Ethnomycology and trade channel of *Cordyceps sinensis* (Berk.) Sacc. in Arunachal Pradesh, North East India

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Research

Abstract

Background: Cordyceps sinensis a mysterious andnecrotrophic but highly medicinal fungus found naturally dispersed in Himalayan region. It is commonly known like **Yartsagunbu**, **Yarsagumba**, **Keeda Jadi** or **Caterpillar fungus**. This species is collected from wild and used invarious traditional healing practices thus has attracted herbalists and contemporary researchers both. The purpose of this study was to explore ethnomycological information among ethnic groups, availability, harvesting, trade channel, and marketing of this valuable fungus in Arunachal Pradesh, India.

Methods: The survey was conducted among Monpa, Sherdukpen, Memba and Nepali communities residing in three districts of the state located between 3500-5000m altitudes above sea levelthrough semi-structured questionnaire. The quantitative ethnobiological data analysis such as relative frequency of citation and cultural importance index were done following standard methods.

Results: The results revealed that *C. sinensis* is primarily used for treating tumours, inflammation, liver and kidney disorders, diabetes, and as a sexual stimulant and anti-aging agent. The study highlights how this mushroom play crucial role in local health, traditions and rural economies, with prices ranging from 250–400 INR per piece. Despite its significance, the trade remains informal and lacks a structured market. The findings underscore the urgent need for documentation and sustainable harvesting practices to preserve both indigenous knowledge and the ecological future of this valuable resource.

Conclusion: This study provides a comprehensive ethnomycological account of *Cordyceps sinensis* among the high-altitude tribes of Arunachal Pradesh, revealing its vital role in traditional healthcare, cultural practices, and local economies.

Keywords: Arunachal Pradesh, *Cordyceps sinensis*, Market value, Monpa tribe, Traditional knowledge.

Background

Cordyceps sinensis (Berk.) Sacc.is a mysterious parasitic fungus popularly well-known as **Yartsagunbu**, **Yarsagumba** or **Keeda Jadi** in Nepal, Bhutan and India (Devkota 2006, Gould 2007, Sharma 2004). This has attracted both traditional herbalists and contemporary researchers alike owing to unique medicinal and healing practices associated with it. This extraordinary parasitic fungus often referred to as the "**Caterpillar fungus**" due to its peculiar method of propagation. It is one of the most

expensive mushrooms, because of its medicinal properties and existence in the remote areas of high altitudinal Himalayan mountainous ranges where other livelihood options are minimal (Sharma 2004). In terms of money, it is the costliest selling species of fungi known possess numerous healing properties due to the occurrence of a number of active pharmaceutical compounds.

Ethnomycology is an emerging branch of scientific study about the traditional uses of wild mushrooms which includes identification and recording of indigenous knowledge as medicine or food. Wild mushrooms are used worldwide since time immemorial for their unique pharmacological and medicinal qualities as well as a fine resource of mineral and nutrients, natural antibiotics, in spiritual practices etc. (Militoris 2001). Many mushrooms produce various medicinal bioactive compounds such as anti-diabetic, anti-oxidants, hypo-cholesterolemic, immune-stimulatory, anti-cancer, anti-tumour, anti-allergic, nephro-protective, and as antimicrobial agents (Militoris 2001). Indigenous knowledge had always been passed verbally from one to another generation to creating a possibility of losing important undocumented information. The region of Himalayas is gifted with diverse geographic locations, unique climatic patterns and high levels of vegetation, all of which are ideal for supporting the dense diversity of mushrooms (Singh & Singh 1987).

Many therapeutic properties make this mushroom peculiar from others in its category. It is used from the time immemorial in Chinese traditional medicine in different chronic diseases. Previous studies on *C. sinensis* revealed that it has numerous healing properties such as immunomodulatory (Jang *et al.* 2015), anti-cancer (Chang *et al.* 2020), decreasing blood pressure (Chiou*et al.* 2000), liver protection (Cheng *et al.* 2014), kidney protection (Ding *et al.* 2011), including anti-oxidative, anti-tumor, anti-ageing, sexual potentiator and anti-diabetic effects (Yan *et al.* 2014). etc. The inhabitant of Dopla, located in Nepal use *C. sinensis* as a tonic and sexual stimulant (Devkota 2006). Beta-glucan and polysaccharides contents obtained from *Cordyceps* are important for their use in medication of cancer (Yan *et al.* 2014). The target molecule Cordycepin (nucleosides) is thought to be the cause of its antiviral (HIV) actions because it inhibits the DNA repair pathway (Jiang *et al.* 2011).

This unique caterpillar's parasitic fungus is often found in the high-altitude Mountains of the Himalayan regions of Bhutan, Nepal, China/Tibet, and India. It is mostly found at higher elevations in India in the Kumaun and Garhwal Himalayas, as well as in higher elevations in Arunanchal Pradesh and Sikkim (Singh *et al.* 2010). The purpose of this study explores the ways that native people treat different illness with *C. sinensis*, harvesting knowledge, trade channel and market price of this valuable mushroom among different ethnic group of Arunachal Pradesh, India. Ethnomycological studies specially on *C. sinensis* have been carried out in different parts of India (Pradhan 2016), and the world, especially Nepal, Bhutan, China and Tibet (Chen *et al.* 2010, Devkota 2006,Pouliot *et al.* 2018), but such studies are lacking in Arunachal Pradesh state of India.

Materials and Methods

Study area

The study was conducted in 3 districts of Arunachal Pradesh, North East India namely Tawang, West Kameng and Shi-Yomi based upon the availability of the *C. Sinensis* (Fig 1). The study areas are located at the altitude level ranging from 3500m to 5000m above mean sea level that qualifies these areas are as high altitude regions. The study areas are covered by tropical and alpine forests and grasslands. During winter season most of these areas remain covered with snow from November to February and once the snow starts melting, the caterpillar mushroom starts growing in the high mountain peaks.

Data collection

Ethnomycological surveys were conducted during April to July, the growing season of caterpillar fungus, for three consecutive years in 2021, 2022 and 2023. Prior to actual survey, a preliminary study was also carried out to know the probable habitats from where local people collect the fungus in 2020-2021. The data were collected with the help of semi-structured questionnaire survey, personal interviews, and discussions with the local inhabitants. Mostly village head and the elderly people, local traders, traditional healers and herbalists were chosen and interviewed in detail. A total number of 156 interviews were conducted during the study period. During the surveys, collection of the specimen was also done from the remote areas with the help of the locals and photographs were taken along with the specimen.

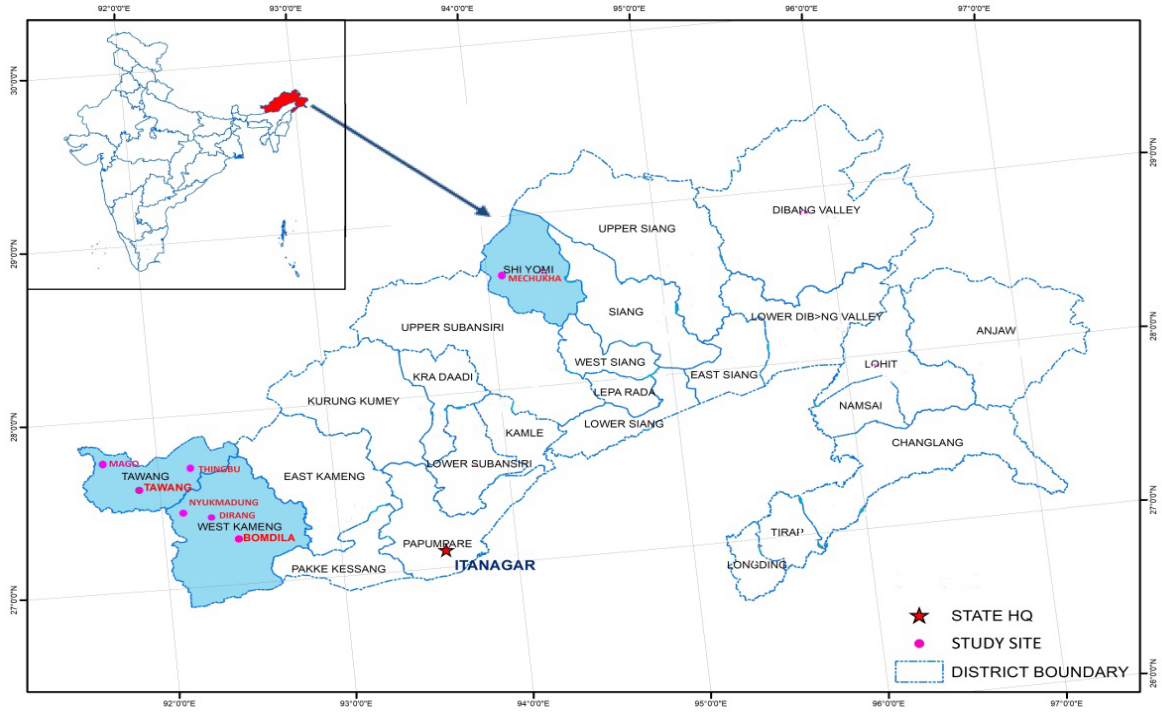

Figure 1. The study area (Highlighted area shows the districts and study sites).

Quantitative ethnobiological data analysis

(A) ***Relative Frequency of Citation (RFC)***

The importance of a plant species within a particular population was evaluated using the RFC (Tardio & Pardo-de-Santayana 2008). It is measured on a scale ranging from 0 to 1, where values closer to 0 indicate a lower frequency of citation and conversely values closer to 1 indicate a higher frequencyof citation. The RFC value was calculated using through the standard formula:

$$RFC = FC/N$$

Where FC=Number of informants mentioning the use of species X; N=Total number of informants.

(B) ***Cultural Importance Index (CI)***

The Cultural Importance Index (CI) is a tool for measuring the knowledge variations among different ethnic groups and assessing the importance of a plant species within a particular category of use (Asseh *et al*. 2019). The formula from which CI was calculated as follows:

$$CI = UR/N$$

Where UR=The number of informants using a given species for a specific category of use; N=Total number of informants.

Results

Demographic characters of informants

A total of 156 (99 male and 57 female) individuals were interviewed in this study for documenting the medicinal knowledge about *Cordyceps* belonging to four local communities (Monpa, Sherdukpen, Memba and Nepali). Male respondents were more in number than the female 99:57 contributing to 63.46% and 36.53% respectively. Older informants (above 40 years of age) were found to be maximum (63.45%), followed by middle aged (between 20-40 years old) with (26.28%) and young aged (below 20 years) with (10.25%).The maximum respondents were farmers (52.56%) by profession, followed by traditional healers (23.71%), government employees (8.97%) and individuals associated with business sector (14.74%). In this survey 43.58% of the respondents were found to be unschooled, 37.82% had primary education, 16.02% had secondary education and only 2.56% were found to have university degrees (Table 1).

Table1. Demographic characters of informants using *Cordyceps sinensis*

Informant categories	Variables	Name of the tribes				Total informers	Percentage
		Monpa	Sherdukpen	Memba	Nepali		
Sex	Male	44	19	14	22	99	63.46
	Female	21	15	11	10	57	36.53
Age level (years)	<20	11	2	0	3	16	10.25
	21-40	17	11	5	8	41	26.28
	41-60	18	11	9	10	48	30.76
	<60	19	10	11	11	51	32.69
Profession	Farmer	30	18	15	19	82	52.56
	Traditional healers	15	8	8	6	37	23.71
	Employees	8	4	1	1	14	8.97
	BusinessSector	12	4	1	6	23	14.74
Educational level	Unschooled	26	15	12	15	68	43.58
	Primary	28	13	8	10	59	37.82
	Secondary	8	5	5	7	25	16.02
	University	3	1	0	0	4	2.56

The surveys and interviews revealed that *Cordyceps sinensis* (Fig 2) is found naturally in certain places of Tawang, West Kameng, and Shi-Yomi district of Arunachal Pradesh, the eastern most state of India. In the study area, local people harvest these mushrooms from the grassland after the snow layer declines following the first rainfall in between April-July months of the year. The collection of these peculiar species is a tedious work as informed by the local collectors. The questionnaire survey revealed that the primary purpose of collection of this mushroom by the locals is for personal uses.They use it as an ingredient of their traditional medicinal preparations and for a subsidiary income generation due to its high market value. The caterpillar fungus is very popular and well known among the local people of high altitude areas of Arunachal Pradesh. Local tribes of these areas are mainly Monpa and Sherdukpen in West Kameng and Tawang districts and Memba in Shi-Yomi district. Their religious belief is mostly Buddhism. The Nepali-origin people also found to consume this fungus in a similar ways, although, they aren't originally from Arunachal Pradesh, and might have settled in towns across the state over the years due to migration. In fact, they make up a significant part of the population in several areas, including some of the study sites.

Harvesting process

Mostly the collection of *Cordyceps* fungus is dealt by some definite group of people of the villages associated with Yak farming. It is a subsidiary output when they take their cattle for grazing to the high altitudinal areas to facilitate them with colder temperature as the higher temperature starts in the lower parts is not suitable. They are also experts in searching and harvesting technique of caterpillar fungus. The places from which collection was undertaken are at the high mountain ranges far away from the human establishments and so remote without any modes of communication and reachable after 2-3 days of trekking. The local people who provide their services as porters to carry ration and other items for military bases inaccessible to vehicles are also involved in collection and harvesting of *Cordyceps* from high altitudes in Arunachal Pradesh. It was also informed that the collection is done from the selected sites periodically in a gap of two to three years. The collection of the species was reported to be a very tough task as only the black part of the mushroom is above ground hidden between the grasses while rest part remains underground. The collection involves hard work and sharp visualization which is again a result of vast experience. Usually, a maximum of 10 specimens is supposed to be collected in a single day. The survey also documented that a living infected larva is very hard to find-out and villagers believe that it's highly effective for the preparation of traditional medicines. A small knife and fingers are the only equipment which fit the process of harvesting by digging carefully and are preserved by drying in direct sunlight (Fig 3).

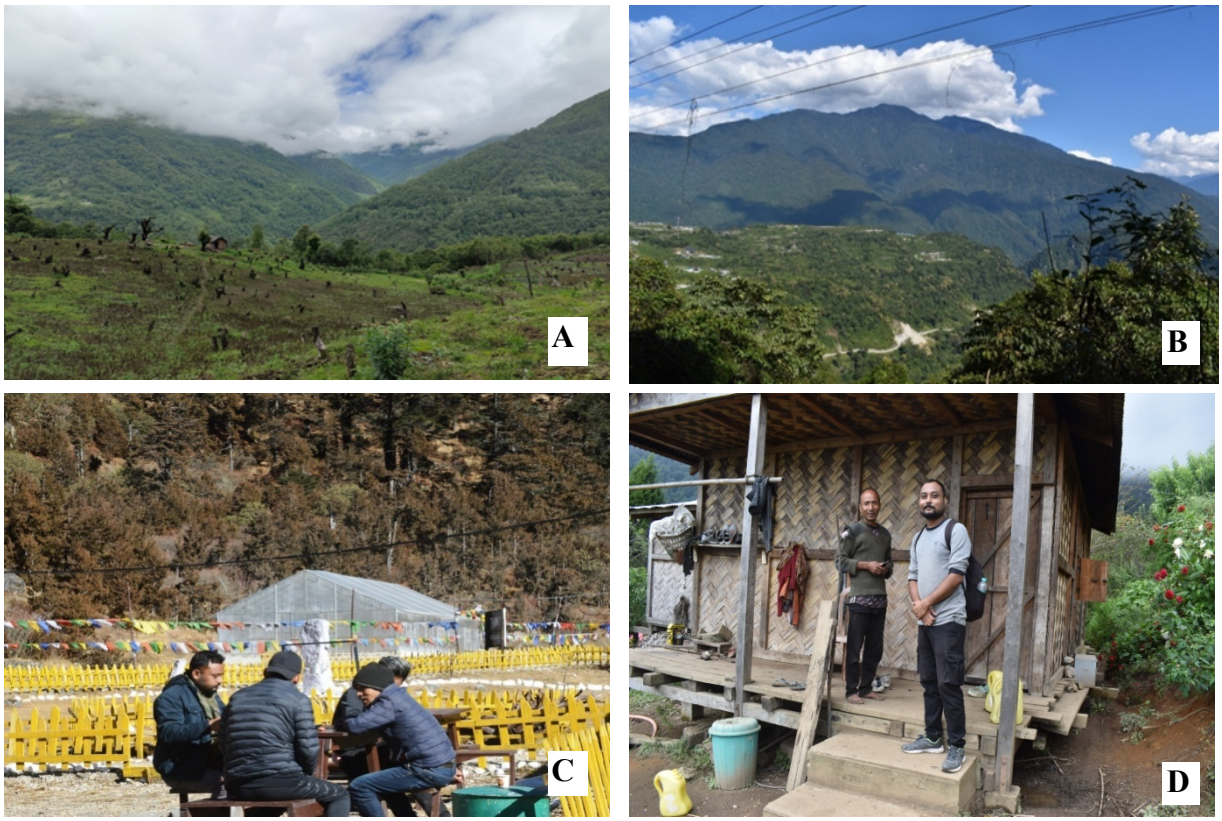

Figure 2. Ethnomycological data collection from study sites [A&B- Hilly terrain of study area; C&D- Interaction with local informants during survey].

Figure 3. *Cordyceps sinensis* [A&B- Drying of specimen for storage; C&D- Size of dried specimen].

Medicinal uses

Ethnomycological studies revealed that local inhabitants of study area use this mushroom as medicine in several health ailments / diseases irrespective of age-group. Common uses documented were in tumour, inflammation of legs and belly, liver and kidney disorders, jaundice, cancer, back and knee pain, diabetes, cough and cold etc. (Table2). It is believed that during pregnancy its consumption is very effective for developing baby'shealth. The respondents also informed that the consumption of *Cordyceps* functions as a sexual stimulant both in male and female. Traditional healers suggest different ways of consumption for *Cordyceps* in different health disorders. Besides using as medicine, the locals use it as a natural tonic for immunity booster, anti-aging and longevity. The survey revealed that *Cordyceps* is predominantly utilized by the local population (18.2%) as an anti-aging agent (Fig 4). Additionally, it is employed as an immunity booster (14%), and for the treatment of tumours (12%), cancer (12.3%), and inflammation of body parts (11.4%). These findings indicate a strong traditional reliance of local tribes on *Cordyceps* for enhancing their general health, managing chronic diseases, and mitigating age-related conditions.

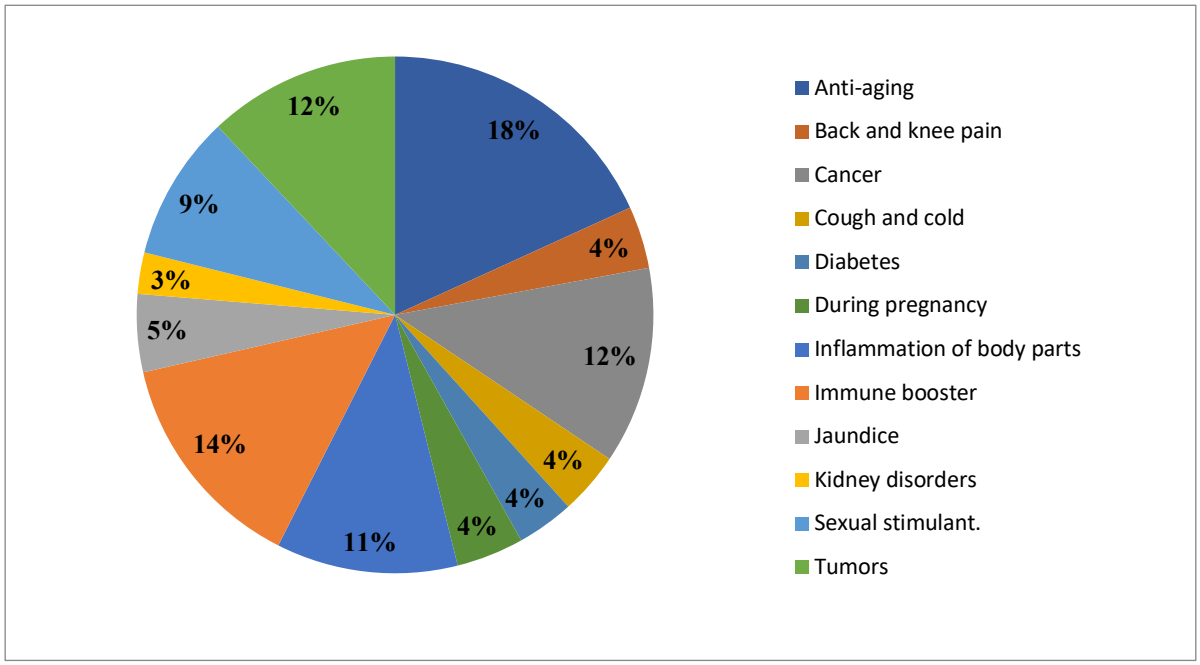

Figure 4. Uses of *Cordyceps sinensis* in the treatment of various health ailments.

Mode of utilisation

The most commonly followed method of consuming *Cordyceps* is by roasting (24.8%) as a whole. Another popular method involves combining it with their traditional alcoholic beverage, popularly known as **'aara'** (20.1%). In this process, a single piece of *Cordyceps* is dipped into a glass of hot aara for several hours to overnight and the drink is consumed along with hot yak milk ghee. Sometimes, boiled water (12.8%) replaces aara during consumption (Fig 5). Other methods include consuming the *Cordyceps* in the form of dry powder (8%) or mixing it with milk (9.9%) or by roasting with yak milk ghee. It is also sometimes consumed raw (15.3%) or mixed with other traditional herbs (9.1%).

Trade channels

The trade of *Cordyceps* in the study area is very typical as it lacks a discernible market channel which has been resulted into its varied prices. The market value is mainly dependent on the size and colour of the material; the bigger in size with yellowish colour evaluated highest. During the study period, the average price recorded was 250–400 rupees per piece (Table 2). The average weight of its single piece was recorded 0.13mg. Two market channels were recognized for sale of this fungus during this survey. Firstly, the harvesters sell the dried collection to the local agents directly. Secondly, the purchase by the regional or national agents from various parts of the state/country with a gradual increase in price. A field collector normally generates about 1-2 lakh rupees in a season. Due to secretive in nature, it is very hard to know the actual price structure between local agents and regional agents as they do not reveal actual transactions. Nearest town from site of collection is the primary hub for dealing agents. For example, in West Kameng district, it is Dirang and Bomdila, in Tawang district, Tawang town itself and in Shi-Yomi district, it is Mechukha.

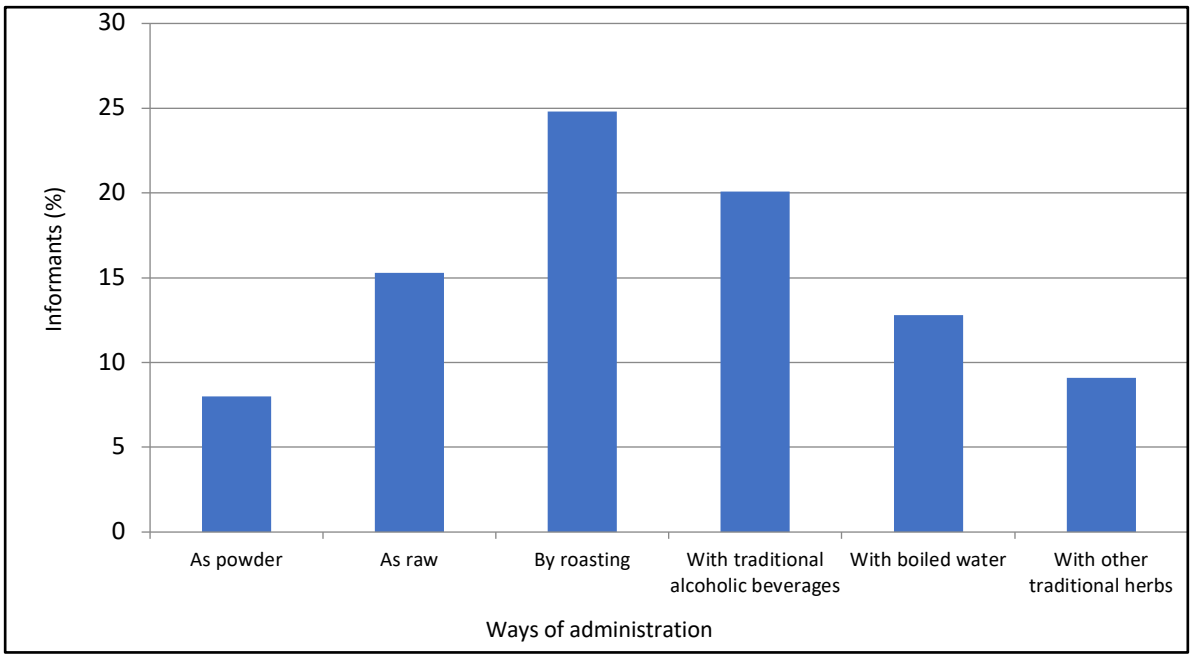

Figure 5. Mode of utilisation of *Cordyceps sinensis* reported by informants.

Quantitative data analysis

In the present study, *Cordyceps sinensis* exhibited a high Relative Frequency of Citation (RFC) value of 0.74. The elevated RFC value indicates that the fungus is frequently utilized by local communities for a variety of medicinal purposes. Among the four ethnic groups studied, the Cultural Importance Index (CI) values varied. The Monpa tribe exhibited the highest CI value (0.93), indicating that nearly all members of this group are familiar with the various uses of *Cordyceps*. This was followed by the Memba (0.72), Nepali (0.62), and Sherdukpen (0.50) communities (Fig 6).

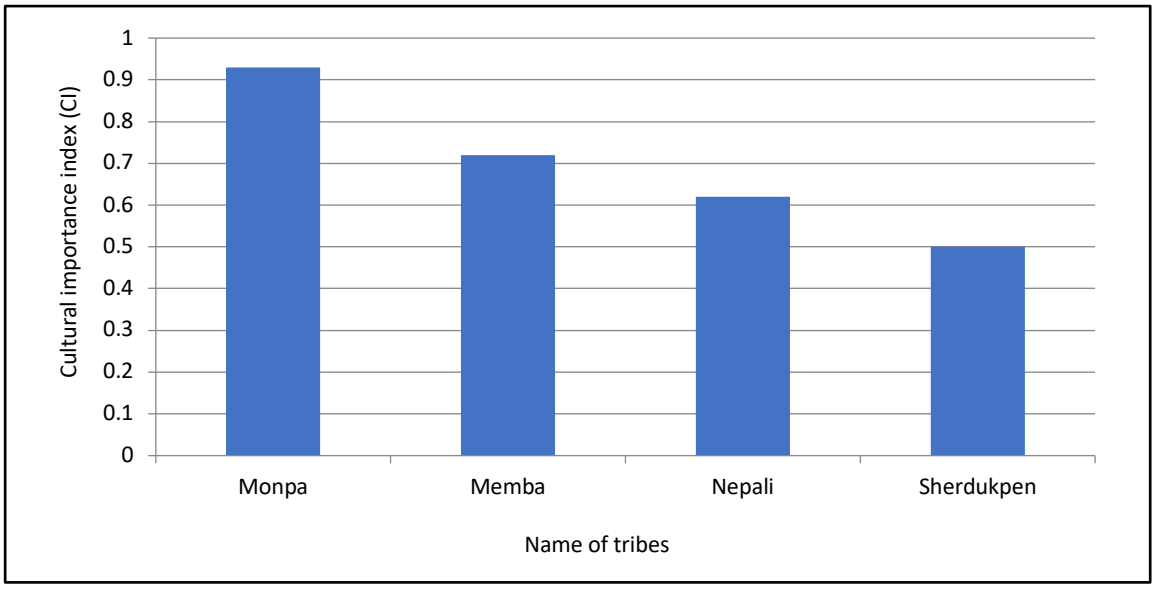

Figure 6. Cultural Importance Index (CI) of *Cordyceps sinensis* among the different tribes.

Table 2. Ethnomycological uses of *Cordyceps sinensis* by the local people of Arunachal Pradesh, India

Study area	District	Tribes	Price/piece (in INR)	Used in the treatment of	Preparation
Nyukmadung	West Kameng	Monpa	250-350	Anti-aging, Tumours, inflammation of legs and belly, liver and kidney disorders, Jaundice, back and knee pain.	Used along with traditional alcoholic beverages, consumed as raw or roasted with yak milk ghee, eaten with other traditional herbs.
Bomdila	West Kameng	Monpa, Sherdukpen and Nepali	350-400	Swelling of belly, legs, tumours and anti-aging.	Do
Dirang	West Kameng	Monpa and Nepali	350-400	Inflammation of body parts, and for liver and kidney disorders.	Do
Tawang	Tawang	Monpa and Nepali	300-350	Tumour, cancer, diabetes and as sexual stimulant both in male and female.	Consumed raw or used along with traditional alcoholic beverages or with boiled water and yak milk.
Thingbu	Tawang	Monpa	250-300	Cancer, back and knee pain, diabetes, cough and cold and during pregnancy for developing baby's health.	Do
Mago	Tawang	Monpa	250-300	Cancer, tumours, anti-aging and as immune booster.	Do
Mechukha	Shi-Yomi	Memba	300-400	Immunity development, anti-aging and as sexual stimulant.	Used as dry powder, also consumed with milk or fried with ghee.

Discussion

Mushrooms are being used as source of protein and different forms of medicines since earlier times. Ethnomycological knowledge among different tribes of Arunachal Pradesh on *C. sinensis* had been found to be similar with the other parts of India, Bhutan, Nepal and Tibet (Bhatt *et al.* 2018, Boesi& Cardi 2009, Chen *et al.* 2010).This may be due to their common faiths or sources of traditional beliefs. The findings of this study reaffirm the significant ethnomedicinal and economic importance of *Cordyceps sinensis* in the Himalayan region, particularly among the indigenous communities of Arunachal Pradesh.In this study,it was found that almost all individuals of local communities here possess great knowledge on importance of highly valued *C. sinensis* for its therapeutic properties, particularly in treating fatigue, kidney and liver disorders, and enhancing sexual vitality. This confirms the previous findings from Nepal and China (Sharma 2004, Winkler 2008).The high values of Relative Frequency of Citation (RFC) and Cultural Importance Index (CI) observed in this study highlight the significant cultural and medicinal relevance of *Cordyceps sinensis* among the local communities. The consumption method and medicinal uses of this fungal species werefound to be similar with that of other tribes of Himalayan region. Local people of Dopla in Nepal consumed the mushroom with milk and ghee along with local wine and hot water (Devkota 2006). In Bhutan, it is consumed as hot soup with local made wine (Panda & Swain 2011) and people of Sikkim also consumed with local wine. Studies had revealed that price of mushroom is comparatively higher and have been increasing day by day. The prices have been reported to be increased by 2,000% in some countries as reported in Nepal in the last 10 years (Stone 2015). In India, the price of the *Cordyceps* mushroom was recorded 1lakh per kg (Sharma 2004), which has now documented to increase up to 20 to 25lakh for 1 kg of dry mass in the present study. Hence, it has turned into a major source of income for rural tribes due to increased demand and prices in the world market (Negi *et al.* 2014). The fungus acts as a source of financial security in some rural communities of the Himalayas (Karki *et al.* 2020, Shrestha &Bawa 2014, Yadav *et al.* 2019) providing house hold income up to 50-70% (Wang *et al.* 2022). In Alpine area of Arunachal Pradesh, local inhabitants can earn up to 1-2 lakh in a season. In some area of Sikkim a household can earn about US$ 2916 (Pradhan *et al.* 2020). Markets and trade channels for *C. Sinensis*are almost invisible in nature in India (Maity 2013) but very mush operative regularly. In the study region, the mushrooms cost was found to vary due to unavailability of any proper market or trading channel. Earlier reports (Bashyal& Roberts 2024) revealed that *Cordyceps sinensis* is available in the e-commerce websites too with a highest advertised value of 155 US$. The collectors or sellers sometimes get a good trade up to 1500000 INR per season but often fail to hit the target price on regular basis.

Conclusion

This study provides a comprehensive ethnomycological account of *Cordyceps sinensis* among the tribes of Arunachal Pradesh inhabiting high-altitudinal areas, revealing its vital role in traditional healthcare, cultural practices, and local economies. The fungus is highly revered for its wide range of medicinal applications thus serves as a critical source of supplementary income for rural households thereby contributing to enhance their socio-economy. The data indicate a high cultural importance and frequency of use among different ethnic groups, particularly among the Monpa community. However, the lack of an organized market and the secretive nature of the trade create discrepancies in pricing and benefits to the collectors. Given the increasing global demand and significant price escalation, sustainable harvesting and regulated trade practices are crucial. Additionally, there is a pressing need for systematic documentation and scientific validation of indigenous knowledge to prevent its erosion and to ensure the conservation of this invaluable natural resource for future generations.

Declarations

List of abbreviations: CI- Cultural Importance Index, INR- Indian Rupees, RFC- Relative Frequency of Citation, US$- United States dollar.

Ethics approval and consent to participate: The study was conducted in accordance with ethical research guidelines. All participants were fully informed about the objectives and scope of the study prior to participation.

Consent for publication: All people shown in images gave their consent to have the image published.

Availability of data and materials: Not applicable.

Competing interests: The authors declare that there is no conflict of interest.

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Author contributions: Conceptualization of research (KS, AB); Design of the experiment (KS, AB, SSS); Contribution of experimental materials (KS); Execution of field /lab experiments and data collection (AB, KS); Analysis of data and interpretation (AB, KS); Preparation of the manuscript (AB, KS).

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