J. Microbiol. Biotechnol. (2016), 26(8), 1367–1374
http://dx.doi.org/10.4014/jmb.1603.03009

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Antioxidant and Anti-Inflammatory Effects of Various Cultivars of Kiwi Berry (*Actinidia arguta*) on Lipopolysaccharide-Stimulated RAW 264.7 Cells

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Received: March 4, 2016
Revised: April 15, 2016
Accepted: May 9, 2016

First published online
May 9, 2016

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pISSN 1017-7825, eISSN 1738-8872

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The present study evaluated the total phenolic and flavonoid contents as well as total antioxidant capacity (TAC) of three cultivars of *Actinidia arguta* Planch. kiwi berries; cv. Mansoo (Mansoo), cv. Chiak (Chiak), and cv. Haeyeon (Haeyeon). In addition, the anti-inflammatory effects of the three cultivars of kiwi berries were investigated using a lipopolysaccharide (LPS)-stimulated RAW 264.7 murine macrophage cell line. Mansoo had the highest total phenolic content and TAC among the three cultivars, whereas Chiak had the highest total flavonoid content. The total antioxidant capacities of the kiwi berry extracts were more strongly correlated with total phenolic content than with total flavonoid content. The kiwi berry extracts suppressed the secretion of pro-inflammatory cytokines, including interleukin-6 and tumor necrosis factor-α, from LPS-stimulated RAW 264.7 cells. The release of nitrite, an indirect indicator of nitric oxide, was also ameliorated by pre-treatment with the kiwi berry extracts in a dose-dependent manner. Cellular-based measurements of antioxidant capacity exhibited that the kiwi berry extracts had cellular antioxidant capacities. Such cellular antioxidant effects are possibly attributed to their direct antioxidant capacity or to the inhibition of reactive oxygen species generation via anti-inflammatory effects. Our findings suggest that kiwi berries are potential antioxidant and anti-inflammatory agents.

Keywords: *Actinidia arguta* Planch., kiwi berries, total phenolics, antioxidant capacity, anti-inflammatory activity

Introduction

Reactive oxygen species (ROS) and inflammatory responses have essential physiological functions in cell signaling and immune defense [4]. However, excessive or prolonged ROS generation and inflammatory responses cause various health problems, such as cardiovascular disease, insulin resistance, type 2 diabetes, osteoporosis, arthritis, asthma, and inflammatory bowel disease [5, 14, 31]. Therefore, regulation of ROS levels and inflammatory reactions is critical for reducing the risk of related chronic diseases.

Fruits and vegetables are rich in dietary antioxidants, such as vitamins and phenolics [36]. Phenolics are known to have not only antioxidant capacity, but also anti-inflammatory effects. Previous studies have reported that the dietary intake of phenolics is highly correlated with plasma antioxidant capacity and have demonstrated the effects of antioxidant capacity in vivo [37, 38]. In addition,

phenolics have been shown to exhibit anti-inflammatory effects in vivo and in vitro [15, 22]. Several studies have revealed that the health benefits of fruit and vegetable consumption are in part attributed to their antioxidant and anti-inflammatory effects [11, 19].

Kiwi fruits (*Actinidia* spp.) have a high antioxidant capacity [26] due to their high levels of phenolics and vitamin C [18]. Kiwi fruit has been ranked as the second highest antioxidant fruit among commonly consumed fruits, following plums [36]. Kiwi fruit is native to northern China and is one of the most popular fruits in New Zealand, the USA, and many European countries [9]. Around 60 species of the genus *Actinidia* are present in the world. The most common *Actinidia* species are *A. deliciosa, A. chinensis, A. coriacea, A. arguta, A. kolomikta, A. melandra, A. polygama*, and *A. purpurea* [8, 9].

Among the many species of kiwi fruit, *A. arguta*, known as the kiwi berry, has an edible soft skin and can be consumed without peeling [10]. Previous studies have shown that the skin of the kiwi fruit has considerably higher total phenolic and total flavonoid levels [23, 25]. The skin of kiwi fruit also exhibits higher antioxidant capacity compared with the fleshy part [25], indicating that the consumption of whole kiwi berry is not only convenient but also beneficial for health-promoting effects. For this reason, kiwi berry has attracted a great deal of attention from researchers attempting to investigate and develop cultivars to improve the functional compound content and taste, as well as disease and insect resistance [27, 29]. However, there have been few reports discussing the antioxidant capacity and anti-inflammatory effects of developed kiwi berry cultivars.

Therefore, the objectives of this study were to evaluate the total phenolic and flavonoid contents, and antioxidant capacity of three cultivars of kiwi berries: cv. Mansoo (Mansoo), cv. Chiak (Chiak), and cv. Haeyeon (Haeyeon), and to investigate the anti-inflammatory effects and intracellular antioxidant capacities of kiwi berries using RAW 264.7 murine macrophage cells.

Materials and Methods

Materials

Three kiwi berry cultivars (*A. arguta* Planch.), Mansoo, Chiak, and Haeyeon, were provided by the Jeonnam Agricultural Research and Extension Services, South Korea in September 2014.

Ascorbic acid, 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS), catechin, 2′,7′-dichlorofluorescin diacetate (DCFH-DA), 2,2-diphenyl-1-picrylhydrazyl (DPPH), fluorescein sodium salt, dimethyl sulfoxide (DMSO), Folin-Ciocalteu's phenol reagent, gallic acid, 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT), lipopolysaccharide (LPS), and Griess reagent were purchased from Sigma Chemical Co., LLC (USA). 2,2′-Azobis(2-methylpropionamidine) dihydrochloride (AAPH) was obtained from Wako Pure Chemical Industries, Ltd. (Japan). Dulbecco's phosphate-buffered saline (DPBS), Dulbecco's Modified Eagle's Medium (DMEM), fetal bovine serum (FBS), and penicillin/streptomycin were purchased from Welgene Inc. (Republic of Korea). Tumor necrosis factor-α (TNF-α) and interleukin-6 (IL-6) enzyme-linked immunosorbent assay (ELISA) kits were purchased from BD Biosciences (USA).

Extraction of Kiwi Berry Phenolics

Twenty grams of whole kiwi berries was extracted using 80% (v/v) aqueous ethanol. Kiwi berries were homogenized with 80% (v/v) aqueous ethanol using a Polytron homogenizer (Switzerland) at 15,000 rpm for 2 min. The homogenized mixture was filtered through Whatman #2 filter paper (UK) using a chilled Büchner funnel. The filtrate was evaporated using a rotary evaporator under reduced pressure at 40°C. The final extract was stored at –20°C until use. All experiments were conducted in triplicates.

Determination of Total Phenolic Content

The total phenolic content of kiwi berries was measured using a colorimetric method with Folin-Ciocalteu's phenol reagent [33]. Each extract (200 μl) was diluted by mixing with 2.6 ml of deionized water (DW) followed by adding 200 μl of Folin-Ciocalteu's phenol reagent. After a 6 min incubation, 2.0 ml of 7% (w/v) Na_2CO_3 solution was added to the reaction mixture. At 90 min, absorbance was measured at 750 nm. Total phenolic content was expressed as mg gallic acid equivalents (GAE)/100 g fresh weight (FW) of kiwi berries.

Determination of Total Flavonoid Content

The total flavonoid content of the kiwi berry extract was measured using a modified method of Kim *et al*. [20]. Briefly, 500 μl of diluted kiwi berry extracts or catechin standards were mixed with 3.2 ml of DW. Five minutes after adding 150 μl of 5% (w/v) $NaNO_2$, an equal volume of 10% (w/v) $AlCl_3$ was added. After 6 min of incubation, the reaction was stopped by adding 1 ml of 1 M NaOH. The absorbance of the solution was measured immediately at 510 nm. Total flavonoid content was expressed as mg catechin equivalents (CE)/100 g FW of kiwi berries.

Determination of Antioxidant Capacity Using ABTS Assay

The total antioxidant capacity (TAC) of kiwi berries was evaluated using dark green ABTS radicals [21]. Fresh ABTS radical solution was prepared by dissolving 1.0 mM of AAPH and 2.5 mM of ABTS in 100 ml of phosphate buffer solution, pH 7.4, and allowing the mixture to react for 30 min at 70°C. To measure the TAC of extracts, diluted samples (10 μl) were reacted with the ABTS radical working solution (990 μl) at 37°C for 10 min. The absorbance of the mixture was measured at 734 nm. The TAC of

kiwi berries was expressed as mg vitamin C equivalents (VCE)/ 100 g FW of kiwi berries.

Determination of Antioxidant Capacity Using DPPH Assay

The TAC of kiwi berry extracts was measured as purple DPPH radicals [3]. Fresh DPPH radical solution was prepared by dissolving 1.0 mM of DPPH in 200 ml of 80% (v/v) aqueous methanol. After the solution was diluted with 80% (v/v) methanol to an absorbance of 0.650 ± 0.020 at 517 nm, 50 μl of diluted kiwi berry extract was added to 2.95 ml of the DPPH solution. The decrease in absorbance of the reaction mixture at 30 min was measured at 517 nm. The TAC of kiwi berries by the DPPH assay was expressed as mg VCE/100 g FW of kiwi berries.

Determination of Antioxidant Capacity Using the Oxygen Radical Absorbance Capacity (ORAC) Assay

The ORAC assay was performed to determine the TAC of kiwi berry using a fluorescent probe [16]. The ORAC assay is a measurement of the oxidative decomposition of fluorescein following mixing and heating with a free-radical generator, AAPH; the more oxidative decomposition of fluorescein, the less fluorescent intensity. Standard (vitamin C) or kiwi berry extract (25 μl) was mixed with 150 μl of fluorescein solution (81.6 nM) in a 96-well plate followed by incubating at 37°C for 10 min. Then, 25 μl of AAPH (153 mM) was added. Fluorescence was detected every minute for 90 min using a fluorometer (Tecan Austria GmbH, Austria) at 485 nm for excitation and 520 nm for emission. The regression equation was obtained between vitamin C concentration and the net area under curve. The antioxidant capacity measured using the ORAC assay was also expressed as mg VCE/100 g FW of kiwi berries.

Cell Culture

The murine macrophage RAW 264.7 cell line was obtained from the Korean Cell Line Bank (Seoul, Korea). Cells were cultured in DMEM supplemented with 10% FBS, 100 units/ml of penicillin, and 100 μg/ml of streptomycin. The cells were maintained in a 37°C and 5% CO_2 incubator (Thermo Fisher Scientific Inc., Germany).

Cytotoxicity of Kiwi Berry Extract on RAW 264.7 Macrophages

Cell cytotoxicity by pre-treatment with kiwi berry extract was determined using the MTT assay. Briefly, RAW 264.7 cells (2×10^4 cells/well) were seeded in 96-well plates and incubated for 24 h before kiwi berry extract treatment. Kiwi berry extracts at 31, 63, 125, 250, 500, and 1,000 μg/ml were added to each well, and cells were incubated for a further 24 h. Subsequently, 100 μl of MTT solution (5 mg/ml) was added to each well, and the plates were incubated in a 37°C and 5% CO_2 incubator in the dark for 3 h. After incubation, 50 μl of DMSO was added to dissolve the purple formazan formed by reduction of the MTT reagent. The absorbance of the formazan solution was determined using a microplate reader (Tecan Austria GmbH) at 570 nm with reference wavelength at 630 nm.

Analysis of Pro-Inflammatory Cytokine Secretions Using Enzyme-Linked Immunosorbent Assay (ELISA)

Anti-inflammatory effects of the kiwi berry extracts were analyzed on LPS-induced RAW 264.7 cells. Cells were seeded in 48-well culture plates at a density of 2×10^5 cells/well and incubated for 24 h. The cells were exposed to 100 ng/ml of LPS with kiwi berry extracts at concentrations of 10, 50, 100, and 500 μg/ml for 24 h. Levels of TNF-α and IL-6 in the cell culture media were measured using an ELISA kit following the manufacturer's protocols (Pharmingen, USA).

Nitrite Assay

Nitric oxide (NO) production was determined using the Griess reagent. RAW 264.7 cells were seeded in 96-well plates at a density of 5×10^4 cells/well and were incubated for 24 h. Cells were exposed to 500 ng/ml of LPS with kiwi berry extracts at concentrations of 10, 50, 100, and 500 μg/ml for 24 h. Nitrite in the culture medium was measured as an indicator of NO production by RAW 264.7 cells [13]. Briefly, equal amounts of Griess reagent and culture medium were mixed and incubated for 10 min in the dark at room temperature. Absorbance at 540 nm was determined using a microplate reader (Tecan Austria GmbH). Sodium nitrite at 0 to 100 μM was used to create a standard curve to calculate the nitrite concentrations.

Measurement of Intracellular Antioxidant Capacity of Kiwi Berry Extracts

Intracellular antioxidant capacities of the kiwi berry extracts were determined using the DCFH-DA assay [39]. RAW 264.7 cells were seeded in a 96-well plate at a density of 2×10^4 cells/well. After 24 h incubation, cells were pretreated with serum-free culture medium with 10, 50, 100, and 500 μg/ml of kiwi berry extracts for 3 h. Subsequently, the medium was replaced with 50 μM DCFH-DA in DPBS. After 30 min, oxidative stress was induced for 1 h by adding 50 μM of AAPH. Fluorescence by 2′,7′-dichlorofluorescein (DCF) production was measured using a microplate reader (Tecan Austria GmbH) at 485 nm for excitation and at 530 nm for emission.

Statistical Analysis

One-way ANOVA was performed using SAS software (ver. 8.2, SAS Institute, Inc., USA). Significant differences were verified by Duncan's multiple range test at a 95% confidence level.

Results and Discussion

Total Phenolic Content, Total Flavonoid Content, and Total Antioxidant Capacity

The results of our studies on the total phenolic and flavonoid contents and total antioxidant capacities of kiwi berries are shown in Table 1. The highest total phenolic content was found in the Mansoo cultivar (191.6 mg GAE/

Table 1. Levels of total phenolics, total flavonoids, and antioxidant capacity of three cultivars of *Actinidia arguta* kiwi berries[A].

Cultivars	Total phenolics (mg GAE/100 g FW)	Total flavonoids (mg CE/100 g FW)	Antioxidant capacity (mg VCE/100 g FW)		
			ABTS	DPPH	ORAC
Mansoo	191.6 ± 8.6[a]	40.4 ± 1.8[b]	203.4 ± 7.0[a]	191.8 ± 17.0[a]	1,202.7 ± 190.7[a]
Chiak	148.1 ± 10.6[b]	42.6 ± 0.6[a]	135.5 ± 7.2[b]	126.6 ± 10.2[b]	1,057.2 ± 167.5[b]
Haeyeon	118.2 ± 4.3[c]	28.8 ± 1.9[c]	115.0 ± 4.6[c]	104.7 ± 23.7[c]	1,006.6 ± 123.2[c]

[A]Data are presented as the mean ± standard deviation (n = 3). GAE, CE, VCE, and FW stand for gallic acid equivalents, catechin equivalents, vitamin C equivalents, and fresh weight, respectively. Different superscripts in the same column indicate significant differences by Duncan's multiple range test ($p < 0.05$).

100 g FW), followed by Chiak (148.1 mg GAE/100 g FW) and Haeyeon (118.2 mg GAE/100 g FW). The Chiak cultivar showed the highest total flavonoid content among the three kiwi berries at 42.6 mg CE/100 g FW, followed by Mansoo and Haeyeon. According to our previous study, the total flavonoid content of whole kiwi berries was much higher than that of the berry flesh, which indicates that the flavonoids of kiwi berry are predominantly present in the skin of the kiwi berry [25]. The Mansoo cultivar had the highest antioxidant capacity at 203.4 mg VCE/100 g FW as measured using the ABTS assay, 191.8 mg VCE/100 g FW using the DPPH assay, and 1,202.7 mg VCE/100 g FW using the ORAC assay. The Chiak cultivar had an antioxidant capacity of 135.5 VCE/100 g FW and the Haeyeon cultivar had 115.0 VCE/100 g FW by the ABTS assay. The Chiak cultivar had significantly ($p < 0.05$) higher antioxidant capacity than the Haeyeon cultivar by the ABTS, DPPH, and ORAC assays.

The relationship between the TAC and total phenolic content is shown in Fig. 1A, and between TAC and total flavonoid content in Fig. 1B. The TAC of the kiwi berries exhibited a higher correlation with the total phenolic content than with the total flavonoid content. These results were in a good agreement with other studies [6, 24, 25]. Since flavonoids are mainly present in the skins of fruits, this higher correlation between total phenolic content and TAC may result from other compounds, such as phenolic acids and vitamin C in the flesh of the fruits. One study reported that the total phenolic content and vitamin C content were significantly correlated with TAC measure by ABTS, DPPH, and ORAC assays, whereas the total flavonoid content was not [6]. In particular, vitamin C not only reduces the Folin-Ciocalteu's phenol reagent in the total phenolic assay but it also can have an antioxidant capacity. Therefore, vitamin C might be a key compound accounting for the high correlation of total phenolic content and TAC.

Anti-Inflammatory Effects of Kiwi Berry Extracts on LPS-Simulated RAW 264.7 Cells

Investigation of cytotoxic effects of extracts of Mansoo, Chiak, and Haeyeon cultivars on the viability of RAW 264.7 cells demonstrated that none of the kiwi berry extracts had any cytotoxicity at up to 500 µg/ml (Fig. 2). Thus, kiwi berry extracts for anti-inflammatory and intracellular antioxidant studies on RAW 264.7 cells were performed using concentrations under 500 µg/ml.

LPS is a cell wall component of gram-negative bacteria

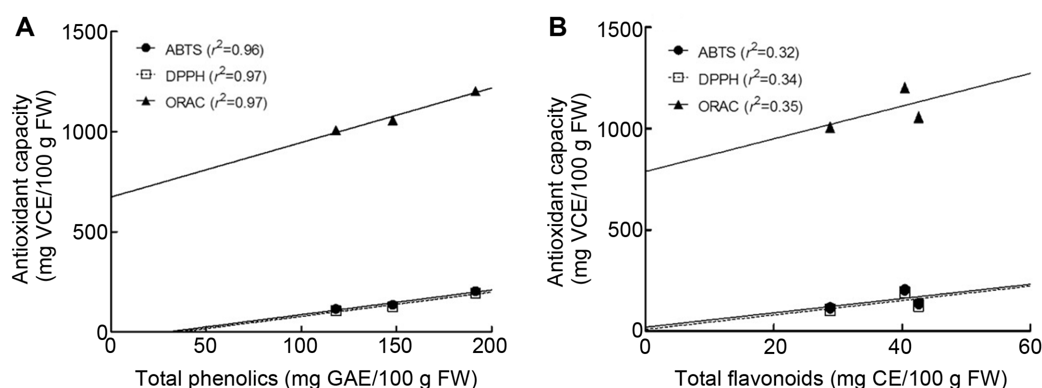

Fig. 1. Relationship between antioxidant capacity and total phenolics (**A**) and total flavonoids (**B**) of three different cultivars of *Actinidia arguta* kiwi berries.

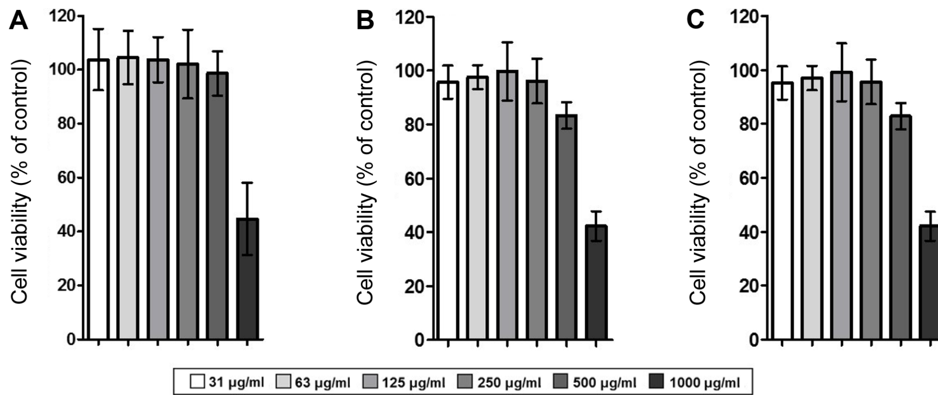

Fig. 2. Cytotoxicity of cv. Mansoo (**A**), cv. Chiak (**B**), and cv. Haeyeon (**C**) on RAW 264.7 cells.
Cell viability over 80% was considered non-toxic.

and acts as an endotoxin. LPS has an important role in the structural integrity of bacteria and the protection of bacterial membranes from certain kinds of chemical attack. It can induce an immune response by binding to the Toll-like receptor 4 (TLR4) complex in various immune cells, including monocytes, dendritic cells, macrophages, and B cells [17]. TLR4 activates the translocation of nuclear factor kappa B (NF-κB) cells, the pro-inflammatory transcription factor, to the nucleus followed by binding to response elements for upregulation of various pro-inflammatory cytokines and molecules, including TNF-α, IL-6, NO, and eicosanoids [17]. Therefore, inhibition of this pathway could be a possible mechanism of the anti-inflammatory effects of the kiwi berry extracts. Many of the phenolics that have been identified in kiwi fruit showed inhibition of NF-κB translocation [22]. Treatment of RAW 264.7 cells with 100 ng/ml of LPS induced the secretion of IL-6 (Fig. 3A) and TNF-α (Fig. 3B). However, pre-treatment with Mansoo, Chiak, and Haeyeon significantly reduced the release of IL-6 and TNF-α in a dose-dependent manner ($p < 0.05$).

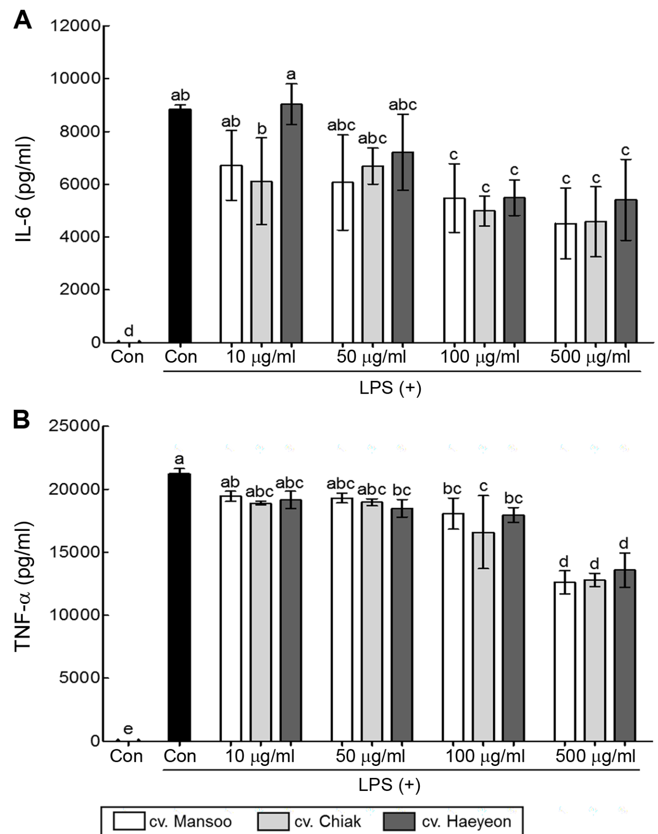

Fig. 3. Inhibitory effects of three kiwi berry cultivars (cv. Mansoo, cv. Chiak, and cv. Haeyeon) on the secretion of IL-6 (**A**) and TNF-α (**B**) from LPS-simulated RAW 264.7 cells.
Different alphabets indicate significant differences ($p < 0.05$) among treatments.

Inhibition of NO Production by Kiwi Berry Extracts on LPS-Simulated RAW 264.7 Cells

NO is synthesized from L-arginine by three nitric oxide synthase (NOS) isomers: endothelial NOS, neuronal NOS, and inducible NOS (iNOS). NO is involved in various physiological functions such as tumor cell killing, host defense, vasodilatation, neurotransmission, and inhibition of platelet aggregation [30]. NO produced by iNOS is involved in immune response; however, when iNOS produces excessive amounts of NO, it can react with superoxide to form peroxynitrite, which results in oxidative damage to cells [2, 7].

Here, we determined that the nitrite levels significantly increased to approximately three times that of the negative control when RAW 264.7 cells were exposed to 500 ng/ml of LPS ($p < 0.05$) (Fig. 4); however, kiwi berry extracts

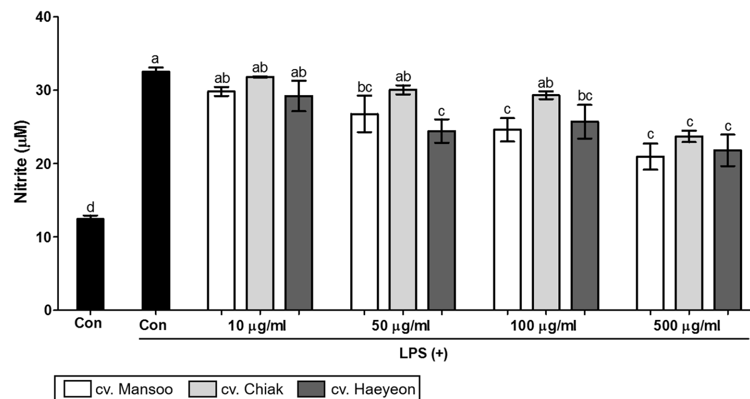

Fig. 4. Inhibitory effects of three kiwi berry cultivars (cv. Mansoo, cv. Chiak, and cv. Haeyeon) on the secretion of nitric oxide by LPS-simulated RAW 264.7 cells.

The concentration of nitrite reflects the amount of nitric oxide generated from RAW 264.7 cells. Different alphabets indicate significant differences ($p < 0.05$) among treatments.

suppressed the production of NO by LPS-stimulated RAW 264.7 cells in a dose-dependent manner. In particular, pre-treatment with 500 μg/ml of Mansoo, Chiak, and Haeyeon cultivar extracts inhibited NO generation by approximately 36%, 27%, and 33%, respectively. iNOS is upregulated by the activation of the NF-κB pathway through an upstream pattern recognition receptor, such as TLR4 by LPS stimulus [32]. The maximum induction of iNOS genes occurs along with the upregulation of other pro-inflammatory cytokines, including TNF-α and IL-1β [32]. Therefore, the suppression of TNF-α secretion by kiwi berry extracts is likely related to its inhibition of NO secretion. Although Mansoo contains the highest amount of total phenolics and TAC among three cultivars of kiwi berries tested in this study (Table 1), the inhibition of NO secretion by Mansoo was lower than that of Chiak and Haeyeon (Fig. 4). Such discrepancy between TAC and anti-inflammatory effect of the three cultivars kiwi berries implies that certain functional compounds might be involved in the anti-inflammatory effects directly, regardless of their antioxidant capacity. Identification of the anti-inflammatory compounds and their mechanisms should be further investigated.

Kiwi fruits contain various types of phenolics that have anti-inflammatory effects, including (+)-catechin, chlorogenic acid, (-)-epicatechin, quercetin, rutin, gallic acid, and caffeic acid [22]. Many studies have reported that flavonoids attenuate the translocation of NF-κB from the cytosol to the nucleus, which results in the prevention of NF-κB activation to response elements for the expression of pro-inflammatory cytokines [22, 35]. Our study was in good agreement with another study that showed antioxidant and anti-NO production by kiwi extracts [28].

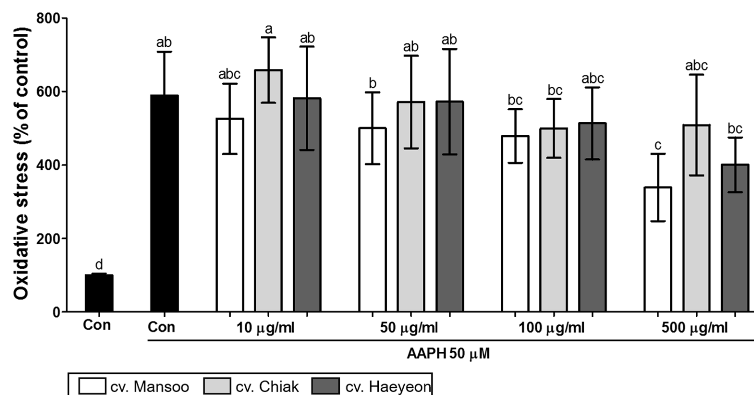

Fig. 5. Intracellular antioxidant capacities of the three kiwi berry cultivars (cv. Mansoo, cv. Chiak, and cv. Haeyeon) on RAW 264.7 cells.

Intracellular antioxidant capacity was measured using the DCFH-DA assay. Different alphabets indicate significant differences ($p < 0.05$) among treatments.

Intracellular Antioxidant Capacity

Results of the intracellular antioxidant capacity measurements of the kiwi berry extracts using the DCFH-DA assay are shown in Fig. 5. RAW 264.7 cells exposed to oxidative stress of 50 μM AAPH significantly increased ROS levels to 589% of the control ($p < 0.05$). However, pre-treatment with the kiwi berry extracts significantly decreased intracellular ROS levels in a dose-dependent manner compared with the control treated with AAPH only ($p < 0.05$). Treatments with Mansoo, Chiak, and Haeyeon extracts at 500 μg/ml each reduced intracellular ROS levels by 338%, 508%, and 400%, respectively, implying that the antioxidants in kiwi berries can be absorbed by cells.

There are two possible mechanisms for the intracellular antioxidant capacity of kiwi berry extracts. First, kiwi berry extract could directly eliminate ROS generated from RAW 264.7 macrophages through radical scavenging activity, as was previously shown [34]. Non-fluorescent DCFH-DA crosses cell membranes and is hydrolyzed by intracellular esterase to non-fluorescent DCFH, which can be further oxidized to fluorescent DCF by hydroxyl radicals converted from hydrogen peroxide [12]. Based on our results, the kiwi berry extracts may have been absorbed into the cells and removed cellular hydroxyl radicals so that the production of fluorescent DCF was inhibited. Second, kiwi berry extract could prevent ROS generation through anti-inflammatory effects. Kiwi berries have been shown to have anti-inflammatory effects via suppressing pro-inflammatory TNF-α [22].

In this study, we showed that NO production was attenuated by treating RAW 264.7 cells with kiwi berry extracts. TNF-α and iNOS are in part involved in the mechanism of ROS generation by NADPH oxidase on macrophage [1, 2]. Under pro-inflammatory conditions, macrophages can induce pro-inflammatory cytokines that subsequently upregulate iNOS. NO then induces the expression of another inflammatory enzyme, COX2, followed by the activation of NADPH oxidase [34]. Activated NADPH oxidase produces superoxide radicals, which are converted to hydrogen peroxide by superoxide dismutase [34]. Kiwi berries may reduce the production of ROS-mediated fluorescent DCF through their anti-inflammatory effects. Previous studies reported that various phenolics act as excellent anti-inflammatory agents and play an important role between oxidative stress and inflammation [32, 40].

In summary, the total phenolic and flavonoid contents as well as the TAC of three cultivars of kiwi berries, Mansoo, Chiak, and Haeyeon, were investigated. The intracellular antioxidant capacity and anti-inflammatory effects of the kiwi berries were also investigated. Each kiwi berry cultivar showed distinct total phenolic and flavonoid contents and total antioxidant capacities. The production of pro-inflammatory cytokines and NO production on LPS-simulated RAW 264.7 cells were attenuated in a dose-dependent manner by pre-treatment with the kiwi berry extracts. The three kiwi berry extracts also showed intracellular antioxidant capabilities. These functional effects can be attributed to the phenolics present in kiwi berries. Further studies are needed to identify and quantify the phenolics of kiwi berries. In addition, further study is warranted to investigate the underlying mechanisms of the intercellular antioxidant and the anti-inflammatory effects of kiwi berries.

Acknowledgments

This research was supported by the Agricultural Biotechnology Development Program (Project No. 114076-3), Ministry of Agriculture, Food and Rural Affairs, Republic of Korea.

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