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Biochemical Analysis of Black and White Sesame Seeds from China

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ABSTRACT

An analytical comparison of the biochemical composition of Black Sesame (BS) and White Sesame (WS) produced in China was carried out. The aim of the study was to analyze the black and white sesame seeds grown in China and compare their biochemical properties. Various approved methods that have been reported by researchers were used to do the analysis. Gas Chromatography/Mass Spectra (GC/MS) system was used to identify and quantify the fatty acids. Nicolet 360Ft-IR spectrometer was used to determine the Infrared (IR) spectra of WS and BS. Protein for WS was 22.20%; BS 20.82%; fat WS was 52.61% and BS 48.40%; moisture was higher in WS than BS but ash was higher in BS than WS and the amount was significantly different at ($p<0.05$); carbohydrate was higher in BS than WS. The two colors were good sources of minerals. Vitamins vary in quantity for the two colors, the same was also observed for the sugars. The fatty acids, oleic and linoleic, were the major unsaturated fatty acids while palmitic and stearic were the main saturated fatty acids significantly observed in both samples. Both colors were higher in essential amino acids with the exception of lysine. The IR spectra of WS and BS showed different peak structures and both possess different functional groups at different regions of their spectra. The overall results indicated that WS and BS have different biochemical properties.

Key words: Amino acid, biochemical, fatty acid, functional groups, infrared, sesame

INTRODUCTION

Sesame seed (*Sesamum indicum* L.) is one of the world's most important and oldest oilseed crops known to man (Abou-Gharbia *et al.,* 2000). Sesame seed, also known as sesamum, gingelly, bennissed, 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 of edible oil and protein (Johnson *et al.,*1979). India and China are the world's largest producers of sesame, followed by Myanmar (Burma) (Namiki, 1995). 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 (Abou-Gharbia *et al.,* 2000). The oil has a mild odor and pleasant taste and as such, is a natural salad oil requiring little or no winterization (Yoshida, 1994). It is a cooking oil in the form of shortening and margarine, used as a soap fat in pharmaceuticals and as a synergist for insecticides (Abou-Gharbia *et al.,* 2000).

Sesame plays an important role in human nutrition. Its seeds are not only essential for oil and paste (tehineh) production but also in food formulation such as Halaweh (sweetened tehineh), java beans and bennimix in Sierra Leone (Abou-Gharbia *et al.,* 2000; Namiki, 1995; Abu-Jdayil *et al.,* 2002; Kanu *et al.,* 2007a). 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; China grows both black and white sesame seeds (Namiki, 1995). 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 (Namiki, 1995).

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 with stress in hypercholesterolemic rabbits (Kang *et al.,* 1999), extraction methods effect on sesame oil stability. proximate composition of Turkish sesame seeds and characterization of their oils (Unal and Yalcsn, 2008), influenced of pH and/ or salt concentration on solubility and functional properties (Khalida *et al.,* 2003), optimization of enzymatic hydrolysis of defatted sesame flour by different proteases (Kanu *et al.,* 2009), modeling of moisture, color and texture changes during conventional roasting and the protein of white sesame seeds (Kahyaoglu and Kaya, 2006), functional properties of sesame protein isolate as influenced by pH, temperature, time and ratio of flour to water during its production (Kanu *et al.,* 2007b, c), the antioxidant activity of white and black sesame seeds and their hull fraction (Shahidi *et al.,* 2006) and the nutraceutical importance of sesame seed and oil (Kanu *et al.,* 2010). 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 seeds grown in China. China is one of the leading producing countries of sesame seeds in the world as reported (Namiki, 1995). The two popular sesame seed used in most products in China are the black and white sesame seeds. But no comprehensive study has been reported simultaneously to show the biochemical 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 BS and WS seeds that were identified as *Sesamum indicum,* L. were purchased from a local market in Wuxi, People's Republic of China in March 2009. Chemicals and reagents were obtained from local manufacturers (Sinopharm Chemical Reagent Co., Ltd. (SCRC) Shanghai People's Republic of China) through the Jiangnan University chemical store, Wuxi, PR China. All chemicals and/or reagents used in this work were of food grade.

Methods

Proximate analysis

The total protein: The total protein (N×6.25) content of BS and WS was determined using the Kjeldahl method according to AOAC (1995). The extraction and determination of fat from BS and WS was performed using n-hexane according to the method of Unal and Yalcsn (2008).

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

Ash and mineral content: Ash for BS and WS was determined by combusting the samples in a muffle furnace at 550°C for 12 h (Bryant and McClements, 2000). The residues of both samples were dissolved in 10 mL of 50% of nitric acid solution with distilled water making the final volume to 25 mL. After that, minerals (Ca, K, Mg, Fe, Cu, Zn, Na, Mn, Pb, Cd, As and Se) were analyzed separately, using an Atomic Absorption Spectrometer of Specter AA 220, USA Varian. Phosphorus (P) content was determined by the phosphomolybdate method of AOAC (1995). The data reported represents the average of three determinations.

The carbohydrate content: The carbohydrate content was estimated by subtracting the sum of 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.* (2002) with slight modification. Five gram of each BS and WS was dissolved in 100 mL of 4 mol/L/CH_3CH_2OH, 0.5 g vit. C powder and 0.2 g BHT were added and heated in a water bath at 85°C for 40 min. Then the solution was cooled to room temperature (23-25°C) and extracted three times with petroleum ether. The three extracts were combined and concentrated to less than 10 mL with isopropyl alcohol to make it up to 10 mL. The 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×180 mm) as per 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.* (1996) with slight modification. The WS and BS were prepared by homogenizing 2 g of both BS and WS flour in 3 mL of distilled water and 7 mL of 95% ethanol and well shaken before being centrifuged at 5000 rpm for 20 min. The clear supernatant was filtered through 0.45 μm filter paper before HPLC analysis. The HPLC conditions used were as follows: Column; sugarpark 1, 6.5*300 nm, mobile phase; water flow rate: 0.5 mL min^{-1}, Column temperature; 85°C, Detection: RI, Injection volume; 10 μL.

Oil extraction: Sesame seed oil was extracted from BS and WS flours with hexane at 20°C for 72 h, then filtered by vigorous shaking the sample in stainless-steel bowl as described by Unal and Yalcsn (2008). This process was repeated three times using fresh solvent each time 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 5°C. The solvent was evaporated from the extracted oil as described for the flour above. The extracted oil was used to determine the fatty acids content for both the black and white sesame seeds, while the flour was used to check for the IR and other chemical properties.

Fatty acid: Fatty acid for the BS and WS was determined according to the method of James (1995) with slight modifications. Fat was extracted with methyl ether that was prepared directly with the

treatment of the fat with sodium methoxide. 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 30 m×0.25 mm Ov-1701 column. Column flow rate was 0.8 mL min^{-1} with helium as the gas carrier, split was 64 mL min^{-1} and the source temperature was 270°C. The fatty acid methyl esters were identified by comparison with the retention times of NU CHECK Inc. standards (Elysian, 1 L) and quantified by internal normalization.

Amino acids analysis: The BS and WS (20 μg each) were dried in conventional hydrolysis tubes. To each tube 100 μL of 6 mol L^{-1} HCl containing 30 mL phenol and 10 mL 2-mercaptoethanol (6 mol L^{-1} HPME) were added and the tubes were evacuated, sealed and hydrolyzed for 110°C for 22 h. After hydrolysis, HCl was evaporated in a vacuum bottle heated to ~60°C. The residue was dissolved in sample buffer and subjected to amino acid analysis, which utilized a post-column derivatizing high-performance liquid chromatographic system (Shimadzu, Kyoto, Japan) consisting of a Shimadzu RF 10 Axl fluorescence detector, Shimadzu SCL-10Avp controller with thermostated column area and a Shimadzu SIL-10ADvp autosampler, operated using CLASS-VP software (version 5.03). The column was a Shim-pack ISC-o7/S1504 Na with a flow rate of 0.6 mL min^{-1}. Excitation wavelength (Ex) at 348 nm and emission wavelength (Em) at 450 nm were chosen. The column oven was maintained at 60°C. The elution solvent systems were (A) 0.2 mol L^{-1} citrate buffer (pH 3.3), (B) 0.6 mol L^{-1} citrate/0.2 mol L^{-1} boric buffer (pH 10) and (C) 0.2 mol L^{-1} NaOH. Amino acids were quantified by calculation from the recorded chromatogram.

For cystine determination, samples (50 μg 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 Pinters-Szakacs and Molnar-Peri (1990) with minor modification. One gram of the sample was taken in a 25 mL polypylene test tube with caps and 10 mL of 0.075 N NaOH was added, mixed until the solution became clear. The dispersion was shaken for 30 min and was centrifuged at 5000 rpm for 10 min and the supernatant was transferred to a clean test tube. 0.5 mL of the supernatants, 5 mL of ninhydrin reagent (1.0 g 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 2 h. After incubation, the solution was cooled to room temperature (23-25°C) 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 equipments as described above for the other amino acids.

The IR: The IR analysis for BS and WS sesame powders was carried out by mixing 0.1 g sample with 0.5 g of finely ground potassium bromide (KBr). A thin film of 1 cm^{-1} diameter and uniform thickness was prepared from the powder of both 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 (ANOVA) 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 $p<0.05$.

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 but lower in the BS (22.20 and 20.82%, respectively), significantly different at ($p<0.05$). These values are similar to the values reported for non-Nigerian benniseed (Dashak and Fali, 1993).

The fat was observed to be significantly higher in the WS seeds than in BS seeds (52.61 and 48.40%, respectively). Tashiro *et al.* (1990) 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 strain. The result of oil content was consistent with the range reported by Tashiro *et al.* (1990). Although Bahkali *et al.* (1998) reported lower oil content in Saudi and Indian sesame seeds ranging from 43.2 to 54.0%. Baydar *et al.* (1999) 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 seeds 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 not significant ($p<0.05$) with a marginal difference of 0.51 between the two colors (Table 1). Bahkali *et al.* (1998) reported that the moisture content of different cultivars from

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

Nutritional composition	Black sesame	White sesame
Protein (%)	20.82±1.50[a]	22.20±0.67[b]
Fat (%)	48.40±2.12[a]	52.61±0.87[a]
Moisture (%)	4.20±0.92[a]	4.71±1.34[a]
Ash (%)	6.10±1.60[a]	4.32±2.41[a]
Carbohydrate (%)	17.10±1.43[a]	15.54±0.74[b]
Minerals (µg g^{-1})		
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 100 g^{-1})		
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 letter(s) in the same column are not significant at level ($p<0.05$) but significant at $p<0.01$

different countries was in the range of 3.65-5.60%, which agrees with the results of this study. 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 and Fali (1993).

Ash content was observed to be significantly different ($p<0.05$) between the two colors 6.10 and 4.32% for BS and WS, respectively (Table 1). Ozcan and Akgul (1995) reported ash values to be between 3.67 and 5.39% for Turkish and foreign varieties (Mexican, Uganda and Venezuela) sesame seeds which corroborate 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 significant difference at $p<0.05$. The two results are consistent with the results of Elleuch *et al.* (2007).

The 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 quantity than in WS. Arsenic and selenium were not detected in the WS (Table 1). The mineral elements contents varied significantly ($p<0.05$) between the BS and the WS. The results of Dashak and Fali (1993) were found to be slightly higher than our results thought the difference for some mineral was not significant ($p<0.05$). This might be attributed to the type of soil where the seeds were grown or perhaps such mineral elements were eliminated during the dehulling of sesame seed coat, as reported by Johnson *et al.* (1979) 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 obtained from Vit A) are important natural antioxidants, which inhibit lipid peroxidation and high intake of these vitamins, particularly vitamin E, is related to reduced incidence of ischemic heart disease (Sharma *et al.,* 2000). Vit A in particular is an essential nutrient for all animal species for normal vision, growth and cellular differentiation. Vit E was highest in both BS and WS as could be seen at the peaks developed in Fig. 1a and b. For both samples, Vit E displays the broadest peaks while Vit C showed narrow peaks. In Fig. 1a and b, the vitamins were eluted in this order for the BS and 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 vitamin E and A increases glutathione, a reservoir for the aldehyde binding compound cysteine and significantly lowers blood pressure in rats (Newaz and Nawal, 1998). This scenario portrays the sesame as a good dietary supplement for human consumption.

Sugars: The sugar profile is shown in Fig. 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 which 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 (Robyt, 1998).

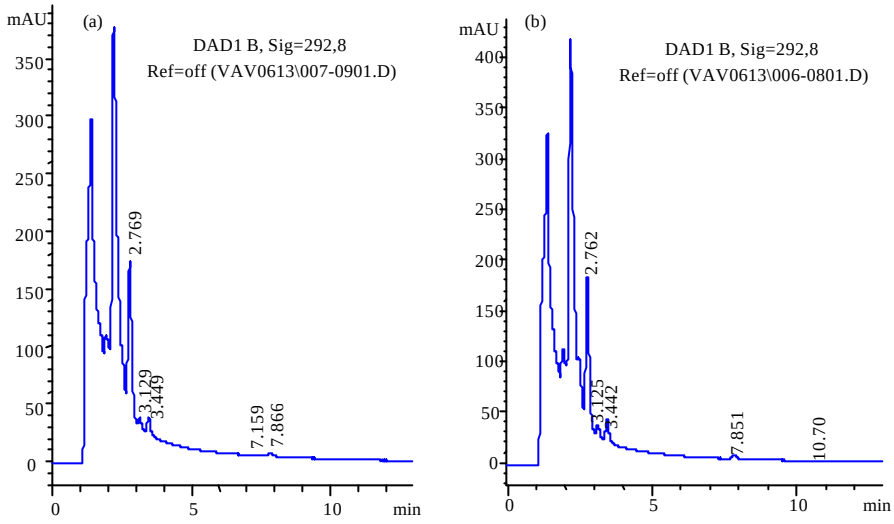

Fig. 1: Peaks for vitamins (a) black sesame seeds and (b) white sesame seeds

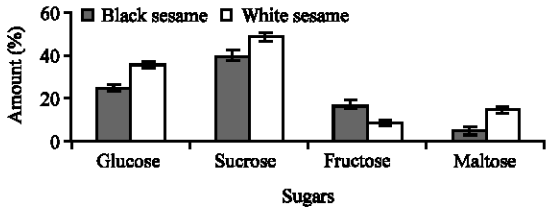

Fig. 2: The sugar content in black and white sesame seeds

Table 2: Fatty acids 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	9.23	9.36
Palmitoleic Acid	9-Hexadecenoic acid	1.32	0.13
Stearic acid	Octadecanoic acid	5.88	7.86
Oleic acid	9-Octadecenoic acid	46.27	45.85
Linoleic acid	9,12-Octadecadienoic acid	38.79	37.89
Linolenic Acid	9,12,15-Octadecatrienoic acid	0.34	0.29
Ricinoleic acid/Nutmeg	12-Hydroxy-9-octadecenoic acid	0.26	0.07
Arachidic acid	Eicosanoic acid	0.70	0.89
Gadoleic Acid	9-Eicosenoic acid	0.20	0.25
Lauric acid	Dodecanoic acid	0.20	0.08
Behenic acid	Docosanoic acid	0.32	0.07

Fatty acid: 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 colors. The most abundantly found fatty acids in BS and WS were 18:1 (oleic acid) 46.27 and 45.85% followed by

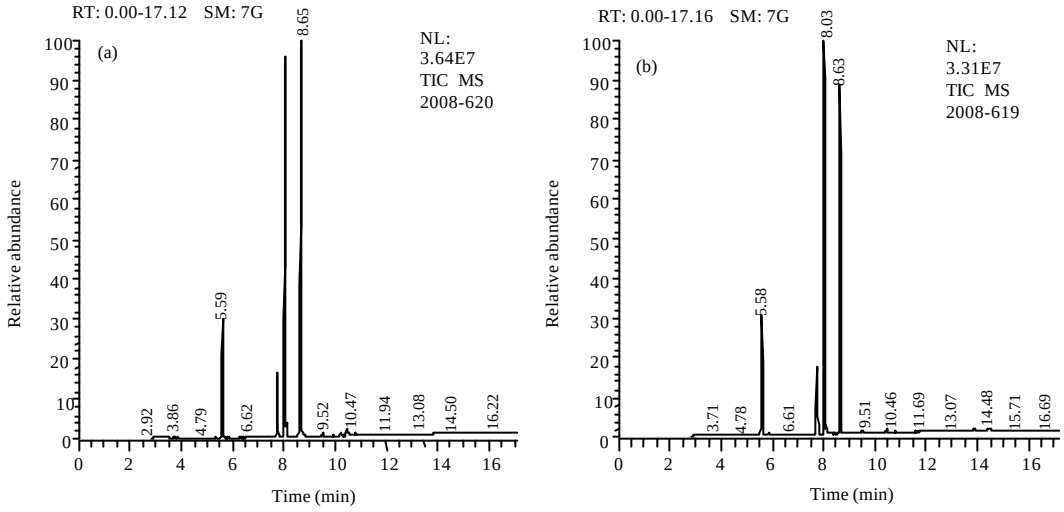

Fig. 3: Peaks of fatty acid (a) black sesame seeds and (b) white sesame seeds

18:2 (linoleic acid) 38.79 and 37.89%, respectively, as could be seen from the peaks in Fig. 3a and b. Other fatty acids found in considerable amount were 16:0 (Palmitic acid) 9.23% 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.* (2007), oleic and linoleic acids 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 reported results of Yoshida (1994) and Yoshida *et al.* (2000) their results were lower in oleic acid (38%) but were higher in linoleic aid (48%). Further comparison with results reported by Mohamed and Awatif (1998), who studied 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 seed 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 color seeds. For both palmitic and stearic acids our results were higher for all the two colors they studied. Nonetheless, the content of linolenic acid ω-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 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.

Amino acids analysis: Amino acid composition of BS and WS with the FAO/WHO (1990), requirement is shown in Table 3. Almost all the Essential Amino Acid (EAA) composition of BS and

Table 3: Amino acid profile of dehulled and defatted black and white sesame

Amino acid	Black sesame (g 100 g^{-1})	White sesame (g 100 g^{-1})	EAA[a] infant adult
EAA			
Histidine (His)	3.22	3.09	1.90 1.60
Threonine (Thr)	3.84	4.29	3.40 0.90
Valine (Val)	4.06	5.18	3.50 1.30
Lysine (Lys)	2.43	3.30	5.80 1.60
Leucine (Leu)	6.67	7.50	6.60 1.90
Isoleucine (Ile)	3.08	4.29	2.80 1.30
Tryptophan (Try)	2.12	2.53	1.10 0.05
Methionine (Met)	2.83	3.46	2.50[b] 1.70[b]
nEAA			
Tyrosine (Tyr)	3.38	3.84	
Phenylalanine (Phe)	4.52	4.58	
Alanine (Ala)	1.93	3.37	
Arginine (Arg)	3.88	4.39	
Serine (Ser)	1.38	3.14	
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]. [b]Methionine + Cysteine. EAA: Essential amino acid, nEAA: Non essential amino acid

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 (Johnson *et al.,* 1979). 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 adult requirement as required by FAO/WHO. Methionine and cysteine which are sulphur-containing amino acids (Johnson *et al.,* 1979) 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 acids quantity for the two colors was not significant. The amino acid component found in BS and WS corroborates the results reported by Radha *et al.* (2008). The sesame seeds produced in China was observed to have more amino acids as shown in (Fig. 4a and b) as compared to the report of Kinsella and Mohite (1985), they reported 13 amino acids. In Fig. 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 to the recommended requirement suggested by FAO/WHO. The result shows that sesame seeds of black and white colors 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 a protein food.

The infrared: The Infrared (IR) spectra of BS and WS flours were shown in Fig. 5a and b respectively. IR spectrum tells about the presence or absence of particular functional groups (Lau, 1999). A comparison of IR spectra of BS and WS seeds tells about structural similarities and differences between the two samples. The BS and WS seeds are different in structure as indicated

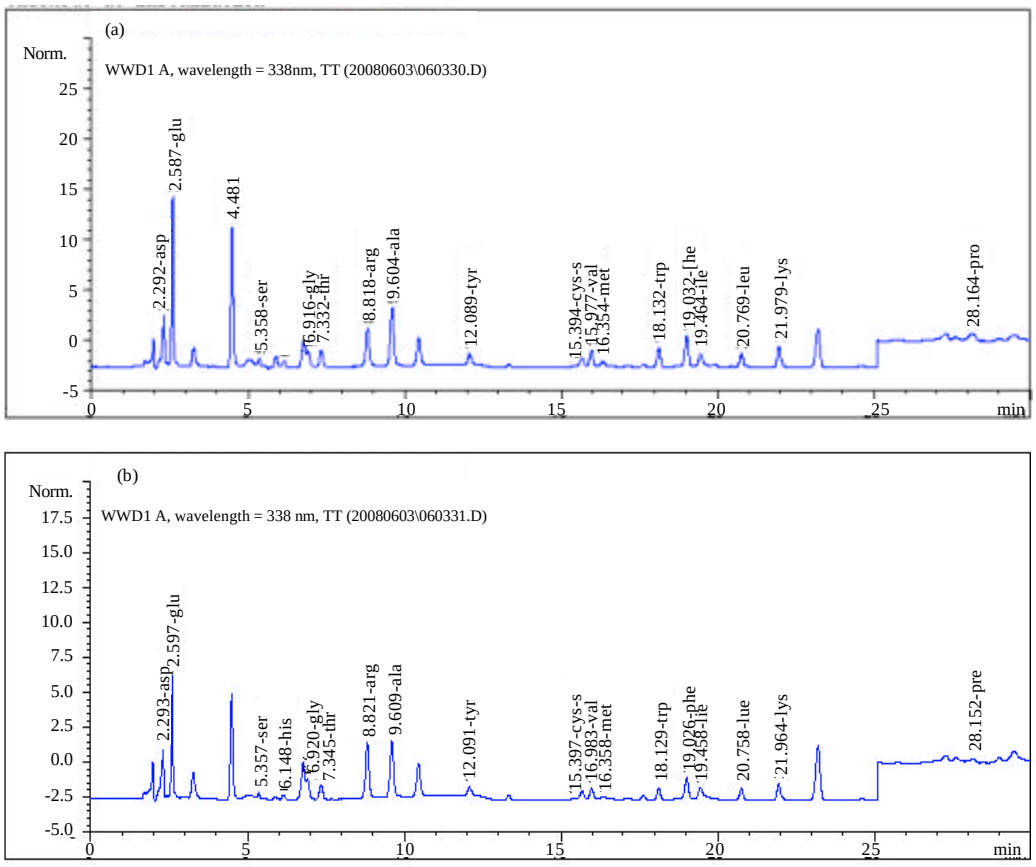

Fig. 4: Amino acid spractra (a) black sesame flour and (b) white sesame seed flour

in Fig. 5a and b. Since each type of a covalent bond has its own characteristic absorption frequencies, no two molecules precisely have the same spectrum (Demirdoven *et al.*, 2004). 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 to 600 cm^{-1}, a region called the finger print. By comparing spectra, particularly in the finger print 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 have different molecular structure. The interpretation of the IR as observed is that, there exist 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 3336.22 cm^{-1} region, a peak not as broad as that observed for the BS. Also at the right hand side of the peak, C-H compound was observed to be likely present in both samples at the region of (2925.92 cm^{-1}) for BS, but the WS initially displayed one peak and ended up splitting into two peaks, both falling within the region of C-H presence Fig. 5a and b. Within the finger print 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 samples. Moreover, for the WS, the two amide bands were also present at the different regions

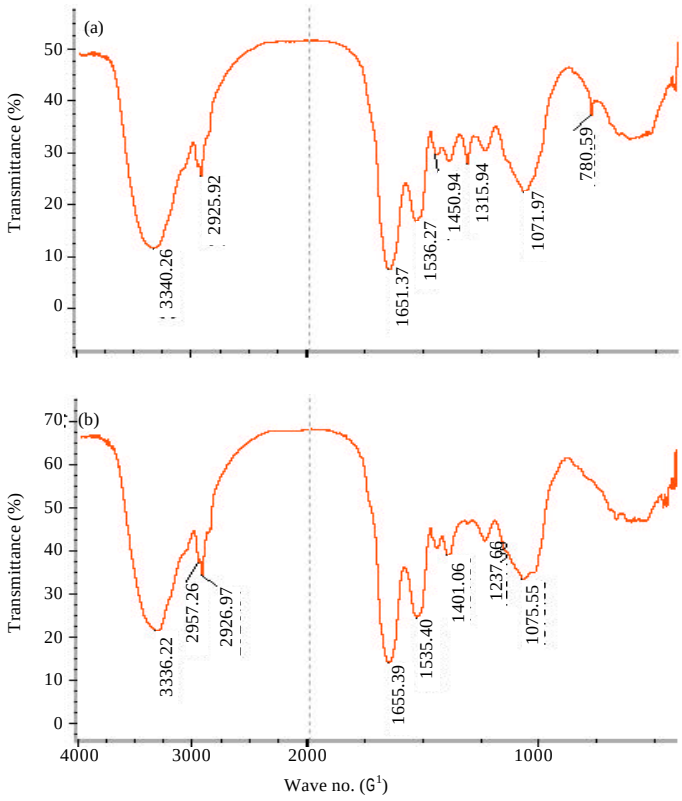

Fig. 5: (a) IR for defatted black sesame seed flour and (b) IR for defatted white sesame seed flour

(1655.39 and 1539.40 cm^{-1}) and weak absorption was found with three peaks that also confirmed the presence of C-O, but the presence of different sugars was less than that of the BS. The difference observed shows that, though the two samples possess almost the same compounds but at different regions, IR radiation between 4000 and 600 cm^{-1} excites both stretching and bending vibrations. Virtually, all organic molecules were infrared active because radiation in this region of the spectrum corresponds to the energy required to excite the natural vibration frequencies of covalent bonds (Mukamel, 2000). 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 investigated the differences in biochemical properties of BS and WS produced in China, our results showed significant 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 EAAs composition of BS and WS were found to be significantly higher than FAO/WHO requirements for humans with the exception of lysine.

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