Biomedical Science Letters 2022, 28(3): 170~177
https://doi.org/10.15616/BSL.2022.28.3.170
eISSN : 2288-7415

Original Article

Anti-inflammatory and Anti-oxidant Activities of Aster Scaber Ethanol Extract

Evelyn Saba[1,*], Nayeong Je[2,*], Ji Eun Song[2,*], Sangwoo Shi[2,*], Juho Lee[2,*], Oneyoung Jung[2,*], Beom Jun Han[2,*], Soo Young Lee[2,*], Jongwon Park[2,*], Yuan Yee Lee[3,†,**] and Man Hee Rhee[2,4,†,***]**

[1]*Department of Veterinary Biomedical Sciences, Faculty of Veterinary and Animal Sciences, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi 46000, Pakistan*
[2]*Department of Veterinary Medicine, College of Veterinary Medicine, Kyungpook National University, Daegu 41566, Korea*
[3]*Department of Animal and Avian Sciences, University of Maryland, College Park, Maryland 20742, United States*
[4]*Companion Animal Medical Institute, College of Veterinary Medicine, Kyungpook National University, Daegu 41566, Korea*

In mountainous regions, wild herbs which can also be edible in nature for humans and animals possess a wide array of biologically diversified properties. It is because of the fact that due to the cold weather of mountains; they are enriched in certain kinds of phytochemicals such as anti-oxidants, anti-inflammatory and many more. One such kind of an herb is Aster scaber (AS) in Korean. It is a widely cultivated culinary herb in Korean peninsula and used as a side dish in Korean culinary cuisine. In view of its extensive use in cuisine, we geared to unravel the anti-oxidant and anti-inflammatory effects of AS in murine alveolar macrophage cell line (MH-S). 2,2'-Azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS) and 2,2-diphenyl-1-picryl-hydrazyl-hydrate (DPPH) assays revealed a dose dependent (7.8~1,000 μg/mL) inhibition of oxidation by AS 70% ethanol (ASE) extract as compared to Trolox and Ascorbic acid respectively. Nitric oxide assay (NO) showed a dose dependent decrease (5~40 μg/mL) in MH-S cells with ASE when stimulated with Coal Fly Ash (CFA). Moreover, this dose for NO reduction was also found to be least cytotoxic for cells as determined by cellular viability (MTT) assay. The gene expression of pro-inflammatory mediators (iNOS and COX-2) and cytokines (IL-6 and IL-1β) and were also dose dependently inhibited by ASE in MH-S cells through RT-PCR. Therefore, in light of these findings, AS exhibited a strong anti-oxidant and anti-inflammatory agent. These results also justify the extensive use of this mountainous herb in culinary practices for beneficial effects on human health.

Key Words: Aster scaber, Anti-oxidant, Anti-inflammatory, DPPH, ABTS, NO, RT-PCR

Received: August 10, 2022 / Revised: September 5, 2022 / Accepted: September 14, 2022
[*]Undergraduate student, [**]Post-Doctor, [***]Professor.
[†]Corresponding author: Man Hee Rhee. Department of Veterinary Medicine, College of Veterinary Medicine, Kyungpook National University, Daegu 41566, Korea.
Tel: +82-53-950-5967, Fax: +82-53-950-5955, e-mail: rheemh@knu.ac.kr
[†]Corresponding author: Yuan Yee Lee. Department of Animal and Avian Sciences, University of Maryland, College Park, Maryland 20742, United States.
Tel: +1-301-433-1951, e-mail: yuanyee@umd.edu
©The Korean Society for Biomedical Laboratory Sciences. All rights reserved.
This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/3.0/) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

INTRODUCTION

Thousands of different varieties of edible plants and herbs are used worldwide as food. Plants in their raw form are used in Asian cultures to prepare soups, stews, and other foods. When correctly selected, plants and herbs can provide a wide range of nutritional benefits, such as readily available protein, carbohydrates, fiber, vitamins, and minerals required for the functioning of the human body. In addition to the supply of macronutrients, plants also provide enzyme and hormone precursors for the activation of many biological pathways in the body (Vazquez-Fresno et al., 2019). One such plant commonly consumed in the Korean Peninsula is *Doellingeria scabra* (Aster scaber, AS).

AS is a perennial herb native to the Eurasian region that belongs to the Asteraceae family. It is widely found in mountainous regions of Korea, China, Japan, and Russia. It is characterized by a distinctive taste and fragrance and is commonly used in Korean cuisine. Its Korean name is chamchwi, and it is called chwinamul by the Korean people (Lee, 1989; Kwon et al., 2000a). AS, both as a whole extract and individual components, has been reported to have many beneficial biological attributes, such as anti-inflammatory, antioxidant, and anti-adipogenic properties (Kim et al., 2009; Kim et al., 2015; Choi et al., 2020). It is rich in vitamin C, calcium, iron, and β-carotene (Chung et al., 1993).

The energy demands of biological tissues require oxygen. Oxygen consumption results in the generation of free radicals, which are removed by the body. A disturbed balance between radical production and radical scavenging leads to the accumulation of free radicals in the body that damage cells, resulting in oxidative stress (OS) (Pizzino et al., 2017). OS is the leading cause of many serious diseases, particularly neurodegenerative diseases (Halliwell, 2001). Therefore, timely radical scavenging is necessary for the prevention of OS and subsequent disease. In this context, a recent report demonstrated that AS inhibited reactive oxygen species and lipogenesis in 3T3L1 cell line (Choi et al., 2020). Moreover, AS extract and its individual components, along with other Korean wild herbs, have been reported to exhibit antioxidant, anti-lipogenic, and anti-viral activities (Kwon et al., 2000b; Lee et al., 2013).

Intrusion of foreign particles in the body results in the generation of an inflammatory response. This response is considered a self-defense mechanism of the body to neutralize foreign particles; however, if the threshold of pathogen load exceeds the body's defense mechanism, it leads to clinical manifestations of inflammation (Sahlmann and Strobel, 2016). Therefore, timely regulation of the inflammatory response is necessary for homeostasis. While many allopathic drugs are available for anti-inflammatory purposes, their prolonged use is associated with side effects. For this reason, herbs and natural remedies present better clinical and prophylactic treatment (Azab et al., 2016). AS has been shown to have potent anti-inflammatory activity in the murine macrophage cell line RAW 264.7 cells via the downregulation of the classic NF-κB pathway (Lee et al., 2011).

To further current knowledge in the field, we aimed to investigate the anti-inflammatory effects of AS 70% ethanol extract (ASE) on murine alveolar macrophage cell line MH-S cells. Moreover, we examined the antioxidant effects of ASE using DPPH and ABTS assays. Our results shed light on the anti-inflammatory and antioxidant effects of AS.

MATERIALS AND METHODS

Chemicals and reagents

Dulbecco's modified Eagle's medium (DMEM; Daegu, Republic of Korea), Fetal bovine serum (FBS), Dulbecco's phosphate buffered saline (DPBS; WelGene Co., Republic of Korea), streptomycin, and penicillin (Lonza, MD, USA), TRIZOL® reagent (Invitrogen, Carlsbad, CA, USA), oligo-dT, iNOS, COX-2, TNF-α, IL-6, IL-1β primers were obtained from Bioneer (Bioneer, Daejeon, Republic of Korea). CFA, 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) and 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazoliumbromide (MTT), were purchased from Sigma-Aldrich (St. Louis, MO, USA).

Sample preparation

Aster scaber (AS) was obtained Jirisan Hanyaknara cor-

poration (Seoul, Republic of Korea). The dried whole plant were crushed and extracted with 70% ethanol for 2 h at 80℃ on a reflux system (1-part dried leaves: 20-part solvent). The extract was then condensed with a rotary evaporator, frozen and lyophilized in a freeze dryer to obtain the powder. The powder of AS was weighed and dissolved in dimethyl sulfoxide for further analysis and thereafter called as ASE.

2,2-diphenyl-1-picryl-hydrazyl-hydrate (DPPH) and 2,2'-Azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS) assay

The radical scavenging activity of ASE was determined by ABTS and DPPH assay as previously reported (Lee et al., 2018).

Cell culture

Murine alveolar macrophage cell line MH-S, originating from the American Type culture collection, was cultured in DMEM supplemented with 10% FBS (WelGene Co, Daejeon, Republic of Korea) and 100 IU/mL penicillin and 100 μg/mL streptomycin sulphate (Lonza, MD, USA). The incubating conditions were humidified 5% CO_2 at 37℃.

Nitric oxide (NO) assay

NO was measured using the method based on the Griess reaction assay. Briefly, MH-S cells were seeded in a 96-well plate and incubated with or without CFA (50 μg/mL) in the absence or presence of ASE (5~40 μg/mL) for 18 h. The cell culture supernatants (100 μL) were mixed with Griess reagent (0.2% naphthylethylenediamine dihydrochloride and 2% sulphanilamide in 5% phosphoric acid) in DDW at equal volumes and incubated for 5 min at 20~25℃. The absorbance in each well was then analysed at 540 nm in microplate reader (Versamax, Microplate Reader, Molecular devices, CA, USA).

Cell Viability (MTT) assay

To determine the cytotoxic effects of sample, a cell viability assay was performed using 3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide reagent which was added to the culture medium at a final concentration of 0.1 mg/mL. After 4 h of incubation at 37℃ in 5% CO_2, the resulting violet-coloured crystals were dissolved in 100 μL/well dimethyl sulfoxide (DMSO) and the absorbance measured at 560 nm.

Table 1. Sequence of primers used for RT-PCR

Gene	Primer	Oligonucleotide sequence (5'-3')
GAPDH	F	5'CAATGAATACGGCTACAGCAAC3'
	R	5'AGGGAGATGCTCAGTGTTGG3'
iNOS	F	5'CCCTTCCGAAGTTTCTGGCAGCAGC3'
	R	5'GGCTGTCAGAGCCTCGTGGCTTTGG3'
COX-2	F	5'TCTCAGCACCCACCCGCTCA3'
	R	5'GCCCCGTAGACCCTGCTCGA3'
IL-1β	F	5'CAGGGTGGGTGTGCCGTCTTTC3'
	R	5'TGCTTCCAAACCTTTGACCTGGGC3'
TNF-α	F	5'TTGACCTCAGCGCTGAGTTG3'
	R	5'CCTGTAGCCCACGTCGTAGC3'
IL-6	F	5'GTACTCCAGAAGACCAGAGG3'
	R	5'TGCTGGTGACAACCACGGCC3'

RNA extraction and Polymerase chain reaction (PCR)

MH-S cells were pre-treated with or without ASE (5~40 μg/mL) for 30 min, followed by stimulation with CFA (50 μg/mL) for 18 h. RNA was collected from cells and lung tissue using TRIZOL® reagent following the manufacturer's instructions. Total RNA (2 μg) was annealed with Oligo-dT for 10 min at 70℃, cooled for 5 min on ice, reverse transcribed using reverse transcriptase pre-mix in 20 μL of reaction mixture and ran for 90 min at 42.5℃ on a thermocycler. To inactivate the reverse transcriptase, the reaction was terminated at 95℃ for 5 min. The Reverse Transcription Polymerase Chain Reaction (RT-PCR) was performed using aliquots of cDNA obtained from RT reaction in a PCR premix. The PCR products were then electrophoresed on 1% agarose gel stained with ethidium bromide and visualized using Image quant LAS 500 (GE Health Care Life Sciences, Seoul, Republic of Korea). The intensity of band densities was normalized to GAPDH, a housekeeping gene used as the RNA internal standard, and the ratios compared. PCR primer sequences are listed in Table 1.

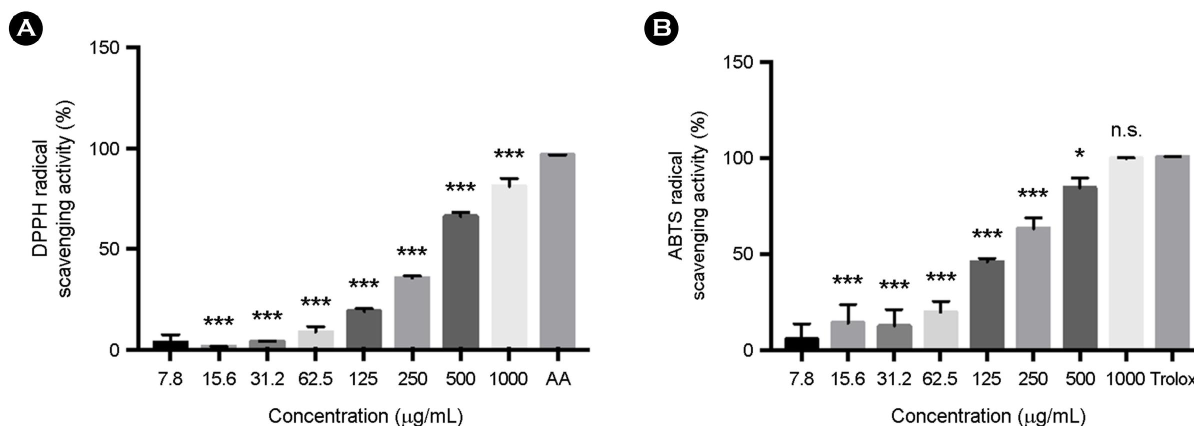

Fig. 1. Radical scavenging activity of ASE using DPPH and ABTS assay. The antioxidant activity of the ASE was tested and compared to 100 μg/mL of ascorbic acid (AA), which was used as a positive control in DPPH assay (A). Trolox (5 mM) was used as a positive control in ABTS assay. The absorbance was read at 734 nm using a microplate reader and the radical scavenging activity was calculated (B). Values in the bar graph are mean ± SEM of at least 3 independent experiments. ***$P < 0.001$; significantly lesser than AA only treatment. ***$P < 0.001$, and *$P < 0.05$ indicates significance against Trolox treatment. n.s. denotes non-significance.

Statistical analysis

Data were analyzed by one-way analysis of variance (ANOVA) with Dunnett's posttest with GraphPad Prism version 7.00 (San Diego, CA, USA). The results are presented as mean ± SEM, and significant differences denoted as *$P < 0.05$, and ***$P < 0.001$ (compared CFA).

RESULTS

Radical scavenging activity of ASE by DPPH and ABTS assay

For assessing the anti-oxidant potential of ASE, we performed DPPH and ABTS assay. Our results as shown in Fig. 1A, demonstrate that ASE in a dose dependent manner showed, potent anti-oxidant effects with highest effects observed at 1,000 μg/mL when compared with ascorbic acid as positive control. The same trend was observed in Fig. 1B, where ABTS radical scavenging activity by ASE was highest at 1,000 μg/mL when compared with Trolox as positive control. This result shows that AS is a potent anti-oxidant agent.

Reduction in nitric oxide generation without cytotoxicity by ASE

Nitric Oxide (NO) is a product of foreign invasion. Even though the production of NO is a self-defense mechanism of cells but over production leads to cellular death (Ignarro, 1996). ASE dose dependently decreased the NO production as a result of CFA induced inflammation as shown in Fig. 2A. Moreover, the doses of ASE reducing NO posed no cytotoxicity to cells as shown in Fig. 2B. The cell viability was not affected as ASE treatment therefore it is not cytotoxic to cells within the prescribed dosage.

Suppression of pro-inflammatory mediators and cytokines by ASE

Upon the entry of foreign particle within the cell (CFA), there is activation of toll like receptors (TLRs) that activate the inflammatory pathways. The mediators for the activation are inducible nitric oxide synthase (iNOS) and cyclooxygenase-2 (COX-2) (Takeda and Akira, 2015). According to Fig. 3, the level of both of these mediators were suppressed by ASE treatment to cells. Activation of mediators then produce proinflammatory cytokines such as interleukins (IL-6 and IL-1β) and tumor necrosis factor-α (TNF-α) (Dinarello, 2000). Two of these pro-inflammatory cytokines, IL-6 and IL-1β were also reduced by treatment of cells with ASE as shown in Fig. 3. Therefore, in light of these findings, AS possess strong anti-inflammatory activity *in vitro*.

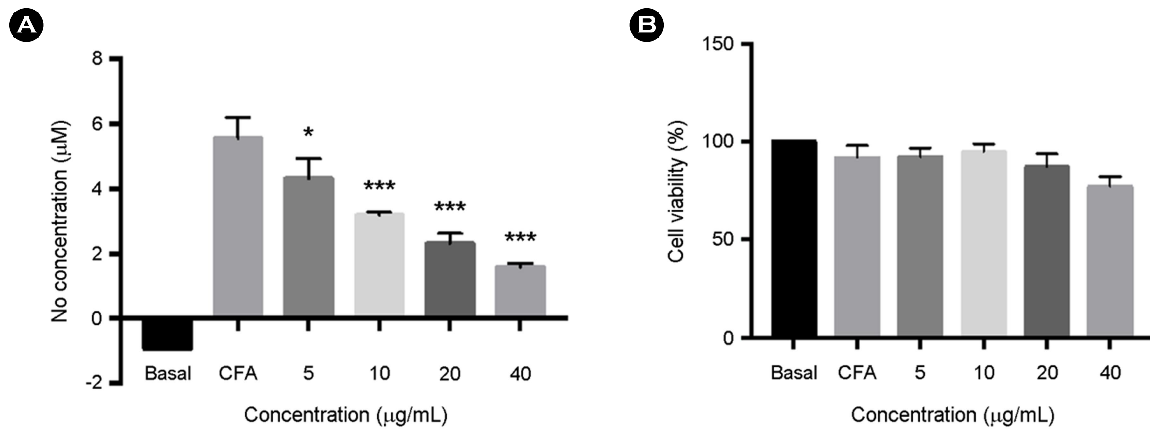

Fig. 2. Inhibition of nitric oxide (NO) and cell Viability by ASE. MH-S cells were preincubated with varying doses of ASE for 30 min and then stimulated with CFA for 18 h. Cell supernatant was then mixed with equal amounts of Griess reagent and NO production was measured (A). Effects of ASE on cell viability were measured by MTT assay (B). Values in the bar graph are mean ± SEM of at least 3 independent experiments. ****P* < 0.001, and **P* < 0.05 when compared to CFA only treatment.

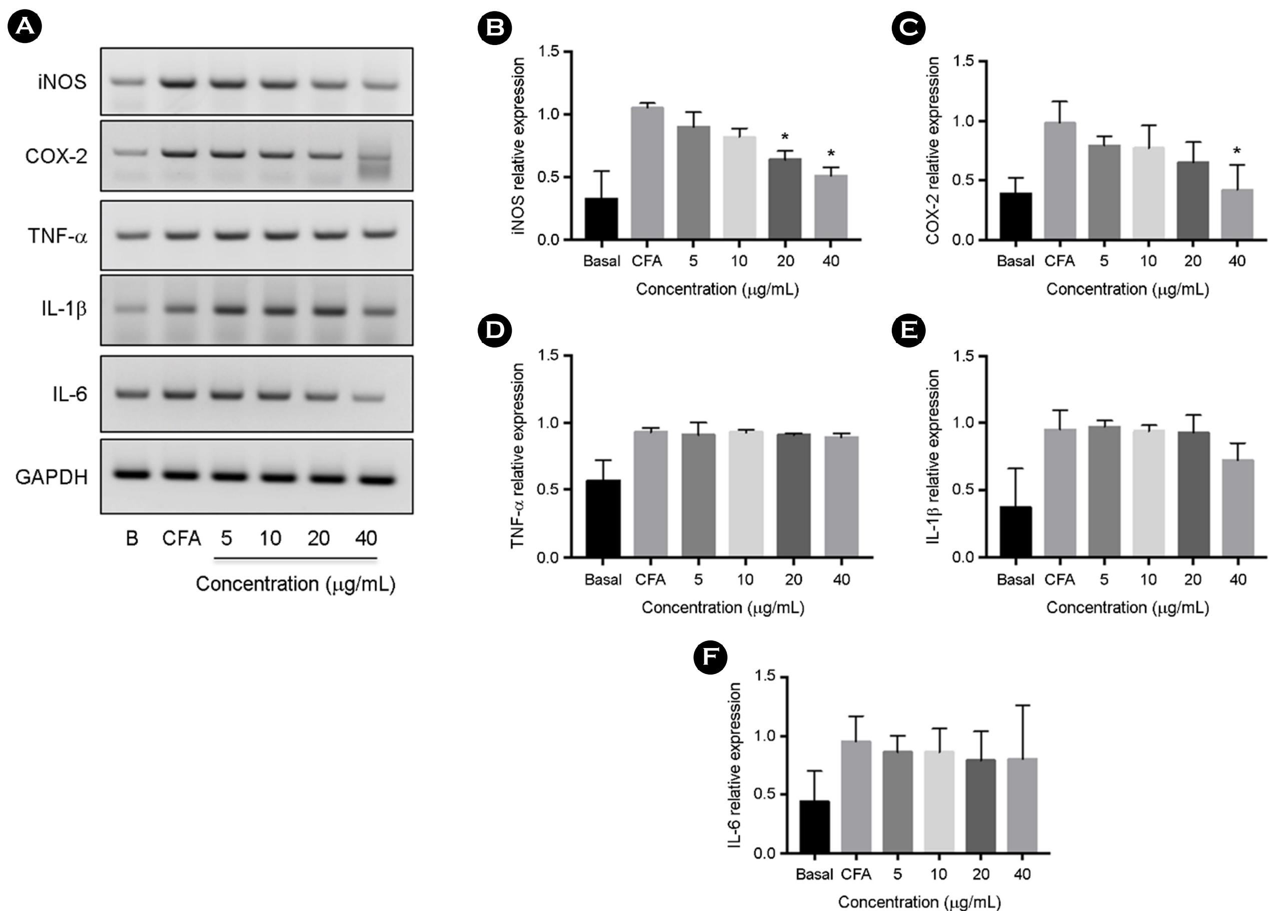

Fig. 3. Reverse-transcriptase polymerase chain reaction for pro-inflammatory mediators and cytokines by ASE. MH-S cells were seeded into 6-well plates for 24 h, treated with or without ASE at and then treated with or without CFA 30 min later. RNA was extracted 18 h later using TRIZOL solution and RT-PCR was carried out. iNOS, COX-2, TNF-α, IL-1β, IL-6, and GAPDH expression was determined (A). Gel image quantification for relative (B) iNOS, (C) COX-2, (D) TNF-α, (E) IL-1β, and (F) IL-6 expression against GAPDH was carried out in triplicates using the ImageJ software. Values in the bar graph are mean ± SEM of at least 3 independent experiments. **P* < 0.05 when compared to CFA only treatment. B; Basal, CFA; Coal Fly Ash.

DISCUSSION

Aster scaber extract predominantly consists of phenolic compounds and flavanols besides many other phytochemicals. The most abundant phenolic compounds in it are caffeic acid, gallic acid, gentisic acid and homogentisic acid, whereas the most predominant flavanols in it are myricetin, kaempferol and quercetin (Thiruvengadam et al., 2014). All of the above-mentioned compounds separately possess potent anti-oxidant activities which may attribute to the anti-oxidant properties of ASE. Moreover, the types of extracting solvents also effect the anti-oxidant capacity of AS extract. It was twice reported that AS extracted with ethyl acetate has the highest anti-oxidant capability as compared to other solvents like methanol, butanol, ether and water (Jeon et al., 2012; Thiruvengadam et al., 2014). Furthermore, not only solvent influences the anti-oxidant activity of AS but the type processing method affects the anti-oxidant capacity of AS. A study has reported varying levels of anti-oxidant profiles in blanched, pan-fired and microwaved AS extract (Kim et al., 2014). AS ethanol extract has been reported to possess the anti-oxidant activity by reducing DPPH and anti-adipogenic activity by suppressing the preadipocyte conversion in 3T3L1 cells (Choi et al., 2013). Hydrogen peroxide induced cell death in brain neuroblastoma SK-N-SH cells was also reported to be reversed by AS extract (Chung et al., 2016).

Astragalin and Isoquercetin isolated from AS in this have been reported to suppress LPS-induced neuroinflammatory responses in microglial cells (Kim et al., 2022). Isoquercetin from AS alone has also been reported for its potent anti-inflammatory activity via inhibition of ERK/P38 MAPK pathway in RAW 264.7 cells (Lee et al., 2019). In addition to this, Astragalin from AS also been reported separately for its anti-inflammatory effects in RAW 264.7 cells (Kim et al., 2021). Spinasterol from AS was also reported to present anti-inflammatory effects via induction of heme oxygenase-1 in murine hippocampal and microglial cell lines (Jeong et al., 2010). We believe that presence of the above-mentioned single compounds in ASE contribute to the overall potent anti-inflammatory effects of ASE as shown in our study (Fig. 2 and 3).

COVID-19 pandemic has become the most dangerous infectious disease since its outbreak in 2019. Among many etiological causes of COVID-19, air pollution holds a prime importance for the enhanced susceptibility of living beings to contract, this pandemic infection (Whiteside and Herndon, 2020). In fact, since its outbreak, population living in high Air Pollution Indices (API's) areas, showed a 200% more predisposition to mortality due to COVID-19 as compared to population living in lower API's areas (Cui et al., 2003). The most important component in the air pollution is Coal Fly Ash (CFA) particles. CFA together with other air pollutants increase the epithelial cells permeability to viral receptors and thus suppressing the host defensive mechanisms and inhibiting the major macrophage functions like antigen processing, phagocytosis and release of cytotoxic T cells and Natural Killers cells (Andrée, 2020; Karan et al., 2020). Our study has shown that ASE potently suppressed the CFA induced inflammation in MH-S cells directly correlating to its beneficial effects for COVID-19 contractibility in high API's population areas.

Therefore, in light of these findings and with the supporting previously published data, AS should be considered as a potent candidate for functional food on commercial basis provided that more *in vivo* studies are guaranteed.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2022R1A2C1012963).

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

REFERENCES

Andrée BPJ. Incidence of Covid-19 and connections with air pollution exposure: Evidence from the netherlands. medRxiv 2020. 04. 27. 20081562.

Azab A, Nassar A, Azab AN. Anti-inflammatory activity of natural products. Molecules. 2016. 21: 1321.

Choi JH, Park YH, Lee IS, Lee SP, Yu MH. Antioxidant activity and inhibitory effect of aster scaber thunb. Extract on adipocyte differentiation in 3t3-l1 cells. Korean J Food Sci Technol. 2013. 45: 356-363.

Choi YE, Choi SI, Han X, Men X, Jang GW, Kwon HY, Kang SR, Han JS, Lee OH. Radical scavenging-linked anti-adipogenic activity of aster scaber ethanolic extract and its bioactive compound. Antioxidants (Basel). 2020. 9: 1290.

Chung MJ, Lee S, Park YI, Lee J, Kwon KH. Neuroprotective effects of phytosterols and flavonoids from cirsium setidens and aster scaber in human brain neuroblastoma sk-n-sh cells. Life Sci. 2016. 148: 173-182.

Chung TY, Eiserich JP, Shibamoto T. Volatile compounds isolated from edible korean chamchwi (aster scaber thunb). J Agric Food Chem.1993. 41: 1693-1697.

Cui Y, Zhang ZF, Froines J, Zhao J, Wang H, Yu SZ, Detels R. Air pollution and case fatality of sars in the people's republic of china: An ecologic study. Environ Health. 2003. 2: 15.

Dinarello CA. Proinflammatory cytokines. Chest. 2000. 118: 503-508.

Halliwell B. Role of free radicals in the neurodegenerative diseases: Therapeutic implications for antioxidant treatment. Drugs Aging. 2001. 18: 685-716.

Ignarro LJ. Physiology and pathophysiology of nitric oxide. Kidney Int Suppl. 1996. 55: S2-S5.

Jeon SM, Lee JY, Kim HW, Lee YM, Jang HH, Hwang KA, Kim HR, Park DS. Antioxidant activity of extracts and fractions from aster scaber. J Korean Soc Food Sci Nutr. 2012. 41: 1197-1204.

Jeong GS, Li B, Lee DS, Kim KH, Lee IK, Lee KR, Kim YC. Cytoprotective and anti-inflammatory effects of spinasterol via the induction of heme oxygenase-1 in murine hippocampal and microglial cell lines. Int Immunopharmacol. 2010. 10: 1587-1594.

Karan A, Ali K, Teelucksingh S, Sakhamuri S. The impact of air pollution on the incidence and mortality of covid-19. Glob Health Res Policy. 2020. 5: 39.

Kim EH, Lee S, Chung MJ. Anti-inflammatory and neuroprotective effects of astragalin isolated from aster scaber. Korean J Food Preserv. 2021. 28: 1000-1009.

Kim EH, Shim YY, Lee HI, Lee S, Reaney MJT, Chung MJ. Astragalin and isoquercitrin isolated from aster scaber suppress lps-induced neuroinflammatory responses in microglia and mice. Foods. 2022. 11: 1505.

Kim GM, Hong JY, Woo SY, Lee HS, Choi YJ, Shin SR. Antioxidant activities of ethanol extracts of aster scaber grown in wild and culture field. Korean J Food Preserv. 2015. 22: 567-576.

Kim GH, Choi HY, Park HS. Antioxidant activity of aster scaber thunb. With different cooking methods (LB409). FASEB J. 2014. 28.

Kim J, Park CS, Lim Y, Kim HS. Paeonia japonica, houttuynia cordata, and aster scaber water extracts induce nitric oxide and cytokine production by lipopolysaccharide-activated macrophages. J Med Food. 2009. 12: 365-373.

Kwon HC, Jung CM, Shin CG, Lee JK, Choi SU, Kim SY, Lee KR. Dictionary of Chinese herbs 1431. Bulletin P. 2000a. 48: 1796-1798.

Kwon HC, Jung CM, Shin CG, Lee JK, Choi SU, Kim SY, Lee KR. A new caffeoly quinic acid from aster scaber and its inhibitory activity against human immunodeficiency virus-1 (hiv-1) integrase. Bulletin P. 2000b. 48: 1796-1798.

Lee HI, Kim EH, Lee S, Chung MJ. Anti-inflammatory and neuroprotective effects of isoquercitrin isolated from aster scaber. J Korean Soc Food Sci Nutr. 2019. 48: 1205-1213.

Lee SE, Lee JH, Kim JK, Kim GS, Kim YO, Soe JS, Choi JH, Lee ES, Noh HJ, Kim SY. Anti-inflammatory activity of medicinal plant extracts. Korean J Crop Sci. 2011. 19: 217-226.

Lee TB. Illustrated flora of Korea. HMS. 1989.

Lee YJ, Kim DB, Lee JS, Cho JH, Kim BK, Choi HS, Lee BY, Lee OH. Antioxidant activity and anti-adipogenic effects of wild herbs mainly cultivated in Korea. Molecules. 2013. 18: 12937-12950.

Lee YY, Saba E, Kim M, Rhee MH, Kim HK. Antioxidant and anti-inflammatory properties of raw and processed fruits and vegetables. Biomed Sci Lett. 2018. 24: 196-205.

Pizzino G, Irrera N, Cucinotta M, Pallio G, Mannino F, Arcoraci V, Squadrito F, Altavilla D, Bitto A. Oxidative stress: Harms and benefits for human health. Oxid Med Cell Longev. 2017. 2017: 8416763.

Sahlmann CO, Strobel P. Pathophysiology of inflammation. Nuklearmedizin. 2016. 55: 1-6.

Takeda K, Akira S. Toll-like receptors. Curr Protoc Immunol. 2015. 109: 14.12. 1-14.12. 10.

Thiruvengadam M, Praveen N, Yu BR, Kim SH, Chung IM. Polyphenol composition and antioxidant capacity from different extracts of aster scaber. Acta Biol Hung. 2014. 65: 144-155.

Vazquez-Fresno R, Rosana ARR, Sajed T, Onookome-Okome T, Wishart NA, Wishart DS. Herbs and spices-biomarkers of intake based on human intervention studies - a systematic

review. Genes Nutr. 2019. 14: 18.
Whiteside M, Herndon JM. Covid-19 immunopathology, particle pollution, and iron balance. J Adv Med Med Res. 2020. 32: 43-60.

https://doi.org/10.15616/BSL.2022.28.3.170
Cite this article as: Saba E, Je N, Song JE, Shi S, Lee J, Jung O, Han BJ, Lee SY, Park J, Lee YY, Rhee MH. Anti-inflammatory and Anti-oxidant Activities of Aster Scaber Ethanol Extract. Biomedical Science Letters. 2022. 28: 170-177.