Original Article

Dioscorea japonica extract down-regulates prostaglandin E_2 synthetic pathway and induces apoptosis in lung cancer cells

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Prostaglandin E_2 plays a role in an array of pathophysiological responses, including inflammation, carcinogenesis and so on. Prostaglandin E_2 is synthesized from arachidonic acid by the enzymes cyclooxygenase and prostaglandin E synthase. In some pathological conditions, the isozymes cyclooxygenase-2 and microsomal prostaglandin E synthase-1 are transiently induced, leading to prostaglandin E_2 overproduction. The present study showed that *Dioscorea japonica* extract suppresses mRNA expression of cyclooxygenase-2 and microsomal prostaglandin E synthase-1 in human non-small-cell lung carcinoma A549 cells in a dose-dependent manner. The suppressive effects of *Dioscorea japonica* extract on the expression of cyclooxygenase-2 and microsomal prostaglandin E synthase-1 were confirmed by Western blotting, cyclooxygenase activity and prostaglandin E_2 production. *Dioscorea japonica* extract induced the translocation of nuclear factor-κB from the nucleus to the cytosol and inhibited the activity of the cyclooxygenase-2 promoter. Furthermore *Dioscorea japonica* extract suppressed the expression of the anti-apoptotic factor B-cell chronic lymphocytic leukemia/lymphoma 2 and enhanced apoptotic terminal deoxynucleotidyl transferase-mediated dUTP nick end labeling-positive intensity in A549 cells. These results suggest that *Dioscorea japonica* extract suppresses the expression of cyclooxygenase-2 and microsomal prostaglandin E synthase-1, with the regulation of the transcriptional activity of cyclooxygenase-2, and induces apoptosis in cancer cells. Thus, *Dioscorea japonica* may contribute to the prevention of prostaglandin E_2-mediated pathophysiological responses such as carcinogenesis and inflammation.

Key Words: ***Dioscorea japonica*, cyclooxygenase-2, microsomal prostaglandin E synthase-1, cancer cells, apoptosis**

The lipid mediator prostaglandin E_2 (PGE_2) is derived from arachidonic acid and mediates an array of pathophysiological responses such as inflammation, inhibition of gastric acid secretion, pain transmission, neurodegeneration, and carcinogenesis.[1,2] Biosynthesis of PGE_2 from arachidonic acid involves the enzymes cyclooxygenase (COX) and prostaglandin E synthase (PGES). COX is the rate limiting enzyme responsible for the production of PGs and thromboxane from arachidonic acid. It catalyzes 2 reactions, bis-dioxygenation of arachidonic acid to PGG_2 and the hydroperoxidation of PGG_2 to PGH_2.[3] COX has 2 isozymes, COX-1 and COX-2. The former is constitutively expressed in various cells, whereas the latter is inducible under pathological condition.[4] PGES acts downstream of COX and catalyzes the isomerization of PGH_2 to PGE_2. PGES has at least 3 isozymes, microsomal PGES (mPGES)-1,[5] mPGES-2,[6,7] and cytosolic PGES (cPGES).[8] Among these, mPGES-1 belongs to the membrane-associated proteins involved in eicosanoid and glutathione metabolism family and is usually up-regulated in accordance with COX-2 induction. In several types of cancer cells, both COX-2 and mPGES-1 are highly expressed, and the consequent excessive production of PGE_2 worsens the symptoms.[2,9,10]

COX-2 has been considered an attractive target for PGE_2 inhibition. Indeed, selective COX-2 inhibitors, as well as other traditional non-steroidal anti-inflammatory drugs (NSAIDs), are used to provide symptomatic relief to patients with chronic diseases.[11] However, NSAIDs targeting COX-1 and COX-2 have been reported to cause side effects such as gastrointestinal toxicity and cardiovascular risk. In light of this, inhibition of mPGES-1, which acts downstream of COX-2, represents an attractive target for selective inhibition of PGE_2 production, with a potentially safer profile than COX-2 inhibitors. Thus, identification of natural substances from foods that have safe and functional effects on the regulation of PGE_2 production is essential. Accordingly, in this study, we focused on the functional effect of *Dioscorea japonica (D. japonica)* on the regulation of the expression of COX-2 and mPGES-1.

D. japonica, a wild yam, is a relative of the *Dioscoreaceae* family native to Japan. *Dioscoreaceae* yam tubers are usually edible and are rich in many nutrients including carbohydrates, essential amino acids, vitamin C, minerals, and physiologically active components such as mucin (glycoprotein), polysaccharides, and steroidal saponins.[12–15] It is well known that *D. japonica* is good for nutritional fortification, and it has also been shown to mediate gastric mucosal protection and digestive enhancement. However, the other physiological effects of *D. japonica* have not been completely elucidated.

The aim of this study was to explore the novel functional effects of *D. japonica* on the regulation of the PGE_2 synthesis pathway. We also examined the possibility that *D. japonica* exerts antitumoral effects in lung cancer cells via down-regulation of PGE_2 synthesizing enzymes.

Materials and Methods

Preparation of *D. japonica* powder and extract.

D. japonica was obtained from Autoraimu Yoshio Ltd. (Niimi, Japan). *D. japonica* was pared away the outer skin and was dried under 40°C. The ground *D. japonica* was prepared to uniform

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powders through 250 μm mesh. The powders were eluted with 20–80% ethanol (v/v, EtOH), and the extracts were immediately dried-up with nitrogen gas and were completely filling with the gas to protect oxidation. They were stored at –80°C until using for the experiments. When the *D. japonica* extract (DJE) was added to the medium for cell culture, the dried DJE was re-dissolved in DMSO as a vehicle. The final concentration of DMSO was 0.1% in the medium for control cells and DJE-treated cells.

Cell culture. Human non-small cell lung carcinoma cell line A549 (ATCC CCL-185) and human colon carcinoma cell line Caco-2 (ECACC 86010202) were obtained from RIKEN BioResource Center (Tsukuba, Japan). The cells were cultured in Dulbeco's modified Eagle's medium supplemented with 10% fetal bovine serum, 100 U/ml penicillin, and 100 mg/ml streptomycin. The cells were treated with 0–100 μg/ml DJE in dimethyl sulfoxide, 0–10 μM diosgenin (Sigma, St. Louis, MO) in dimethyl sulfoxide or were added only vehicle as a control.

RNA purification and quantitative RT-coupled real-time PCR. A549 or Caco-2 cells after the treatment for 24 h were collected and the total RNA was isolated using the acid guanidinium thiocyanate procedure and analyzed for gene expression by real-time quantitative RT-PCR (iQ5 real-time PCR system, Bio-Rad, Hercules, CA). After converting total RNA to cDNA using High-Capacity cDNA Reverse Transcription Kit (Applied Biosystems, Foster City, CA), quantitative PCR was performed using Eva Green-Comparative Ct method (Bio-Rad). The following primer pairs were used for amplification of COX-2, mPGES-1, B-cell chronic lymphocytic leukemia/lymphoma 2 (Bcl-2) and glyceraldehyde 3-phosphate dehydrogenase (GAPDH); 5'-TGCATTCTTTGCCCAGCACT-3' (COX-2 forward), 5'-AAAGGCGCAGTTTACGCTGT-3' (COX-2 reverse), 5'-TGATCACACCCACAGTTGAGC-3' (mPGES-1 forward), 5'-TGATGATGGCCACCACGTA-3' (mPGES-1 reverse), 5'-TGGATGACTGAGTACCTGAA-3' (Bcl-2 forward), 5'-CCAGGAGAAATCAAACAGAG-3' (Bcl-2 reverse), 5'-CGACATCCCTCCAAAATCAA-3'(GAPDH forward), and 5'-TTCACACCCATGACGAACAT-3' (GAPDH reverse). The cycling conditions were 30 s at 95°C, followed by 40 cycles of 95°C for 5 s and 60°C for 10 s. Expression levels of COX-2, mPGES-1 and Bcl-2 mRNAs were normalized to those of GAPDH mRNA. The relative expression levels were shown against control and were mean ± SD of 5 separate experiments.

Western blotting. Collected A549 cells (5×10^5 cells) after the treatment with or without DJE for 48 h were sonicated in 100 μl of 10 mM Tris-HCl (pH 7.6) and then were centrifuged at $10{,}000 \times g$. The supernatants (30 μg protein/well) were subjected to 10% sodium dodecyl sulfate-polyaclylamidegel electrophoresis, and were transferred electrophoretically to a Hybond-P polyvinylidene difluoride membrane (Amersham Biosciences, Buckinghamshire, UK). After treatment with blocking reagent (Roche, Penzberg, Germany), the membrane was incubated with rabbit anti-COX-2 antibody (1:1000, Immuno-Biological Laboratories Co., Ltd., Gumma, Japan), rabbit anti-mPGES-1 antibody (1:1000, Cayman Chemical Co. Ann Arbor, MI) or rabbit anti β-actin anibody (1:1000, Cell Signaling Technology, Boston, MA). The immunoreactive proteins were visualized using BM chemiluminescence Western blotting kit (Roche). The density of each protein bands was analyzed with Fujifilm Multi Gauge ver. 3.0 software (Fujifilm, Tokyo, Japan). Protein concentration was determined using a BCA protein assay kit (Thermo Scientific Inc., Rockford, IL).

COX activity assay. COX activity was analyzed as described previous report.[16] The lysates were incubated with 100 mM Tris–HCl buffer (pH 7.4) containing 25 mM linoleic acid, and the products were analyzed by reversed-phase HPLC using a COSMOSIL 5C18-MS-II column (5 mm particle, 4.6 × 250 mm, Nacalai Tesque, Kyoto, Japan) with a solvent system of methanol/water/acetic acid (80:20:0.01, v/v). The produced 9- and 13-hydroxyoctadecadienoic acids (HODEs) which cochromatographed on reversed-phase HPLC as a single peak were quantified by the comparison of the area of the peak with that of an internal standard, 15-hydroxyeicosatetraenoic acid (HETE).

Enzyme immunoassay. After the treatment with or without DJE by 50% ethanol (100 μg/ml) for 48 h, arachidonic acid (10 μM) was added to the culture medium of A549 cells. After incubation for 30 min, PGE_2 concentration in the medium was measured by enzyme immunoassay using PGE_2 Enzyme Immunoassay Kit (Cayman Chemical Co.) as instructed by the manufacturer.

Immunocytochemistry. The intracellular localization of transcription factor nuclear factor-κB (NF-κB) was analyzed by fluorescence immunocytochemistry. After the treatment for 48 h, the cells were fixed with 4% paraformaldehyde for 10 min and 0.5% ethanol for 2 min. After blocking with Block Ace (Dainippon Seiyaku, Osaka, Japan), the cells were incubated with anti-NF-κB p65 (C22B4) rabbit antibody (Cell Signaling Technology), and then were incubated with Cyanine (Cy) 3-labeled donkey anti-rabbit IgG (1:400, Jackson ImmunoResearch Laboratories, Inc., West Grove, PA). The cells were counter stained with 4',6-diamidino-2-phenylindole (DAPI). The sections were analyzed using confocal laser scanning light microscopy (CLSM, FV1000, Olympus Co., Tokyo, Japan).

Promoter assay. COX-2 promoter assay was carried out as described previously.[17] COX-2/Cluc plasmid with COX-2 promoter region and Cypridina luciferase (Cluc) as a reporter gene was transfected to A549 cells. After the transfection, A549 cells were treated with 0.1 mM 12-*O*-tetradecanoylphorbol 13-acetate (TPA) and with or without DJE for 48 h, and the luciferase activity in the culture medium was measured using BioLux™ Cypridina Luciferase Assay Kit (New England BioLabs Inc., MA). A549 cells without the treatment of TPA and DJE was used as a control.

TUNEL assay. After treatment of with or without DJE for 48 h, terminal deoxynucleotidyl transferase-mediated dUTP nick end labeling (TUNEL) assay was carried out for identification of the extent of DNA fragmentation in A549 cells, using Peroxidase In Situ Apoptosis Detection Kit (EMD Millipore, Billerica, MA) as instructed by the manufacturer. TUNEL positive reactivity was observed with a light microscope (ECLIPSE 80*i*; Nikon Co., Tokyo, Japan).

Statistics. Data were statistically evaluated by Student's *t* test (Fig. 2B and 4) and ANOVA with Bonferonni's (Fig. 2A, 3B, 6A)

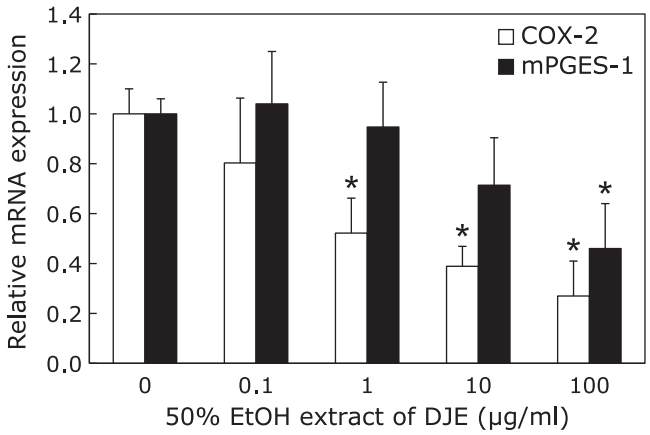

Fig. 1. Dose-dependent effect of DJE on the expression of COX-2 and mPGES-1 in A549 cells. DJE by 50% ethanol (0–100 μg/ml) was added to A549 cells. mRNA expression of COX-2 (open column) and mPGES-1 (closed column) was measured by real-time PCR, as described in the Materials and Methods section. The values are represented as a relative value against 0 μg/ml extract-treated cells and represent mean ± SD of 5 separate experiments. *p<0.05 compared with treatment with 0 μg/ml extract.

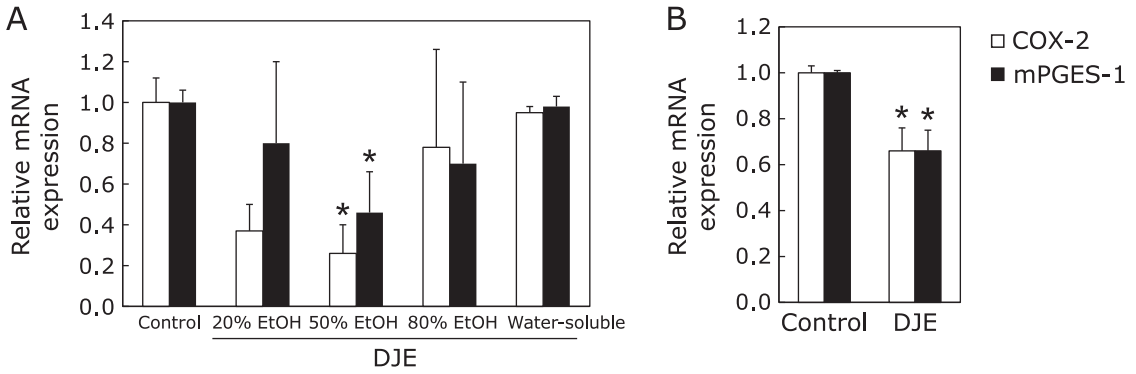

Fig. 2. Effect of water-soluble and Ethanol extract of *D. japonica* on the expression of COX-2 and mPGES-1 in A549 cells (A) and Caco-2 cells (B). Water-soluble or Ethanol (20, 50, and 80%) extract of *D. japonica* (100 μg/ml) was added to A549 cells (A), and the DJE by 50% ethanol (100 μg/ml) was added to Caco-2 (B). mRNA expression of COX-2 (open column) and mPGES-1 (closed column) was measured using real-time PCR. The values are represented as a relative value control cells and represent mean ± SD of 5 separate experiments. $^{**}p<0.01$ compared with the control.

or Dunnett's (Fig. 1 and 7) post-hoc test at significance level of $p<0.05$ or 0.01.

Results

Dose-dependent effect of DJE on the expression of COX-2 and mPGES-1 in A549 cells. COX-2 and mPGES-1 are constitutively and highly expressed in human lung carcinoma A549 cells. A549 cells were treated with DJE by 50% ethanol at 0.1–100 μg/ml concentration, and mRNA expression of COX-2 and mPGES-1 in the cells was analyzed by real-time PCR. DJE suppressed the expression of COX-2 and mPGES-1 in a dose-dependent manner (Fig. 1). Treatment with 100 μg/ml DJE significantly decreased mRNA levels of COX-2 and mPGES-1 to 27% and 46% compared with the control, respectively. Therefore, this concentration of DJE (100 μg/ml) was used for the following experiments. Addition of DJE made no significant difference on cell proliferation in the experimental period.

Suppression of the expression of COX-2 and mPGES-1 by DJE. Among the water-soluble extract of *D. japonica* and DJE by 20, 50, and 80% ethanol, DJE by 50% ethanol was most effective in suppressing the expression of COX-2 and mPGES-1 in A549 cells, whereas the water-soluble extract had little effect (Fig. 2A). Further, in human colon carcinoma model Caco-2 cells, treatment with DJE led to the suppression of COX-2 and mPGES-1 mRNAs to approximately 67% compared with the control (Fig. 2B).

After treatment with DJE by 50% ethanol for 48 h, COX-2 and mPGES-1 protein levels were decreased to 1.37 and 0.82, respectively, compared with the control (2.67 and 5.58) in A549 cells (Fig. 3).

Changes in COX activity and PGE_2 production by DJE treatment . COX activity was assayed by quantifying the metabolism of linoleic acid to HODEs using A549 and Caco-2 cells lysates as enzyme sources, as described in the Materials and Methods section. COX catalyzes the metabolism of arachidonic acid to PGH_2 and linoleic acid to 9- and 13-HODEs.[18] In the present study, linoleic acid was used as the substrate because it presents several advantages over arachidonic acid. HODEs metabolized from linoleic acid were stable and these are quantified by the typical reversed-phase HPLC analysis for low-molecular-weight lipids, although PGH_2 synthesized from arachidonic acid is highly unstable and is immediately and non-enzymatically metabolized to several PGs. After treatment with DJE for 48 h, COX activity was decreased to 46% (39 pmol/min/mg protein) and 50% (27 pmol/min/mg protein) when compared with each control in A549 cells and Caco-2 cells, respectively (Fig. 4A).

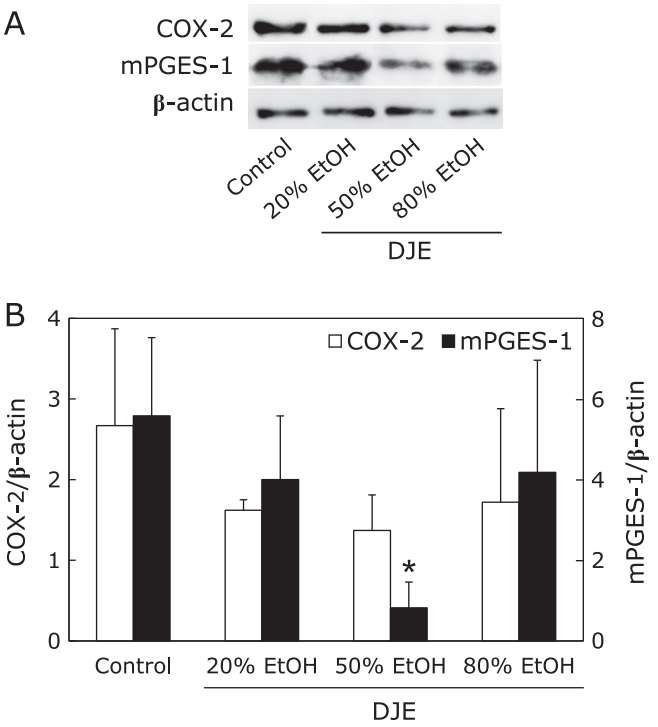

Fig. 3. Changes in protein expression of COX-2 and mPGES-1 after treatment with DJE. The protein expression levels of COX-2 and mPGES-1 were analyzed by Western blotting. The detected COX-2 and mPGES-1 proteins (30 μg total protein/well) were visualized as approximately 70 and 16 kDa bands, respectively (A). The density of each protein band was compared in 3 separate experiments with β-actin (approximately 45 kDa) as a control (B). $^{*}p<0.1$ compared with the control.

PGE_2 production was quantified by enzyme immunoassay. Released PGE_2 in the culture medium of A549 cells was also significantly decreased to 31% (647 pg/ml) by DJE treatment (Fig. 4B).

Translocation of NF-κB and suppression of COX-2 promoter activity by DJE. After treatment with DJE by 50% ethanol (100 μg/ml) for 48 h, localization of the transcription factor NF-κB was analyzed by immunocytochemistry (Fig. 5A). In some pathological conditions such as cancer and inflammation, NF-κB is translocated from the cytosol to the nucleus and plays a key role in regulating COX-2 transcriptional activity. NF-κB immunoreactivity merged with the nuclear counterstain DAPI in

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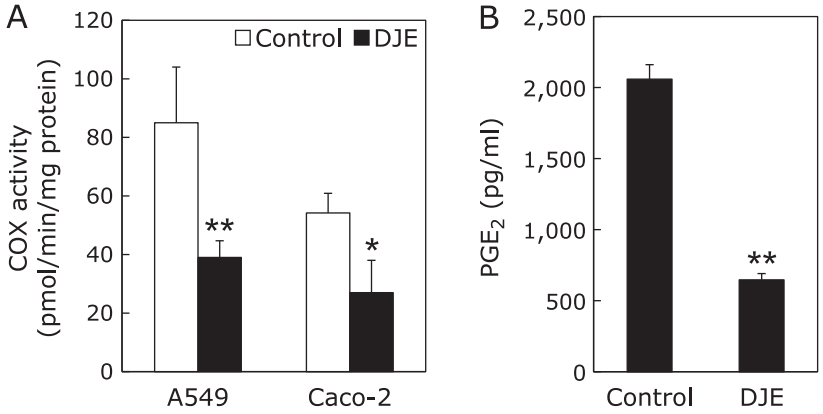

Fig. 4. Decrease in COX activity (A) and PGE_2 production (B) after treatment with DJE. COX activity after the treatment without (open column) or with (closed column) DJE (100 μg/ml) was measured. Supernatants obtained from the centrifugation (10,000 × *g*) of lysates from A549 and Caco-2 cells were used as enzyme sources for measurement of COX activity. The supernatants were incubated with 25 mM linoleic acid at 24°C for 5 min in the standard COX reaction mixture and the products were quantified using reversed-phase HPLC, as described in the Materials and Methods section. PGE_2 released in the culture medium of A549 cells was quantified by enzyme immunoassay. The values represent mean ± SD of 5 separate experiments. *$p<0.05$ and **$p<0.01$ compared with the control.

control A549 cells (Fig. 5A top panels). The findings indicate that NF-κB is constitutively localized in the nucleus in A549 cancer cells, which exhibit high levels of COX-2. In contrast, DJE treatment induced the translocation of NF-κB from the nucleus to the cytosol (Fig. 5A bottom panels). Additionally the COX-2 promoter activity was measured using COX-2/Cluc plasmid with Cypridina luciferase reporter gene (Fig. 5B). TPA (0.1 μM), a COX-2 inducer, increased luciferase activity by approximately 4-fold, and addition of DJE significantly decreased TPA-induced luciferase activity to a level similar to that of the control.

Suppression of Bcl-2 mRNA expression and induction of apoptosis by DJE. mRNA expression of the anti-apoptotic factor Bcl-2 was suppressed after treatment with DJE for 24 h (Fig. 6A). Compared with the control, DJE by 50% ethanol significantly decreased Bcl-2 mRNA levels to 18%.

Further, *in situ* detection of apoptotic cells with TUNEL method revealed a large number of brown-colored positive A549 cells after DJE treatment, although colored cells were hardly observed in the control cells (Fig. 6B).

Effect of diosgenin on the expression of COX-2 and mPGES-1 in A549 cells. Diosgenin is a major steroidal saponin constituent and is found more abundantly in *D. japonica* compared with other food substances. Diosgenin suppressed COX-2 expression in A549 cells in a dose-dependent manner (0–10 μM), and 10 μM diosgenin reduced COX-2 expression to 46% compared with the control (Fig. 7). In contrast, diosgenin did not have a significant effect on the expression of mPGES-1.

Discussion

Of all cancers, lung cancer has the highest mortality, and the 5-year survival rate is very low. Therefore, new approaches for the management and prevention of lung cancer are highly essential. Increased expression of COX-2 is commonly observed in lung tumors as well as in many other tumors.[19,20] Similarly, the expression of inducible mPGES-1, preferentially coupled with COX-2, for PGE_2 synthesis is enhanced in tumors.[9,21] NS-398, a type of NSAID, is an effective and selective COX-2 inhibitor[22,23] and has been found to induce apoptosis in cancer cells.[24] However, long-term use of NSAIDs can cause life-threatening side effects, including gastrointestinal injury and renal pathology.[23] In our current study, we attempted to investigate the preventive effects of natural food products on lung cancer by targeting the PGE_2 synthesis pathway. We demonstrated that DJE suppressed the expression of COX-2 and mPGES-1 and exerted anti-carcinogenic effects in human lung carcinoma A549 cells.

Our data show that DJE suppressed mRNA and protein expressions of COX-2 and mPGES-1 and consequently decreased COX activity and PGE_2 production. Furthermore, DJE induced the translocation of NF-κB, the typical transcription factor of COX-2, from the nucleus to the cytosol in A549 cells (Fig. 5A). This finding indicated that DJE regulates COX-2 signal transduction pathway mediating COX-2 induction. Consistent with this hypothesis, the transcriptional activity of COX-2 was significantly decreased by DJE, as shown using an expression plasmid containing COX-2 promoter with a Cluc reporter gene (Fig. 5B). In lung cancer cells, inhibition of COX-2 by trichostatin A,[25] a histone deacetylase inhibitor, or celecoxib,[26] a NSAID that acts as a selective COX-2 inhibitor, correlates with a decrease in PGE_2 production. Such inhibitors suppress tumor growth with decreasing the levels of the anti-apoptotic factor Bcl-2. Our results also showed that DJE suppressed the expression of COX-2 and mPGES-1, which are key enzymes for PGE_2 production, and induced apoptosis with suppression of the anti-apoptotic factor Bcl-2 in cancer cells.

Several phytochemicals from other natural products, such as resveratrol,[27] humulon,[28] and chrysin,[29] have been shown to suppress the expression of COX-2. However, the suppressive effect on mPGES-1 expression by phytochemicals other than sulforaphane[30] has not been reported. Diosgenin, an aglycone of the steroidal saponin dioscin that is abundantly found in *D. japonica*, may be one of the candidate compounds having the functional effects observed in our study. There are some reports that support our results that diosgenin may have suppressive effects on the signal transduction pathway mediating COX-2 induction. Diosgenin inhibits Akt signaling and its downstream targets, NF-κB and Bcl-2, in human breast cancer cells.[31] In addition, diosgenin has been shown to induce apoptosis in HepG2 and HEL cells.[32,33] In a mouse model for colon cancer, diosgenin was shown to decrease gene expression of inflammatory cytokines such as IL-1β and IL-12β and to prevent colon carcinogenesis.[34] In the present study, the effect of diosgenin (0–10 μM) on the expression of COX-2 and mPGES-1 in A549 cells was investigated. Diosgenin suppressed COX-2 expression in a dose-dependent manner, and COX-2 expression was decreased to 47% by 10 μM diosgenin (Fig. 6). However, the effect of diosgenin on COX-2 expression was lower than that of DJE by 50%

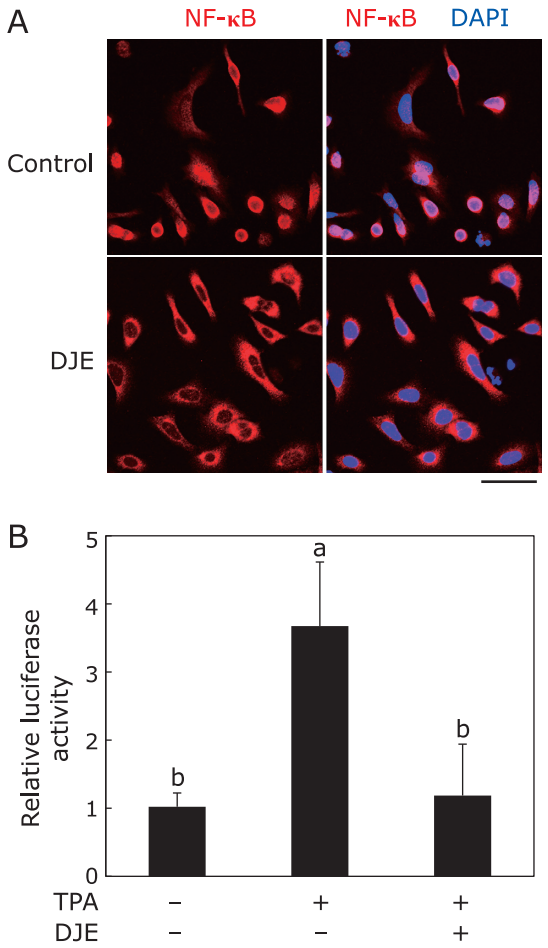

Fig. 5. Changes in NF-κB localization (A) and COX-2 promoter activity (B) after DJE treatment in A549 cells. Localization of the transcription factor NF-κB (red) and DAPI (blue, nuclear counterstain) was visualized by confocal laser scanning microscopy (A). Scale bar indicates 50 μm. Cluc reporter plasmid with COX-2 promoter was used for the promoter activity assay, as described in the Materials and Methods section (B). TPA (0.1 M) was used as an inducer of COX-2 expression. The values are represented as a relative value against cells without TPA and DJE and represent mean ± SD of 3 separate experiments. [a]$p<0.01$ compared with the control without TPA and DJE and [b]$p<0.01$ compared with TPA treatment without DJE.

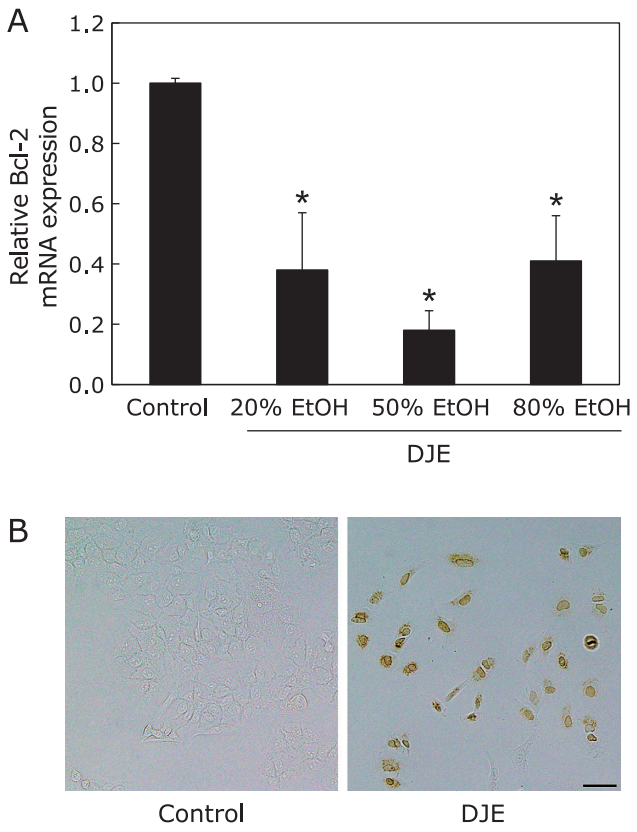

Fig. 6. Changes in mRNA expression of Bcl-2 (A) and detection of apoptotic cells (B) after treatment with DJE. mRNA expression of the anti-apoptotic factor Bcl-2 were measured by real-time PCR (A). The values are represented as a relative value control cells and represent mean ± SD. of 5 separate experiments. *$p<0.01$ compared with the control. *In situ* apoptotic cells were detected by TUNEL method, as described in the Materials and Methods section (B). TUNEL-positive cells were brown-colored. Scale bar indicates 20 μm.

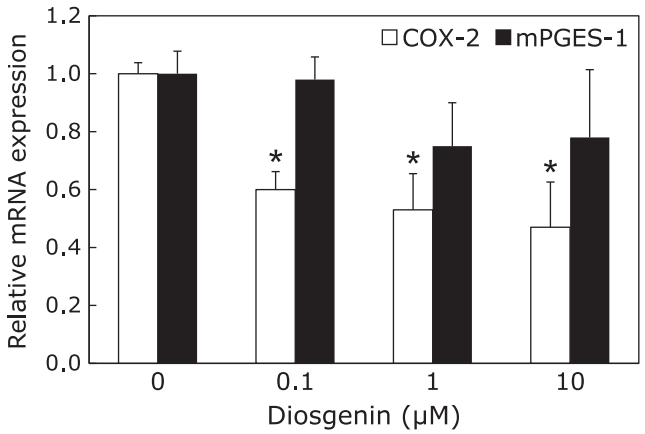

Fig. 7. Effect of diosgenin on the expression of COX-2 and mPGES-1 in A549 cells. Diosgenin (0.1–10 μM) was added to A549 cells. mRNA expression of COX-2 (open column) and mPGES-1 (closed column) was measured by real-time PCR, as described in the Materials and Methods section. The values are represented as a relative value against 0 μM diosgenin-treated cells and represent mean ± SD of 5 separate experiments. *$p<0.05$ compared with treatment with 0 μM diosgenin.

ethanol (100 μg/ml DJE), which decreased COX-2 expression to 27% (Fig. 2A). On the other hand, diosgenin did not have a significant effect on mPGES-1 expression. This suggests that multiple components in DJE mediate its ability to inhibit the expression of COX-2 and mPGES-1, leading to anti-inflammation and anti-carcinogenesis, suggesting there may be a novel functional component in DJE that has yet to be identified.

In conclusion, based on the present results, we propose that *D. japonica* results in the suppression of COX-2 and mPGES-1 expression and ultimately inhibits the production of PGE_2. Thus, it may prove valuable in controlling inflammatory and metabolic processes as well as carcinogenesis. Our results may be important in understanding the preventive effects of *D. japonica* against the lifestyle-related disease conditions that are mediated by PGE_2, although additional *in vivo* studies are required to address the physiological significance of our findings.

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Abbreviations

Bcl-2	B-cell chronic lymphocytic leukemia/lymphoma 2
Cluc	Cypridina luciferase
COX	cyclooxygenase
DJE	*Dioscorea japonica* extract
GAPDH	glyceraldehyde 3-phosphate dehydrogenase
HETE	hydroxyeicosatetraenoic acid
HODEs	hydroxyoctadecadienoic acids
mPGES	microsomal prostaglandin E synthase
NF-κB	nuclear factor-κB
NSAIDs	non-steroidal anti-inflammatory drugs
PG	Prostaglandin
TPA	12-*O*-tetradecanoylphorbol 13-acetate TUNEL, terminal deoxynucleotidyl transferase-mediated dUTP nick end labeling

Conflict of Interest

No potential conflicts of interest were disclosed.

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