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Biochemical Analysis of Black and White Sesame Seeds

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Introduction

Sesame seed (*Sesamum indicum, L.)* is one of the world's most important and oldest oilseed crops known to man [1]. Sesame seed, also known as sesamum, gingelly, benissed, sim-sim and till is an important annual oilseed crop. It has been cultivated for centuries, particularly in Asia and Africa, for its high content in edible oil and protein [2]. India and China are the world's largest producers of sesame, followed by Myanmar (Burma) [3].

Nearly 70% of the world production is from Asia. Africa grows 26% of the world's sesame, with Sierra Leone, Sudan, Nigeria, and Uganda being key producers. Latin America grows 4% of the total world production in Mexico, Guatemala, and Venezuela [1]. The oil has a mild odor and pleasant taste and as such, is a natural salad oil requiring little or no winterization [4]. It is a cooking oil in the form of shortening and margarine, as a soap fat in pharmaceuticals, and as a synergist for insecticides [1].

Sesame plays an important role in human nutrition. Its seeds are not only essentially used for oil production, but also in the production of the paste (tehineh) and food formulations such as Halaweh (sweetened tehineh), java beans, and bennimix in Sierra Leone [1,3,5,6]. The seeds vary in color with two main colors; white and black. White sesame seed is grown in Mexico, Guatemala, and El Salvador, while black sesame comes more from Thailand; while China grows both black and white sesame seeds [3]. The sesame seeds, mainly grown in North and Northeast China, play a major role in Chinese agriculture, supplying edible and industrial oils as well as other food products, which constitute an important share of exports. East Asian cuisines, like Chinese cuisine, use sesame seeds and oil in some dishes, such as the *dim sum dish*, they also use sesame seeds as traditional food with health benefits [3]. Several studies have reported the antioxidant activities of white and black sesame seeds and their hull fraction like protein content of white sesame seeds, dietary defatted sesame flour in relation to stress in hypercholesterolemic rabbits [7] extraction methods effect on sesame oil stability, proximate composition of Turkish sesame seeds and characterization of their oils [8] influenced of pH and/or salt concentration on solubility and functional properties [9] modeling of moisture, color and texture changes during conventional roasting and the protein of white sesame seeds [10], functional properties of sesame protein isolate as influenced by pH, temperature, time and ratio of flour to water during its production [11,12]. The antioxidant activity of white and black sesame seeds and their hull fraction [13]. The above areas have received considerable attention but there is very limited information on the analytical comparison of some of the biochemical composition of black and white sesame seed grown in China. China is one of the world's leading producing countries of sesame seeds as reported [3]. The two popular sesame seeds used in China in most products are black and white. But no comprehensive study has been reported simultaneously to show the similarities and differences. Therefore, the main objective of this study was to analyze the black and white sesame seeds grown in China and compare their biochemical properties.

Materials and Methods

Materials

Dehulled black sesame (BS) and white sesame (WS) seeds which were identified as *Sesamum indicum, L*. were purchased from a local market in Wuxi, People's Republic of China. Chemicals and reagents were obtained from local manufacturers (Sinopharm Chemical Reagent Co., Ltd. (SCRC) Shanghai People's Republic of China) and made available to the Jiangnan University chemical store, Wuxi, PR China. All chemicals and/or reagents used in this work were food-grade.

Methods

Proximate Analysis

The total protein: The total protein (N x 6.25) content of the samples (WS and BS) was determined using the Kjeldahl method according to AOAC [14]. The extraction and determination of fat

from the samples was performed using n-hexane according to the method of Ünal1 & Yalçin [8].

Moisture Content

The moisture content was determined by placing 2g of both BS and WS into a pre-weighed aluminum dish and thereafter, dried in a forced-air convection oven at 105ºC until a constant weight was reached. The data reported represents three determinations for BS and WS.

Ash and Mineral content

Ash was determined by combusting the samples in a muffle furnace at 550°C for 12 h. The residues of both samples were dissolved in 10mL of 50% of nitric acid solution and made up to final volume of 25mL of distilled water. After that the minerals (Ca, K, Mg, Fe, Cu, Zn, Na, Mn, Pb, Cd, As, and Se) were analyzed separately, using an Atomic Absorption Spectrometer of Spectrr AA 220, USA Varian. Phosphorus content (P) was determined by the phosphomolybdate method of AOAC [14]. The data reported represents the average of three determinations.

The Carbohydrate Content

The carbohydrate content was estimated by subtracting the sum of the percentage of moisture, fat, protein, and ash contents from 100%.

Vitamins (A, B, D, E and K)

The above vitamins were determined for both BS and WS according to the method described by Mathiasson et al. [16], with some modifications. 5g of each of the BS and WS was dissolved in 100mL of 4mol/L/CH_3CH_2OH, 0.5g Vit. C powder and 0.2g BHT were added and heated in a water bath at 85°C for 40 min. After that, the solution was cooled to room temperature (23-25°C) and extracted three times with petroleum ether. The three extracted solutions were combined and concentrated to less than 10mL. Isopropyl alcohol was used to make it up to 10mL and reversed-phase high-performance liquid chromatography (RP-HPLC) analysis in an Agilent 1100 (Agilent Technologies, Palo Alto, CA 94306, USA) assembly system using a Zorbax 80A C18 column (4.6 id x 180 mm) as by the conditions set by the equipment manufacturer was used to analysis the vitamins.

Sugar Profile

Certain sugars (glucose, sucrose, fructose, and maltose) were extracted with ethanol according to the method of Larrauri et al. [17], with slight modification. WS and BS were prepared by homogenizing 2g of the flour of both BS and WS in 3mL of distilled water and 7mL 95% ethanol and shaken before being centrifuged at 5000rpm for 20 min the clear supernatant was filtered through 0.45µm filter paper before HPLC analysis. The HPLC conditions used were as follows: Column; sugar-park 1, 6.5*300nm, mobile phase; water flow rate: 0.5mL/min, Column temperature; 85°C, Detection: RI, Injection volume; 10µL.

Oil Extraction

Sesame seed oil was extracted from the sesame flour of both BS and WS with hexane at 20°C for 72 hours; then filtered by vigorous shaking of the sesame flour in a stainless-steel bowl as described by Ünal1 & Yalçin [8]. This process was repeated three times using fresh solvent each time in order to extract almost all of the oil from the flour. The flour was collected, mixed, and air-dried for 24 h in a fume hood and stored at 5ºC. The solvent was evaporated from the extracted oil as described for the flour above. The extracted oil was used to determine the fatty acids for both the BS and WS seeds, while the flour was used to check the IR and other chemical properties.

Fatty Acid

Fatty acid for the BS and WS was determined according to the method of James [18]. Fat was extracted with methyl ether that was prepared directly with the treatment of the fat with sodium methoxide. A gas chromatography/mass spectrum (GC/MS) system was used to identify and quantify the fatty acids of the product developed on a FINNIGAN TRACE MS gas chromatograph/mass spectra equipped with a 30m x 0.25mm Ov-1701 column. The column flow rate was 0.8ml/min with helium as the carrier gas, split was 64ml/min and the source temperature was 270ºC. The fatty acid methyl esters were identified by comparison with the retention times of NU CHECK Inc. standards (Elysian, 1L) and quantified by internal normalization.

Amino Acid

The BS and WS (20 µg each) were dried in conventional hydrolysis tubes. To each tube 100 µL of 6mol L^{-1} HCl containing 30mL phenol and 10mL 2-mercaptoethanol (6 mol L^{-1} HPME) were added, and the tubes were evacuated, sealed, and hydrolyzed for 110ºC for 22 h. After hydrolysis, HCl was evaporated in a vacuum bottle heated to ~60ºC. The residue was dissolved in sample buffer and subjected to amino acid analysis, which utilized RP-HPLC analysis in an Agilent 1100 (Agilent Technologies, Palo Alto, CA 94306, USA) assembly system using a Zorbax 80A C18 column (4.6 id x 180 mm) as per the conditions set by the equipment. Excitation wavelength (Ex) at 348nm and emission wavelength (Em) at 450nm was chosen. The column oven was maintained at 60ºC. Amino acids were quantified by calculation from the recorded chromatogram. For cystine determination, samples (50µg of BS and WS) were first oxidized with 10 µL performic acid in an ice-water bath for 4 h. The mixtures were evaporated with a vacuum pump to remove performic acid before hydrolysis.

Determination of tryptophan was done by the ninhydrin method of Swakais & Pest [19]. With minor modifications. 1g of the sample was taken in a 25mL polypylene test tube with caps and 10mL of 0.075N NaOH was added, and mixed until the solution became clear. The dispersion was shaken for 30 min and was centrifuged at 5000rpm for 10 min and the supernatant was transferred to a clean test tube. 0.5 mL of the supernatants, 5 mL of ninhydrin reagent (1.0g of ninhydrin in 100 mL mixture of 37% HCL and 96% HCOOH) at a ratio of 2:3 for both BS and WS were added and incubated at 35°C for 2hrs. After incubation, the solution was cooled to room temperature (23-25ºC), and the volumes were made up to 10 mL with diethyl ether, thoroughly mixed with a

vortex mixer, filtrated, and the clear filtrates were analyzed with the same equipment as described above for the other amino acids.

The Infrared (IR)

The IR analyses of BS and WS sesame powders were carried out by mixing 0.1g sample and 0.5g potassium romide (KBr) were finely ground. A thin film of 1 cm^{-1} diameter and uniform thickness was prepared from the powder of both the BS and WS on a special apparatus provided for that work and the infrared absorption of the thin film at 1800 to 800 Cm^{-1} was recorded using a Nicolet 360Ft-IR spectrometer (USA) to develop the peaks according to the compounds present in the BS and WS.

Statistical Analysis

Data were evaluated by analysis of variance and means were compared using Duncan's multiple-range test. Results are presented as the mean value of triplicate samples together with the standard error of the mean (SEM). The statistically significant difference was defined as $P< 0.05$.

Table 1: Proximate nutritional composition of dehulled black and white sesame.

Nutritional composition	*Black Sesame*	*White sesame*
PROTEIN (%)	20.82 ±1.50a	24.20 ±0.67b
FAT (%)	48.40 ±2.12a	52.61 ±0.87a
MOISTURE (%)	4.20 ±0.92a	4.71 ±1.34a
ASH (%)	6.10 ±1.60a	4.32 ±2.41a
CARBOHYDRATE (%)	17.10 ±1.43a	15.54 ±0.74b
MINERALS (µg/g)		
Iron (Fe)	121	111
Zinc (Zn)	161	170
Manganese (Mn)	78	35
Copper (Cu)	44	51
Potassium (K)	10250	9722
Sodium (Na)	769	1544
Magnesium (Mg)	73	90
Calcium (Ca)	22854	1167
Phosphorus (P)	158	134
Lead (pb)	0.72	0.44
Cadmium (Cd)	0.063	0.039
Arsenic (As)	0.147	ND
Selenium (Se)	ND	ND
VITAMINS (mg/100g)		
Vit. A	9.52	8.92
Vit. D	12.63	11.57
Vit. C	4.25	6.21
Vit. E	17.45	28.46
Vit. K	13.61	19.57

ND: Not detected.

[a]Values are mean ± SEM (n = 3), different letters in the same column are not significant at level ($p< 0.05$) but significant at $p< 0.01$.

Results and Discussion

The Proximate Chemical Properties

The proximate chemical properties (protein, fat, moisture, ash, and carbohydrate) of BS and WS are shown in Table 1. Protein content was found to be higher in WS and lower in the BS (24.20% and 20.82%, respectively), significantly different at ($P < 0.05$). These values are similar to the values reported for non-Nigerian benniseed [20]. The fat was observed to be significantly higher in the WS seeds than in the BS sesame seeds (52.61 % and 48.40 % respectively). Tashiroa et al. [21] reported the oil content range of 43.4 to 58.8% for 42 strains of Sesamum with the highest oil content found in white-seeded strains. The results of this work are within the range reported by Tashiroa et al. [21]. Although Bahkali et al. [22], reported lower oil content in Saudi and Indian sesame seeds ranging from 43.2% to 54.0%. Baydar et al. [23], reported a significantly higher oil content of 63.25% in the Turkish sesame seeds of the TSP 933749 line selected from the TSP 9337 population, as compared to that of our result. The differences might be attributed to the different regions of seed production. The economic value of sesame seeds in most countries and China is not an exception dependent on its oil content.

The moisture content was found to be higher in the WS as compared to the BS but the difference was not significant ($P < 0.05$) with a marginal difference of 0.51 between the two colours (Table 1). Bahkali et al. [22], reported that the moisture content of different cultivars from different countries was in the range of 3.65-5.60%, which agrees with the results of this work. These values (4.20% and 4.71% for BS and WS respectively) are also similar to the values (4.12%-4.73%) reported by Dashak & Fali [20].

Ash content was observed to be significantly different ($P < 0.05$) between the two colours 6.10% and 4.32% for BS and WS respectively (Table 1). Özcan & Akgül [24], reported ash values to be between 3.67% and 5.39% for Turkish and foreign varieties (Mexican, Uganda, and Venezuela) sesame seeds which corroborates our result for WS being found within the range but disagree with BS though not significantly different at $P < 0.05$ with the sesame seeds from those countries. Carbohydrate content was higher in the BS than in WS with a significant difference at $P < 0.05$. The two results are consistent with the results of Elleuch et al. [25].

Table 2: Fatty acid content of BS and WS.

Fatty Acid		*Black sesame*	*White sesame*
Common name	**Scientific name**	%	%
Capric acid	Decanoic acid	0.32	0.25
Palmitic acid	Hexadecanoic acid	7.23	9.36
Palmitoleic Acid	9-Hexadecenoic acid	1.32	0.13
Stearic acid	Octadecanoic acid	5.88	7.86
Oleic acid	9-Octadecenoic acid	45.85	49.27
Linoleic acid	9,12-Octadecadienoic acid	37.89	42.79
Linolenic Acid	9,12,15-Octadecatrienoic acid	0.34	0.29
Ricinoleic acid	12-Hydroxy-9-octadecenoic acid	0.26	0.07
Arachidic acid	Eicosanoic acid	0.7	0.89
Gadoleic Acid	9-Eicosenoic acid	0.2	0.25
Lauric acid	Dodecanoic acid	0.2	0.08
Behenic acid	Docosanoic acid	0.32	0.07

Mineral Composition

The mineral composition of both BS and WS is also shown in Table 1. The BS had calcium as the predominant mineral followed by potassium, sodium, zinc, phosphorus, iron, manganese, magnesium, and small traces of lead, arsenic, and cadmium. With the exception of sodium, zinc, magnesium, and copper, the above minerals were found in significantly higher quantities than in WS. Arsenic and selenium were not detected in the WS (Table 1). The mineral element contents varied significantly ($P < 0.05$) between the BS and the WS. The mineral element contents varied significantly ($P < 0.05$) between the BS and the WS. The results of Dashak & Fali [20]. Were found to be slightly higher than our results though the difference for some minerals was not significant ($P < 0.05$). This might be attributed to the type of soil the seeds were grown or perhaps such mineral elements were eliminated during the dehulling of the sesame seed coat, as was reported by Johnson et al. [2] that the mineral content of sesame seed is mostly found in the seed coat.

Vitamins

Vitamins are shown in Table 1. It was found that the WS was higher in Vit. E, K, and C as compared to that of BS, and the differences were significant ($P < 0.05$), while BS was found to be higher in Vit A and B though the differences were not significant ($P < 0.05$). Vitamins C, E, and ß-carotene (which could be got from Vit A) are important natural antioxidants, that inhibit lipid peroxidation, and a high intake of these vitamins, particularly vitamin E, is related to reduced incidence of ischemic heart disease [26]. Vit A in particular is an essential nutrient for all animal species for normal vision, growth, and cellular differentiation. Vit E was found to be the highest in both BS and WS as could be seen in the peaks developed in Figure 1 (A and B), for both the two samples Vit E displays the broadest peaks while Vit C has very narrow peaks for both BS and WS. In Figure 1(A and B), the vitamins were eluted in this order for the BS and the WS, Vit E, K, B, A, and C when the standard was used to compare with the peaks eluted in the chromatogram. Some of the cardioprotective effects of vitamin E may be due to its beneficial effect in reducing excess tissue aldehydes. Dietary supplementation of vitamins E and A increases glutathione, a reservoir for the aldehyd-binding compound cysteine, and significantly lowers blood pressure in rats [27]. This scenario makes the sesame to be a good dietary supplement for human consumption.

Sugars

The sugar profile is shown in Figure 2. Sucrose, glucose, and maltose were found to be higher in WS (49%, 36%, and 15% respectively), while fructose was found to be higher in BS (17%). The differences were significant ($P < 0.05$). Sugars are relatively simple carbohydrates that include monosaccharides, disaccharides, trisaccharides and the oligosaccharides containing 1, 2, 3, and 4 or more monosaccharide units respectively. Sugars contain either aldehyde groups (-CHO) or ketone groups (C=O), where there are carbon-oxygen double bonds, making the sugars reactive [28].

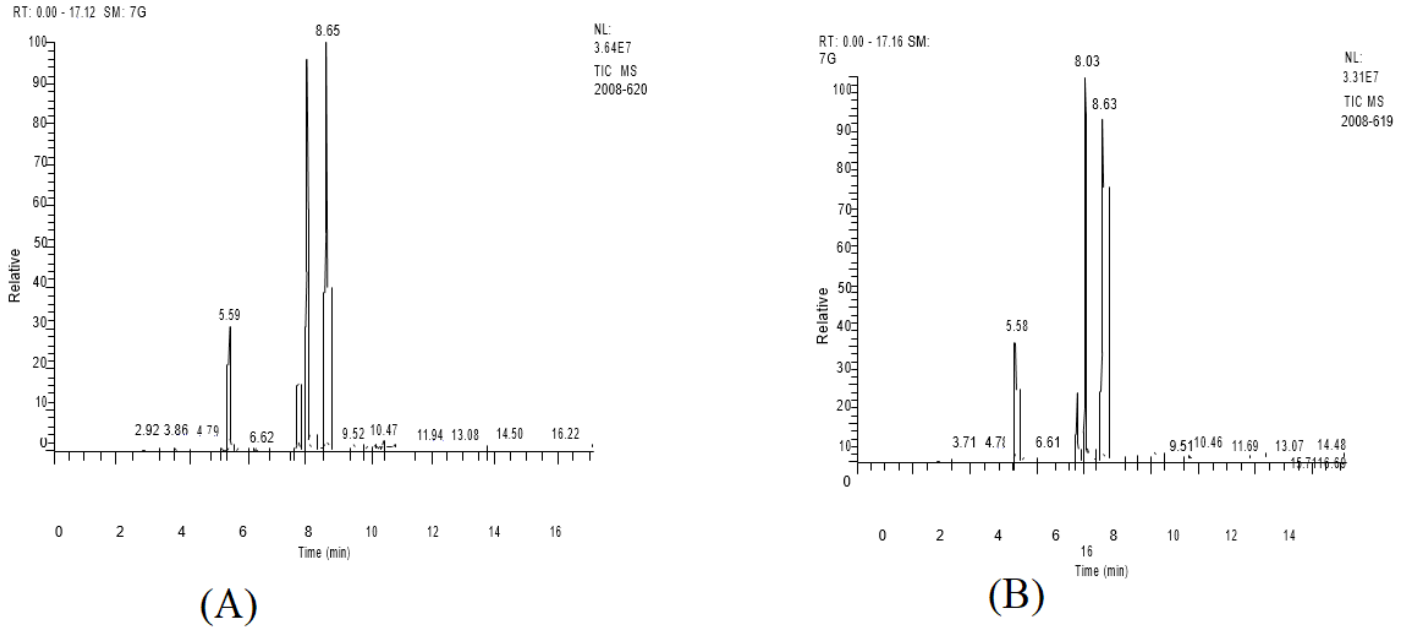
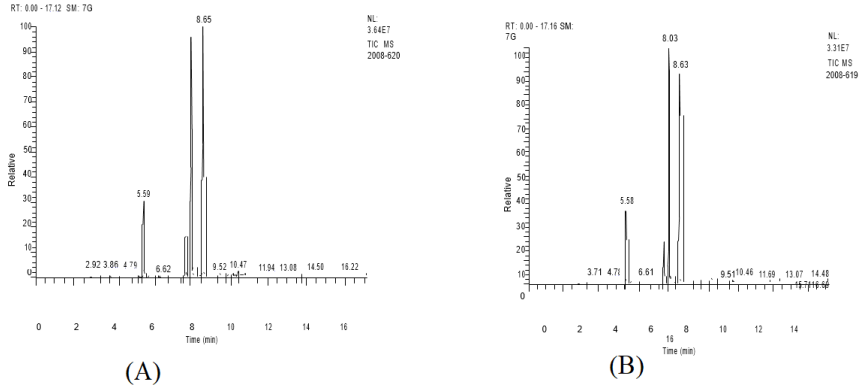


Figure 1: Peaks for vitamins (A) BS (B) WS.

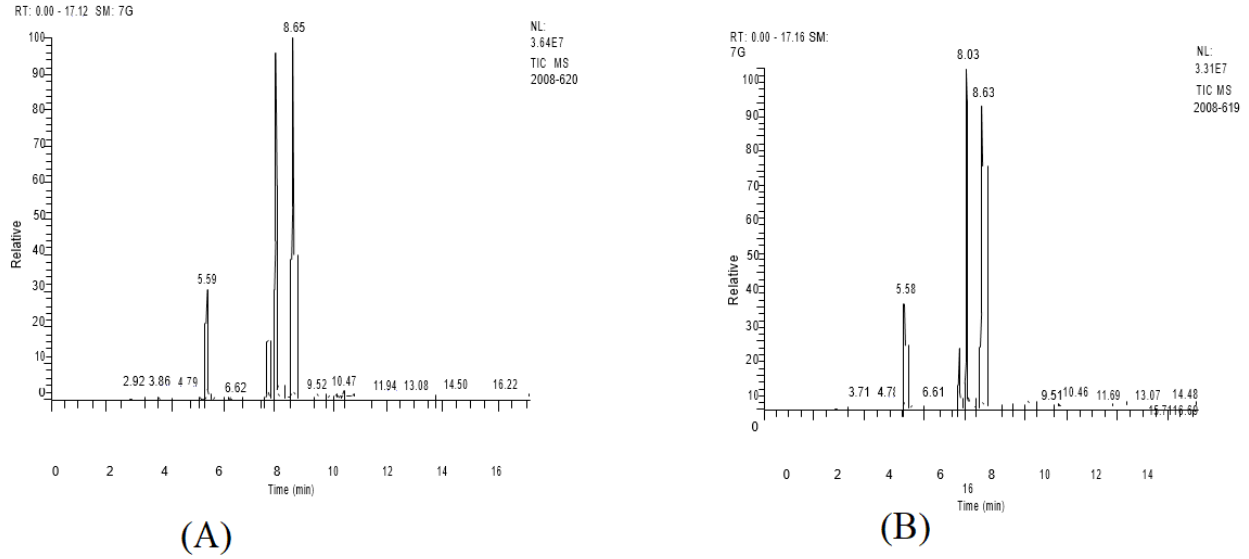
Fatty acid composition of the oil extracted from BS and WS is shown in (Table 2) No significant differences ($P < 0.05$) were observed between the two sesame colours. The most abundantly found fatty acids in WS and BS were 18:1 (oleic acid) 49.27% and 45.85% followed by 18:2 (linoleic acid) 42.79% and 37.89% respectively, as could be seen from the peaks in Figure 3 (A and B). Other fatty acids found in considerable amounts were 16:0 (Palmitic acid) 7.23% and 9.36% and 18:0 (stearic acid) 5.88% and 7.86% for BS and WS respectively. Compared with the white Sudanese variety studied by Elleuch et al. [25] oleic and linoleic acid contents were lower than our result. They reported 43% and 35% respectively, almost the same result as ours for the WS which they reported to be like our results but the BS sesame in this study was found to be lower than their reported result. Also, when compared with the reported results of Yoshida [4] and Yoshida et al. [29] their results were lower in oleic acid (38%) but were higher in linoleic acid (48%). Further comparison with results reported by Mohamed & Awatif [30]. who studied the Egyptian variety of unroasted and roasted black and brown sesame seeds shows our result corroborates their result for oleic for unroasted and roasted white sesame seeds (46.8% and 47.2% respectively) but disagrees with the brown unroasted and roasted sesame seeds as oleic acid for our results was lower than theirs, they reported 53.9 and 54.1% respectively.

The linoleic acid for the white unroasted sesame was also similar to both the BS and WS seeds but our results were higher than their results for the brown colour seeds. For both palmitic and stearic acids our results were higher for all the two colours they studied. Nonetheless, the content of linolenic acid -3 fatty acid, which is beneficial to human health, is very low for both the black and white Chinese sesame. Therefore, the oil content enhancement of



(A) (B)

Figure 2: The sugar content in black and white sesame seeds.



(A) (B)

Figure 3: Peaks of fatty acid (A) BS (B) WS.

this fatty acid for the black and white Chinese sesame could be a focus of study. As observed from our results, the difference in the fatty acid composition might be related to the different origins of the sesame. Another possible reason for such difference might be attributed to the oil extraction method employed for fatty acids analysis in sesame seeds. In general, unsaturated fatty acids, (oleic and linoleic acids) and saturated fatty acids (palmitic and stearic acids) are the most predominant lipid groups observed in the Chinese black and white sesame seeds.

Table 3: Amino acid profile of dehulled and defatted BS and WS.

Amino Acid	Black Sesame (g/100g)	White Sesame (g/100g)	EAAa	
			Infant	Adult
EAA				
Isoleucine (Ile)	3.08	4.29	2.80	1.30
Leucine (Leu)	6.67	7.50	6.60	1.90
Lysine (Lys)	2.43	3.30	5.80	1.60
Histidine (His)	3.22	3.09	1.90	1.60
Valine (Val)	4.06	5.18	3.50	1.30
Threonine (Thr)	3.84	4.29	3.40	0.9
Methionine (Met)	2.83	3.46	2.50	1.70
Tryptophan (Try)	2.12	2.53	1.10	0.05
nEAA				
Tyrosine (Tyr)	3.38	3.84		
Alanine (Ala)	1.93	3.37		
Cysteine (Cys-s)	2.37	3.09		
Phenylalanine (Phe)	4.52	4.58		
Serine (Ser)	1.38	3.14		
Arginine (Arg)	3.88	4.39		
Glycine (Gly)	2.81	3.33		
Proline (Pro)	3.19	1.31		
Aspartic acid (Asp)	8.10	8.95		
Glutamic acid (Glu)	15.52	17.68		

[a]Suggested profile of essential amino acid requirement for infant and adult [31].

EAA= Essential Amino Acid; nEAA= Non Essential Amino Acid.

Amino acid

The amino acid composition of BS and WS with the essential amino acids (EAA) FAO/WHO [31] requirement for humans is shown in Table 3. Almost all the EAA composition of BS and WS were found to be significantly higher than the FAO/WHO requirements for both infants and adults except lysine, which has been reported to be available in low quantity in sesame seeds [2]. Lysine was found to be lower in quantity in BS and WS for the infant category significantly different at $P < 0.05$ but fulfills the adults requirement as required by FAO/WHO. Methionine and cysteine which are sulfur-containing amino acids [2]. Were found in significantly higher quantity than FAO/WHO requirements for both infants and adults. Non-essential amino acids (nEAA) were also found to be in higher quantity. The difference in amino acid quantity for the two colours was not significant ($P < 0.05$). The amino acid component found in BS and WS corroborated the results reported by Radha et al. [32]. The sesame seeds produced in China were observed to have more amino acids as shown in (Figure 4A and B) as compared to the report of Kinsella and Mohite [33], they reported 13 amino acids. In Figure 4A and B,

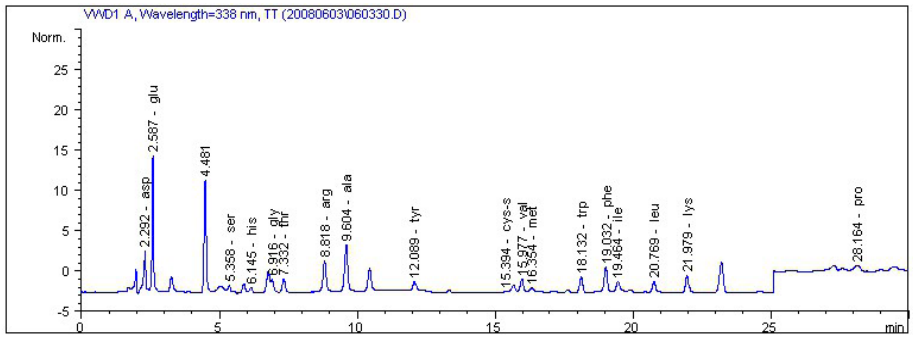
18 amino acids were shown from the chromatographs but methionine and cysteine were combined in Table 3 to make it possible to compare the results of the recommended requirement suggested by FAO/WHO. The result shows that sesame seeds of black and white colours grown in China could be utilized as a protein source and mixing them with other seeds like cereals could help to improve the lysine content, making them more useful for all categories of people utilizing them as protein food.

The IR

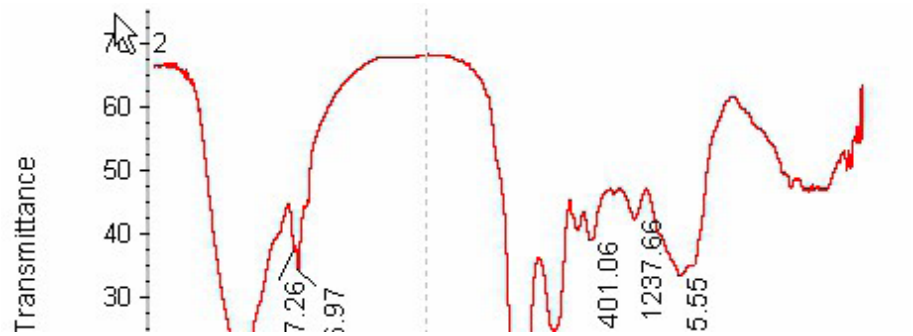
The IR spectra of BS and WS flour are shown in Figure 5 (A and B) respectively. IR spectrum tells about the presence or absence of particular functional groups [34]. A comparison of IR spectra of BS and WS seeds can often tell about structural similarities and differences between the two samples. The BS and WS seeds are different in structure as could be seen in Figure 5 (A and B). Since each type of a covalent bond has its characteristic absorption frequencies, no two molecules precisely have the same spectrum [35]. Nonetheless, many absorption frequencies may be the same for closely related substances, though at times there are differences. In general, these differences appear in the range from 1600 cm^{-1} to 600 cm^{-1}, this region of IR is called the fingerprint. By comparing spectra, particularly in the fingerprint region, it is often possible to tell whether or not two compounds are identical. If the spectra are identical, peak for peak, then it is almost certain that the two substances are identical. On the other hand, if the spectra are not identical, the two substances do not have the same molecular structure.

The interpretation of the IR as observed shows that there exists a very broad strong peak, for the BS at the region (3340.26 cm^{-1}) denoting the likely presence of O-H. This was also observed for the WS, but at the region of (3336.22 cm^{-1}), this peak was not as broad as the one observed for the BS. Also at the right-hand side of the peak, C-H compound was observed to be likely present in both the black and white sesame samples Figure 5 (A and B), at the region of (2925.92 cm^{-1}) for black sesame, but the white sesame initially displayed one peak and ended up splitting into two peaks both falling within the region of C-H presence.

Within the fingerprint region (1600-600 cm^{-1}), BS was observed to have peaks that depicted the presence of Amide I band (1651.31 cm^{-1}) and Amide II band (1536.27 cm^{-1}) plus medium absorption with six peaks that also depicted the presence of some C-O, raising suspicion that different sugars might be present within the sample. Moreover, for the white sesame, the two amide bands were also present at the different regions (1655.39cm^{-1} and 1539.40 cm^{-1} respectively), and weak absorption was found with three peaks that also confirmed the presence of C-O, but the presence of different sugars might be less than that of the black sesame. The difference observed shows that, though the two samples possess almost the same compounds but at different regions, IR radiation between 4000 cm^{-1} and 600 cm^{-1} both stretching and bending vibrations. Virtually all organic molecules are infrared active

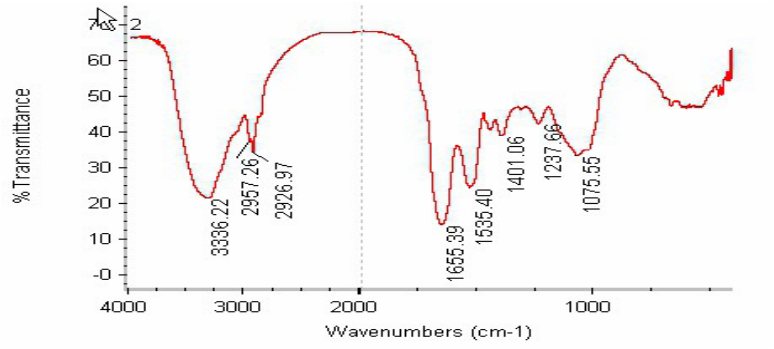


(A)

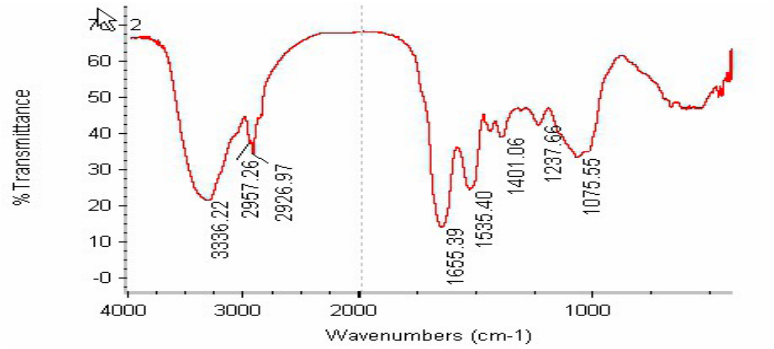


(B)

Figure 4: Amino acid chromatogram (A) black sesame flour (B) white sesame seed flour.



(A)



(B)

Figure 5: (A) IR spectra for defatted Black sesame seed flour, (B) IR spectra for defatted white sesame seed flour.

because radiation in this region of the spectrum corresponds to the energy required to excite the natural vibration frequencies of covalent bonds [36]. This is the phenomenon that takes place in the two samples to give the above peaks in their various regions. The similarity of the two colors is that both possess functional groups like the O-H and the N-H according to the IR spectra but did not show a peak-for-peak relationship.

Conclusion

When analytically investigating the differences in biochemical properties of BS and WS produced in China, our results showed significantly different patterns in biochemical properties between the BS and WS seeds. Protein, fat, and moisture contents were higher in the WS than in BS seeds while ash and carbohydrate contents were higher in BS than in WS. The two sesame seeds are good sources of minerals. Vitamin E, K, and C were higher in WS while Vitamin A and B were higher in BS. Almost all the EAA compositions of BS and WS were found to be significantly higher than FAO/WHO requirements for humans with the exception of lysine. According to the results from this study, it was observed that WS possesses better nutritional attributes as compared to BS, thus, WS seed was then selected for this research.

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