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Research article

Potential utilization of edible insects as nitrogen sources on growth characteristics and bioactive compound production in *Isaria tenuipes*

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Abstract

Importance of the work: *Isaria tenuipes* is an entomopathogenic fungus that has been used as a traditional medicine due to its biochemical and pharmaceutical properties. Preliminary research revealed that medium supplemented with insects promoted mycelial growth and cordycepin production.

Objectives: To evaluate the suitability of edible insects as a substrate for *I. tenuipes* cultivation and to investigate the mycelial growth, formation of fruiting bodies and concentrations of cordycepin and adenosine.

Materials & Methods: Seven edible insects were used as nitrogen sources in *I. tenuipes* cultivation. The mycelial growth on potato dextrose agar with different edible insects was measured on days 7, 14 and 21. Fruiting body formation and bioactive compounds were analyzed 60 d after being cultured on brown rice medium containing each edible insect.

Results: Eri silkworm (*Samia ricini* D.) and silkworm were used to produce the fastest mycelial development on days 7 and 14, with the most extended colonies recorded at 90 mm on day 21; however, this was not significantly different from mealworm, sago palm weevil and the control. The fresh and dry weights of fruiting bodies increased in the brown rice media containing Eri silkworm. The highest cordycepin content (244 mg/100 g) and the highest adenosine content (57.7 mg/100g) were found in the fruiting bodies cultured on brown rice supplemented with Eri silkworm.

Main finding: Eri silkworm could be suitable for use as a nitrogen source in *I. tenuipes* cultivation, resulting in a high amount of bioactive compound content.

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Introduction

Isaria is an entomopathogenic fungus with over 100 species that contribute to biodiversity conservation and is used in medicine and agriculture (Zhang et al., 2019). *Isaria tenuipes* Yasuda, or *Isaria japonica,* an anamorph of the *Cordyceps* species, is a widespread fungus that frequently infects and kills insects before releasing its white, powdery spores (Zhang et al., 2019). *I. tenuipes* is known as "snow-flake Dongchunghacho" in Korea (Che et al., 2015). Several entomopathogenic fungi, such as *Cordyceps* species, have long been utilized in Asia as traditional health food and medicine ingredients (Chhetri et al., 2020). One of the most potent species in the genus *Isaria* is *Isaria tenuipes*, which has been discovered to contain various bioactive compounds with medicinal value (Supothina et al., 2011; Chhetri et al., 2020). The bioactive compounds produced by *I. tenuipes* have been identified as cordycepin, adenosine, isariotins, beauvericin, beauveriolides and fingolimod (Hong et al., 2007; Chhetri et al., 2020). Culture techniques of *I. tenuipes* have been developed for fruiting body production; the morphogenesis of edible mushrooms in cultivation is known to be influenced by environmental elements such as light, carbon dioxide concentration, temperature, and gravity (Inatomi et al., 2000). The morphology of the fruiting body in *I. tenuipes* is known to be affected by light illumination and CO_2 concentration (Namba et al., 2003). Specific amino acids, precursors, inducers or elicitors are required to produce secondary metabolites by microbes, including fungi (Lee et al., 2019; Oh et al., 2019). Furthermore, carbon and nitrogen supply are also crucial, since cell growth and metabolite biosynthesis are intimately related (Lee et al., 2019). Among various grain substrates, brown rice has been reported to be the best basal substrate for fruiting body and cordycepin production (Kim et al., 2010; Wen et al., 2014; Li et al., 2020). Brown rice that has been hydrolyzed contains enough reducing sugar to provide *Cordyceps militaris* with an abundant carbon source for growth (Xie et al., 2009). Among various nitrogen sources, such as yeast extract, soybeans, skim milk powder, egg yolk, fresh pupa, and dry pupa, the best nitrogen source to produce cordycepin was the dry pupa (Li et al., 2020). In nature, insects serve as a direct source of nutrition for *Cordyceps*, such as protein and fat. In order to simulate natural circumstances, insects like pupae have been added to increase the cordycepin content (Turk et al., 2022), with the amount of cordycepin in *Cordyceps* grown on pupae being significantly higher than in rice (Turk et al., 2021). Many researchers have focused on the cultivation practices of *Cordyceps* by using silkworm varieties as a host for the fruiting body formation (Lee et al., 2001; Kang et al., 2010; Hong et al., 2011). Besides silkworm, other edible insects have been investigated, such as *Tenebrio molitor* (mealworm), *Gryllus bimaculatus* (cricket), *Caelifera* sp. (grasshoppers), *Allomyrina dichotoma* (beetle) and *Protaetia brevitarsis* larvae (Turk et al., 2022). On a fresh weight basis, edible insects, including the mulberry silkworm, Bombay locust, house cricket, and scarab beetle have high protein contents, in the range 27–54 g/100g edible portion (Köhler et al., 2019). There is potential to use edible insects as nitrogen sources in the *Cordyceps* cultivation process. Therefore, the current study aimed to screen the potential of edible insect utilization as substrate for *I. tenuipes* cultivation and to investigate mycelial growth, fruiting body formation and the cordycepin and adenosine contents.

Materials and Methods

Fungal strain

The *Isaria tenuipes* sample used in this experiment was obtained from SP. Cordyfarm; Saraburi, Thailand. The *I. tenuipes* were maintained on potato dextrose agar (PDA) and kept at 4 °C.

Edible insects

Eri silkworm pupae (*Samia ricini* D.), silkworm pupae (*Bombyx mori* L.), adult field cricket (*Gryllus bimaculatus* De Geer), adult house cricket (*Acheta domesticus* L.), sago palm weevil larvae (*Rhynchophorus ferrugineus* Olivier), adult giant water bug (*Lethocerus indicus* Lep. and Serv.) and mealworm larvae (*Tenebrio molitor* L.) were bought from local organic farms in Nakhon Ratchasima, Thailand. The protein content of each edible insect has been reported by Wongsorn et al. (2021), with the highest amount in the Eri silkworm (75.0%), followed by house cricket (65.36%), field cricket (55.87%), silkworm (52.44%), giant water bug (49.79%), mealworm (49.06%) and sago palm weevil (24.52%). Furthermore, they reported that sago palm weevil, mealworm, giant water bug, silkworm, field cricket, house cricket and Eri silkworm had average nitrogen contents on a dry matter basis of 3.92%, 7.85%, 7.97%, 8.39%, 8.94%, 10.46%, and 12.01%, respectively.

Effect of boiled edible insects on the I. tenuipes mycelial growth

The ratios of edible insects used in this study were modified according to Li et al. (2020). A sample (10 g) of each edible insect was boiled in 100 mL of water at 95 °C for 20 min. Then, the boiled edible insects were mashed and filtered. The filtered solution was combined with PDA at a proportion of 1:10 (weight per volume, w/v). Each PDA and edible insect mixture was sterilized at 121 °C for 20 min before being put into a sterile Petri dish. A mycelial plug (5 mm) of *I. tenuipes* grown on PDA (14 d of cultivation) was inoculated onto the center of the PDA containing each insect filtrate solution. The inoculated PDA plates were incubated in darkness at 22 °C for 21 d. A completely randomized design was used for the experiment, which consisted of eight treatments (PDA, PDA+Eri silkworm, PDA+silkworm, PDA+giant water bug, PDA+field cricket, PDA+house cricket, PDA+mealworm, PDA+sago palm weevil), with three replications of each treatment and five plates for each replication. The mycelial growth of *I. tenuipes* was measured as the diameter of the fungal colony after incubation for 7, 14 and 21 d.

Cultivation of fruiting bodies of I. tenuipes on brown rice medium supplemented with edible insects

I. tenuipes was cultivated in brown rice medium containing boiled edible insects, as described by Guo et al. (2016). Briefly, *I. tenuipes* was cultivated on PDA and incubated at 20 °C for 10 d and then inoculated into potato dextrose broth (PDB) by cutting a circle (5 mm in diameter) from the agar plate culture using a sterile blade. The cultures were cultivated in separate 500 mL bottles containing 150 mL of PDB medium and incubated at 18 °C for 7 d under shaking conditions (150 revolutions per minute, rpm). Basal liquid medium was prepared as follows: 200 grams of potato and 50 g of baby corn were boiled in 1,000 mL of water and filtered using a double cheesecloth. Glucose (15 g/L), peptone (10 g/L), yeast extract (10 g/L), thiamine (200 mg/L) and magnesium sulfate (0.5 g/L) were added to the filtrate. Each edible insect (10% w/v) was blended with the basal liquid medium. Then, 35 mL of additive broth supplemented with each edible insect was added into a glass bottle containing 16 g of brown rice. The bottles were capped and autoclaved at 121 °C for 20 min. The seed cultures were inoculated with brown rice medium containing each boiled edible insect in a 250 mL glass bottle at 18 °C with relative humidity >80% and 12 hour light-to-12 hour dark conditions at a light intensity of 500 lx. In each experiment, the fresh and dry weights of fruiting bodies and total weight were recorded after 60 d of inoculation. According to Lin et al. (2010), biological efficiency (BE) values were computed using the formula: [dry weight of fruiting bodies / dry matter content of growth substrate] × 100%.

Cordycepin and adenosine extraction and high-performance liquid chromatography analysis

The preparation of the *Cordyceps* extracts was carried out following Wang et al. (2015). Fresh fruiting bodies were dried in a hot-air oven at 50 °C for 24 hr and then ground into powder. The *Cordyceps* powder was dissolved in deionized water at a solid-to-solvent ratio of 5% (w/v). After that, the extraction was sonicated for 2 hr at 50°C in a sonication bath. The supernatant was obtained after centrifugation at 4,000 rpm for 20 min, which was then passed through a 0.22 μm filter. Subsequently, high-performance liquid chromatography (HPLC) analysis was performed on the resultant extracts.

HPLC was carried out using an RP-18 column (150252 Purospher STAR RP-18 end-capped (5 μm) LiChroCART 250-4; Merck) at a flow rate of 1 mL/min. A 20% methanol-to-H_2O ratio constituted the mobile phase. A diode array detector (DAD) and the appropriate retention periods of the various standard compounds under identical HPLC conditions were used to detect two specified components—adenosine and cordycepin—at 260 nm. Quantitative analysis was done following each compound's specified standard curve.

Data analysis

The data were analyzed using analysis of variance and means were compared using Duncan's new multiple range test.

Results and Discussion

Effect of edible insect on I. tenuipes mycelial growth

The boiled edible insect filtrate solution was combined with PDA in a 1:10 (w/v) ratio as the nitrogen source. The diameter of the fungal colony was measured on days 7, 14 and 21 to estimate the growth of *I. tenuipes* on PDA supplemented with each edible insect (Table 1; Fig. 1). The colony diameter of *I. tenuipes* varied depending on the edible insects used as a nitrogen source in the PDA medium. Among the nitrogen sources tested, Eri silkworm tended to perform better than the other sources as shown by the highest colony diameter in days 7 and 14 and even in day 21 it was among the supplementations with good performance despite of the non-significant results compared with the control (Table 1). Silkworm significantly produced the fastest mycelium development only at day 7 and it showed similar performance with the control in day 14 and 21 after incubation. In this study, *I. tenuipes* on PDA supplemented with edible insects, such as house crickets and giant water bugs, produced lower radial mycelial growth than on PDA alone (the control) but with slightly greater mycelial thicknesses. The edible insects supported the mycelial density of *I. tenuipes* as evidenced by relatively thin mycelial density of fungi grown on PDA without them compared to the others (Fig. 1). Wongsorn et al. (2021) reported that the nitrogen and protein contents of these edible insects were in the ranges 3.9–12.0% dry matter and 24.5–75.0% dry matter, respectively. The highest nitrogen (12%) and protein (75%) dry matter contents were produced by the Eri silkworm (*Samia ricini* D.). Consequently, the Eri silkworm could enhance mycelial formation better than the other insect supplementations, at least at 14 d. The findings in the current study were consistent with those of Wongsorn et al. (2021), who reported on silkworms that had been used to cultivate *Cordyceps* and had increased mycelial formation. According to Laursen (2018), the radial mycelial growth and thickness significantly differed depending on the available nitrogen source for three strains of *Pleurotus ostreatus.* Typically, the optimal nitrogen source for the growth of fungal mycelia is evaluated using complex organic nitrogen, amino acids and inorganic nitrogen (Liu et al., 2018). Mycelial development could be better supported by complex organic nitrogen sources, such as yeast extract, peptone and tryptone, rather than by carbon sources (Sung et al., 2011). Besides the protein and nitrogen content, edible insects have been reported to have different fat and carbohydrate contents (Turk et al., 2022). Depending on the species of insect, their cuticular and internal fatty acids are known to have a variety of poisonous and fungistatic effects on the germination of fungal spores and mycelial growth, while certain fatty acids have also been reported to have stimulatory effects (Gołębiowski et al., 2013; Kaczmarek and Boguś, 2021). It has been reported that the cuticle of *B. mori* larvae contained short-chain free fatty acids that prevented *B. bassiana* and *Isaria fumosorosea* from proliferating (Saito and Aoki, 1983; Gołębiowski et al., 2013). Furthermore, linoleic acid—but not oleic acid—could inhabit the mycelial growth of *Alternaria solani*, *Fusarium oxysporum* f. sp. *lycopersici*, *F. oxysporum* f. sp. *cucumerinum* and *Crinipellis perniciosa* (Liu et al., 2008). It could be that this variance in mycelial formation is caused by the different nutrient contents of edible insects, such as protein and fat. These results supported the hypothesis that some edible insects could be used as the substrate for fungal cultivation. However, the effects on fungal growth of the fatty acid and amino acid contents of each edible insect have yet to be fully understood and further studies are required.

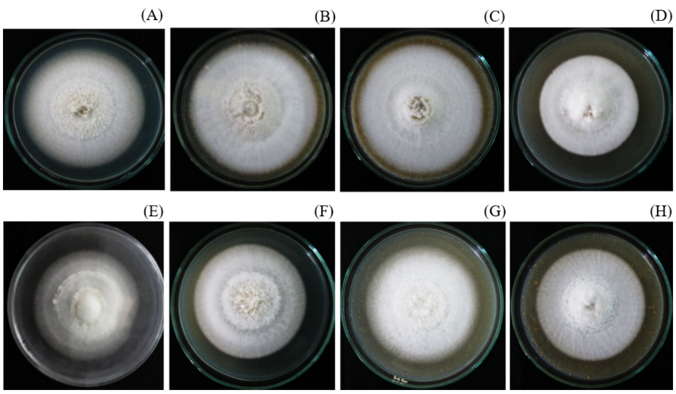

Fig. 1 Mycelial growth of *Isaria tenuipes* on potato dextrose agar containing various edible insects: (A) no addition (control); (B) Eri silkworm; (C) silkworm; (D) giant water bug; (E) field cricket; (F) house cricket; (G) mealworm; (H) sago palm weevil

Table 1 Colony diameter of *Isaria tenuipes* cultured on potato dextrose agar mixed with various boiled edible insects

Culture medium	Colony diameter (mm)		
	7 d	14 d	21 d
PDA (Control)	32.50 ± 0.86^{b}	65.16 ± 2.02^{b}	87.83 ± 1.04^{ab}
PDA + Eri silkworm	35.50 ± 1.00^{a}	73.00 ± 2.50^{a}	90.00 ± 0.00^{a}
PDA + Silkworm	34.83 ± 0.57^{a}	65.50 ± 1.73^{b}	90.00 ± 0.00^{a}
PDA + Giant water bug	25.66 ± 0.28^{e}	47.66 ± 0.28^{f}	71.83 ± 1.52^{d}
PDA + Field cricket	24.16 ± 0.28^{e}	51.16 ± 4.04^{ef}	85.50 ± 1.73^{b}
PDA + House cricket	28.00 ± 1.00^{d}	53.83 ± 0.57^{de}	81.00 ± 1.80^{c}
PDA + Mealworm	29.66 ± 1.04^{c}	60.50 ± 1.50^{c}	88.66 ± 2.30^{ab}
PDA + Sago palm weevil	28.66 ± 1.44^{cd}	56.50 ± 3.12^{d}	86.33 ± 4.04^{ab}
p value	< 0.0001	< 0.0001	< 0.0001
CV (%)	3.00	3.88	2.32

PDA = potato dextrose agar; CV = coefficient of variation

Mean±SD in each column superscripted with different lowercase letters are significantly different ($p < 0.05$).

Effect of brown rice media supplemented with edible insects on fruiting body formation of I. tenuipes

To observe the effect of edible insects on the induction of fruiting bodies, a brown rice medium supplemented with each edible insect was used for culturing *I. tenuipes* (Table 2; Fig. 2). Different insect supplementations yielded non-significant different total weight (either fresh or dry weight) which was not different with the control (Table 2). In terms of the fruiting body (fresh and dry), three insect supplements (Eri silkworm, silkworm, and mealworm) gave significantly ($p < 0.05$) higher yield than that of the control while non-significant differences were observed between the other insect supplements and that of the control. Interestingly, in terms of biological efficiency (the ratio of the dry weight of the fruiting body per dry weight of substrate), only Eri silkworm and silkworm supplements performed better ($p < 0.05$) than the control, while the other supplements gave either similar ($p \geq 0.05$; house cricket and sako palm weevil) or lower ($p < 0.05$; giant water bug, field cricket, and mealworm) biological efficiency as compared to the control. Cereals with organic compounds have been widely utilized in the industrial production of *C. militaris* (Lin et al., 2017). Among such tested cereals, the best fruiting body production of *Cordyceps cardinalis* and *C. militaris* was achieved when brown rice was used as a carbon source (Kim et al., 2010; Wen et al., 2014; Li et al., 2020). The results of the current study are consistent with those of Ban et al. (1998), who reported the highest yield of fruiting bodies of *I. tenuipes* was obtained in a carbon-rich medium supplemented with pupal powder from silkworm. Rice combined with silkworm pupae has outperformed other substrates and is widely utilized for the production of fruiting bodies of *Cordyceps* sp. which progressively improved as the silkworm pupae and larvae were added to the grains as a nitrogen source (Kim et al., 2010, Li et al., 2020). The nitrogen requirements of *C. militaris* strains are comparatively low; consequently, excessive nitrogen may impair fruiting-body differentiation (Shrestha et al., 2012). According to Lin et al. (2010), a C-to-N ratio of 12:1 produced the highest fruiting body yields and biological efficiency of *Cordyceps guangdongensis*. Turk et al. (2022) characterized the nutrition composition of six edible insects: *Bombyx mori* (silkworm pupae), *Tenebrio molitor* (mealworm), *Gryllus bimaculatus* (cricket), *Caelifera* sp. (grasshoppers),

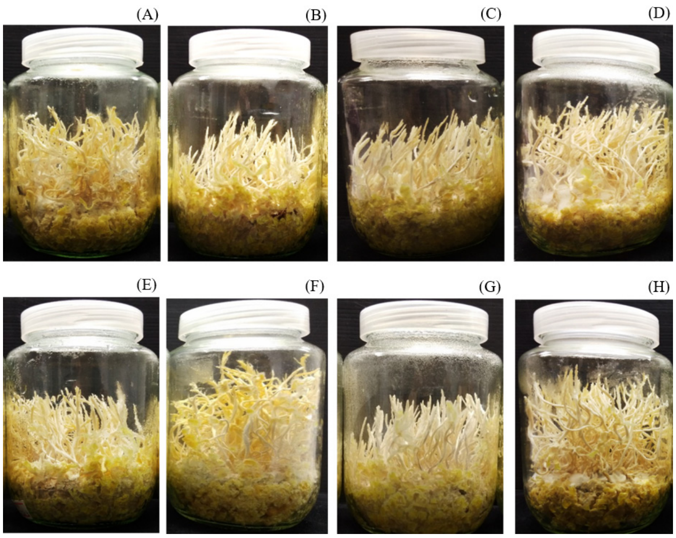

Fig. 2 Fruiting body formation of *Isaria tenuipes* on brown rice containing various edible insects: (A) no addition (control); (B) Eri silkworm; (C) silkworm; (D) giant water bug; (E) field cricket; (F) house cricket; (G) mealworm; (H) sago palm weevil

Table 2 Total weight, fresh weight and dry weight of fruiting body and biological efficiency of *Isaria tenuipes* cultured for 60 d on brown rice supplemented with various boiled edible insects

Medium	Product (mean ± SD)				Biological efficiency (%)
	Total weight (g/bottle)		Fruiting body (g/bottle)		
	Fresh weight	Dry weight	Fresh weight	Dry weight	
Brown rice (Control)	62.38±2.66	18.69±1.14	10.69±4.26[b]	1.79±0.69[c]	10.64±1.09[e]
Brown rice + Eri silkworm	60.32±1.25	20.04±1.06	21.88±0.06[a]	4.43±0.79[a]	28.31±1.48[a]
Brown rice + Silkworm	63.17±2.54	19.00±1.07	22.61±1.98[a]	3.73±0.38[ab]	24.62±3.76[ab]
Brown rice + Giant water bug	63.14±1.92	21.08±0.97	14.69±2.67[b]	2.64±0.81[bc]	14.27±1.56[e]
Brown rice + Field cricket	62.06±1.29	20.21±0.54	13.30±4.98[b]	2.30±0.85[bc]	12.91±1.77[e]
Brown rice + House cricket	62.12±2.20	18.80±1.23	22.45±1.17[a]	3.40±0.89[ab]	22.09±0.55[bc]
Brown rice + Mealworm	62.83±1.58	20.47±1.50	15.57±6.80[ab]	2.66±0.99[bc]	15.61±3.92[de]
Brown rice + Sago palm weevil	62.70±0.78	19.46±1.96	18.95±5.42[ab]	3.07±0.65[bc]	19.01±3.61[cd]
p value	0.1960	0.2520	0.0244	0.0174	<0.0001
CV (%)	2.00	6.31	25.21	25.81	13.94

CV = coefficient of variation

Mean±SD in each column superscripted with different lowercase letters are significantly different ($p < 0.05$).

Allomyrina dichotoma (beetle) and *Protaetia brevitarsis* (larvae). They found that all six contained high levels of protein and fat but the amounts differed among the insects. After 35 d of cultivation, the development of fruiting bodies was remarkable on *B. mori* and *T. molitor*, good on *A. dichotoma* and *G. bimaculatus*, and weak on *P. brevitarsis* and *Caelifera* spp. (Turk et al., 2022). Each insect had a very diverse pattern of fruiting body growth and development.

Cordycepin and adenosine analysis

Cordycepin and adenosine in the fruiting bodies of *I. tenuipes* were analyzed and compared among the different edible insect substrates as shown in Table 3. The cordycepin and adenosine contents were in the ranges 171.3–244.0 mg/100 mg and 36.2–57.7 mg/100 mg, respectively. In terms of bioactive compounds, Eri silkworm supplement also performed the best with the maximum content of cordycepin (244.0 mg/100g) and adenosine (57.7 mg/100g). However, the latter did not significantly differ from that of silkworms (53.4 mg/100g). It should be noted that silkworm supplement gave almost the lowest production of cordycepin while its adenosine production was among the highest. Several factors impacted on the bioactive components in *Cordyceps* fruiting bodies, including medium composition, grain substrate, nitrogen source, light, and culture conditions (Wen et al., 2014; Lin et al., 2017). Among solid substrates, rice, brown rice, oats, and wheat, including spent brewery grains, were the optimal culture substrates for high cordycepin production (Gregori et al., 2014; Wen et al., 2014; Adnan et al., 2017). In the case of nitrogen sources, organic nitrogen has been reported to be advantageous for both the growth and biosynthesis of metabolites (Kang et al., 2014). Furthermore, medium supplemented with insects such as silkworms has been reported to increase the cordycepin and adenosine content (Turk et al., 2021, 2022; Wen et al., 2019; Li et al., 2020). Cordycepin, carotenoids, superoxide dismutase (SOD) and nitrogen contents have been reported to be higher in pupae-fruiting bodies than wheat-fruiting bodies (Guo et al., 2016). Additionally, to silkworm, *Cordyceps cicadae* MP12 was inoculated into *Cryptotympana atrata* cicada pupae for *in vivo* culture, where the fungus developed its fruiting body and included the contents of adenosine and cordycepin in dried fruiting bodies after culture, which were 1421.45 g/g and 1398.12 g/g, respectively. Turk et al. (2022) reported that proteins, lipids and carbohydrates act as sources of carbon and nitrogen for the synthesis of cordycepin, with the amount of cordycepin produced by *Cordyceps* grown on each edible insect dependent on how much of the insect's nutrients are utilized. *Cordyceps* has developed a variety of enzymes and transporters to extract different nutrients from insect hosts (Raethong et al., 2020). Even though mealworms and silkworm pupae provided the best conditions for *Cordyceps* growth, rhinoceros beetles (*Allomyrina dichotoma*) were the source of the highest cordycepin (Turk et al., 2022). *Cordyceps* grown on these beetles produced the most significant production of cordycepin, which was 34 times more than that of *B. mori* pupae. Besides the protein content, a critical factor in cordycepin production was correlated with the content of fatty acids in the insects, specifically the concentration of oleic acid (Turk et al., 2022). Longvah et al. (2011) demonstrated that the Eri silkworm prepupae, along with pupae, raised on either castor or tapioca were good sources of protein, fat and minerals due to their nutrient composition and mineral levels. In addition, the glutamate amino acid was as high as in Eri silkworm. The biosynthesis of cordycepin has been reported to be regulated by the glutamine and glutamate pathways, based on amino acid metabolism (Oh et al., 2019; Lee et al., 2019). Hence, the presence of the nucleotide precursor glutamate in large amounts in Eri silkworm may influence cordycepin production by encouraging nucleotide synthesis. Cordycepin and adenosine are related because adenosine served as the initiating substance to produce cordycepin, which was then produced by a sequence of phosphorylations and dephosphorylations carried out by related enzymes and oxidoreductase (Wang et al., 2023). The cordycepin and adenosine contents varied considerably depending on the insect type.

Table 3 Quantitative results of adenosine and cordycepin extracts from *Isaria tenuipes* cultured in brown rice supplemented with various boiled edible insects

Medium	Bioactive compound (mg/100 g)	
	Cordycepin	Adenosine
Brown Rice (control)	216.68±7.19^{bcd}	37.78±0.49^{cd}
Brown Rice + Eri silkworm	244.01±11.54^{a}	57.74±7.29^{a}
Brown Rice + Silkworm	213.68±6.76^{cd}	53.37±7.13^{a}
Brown Rice + Giant water bug	198.45±0.75^{e}	36.20±0.87^{d}
Brown Rice + Field cricket	219.99±0.20^{bc}	39.93±0.85^{cd}
Brown Rice + House cricket	171.27±1.43^{f}	46.67±1.34^{bc}
Brown Rice + Mealworm	208.33±0.68^{de}	45.39±5.18^{bcd}
Brown Rice + Sago palm weevil	225.39±6.80^{b}	38.34±9.26^{cd}
p value	< 0.0001	0.0008
C.V. (%)	2.91	11.85

CV = coefficient of variation

Mean±SD in each column superscripted with different lowercase letters are significantly different ($p < 0.05$).

Based on the current results, it can be concluded that not all edible insects have the potential to be utilized for promoting mycelial growth, fruiting body formation and bioactive compound production. Among seven edible insects, the highest fresh, and dry weights of fruiting bodies and bioactive compound (cordycepin and adenosine) content, were observed on brown rice media supplemented with Eri silkworm. Therefore, the Eri silkworm is promising for use in *I. tenuipes* cultivation.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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