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Article

Correlation of Lignan Contents with Protein and Oil Contents in the Seeds of *Sesamum indicum* L.

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The contents of lignan, protein, and oil of nine *Sesamum indicum* cultivars were analyzed. To determine the lignan contents, sesamin 1 and sesamolin 2 were isolated from the ethylacetate extracts of the Suwon cultivar, and the structures were fully characterized by spectral and physical methods. The seeds of nine cultivars were screened for two lignans, which were determined by HPLC using a C_{18} reversed phase column coupled with a photodiode array detector. Suwon cultivar showed the highest concentration (1: 6.24±0.04 and 2: 3.58±0.01 mg/g), whereas Soonheuk displayed the lowest (1: 0.91±0.01 and 2: 0.73±0.01 mg/g). The average content ratio of sesamin 1 (3.64 mg/g) was significantly higher than that of sesamolin 2 (2.57 mg/g). The protein content ranged from 21.52±0.35 to 31.22±0.25%, Suwon containing the highest level and Soonheuk had the lowest. Kwangbaek showed the highest oil level (49.84±0.40%), while Soonheuk exhibited the lowest (42.52±0.05%). Sesamin 1 exhibited a stronger radical-scavenging activity in the ABTS (IC_{50}: 63.2±2.4 μM) than its DPPH radical-scavenging activity (IC_{50}>200 μM). These results lead to the conclusion that lignan content is affected by protein and oil contents. Concentration of the chemical components in the cultivars could be a key factor in the selection process of a high quality species.

Key words : *ABTS, antioxidant, cultivar, lignan, oil, protein,* S. indicum, *seed*

Sesamum indicum L (Sesame) belonging to the Pedaliaceae family has been categorized as one of the traditional health foods [Sugano *et al.*, 1993]. In Korea and other Asian countries, the sesame is considered to be the most important oil seed crop due to its high oil content as well as its medicinal effects and resistance to the oxidative deterioration [Hu *et al.*, 2004; Kang *et al.*, 2000]. Several studies have well demonstrated that lignans in the sesame are responsible for various physiological activities including antioxidative [Yamashita *et al.*, 2000], anticarcinogenenic [Hirose *et al.*, 1992], blood pressure-lowering [Matsumura *et al.*, 1998], serum lipid-lowering [Hirata *et al.*, 1996; Hirose *et al.*, 1991; Ashakumary *et al.*, 1999], anti-inflammatory [Hsu *et al.*, 2000], and estrogenic [Wu *et al.*, 2006] activities. The sesame protein and oil are also important nutritional sources [Abou-Gharbia *et al.*, 1997]. In particular, the sesame oil is fast becoming popular due to its low cholesterol level and its ability to reduce the incidences of hypertension and certain cancers [Lemcke-Norojarvi *et al.*, 2001; Hibasami *et al.*, 2000].

Antioxidants such as flavonoids, tannins, coumarins, xanthones, and phenolics are found in various plant products [Larson RA, 1988]. For this reason, there is a growing interest in the extraction of these plant antioxidants for use as natural antioxidants. The ABTS

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Abbreviations: ABTS, 2,2'-azino-*bis*-(3-ethylbenzthiazoline-6-sulfonic acid); BHA, butylated hydroxyl anisol; HPLC, high-performance liquid chromatography; NIRS, near-infrared reflectance spectroscopy; TFA, trifluoro acetic acid; Trolox, 6-hydroxy-2,5,7,8-tetrame-thylchroman-2-carboxylic acid

and DPPH systems have both been commonly used to measure the total antioxidative status of various biological specimens due to their good reproducibility and easy quality control [Brand-williams *et al.*, 1995; Re *et al.*, 1999]. Although many secondary metabolites from the sesame exhibit antioxidant activities [Osawa *et al.*, 1985; Fukuda *et al.*, 1985], these activities have not yet been evaluated clearly through the ABTS and DPPH radical systems, which is of great importance to the enhancement of the value of sesame not only as a functional material but also as a dietary supplement. In spite of the many reports published on the sesame [Wu *et al.*, 2007; Were *et al.*, 2006; Elleuch *et al.*, 2007], studies on the exact characterization of the composition and contents of lignans, protein, and oil from different sesame cultivars are limited. The objective of current study was to determine the contents of lignan, protein, and oil from sesame seeds to provide the basic information on their compositional components for the development of high quality sesame cultivars.

In this study, we isolated two lignans **1** and **2** from Suwon one of the *S. indicum* cultivars, and their structures were identified using 2D-NMR together with other spectroscopic data. The contents of the lignans **1** and **2** obtained from nine Korean sesame cultivars were determined by HPLC using a C_{18} reversed phase column. We also investigated the primary constituents such as protein and oil concentrations as well as demonstrated the selective ABTS radical-scavenging activity compared to the DPPH radical of sesamolin **2**.

Materials and Methods

Plant material. The seeds of nine sesame (*S. indicum*) cultivars were collected on September 10, 2005 at the experimental field of Yeongnam Agricultural Research Institute, Miryang, Korea, and air-dried in the shade for 7 days. The collected seeds were stored at 4°C until use.

Reagents. 2,2'-Azino-*bis*-(3-ethylbenzthia-zoline-6-sulfonic acid) (ABTS), 1,1-diphenyl-2-picrylhydrazyl (DPPH), 6-hydroxy-2,5,7,8-tetrame-thylchroman-2-carboxylic acid (Trolox), sodium presulfate, and butylated hydroxyl anisol (BHA) were purchased from Sigma (St. Louis, MO). HPLC-grade water (99.9% v/v) and methanol (99.9% v/v) were from Merck (Darmstadt, Germany). Trifluoroacetic acid (TFA, 99.8% v/v) was purchased from Sigma. All reagents used in the experiments were of analytical grade.

Instruments. The purities of the two lignans were monitored by TLC (Merck), using the commercially available glass-backed plates and visualized under UV or sprayed with 10% H_2SO_4 solution. The column chromatography was carried out using a 230-400 mesh silica gel (kieselgel 60, Merck). The melting points were measured on a Thomas Scientific capillary melting point apparatus (Electrothermal 9300, Essex, London, UK) and are uncorrected. The IR spectra were recorded on a Bruker IFS66 (Bruker, Karlsruhe, Germany) infrared Fourier transform spectrophotometer (KBr), and the UV spectra were measured on a Beckman DU650 spectrophotometer (Beckman Coulter, Fullerton, CA). ^1H, ^{13}C, and 2D NMR data were obtained on a Bruker AM 500 (^1H NMR at 500 MHz, ^{13}C NMR at 125 MHz) spectrometer (Bruker) in $CDCl_3$. The mass spectrometer was a Bruker Daltonick GmbH (Bruker) equipped with an electrospray ionization (ESI) source and an ion trap mass analyzer. The chromatographic separation was achieved using an Agilent 1100 liquid chromatograph (Agilent Technologies, Palo Alto, CA) equipped with a quaternary HPLC pump, a vacuum degasser, an autosampler, and a wavelength UV detector. Analysis of the isolated lignans was carried out using the reverse phase separation on a C_{18} column [LichroCART 125-4 HPLC-Cartridge (Lichrophore 100 RP-18e) (Merck)]. The NIR spectroscopic data were collected using a Foss NIRSystems spectrophotometer (model 6500, NIRSystem Inc., Silver Spring, MD) and the oil contents were determined using a BÜCHI B-811 Extraction System (Büchi, Schweiz, Germany).

Extraction and isolation. To evaluate the contents of the lignans, lignans **1** and **2** were isolated from the seeds of *S. indicum* (Suwon cultivar) using several silica gel column chromatography methods. The dried seeds of *S. indicum* (2.5 kg) were ground and extracted twice with EtOAc (5L×2) for 7 days at room temperature. The combined extracts were concentrated *in vacuo* to yield a brown gum (85.5 g), and the residue was sequentially partitioned with *n*-hexane (38.2 g), EtOAc (21.7 g), and MeOH (26.0 g). The EtOAc fraction was chromatographed on a silica gel (6×50 cm, 230-400 mesh, 420 g) using *n*-hexane/EtOAc (16 : 1→1 : 2) to give five fractions (A-E). Fraction C (3.8 g) was applied to a silica gel column (4.5 ×50 cm, 230-400 mesh, 110 g) chromatography with *n*-hexane/EtOAc (12 : 1→2 : 1) to afford 28 subfractions, among which subfractions 20-24 (0.8 g) were subjected to the silica gel column (2.5×40 cm, 230-400 mesh, 80 g) chromatography with hexane/acetone (10 : 1→4 : 1) to yield compound **2** (240 mg). Fraction D (4.9 g) was chromatographed over a silica gel as a stationary phase using *n*-hexane/EtOAc (12 : 1→1 : 2) as the mobile phase to afford 15 subfractions (1-15). Compound **1** (365 mg) was purified from the subfractions 8-12 by recrystallization in the *n*-hexane/acetone mixture (3 : 1).

HPLC apparatus and measurements. The pulverized seeds of *S. indicum* (1.0 g) were extracted with 20 mL

MeOH using a vortex mixer for 6 h at room temperature, followed by centrifugation at 3,000 rpm for 5 min (VS-6000CFN, VISION, Seoul, Korea). The extracts used for HPLC analysis were passed through 0.45-μm filters (Millipore, MSI, Westboro, MA) before injection into a reverse phase LichroCART 125-4 HPLC-Cartridge (Lichrophore 100 RP-18e, φ 5 μm) (Merck), and 20 μL each of these solutions were injected into the HPLC system. The column temperature was set at 30°C, and the flow rate was set at 0.8 mL/min with isocratic elution, using 60% methanol-0.1% TFA with monitoring at 290 nm.

Preparation of calibration curve from isolated lignans 1 and 2. Approximately 2 mg each of the isolated lignans **1** and **2** were weighed and dissolved in a 10-mL volumetric flask containing MeOH to obtain the stock solutions. Each stock solution was diluted sequentially with 100, 80, 60, 40, 20, 10, and 5 μg/mL MeOH. All stock solutions were stored at 4°C and brought to room temperature before use. Mean areas (n=3) generated from the standard solution were plotted the concentrations to establish the calibration equation. A high linearity (r^2> 0.999) was obtained for each calibration curve. The two lignans were identified based on their retention times or by co-chromatography with other authentic examples, and their concentrations were calculated by comparing the peak areas of the samples with those of the standards.

Protein and oil analyses. The seeds of *S. indicum* cultivars were finely ground using a coffee grinder (PHILIPS, HR2860, Amsterdam, Netherlands). The protein content was determined according to the data from the near-infrared reflectance spectroscopy (NIRS) [Kim *et al.*, 2006]. The NIR data were collected in the range of 400 to 2500 nm at 2-nm intervals using a Foss NIRSystems spectrophotometer (model 6500, NIRSystem Inc., Silver Spring, MD) and stored as the reciprocal logarithm (log 1/R) of the reflected energy. All statistics, regressions, and predictions were performed using the WINISI software (version 1.05) from Foss NIRSystem. Coefficient of determination (r^2) and standard errors of calibration (SEC) were used to evaluate how well the calibration of the sample or multiple linear regressions fits the data. The oil content was measured by the Soxhlet method using the Buchi B-811 extracted system [Kim *et al.*, 2006]. Two grams of the pulverized seed was added to 200 mL of *n*-hexane in an extraction thimble and boiled for 2 h at 105°C. After cooling to room temperature in a desiccator, the extracted oil was weighted. Total oil contents were determined on a dry matter basis of the seeds.

Measurement of Trolox equivalent antioxidant capacity (TEAC). TEAC assay is based on the relative ability of the antioxidants to scavenge the radical cation $ABTS^{\cdot+}$ in comparison to a standard (Trolox) [Re *et al.*, 1999; Choi *et al.*, 2005]. The radical cation was prepared by mixing 7 mM ABTS stock solution with 2.45 mM potassium persulfate. The reaction mixture was maintained for 4-8 h until completely mixed and the absorbance stable. The $ABTS^{\cdot+}$ solution was diluted with ethanol, and the absorbance was read at 734 nm. For the photometric assay 0.9 mL $ABTS^{\cdot+}$ solution and 0.1 mL isolated compounds were mixed for 45 s, and the absorbance was measured immediately after 1 min at 734 nm. The antioxidant activities of the isolated compounds were calculated by determining the decrease in absorbance at different concentrations using the following equation: E= Ao-Ae/Ao×100, where Ae and Ao are absorbances of the samples with and without isolated compounds, respectively. The antioxidant activity was expressed as a TEAC value, which expresses the μM of Trolox having the antioxidant capacity corresponding to 1.0 μM of the test substance.

Measurement of DPPH radical-scavenging activity. The antioxidant activities of the isolated compounds were measured on the basis of the scavenging activity of the stable DPPH free radical following the method described by Braca *et al.* [2001]. Various concentrations of the isolated compounds were added to EtOH to form a 0.15 mM mixture which was then shaken vigorously. The absorbance at 517 nm was determined after 30 min, and the radical-scavenging effect was calculated as Ao-Ae/Ao×100, where Ae and Ao were the absorbances of the samples with and without the isolated compounds, respectively.

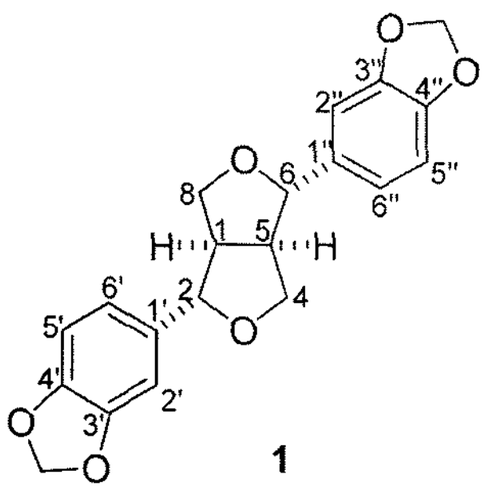
Data analysis and curve fitting. Each assay was conducted separately in triplicate. The data analysis was performed using the Sigma Plot 2001. The inhibitory concentration leading to 50% activity loss (IC_{50}) was obtained by fitting the experimental data to the logistic curve using the following equation [Coperland, 2000].

$$\text{Inhibition (\%)} = 100[1/(1+(IC_{50}/[I]))]$$

Results and Discussions

Identification of the isolated compounds. Through various chromatographic purifications of EtOAc fraction, two compounds **1** and **2** were isolated and analyzed using the physical and the spectral data to determine their structures (Fig. 1).

Compound 1: amorphous white powder; mp 122-123°C; IR (KBr) ν_{max} 2849, 1510, 1445, 1246 ,1035 cm^{-1}; $[\alpha]_D^{20}$ +65.0 (*c* 0.9, $CHCl_3$); UV λ_{max} 290, 210 nm ($CHCl_3$); ^1H NMR (500 MHz, $CDCl_3$) δ 3.07 (2H, m, H-1 and H-5), 3.90 (2H, dd, *J*=3.7, 9.2 Hz, H-4α and H-8α), 4.26



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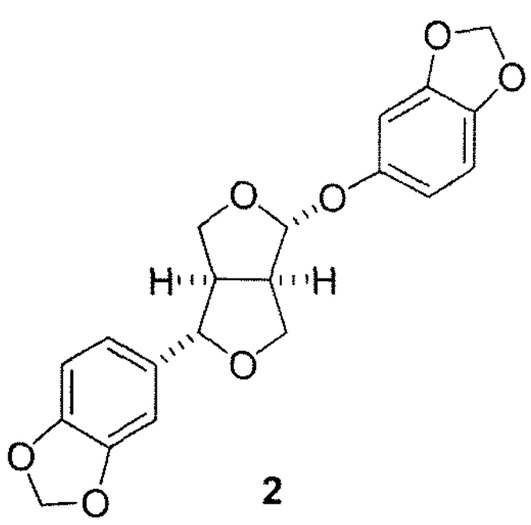

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Fig. 1. Chemical structures of the isolated compounds 1 and 2 from seeds of *S. indicum*.

(2H, dd, *J*=6.9, 9.1 Hz, H-4β and H-8β), 4.75 (2H, d, *J*= 4.4 Hz, H-2 and H-6), 5.97 (4H, s, 2×-OCH_2O-), 6.79-6.88 (4H, m, H-5, H-6, H-5', and H-6'), and 7.29 (2H, s, H-2' and H-2''). ^{13}C NMR (125 MHz, $CDCl_3$): see Table 1.

Compound 2: amorphous white powder; mp 90-90°C; IR (KBr) ν_{max} 2860, 1510 cm^{-1}; $[\alpha]_D^{20}$ -198.0 (*c* 0.5, $CHCl_3$); UV λ_{max} 290, 280, 210 nm ($CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 2.98 (1H, dd, *J*=1.3, 9.2 Hz, H-1), 3.33 (1H, d, *J*=7.6 Hz, H-5), 3.67 (1H, dd, *J*=7.4, 9.2 Hz, H-4α), 4.00 (1H, d, *J*=9.1 Hz, H-8α), 4.17 (1H, dd, *J*= 6.0, 9.2 Hz, H-8β), 4.44 (1H, d, *J*=6.8 Hz, H-2), 4.47 (1H, d, *J*=8.8 Hz, H-4β), 5.53 (1H, s, H-2'), 5.97 (2H, s, 4' and 5'-OCH_2O), 5.98 (2H, s, 4'', 5''-OCH_2O), 6.54 (1H, dd, *J*=2.4, 8.4 Hz, H-6'), 6.66 (1H, d, *J*=2.4 Hz, H-6), 6.74 (1H, d, *J*=8.4 Hz, H-5''), 6.82 (1H, d, *J*=7.9 Hz, H-5'), 6.89 (1H, m, H-6''), and 6.90 (1H, s, H-2''). ^{13}C NMR (125 MHz, $CDCl_3$): see Table 1.

Compound **1** was obtained as an amorphous white powder and in the LC-MS, the molecular ion peak $[M+Na]^+$ showed at *m/z* 377. The UV spectrum analysis showed an absorption maximum at 290 nm and IR spectrum analysis showed strong absorption bands for CO (1035 cm^{-1}). The ^{1}H NMR spectrum of compound **1** showed the presence of methylene dioxy groups at d 5.97 (4H, s, 2×-OCH_2O-), furanofuran moieties [δ 3.07 (2H, H-1 and H-5), 4.75 (2 H, H-2 and H-6), 3.90 (2H, H-4α and H-8α), and 4.26 (2H, H-4β and H-8β)], and six aromatic protons [δ 6.79-6.88 (4H, H-5, H-6, H-5', and H-6') and 7.29 (2H, H-2' and H-2'')]. The H-1 appeared as a multiplet due to the couplings with H-8α, H-8β, H-5, and H-2, whereas H-5 appeared as a multiplet due to the couplings with H-4α, H-4β, H-1, and H-6, as confirmed by the ^{1}H-^{1}H COSY spectrum. The HMBC spectrum showed coupling between H-6''/H-2'' and C-6 as well as between the methylene dioxy group protons (δ 5.97) and C-4'' (δ 147.5), confirming the presence of the methylene dioxy group protons on this aromatic ring. On the other aromatic ring of the molecule, the HMBC spectrum showed the coupling between H-6'/H-2' and C-2. On the basis of these spectral data and careful analysis of the HMQC and HMBC data, the compound **1** was identified as a sesamin, one of the lignans [Kim *et al.*, 2006]. Compound **2** was obtained as an amorphous white powder, and in the LC-MS, the molecular ion peak $[M+Na]^+$ showed up at *m/z* 393. The UV spectrum showed an absorption maximum at 290 nm. The ^{1}H NMR spectrum of **1** exhibited two methylene dioxy group protons (δ 5.97, s and 5.98, s), six aromatic protons [(δ 6.54, H-2'), (δ 5.53, H-6'), (δ 6.74, H-5''), (δ 6.82, H-3'), (δ 6.89, H-6''), and (δ 6.90, H-2'')], and eight furanofuran protons [(δ 2.98, H-1), (δ 3.33, H-5), (δ 3.67, H-4α), (δ 4.00, H-8α), (δ 4.17, H-8β), (δ 4.44, H-2), (δ 4.47, H-4β), and (δ 6.66, H-6)]. The ^{13}C NMR spectrum of **2** showed two methylene

Table 1. ^{13}C NMR of compounds 1 and 2 at 125 MHz (ppm, m)[a]

Position	Compound	
	1	**2**
1	54.8 (d)	53.1 (d)
2	86.2 (d)	87.5 (d)
4	72.1 (t)	71.7 (t)
5	54.8 (d)	53.7 (d)
6	86.2 (d)	100.6 (d)
8	72.1 (t)	70.3 (t)
1'	135.5 (s)	134.9 (s)
2'	107.0 (d)	107.4 (d)
3'	148.4 (d)	152.3 (d)
4'	147.5 (s)	148.5 (s)
5'	108.6 (s)	108.6 (s)
6'	119.7 (d)	109.5 (d)
1''	135.5 (s)	143.1 (s)
2''	107.0 (d)	107.0 (d)
3''	148.4 (s)	148.6 (s)
4''	147.5 (s)	147.8 (s)
5''	108.6 (d)	108.4 (d)
6''	119.7 (d)	120.1 (d)
2×-OCH_2O-	101.5 (t)	
3',4'-OCH_2O-		101.5 (t)
3'', 4''-OCH_2O-		101.7 (t)

[a]The chemical shifts of compounds **1** and **2** were determined in $CDCl_3$

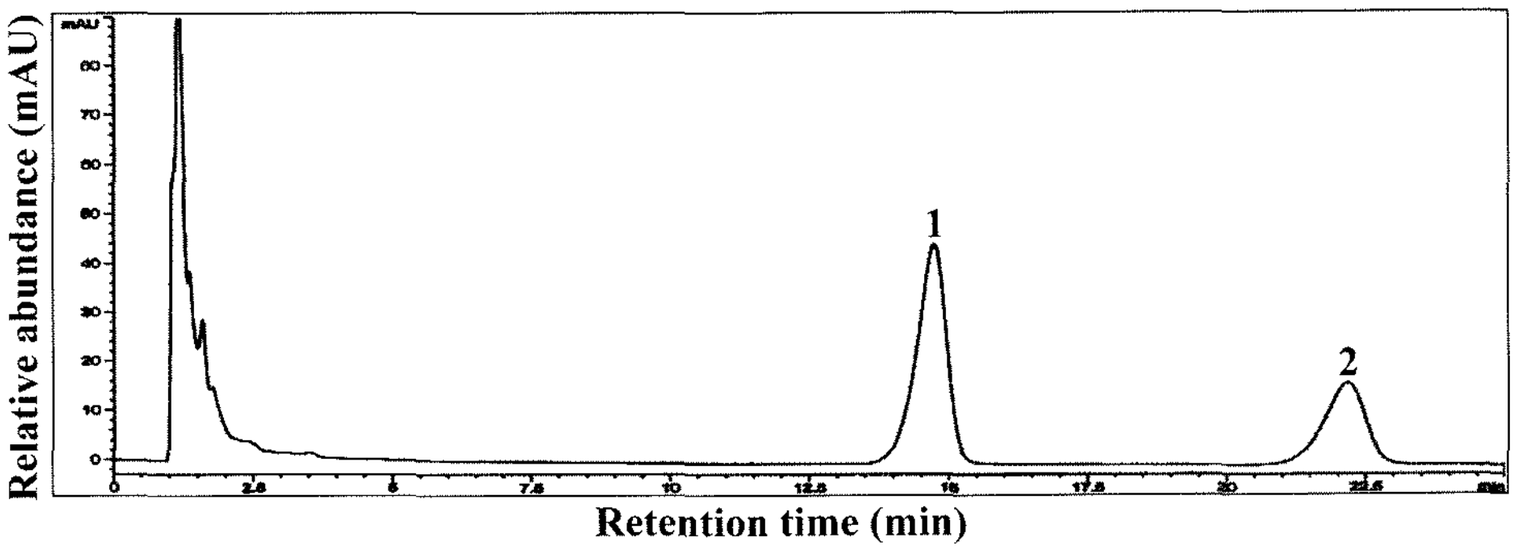

Fig. 2. HPLC chromatogram of the compounds isolated from the seeds of *S. indicum*.

dioxy group carbons (δ 101.5 and 101.7), six aromatic carbons [(δ 107.4, C-2'), (δ 108.6, C-5'), (δ 109.5, C-6'), (δ 107.0, C-2"), (δ 108.4, C-5"), and (δ 120.1, C-6")], and six furanofuran moieties carbons [(δ 53.1, C-1), (δ 87.5, C-2), (δ 71.7, C-4), (δ 53.7, C-5), (δ 100.6, C-6), and (δ 70.3, C-8)]. The HMBC spectrum displayed ^{1}H-^{13}C long-range coupling from C-1' to H-1, H-2, H-2', H-3', H-5', and H-6', from C-1" to H-6 and H-6". Thus, these assignments and analysis of the HMBC spectra allowed the unequivocal assignment of all carbons. All data mentioned above indicated that the structure of compound **2** is sesamolin [Kato *et al.*, 1998].

Lignan analysis of the seeds of sesame cultivars. On the basis of the isolated lignans **1** and **2** (authentic compounds), a typical HPLC chromatogram of the lignans from the seeds of sesame was obtained (Fig. 2). The retention times were as follows: compound **1** (sesamin: t_R=14.7 min) and compound **2** (sesamolin: t_R= 22.1 min).

The concentrations of compounds **1** and **2** were determined on the basis of the peak areas in the chromatogram as follows: **1**, y=28.66x−7.00, r^2=0.999 and **2**, y=18.92x−1.36, r^2=0.999. The contents of the two lignans of the nine sesame cultivars grown in Milyang are shown in Table 2. Significant differences were observed in the lignan contents among the cultivars. The highest total lignan content was observed in the Suwon cultivar at 9.82 mg/g (**1**: 6.24 and **2**: 3.58 mg/g) and the lowest was 1.64 mg/g (**1**: 0.91 and **2**: 0.73 mg/g) found in the Soonheuk cultivar. The content of compound **1** ranged from 0.91± 0.01 to 6.24±0.04 mg/g and that of compound **2** ranged from 0.73±0.01 to 3.58±0.01 mg/g (Table 2). In all nine Korean cultivars examined, the average content of compound **1** (3.64 mg/g) was significantly higher than that of compound **2** (2.57 mg/g).

The HPLC chromatograms of the isolated lignans **1** and **2** in the nine sesame cultivars are shown in Fig. 4A-4C.

The lignans **1** and **2** were found only in low amounts from Konheuk and Soonheuk cultivars, whereas Seodun, Namam, and Suwon cultivars, which have used as the standard cultivars for sesame breeding, showed 2-3 times higher lignan contents than those of the other cultivars (Fig 3, Table 2). These results demonstrate that Seodun, Namam, and Suwon cultivars are suitable for use as standard cultivars for the development of high quality sesame seeds.

Table 2. Contents of compounds 1 and 2 from the seeds of *S. indicum* cultivars

Cultivar	Contents of two compounds (mg/g)[a]	
	Compound **1** (Sesamin)	Compound **2** (Sesamolin)
Seodun	4.16±0.03	3.24±0.02
Konheuk	1.64±0.02	1.26±0.01
Doobul	3.40±0.03	2.12±0.02
Jinbaek	3.99±0.04	3.49±0.04
Namsan	4.08±0.03	2.70±0.04
Naman	4.40±0.02	3.53±0.03
Soonheuk	0.91±0.01	0.73±0.01
Suwon	6.24±0.04	3.58±0.01
Kwangbaek	3.97±0.03	2.48±0.02

[a]Values indicate the means of three replications.

Analysis of protein and oil in sesame cultivars. Protein and oil are also important nutritional sources found in the sesames [Abou-Gharbia *et al.*, 1997]. Contents of these components are shown in Table 3. The highest and the lowest protein content, determined according to the NIRS procedure were respectively found in Suwon cultivar (31.22±0.25%) and Soonheuk cultivar (21.52±0.35%). The protein contents of Konheuk (23.13 ±0.54%) and Soonheuk (21.52±0.35%) cultivars were lower than the average content of the total cultivars (28.46%), while those of the other seven cultivars were higher than the total average. The oil content was measured by a Soxhlet method. Kwangbaek cultivar exhibited the highest content (49.84±0.40%), whereas that of Soonheuk cultivar was the lowest (42.52±0.05%). The average oil

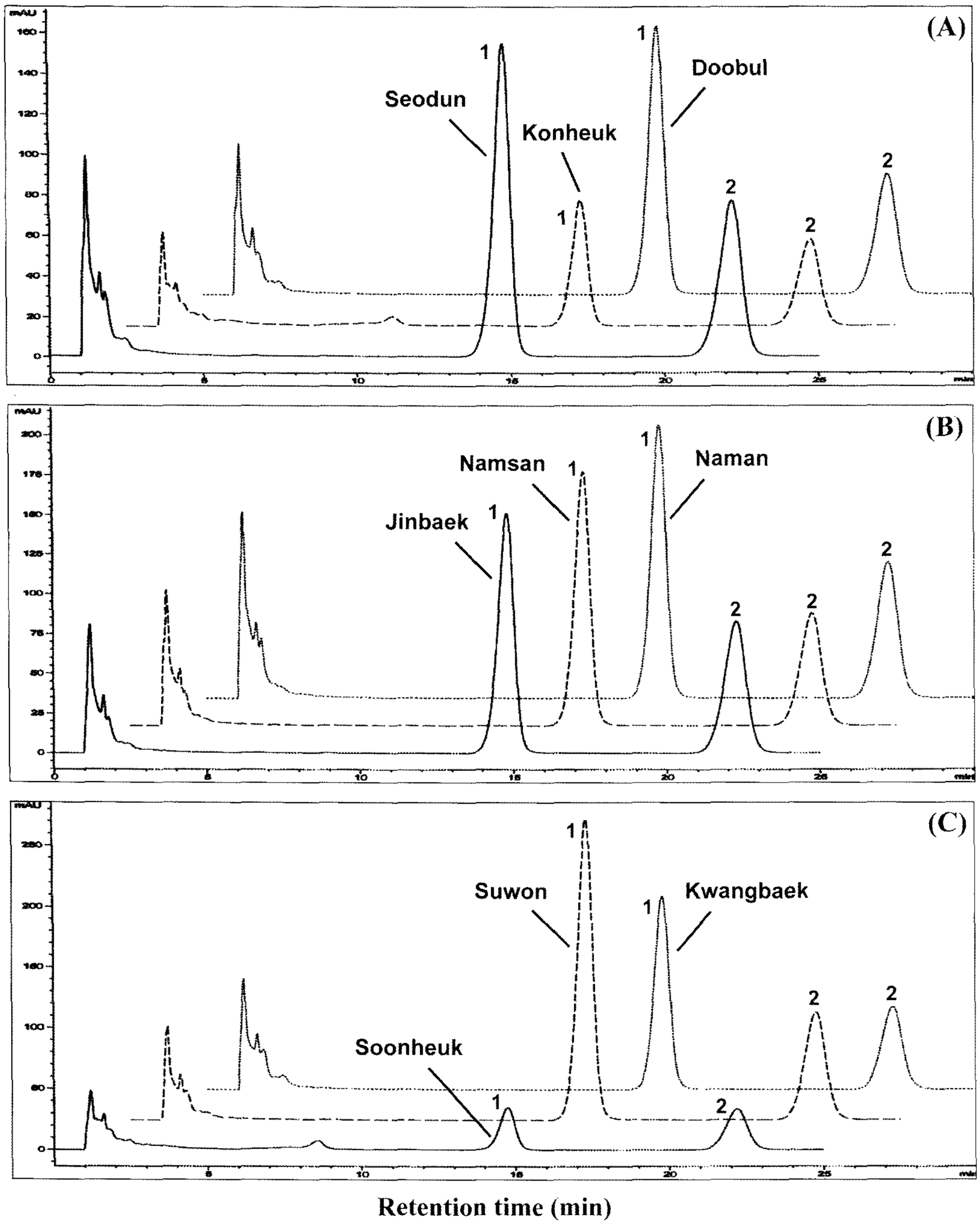

Fig. 3. HPLC chromatogram of 60% methanol-0.1% TFA extracts from the seeds of nine *S. indicum* cultivars. (A) Seodun, Konheuk, and Doobul cultivars, (B) Jinbaek, Namsan, and Naman cultivars, (C) Soonheuk, Suwon, and Kwangbaek cultivars.

content of the nine Korean sesame seeds was 46.32% (Table 3).

The protein and oil contents of the sesame seeds showed moderate positive correlations (Suwon cultivar) (Table 3). Moreover, the lignan and protein contents of Seodun, Jinbaek, Naman, and Suwon cultivars also showed significant positive correlations (Tables 2 and 3).

ABTS and DPPH radical-scavenging activities of isolated compounds 1 and 2. The systems ABTS and DPPH are both commonly used to measure the total antioxidant status of various biological specimens due to their reproducibility and ease of quality control [Re *et al.*, 1999; Choi *et al.*, 2005; Braca *et al.*, 2001]. Moreover, the ABTS and DPPH radical-scavenging activities of the isolated compounds **1** and **2** have not yet been elucidated clearly. Therefore, the ABTS and DPPH radicals were chosen to evaluate the antioxidant activities of the isolated compounds. The change in the absorbance produced by the reduced DPPH was used to evaluate the abilities of the isolated compounds **1** and **2** to act as free radical

Table 3. Contents of protein and oil from the seeds of *S. indicum* cultivars

Cultivar	Contents of protein and oil	
	Protein (%)[a]	Oil (%)[a]
Seodun	30.37±0.95	46.44±0.51
Konheuk	23.13±0.54	43.08±0.10
Doobul	29.87±0.07	46.23±0.41
Jinbaek	31.19±0.28	46.17±0.49
Namsan	28.82±0.41	48.64±0.45
Naman	30.99±0.53	46.63±0.42
Soonheuk	21.52±0.35	42.52±0.05
Suwon	31.22±0.25	47.35±0.14
Kwangbaek	29.04±0.40	49.84±0.40

[a]Values indicate the means of three replications.

Table 4. Antioxidant activities of isolated compounds 1 and 2 on ABTS and DPPH radicals

Compound	IC_{50} (μM)[a]	
	ABTS	DPPH
1	23.3%[b]	>200
2	63.2±2.4[a]	>200
BHA/Trolox	19.4±1.3[a] (Trolox)	35.4±2.2[a] (BHA)

[a]Inhibitory activity was expressed as the mean of 50% inhibitory concentration of triplicate determinations.
[b]Percentage at 100 μM.

scavengers. At 200 μM, compounds **1** and **2** showed less than 10% scavenging activities (Table 4). The ABTS radical-scavenging activity was measured immediately after the addition of potassium persulfate to an ABTS solution. Compound **2** suppressed the absorbance of the ABTS radicals with an IC_{50} value of 63.2±2.4 μM and, when Trolox was used as a positive control, exhibited IC_{50} value of 19.4±1.3 μM. The scavenging activity of compound **2** against ABTS was higher than the DPPH radical-scavenging activity (Table 4). On the other hand, the scavenging activity of compound **1** against ABTS was 23.3% at 100 μM.

This study reports the compositional components including lignans, protein, and oil found in the Korean sesame cultivars. Two lignans **1** and **2** were isolated from the ethylacetate extract of Suwon cultivar and characterized using the physical and spectroscopic data. The seeds of nine sesame cultivars were screened for the two lignans. Suwon cultivar showed the highest concentration (**1**: 6.24 ±0.04 and **2**: 3.58±0.01 mg/g), while Soonheuk cultivar had the lowest (**1**: 0.91±0.01 and **2**: 0.73±0.01 mg/g). Suwon and Soonheuk cultivars respectively showed the highest and the lowest protein contents. In the oil content, Kwangbaek and Soonheuk respectively showed the highest (49.84±0.40%) and the lowest (42.52±0.05%) contents. Moreover, compound **1** exhibited a strong radical-scavenging activity against the ABTS (IC_{50}: 63.2 ±2.4 μM). After further processing for use as food ingredients, the Korean sesame cultivars may contribute to the enhancement of the human health. In addition, the evaluation of sesame quality in breeding aspect could be important in increasing the value of the functional materials. The relationships between lignans as the quality factors and the protein and oil contents will become increasingly important in improving the quality of the sesame seeds.

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