Antioxidant-mediated protective role of Hericium erinaceus (Bull.: Fr.) Pers. against oxidative damage in fibroblasts from Friedreich's ataxia patient

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Abstract
Friedreich's ataxia (FRDA) is a progressive neuromuscular disorder caused by substantial decrease of mitochondrial protein frataxin responsible for biogenesis of iron-sulphur clusters and protection from oxidative damage. In this study, we investigated the antioxidative activities of a standardized aqueous extract from fruiting bodies of Hericium erinaceus mushroom (HESAE) and its protective effects against oxidative damage induced by L-Buthionine sulfoximine (BSO) in fibroblasts derived from FRDA patient. The lactate dehydrogenase-based viability assay showed that FRDA fibroblast was sensitive to 12.5 mM BSO with a reduction of viability to 52.51 ± 13.92% after 24 h of BSO exposure. Interestingly, co-incubation with 32 mg/mL HESAE increased the viability to 85.35 ± 3.4%. Further, 12.5 mM BSO caused a decrease in the ratio of cellular reduced glutathione (GSH) to oxidised GSH (GSSG) that leads to cell death. Nevertheless, the damage was reduced by co-incubation with 32 mg/mL HESAE. Nuclear fluorescence staining revealed that 12.5 mM BSO induced cell death and the apoptosis was decreased by co-incubation with HESAE. These findings suggest the ability of HESAE in attenuating BSO-mediated cytotoxicity through maintenance of membrane integrity and optimal GSH/GSSG ratio, that are closely linked to its antioxidant activities. Further in vivo trials are highly warranted to clarify its potential benefits in management of FRDA.

Keywords: Hericium erinaceus; Friedreich's ataxia; dermal fibroblasts; antioxidant; oxidative damage.

Practical Application: A standardized aqueous extract of Hericium erinaceus is beneficial in attenuating BSO-mediated oxidative damage in fibroblasts from Friedreich's ataxia patient. The medicinal mushroom acts as a potent protector against oxidative damage-induced cell death and could be a possible therapeutic for delaying the FRDA symptoms. The observed effects were better than idebenone, a lipid antioxidant that has mild adverse effects. Further, the cellular model is an important tool for the discovery of novel therapeutic approach in FRDA in which reactive radicals and oxidative damage are involved.

1 Introduction
In the 1860s, Nikolaus Friedreich, a German neurologist described a mysterious inherited disease marked by progressive loss of coordination and neuronal degeneration, and coined the term Friedreich's ataxia (FRDA). The prevalence of the most common hereditary ataxia was estimated at 1 in 29 000, with a carrier frequency of 1 in 85 in the individuals of Caucasian descent (Delatycki & Corben, 2012; Koeppen, 2013). FRDA is known to be a debilitating, life-shortening and degenerative neuromuscular disorder where the patients suffer from progressive gait and limb ataxia, lack of tendon reflexes in the legs, dysarthria, slurred speech and pyramidal weakness of lower limbs. The non-neurological symptoms include hypertrophic cardiomyopathy, scoliosis, diabetes mellitus or skeletal deformities (Delatycki & Corben, 2012).

The pathogenic mutation in FRDA is caused by expansion of guanine-adenine-adenine (GAA) trinucleotide repeat in the first intron of the frataxin gene on chromosome 9q13-21 that leads to a substantial decrease of mitochondrial protein frataxin (Jauslin et al., 2007). Reduced frataxin level causes an increase of cellular oxidative damage and impaired formation of iron-sulfur (Fe-S) clusters such as heme, electron transport chain (ETC) complexes I-III and the Kreb's cycle protein aconitase (Lodi et al., 2006).

In recent years, culinary and medicinal mushrooms are gaining considerable attention for potentials in promoting neuronal health. One such mushroom, Hericium erinaceus (Bull.:Fr.) Pers. or lion's mane mushroom is increasingly studied for its neuroprotective effects. It is one of the culinary and medicinal mushrooms found in Asia, Europe and North America (Wong et al., 2011).

Hericium erinaceus has been extensively tested in in vitro trials as the neurite outgrowth stimulator in the cultured cells of neural hybrid clone NG108-15 and rat pheochromocytoma (Wong et al., 2007). We also explored its ability in the enhancement of peripheral nerve regeneration and acceleration of motor and sensory functional recovery after crush injury (Wong et al., 2011).
2015). Inanaga (2014) reported an improved neurocognitive function in an 86-year-old male patient with recurrent depressive disorder while Okamura et al. (2015) reported improved sleep quality and subjective well-being among female undergraduate students after taking the mushroom tablets, Amyloban® 3399. In a study by Nagano et al. (2010), *H. erinaceus* cookies was shown to reduce depression and anxiety in 30 females between age 40-45. The broad therapeutic benefits of *H. erinaceus* may be associated to its strong antioxidant effects (Friedman, 2015). Therefore, the potential of *H. erinaceus* in combating oxidative damage-related neurodegenerative diseases including hereditary ataxia could be explained by the neuroprotective activity and its plentiful source of exogenous antioxidants.

This prompted our interest to investigate the protective effects of a standardized aqueous extract from fruiting bodies of *H. erinaceus* (HESAE) against oxidative damage induced by L-Buthionine sulfoximine (BSO) in fibroblasts from a FRDA patient and to link the effectiveness to its antioxidant properties. To the best of our knowledge, there are no reports on therapeutic application of medicinal mushrooms in FRDA. HESAE is a dietary supplement manufactured in Malaysia that targets on the general health maintenance. BSO is a specific inhibitor of γ-glutamylcysteine synthetase and its downregulation results in reduction of mitochondrial glutathione, increased oxidative damage and decreased mitochondrial function (Reliene & Schiestl, 2006).

2 Materials and methods

2.1 Mushroom sample

The aqueous extract of *H. erinaceus* (HESAE; NevGro®; batch No. 7H2308X) was obtained from Ganofarm R&D Private Limited, Tanjung Sepat, Selangor, Malaysia. NevGro® is a standardized aqueous extract from fresh fruiting bodies of *H. erinaceus* that contains not less than 20.66% beta 1,3-1,6 glucan and 0.17% adenosine (Nova Laboratories Private Limited, Sepang, Selangor, Malaysia). Total glucan and α-glucan were determined by the β-glucan assay kit (yeast & mushroom) K-YBGL (Megazyme International, Wicklow, Ireland). The β-glucan content was calculated by subtracting the α-glucan from the total glucan content. Adenosine content was analyzed and quantified by high-performance liquid chromatography (HPLC) using an in-house method (Nova Laboratories Private Limited, Sepang, Selangor, Malaysia). A stock solution of 64 mg/mL was prepared by dissolving HESAE in distilled water for the assessment of phytochemical contents and in vitro antioxidant activities or in phenol red-free Dulbecco’s Modified Eagle Medium (DMEM) and filter sterilized through a 0.2 µm nylon membrane filter for the measurement of oxidative damage.

2.2 Determination of total phenolic content

The concentration of phenolic compounds in HESAE and idebenone (Cayman Chemical, Ann Arbor, MI, USA), expressed as gallic acid equivalent (GAE), was determined according to a method as described by Singleton et al. (1999) and Pang et al. (2018).

2.3 Determination of total flavonoid content

The concentration of flavonoid compounds in HESAE and idebenone, expressed as quercetin equivalent (QE), was determined according to a method as described by Pękal & Pyrzynska (2014) and Pang et al. (2018).

2.4 DPPH free radical scavenging assay

The scavenging activity of HESAE on 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical was measured according to the method of Brand-Williams et al. (1995). Idebenone was used as a positive control. The scavenging ability of HESAE was expressed as EC50 value (mg/mL), which is the effective concentration at which 50% of DPPH radicals were scavenged.

2.5 ABTS free radical scavenging assay

The scavenging activity of HESAE on 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) radical was measured according to the method of Miller et al. (1993). Idebenone was used as a positive control. The scavenging ability of HESAE was expressed as EC50 value (mg/mL), which is the effective concentration at which 50% of ABTS radicals were scavenged.

2.6 Reducing power assay

Reducing power of HESAE was determined according to the method of Oyaizu (1986). Idebenone was used as a positive control. The reducing power of HESAE was expressed as EC50 value (mg/mL), at which the absorbance was 0.5.

2.7 Dermal fibroblasts culture

Dermal fibroblasts from a 30-year-old FRDA male patient (GM04078) and dermal fibroblasts from a healthy 11-year-old female (GM02036) were purchased from Coriell Institute (Camden, NJ, USA). The fibroblasts were maintained in Dulbecco’s Modified Eagle Medium (DMEM) supplemented with 15% fetal bovine serum and 1% penicillin-streptomycin. The medium was changed to phenol red- and sodium pyruvate-free DMEM containing 1% fetal bovine serum and 1% penicillin-streptomycin. Fibroblasts treated with 5 µM of idebenone served as a positive control (Jauslin et al., 2002), while fibroblasts in complete DMEM without treatment served as a negative control.

2.8 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) viability assay

MTT assay was used to assess the effect of BSO or HESAE on viability of normal and FRDA fibroblasts. Fibroblasts were plated at a density of 5 × 104 cells per well in 96-well plates and incubated for 24 h at 37 ± 2°C in a 5% CO2-humidified incubator. Then, the medium was replaced with fresh medium containing BSO or HESAE. After 24 h of incubation, the morphology of fibroblasts was acquired on Nikon Eclipse Ti-S inverted microscope equipped with a digital camera controller (DS-U3).
and NIS-Elements algorithm (NIS-Elements Advanced Research, Nikon Corporation, Tokyo, Japan). The extent of MTT reduction was determined by measuring the absorbance at 570 nm with 630 nm as background absorbance in a multimode microplate reader (SpectraMax M3, Molecular Devices, San Jose, CA, USA). The fibroblasts in complete DMEM without treatment served as a negative control. The 50% inhibitory concentration (IC_{50}) was interpolated from the response curve.

### 2.9 Lactate dehydrogenase (LDH) viability assay

LDH assay was used to determine the protective effect of HESAE against BSO-induced cytotoxicity in FRDA fibroblasts based on the measurement of LDH released from the cytosis of damaged fibroblasts into the supernatant. The fibroblasts were plated at a density of 5 × 10^{3} cells per well in 96-well plates and incubated for 24 h at 37 ± 2 °C in a 5% CO_{2}-humidified incubator. The medium was replaced with fresh medium containing BSO, BSO-HESAE or BSO-idebenone and incubated for another 24 hr. Fibroblasts treated with 5 μM of idebenone served as a positive control while fibroblasts in complete DMEM without treatment served as a negative control. After incubation, the plate was centrifuged at 1500 rpm for 5 min at 18 °C. Culture supernatant was subjected to LDH measurement according to the manufacturer’s protocol of LDH cytotoxicity detection kit (Roche, Mannheim, Germany). LDH activity was determined by measuring the absorbance at 492 nm with 690 nm as background absorbance in a multimode microplate reader (SpectraMax M3, Molecular Devices, San Jose, CA, USA).

### 2.10 Reduced glutathione/oxidized glutathione (GSH/GSSG) assay

GSH/GSSG assay is a luminescence-based system for the detection and quantification of total glutathione and oxidised glutathione (GSSG) in cultured cells. The ratio of reduced glutathione (GSH) to oxidised GSH (GSSG) is an indicator of cellular health, with reduced GSH making up to 98% of cellular GSH under normal conditions. Fibroblasts were plated at a density of 5 × 10^{3} cells per well in white opaque 96-well plates and incubated for 24 h at 37 °C in a 5% CO_{2}-humidified incubator. The medium was replaced with fresh medium containing BSO, BSO-HESAE or BSO-idebenone and incubated for another 24 h. Fibroblasts treated with 5 μM of idebenone served as a positive control while fibroblasts in complete DMEM without treatment served as a negative control. After incubation, the medium was removed and subjected to total glutathione and GSSG measurement according to the manufacturer’s protocol of GSH/GSSG-Glo glutathione assay kit (Promega Corporation, Madison, WI, USA) in a multimode microplate reader (SpectraMax M3, Molecular Devices, San Jose, CA, USA).

### 2.11 Hoechst 33258 staining of apoptotic nuclei

Fibroblasts were plated at a density of 5 × 10^{5} cells per well in black 96-well plates and incubated for 24 h at 37 ± 2 °C in a 5% CO_{2}-humidified incubator. Then, the medium was replaced with fresh medium containing BSO, BSO-HESAE or BSO-idebenone. Fibroblasts treated with 5 μM idebenone served as a positive control, while fibroblasts in complete DMEM without treatment served as a negative control. After 24 h of incubation, the medium was discarded and loaded with 5 μg/mL Hoechst 33258 in PBS, further incubated in the dark for 10 min and washed twice with PBS. Images were acquired on Nikon Eclipse Ti-S inverted microscope and Intensilight C-HGFI Precentered Fiber Illuminator (Nikon Corporation, Tokyo, Japan) at 460 nm. Bright-blue fluorescence indicated nuclear apoptosis. ImageJ (National Institutes of Health, 2019) was used to quantify the blue fluorescence intensity in nine randomly chosen microscopic fields (Zhu et al., 2015).

### 2.12 Statistical analysis

Statistical significance was analyzed with independent t-test and one-way ANOVA followed by Tukey’s and Dunnett’s multiple comparison tests. Differences with p value less than 0.05 (p < 0.05) were considered statistically significant.

## 3 Results

### 3.1 In vitro antioxidant activities of HESAE

Table 1 shows the phytochemical contents and in vitro antioxidant activities of HESAE on DPPH and ABTS free radical scavenging, and reducing power assays. The total phenolic and flavonoid contents of HESAE were found to be 7.19 ± 0.6 mg GAE/g and 5.31 ± 0.3 mg QE/g, respectively. HESAE exhibited similar levels of total flavonoid content, DPPH and ABTS free radical scavenging activities (p > 0.05) as compared to idebenone and possessed significantly higher total phenolic content (p < 0.05) of 7.19 ± 0.6 mg GAE/g and lower EC_{50} value (p < 0.05) of 58.23 ± 3.9 mg/mL in reducing power than idebenone.

| HESAE / Idebenone | Total phenolic content (mg GAE/g) | Total flavonoid content (mg QE/g) | DPPH radical scavenging | ABTS radical scavenging | Reducing power |
|-------------------|----------------------------------|----------------------------------|-------------------------|--------------------------|---------------|
| HESAE             | 7.19 ± 0.6 a                     | 5.31 ± 0.3                       | 13.22 ± 0.3             | 14.34 ± 0.9              | 58.23 ± 3.9a  |
| Idebenone         | 2.38 ± 0.7 b                     | 4.73 ± 0.5                       | 16.34 ± 4.3             | 17.74 ± 2.5              | 120.19 ± 19.99b |

HESAE = standardized aqueous extract from fruiting bodies of Hericium erinaceum; EC_{50} = half-maximal effective concentration; DPPH = 2,2-diphenyl-1-picrylhydrazyl; ABTS = 2,2’-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid).

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3.2 Effects of BSO on the viability of normal and FRDA fibroblasts

The vulnerability of normal and FRDA fibroblast to oxidative damage caused by glutathione depletion was investigated through exposure to BSO at varying concentrations ranged from 1.56 to 100 mM. Figure 1 shows morphological features of normal [A(I)-D(I)] and FRDA fibroblasts [A(II)-D(II)] following incubation in BSO for 24 h. At 12.5 and 25 mM BSO, FRDA fibroblast showed distinct alteration with floating debris and loss of spindle shape [C(II)-D(II)]. However, normal fibroblasts retained their typical spindle shape at 6.25 and 12.5 mM BSO [B(I)-C(I)]. Figure 1E shows the dose-response curve of viability of normal and FRDA fibroblasts following incubation with varying concentrations of BSD for 24 h. Asterisks (*) and hash signs (#) indicate significant differences (p < 0.05) in viability for different groups of normal and FRDA fibroblasts, respectively, compared to the negative control group.
fibroblasts following exposure to varying concentrations of BSO for 24 h. All tested concentrations of BSO significantly reduced (p < 0.05) the viability of FRDA fibroblasts. The viability of FRDA fibroblasts decreased gradually as the concentration of BSO increases with a sharp decrease in viability at 12.5 mM BSO. Large-scale death of FRDA fibroblasts was markedly pronounced by challenging the cells with 12.5 mM BSO in which the viability was reduced to 37.47 ± 0.23%. On the other hand, 12.5 mM BSO produced mild cytotoxicity effects in normal fibroblasts.

As 12.5 mM BSO produced more than 50% reduction (p < 0.05) in the viability of FRDA fibroblasts, therefore the concentration was selected in the subsequent assays to induce oxidative damage in FRDA fibroblasts.

3.3 Effects of HESAE on the viability of normal and FRDA fibroblasts

Prior to the investigation of cytoprotective activities, the effects of HESAE on the viability of normal and FRDA fibroblasts was assessed by MTT assay to exclude any possibilities of cytotoxicity effects of the extract. Figure 2 shows that HESAE in the range of 1 to 32 mg/mL exerted neither inhibition nor increase in the viability of fibroblasts, and therefore was selected for LDH viability assay to study its protective effects against 12.5 mM BSO-induced cytotoxicity in FRDA fibroblasts. Further, the 50% inhibitory concentration of HESAE on normal and FRDA fibroblasts was 52.26 mg/mL and 46.77 mg/mL, respectively.

3.4 Effects of HESAE on the viability of BSO-treated FRDA fibroblasts determined by quantification of LDH

The protective effects of HESAE against BSO-induced cytotoxicity in FRDA fibroblasts was investigated by co-incubating varying concentrations of HESAE with 12.5 mM BSO. As shown in Figure 3, the viability of FRDA fibroblasts was reduced from 100.00 ± 0.8% to 52.51 ± 13.92% by 12.5 mM BSO (p < 0.05). However, co-incubation with 32 mg/mL HESAE significantly increased the viability of FRDA fibroblasts to 85.35 ± 3.4% (p < 0.05) that was 2-fold higher compared to 5 μM idebenone at 40.09 ± 0.41% (p < 0.05).

Mechanisms of cell death and survival were further examined by quantification of glutathione content and induction of apoptosis. As 32 mg/mL HESAE promoted highest percentage of viability of BSO-induced oxidative damage in FRDA fibroblasts, the concentration was selected for subsequent assays.

3.5 Effects of HESAE on the ratio of GSH/GSSG in BSO-treated FRDA fibroblast

This reduction in the GSH/GSSG ratio indicates redox imbalance and increase in oxidants due to neurodegenerative diseases. The GSH/GSSG ratio was determined in FRDA fibroblasts following co-incubation of 12.5 mM BSO with 32 mg/mL HESAE for 24 h. As shown in Figure 4, BSO significantly depleted the GSH/GSSG ratio up to 50-fold compared to negative control (p < 0.05), and HESAE appeared to increase the GSH/GSSG ratio up to 17-fold and 80-fold, compared to BSO and BSO-idebenone groups, respectively (p < 0.05). The data show that HESAE prevented BSO from depleting intracellular GSH/GSSG ratio or induced glutathione synthesis in vitro.
3.6 Effects of HESAE on nuclear apoptosis in BSO-treated FRDA fibroblasts

As shown in Figure 5A-D, nuclei of untreated FRDA fibroblasts exhibited homogeneously dim-blue and round shape structure after labeling with Hoechst 33258. The introduction of 12.5 mM BSO into FRDA fibroblasts causes induction of apoptosis indicated by bright-blue fluorescence. However, co-incubation with 5 μM idebenone or 32 mg/mL HESAE reduced the fluorescence intensity. Figure 5E shows that BSO significantly increased the fluorescence intensity from 100.00 ± 8.73% to 121.74 ± 2.04% (p < 0.05). The intensity was reduced to 98.74 ± 4.23% (p < 0.05) by co-incubation with 32 mg/mL HESAE. On the other hand, the intensity of 153.41 ± 2.08% was obtained by co-incubation with 5 μM idebenone.

4 Discussion

Natural products have been traditionally accepted as remedies due to popular belief that they present minor adverse effects. There is currently no reports of natural product that possesses protective effects in an in vitro model of FRDA. This circumstance stimulated our interest to explore HESAE and to probe the mechanism underlying the protective effects in FRDA.

Phenolic acids that possess hydroxyl groups are the major bioactive components in medicinal mushrooms and are also associated with their antioxidant properties (Ferreira et al., 2009; Heleno et al., 2012). The total phenolic content of HESAE obtained from this study was higher compared to that of methanolic extracts of fresh fruiting bodies (0.26 mg GAE/g extract),

**Figure 5.** FRDA fibroblasts stained as blue fluorescence with Hoechst 33258 for the detection of apoptotic nuclei after 24 h. (A) FRDA fibroblasts in negative control group; (B) FRDA fibroblasts exposed to 12.5 mM BSO; (C) FRDA fibroblasts following co-incubation of 12.5 mM BSO and 5 μM idebenone; (D) FRDA fibroblasts following co-incubation of 12.5 mM BSO and 32 mg/mL HESAE. Scale bar = 100 μm; (E) Intensity of Hoechst 33258 blue fluorescence in the FRDA fibroblasts. Asterisks (*) and hash signs (#) indicate significant differences (p < 0.05) in fluorescence intensity for different groups compared to the BSO-treated group and BSO-idebenone group, respectively.
oxidative damage/dysfunction during aging, multiple chronic diseases and cataracts (Lodi et al., 2006). Remarkably, our results demonstrated that HESAE increased the ratio compared to BSD or co-incubation with idebenone. Nevertheless, our present findings are in contrast to Richardson et al. (2012) who reported that estrogen-like compounds failed to prevent BSD from causing GSH depletion or to increase the expression of GSH.

Figure 6 demonstrates the mechanisms by which BSD promotes apoptosis in FRDA fibroblasts and protective effects of HESAE against the oxidative damage. As FRDA fibroblasts are lacking in frataxin, the cells are extremely sensitive to BSD-induced oxidative stress compared to normal fibroblasts. Frataxin has been shown to be influential in the production of Fe-S cluster containing proteins (Richardson et al., 2012). We postulated that synthesis of glutathione in FRDA fibroblasts was greatly diminished following incubation in BSD as evidenced by extreme reduction in GSH/GSSG ratio up to 50-fold. Disruption in the redox state of FRDA fibroblasts resulted in an increase of cytosolic LDH causing a 48% reduction in viability that leads to 22% increase in apoptosis compared to negative control. Viability of FRDA fibroblasts was inhibited by more than half with prominent alteration in the morphology. However, HESAE could attenuate the cytotoxicity effects through the prevention of glutathione depletion, decreasing the level of LDH that reflects the integrity of plasma membrane and anti-apoptotic activity. The elevation in serum LDH level is a reliable biomarker of FRDA. On a case report by Krongrad & Joos (1972), a 7-year-old Caucasian girl with FRDA and myocardial infarction had persistent elevation of cardiac specific LDH isoenzyme 5.

Antioxidant therapy with idebenone is currently the only treatment option resulting in an improvement of hypertrophic cardiomyopathy (Jauslin et al., 2007). In our study, idebenone did not protect BSD-induced oxidative insult to FRDA fibroblast as measured by apoptotic cell death and release of LDH from damaged cells owing to membrane disintegration. Several studies have also reported conflicting results of idebenone in cardiovascular clinical trials of FRDA (Kearney et al., 2016).
FRDA comprises both neurological symptoms and cardiac hypertrophy. Irreversible destruction of neurons and poor antioxidant effect of idebenone in the neurons may contribute to the differential effect observed in FRDA patients with cardiac hypertrophy and neurological symptoms. Idebenone did not have noticeable effects on ataxia (Rustin, 2003).

Ebselen, a glutathione peroxidase mimetic (Jauslin et al., 2002) and a novel synthetic antioxidant (Fe-Aox29) combining the active groups from idebenone and vitamin E (Jauslin et al., 2007) are more potent in preventing BSO-mediated cell death in FRDA fibroblasts compared to either idebenone or vitamin E alone. Similarly, 17β-estradiol and estrogen-like compounds (Richardson et al., 2011), estrogen receptor β agonist of R- and S-forms of equol bifcnolic compounds (Richardson & Simpkins, 2012) and phenolic estrogens (Richardson et al., 2012) were able to prevent cell death in FRDA fibroblasts. Compounds with increased numbers of phenolic rings showed an increased protective effect. The phenolic or hydroxyl group-containing estrogens were able to prevent lipid peroxidation and mitochondrial membrane potential collapse, maintain the level of ATP and aconitase, and increase oxidative phosphorylation in FRDA fibroblasts (Richardson et al., 2012). Based on our phytochemical findings, we have demonstrated a potential protective effects of HESAE against oxidative damage in FRDA fibroblast that was attributed to its high phenolic content.

5 Conclusion

In this study, a standardized aqueous extract from fresh fruiting bodies of H. erinaceus was found to be beneficial in attenuating BSO-mediated oxidative damage in FRDA fibroblasts. Our data support the hypothesis that antioxidative capability of the extract could be responsible for prevention of oxidative damage. It remains to be determined if the use of pure antioxidant molecules isolated from the extract can further amplify defences against the oxidative insult.

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