 2014. Scientific Validation of the Chinese Caterpillar Medicinal Mushroom, *Ophiocordyceps sinensis* (Ascomycetes) from India: Immunomodulatory and Antioxidant Activity. *International Journal of Medicinal Mushrooms* 16:541–553.
- Ren, S.-Y., and Y.-J. Yao. 2013. Evaluation of nutritional and physical stress conditions during vegetative growth on conidial production and germination in *Ophiocordyceps sinensis*. *Fems Microbiology Letters* 346:29–35.
- Ren, Y., Y. Qiu, D.-G. Wan, X.-M. Lu, and J.-L. Guo. 2013. Preliminary study on correlation between diversity of soluble proteins and producing area of *Cordyceps sinensis*. *Zhongguo Zhongyao Zazhi* 38:1375–1377.
- Renhe, X., and P. Xiang'e. 1988. Effects of cordyceps sinensis on natural killer activity and formation of Lewis lung carcinoma colonies. *Bulletin of Hunan Medical College* 13:107–111.
- Ribeiro, J. A. 1995. Purinergic inhibition of neurotransmitter release in the central nervous system. *Pharmacology & Toxicology* 77:299–305.
- Rossi, P., D. Buonocore, E. Altobelli, F. Brandalise, V. Cesaroni, D. Iozzi, E. Savino, and F. Marzatico. 2014. Improving Training Condition Assessment in Endurance Cyclists: Effects of *Ganoderma lucidum* and *Ophiocordyceps sinensis* Dietary Supplementation. *Evidence-Based Complementary and Alternative Medicine*:979613.
- Sangeetha, C., A. S. Krishnamoorthy, N. K. Kumar, and I. A. Pravin. 2018. Effect of headspace and trapped volatile organic compounds (vocs) of the chinese caterpillar mushroom, *Ophiocordyceps sinensis* (ascomycetes), against soil-borne plant pathogens. *International Journal of Medicinal Mushrooms* 20:825–835.
- Sangeetha, C., A. S. Krishnamoorthy, S. Nakkeeran, S. Ramakrishnan, and D. Amirtham. 2015. Evaluation of bioactive compounds of *Ophiocordyceps sinensis* [Berk.] Sacc. against *Fusarium* spp. *Biochemical and Cellular Archives* 15:431–435.
- Seth, R., S. Z. Haider, and M. Mohan. 2014. Pharmacology, phytochemistry and traditional uses of *Cordyceps sinensis* (Berk.) Sacc: A recent update for future prospects. *Indian Journal of Traditional Knowledge* 13:551–556.
- Seth, R., S. Z. Haider, and M. Mohan. 2014. Pharmacology, phytochemistry and traditional uses of *Cordyceps sinensis* (Berk.) Sacc: A recent update for future prospects. *Indian Journal of Traditional Knowledge* 13:6.
- Shahed, A. R., S. I. Kim, and D. A. Shoskes. 2001. Down-regulation of apoptotic and inflammatory genes by cordyceps sinensis extract in rat kidney following ischemia/reperfusion. *Transplantation Proceedings* 33:2986–2987.
- ShaoPeng, Z., F. Hui, L. XiaoYan, J. YongSan, and D. Wei. 2010. Genome research profile of two *Cordyceps sinensis* cDNA libraries. *Chinese Science Bulletin* 55:1403–1411.

- Sharma, S. 2004. Trade of *Cordyceps sinensis* from high altitudes of the Indian Himalaya: Conservation and biotechnological priorities. *Current Science* 86:1614–1619.
- Shashidhar, G. M., and B. Manohar. 2018. Nanocharacterization of liposomes for the encapsulation of water soluble compounds from *Cordyceps sinensis* CS1197 by a supercritical gas anti-solvent technique. *Rsc Advances* 8:34634–34649.
- Shashidhar, G. M., P. Giridhar, and B. Manohar. 2015. Functional polysaccharides from medicinal mushroom *Cordyceps sinensis* as a potent food supplement: extraction, characterization and therapeutic potentials - a systematic review. *Rsc Advances* 5:16050–16066.
- Shashidhar, G. M., S. S. Kumar, P. Giridhar, and B. Manohar. 2017. Antioxidant and Cholesterol Esterase Inhibitory Properties of Supplementation with Coconut Water in Submerged Cultivation of the Medicinal Chinese Caterpillar Mushroom, *Ophiocordyceps sinensis* CS1197 (Ascomycetes). *International Journal of Medicinal Mushrooms* 19:337–345.
- Shashidhar, M. G., and B. Manohar. 2016. Acidified Hot Water Extraction of Adenosine, Cordycepin, and Polysaccharides from the Chinese Caterpillar Mushroom, *Ophiocordyceps sinensis* CS1197 (Ascomycetes): Application of an Artificial Neural Network and Evaluation of Antioxidant and Antibacterial Activities. *International Journal of Medicinal Mushrooms* 18:915–926.
- Shashidhar, M. G., P. Giridhar, K. U. Sankar, and B. Manohar. 2013. Bioactive principles from *Cordyceps sinensis*: A potent food supplement - A review. *Journal of Functional Foods* 5:1013–1030.
- Shen, Y. D., X. T. Shao, Y. D. Ni, H. Xu, and X. M. Tong. 2009. *Cordyceps sinensis* polysaccharide enhances apoptosis of HL-60 cells induced by triptolide. *Zhejiang da xue xue bao. Yi xue ban = Journal of Zhejiang University. Medical sciences* 38:158–162.
- Sheng, L., J. Chen, J. Li, and W. Zhang. 2011. An Exopolysaccharide from Cultivated *Cordyceps sinensis* and its Effects on Cytokine Expressions of Immunocytes. *Applied Biochemistry and Biotechnology* 163:669–678.
- Shi, B., Z. Wang, H. Jin, Y. W. Chen, Q. Wang, and Y. Qian. 2009. Immunoregulatory *Cordyceps sinensis* increases regulatory T cells to Th17 cell ratio and delays diabetes in NOD mice. *International Immunopharmacology* 9:582–586.
- Shi, P., Z. Lu, Y. He, S. Chen, J. Yan, J. Li, and X. Zhang. 2015. Molecular Cloning and Characterization of a Subtilisin-Like Serine Protease Gene (Pr1) from the Medicinal Chinese Caterpillar Mushroom, *Ophiocordyceps sinensis* (Ascomycetes). *International Journal of Medicinal Mushrooms* 17:1087–1093.
- Shi, P., Z. Lu, Y. He, S. Chen, S. Qin, Y. Qing, and J. Yan. 2016. Complete mitochondrial genome of *Hepialus gonggaensis* (Lepidoptera: Hepialidae), the host insect of *Ophiocordyceps sinensis*. *Mitochondrial Dna Part A* 27:4205–4206.
- Shi, S. M., W. Z. Nan, L. L. Juian, L. J. Yea, and W. J. Jen. 1994. Profiles of nucleosides and nitrogen bases in Chinese medicinal fungus *Cordyceps sinensis* and related species. *Botanical Bulletin of Academia Sinica* 35:261–267.
- Shiao, M., Z. Wang, L. Lin, J. Lien, and J. Wang. 1994. Profiles of Nucleosides and Nitrogen Bases in Chinese Medicinal Fungus *Cordyceps Sinensis* and Related Species. *Botanical Bulletin of Academia Sinica* 35:261–267.
- Shiwei, H., W. Jingfeng, L. Zhaojie, F. Jia, W. Yuming, and X. Changhu. 2014. Hpyerglycemic effect of a mixture of sea cucumber and *cordyceps sinensis* in streptozotocin-induced diabetic rat. *Journal of Ocean University of China* 13:271–277.
- Shoji, O. 2015. Charm of *Cordyceps sinensis*. *Seibutsu-kogaku Kaishi* 93:769–773.
- Shrestha, B., and J.-M. Sung. 2005. Notes on *Cordyceps* species Collected from the Central Region of Nepal. *Mycobiology* 33:235–239.
- Shrestha, B., W. Zhang, Y. Zhang, and X. Liu. 2010. What is the Chinese caterpillar fungus *Ophiocordyceps sinensis* (Ophiocordycipitaceae)? *Mycology* 1:228–236.

- Shrestha, U. B., and K. S. Bawa. 2013a. Trade, harvest, and conservation of caterpillar fungus (*Ophiocordyceps sinensis*) in the Himalayas. *Biological Conservation* 159:514–520.
- Shrestha, U. B., and K. S. Bawa. 2013b. Dimensions of caterpillar fungus (*Ophiocordyceps sinensis*) decline-A response to Stewart et al. *Biological Conservation* 167:448–449.
- Shrestha, U. B., and K. S. Bawa. 2014a. Economic contribution of Chinese caterpillar fungus to the livelihoods of mountain communities in Nepal. *Biological Conservation* 177:194–202.
- Shrestha, U. B., and K. S. Bawa. 2014b. Impact of Climate Change on Potential Distribution of Chinese Caterpillar Fungus (*Ophiocordyceps sinensis*) in Nepal Himalaya. *Plos One* 9:e106405.
- Shrestha, U. B., and K. S. Bawa. 2015. Harvesters' perceptions of population status and conservation of Chinese caterpillar fungus in the Dolpa region of Nepal. *Regional Environmental Change* 15:1731–1741.
- Shrestha, U. B., K. R. Dhital, and A. P. Gautam. 2019. Economic dependence of mountain communities on Chinese caterpillar fungus *Ophiocordyceps sinensis* (yarsagumba): a case from western Nepal. *Oryx* 53:256–264.
- Shrestha, U. B., K. R. Dhital, and A. P. Gautam. 2019. Economic dependence of mountain communities on Chinese caterpillar fungus *Ophiocordyceps sinensis* (yarsagumba): a case from western Nepal. *Oryx* 53:256–264.
- Shrestha, U. B., S. Shrestha, S. Ghimire, K. Nepali, and B. B. Shrestha. 2014. Chasing Chinese Caterpillar Fungus (*Ophiocordyceps sinensis*) Harvesters in the Himalayas: Harvesting Practice and Its Conservation Implications in Western Nepal. *Society & Natural Resources* 27:1242–1256.
- Sigdel, S. R., M. B. Rokaya, Z. Munzbergova, and E. Liang. 2017. Habitat Ecology of *Ophiocordyceps sinensis* in Western Nepal. *Mountain Research and Development* 37:216–223.
- Singh, K. P., H. S. Meena, and P. S. Negi. 2014a. Enhancement of Neuromuscular Activity by Natural Specimens and Cultured Mycelia of *Cordyceps sinensis* in Mice. *Indian Journal of Pharmaceutical Sciences* 76:458–461.
- Singh, M., R. Tulsawani, P. Koganti, A. Chauhan, M. Manickam, and K. Misra. 2013. *Cordyceps sinensis* Increases Hypoxia Tolerance by Inducing Heme Oxygenase-1 and Metallothionein via Nrf2 Activation in Human Lung Epithelial Cells. *Biomed Research International*:569206.
- Singh, R., P. S. Negi, and S. K. Dwivedi. 2018. *Ophiocordyceps sinensis*: The medicinal caterpillar mushroom. Pages 15–133 *New Age Herbs: Resource, Quality and Pharmacognosy*. Springer Singapore.
- Singh, R., P. S. Negi, and Z. Ahmed. 2010. *Ophiocordyceps sinensis* - valuable caterpillar fungus from the Himalayan hills. *Current Science* 99:865–865.
- Singh, S., P. S. Negi, M. Arif, and M. Nasim. 2014b. Studies on the evaluation of bio-active compounds in wild specimen, in vitro cultured mycelium, stromae and insect host of *ophiocordyceps sinensis*. *Biochemical and Cellular Archives* 14:109–117.
- Sirisidthi, K., P. Kosai, and W. Jiraungkoorskul. 2015. Antihyperglycemic activity of *Ophiocordyceps sinensis*: A Review. *Indian Journal of Agricultural Research* 49:400–406.
- Smirnov, D. A., V. G. Babitskaya, T. A. Puchkova, V. V. Shcherba, N. A. Bisko, and N. L. Poyedinok. 2009. Some Biologically Active Substances from a Mycelial Biomass of Medicinal Caterpillar Fungus *Cordyceps sinensis* (Berk.) Sacc. (Ascomycetes). *International Journal of Medicinal Mushrooms* 11:69–76.
- Smith, J. E., N. J. Rowan, and R. Sullivan. 2002. Medicinal mushrooms: a rapidly developing area of biotechnology for cancer therapy and other bioactivities. *Biotechnology Letters* 24:1839–1845.
- Soltani, M., H. Kamyab, and H. A. El-Enshasy. 2013. Molecular Weight (Mw) and Monosaccharide Composition (MC): Two Major Factors Affecting the Therapeutic Action of Polysaccharides Extracted from *Cordyceps sinensis*-Mini Review. *Journal of Pure and Applied Microbiology* 7:1601–1613.

- Song, A.-X., Y.-H. Mao, K.-C. Siu, and J.-Y. Wu. 2018. Bifidogenic effects of *Cordyceps sinensis* fungal exopolysaccharide and konjac glucomannan after ultrasound and acid degradation. *International Journal of Biological Macromolecules* 111:587–594.
- Song, D., J. Lin, F. Yuan, and W. Zhang. 2011. Ex vivo stimulation of murine dendritic cells by an exopolysaccharide from one of the anamorph of *Cordyceps sinensis*. *Cell Biochemistry and Function* 29:555–561.
- Song, D., Z. He, C. Wang, F. Yuan, P. Dong, and W. Zhang. 2013. Regulation of the exopolysaccharide from an anamorph of *Cordyceps sinensis* on dendritic cell sarcoma (DCS) cell line. *European Journal of Nutrition* 52:687–694.
- Song, L.-Q., Y. Si-Ming, M. Xiao-Peng, and J. Li-Xia. 2010. The protective effects of *Cordyceps sinensis* extract on extracellular matrix accumulation of glomerular sclerosis in rats. *African Journal of Pharmacy and Pharmacology* 4:471–478.
- Stensrud, O., T. Schumacher, K. Shalchian-Tabrizi, I. B. Svegarden, and H. Kauserud. 2007. Accelerated nrDNA evolution and profound AT bias in the medicinal fungus *Cordyceps sinensis*. *Mycological Research* 111:409–415.
- Stewart, M. O. 2014. Constructing and deconstructing the commons: Caterpillar fungus governance in developing yunnan. Pages 175–197 *Mapping Shangrila: Contested Landscapes in the Sino-Tibetan Borderlands*.
- Stewart, M. O., K. E. Bushley, and Y. Yongping. 2013. Regarding the social-ecological dimensions of caterpillar fungus (*Ophiocordyceps sinensis*) in the Himalayas - Reply to Shrestha and Bawa. *Biological Conservation* 167:446–447.
- Su, C. L., B. J. Wang, Z. R. Yu, and S. J. Won. 2004. Induction of apoptosis in human colorectal carcinoma cells by *Cordyceps sinensis* from supercritical fluid extractive fractionation. *Faseb Journal* 18:A888–A888.
- Su, C. L., Z. R. Yu, B. J. Wang, and S. J. Won. 2003. The extracts of *Cordyceps sinensis* exhibited cytotoxicity by altering cell cycle and inducing apoptosis in human hepatocellular carcinoma. *Faseb Journal* 17:A1155–A1155.
- Su, N.-W., S.-H. Wu, C.-W. Chi, T.-H. Tsai, and Y.-J. Chen. 2019. Cordycepin, isolated from medicinal fungus *Cordyceps sinensis*, enhances radiosensitivity of oral cancer associated with modulation of DNA damage repair. *Food and Chemical Toxicology* 124:400–410.
- Sulek, E. 2010. Disappearing sheep: The unexpected consequences of the emergence of the caterpillar fungus economy in Golok, Qinghai, China. *Himalaya* 30:9–22.
- Sulek, E. R. 2016. Caterpillar fungus and the economy of sinning. On entangled relations between religious and economic in a Tibetan pastoral region of golog, Qinghai, China. *Etudes Mongoles et Siberiennes, Centrasiatiques et Tibetaines* 2016.
- Sun, B., M. Luo, H. Xun, and C. Liu. 2006. Effects of *Cordyceps Sinensis* on hepatic steato fibrosis in rats. *Journal of Gastroenterology and Hepatology* 21:A154–A154.
- Sun, F., Q. Huang, and J. Wu. 2014. Rheological behaviors of an exopolysaccharide from fermentation medium of a *Cordyceps sinensis* fungus (Cs-HK1). *Carbohydrate Polymers* 114:506–513.
- Sun, S., J. Xie, T. Peng, B. Shao, K. Zhu, Y. Sun, K. Yao, Q. Gu, J. Zhang, C. Fan, Y. Chen, and H. Jiang. 2017a. Broad-spectrum immunoaffinity cleanup for the determination of aflatoxins B-1, B-2, G(1), G(2), M-1, M-2 in *Ophiocordyceps sinensis* and its pharmaceutical preparations by ultra performance liquid chromatography tandem mass spectrometry. *Journal of Chromatography B-Analytical Technologies in the Biomedical and Life Sciences* 1068:112–118.
- Sun, X., H.-L. Liu, K. Huang, Z.-M. Zhao, J. Lv, and C.-H. Liu. 2017b. Effects of three active components in *Cordyceps sinensis* regulating liver endothelial cells functions based on angiogenesis [3]. *Chinese Traditional and Herbal Drugs* 48:5217–5223.
- Sun, X., Z. Do, N. Li, X. Feng, Y. Liu, A. Li, X. Zhu, C. Li, and Z. Zhao. 2018. Nucleosides isolated from *Ophiocordyceps sinensis* inhibit cigarette smoke extract-induced inflammation via the SIRT1-nuclear factor-kappa B/p65 pathway in RA W264.7 macrophages and in COPD mice. *International Journal of Chronic Obstructive Pulmonary Disease* 13:2821–2832.

- Sun, Y. H. 1985. *Cordyceps sinensis* and cultured mycelia. *Zhong yao tong bao* (Beijing, China : 1981) 10:3–5.
- Tan, N.-Z., J. L. Barger, Y. Zhang, S. B. Ferguson, Z.-M. Wu, T. A. Prolla, M. Bartlett, and J.-S. Zhu. 2011a. *Cordyceps sinensis* Cs-4 restores aging-associated changes in gene expression and extends lifespan in normal aged mice. *Faseb Journal* 25.
- Tan, N.-Z., J. L. Barger, Y. Zhang, S. B. Ferguson, Z.-M. Wu, T. A. Prolla, M. Bartlett, and J.-S. Zhu. 2011b. The lifespan-extending effect of *Cordyceps sinensis* Cs-4 in normal mice and its molecular mechanisms. *Faseb Journal* 25.
- Tang, D.-Y., Q.-F. Hu, G.-Y. Yang, and J.-Y. Yin. 2003. HPLC determination of mannitol in *cordyceps sinensis* with solid-phase extraction. *Lihua Jianyan: Huaxue Fence/Physical Testing and Chemical Analysis Part B:Chemical Analysis* 39:585.
- Tang, L., and G. Liu. 2009. Immunosuppressive effect of *Cordyceps sinensis*: inducing the phenotypic and functional immaturities of human derived dendritic cells. *Journal of Pharmacological Sciences* 109:270P-270P.
- Tang, R., Q. Zhou, J. Shu, T. Tang, X. Ao, W. Peng, and Y. Zhang. 2009. Effect of *cordyceps sinensis* extract on Klotho expression and apoptosis in renal tubular epithelial cells induced by angiotensin II. *Journal of Central South University (Medical Sciences)* 34:300–307.
- Tao, Z., L. Cao, Y. Zhang, Y. Ye, and R. Han. 2016. Laboratory Rearing of *Thitarodes armoricanus* and *Thitarodes jianchuanensis* (Lepidoptera: Hepialidae), Hosts of the Chinese Medicinal Fungus *Ophiocordyceps sinensis* (Hypocreales: Ophiocordycipitaceae). *Journal of Economic Entomology* 109:176–181.
- Teng, I.-H., S.-D. Lee, Y.-J. Cheng, and H.-C. Ou. 2010. Protective effects of *Cordyceps sinensis* and exercise training on septic shock. *Faseb Journal* 24.
- Thakur, A., R. Hui, Z. Hongyan, Y. Tian, C. Tianjun, and C. Mingwei. 2011. Pro-apoptotic effects of *Paecilomyces hepiali*, a *Cordyceps sinensis* extract on human lung adenocarcinoma A549 cells in vitro. *Journal of Cancer Research and Therapeutics* 7:421–426.
- Thapa, B. B., S. Panthi, R. K. Rai, U. B. Shrestha, A. Aryal, S. Shrestha, and B. Shrestha. 2014. An assessment of *Yarsagumba* (*Ophiocordyceps sinensis*) collection in Dhorpatan Hunting Reserve, Nepal. *Journal of Mountain Science* 11:555–562.
- Thuy, H. L. T., C. H. Bao, T. V. T. Phuong, D. B. Lap, N. T. V. Hai, H. D. Minh, and T. N. Tien. 2018. Deproteinization in purification of exopolysaccharide from *Ophiocordyceps sinensis* olive oil - stimulated culture. *International Journal of Agricultural Technology* 14:2151–2162.
- Tiamyom, K., K. Sirichaiwetchakoon, T. Hengpratom, S. Kupittayanant, R. Srisawat, A. Thaeomor, and G. Eumkeb. 2019. The Effects of *Cordyceps sinensis* (Berk.) Sacc. and *Gymnema inodorum* (Lour.) Decne. Extracts on Adipogenesis and Lipase Activity In Vitro. *Evidence-Based Complementary and Alternative Medicine*:5370473.
- Tian, J., X. M. Chen, and L. S. Li. 1991. Effects of *Cordyceps sinensis*, rhubarb and serum renotropin on tubular epithelial cell growth. *Zhong xi yi jie he za zhi = Chinese journal of modern developments in traditional medicine / Zhongguo Zhong xi yi jie he yan jiu hui (chou), Zhong yi yan jiu yuan, zhu ban* 11:547–549, 518.
- Toda, N., H. Okunishi, K. Taniyama, and M. Miyazaki. 1982. Responses to adenine nucleotides and related compounds of isolated dog cerebral, coronary and mesenteric arteries. *Blood Vessels* 19:226–236.
- Tong, X., Y. Wang, Z. Xue, L. Chen, Y. Qiu, J. Cao, C. Peng, and J. Guo. 2018. Proteomic identification of marker proteins and its application to authenticate *Ophiocordyceps sinensis*. *3 Biotech* 8:246.
- Tsai, Y.-J., L.-C. Lin, and T.-H. Tsai. 2010. Pharmacokinetics of Adenosine and Cordycepin, a Bioactive Constituent of *Cordyceps sinensis* in Rat. *Journal of Agricultural and Food Chemistry* 58:4638–4643.
- Tsuk, S., J. H. Lev, A. Rotstein, R. Carasso, A. Zeev, Y. Netz, T. Dwolatski, and G. Steiner. 2017. Clinical Effects of a Commercial Supplement of *Ophiocordyceps sinensis* and *Ganoderma lucidum* on Cognitive Function of Healthy Young Volunteers. *International Journal of Medicinal Mushrooms* 19:667–673.

- Tsuk, S., Y. H. Lev, A. Rotstein, A. Zeev, R. Carasso, and G. Steiner. 2018. Effects of a commercial supplement of *Ophiocordyceps sinensis* and *ganoderma lucidum* on physiological responses to maximal exercise in healthy young participants. *International Journal of Medicinal Mushrooms* 20:359–367.
- Tu, S., Q. Zhou, R. Tang, T. Tang, S. Hu, and X. Ao. 2012. Proapoptotic effect of angiotensin II on renal tubular epithelial cells and protective effect of *Cordyceps sinensis*. *Journal of Central South University (Medical Sciences)* 37:67–72.
- Tuli, H. S., S. S. Sandhu, and A. K. Sharma. 2014. Pharmacological and therapeutic potential of *Cordyceps* with special reference to *Cordycepin*. *3 Biotech* 4:1–12.
- Uchida, M., M. Suzuki, and K. Shimizu. 2016. Mycelial extract of cultured *cordyceps sinensis* improves the sleep disturbance induced by placing rats on the grid suspended over water. *Japanese Pharmacology and Therapeutics* 44:881–885.
- Varshney, V. K., A. Pandey, A. Kumar, D. Rathod, and P. Kannoja. 2011a. Chemical Screening and Identification of High *Cordycepin* Containing Cultured Isolate(s) of Medicinal Chinese Caterpillar Mushroom, *Ophiocordyceps sinensis* (Berk.) GH Sung et al. *International Journal of Medicinal Mushrooms* 13:327–333.
- Varshney, V. K., A. Pandey, A. Kumar, D. Rathod, and P. Kannoja. 2011b. Chemical screening and identification of high *cordycepin* containing cultured isolate(s) of medicinal chinese caterpillar mushroom, *Ophiocordyceps sinensis* (Berk.) G.H. Sung et al. *International Journal of Medicinal Mushrooms* 13:327–333.
- Vasiljevic, J., L. Zivkovic, A. Cabarkapa, V. Bajic, N. Djelic, and B. Spremo-Potparevic. 2016. *Cordyceps sinensis*: Genotoxic Potential in Human Peripheral Blood Cells and Antigenotoxic Properties Against Hydrogen Peroxide by Comet Assay. *Alternative Therapies in Health and Medicine* 22:24–31.
- Ved, D. K., and G. S. Goraya. 2007. Demand and Supply of Medicinal Plants in India. NMPB, New Delhi & FRLHT, Bangalore, India:18.
- Vedeld, P., A. Angelsen, J. Bojö, E. Sjaastad, and G. Kobugabe Berg. 2007. Forest environmental incomes and the rural poor. *Forest Policy and Economics* 9:869–879.
- Walker, T. B. 2006. Does *Cordyceps sinensis* ingestion aid athletic performance? *Strength and Conditioning Journal* 28:21–23.
- Wallrapp, C., M. Keck, and H. Faust. 2019a. Governing the yarshagumba ‘gold rush’: A comparative study of governance systems in the Kailash Landscape in India and Nepal. *International Journal of the Commons* 13:455–478.
- Wallrapp, C., M. Keck, and H. Faust. 2019b. Governing the yarshagumba ‘gold rush’: A comparative study of governance systems in the Kailash Landscape in India and Nepal. *International Journal of the Commons* 13:455–478.
- Wan, R., M. Kobayashi, and M. Tamesada. 2006. Effect of the hot-water extract of *Cordyceps sinensis* on lung metastasis of B16 melanoma cells. *Journal of Traditional Medicines* 23:83–87.
- Wang, B. J., S. J. Won, Z. R. Yu, and C. L. Su. 2005. Free radical scavenging and apoptotic effects of *Cordyceps sinensis* fractionated by supercritical carbon dioxide. *Food and Chemical Toxicology* 43:543–552.
- Wang, B., M. Yu, and H. Z. Qi. 2004. Protective effect of the mycelial fermentation product of *Cordyceps sinensis* (CSFP) on oxidant-induced lung injury. *Faseb Journal* 18:A952–A952.
- Wang, B.-S., C. P. Lee, Z.-T. Chen, H. M. Yu, and P.-D. Duh. 2012a. Comparison of the hepatoprotective activity between cultured *Cordyceps militaris* and natural *Cordyceps sinensis*. *Journal of Functional Foods* 4:489–495.
- Wang, C., X. Hou, H. Rui, L. Li, J. Zhao, M. Yang, L. Sun, H. Dong, H. Cheng, and Y.-P. Chen. 2018a. Artificially Cultivated *Ophiocordyceps sinensis* Alleviates Diabetic Nephropathy and Its Podocyte Injury via Inhibiting P2X7R Expression and NLRP3 Inflammasome Activation. *Journal of Diabetes Research*:1390418.

- Wang, C., Z. Tang, and Z. Nan. 2018b. The caterpillar fungus boom on the Tibetan Plateau: Curse or blessing? *China Economic Review* 47:65–76.
- Wang, D., M. Xu, H.-T. Zhu, K.-K. Chen, Y.-J. Zhang, and C.-R. Yang. 2007. Biotransformation of gentiopicoside by asexual mycelia of *Cordyceps sinensis*. *Bioorganic & Medicinal Chemistry Letters* 17:3195–3197.
- Wang, H.-P., C.-W. Liu, H.-W. Chang, J.-W. Tsai, Y.-Z. Sung, and L.-C. Chang. 2013a. *Cordyceps sinensis* protects against renal ischemia/reperfusion injury in rats. *Molecular Biology Reports* 40:2347–2355.
- Wang, J., J. Peng, Y. Wang, M. Shao, and F. Qian. 2018d. Bioinformatics Study on the Effect of *Cordyceps Sinensis* Combined with Pluripotent Stem Cell for Pulmonary Fibrosis. *Journal of Medical Imaging and Health Informatics* 8:1126–1130.
- Wang, J., L. Kan, S. Nie, H. Chen, S. W. Cui, A. O. Phillips, G. O. Phillips, Y. Li, and M. Xie. 2015a. A comparison of chemical composition, bioactive components and antioxidant activity of natural and cultured *Cordyceps sinensis*. *Lwt-Food Science and Technology* 63:2–7.
- Wang, J., R. Liu, B. Liu, Y. Yang, J. Xie, and N. Zhu. 2017a. Systems Pharmacology-based strategy to screen new adjuvant for hepatitis B vaccine from Traditional Chinese Medicine *Ophiocordyceps sinensis*. *Scientific Reports* 7:44788.
- Wang, J., S. Nie, L. Kan, H. Chen, S. W. Cui, A. O. Phillips, G. O. Phillips, and M. Xie. 2017c. Comparison of structural features and antioxidant activity of polysaccharides from natural and cultured *Cordyceps sinensis*. *Food Science and Biotechnology* 26:55–62.
- Wang, J., S. Nie, S. Chen, A. O. Phillips, G. O. Phillips, Y. Li, M. Xie, and S. W. Cui. 2018c. Structural characterization of an alpha-1, 6-linked galactomannan from natural *Cordyceps sinensis*. *Food Hydrocolloids* 78:77–91.
- Wang, J., S. Nie, S. W. Cui, Z. Wang, A. O. Phillips, G. O. Phillips, Y. Li, and M. Xie. 2017b. Structural characterization and immunostimulatory activity of a glucan from natural *Cordyceps sinensis*. *Food Hydrocolloids* 67:139–147.
- Wang, J., Y.-M. Liu, W. Cao, K.-W. Yao, Z.-Q. Liu, and J.-Y. Guo. 2012b. Anti-inflammation and antioxidant effect of Cordymin, a peptide purified from the medicinal mushroom *Cordyceps sinensis*, in middle cerebral artery occlusion-induced focal cerebral ischemia in rats. *Metabolic Brain Disease* 27:159–165.
- Wang, J., Y.-M. Liu, W. Cao, K.-W. Yao, Z.-Q. Liu, and J.-Y. Guo. 2012. Anti-inflammation and antioxidant effect of Cordymin, a peptide purified from the medicinal mushroom *Cordyceps sinensis*, in middle cerebral artery occlusion-induced focal cerebral ischemia in rats. *Metabolic Brain Disease* 27:159–165.
- Wang, K.-F. 2003. *Cordyceps sinensis* and sports fatigue. *Chinese Journal of Clinical Rehabilitation* 7:3016–3017.
- Wang, L., G. Wang, J. Zhang, G. Zhang, L. Jia, X. Liu, P. Deng, and K. Fan. 2011a. Extraction optimization and antioxidant activity of intracellular selenium polysaccharide by *Cordyceps sinensis* SU-02. *Carbohydrate Polymers* 86:1745–1750.
- Wang, L.-Y., K.-L. Cheong, D.-T. Wu, L.-Z. Meng, J. Zhao, and S.-P. Li. 2015b. Fermentation optimization for the production of bioactive polysaccharides from *Cordyceps sinensis* fungus UM01. *International Journal of Biological Macromolecules* 79:180–185.
- Wang, M., and X. Hu. 2017. Antimicrobial peptide repertoire of *Thitarodes armoricanus*, a host species of *Ophiocordyceps sinensis*, predicted based on de novo transcriptome sequencing and analysis. *Infection Genetics and Evolution* 54:238–244.
- Wang, M., Q. Zhu, and Y. He. 2013b. Treatment with *Cordyceps sinensis* enriches treg population in peripheral lymph nodes and delays type I diabetes development in NOD mice. *Pharmazie* 68:768–771.
- Wang, N., J. Li, X. Huang, W. Chen, and Y. Chen. 2016a. Herbal Medicine *Cordyceps sinensis* Improves Health-Related Quality of Life in Moderate-to-Severe Asthma. *Evidence-Based Complementary and Alternative Medicine*:6134593.

- Wang, N.-N., Y.-J. Wang, and X. Zhang. 2003. Effects of cordyceps sinensis on blood glucose, plasma insulin, histology of liver and kidney in rats. *Chinese Pharmaceutical Journal* 38:924–926.
- Wang, P.-W., Y.-C. Hung, W.-T. Li, C.-T. Yeh, and T.-L. Pan. 2016b. Systematic revelation of the protective effect and mechanism of Cordyceps sinensis on diethylnitrosamine-induced rat hepatocellular carcinoma with proteomics. *Oncotarget* 7:60270–60289.
- Wang, Q., and Y. Zhao. 1987. Comparison of some pharmacological effects between Cordyceps sinensis (Berk). Sacc. and Cephalosporium sinensis Chen sp. nov. *Zhong yao tong bao* (Beijing, China : 1981) 12:42–44, 64.
- Wang, S. M., L. J. Lee, W. W. Lin, and C. M. Chang. 1998. Effects of a water-soluble extract of Cordyceps sinensis on steroidogenesis and capsular morphology of lipid droplets in cultured rat adrenocortical cells. *Journal of Cellular Biochemistry* 69:483–489.
- Wang, S., F.-Q. Yang, K. Feng, D.-Q. Li, J. Zhao, and S.-P. Li. 2009. Simultaneous determination of nucleosides, myriocin, and carbohydrates in Cordyceps by HPLC coupled with diode array detection and evaporative light scattering detection. *Journal of Separation Science* 32:4069–4076.
- Wang, S.-Y., and M.-S. Shiao. 2000. Pharmacological functions of Chinese medicinal fungus Cordyceps sinensis and related species. *Journal of Food and Drug Analysis* 8:248–257.
- Wang, W., K. Wang, X. Wang, R. Yang, Y. Li, and Y. Yao. 2018e. Investigation on natural resources and species conservation of Ophiocordyceps sinensis, the famous medicinal fungus endemic to the Tibetan Plateau. *Protein & Cell* 9:671–673.
- Wang, W.-N., B.-X. Yan, W.-D. Xu, Y. Qiu, Y.-L. Guo, and Z.-D. Qiu. 2015c. Highly Selective Bioconversion of Ginsenoside Rb1 to Compound K by the Mycelium of Cordyceps sinensis under Optimized Conditions. *Molecules* 20:19291–19309.
- Wang, X., C. Zhu, G. Liu, and G. Zhou. 2016c. Analysis of key active compounds and fermentation technology of Ophiocordyceps sinensis mycelium. *Journal of Chinese Institute of Food Science and Technology* 16:91–98.
- Wang, X.-L., and Y.-J. Yao. 2011. Host insect species of Ophiocordyceps sinensis: a review. *Zookeys*:43–59.
- Wang, X.-L., G.-Q. Liu, C.-Y. Zhu, G.-Y. Zhou, and S.-M. Kuang. 2011b. Enhanced production of mycelial biomass and extracellular polysaccharides in caterpillar-shaped medicinal mushroom Cordyceps sinensis CS001 by the addition of palmitic acid. *Journal of Medicinal Plants Research* 5:2873–2878.
- Wang, X.-L., R.-H. Yang, and Y.-J. Yao. 2011c. Development of Microsatellite Markers for Ophiocordyceps Sinensis (ophiocordycipitaceae) Using an I SSR-Tail-PCR Method. *American Journal of Botany* 98:E391–E394.
- Wang, Y., D. Liu, H. Zhao, H. Jiang, C. Luo, M. Wang, and H. Yin. 2014. Cordyceps sinensis polysaccharide CPS-2 protects human mesangial cells from PDGF-BB-induced proliferation through the PDGF/ERK and TGF-beta 1/Smad pathways. *Molecular and Cellular Endocrinology* 382:979–988.
- Wang, Y., H. Yin, X. Lv, Y. Wang, H. Gao, and M. Wang. 2010. Protection of chronic renal failure by a polysaccharide from Cordyceps sinensis. *Fitoterapia* 81:397–402.
- Wang, Y., H.-P. Yin, T. Chen, and M. Wang. 2009b. Preliminary structural identification and protection on renal cell injury of acidic polysaccharide from Cordyceps sinensis. *Journal of China Pharmaceutical University* 40:559–564.
- Wang, Y., M. Wang, Y. Ling, W. Fan, Y. Wang, and H. Yin. 2009a. Structural Determination and Antioxidant Activity of a Polysaccharide from the Fruiting Bodies of Cultured Cordyceps sinensis. *American Journal of Chinese Medicine* 37:977–989.
- Wang, Y., Y. Wang, D. Liu, W. Wang, H. Zhao, M. Wang, and H. Yin. 2015d. Cordyceps sinensis polysaccharide inhibits PDGF-BB-induced inflammation and ROS production in human mesangial cells. *Carbohydrate Polymers* 125:135–145.
- Wang, Z. X., X. M. Wang, and T. Z. Wang. 1995. Current status of pharmacological study on Cordyceps sinensis and Cordyceps hyphae. *Zhongguo zhong xi yi jie he za zhi Zhongguo Zhongxiyi jiehe zazhi* = Chinese journal of integrated traditional and

- Western medicine / Zhongguo Zhong xi yi jie he xue hui, Zhongguo Zhong yi yan jiu yuan zhu ban 15:255–256.
- Wang, Z., and S. Wang. 2010. Cordyceps sinensis Derivative Cultures Induces a Reduction in Transforming Growth Factor-beta(1), Dyslipidemia, Proteinuria in Diabetic Rats. *Diabetes* 59:A253–A253.
- Wang, Z., N. Li, M. Wang, Y. Wang, L. Du, X. Ji, A. Yu, H. Zhang, and F. Qiu. 2013c. Simultaneous determination of nucleosides and their bases in Cordyceps sinensis and its substitutes by matrix solid-phase dispersion extraction and HPLC. *Journal of Separation Science* 36:2348–2357.
- Wang, Z.-M., X. Peng, K.-L. D. Lee, J. C. Tang, P. C.-K. Cheung, and J.-Y. Wu. 2011d. Structural characterisation and immunomodulatory property of an acidic polysaccharide from mycelial culture of Cordyceps sinensis fungus Cs-HK1. *Food Chemistry* 125:637–643.
- Wangchuk, S., N. Norbu, and N. Sherub. 2010. Impacts of Cordyceps Collection on Livelihoods and Alpine Ecosystems in Bhutan as Ascertained from Questionnaire Survey of Cordyceps Collectors. Royal Government of Bhutan, UWICE Press, Bumthang.
- Weckerle, C. S., Y. Yang, F. K. Huber, and Q. Li. 2010. People, money, and protected areas: the collection of the caterpillar mushroom Ophiocordyceps sinensis in the Baima Xueshan Nature Reserve, Southwest China. *Biodiversity and Conservation* 19:2685–2698.
- Wei, X., and S. Li. 2011. The Differential Proteomics of Cultured Cordyceps Sinensis on Lung Fibroblasts from Nsip Patient. *Respirology* 16:324–324.
- Wei, X., H. Hu, B. Zheng, Z. Arslan, H.-C. Huang, W. Mao, and Y.-M. Liu. 2017. Profiling metals in Cordyceps sinensis by using inductively coupled plasma mass spectrometry. *Analytical Methods* 9:724–728.
- Wei, X., N. Xu, D. Wu, and Y. He. 2014. Determination of Branched-Amino Acid Content in Fermented Cordyceps sinensis Mycelium by Using FT-NIR Spectroscopy Technique. *Food and Bioprocess Technology* 7:184–190.
- Wen, T. C., D. P. Wei, F. Y. Long, X. Y. Zeng, and J. C. Kang. 2016. Multigene phylogeny and HPLC analysis reveal fake Ophiocordyceps sinensis in markets. *Mycosphere* 7:853–867.
- Winkler, D. 2005. Cordyceps sinensis (Berk.) Sacc: Economy, Ecology, and Ethno-Mycology of Yartsa Gunbu, a Medicinal Fungus Endemic for the Tibetan Plateau. *International Journal of Medicinal Mushrooms* 7.
- Winkler, D. 2008. Yartsa Gunbu (Cordyceps sinensis) and the Fungal Commodification of Tibet's Rural Economy. *Economic Botany* 62:291–305.
- Winkler, D. 2009. Caterpillar Fungus (Ophiocordyceps sinensis) Production and Sustainability on the Tibetan Plateau and in the Himalayas. *Asian Medicine* 5:291–316.
- Winkler, D. 2010. Cordyceps sinensis: A precious parasitic fungus infecting Tibet. *Field Mycology* 11:60–67.
- Winkler, D. 2010. Cordyceps sinensis: A precious parasitic fungus infecting tibet. *Field Mycology* 11:60–67.
- Wong, K. L., E. C. So, C. C. Chen, R. S. C. Wu, and B.-M. Huang. 2007. Regulation of steroidogenesis by Cordyceps sinensis mycelium extracted fractions with (hCG) treatment in mouse Leydig cells. *Archives of Andrology* 53:75–77.
- Woodhouse, E., P. McGowan, and E. J. Milner-Gulland. 2014. Fungal gold and firewood on the Tibetan plateau: examining access to diverse ecosystem provisioning services within a rural community. *Oryx* 48:30–38.
- Wu, D.-T., G.-P. Lv, J. Zheng, Q. Li, S.-C. Ma, S.-P. Li, and J. Zhao. 2016. Cordyceps collected from Bhutan, an appropriate alternative of Cordyceps sinensis. *Scientific Reports* 6:37668.
- Wu, D.-T., L.-Z. Meng, L.-Y. Wang, G.-P. Lv, K.-L. Cheong, D.-J. Hu, J. Guan, J. Zhao, and S.-P. Li. 2014a. Chain conformation and immunomodulatory activity of a hyperbranched polysaccharide from Cordyceps sinensis. *Carbohydrate Polymers* 110:405–414.

- Wu, J. Y., Q. X. Zhang, and P. H. Leung. 2007a. Inhibitory effects of ethyl acetate extract of *Cordyceps sinensis* mycelium on various cancer cells in culture and B16 melanoma in C57BL/6 mice. *Phytomedicine* 14:43–49.
- Wu, J. Y., Q. X. Zhang, P. H. Leung, J. Y. Yin, Y. P. Liang, and X. Y. Xie. 2005a. Anti-proliferative activities of *Cordyceps sinensis* mycelium extracts on cancer cells. Abstracts of Papers of the American Chemical Society 230:U90–U90.
- Wu, J.-Y., H.-P. Leung, W.-Q. Wang, and C.-P. Xu. 2014b. Mycelial Fermentation Characteristics and Anti-fatigue Activities of a Chinese Caterpillar Fungus, *Ophiocordyceps sinensis* Strain Cs-HK1 (Ascomycetes). *International Journal of Medicinal Mushrooms* 16:105–114.
- Wu, J.-Y., P.-H. Leung, and J.-K. Yan. 2009. BIOT 89-Characteristics of mycelial liquid fermentation and polysaccharide production of a medicinal fungus *Cordyceps sinensis* Cs-HK1. Abstracts of Papers of the American Chemical Society 238.
- Wu, R., J.-P. Gao, H.-L. Wang, Y. Gao, Q. Wu, and X.-H. Cui. 2015. Effects of fermented *Cordyceps sinensis* on oxidative stress in doxorubicin treated rats. *Pharmacognosy Magazine* 11:724–731.
- Wu, R., P.-A. Yao, H.-L. Wang, Y. Gao, H.-L. Yu, L. Wang, X.-H. Cui, X. Xu, and J.-P. Gao. 2018. Effect of fermented *Cordyceps sinensis* on doxorubicin-induced cardiotoxicity in rats. *Molecular Medicine Reports* 18:3229–3241.
- Wu, T., G. Liu, X.-G. Li, L. Gao, T.-G. Qi, and G.-J. Guan. 2006a. Expression of NF-kappa B and gelatinase B in renal tissue of mesangial proliferative glomerulonephritis rats and effect of *Cordyceps sinensis* on it. *Chinese Journal of Pharmacology and Toxicology* 20:102–107.
- Wu, Y. L., C. R. Sun, and Y. J. Pan. 2005c. Structural analysis of a neutral (1 → 3),(1 → 4)-beta-D-glucan from the mycelia of *Cordyceps sinensis*. *Journal of Natural Products* 68:812–814.
- Wu, Y. L., C. R. Sun, and Y. J. Pan. 2006b. Studies on isolation and structural features of a polysaccharide from the mycelium of an Chinese edible fungus (*Cordyceps sinensis*). *Carbohydrate Polymers* 63:251–256.
- Wu, Y. L., O. Ishurd, C. R. Sun, and Y. J. Pan. 2005b. Structure analysis and antitumor activity of (1 → 3)-beta-D-glucans (*Cordyglucans*) from the mycelia of *Cordyceps sinensis*. *Planta Medica* 71:381–384.
- Wu, Y., C. Sun, and Y. Pan. 2005d. Erratum: Structural analysis of a neutral (1 3),(1 4)- -D- glucan from the mycelia of *Cordyceps sinensis* (*Journal of Natural Products* (2005) 68 (812)). *Journal of Natural Products* 68:1140.
- Wu, Y., H. Sun, F. Qin, Y. Pan, and C. Sun. 2006c. Effect of various extracts and a polysaccharide from the edible mycelia of *Cordyceps sinensis* on cellular and humoral immune response against ovalbumin in mice. *Phytotherapy Research* 20:646–652.
- Wu, Y., N. Hu, Y. Pan, L. Zhou, and X. Zhou. 2007b. Isolation and characterization of a mannoglucan from edible *Cordyceps sinensis* mycelium. *Carbohydrate Research* 342:870–875.
- Wu, Y.-H. S., J.-K. Tseng, C.-H. Chou, C.-H. Chiu, Y.-L. Lin, and Y.-C. Chen. 2017. Preventive effects of *Ophiocordyceps sinensis* mycelium on the liver fibrosis induced by thioacetamide. *Environmental Toxicology* 32:1792–1800.
- Wu, Z. L., X. X. Wang, and W. Y. Cheng. 2000a. Inhibitory effect of *Cordyceps sinensis* and *Cordyceps militaris* on human glomerular mesangial cell proliferation induced by native LDL. *Cell Biochemistry and Function* 18:93–97.
- Wu, Z.-L., X.-X. Wang, and W.-. Cheng. 2000b. Inhibitory effect of *Cordyceps sinensis* and *Cordyceps militaris* on human glomerular mesangial cell proliferation induced by native LDL. *Cell Biochemistry and Function* 18:93–97.
- Xia, E.-H., D.-R. Yang, J.-J. Jiang, Q.-J. Zhang, Y. Liu, Y.-L. Liu, Y. Zhang, H.-B. Zhang, C. Shi, Y. Tong, C. Kim, H. Chen, Y.-Q. Peng, Y. Yu, W. Zhang, E. E. Eichler, and L.-Z. Gao. 2017. The caterpillar fungus, *Ophiocordyceps sinensis*, genome provides insights into highland adaptation of fungal pathogenicity. *Scientific Reports* 7:1806.
- Xia, F., Y. Liu, G.-R. Shen, L.-X. Guo, and X.-W. Zhou. 2015. Investigation and analysis of microbiological communities in natural *Ophiocordyceps sinensis*. *Canadian Journal of Microbiology* 61:104–111.

- Xiang, F., L. Lin, M. Hu, and X. Qi. 2016. Therapeutic efficacy of a polysaccharide isolated from *Cordyceps sinensis* on hypertensive rats. *International Journal of Biological Macromolecules* 82:308–314.
- Xiang, L., J. Song, T. Xin, Y. Zhu, L. Shi, X. Xu, X. Pang, H. Yao, W. Li, and S. Chen. 2013. DNA barcoding the commercial Chinese caterpillar fungus. *FEMS Microbiology Letters* 347:156–162.
- Xiang, L., Y. Li, Y. Zhu, H. Luo, C. Li, X. Xu, C. Sun, J. Song, L. Shi, L. He, W. Sun, and S. Chen. 2014. Transcriptome analysis of the *Ophiocordyceps sinensis* fruiting body reveals putative genes involved in fruiting body development and cordycepin biosynthesis. *Genomics* 103:154–159.
- Xiao, C., P. Xiao, X. Li, X. Li, H. Li, Y. Chen, Y. Wang, Y. Xu, G. Huang, and Q. Zhou. 2018. *Cordyceps sinensis* may inhibit Th22 cell chemotaxis to improve kidney function in IgA nephropathy. *American Journal of Translational Research* 10:857–865.
- Xiao, G., A. Miyazato, Y. Abe, T. Zhang, K. Nakamura, K. Inden, M. Tanaka, D. Tanno, T. Miyasaka, K. Ishii, K. Takeda, S. Akira, S. Saijo, Y. Iwakura, Y. Adachi, N. Ohno, N. Yamamoto, H. Kunishima, Y. Hirakata, M. Kaku, and K. Kawakami. 2010. Activation of myeloid dendritic cells by deoxynucleic acids from *Cordyceps sinensis* via a Toll-like receptor 9-dependent pathway. *Cellular Immunology* 263:241–250.
- Xiao, L., Y. Ge, L. Sun, X. Xu, P. Xie, M. Zhan, M. Wang, Z. Dong, J. Li, S. Duan, F. Liu, and P. Xiao. 2012. Cordycepin inhibits albumin-induced epithelial-mesenchymal transition of renal tubular epithelial cells by reducing reactive oxygen species production. *Free Radical Research* 46:174–183.
- Xiao, Y. Q. 1983. Studies on chemical constituents of *Cordyceps sinensis* I. *Zhong yao tong bao* (Beijing, China : 1981) 8:32–33.
- Xiao, Y., Q. Huang, Z. Zheng, H. Guan, and S. Liu. 2017. Construction of a *Cordyceps sinensis* exopolysaccharide-conjugated selenium nanoparticles and enhancement of their antioxidant activities. *International Journal of Biological Macromolecules* 99:483–491.
- Xiao, Y.-C., F.-Z. Hu, Q. Dong, X.-F. Chi, and T. Ji. 2014. Comparative study of fifteen kinds of nucleosides in *Cordyceps sinensis* from different origin of Yushu prefecture, Qinghai Province. *Chinese Pharmaceutical Journal* 49:1983–1988.
- Xiao, Y.-C., X.-F. Chi, Q. Dong, L. Tan, and F.-Z. Hu. 2015. Qualitative and quantitative comparative analysis of fatty acids in *Cordyceps sinensis* from different regions of Yushu prefecture of Qinghai Province. *Chinese Pharmaceutical Journal* 50:1098–1103.
- Xie, C., N. Xu, Y. Shao, and Y. He. 2015. Using FT-NIR spectroscopy technique to determine arginine content in fermented *Cordyceps sinensis* mycelium. *Spectrochimica Acta Part a-Molecular and Biomolecular Spectroscopy* 149:971–977.
- Xie, J.-W., L.-F. Huang, W. Hu, Y.-B. He, and K. P. Wong. 2010. Analysis of the Main Nucleosides in *Cordyceps Sinensis* by LC/ESI-MS. *Molecules* 15:305–314.
- Xing, X. K., and S. X. Guo. 2008. The structure and histochemistry of sclerotia of *Ophiocordyceps sinensis*. *Mycologia* 100:616–625.
- Xu, F., J. B. Huang, L. Jiang, J. Xu, and J. Mi. 1995a. Amelioration of cyclosporin nephrotoxicity by *cordyceps sinensis* in kidney-transplanted recipients. *Nephrology Dialysis Transplantation* 10:142–143.
- Xu, F., J. Huang, L. Jiang, J. Xu, and J. Mi. 1995b. Amelioration of Cyclosporine Nephrotoxicity by *Cordyceps Sinensis* in Kidney-Transplanted Recipients. *Nephrology Dialysis Transplantation* 10:142–143.
- Xu, F.-L., W.-Y. Huan, T.-X. Wu, X. Qiu, H. Zhang, and X.-H. Liu. 2006. Clinical efficacy of *cordyceps sinensis* for chronic kidney diseases: A systematic review. *Chinese Journal of Evidence-Based Medicine* 6:804–808.
- Xu, H., S. Li, Y. Lin, R. Liu, Y. Gu, and D. Liao. 2011. Effectiveness of cultured *Cordyceps sinensis* combined with glucocorticosteroid on pulmonary fibrosis induced by bleomycin in rats. *Zhongguo Zhongyao Zazhi* 36:2265–2270.

- Xu, J., Y. Huang, X.-X. Chen, S.-C. Zheng, P. Chen, and M.-H. Mo. 2016. The Mechanisms of Pharmacological Activities of *Ophiocordyceps sinensis* Fungi. *Phytotherapy Research* 30:1572–1583.
- Xu, M., M. Xu, and R. Li. 2019. Progress of several crucial aspects in the biological and ecological research on the Chinese caterpillar fungus, *Ophiocordyceps sinensis*. *Shengtai Xuebao/ Acta Ecologica Sinica* 39:1853–1862.
- Xu, R., X. Peng, G. Chen, and G. Chen. 1992. Effects of *Cordyceps-Sinensis* on Natural-Killer Activity and Colony Formation of B16 Melanoma. *Chinese Medical Journal* 105:97–101.
- Xu, Y.-D., C. Xu, Y.-H. Zhai, S.-J. Chao, J.-Q. Du, C.-C. Liu, and L.-B. Zhang. 2013. The impact of *cordyceps sinensis* excavation on grassland vegetation in the Sanjiangyuan region. *Research of Environmental Sciences* 26:1194–1200.
- Xun, C., N. Shen, B. Li, Y. Zhang, F. Wang, Y. Yang, X. Shi, K. Schafermyer, S. A. Brown, and J. S. Thompson. 2008. Radiation mitigation effect of cultured mushroom fungus *Hirsutella sinensis* (CorImmune) isolated from a Chinese/Tibetan herbal preparation - *Cordyceps sinensis*. *International Journal of Radiation Biology* 84:139–149.
- Yadav, P. K., S. Saha, A. K. Mishra, M. Kapoor, M. Kaneria, M. Kaneria, S. Dasgupta, and U. B. Shrestha. 2019. Yartsagunbu: transforming people's livelihoods in the Western Himalaya. *Oryx* 53:247–255.
- Yamaguchi, N., J. Yoshida, L. J. Ren, H. Chen, Y. Miyazawa, Y. Fujii, Y. X. Huang, S. Takamura, S. Suzuki, S. Koshimura, and F. D. Zeng. 1990. Augmentation of various immune reactivities of tumor-bearing hosts with an extract of *Cordyceps sinensis*. *Biotherapy* 2:199–205.
- Yamaguchi, Y., S. Kagota, K. Nakamura, K. Shinozuka, and M. Kunitomo. 2000a. Antioxidant activity of the extracts from fruiting bodies of cultured *Cordyceps sinensis*. *Phytotherapy Research* 14:647–649.
- Yamaguchi, Y., S. Kagota, K. Nakamura, K. Shinozuka, and M. Kunitomo. 2000b. Inhibitory effects of water extracts from fruiting bodies of cultured *Cordyceps sinensis* on raised serum lipid peroxide levels and aortic cholesterol deposition in atherosclerotic mice. *Phytotherapy Research* 14:650–652.
- Yan, F., B. Wang, and Y. Zhang. 2014a. Polysaccharides from *Cordyceps sinensis* mycelium ameliorate exhaustive swimming exercise-induced oxidative stress. *Pharmaceutical Biology* 52:157–161.
- Yan, F., Y. Zhang, and B. Wang. 2012. Effects of polysaccharides from *Cordyceps sinensis* mycelium on physical fatigue in mice. *Bangladesh Journal of Pharmacology* 7:217–221.
- Yan, J. K., L. Li, Z. M. Wang, P. H. Leung, W. Q. Wang, and J. Y. Wu. 2009. Acidic degradation and enhanced antioxidant activities of exopolysaccharides from *Cordyceps sinensis* mycelial culture. *Food Chemistry* 117:641–646.
- Yan, J.-K., and J.-Y. Wu. 2014. Submerged fermentation of medicinal fungus *cordyceps sinensis* for production of biologically active mycelial biomass and exopolysaccharides. Pages 93–120 *Production of Biomass and Bioactive Compounds Using Bioreactor Technology*. Springer Netherlands.
- Yan, J.-K., and Y.-Y. Wang. 2015. Random-Centroid Optimization of Ultrasound-Assisted Extraction of Polysaccharides from *Cordyceps Sinensis* Mycelium. *Current Topics in Nutraceutical Research* 13:167–171.
- Yan, J.-K., H.-L. Ma, J.-J. Pei, Z.-B. Wang, and J.-Y. Wu. 2014b. Facile and effective separation of polysaccharides and proteins from *Cordyceps sinensis* mycelia by ionic liquid aqueous two-phase system. *Separation and Purification Technology* 135:278–284.
- Yan, J.-K., L. Li, Z.-M. Wang, and J.-Y. Wu. 2010. Structural elucidation of an exopolysaccharide from mycelial fermentation of a *Tolypocladium* sp fungus isolated from wild *Cordyceps sinensis*. *Carbohydrate Polymers* 79:125–130.
- Yan, J.-K., W.-Q. Wang, and J.-Y. Wu. 2014c. Recent advances in *Cordyceps sinensis* polysaccharides: Mycelial fermentation, isolation, structure, and bioactivities: A review. *Journal of Functional Foods* 6:33–47.

- Yan, J.-K., W.-Q. Wang, H.-L. Ma, and J.-Y. Wu. 2013a. Sulfation and Enhanced Antioxidant Capacity of an Exopolysaccharide Produced by the Medicinal Fungus *Cordyceps sinensis*. *Molecules* 18:167–177.
- Yan, X.-F., Z.-M. Zhang, H.-Y. Yao, Y. Guan, J.-P. Zhu, L.-H. Zhang, Y.-L. Jia, and R.-W. Wang. 2013b. Cardiovascular protection and antioxidant activity of the extracts from the mycelia of *Cordyceps sinensis* act partially via adenosine receptors. *Phytotherapy Research* 27:1597–1604.
- Yan, Y., Y. Li, W.-J. Wang, J.-S. He, R.-H. Yang, H.-J. Wu, X.-L. Wang, L. Jiao, Z. Tang, and Y.-J. Yao. 2017. Range shifts in response to climate, change of *Ophiocordyceps sinensis*, a fungus endemic to the Tibetan Plateau. *Biological Conservation* 206:143–150.
- Yan, Y., Y. Li, W.-J. Wang, J.-S. He, R.-H. Yang, H.-J. Wu, X.-L. Wang, L. Jiao, Z. Tang, and Y.-J. Yao. 2017. Range shifts in response to climate change of *Ophiocordyceps sinensis*, a fungus endemic to the Tibetan Plateau. *Biological Conservation* 206:143–150.
- Yang, F. Q., D. Q. Li, K. Feng, D. J. Hu, and S. P. Li. 2010. Determination of nucleotides, nucleosides and their transformation products in *Cordyceps* by ion-pairing reversed-phase liquid chromatography-mass spectrometry. *Journal of Chromatography. A* 1217:5501–5510.
- Yang, H. Y., S. F. Leu, Y. K. Wang, C. S. Wu, and B. M. Huang. 2006. *Cordyceps sinensis* mycelium induces MA-10 mouse Leydig tumor cell apoptosis by activating the caspase-8 pathway and suppressing the NF-kappa B pathway. *Archives of Andrology* 52:103–110.
- Yang, J. Y., W. Y. Zhang, P. H. Shi, J. P. Chen, X. D. Han, and Y. Wang. 2005. Effects of exopolysaccharide fraction (EPSF) from a cultivated *Cordyceps sinensis* fungus on c-Myc, c-Fos, and VEGF expression in B16 melanoma-bearing mice. *Pathology Research and Practice* 201:745–750.
- Yang, J.-L., W. Xiao, H.-X. He, H.-X. Zhu, S.-F. Wang, K.-D. Cheng, and P. Zhu. 2008. Molecular phylogenetic analysis of *Paecilomyces hepiali* and *Cordyceps sinensis*. *Yaoxue Xuebao* 43:421–426.
- Yang, J.-Y., Y. Zhang, Y.-Z. Dong, N.-Z. Tan, J.-H. Lu, and J.-S. Zhu. 2013. *Cordyceps sinensis* Cs-5 enhances sexual functions in normal and impotent models. *Faseb Journal* 27.
- Yang, L. Y., W. J. Huang, H. G. Hsieh, and C. Y. Lin. 2003a. H1-A extracted from *Cordyceps sinensis* suppresses the proliferation of human mesangial cells and promotes apoptosis, probably by inhibiting the tyrosine phosphorylation of Bcl-2 and Bcl-XL. *Journal of Laboratory and Clinical Medicine* 141:74–80.
- Yang, L., X. Jiao, J. Wu, J. Zhao, T. Liu, J. Xu, X. Ma, L. Cao, L. Liu, Y. Liu, J. Chi, M. Zou, S. Li, J. Xu, and L. Dong. 2018a. *Cordyceps sinensis* inhibits airway remodeling in rats with chronic obstructive pulmonary disease. *Experimental and Therapeutic Medicine* 15:2731–2738.
- Yang, L.-Y., A. Chen, Y.-C. Kuo, and C.-Y. Lin. 1999. Efficacy of a pure compound H1-A extracted from *Cordyceps sinensis* on autoimmune disease of MRL lpr/lpr mice. *Journal of Laboratory and Clinical Medicine* 134:492–500.
- Yang, M.-L., P.-C. Kuo, T.-L. Hwang, and T.-S. Wu. 2011. Anti-inflammatory Principles from *Cordyceps sinensis*. *Journal of Natural Products* 74:1996–2000.
- Yang, M.-L., P.-C. Kuo, T.-L. Hwang, and T.-S. Wu. 2011. Anti-inflammatory Principles from *Cordyceps sinensis*. *Journal of Natural Products* 74:1996–2000.
- Yang, N., Y. Cheng, and H. Qu. 2003b. Quantitative determination of mannitol in *Cordyceps sinensis* using near infrared spectroscopy and artificial neural networks. *Fenxi Huaxue* 31:664–668.
- Yang, P., X.-X. Zhao, and Y.-W. Zhang. 2018b. Comparison and review on specifications of fermented *Cordyceps sinensis* products. *Zhongguo Zhongyao Zazhi* 43:463–468.

- Yang, R.-H., X.-L. Wang, J.-H. Su, Y. Li, S.-P. Jiang, F. Gu, and Y.-J. Yao. 2015. Bacterial diversity in native habitats of the medicinal fungus *Ophiocordyceps sinensis* on Tibetan Plateau as determined using Illumina sequencing data. *Fems Microbiology Letters* 362:fnu044.
- Yang, S., and H. Zhang. 2016. Production of intracellular selenium-enriched polysaccharides from thin stillage by *Cordyceps sinensis* and its bioactivities. *Food & Nutrition Research* 60:30153.
- Yang, T., W. Xiong, and C. Dong. 2014. Cloning and analysis of the *Oswc-1* gene encoding a putative blue light photoreceptor from *Ophiocordyceps sinensis*. *Mycoscience* 55:241–245.
- Yang, Z., S.-Y. Chi, C.-H. Zhang, and A. Wu. 2007. Quantitative analysis of adenosine and cordycepin in *Cordyceps sinensis* and its substitutes with LC-MS-MS. *Zhongguo Zhongyao Zazhi* 32:2018–2021.
- Yao, P.-A., R. Wu, Y.-L. Zhang, X.-H. Cui, K.-Z. Wei, X. Xu, and J.-P. Gao. 2018. Alleviation of Doxorubicin-induced Hepatic Toxicity with Fermented *Cordyceps sinensis* via Regulating Hepatic Energy Metabolism in Rats. *Pharmacognosy Magazine* 14:283–289.
- Yao, X., S. Meran, Y. Fang, J. Martin, A. Midgley, M.-M. Pan, B.-C. Liu, S. W. Cui, G. O. Phillips, and A. O. Phillips. 2014a. *Cordyceps sinensis*: In vitro anti-fibrotic bioactivity of natural and cultured preparations. *Food Hydrocolloids* 35:444–452.
- Yao, Y., L. Gao, Y. Li, S. Ma, Z. Wu, N. Tan, J. Wu, L. Ni, and J. Zhu. 2014b. Amplicon density-weighted algorithms for analyzing dissimilarity and dynamic alterations of RAPD polymorphisms of *Cordyceps sinensis*. *Beijing da xue xue bao. Yi xue ban = Journal of Peking University. Health sciences* 46:618–628.
- Yao, Y., Y. Zhou, and J.-S. Zhu. 2008. Declines of proliferation predominance of *Hirsutella sinensis* associate with unparallel alterations of its DNA copies during maturation of *Cordyceps sinensis*. *Faseb Journal* 22.
- Yao, Y., Y. Zhou, W. Chen, and J.-S. Zhu. 2009. Transition mutations of *Hirsutella sinensis* genes and expressions of *Paecilomyces hepiali* genes during germination and early development of *Cordyceps sinensis* stroma. *Faseb Journal* 23.
- Yao, Y.-S., and J.-S. Zhu. 2016. Indiscriminate use of Latin name for natural *Cordyceps sinensis* insect-fungi complex and multiple *Ophiocordyceps sinensis* fungi. *Zhongguo Zhong yao za zhi = Zhongguo zhongyao zazhi = China journal of Chinese materia medica* 41:1361–1366.
- Yao, Y.-S., L. Gao, J. Zhao, and J.-S. Zhu. 2012. Two GC-biased genotypes of *Ophiocordyceps sinensis* with distinct maturational patterns in the stroma of *Cordyceps sinensis*. *Faseb Journal* 26.
- Ye, M. Q., Z. Hu, Y. Fan, L. He, F. B. Xia, and G. L. Zou. 2004b. Purification and characterization of an acid deoxyribonuclease from the cultured mycelia of *Cordyceps sinensis*. *Journal of Biochemistry and Molecular Biology* 37:466–473.
- Ye, M., Z. Hu, Y. Fan, L. He, F. Xia, and G. Zou. 2004a. Purification and characterization of an acid deoxyribonuclease from the cultured mycelia of *Cordyceps sinensis*. *Journal of Biochemistry and Molecular Biology* 37:466–473.
- Yeh, E. T., and K. T. Lama. 2013. Following the caterpillar fungus: nature, commodity chains, and the place of Tibet in China's uneven geographies. *Social and Cultural Geography* 14:318–340.
- Yi, J., C. Guo, Z. Zou, and G. Zhang. 2015. Seasonal changes of fatty acid composition in *Thitarodes pui* Larvae, a host of *Ophiocordyceps sinensis*. *Cryo-Letters* 36:205–212.
- Yin, D., and X. Tang. 1995. Advances in the study on artificial cultivation of *Cordyceps sinensis*. *Zhongguo Zhong yao za zhi = Zhongguo zhongyao zazhi = China journal of Chinese materia medica* 20:707–709, inside back cover.
- Yochikawa, N., K. Nakamura, Y. Yamaguchi, S. Kagota, K. Shinozuka, and M. Kunitomo. 2007. Reinforcement of antitumor effect of cordyceps sinensis by 2'-deoxycoformycin, an adenosine deaminase inhibitor. *In Vivo* 21:291–295.
- Yoon, T. J., K.-W. Yu, K.-S. Shin, and H. J. Suh. 2008. Innate immune stimulation of exo-polymers prepared from *Cordyceps sinensis* by submerged culture. *Applied Microbiology and Biotechnology* 80:1087–1093.

- Yoshida, J., S. Takamura, N. Yamaguchi, L. Ren, H. Chen, S. Koshimura, and S. Suzuki. 1989. Antitumor-Activity of an Extract of *Cordyceps-Sinensis* (berk) Sacc Against Murine Tumor-Cell Lines. *Japanese Journal of Experimental Medicine* 59:157–161.
- Yoshikawa, N., E. Kubo, S. Kagota, K. Shinozuka, M. Kunitomo, and K. Nakamura. 2008. Effect of *Cordyceps Sinensis* on Spontaneous Metastatic Model Mice. *Anticancer Research* 28:3549–3549.
- Yoshikawa, N., E. Kubo, Y. Takahashi, S. Kagota, K. Shinozuka, M. Kunitomo, and K. Nakamura. 2009. Hydroxyurea reinforces the anti-metastatic effect of water extract of *Cordyceps sinensis*. *Journal of Pharmacological Sciences* 109:54P–54P.
- Yoshikawa, N., K. Nakamura, Y. Yamaguchi, N. Nejime, S. Kagota, K. Shinozuka, and M. Kunitomo. 2007b. Anti-metastatic effect of cordycepin, an ingredient of *Cordyceps sinensis*, is associated with inhibition of platelet aggregation induced by mouse melanoma cells. *Journal of Pharmacological Sciences* 103:62P–62P.
- Yoshikawa, N., K. Nakamura, Y. Yamaguchi, S. Kagota, K. Shinozuka, and M. Kunitomo. 2006. Cordycepin, an active ingredient of *Cordyceps sinensis*, inhibits tumor growth by stimulating adenosine A3 receptor. *Acta Pharmacologica Sinica* 27:65–65.
- Yoshikawa, N., K. Nakamura, Y. Yamaguchi, S. Kagota, K. Shinozuka, and M. Kunitomo. 2007a. Cordycepin and *Cordyceps sinensis* reduce the growth of human promyelocytic leukaemia cells through the Wnt signalling pathway. *Clinical and Experimental Pharmacology and Physiology* 34:S61–S63.
- Yu, H. M., B. S. Wang, S. C. Huang, and P. D. Duh. 2006. Comparison of protective effects between cultured *Cordyceps militaris* and natural *Cordyceps sinensis* against oxidative damage. *Journal of Agricultural and Food Chemistry* 54:3132–3138.
- Yu, H., Q. Zhou, R. Huang, M. Yuan, X. Ao, and J. Yang. 2012a. Effect of *Cordyceps sinensis* on the expression of HIF-1 α and NGAL in rats with renal ischemia-reperfusion injury. *Journal of Central South University (Medical Sciences)* 37:57–68.
- Yu, J., J. Liu, Y. Wu, and J. Yu. 1994. The Application of Cultivated *Cordyceps-Sinensis* in Renal-Transplantation. *Journal of the American Society of Nephrology* 5:1016–1016.
- Yu, L., C. Guozhen, J. Dezhao, Z. Ziqiang, and C. Guolin. 1990. Effect of *cordyceps sinensis* on erythropoiesis in mouse bone marrow. *Bulletin of Hunan Medical University* 15:43–47.
- Yu, L., J. Zhao, Q. Zhu, and S. P. Li. 2007. Macrophage biospecific extraction and high performance liquid chromatography for hypothesis of immunological active components in *Cordyceps sinensis*. *Journal of Pharmaceutical and Biomedical Analysis* 44:439–443.
- Yu, S., Y. Zhang, and M. Fan. 2012b. Analysis of volatile compounds of mycelia of *Hirsutella sinensis*, the anamorph of *ophiocordyceps sinensis*. *Applied Mechanics and Materials* 140:253–257.
- Yu, X., Y. Mao, J. L. Shergis, M. E. Coyle, L. Wu, Y. Chen, A. L. Zhang, L. Lin, C. C. Xue, and Y. Xu. 2019. Effectiveness and Safety of Oral *Cordyceps sinensis* on Stable COPD of GOLD Stages 2-3: Systematic Review and Meta-Analysis. *Evidence-Based Complementary and Alternative Medicine*:4903671.
- Yu, Y. 2013. The Socioeconomic Impact of *Cordyceps Sinensis* Resource Management in Tibetan-Inhabited Regions of Qinghai. Pages 79–97 in L. Wang and L. Zhu, editors. *Breaking Out of the Poverty Trap Case Studies from the Tibetan Plateau in Yunnan, Qinghai and Gansu*. World Scientific Publ Co Pte Ltd, Singapore.
- Yu, Y., W. Wang, L. Wang, F. Pang, L. Guo, L. Song, G. Liu, and C. Feng. 2016. Draft Genome Sequence of *Paecilomyces hepiali*, Isolated from *Cordyceps sinensis*. *Microbiology Resource Announcements* 4:e00606-16.
- Yuan, J.-P., J.-H. Wang, X. Liu, H.-C. Kuang, and S.-Y. Zhao. 2007. Simultaneous determination of free ergosterol and ergosterol esters in *Cordyceps sinensis* by HPLC. *Food Chemistry* 105:1755–1759.
- Yuan, J.-P., J.-H. Wang, X. Liu, H.-C. Kuang, and S.-Y. Zhao. 2007. Simultaneous determination of free ergosterol and ergosterol esters in *Cordyceps sinensis* by HPLC. *Food Chemistry* 105:1755–1759.

- Yuan, M., R. Tang, Q. Zhou, K. Liu, Z. Xiao, and P. Veeraragoo. 2013. Effect of *Cordyceps sinensis* on expressions of HIF-1 α and VEGF in the kidney of rats with diabetic nephropathy. *Journal of Central South University (Medical Sciences)* 38:448–457.
- Yue, G. G.-L., C. B.-S. Lau, K.-P. Fung, P.-C. Leung, and W.-H. Ko. 2008. Effects of *Cordyceps sinensis*, *Cordyceps militaris* and their isolated compounds on ion transport in Calu-3 human airway epithelial cells. *Journal of Ethnopharmacology* 117:92–101.
- Yue, G. G.-L., C. B.-S. Lau, K.-P. Fung, P.-C. Leung, and W.-H. Ko. 2008. Effects of *Cordyceps sinensis*, *Cordyceps militaris* and their isolated compounds on ion transport in Calu-3 human airway epithelial cells. *Journal of Ethnopharmacology* 117:92–101.
- Yue, K., M. Ye, X. Lin, and Z. Zhou. 2013. The Artificial Cultivation of Medicinal Caterpillar Fungus, *Ophiocordyceps sinensis* (Ascomycetes): A Review. *International Journal of Medicinal Mushrooms* 15:425–434.
- Yun, Y. H., S. H. Han, S. J. Lee, S. K. Ko, C. K. Lee, N. J. Ha, and K. J. Kim. 2003. Anti-diabetic Effects of CCCA, CMKSS, and Cordycepin from *Cordyceps militaris* and the Immune Responses in Streptozotocin-induced Diabetic Mice. *Natural Product Sciences* 9:291–298.
- Zan, K., L.-L. Huang, L.-N. Guo, J. Liu, J. Zheng, S.-C. Ma, Z.-M. Qian, and W.-J. Li. 2017. Comparative study on specific chromatograms and main nucleosides of cultivated and wild *Cordyceps sinensis*. *Zhongguo Zhong yao za zhi = Zhongguo zhongyao zazhi = China journal of Chinese materia medica* 42:3957–3962.
- Zang, M. 1979. *Cordyceps* fungi. *Journal of Natural Products* 2:429–430.
- Zeng, W., and S.-J. Chen. 2001. Studies on *paecilomyces muscardine* of *Cordyceps sinensis* host insect. *Zhongguo Zhongyao Zazhi* 26:456.
- Zhang, D., Z. Wang, W. Qi, and G. Zhao. 2014a. The effects of *Cordyceps sinensis* phytoestrogen on estrogen deficiency-induced osteoporosis in Ovariectomized rats. *Bmc Complementary and Alternative Medicine* 14:484.
- Zhang, G., J. Yu, G. Wu, and X. Liu. 2011a. Factors influencing the occurrence of *Ophiocordyceps sinensis*. *Shengtai Xuebao/Acta Ecologica Sinica* 31:4117–4125.
- Zhang, G., Y. Huang, Y. Bian, J. H. Wong, T. B. Ng, and H. Wang. 2006a. Hypoglycemic activity of the fungi *Cordyceps militaris*, *Cordyceps sinensis*, *Tricholoma mongolicum*, and *Omphalia lapidescens* in streptozotocin-induced diabetic rats. *Applied Microbiology and Biotechnology* 72:1152–1156.
- Zhang, H. 1990. Immunopharmacological effect of *Cordyceps sinensis*. *Zhong xi yi jie he za zhi = Chinese journal of modern developments in traditional medicine / Zhongguo Zhong xi yi jie he yan jiu hui (chou), Zhong yi yan jiu yuan, zhu ban* 10:570–571.
- Zhang, H. W., Z. X. Lin, Y. S. Tung, T. H. Kwan, C. K. Mok, C. Leung, and L. S. Chan. 2014b. *Cordyceps sinensis* (a traditional Chinese medicine) for treating chronic kidney disease. *Cochrane Database of Systematic Reviews*:CD008353.
- Zhang, H., X.-X. Tong, F. Wang, Y.-X. Wang, C. Peng, and J.-L. Guo. 2018a. cDNA cloning and prediction of antigenic determinants of protein marker IP4 in *Ophiocordyceps sinensis* [IP4 cDNA]. *Chinese Traditional and Herbal Drugs* 49:4864–4869.
- Zhang, H., Y. Li, J. Mi, M. Zhang, Y. Wang, Z. Jiang, and P. Hu. 2017a. GC-MS Profiling of Volatile Components in Different Fermentation Products of *Cordyceps Sinensis* Mycelia. *Molecules* 22:1800.
- Zhang, J., P. Wang, X. Wei, L. Li, H. Cheng, Y. Wu, W. Zeng, H. Yu, and Y. Chen. 2015a. A metabolomics approach for authentication of *Ophiocordyceps sinensis* by liquid chromatography coupled with quadrupole time-of-flight mass spectrometry. *Food Research International* 76:489–497.
- Zhang, J., Y. Yu, Z. Zhang, Y. Ding, X. Dai, and Y. Li. 2011b. Effect of polysaccharide from cultured *Cordyceps sinensis* on immune function and anti-oxidation activity of mice exposed to Co-60. *International Immunopharmacology* 11:2251–2257.

- Zhang, L., S.-Z. Chen, and S.-S. Liu. 2006b. Prosecutable function of *Cordyceps sinensis* extracts for hepatic mitochondrial oxidative injuries in diabetic mice. *Chinese Journal of Clinical Rehabilitation* 10:132–134.
- Zhang, M., M. Pan, H. Ni, J. Chen, M. Xu, Y. Gong, P. Chen, and B. Liu. 2015b. Effect of *Cordyceps sinensis* powder on renal oxidative stress and mitochondria functions in 5/6 nephrectomized rats. *Zhongguo Zhong xi yi jie he za zhi Zhongguo Zhongxiyi jiehe zazhi = Chinese journal of integrated traditional and Western medicine / Zhongguo Zhong xi yi jie he xue hui, Zhongguo Zhong yi yan jiu yuan zhu ban* 35:443–449.
- Zhang, P., S. Cui, X. Ren, S. Kang, F. Wei, S. Ma, and B. Liu. 2018b. Discriminatory Power Evaluation of Nuclear Ribosomal RNA Barcoding Sequences Through *Ophiocordyceps sinensis* Related Samples. *Frontiers in Microbiology* 9:2498.
- Zhang, P., S. Li, J. Li, F. Wei, X. Cheng, G. Zhang, S. Ma, and B. Liu. 2018c. Identification of *Ophiocordyceps sinensis* and Its Artificially Cultured *Ophiocordyceps* Mycelia by Ultra-Performance Liquid Chromatography/Orbitrap Fusion Mass Spectrometry and Chemometrics. *Molecules* 23:1013.
- Zhang, Q. X., H. Y. Wu, Z. D. Hu, and D. Li. 2004a. Induction of HL-60 apoptosis by ethyl acetate extract of *Cordyceps sinensis* fungal mycelium. *Life Sciences* 75:2911–2919.
- Zhang, Q.-X., J.-Y. Wu, and Z.-D. Hu. 2006c. Growth-inhibition effects of *Cordyceps sinensis* fungus extracts on HL-60 cells and inducement of G2/M arrest. *Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/Journal of Tianjin University Science and Technology* 39:581–584.
- Zhang, S. L. 1985. Activation of murine peritoneal macrophages by natural *Cordyceps sinensis* and its cultured mycelia. *Zhong xi yi jie he za zhi = Chinese journal of modern developments in traditional medicine / Zhongguo Zhong xi yi jie he yan jiu hui (chou), Zhong yi yan jiu yuan, zhu ban* 5:45–47, 5.
- Zhang, S. L. 1987. Lewis lung cancer of mice treated with *Cordyceps sinensis* and its artificial cultured mycelia. *Zhong yao tong bao (Beijing, China : 1981)* 12:53–54.
- Zhang, S. S., D. S. Zhang, T. J. Zhu, and X. Y. Chen. 1991. A pharmacological analysis of the amino acid components of *Cordyceps sinensis* Sacc. *Yao xue xue bao = Acta pharmaceutica Sinica* 26:326–330.
- Zhang, S., X. Lai, B. Li, C. Wu, S. Wang, X. Chen, J. Huang, and G. Yang. 2016a. Application of Differential Proteomic Analysis to Authenticate *Ophiocordyceps sinensis*. *Current Microbiology* 72:337–343.
- Zhang, S., Y.-J. Zhang, X.-Z. Liu, H. Zhang, and D.-S. Liu. 2013. On the reliability of DNA sequences of *Ophiocordyceps sinensis* in public databases. *Journal of Industrial Microbiology & Biotechnology* 40:365–378.
- Zhang, S., Y.-J. Zhang, X.-Z. Liu, H.-A. Wen, M. Wang, and D.-S. Liu. 2011c. Cloning and analysis of the MAT1-2-1 gene from the traditional Chinese medicinal fungus *Ophiocordyceps sinensis*. *Fungal Biology* 115:708–714.
- Zhang, W. Y., J. Y. Yang, J. P. Chen, Y. Y. Hou, and X. D. Han. 2005. Immunomodulatory and antitumor effects of an exopolysaccharide fraction from cultivated *Cordyceps sinensis* (Chinese caterpillar fungus) on tumor-bearing mice. *Biotechnology and Applied Biochemistry* 42:9–15.
- Zhang, W., J. Li, S. Qiu, J. Chen, and Y. Zheng. 2008a. Effects of the exopolysaccharide fraction (EPSF) from a cultivated *Cordyceps sinensis* on immunocytes of H22 tumor bearing mice. *Fitoterapia* 79:168–173.
- Zhang, W., X. Li, L. Ma, U. Urrehman, X. Bao, Y. Zhang, C.-Y. Zhang, D. Hou, and Z. Zhou. 2019. Identification of microRNA-like RNAs in *Ophiocordyceps sinensis*. *Science China-Life Sciences* 62:349–356.
- Zhang, W., X. Zhang, M. Li, Y. Shi, P. Zhang, X.-L. Cheng, F. Wei, and S. Ma. 2017b. Identification of Chinese Caterpillar Medicinal Mushroom, *Ophiocordyceps sinensis* (Ascomycetes), from Counterfeit Species. *International Journal of Medicinal Mushrooms* 19:1061–1070.
- Zhang, X. L., L. Bi-Cheng, S. Al-Assaf, G. O. Phillips, and A. O. Phillips. 2012a. *Cordyceps sinensis* decreases TGF-beta 1 dependent epithelial to mesenchymal transdifferentiation and attenuates renal fibrosis. *Food Hydrocolloids* 28:200–212.

- Zhang, X., Q. Liu, W. Zhou, P. Li, R. N. Alolga, L.-W. Qi, and X. Yin. 2018d. A comparative proteomic characterization and nutritional assessment of naturally- and artificially-cultivated *Cordyceps sinensis*. *Journal of Proteomics* 181:24–35.
- Zhang, X., Y. K. Liu, Q. Zheng, W. Shen, and D. M. Shen. 2003. Influence of *Cordyceps sinensis* on pancreatic islet beta cells in rats with experimental liver fibrogenesis. *Zhonghua gan zang bing za zhi = Zhonghua ganzangbing zazhi = Chinese journal of hepatology* 11:93–94.
- Zhang, X., Y.-K. Liu, W. Shen, and D.-M. Shen. 2004b. Dynamical influence of *Cordyceps sinensis* on the activity of hepatic insulinase of experimental liver cirrhosis. *Hepatobiliary and Pancreatic Diseases International* 3:99–101.
- Zhang, Y., E. Li, C. Wang, Y. Li, and X. Liu. 2012b. *Ophiocordyceps sinensis*, the flagship fungus of china: Terminology, life strategy and ecology. *Mycology* 3:2–10.
- Zhang, Y., L. Xu, S. Zhang, X. Liu, Z. An, M. Wang, and Y. Guo. 2009. Genetic diversity of *Ophiocordyceps sinensis*, a medicinal fungus endemic to the Tibetan Plateau: Implications for its evolution and conservation. *Bmc Evolutionary Biology* 9:290.
- Zhang, Y., M. Yang, S. Gong, Y. Yang, B. Chen, Y. Cai, S. Zheng, Y. Yang, and P. Xia. 2012c. *Cordyceps sinensis* Extracts Attenuate Aortic Transplant Arteriosclerosis in Rats. *Journal of Surgical Research* 175:123–130.
- Zhang, Y., S. Zhang, M. Wang, F. Bai, and X. Liu. 2010. High Diversity of the Fungal Community Structure in Naturally-Occurring *Ophiocordyceps sinensis*. *Plos One* 5:e15570.
- Zhang, Y., X. Liu, and M. Wang. 2008b. Cloning, expression, and characterization of two novel cuticle-degrading serine proteases from the entomopathogenic, fungus *Cordyceps sinensis*. *Research in Microbiology* 159:462–469.
- Zhang, Y.-J., F.-R. Bai, S. Zhang, and X.-Z. Liu. 2012d. Determining novel molecular markers in the Chinese caterpillar fungus *Ophiocordyceps sinensis* by screening a shotgun genomic library. *Applied Microbiology and Biotechnology* 95:1243–1251.
- Zhang, Y.-J., J.-X. Hou, S. Zhang, G. Hausner, X.-Z. Liu, and W.-J. Li. 2016b. The intronic minisatellite OsMin1 within a serine protease gene in the Chinese caterpillar fungus *Ophiocordyceps sinensis*. *Applied Microbiology and Biotechnology* 100:3599–3610.
- Zhang, Y.-S., Y.-Z. Feng, Z.-F. Cao, Z.-L. Gu, Q.-Y. Yang, X.-T. Yang, W.-H. Chou, and C.-Y. Kwok. 2011d. Effect of *Cordyceps sinensis* and *Panax notoginseng* compound extracts on Bleomycin-induced pulmonary fibrosis in rats and its mechanisms. *Chinese Traditional and Herbal Drugs* 42:1766–1772.
- Zhang, Z., X. Wang, Y. Zhang, and G. Ye. 2011e. Effect of *Cordyceps sinensis* on Renal Function of Patients with Chronic Allograft Nephropathy. *Urologia Internationalis* 86:298–301.
- Zhang, Z., Z. Lei, Y. Lue, Z. Lue, and Y. Chen. 2008c. Chemical Composition and Bioactivity Changes in Stale Rice after Fermentation with *Cordyceps sinensis*. *Journal of Bioscience and Bioengineering* 106:188–193.
- Zhao, C., H. B. Qu, and Y. Y. Cheng. 2004a. A new approach to the fast measurement of content of amino acids in cordyceps sinensis by ANN-NIR. *Spectroscopy and Spectral Analysis* 24:50–53.
- Zhao, C., H.-B. Qu, and Y.-Y. Cheng. 2004b. New approach to the fast measurement of content of amino acids in *Cordyceps sinensis* by ANN-NIR. *Guang Pu Xue Yu Guang Pu Fen Xi/Spectroscopy and Spectral Analysis* 24:50.
- Zhao, K., and Q. Gao. 2017. *Cordyceps Sinensis* prevents contrast-induced nephropathy in diabetic rats by inhibiting p38 MAPK and Akt/mTOR/P70S6K signaling pathways. *Journal of the American College of Cardiology* 70:C54–C54.
- Zhao, K., Q. Gao, C. Zong, L. Ge, and J. Liu. 2018. *Cordyceps sinensis* prevents contrast-induced nephropathy in diabetic rats: its underlying mechanism. *International Journal of Clinical and Experimental Pathology* 11:5571–5580.
- Zhao, K., Y. Lin, Y.-J. Li, and S. Gao. 2014. Efficacy of short-term cordyceps sinensis for prevention of contrast-induced nephropathy in patients with acute coronary syndrome undergoing elective percutaneous coronary intervention. *International Journal of Clinical and Experimental Medicine* 7:5758–5764.

- Zhao, S., W.-H. Zhang, Y.-M. Fu, H.-Z. Cui, and Y.-M. Chi. 2007. Effects of Astragalus polysaccharides and Cordyceps sinensis mycelium mixture on the transforming growth factor- 1 expression in chronic rejection of artery transplantation: Experiment with rats. *National Medical Journal of China* 87:851–854.
- Zhao, X., and L. Li. 1993. Cordyceps sinensis in protection of the kidney from cyclosporine A nephrotoxicity. *Zhonghua yi xue za zhi* 73:410–412, 447.
- Zhao, X., H. Yang, Y. Sheng, Y. Jiao, H. Yu, Y. Qin, and G. Zhao. 2019. Application of principal component cluster analysis in the quality of cordyceps sinensis. *IFIP Advances in Information and Communication Technology* 509:279–283.
- Zhao, Y. 1991. Inhibitory effects of alcoholic extract of Cordyceps sinensis on abdominal aortic thrombus formation in rabbits. *Zhonghua yi xue za zhi* 71:612–615, 42.
- Zhao, Y.-Y., X. Shen, X. Chao, C. C. Ho, X.-L. Cheng, Y. Zhang, R.-C. Lin, K.-J. Du, W.-J. Luo, J.-Y. Chen, and W.-J. Sun. 2011. Ergosta-4,6,8(14),22-tetraen-3-one induces G2/M cell cycle arrest and apoptosis in human hepatocellular carcinoma HepG2 cells. *Biochimica Et Biophysica Acta* 1810:384–390.
- Zhen, F., J. Tian, and L. S. Li. 1992. Mechanisms and therapeutic effect of Cordyceps sinensis (CS) on aminoglycoside induced acute renal failure (ARF) in rats. *Zhongguo Zhong xi yi jie he za zhi Zhongguo Zhongxiyi jiehe zazhi = Chinese journal of integrated traditional and Western medicine / Zhongguo Zhong xi yi jie he xue hui, Zhongguo Zhong yi yan jiu yuan zhu ban* 12:288–291, 262.
- Zheng, F., L. Li, and J. Tian. 1992. Mechanism of Cordyceps-Sinensis (cs) in the Treatment of Aminoglycoside Induced Acute-Renal-Failure (arf). *Kidney International* 42:495–495.
- Zheng, L., L. Hao, H. Ma, C. Tian, T. Li, X. Sun, M. Jia, and L. Jia. 2014. Production and in Vivo Antioxidant Activity of Zn, Ge, Se-enriched Mycelia by Cordyceps sinensis SU-01. *Current Microbiology* 69:270–276.
- Zheng, Z., and X. Sui-shen. 1990. Cordyceps Sinensis-I as an immunosuppressant in heterotopic heart allograft model in rats. *Journal of Tongji Medical University* 10:100–103.
- Zheng, Z., Q. Huang, H. Guan, and S. Liu. 2015. In situ synthesis of silver nanoparticles dispersed or wrapped by a Cordyceps sinensis exopolysaccharide in water and their catalytic activity. *Rsc Advances* 5:69790–69799.
- Zhengqi, Z., C. Qiuli, W. Yufeng, Z. Hui, W. Ying, Y. Hongping, and Y. Long. 2017. Protective effects of Cordyceps sinensis polysaccharide CPS-A on angiotensin II-induced injury of liver L02 cells. *Journal of China Pharmaceutical University* 48:490–495.
- Zhong, F., F. Zhong, X. Liu, Q. Zhou, X. Hao, Y. Lu, S. Guo, W. Wang, D. Lin, and N. Chen. 2012. 1h Nmr Spectroscopy Analysis of Metabolites in the Kidneys Provides New Insight into Pathophysiological Mechanisms: Applications for Treatment with Cordyceps Sinensis. *Nephrology Dialysis Transplantation* 27:80–80.
- Zhong, S.-S., Y.-J. Xiang, P.-J. Liu, Y. He, T.-T. Yang, Y.-Y. Wang, A. Rong, J. Zhang, and G.-Z. Liu. 2017. Effect of Cordyceps sinensis on the Treatment of Experimental Autoimmune Encephalomyelitis: A Pilot Study on Mice Model. *Chinese Medical Journal* 130:2296–2301.
- Zhong, X., L. Gu, H. Wang, D. Lian, Y. Zheng, S. Zhou, W. Zhou, J. Gu, G. Zhang, and X. Liu. 2018. Profile of Ophiocordyceps sinensis transcriptome and differentially expressed genes in three different mycelia, sclerotium and fruiting body developmental stages. *Fungal Biology* 122:943–951.
- Zhong, X., L. Gu, S. Li, X. Kan, G. Zhang, and X. Liu. 2016a. Transcriptome analysis of Ophiocordyceps sinensis before and after infection of Thitarodes larvae. *Fungal Biology* 120:819–826.
- Zhong, X., Q. Peng, L. Qi, W. Lei, and X. Liu. 2010. rDNA-targeted PCR primers and FISH probe in the detection of Ophiocordyceps sinensis hyphae and conidia. *Journal of Microbiological Methods* 83:188–193.

- Zhong, X., Q. Peng, S.-S. Li, H. Chen, H.-X. Sun, G.-R. Zhang, and X. Liu. 2014. Detection of *Ophiocordyceps sinensis* in the roots of plants in alpine meadows by nested-touchdown polymerase chain reaction. *Fungal Biology* 118:359–363.
- Zhong, X., S. Li, Q. Peng, J. Zhang, X. Kan, G. Zhang, and X. Liu. 2016b. A *Polycephalomyces* hyperparasite of *Ophiocordyceps sinensis* leads to shortened duration of production and reduced numbers of host ascospores. *Fungal Ecology* 21:24–31.
- Zhou, C., G. Yang, H. Liang, X. Yang, L. Shan, Y. Zhu, G. Guo, T. Zhou, and J. Chen. 2007. Phylogenetic relationships of host insects of *Cordyceps sinensis* inferred from mitochondrial Cytochrome b sequences. *Progress in Natural Science-Materials International* 17:789–797.
- Zhou, D.-L., D. Yan, B.-C. Li, Y.-S. Wu, and X.-H. Xiao. 2009a. Investigation of metabolic action of *Cordyceps sinensis* and its cultured mycelia on *Escherichia coli* by microcalorimetry. *Yaoxue Xuebao* 44:640–644.
- Zhou, J., L. Huang, and F. Guo. 2009b. Rapid simultaneous determination of main nucleosides in *Cordyceps sinensis* with LC-ESI-MS. *Zhongguo Zhongyao Zazhi* 34:2349–2352.
- Zhou, K., J. Zhang, X. Huang, L. Yuan, Z. Luo, L. Shi, and K. Wei. 2018a. Suitability and regionalization of *Ophiocordyceps sinensis* in the Tibetan Plateau. *Shengtai Xuebao/ Acta Ecologica Sinica* 38:2768–2779.
- Zhou, L., Q.-X. Hao, S. Wang, Q. Yang, C.-Z. Kang, W.-Z. Yang, and L.-P. Guo. 2017. Study on distribution of five heavy metal elements in different parts of *Cordyceps sinensis* by microwave digestion ICP-MS. *Zhongguo Zhongyao Zazhi* 42:2934–2938.
- Zhou, L., S. Wang, Q. Hao, L. Kang, C. Kang, J. Yang, W. Yang, J. Jiang, L.-Q. Huang, and L. Guo. 2018b. Bioaccessibility and risk assessment of heavy metals, and analysis of arsenic speciation in *Cordyceps sinensis*. *Chinese Medicine* 13:40.
- Zhou, L., W. Yang, Y. Xu, Q. Zhu, Z. Ma, T. Zhu, X. Ge, and J. Gao. 1990. Short-term curative effect of cultured *Cordyceps sinensis* (Berk.) Sacc. Mycelia in chronic hepatitis B. *Zhongguo zhong yao za zhi = Zhongguo zhongyao zazhi = China journal of Chinese materia medica* 15:53–55, 65.
- Zhou, X., L. Luo, W. Dressel, G. Shadier, D. Krumbiegel, P. Schmidtke, F. Zepp, and C. U. Meyer. 2008. Cordycepin is an Immunoregulatory Active Ingredient of *Cordyceps sinensis*. *American Journal of Chinese Medicine* 36:967–980.
- Zhou, X., L. Luo, W. Dressel, G. Shadier, D. Krumbiegel, P. Schmidtke, F. Zepp, and C. U. Meyer. 2008. Cordycepin is an immunoregulatory active ingredient of *Cordyceps sinensis*. *The American Journal of Chinese Medicine* 36:967–980.
- Zhou, X., Z. Gong, Y. Su, J. Lin, and K. Tang. 2009. *Cordyceps* fungi: natural products, pharmacological functions and developmental products. *The Journal of Pharmacy and Pharmacology* 61:279–291.
- Zhou, X.-W., L.-J. Li, and E.-W. Tian. 2014. Advances in research of the artificial cultivation of *Ophiocordyceps sinensis* in China. *Critical Reviews in Biotechnology* 34:233–243.
- Zhou, Z., Y. Liang, B. Li, C. Xu, and F. Guo. 2004. Relative adsorption analysis of water soluble constituents between cultured *Cordyceps militaris* and *Cordyceps sinensis*. *Fenxi Huaxue* 32:561–564.
- Zhu, J. S., Y. S. Yao, Y. L. Guo, X. J. Liu, and Z. M. Wu. 2006. Molecular identification of *Cordyceps sinensis* related fungi. *Faseb Journal* 20:A431–A431.
- Zhu, J.-S. 2006. Anti-fatigue and endurance-enhancing properties of CordyMax, A fermentation product of *Cordyceps sinensis*. *Acta Pharmacologica Sinica* 27:314–315.
- Zhu, J.-S., G. M. Halpern, and K. Jones. 1998a. The Scientific Rediscovery of an Ancient Chinese Herbal Medicine: *Cordyceps sinensis* Part I. *The Journal of Alternative and Complementary Medicine* 4:289–303.
- Zhu, J.-S., G. M. Halpern, and K. Jones. 1998b. The Scientific Rediscovery of a Precious Ancient Chinese Herbal Regimen: *Cordyceps sinensis* Part II. *The Journal of Alternative and Complementary Medicine* 4:429–457.
- Zhu, J.-S., L. Gao, and J. Lu. 2011. Transition and transversion point mutations of *Ophiocordyceps sinensis* and their maturational alterations in stroma of *Cordyceps sinensis*. *Faseb Journal* 25.

- Zhu, J.-S., L. Gao, Y. Yao, and Y. Zhou. 2010. Maturation alteration of differential expressions of GC:AT-biased genotypes of *Cordyceps sinensis* fungi and *Paecilomyces hepiali* in *Cordyceps sinensis*. *Faseb Journal* 24.
- Zhu, J.-S., L. Ni, Y. Yao, L. Gao, Y. Li, S. Ma, Z. Wu, N. Tan, and J.-Y. Wu. 2014. Altered RAPD polymorphisms in *Cordyceps sinensis* analyzed with amplicon density-weighted algorithms. *Faseb Journal* 28.
- Zhu, J.-S., Y. Guo, and J. Lu. 2008a. Maturation alterations of proliferation predominance of *Hirsutella sinensis* and *Paecilomyces hepiali* in natural *Cordyceps sinensis*. *Faseb Journal* 22.
- Zhu, J.-S., Y. Yao, W. Chen, T. Zheng, J. Lu, and Y. Guo. 2007. Molecular co-existence of *Paecilomyces hepiali* and *Hirsutella sinensis* in caterpillar and fruiting bodies of *Cordyceps sinensis*. *Faseb Journal* 21:A1079–A1079.
- Zhu, J.-S., Z. Wu, Y. Qi, J. Lu, L. Zhang, and L. Zhang. 2008b. Dynamic alterations of chemical component profiles during *Cordyceps sinensis* maturation and comparisons with those for *Hirsutella sinensis* and *Paecilomyces hepiali* mycelia. *Faseb Journal* 22.
- Zhu, L., X. Gao, Z. Zhang, S. Zhou, X. Shang, and Q. Tang. 2017a. Determination of nucleosides in caterpillar fungi by high performance liquid chromatography. *Journal of Food Science and Biotechnology* 36:604–609.
- Zhu, S.-D., L.-Q. Huang, L.-P. Guo, X.-T. Ma, Q.-X. Hao, Z.-Y. Le, X.-B. Zhang, G. Yang, Y. Zhang, and M.-L. Chen. 2017b. Climate change impacts on yield of *Cordyceps sinensis* and research on yield prediction model of *C. sinensis*. *Zhongguo Zhongyao Zazhi* 42:1281–1286.
- Zhu, W., X.-Y. Chen, Y. Wang, and Y. Wang. 2017c. Study on genetic toxicity of *Cordyceps sinensis* and *Panax quinquefolium* compound. *Chinese Traditional and Herbal Drugs* 48:2722–2725.
- Zhu, X. Y., and H. Y. Yu. 1990. Immunosuppressive effect of cultured *Cordyceps sinensis* on cellular immune response. *Zhong xi yi jie he za zhi = Chinese journal of modern developments in traditional medicine / Zhongguo Zhong xi yi jie he yan jiu hui (chou), Zhong yi yan jiu yuan, zhu ban* 10:485–487, 454.
- Zhu, Y., L. Ma, Q. Hu, J. Li, Y. Chen, R. Jia, S. Shen, and Y. Zeng. 2016. In Vitro Anti-HIV-1 Activity of *Cordyceps sinensis* Extracts. *Bing du xue bao = Chinese journal of virology* 32:417–422.
- Zhu, Z.-Y., Q. Yao, Y. Liu, C.-L. Si, J. Chen, N. Liu, H.-Y. Lian, L.-N. Ding, and Y.-M. Zhang. 2012. Highly efficient synthesis and antitumor activity of monosaccharide saponins mimicking components of Chinese folk medicine *Cordyceps sinensis*. *Journal of Asian Natural Products Research* 14:429–435.
- Zong, S.-Y., H. Han, B. Wang, N. Li, T. T.-X. Dong, T. Zhang, and K. W. K. Tsim. 2015. Fast Simultaneous Determination of 13 Nucleosides and Nucleobases in *Cordyceps sinensis* by UHPLC-ESI-MS/MS. *Molecules* 20:21816–21825.
- Zou, Y., Y. Liu, M. Ruan, X. Feng, J. Wang, Z. Chu, and Z. Zhang. 2015. *Cordyceps sinensis* oral liquid prolongs the lifespan of the fruit fly, *Drosophila melanogaster*, by inhibiting oxidative stress. *International Journal of Molecular Medicine* 36:931–946.
- Zou, Y.-X., Y.-X. Liu, M.-H. Ruan, Y. Zhou, J.-C. Wang, and Z.-Y. Chu. 2016. *Cordyceps sinensis* Oral Liquid Inhibits Damage Induced by Oxygen and Glucose Deprivation in SH-SY5Y Cells. *Alternative Therapies in Health and Medicine* 22:37–42.
- Zou, Z., Q. Min, S. Cheng, T. Xin, and B. Xia. 2017. The complete mitochondrial genome of *Thitarodes sejilaensis* (Lepidoptera: Hepialidae), a host insect of *Ophiocordyceps sinensis* and its implication in taxonomic revision of *Hepialus* adopted in China. *Gene* 601:44–55.
- Zou, Z.-W., J.-F. Li, and G.-R. Zhang. 2012. Biology and life cycle of *thitarodes pui* (Lepidoptera, Hepialidae), a host of the caterpillar fungus *ophiocordyceps sinensis* in the Tibetan Plateau. Pages 137–152 *Larvae: Morphology, Biology and Life Cycle*. Nova Science Publishers, Inc.
- Zuo, H.-L., S.-J. Chen, D.-L. Zhang, J. Zhao, F.-Q. Yang, and Z.-N. Xia. 2013. Quality evaluation of natural *Cordyceps sinensis* from different collecting places in China by the contents of nucleosides and heavy metals. *Analytical Methods* 5:5450–5456.
- Zuo, T.-T., Y.-L. Li, H.-Y. Jin, F. Gao, Q. Wang, Y.-D. Wang, and S.-C. Ma. 2018. HPLC-ICP-MS speciation analysis and risk assessment of arsenic in *Cordyceps sinensis*. *Chinese Medicine* 13:19.



About the Authors



Dr. Vikram S. Negi is working as a Scientist 'E' at Center for Biodiversity Conservation and Management (CBCM), G.B. Pant National Institute of Himalayan Environment (GBP-NIHE), Kosi-Katarmal, Almora, Uttarakhand. He received his Doctor of Philosophy degree from H.N.B. Garhwal University, Srinagar (Garhwal). His field of specialization includes Forest Ecology, Phytosociology and Long-term ecological monitoring of plant biodiversity. He has published 113 research papers, chapters in edited books/ proceedings, scientific popular articles, and manuals/ monographs. He has been conferred with Young Scientist Awards (in 2010, 2011, 2012) for significant R&D works. In addition, he has been awarded as a Fellow in Chinese Academy of Sciences (CAS) and DST Fast Track Young Scientist in 2014, and 106th Indian Science Congress in 2019.



Dr. Suresh K. Rana is working as a scientist at GBP-NIHE, Ladakh regional center, Leh. He received his PhD on Wildlife Science from Wildlife Institute of India Dehradun, where he conducted intensive research on the causes of plant elevational and latitudinal diversity gradients and evaluated the climatic, biogeographic and phylogenetic drivers of the Himalayan flora. Currently, his research interests include bibliometrics, biocuration, evolutionary ecology and conservation biogeography of the Himalayan biodiversity. He is member of the International Biogeography Society from developing countries during last six years.



Dr. Lalit Giri is working as a Project Scientist under National Mission on Himalayan Studies (NMHS), GBP-NIHE, Kosi-Katarmal, Almora, Uttarakhand. His field of interest is Plant Biotechnology (Plant Tissue Culture), Genetic and Phytochemical assessment of threatened high value plants of Himalaya. He has been awarded Ph.D. degree in Biotechnology from Kumaun University, Nainital. He has published 25 research papers in peer reviewed Impact Factor Journals, apart from making several conference presentations. He received "Young Scientist Award" in the 6th Uttarakhand Science Congress 2011, and DST- Young Scientist Award in 2013.



Dr. Ranbeer Rawal obtained Ph.D. in Botany from Kumaun University, Nainital, and has research experience of over 30 years. He has been associated with GBP-NIHE for the past 25 years as a scientist, and currently leading the institute as Director. His specialization is in floristic ecology and conservation biology. He has published more than 200 peer reviewed papers. His work on *ex-situ* conservation models, participatory conservation education and transboundary landscape management has been recognized globally. Dr. Rawal has coordinated and supervised various national, international and trans-boundary projects. He has contributed to Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) as a lead author, and was elected 'Sectional President' of Environmental Science section of 'Indian Science Congress 2020'.









G.B. Pant National Institute of Himalayan Environment

G.B. Pant National Institute of Himalayan Environment (GBPNIHE) was established in 1988-89, during the birth centenary year of Bharat Ratna Pt. Govind Ballabh Pant, as an autonomous Institute of the Ministry of Environment, Forest and Climate Change (MoEF&CC), Govt. of India. The Institute has been identified as a focal agency to advance scientific knowledge, to evolve integrated management strategies, demonstrate their efficacy for conservation of natural resources, and to ensure environmentally sound management in the entire Indian Himalayan Region (IHR). The Institute has Headquarters at Kosi-katarmal, Almora (Uttarakhand) and six Regional Center, namely, Himachal Regional Center at Mohal (Kullu, HP), Garhwal Regional Center at Srinagar (Garhwal, Uttarakhand), Sikkim Regional Center at Pangthang (Sikkim), North East Regional Center at Itanagar (Arunachal Pradesh), and Mountain Division Regional Center at MoEF&CC New Delhi. More recently Institute has made functional its Ladakh Regional Centre at Leh (Ladakh)



For further information please contact:

Director
G.B. Pant National Institute of Himalayan Environment
Kosi-Katarmal, Almora 263 643, Uttarakhand, India
Tel: 05962-241015, Fax: 05962-241014
Email: psdir@gbpihed.nic.in

