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Evaluation of Chemical Properties of White Sesame Produced from Different Origin

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산지가 다른 참깨의 이화학적 특성 평가

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Abstract

중국, 수단, 인도 및 파키스탄에서 생산된 참깨(각 10종)의 조지방 함량, 지방산 조성, 세사민, 세사몰린 및 세사미놀 배당체 함량을 측정하여 품질 특성을 평가하였다. 참깨의 조지방 함량은 파키스탄산 42.47 %, 중국산 38.95%, 인도산 34.96% 및 수단산 33.93%로 파키스탄산이 가장 높았으나 지역간에는 유의적인 차이가 나타나지 않았다. 세사민 함량은 중국산 634.75 mg/100 g seed, 수단산 630.66 mg/100 g seed, 인도산 381.55 mg/100 g seed 및 파키스탄산 401.00 mg/100 g seed으로 중국산이 유의적으로 높게 나타났다. 세사몰린 함량은 중국산 218.99 mg/100 g seed, 수단산 234.49 mg/100 g seed, 인도산 (185.64 mg/100 g seed) 및 파키스탄산 (127.04 mg/100 g seed)으로 지역간에 유의적인 차이가 있는 것으로 나타났다. 세사미놀 배당체 함량은 중국산 321.40 mg/100 g seed, 수단산 218.99 mg/100 g seed, 인도산 505.04 mg/100 g seed 및 파키스탄산 342.87 mg/100 g seed로 인도산이 가장 높은 함량이었다. 참깨 핵산 추출물의 전자공여능을 측정한 결과 인도산의 전자공여능이 유의적으로 높았고 파키스탄산 및 중국산순 이었다. 이상의 결과 지역별 참깨 품질 특성에는 유의적인 차이가 있었고 특히 최근에 기능성 성분으로 관심이 집중되고 있는 세사민과 세사몰린 및 세사미놀 배당체는 지역에 따라 현저한 차이가 있는 것으로 나타났다.

Key words : Lignan, sesamin, sesamolin, sesaminol-triglucoside, white sesame.

Introduction

Sesame is well known as a nutritious food that contains lipid (50%), protein(20%), and carbohydrate(15%), minerals (calcium, phosphorus and zinc) and vitamins (B_1 and B_2). In its composition of fatty acids, sesame is also rich in unsaturated fatty acids such as oleic acid and linoleic acid. Interests on physiological functions of sesame have been increasing due to abundance of unsaturated fatty acids in sesame(Hafidi et al 2000). It was suggested that the reason why sesame oil shows high stability against oxidation for long-term storage at high temperature is that it contains a large percentage of antioxidants such as sesamin, sesamolin, and sesaminol (Fukuda et al 1985, Kang et al 1998).

According to research findings and reports, some antioxidants are produced in the process in which methylenedioxyphenyl compounds are changed into dihydrophenyl compounds during metabolism in the body and they work to protect the body by exerting a potent antioxidant effect in the body(Nakai et al 2003).

In this study, likewise, sesamolin showed a limited antioxidant effect *in vitro*. When oxidative stress was measured after the feeding of rats with sesamolin, however, the result proved sesamolin to be powerful in its antioxidant effect. Also, sesamolin contributed to promoting metabolism by conjugation with the glucuronic acid and sulfuric acid. It was reported that sesaminol-triglucoside functions to inhibit the absorption of cholesterol into the intestines of rabbits with sclerosis of the arteries induced by high cholesterol diet, and accordingly has an effect of enhancing blood alcohol concentration (Kang et al 2000a). Furthermore, since the report that sesaminol, one of lignan compounds contained in sesame, strongly inhibits the oxidation of low-density lipoprotein(LDL) even in low concentration, there has been a growing interest in antioxidants contained in sesame(Sirato-Yasumoto et al 2001).

Reflecting such high interest in sesame, especially as an ingredient for functional food, many studies are being con-

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ducted for the development of sesame containing a higher ratio of antioxidants such as sesamin and sesamolin.

Considering the recent global trend towards free trade of agricultural products, it is unavoidable to import them from other countries. This trend is associated with the import of other products including oil(Gerald et al 1997), honey(Isabel et al 1997), and wine(Martin et al 1995). Most of those traded agricultural products, even if they are from the same species of plant or animal, may have different composition profile of substances because of the differences between the regions in climatic conditions and soil properties(Kang et al 2000b, Kim et al 2002). Actually, they show a significant difference in the content of specific substances.

The purpose of this study was to provide preliminary data for evaluation of sesame quality by analyzing the physico-chemical properties and lignan content of sesame imported from some countries producing sesame in large quantities.

Materials and Methods

1. Materials

Forty kinds of sesame seed white coat produced in 2001 were obtained from four countries of China, Sudan, India, and Pakistan through the Agricultural and Fishery Marketing Corporation(Seoul, Korea). They were kept in cold room before and during analysis.

2. Analysis of Crude Fat and Fatty Acid Compositions

The crude oil content was determined twice by comparing the weight of approximately 1 g seed samples before and after oil removal by Soxhlet extract with n-hexane(AOAC 1990). Fatty acid compositions were analyzed after methyl esterification with methanol, benzene and 2,2'-dimethoxy- prophan and n-heptan, and the compositions were measured using a gas chromatography(HP 5890, USA) (Kang et al 2000b). As a detector, FID(flame ionization detector) was used with SPTM 2330 capillary column (30 m×0.25 mm×0.2 μm film thickness). Nitrogen was used as carrier gas with a flow rate of 40 mL per minute, and the temperatures in the column and detector was maintained at 220℃ and 260℃, respectively. The following were purchased from Sigma(USA) and used as standards: palmitic acid methyl ester($C_{16:0}$), stearic acid methyl ester($C_{18:0}$), oleic acid methyl ester($C_{18:1}$), linoleic acid methyl ester($C_{18:2}$), arachidic acid methyl ester($C_{20:0}$), *cis*-11- eicosenoic acid methyl ester($C_{20:1}$), and linolenic acid methyl ester($C_{18:3}$).

3. Determination of Lignan

To determine the sesamin and sesamolin contents in lipid-soluble antioxidants, sesame was extracted with n-hexane. The sesaminol triglucoside in water-soluble antioxidants was extracted with 80% ethanol from defatted sesame dregs after removing lipid soluble antioxidants with n-hexane. Each of the resulting extracts was filtered and evaporated in a vacuum, and the precipitate was resuspended in 1 mL of methanol. The lignan content of extracts was analyzed by conducting a high-performance liquid chromatography(HPLC) under the conditions as shown in Table 1. It was calculated from responses of peak area using a standard curve prepared by HPLC chromatography of known amount of pure lignans including sesamin, sesamolin, and sesaminol-triglucoside and was calculated by linear regression (r^2=0.999).

4. Scavenging of 1,1-diphenyl-picrylhydrazyl(DPPH) radical

The electron-donating ability(EDA) of n-hexane extracts was assayed in the modification method of Blois MS (1958). Half milliliter of each solvent extract and DPPH solutions were vigorously vortexed and placed for 30 minutes in room temperature. And then the absorbance was measured at 517 nm. The electron-donating ability was calculated as follows:

$$EDA\ (\%) = [1 - (A_{Sample}/A_{Blank})\ ] \times 100$$

Where A_{Sample} and A_{Blank} are the absorbance values for the blank and extraction solution.

5. Statistical Analysis

All data are presented as mean±SD. The data was tested by

Table 1. HPLC condition for analysis of lignan compounds

Request	Condition
Instrument	Young - Rin Associate
Column	μ-bondapak C_{18} (3.9×300 mm, Waters
Mobie phase	MeOH : Water = 60 : 40 v/v
Detector	290 nm
Flow rate	1.0 mL/min

ANOVA, followed by Duncant's multiple range test to identify the significance of difference. All analyses were performed using StatView software version 4.51J (Abacus Concepts, Berkeley, CA). The level of α=0.05 was considered statistically significant.

Results and Discussion

1. Crude Fat Content

As shown in Table 2, the content of crude fat was the highest(42.47%) in Pakistani-produced sesame, followed in order by Chinese-produced(38.95%), Indian-produced(34.96%), and Sudanese-produced(33.93%); that is, there was no significant difference between the cultivating countries in the crude fat content. However, significant differences in the crude fat content were found between cultivating districts in each country; the content ranged from 25.71% to 46.31% for Chinese sesame, from 23.21% to 41.11% for Sudanese sesame, from 22.71% to 55.47% for Indian sesame, and from 24.19% to 65.86% for Pakistani sesame. Lee et al (1988) reported that the oil content of sesame showed a slight significant difference according to the countries of origin as 51.6% for Korean-cultivated sesame, 51.2% for Korean-native, 51.4% for Japanese, 50.7% for American, 50.8% for Italian, 50.6% for Indian, and 50.5% for Egyptian. When sesame oil was expressed immediately from sesame roasted at the temperature of 220°C, the amount of extracted oil was slightly higher in Sudanese-produced (53.70%) compared to those produced in Korea (52.10%) and China (50.48%) (Kang et al 2000c).

Table 2. Crude lipid contents of sesame from different origin

Origin	Crude lipid content (%)			CV[2](%)
	Maximum	Minimum	Mean±SD	
China	43.61	25.91	38.95±5.90[NS.1)]	15.15
Sudan	41.41	23.21	33.93±6.54	19.61
Indian	55.47	22.71	34.95±10.11	27.95
Pakistan	65.86	24.19	42.47±14.53	26.79

1) NS: Not significant at α=0.05.

2) CV: Coefficient of Variation.

2. Fatty Acids Composition

Sesame seeds produced in different countries were analyzed of their composition ratios of fatty acids(Table 3) As one of the main fatty acids contained in sesame seed, linoleic acid ($C_{18:2}$) was measured up to more than 40%, especially higher (49.57%) in Chinese-produced sesame. Unsaturated fatty acids of sesame were oleic acid ($C_{18:1}$) and linoleic acid($C_{18:2}$) in major while palmitic acid ($C_{16:0}$) and stearic acid ($C_{18:0}$) in minor. The content of unsaturated fatty acids was 85.9% in Chinese sesame, 85.07% in Sudanese sesame, 86.15% in Indian sesame, and 86.84% in Pakistani sesame. Kang et al (2000c) analyzed the composition of Korean-produced sesame with different seed coat colors. They reported that the content of unsaturated fatty

Table 3. Fatty acid compositions of sesame from different origin

Fatty-acid composition (%)	China	Sudan	India	Pakistan
$C_{16:0}$[1)]	8.83±1.39[9)]	8.30±1.36	8.05±1.39	7.86±1.10
$C_{18:0}$[2)]	4.21±0.68[b10)]	5.60±0.47[a]	4.645±0.49[b]	4.24±0.51[b]
$C_{18:1}$[3)]	36.42±1.06[c]	43.57±1.64[a]	38.81±1.60[b]	37.90±1.44[b]
$C_{18:2}$[4)]	49.57±2.29[a]	41.50±1.43[c]	47.34±2.62[b]	48.94±2.21[ab]
$C_{18:3}$[5)]	0.42±0.17[b]	0.77±0.29[a]	0.69±0.25[a]	0.60±0.23[ab]
$C_{20:1}$[6)]	0.48±0.11	0.24±0.20	0.35±0.10	0.32±0.15
$C_{20:4}$[7)]	0.21±0.13	0.12±0.12	0.22±0.14	0.17±0.19
USFA[8)]	87.10±1.66	86.20±1.53	87.41±2.11	87.93±1.83

1) Palmitic acid ($C_{16:0}$), 2) Stearic acid ($C_{18:0}$), 3) Oleic acid($C_{18:1n9c}$), 4) Linoleic acid($C_{18:2n6c}$),
5) Arachidic acid($C_{20:4}$), 6) *Cis*-11-eicosenoic acid($C_{20:1}$), 7) Linolenic acid($C_{18:3n3}$),
8) USFA: Unsaturated fatty acids($C_{18:1}$+ $C_{18:2}$+$C_{18:3}$+$C_{20:1}$+$C_{20:4}$)
9) Mean±SD.(n=10) of area percent (%) from GC chromatogram.
10) Different letters in the same row show statistically significant differences by Duncan's multiple range test at α=0.05.

acids was 88.88% in white sesame and 89.21% in black sesame, slightly higher than the results of this study. Lee et al (1991) reported that the contents of unsaturated fatty acids were 86.2% for Japanese sesame, 87.7% for American sesame, 85.5% for Italian sesame, and 85.5% for Egyptian sesame, which are similar to the results of this study.

As fatty acids with polyunsaturation have been recently known as increasing physiological activation in the body, more attention is being paid to functions of sesame oil(Lee et al 1992). For sunflower and safflower, new species that are more than 80% in the content of oleic acid are being cultivated. As sunflower and safflower oils containing oleic acid have been reported to have high oxidation stability and to serve to inhibit the absorption of neutral fats in the body, many studies of oil plants have been conducted for the purpose of enhancing their content of unsaturated fatty acids. Up to date, there have been reports that sunflower's content of fatty acids is different according to its growing districts' climatic conditions(何部芳郎 1998), while for sesame the climatic conditions have no significant influence on its composition of fatty acids(Lee et al 1992).

3. Sesamin Content

The content of sesamin, one of the main antioxidants contained in sesame, is shown in Table 4 with sesame producing countries. The average content of sesamin was 634.75 mg/100 g seed produced in Chinese, 540.65 mg/100 g seed produced in Sudan, 381.55 mg/100 g seed produced in India and 401.00 mg/100 g seed produced in Pakistan. The range of variation in the sesamin content was relatively narrow for Chinese sesame (from 555.36 mg/100 g seed to 702.82 mg/100 g seed), while Sudanese and Pakistani sesame showed a wide range of variation (from 512.68 mg/100 g seed to 800.02 mg/100 g seed and from 253.54 mg/100 g seed to 606.13 mg/100g seed, respectively). Sirato-Yasumoto et al(2001) observed the changes made in the liver tissue of white rats after giving them sesame with large quantities of sesamin and sesamolin. They reported that there was an increase in the activation of acyl Co-A oxidase, carnitine palmitoyltransferase, 3-hydroxyacyl- CoA dehydrogenase, and 2-ketoacyl-CoA thiolase and that the weakened activities of fatty acid synthetic enzymes reduced blood triacylglycerol concentration by increasing the liver tissue's oxidation of fatty acids. In addition, sesamin in the human body was proved to work against arterial sclerosis by lowering the blood value of LDL causing the disease (Hirata et al 1996). Akimoto et al (1993) reported that, when sesamin was provided to mice or rats whose liver was damaged by CCl_4, it prevented their liver damage from being further worsened. Sesamin has little antioxidant effect *in vitro*, but there have been reports that it exerts a high antioxidant effect *in vivo* as it is converted into a different matter in the process of metabolism in the intestines after its administration (Nakai et al 2003).

4. Sesamolin Content

The contents of sesamolin in sesame, one of the antioxidants are shown in Table 5. The average contents of sesamolin in Chinese and Sudanese sesame were 218.99 mg/100 g seed and 214.19 mg/100 g seed, respectively, which were significantly higher than those in Indian sesame (185.64 mg/100 g seed) and Pakistani sesame (127.04 mg/100 g seed). The range of variation in the sesamolin content was relatively low for the Chinese sesame (from 193.07 mg/100 g seed to 240.12 mg/100 g seed), but Sudanese and Pakistani sesame showed a wide

Table 4. Sesamin contents of sesame from different origin

Origin	Sesamin (mg/100g seed)			CV[1](%)
	Maximum	Minimum	Mean±SD	
China	702.82	555.36	634.74±54.99[a2)]	8.66
Sudan	472.08	612.25	540.65±48.02[b]	8.88
Indian	428.54	342.42	381.55±31.79[c]	8.33
Pakistan	606.13	253.54	401.00±118.90[c]	29.65

1) CV: Coefficient of Variation.

2) Different letters in the same column show statistically significant differences by Duncan's multiple range test at α=0.05.

Table 5. Sesamolin contents of sesame from different origin

Origin	Sesamolin (mg/100 g seed)			CV[1](%)
	Maximum	Minimum	Mean±SD	
China	240.12	193.07	218.99±16.27[a2)]	7.43
Sudan	253.63	176.38	214.19±22.21[a]	10.37
Indian	216.88	158.82	185.64±19.27[b]	10.38
Pakistan	154.75	87.65	127.04±22.11[c]	17.40

1) CV: Coefficient of Variation.

2) Different letters in the same column show statistically significant differences by Duncan's multiple range test at α=0.05.

range of variation (from 176.38 mg/100 g seed to 294.17 mg/100 g seed and from 87.65 mg/100 g seed to 154.75 mg/100 g seed, respectively).

Kang et al(2000b) reported the contents of sesamolin ranged widely from 37.20 mg/100 g seed to 434.82 mg/100 g in 104 kinds of Korean-produced sesame.

In the study by Shyu & Hwang(2002), the content of sesamolin in Burmese-produced black sesame was measured at 138 mg/100 g, similar to that of sesamolin in Pakistani-produced sesame. Ryu et al(1992) and Lee et al(1999) reported that the contents of sesamolin were 0.3% in *danbaek* sesame cultivated in 1991 and 0.35% in *danbaek* sesame cultivated in 1998.

Also, Tashiro et al(1990) reported that Japanese sesame species contained sesamolin of 332 mg/100 g seed. Kang et al (1998) analyzed sesamolin metabolites of white rats after feeding them with 1% sesamolin for two weeks and reported that about 70% of the metabolites were excreted with the feces and about the remaining 30% were absorbed in the body. It was suggested that the sesamolin metabolites absorbed in the body are carried to each of the tissued to exert antioxidant effect. However, the metabolites still remain unknown, and accordingly they have yet to be identified.

5. Sesaminol-triglucoside Content

Sesaminol-triglucoside, contained in the husk of sesames, recently began to attract much attention because of its ability to prevent arterial sclerosis (Kang et al 1999). Once sesaminol-triglucoside is taken in, it is hydrolyzed by intestine enzymes such as β-glucosidase and then converted into sesaminol of aglycone, before being carried to each of the tissues through the blood, ultimately exerting antioxidant effect(Osawa et al 1990). The contents of sesaminol-triglucoside are shown in Table 6. Indian-produced sesame showed the highest content of sesaminol-triglucoside(505.04 mg/100 g seed), followed in order by Pakistani sesame(342.87 mg/100 g seed), Chinese sesame(321.40 mg/100 g seed), and Sudanese sesame (218.99 mg/100 g seed). Large variation in the content of sesaminol-triglucoside was observed in all the groups of sesame-ranging from 246.36 mg/100 g seed to 398.69 mg/100 g seed for Chinese sesame, from 202.73 mg/100 g seed to 308.49 mg/100 g seed for Sudanese sesame, and from 87.65 mg/100 g seed to 154.75 mg/100 g seed for Pakistani sesame.

Shyu & Hwang(2002) recently reported that the average content of sesaminol-triglucoside in Burmese-produced black sesame was 221 mg/100 g seed, similar to that of in white sesame used in this study. Kang et al(1999), in their experiment, added 10% of sesame dregs containing 0.1% sesaminol-triglucoside to feed Newzealand white rabbits with 1% cholesterol diet for three months. From the results, they reported that the recipe gave the effect of working against arterial sclerosis by inhibiting the deposit of cholesterol on the arterial wall. These results suggest that sesame dregs can be developed as a new value added food ingredient, although they have been used as feed for animals or fish bait.

Table 6. Sesaminol-triglucosides contents of sesame from different origin

Origin	STG[1] (mg/100 g seed)			CV[2](%)
	Maximum	Minimum	Mean±SD	
China	398.69	246.36	321.40±49.00[b3)]	15.25
Sudan	311.44	202.73	259.64±40.55[c]	15.62
Indian	592.34	426.73	505.04±53.04[a]	10.50
Pakistan	371.91	281.15	342.87±28.71[b]	8.11

1) STG: Sesaminol-triglucoside.
2) CV: Coefficient of variation.
3) Different letters in the same column show statistically significant differences by Duncan's multiple range test at α=0.05.

6. Scavenging of 2,2-Diphenyl-1-picrylhydrazyl hydrate free radical

The electron-donating ability indicates a measure of interrupting chain reaction and preventing oxidation by donating electrons to oxidative free radicals involved in chain reaction of lipid peroxidation. Sesame contains a large quantity of antioxidants(sesamin, sesamolin, sesaminol) which inhibit oxidation.

The electron-donating ability of Indian-produced sesame n-hexane extracts showed the highest level followed by Pakistani sesame and Chinese sesame (Fig. 1). Shyu & Hwang (2002) measured DPPH radical scavenging ability of sesamol, sesamin, sesamolin, and sesaminol-triglucoside and reported that sesamol showed the greatest effect in the scavenging ability, followed in order of sesamin, sesamolin, and sesaminol-triglucoside. However, since the brown matter with the strongest effect was not still identified even in these studies, we have yet to identify what kind of matter exhibits such strong antioxidant effect. Hexane was used as an extraction solvent in this study. The hexane solvent extract brown matter and

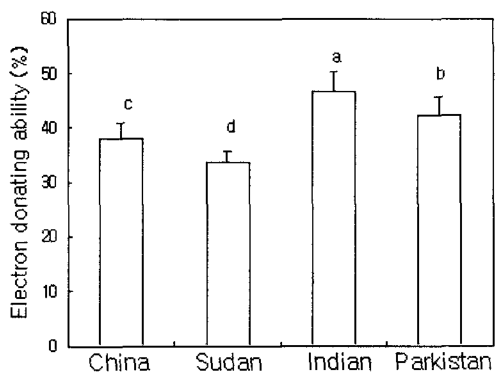

Fig. 1. Electron-donating ability in n-hexane extracts of sesame seeds from different origin. Bars represent mean±S.D. of n=10. Different letters on bars show statistically significant differences by Duncan's multiple range test at α=0.05.

fat-soluble substances such as sesamin and sesamolin, while sesaminol-triglucoside can be extracted with water or ethanol as a water-soluble substance.

Therefore, the observed antioxidant effect is considered to have resulted from brown matter, sesamin, and sesamolin, which were extracted using the hexane solvent. In the measurement of effect on oxidation of human LDL, sesaminol-triglucoside's scavenging ability was weak, but crude extracts showed a strong inhibition effect(Kang et al 1999, Kang et al 2000a). Consequently, this means that such high inhibition effect resulted from combination of antioxidants, but not a single substance. Kang et al(1999) reported that there was a strong effect of inhibiting LDL oxidation in rabbits that were fed with the diet with 10% of sesame dregs containing 1% sesaminol. Supposedly, this antioxidant effect is not generated by sesaminol-triglucoside, but comes from the process in which it is converted into sesaminol after hydrolyzation by hydrolytic enzymes and functions to inhibit oxidation while remaining as the form of sesaminol in blood or LDL.

Summary

In order to measure the chemical properties such as lignan content, antioxidative activity, and fatty acid composition of sesame(*Sesamum indicum* L.), sesame seeds from different countries of origin were analyzed.

The content of crude fat was the highest in Pakistani-produced sesame(42.47%), followed in order by Chinese-produced(38.95%), Indian-produced(34.96%), and Sudanese-produced(33.96%). With the respect to the sesamin content, the Chinese sesame showed the significantly highest content of 634.75 mg/100 g seed, followed in order by the Sudanese-sesame(630.66 mg/100 g seed), Pakistani sesame(401.00 mg/100 g seed), and Indian sesame(381.55 mg/100g seed). The Chinese and Sudanese sesame showed relatively high sesamolin contents of 218.99 mg/100 g seed and 234.49 mg/100 g seed, respectively. The highest sesaminol-triglucoside content was measured at 505.04 mg/100 g in the Indian sesame; followed in order by 342.87 mg/100 g seed in the Pakistani sesame, 321.40 mg/100 g seed in the Chinese sesame, and 218.99 mg/100 g seed in the Sudanese sesame. The electron-donating ability of hexane extracts from sesame showed a significantly higher level with extracts from the Indian sesame, followed by Pakistani sesame and Chinese sesame. In conclusion, sesame showed significant differences in their properties according to their cultivating regions.

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