Journal of King Saud University – Science (2016) **28**, 332–338

King Saud University
**Journal of King Saud University – Science**
www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

# Variations of quality characteristics among oils of different soybean varieties

**Farooq Anwar** [a,b,c,*], **Ghulam Mustafa Kamal** [b,d,e,*], **Farooq Nadeem** [b], **Ghulam Shabir** [b,f]

[a] *Department of Chemistry, University of Sargodha, Sargodha 40100, Pakistan*
[b] *Department of Chemistry, University of Agriculture Faisalabad, 38040, Pakistan*
[c] *Department of Pharmaceutical Chemistry, College of Pharmacy, Prince Sattam bin Abdulaziz University, Al-Kharj 11942, Saudi Arabia*
[d] *State Key Laboratory of Magnetic Resonance and Atomic and Molecular Physics, Center for Magnetic Resonance, Wuhan Institute of Physics and Mathematics, University of Chinese Academy of Sciences, Wuhan 430071, PR China*
[e] *University of Chinese Academy of Sciences, Beijing 100049, PR China*
[f] *Environmental Biotechnology Division, National Institute for Biotechnology and Genetic Engineering (NIBGE), P.O. Box 577, Jhang Road, Faisalabad, Pakistan*

Received 23 June 2015; accepted 1 October 2015
Available online 8 October 2015

**KEYWORDS**

Oil yield;
Oxidation state;
GLC;
Linoleic acid;
Tocopherols;
HPLC

**Abstract** A study was carried out to evaluate the variation of quality attributes among oils from different soybean varieties (Bovender special, Foster and F-8827).Oils were extracted using *n*-hexane as solvent. Results indicated that contents of seed oil among the tested varieties varied from 15.85% to 19.49%, moisture 8.4–10.2%, protein 41.67–45.64%, fiber 6.6–7.6% while ash 5.5–6.9%. The physical and chemical characteristics among the tested oils varied as: color (4.2–5.3R + 40–50Y), iodine value (119–128 g of I/100 g of oil), refractive index (1.4590–1.468), density (0.8698–0.8712 g/cm$^3$ at 36 °C), free fatty acid content (0.39–0.67% as oleic acid), saponification value (181–187 mg KOH/g) and unsaponifiable matter (0.42–0.74%). The oxidation parameters including peroxide value, conjugated dienes and conjugated triene were recorded as 1.80–2.64 meq/kg, 0.41–0.65 and 1.50–1.91, respectively. The fatty acid composition showed the presence of palmitic acid (11.00–13.50%), stearic acid (3.02–4.90%), oleic acid (22.60–24.00%),

* Corresponding authors at: Department of Chemistry, University of Sargodha, Sargodha 40100, Pakistan (F. Anwar), Key Laboratory of Magnetic Resonance in Biological Systems, State Key Laboratory of Magnetic Resonance and Atomic and Molecular Physics, Center for Magnetic Resonance, Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences, Wuhan 430071, PR China (G.M. Kamal).
E-mail addresses: fqanwar@yahoo.com (F. Anwar), kamal_ss@hotmail.com (G.M. Kamal).

Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jksus.2015.10.001

linoleic acid (49.03–53.00%) and linolenic acid (6.50–8.00%). The amounts of α, γ and δ-tocopherols ranged from 66.5 to 90.7 mg/kg, 907.5–1011.9 mg/kg and 399.8–411.5 mg/kg, respectively. Results indicated a significant variation for most of the physicochemical parameters among three soybean oils which can be mainly linked to the specific genetic makeup of each variety as well as the agro-climatic conditions of the harvest.



## 1. Introduction

Vegetable oils being an important ingredient of our diet act as a source of essential fatty acids and nutrition and can be extracted from a variety of plant seeds such as soybean, cotton, sesame, sunflower, safflower, palm, corn and canola (Anwar et al., 2005a).

One of the important oil seed crops namely soybean (*Glycine max* L.) is a member of the *Leguminosae* family [sub-family *Papilionoideae*]. The plant is annual, generally grows to a height of 20–180 cm, and has white or lilac flowers and pods. The pods, which usually contain two or three seeds, are formed in the leaf axils. There are several varieties of soybean with yellow, green, brown or black seeds and cultivars. Soybean is essentially a subtropical crop but can also be grown in tropical to temperate regions up to temperatures as high as 50 °C. Soybean like other legumes is useful for crop rotation due to the ability to fix nitrogen from the air (Anonymous, 1994).

Protein and oil are the two important seed constituents that make soy bean (*Glycine max*) an important crop. It contains 40–42% high quality protein and 18–22% oil comprising up of 85% unsaturated fatty acid. Soybean not only contains high quality protein, but the protein content is also much higher than that of other plant foods. This valuable bean also contains about 12% carbohydrate (Yaklich et al., 2002). Soy protein is valued as a healthy protein due to containing a balanced proportion of all of the important and essential amino acids required by the human body (Potter et al., 1998). It is the only vegetable source that contains a complete protein. It contains all the nine essential amino acids that a human body cannot synthesize and which must be obtained from foods. In fact soybeans can provide two fold more proteins as compared to any other vegetable crop or grain (Anonymous, 2015). The soybean flakes obtained after extraction of oil can be further processed into protein meals and protein isolates for animal and human use. Hydrolyzed soybean protein (HSP) can be used in soups, sauces, gravies, spice blends, canned and frozen vegetables, meats and poultry as a flavor enhancer. Moreover, the textured soy flour is widely used as a meat extender (Anonymous, 1994).

The health attributes of soy have been linked to the isoflavones naturally occurring in soy in conjunction with the soy protein (Potter et al., 1998). Soybean contains two primary isoflavones namely genistein and diadzein. A third isoflavone, glycitin is also reported in small amounts. Typically, genistein is found at the highest level in soy foods (Messina and Loprinzi, 2001).

It is assumed that the oil yield and physicochemical properties of oils are not only varied in relation to different species and different agro-climatic regions rather such variations can also be seen within the oils of different varieties/cultivars of the same species. Some recent reports revealed considerable inter-varietal variations the chemical composition of seed oils of okra and wintermelon (Anwar et al., 2011a,b).

World production of soybean (*Glycine max*) in 2014/15 was over 319.36 million metric tons, with 108.01 million metric tons of this production coming from U.S., where soybean plantings on an annual basis are over 33.61 million ha. Soybeans are desired on the marketplace as a valuable source of protein and oil (USDA, 2015). Although soybean as an oil seed crop was introduced in Pakistan along with sunflower a few decades back, yet it could not make its place in the country. Since its average yield per hectare under local agro-climatic set up is also quite low, its production remained small. Soybean, as an oilseed crop, is under research and production trials in several parts of Pakistan. Several attempts have been made over the decades to introduce soybean for commercial planting but no encouraging success was achieved. Presently, it is grown on a very small area, in Punjab, Sindh and Khyber Pakhtunkhwa provinces of Pakistan (FAO, 2013).

Soybean varieties namely, Bovender special, Foster and F8827, investigated in the present study were grown at Ayub Agricultural Research Institute, Faisalabad, Pakistan for adaptive studies. As the oil yield and the physicochemical properties and attributes of the oils can vary among different varieties of oil seeds with respect to their genetic makeup (Clemente and Cahoon, 2009; Hudson, 2012; Ma et al., 2015), so a need exists to investigate such variations with regard to different soybean cultivars. Until now, a full characterization and comparison of the quality attributes of the oils produced from seeds of mentioned locally cultivated soybean varieties has not yet been investigated. The main objective of the present study was to conduct a detailed analysis and to assess the variations in physicochemical characteristics of soybean seed oils of different varieties cultivated in Pakistan. The main theme behind carrying out this study was to convey information to the local growers and industrialists about the physicochemical attributes of the above varieties thus helping them in selection of the appropriate variety for cultivation and industrial processing at regional level.

## 2. Materials and methods

### 2.1. Chemicals, standards and reagents

Chloroform, oxalic acid, acetic acid, phenolphthalein, hydrochloric acid, potassium iodide, *n*-hexane, sodium sulfate, potassium hydroxide, sodium thiosulfate, potassium permanganate, boric acid, carbon tetrachloride, iso-octane, iodine, sodium hydroxide, methanol, sulfuric acid, *p*-anisidine and pure standards of fatty acid methyl esters (FAMEs) used in the present study were purchased from E-Merck and/or Sigma–Aldrich Chemical Corporation (St. Louis, MO, USA).

### 2.2. Soybean seed samples and oil extraction

The seeds of three varieties (Bovender special, Foster and F-8827) of soybean used in this study were obtained from Ayub Agricultural Research Institute, Faisalabad, Pakistan. The average weight of seeds was recorded to be 0.12–0.20 g. The seeds were crushed and placed in a Pyrex glass Soxhlet extractor, attached with a water condenser and a Pyrex round bottomed flask (500 mL capacity). Extraction was carried out using a water bath with *n*-hexane as extraction solvent. After the oil extraction, the extra solvent was removed under vacuum in a rotary evaporator machine (EYELA, N. N. Series fitted with an Aspirator and a Digital Water Bath SB-651, Japan) at 45 °C.

### 2.3. Analysis of oilseeds residues

The oilseed residues were analyzed for protein, fiber and ash contents. The crude protein was estimated according to ISO method-5983 (ISO Standards, 1981) using micro Kjeldhal apparatus. Fiber contents were determined according to the official method (AOAC, 1990) while ash contents by the ISO method – 749 (ISO, 1977).

### 2.4. Analysis of oils physicochemical parameters

The extracted oils were analyzed for saponification value, unsaponifiable matter, color index, iodine value, conjugated dienes and trienes, refractive index, density, peroxide value following standard methods of AOCS (AOCS, 1997). The color of the oil was read using a Lovibond Tintometer (Tintometer Ltd., Salisbury, Wiltshire, United Kingdom) equipped with a 1-inch cell. For the measurement of conjugated dienes and trienes, in terms of specific extinctions at 232 and 268 nm, respectively, the absorbance of the oil samples, properly diluted with iso-octane, was recorded using a UV–visible spectrophotometer (U-2001, Hitachi Instruments Inc. Tokyo, Japan) and $\varepsilon^{1\%}_{1cm}\ \lambda_{232}$ and $\varepsilon^{1\%}_{1cm}\ \lambda_{268}$ values were calculated following the IUPAC method II D.23 (IUPAC, 1987). A digital refractometer RX-7000α (Atago Co. Ltd., Tokyo, Japan) was used for recording the refractive index of the subject oils.

### 2.5. Preparation of fatty acid methyl esters (FAMEs)

One gram of each soybean oil sample and five fatty acid standards were placed in various test tubes. Five ml of 0.5 M methanolic NaOH solution was then added and allowed to heat on a steam bath for 5 min until they globalized into solution. Ten ml of $BF_3$ in methanol was added to each sample in the test tube and the mixture was again boiled for 2 min. Each of the mixture containing the fatty acid methyl esters (FAME) was extracted with 30 ml petroleum ether (b.p.40–60 °C) and 20 ml saturated NaCl solution in a separating funnel. The lower layer of aqueous methanol was allowed to separate, drained off and discarded, while the upper petroleum ether layer was poured into a test tube and made up to 2 ml. (Mao, 1995; Amos-Tautua et al., 2013).

### 2.6. Fatty acid (FA) analysis by gas chromatograph

Oils were analyzed as fatty acid methyl esters (FAMEs) using a Shimadzu Model 17A gas chromatograph (Shimadzu, Tokyo Japan), attached with FID (flame ionization detection). The separation of the FAMEs was carried out by a SP-2340 (SUPLECO, INC., Supelco Park, Bellefonte, PA, 16823-0048 USA) polar capillary column (30 m × 0.25 mm; stationary phase film thickness 0.20 μm of methyl lignocerate). A sample of 1.0 μL, using the split mode, was injected into the capillary column and flushed with pure nitrogen as a carrier gas with a flow rate of 1.5 mL/min. The column oven temperature was initiated at 180 °C and linearly raised to 210 °C at the rate of 5 °C per min with initial and final hold-up time of 1 and 10 min, respectively. The injector and detector were set at temperatures of 220 and 230 °C, respectively. The FAMEs were identified by matching their relative and absolute retention times with those of authentic/pure standards. The peak areas of the standards were used for the quantitative measurements by constructing a calibration curve. The fatty acid composition in percent (g/100 g FA) was based upon the relative percentage of the total peak area.

### 2.7. Tocopherol analysis

In the HPLC experiment, the samples for tocopherol (α, γ, and δ) analysis were prepared based on the method described in current protocols in "Food Analytical Chemistry" (Wrolstad, 2003). A known quantity of oil (0.1 g) was placed in a test tube (16 × 25 cm), containing ascorbic acid (0.05 g), 5 mL of 90% ethanol and 0.5 mL of 80% aqueous KOH solution. The contents of the tube were mixed well by vortexing the tube for 30 s. The tube was capped after flushing with nitrogen and then placed/incubated in a water bath (70 °C) for 30 min with periodical vortexing. After incubation the tube was removed from the water bath and cooled down by placing in an ice bath for 5 min. After that 3 mL of deionized water and 5 mL *n*-hexane were added to the tube and it was vortexed again for 30 s followed by centrifugation at 1000*g* for 10 min at room temperature. The upper hexane layer was collected in another test tube. The aqueous layer and the residue thus obtained (recovered) was re-extracted by repeating the same procedure. The hexane layers produced from both the extractions were pooled and evaporated to dryness under nitrogen streaming. The concentrated extract recovered was re-dissolved in one mL of mobile phase by vortexing for 30 s and then finally transferred to an HPLC sample vial. A 20 μL prepared sample was injected into a Supelcosil LC-Si column (250 × 4.6 mm, Supelco Inc.). A mobile phase consisting of ethyl acetate/acetic acid/hexane (1:1:98, v/v/v) was used at a flow rate of 1.5 mL/min. Detection of three tocopherol compounds was done at 295 nm with a UV detector. The unknown tocopherols were identified by comparing their retention times with those of pure standards of α-, γ- and δ-tocopherols from Sigma–Alrdrich. These compounds were quantified on the basis of matching of peak areas of the pure standards based on an external standard method using a D-2500 Hitachi Chromato integrator.

### 2.8. Statistical analysis

Data were statistically analyzed to find out significant differences of parameters among varieties analyzed by using MSTATC program (version 2.10).

## 3. Results and discussion

The physicochemical examination of oils is mainly made from the stand point of their edible as well as industrial uses. The quality of vegetable oils can be judged by the knowledge of their physical and chemical characteristics.

### 3.1. Percentage oil yield

The percentage yield of hexane-extracted oil content from different varieties of soybean (Bovender special, Foster and F-8827) seeds was found to be in the range of 15.85–19.49%. A significant variation was observed for oil content among the soybean seed samples analyzed. The oil content (19.84%) was considerably higher for F8827 variety and lower (15.85%) in the seeds of variety Bovender special. The oil content is a quantitative trait whose variability is conditioned with genetic difference between the varieties (Vrataric et al., 1994; Vollmann et al., 2000). The oil content in soybean seeds from different varieties, ranging from 15.85–19.49%, was comparable with the findings of (Maestri et al., 1998) and (Al-Kahtani, 1989) who reported the oil content in different genotypes of soybean to be 198 to 267 g/kg and 15.84–21.35%, respectively. The range of oil content of soybean seeds, recorded in the present work, was also in close agreement with that reported by Anjum[19] for different soybean varieties. The present oil content of soybean was lower as compared with two other oilseed crops: *Cucurbita pepo* (35%) and sunflower hybrids (36–39%) investigated by (Younis et al., 2000) and (Shahbaz and Hassan, 2000), respectively.

### 3.2. Analysis of soybean seed residues

Analysis of oil seed residues revealed a high protein content for the seeds, ranging from 41.675% to 45.645%. Bovender special variety had the highest protein content, while the Soybean variety F-8827 contained the least amount of protein. The protein content investigated presently was comparable (40.57–47.60%) with that reported by (Al-Kahtani, 1989) but higher than (37.6–38%) that investigated by (Yoshida et al., 2006). Compared with some conventional oil seed crops, the protein content of the presently analyzed soybean samples was higher than those of safflower (20–22%), sunflower (16.5–19.6%) and cotton seed (19.40%) as reported in the literature (Pritchard, 1991). As expected, the oilseed samples high in oil content were generally found to be lower in protein, fiber and ash contents. Interestingly soybean based protein is readily digestible and is primarily composed of edestin and albumin, which are the key components of human blood plasma. The crushed soybean by product is suitable for animal feed and as human staple because of the spectrum of amino acids. The analysis showed the soybean meal (after oil recovery) to be a good source of protein with potential to be used in poultry feed as a cheaper source of calories (Anwar et al., 2002).

Fiber and ash contents of soybean seeds samples were found to be in the range of 6.6–7.6%and 5.5–6.9%, respectively. There was no significant variation in fiber and ash contents of soybean seeds among the varieties tested. Ash content was comparable to the previous findings for soybean varieties which were 5.81–6.54% (Al-Kahtani, 1989). Fiber and ash contents in the present analysis were also comparable to that of *Moringa* seeds (6.8–7.5% and 5.9–7%) reported by (Anwar et al., 2005b) as well as to those of most of the vegetable oilseeds reported earlier by (Pritchard, 1991). The crude fiber is an indication of the relative digestibility and bulkiness of foods. The crude fiber is indigestible matter in food stuff, it is made up of cellulose, lignin and nitrogenous matter. Feeds that are rich in fiber are less digestible and therefore, less nutritious than those lower in fiber according to the findings of (Anjum, 1993).

### 3.3. Moisture contents

Percentage of moisture in seeds of different varieties of soybean (Bovender special, Foster and F-8827) was found to be in the range of 8.4–10.2% as shown in Table 1. These values investigated in the present study were closer to that of soybean seed (5.13–7.68%) reported by (Al-Kahtani, 1989) and for soybean and *Xyopia aehihopica* reported by (Yoshida et al., 2006) and (Barminas et al., 1999). The so called critical moisture level for the beginning of rapid spoilage is relatively higher in seeds of low oil contents and relatively low for high oil content seeds. Moisture content in the seeds depends upon the maturity and quality of seeds. The moisture contents of seed determine the ability of all seeds to be stored well.

### 3.4. Physicochemical parameters of oils

The oil color in terms of yellow and red units for different samples of soybean seed oils were in the range of 40–50 Y and 4.0–5.3 R. The intensity of the color of vegetable oils is linked with the presence of different pigments such as chlorophyll and carotenoids which are effectively removed during the processing (de-gumming, refining and especially bleaching) step of oil. The vegetable oils with low color values are better for edible and domestic applications (Table 2).

Values determined for the different physico-chemical attributes of oils were as follows; iodine value (119–128), refractive index (1.4590–1.468) density (0.8698–0.8712 g/cm$^3$ at 36 °C), FFA (0.39–0.67%), unsaponifiable matter (0.42–0.74%), and saponification number (181–187 of KOH/g of oil).

Values for refractive index are comparable with the findings of (Kyenge et al., 2012) who reported RI of 1.470 at 32 °C for soybean oil. Density and refractive indices of investigated oils in the present analysis were in close agreement with some other oilseed crops: *Maurritia flexuosa* oil (0.86 g/cm$^3$ at 36 °C and

**Table 1** Percentage (±SD) of oil and other constituents soybean seeds.

| Constituent (%) | Soybean variety | | |
|---|---|---|---|
| | Bovender special | Foster | F-8827 |
| Oil | 15.85 ± 0.3$^a$ | 16.74 ± 0.25$^b$ | 19.49 ± 0.32$^c$ |
| Fiber | 6.60 ± 0.24$^a$ | 7.10 ± 0.25$^b$ | 7.60 ± 0.23$^b$ |
| Moisture | 10.20 ± 0.22$^c$ | 9.50 ± 0.19$^b$ | 8.40 ± 0.16$^a$ |
| Crude protein | 45.64 ± 2.60$^a$ | 43.66 ± 2.20$^a$ | 41.67 ± 2.07$^a$ |
| Ash | 5.50 ± 0.36$^a$ | 6.20 ± 0.32$^a$ | 6.90 ± 0.26$^b$ |

Values are mean ± SD of three samples from each soybean variety, analyzed individually in triplicate.

**Table 2** Physico-chemical characteristics (±SD) of soybean seed oils.

| Constituent | Soybean variety | | |
|---|---|---|---|
| | Bovender special | Foster | F-8827 |
| Free fatty acids (% as oleic acid) | 0.67 ± 0.03$^{c}$ | 0.45 ± 0.02$^{b}$ | 0.39 ± 0.19$^{a}$ |
| Refractive index (40 °C) | 1.468 ± 0.07$^{a}$ | 1.4673 ± 0.07$^{a}$ | 1.4590 ± 0.07$^{a}$ |
| Density (g/cm$^{3}$) 36 °C | 0.8701 ± 0.05$^{a}$ | 0.8712 ± 0.05$^{a}$ | 0.8698 ± 0.05$^{a}$ |
| Iodine value (g of I/ 100 g of oil) | 119.00 ± 0.05$^{a}$ | 124.0 ± 0.07$^{b}$ | 128.0 ± 0.08$^{c}$ |
| Saponification value (mg of KOH per g of oil) | 187.00 ± 0.05$^{a}$ | 184.0 ± 0.08$^{b}$ | 181.00 ± 0.05$^{a}$ |
| Unsaponifiable matter (%) | 0.60 ± 0.03$^{b}$ | 0.42 ± 0.02$^{a}$ | 0.74 ± 0.04$^{c}$ |
| Color (1-in cell) Red unit | 5.30 ± 0.10$^{b}$ | 4.20 ± 0.15$^{a}$ | 5.30 ± 0.14$^{b}$ |
| Yellow unit | 50.0 ± 1.30$^{c}$ | 42.0 ± 1.60$^{b}$ | 40.0 ± 1.20$^{a}$ |

Values are mean ± SD of three samples from each soybean variety, analyzed individually in triplicate.

1.46 at 40 °C) investigated by (Albuquerque et al., 2005) and cotton seed oil (1.4580–1.4660) reported by (Rossell, 1991). The saponification number (181–187 mg of KOH/g of oil) of soybean seed oil was almost comparable with the findings of (Kyenge et al., 2012) who reported the saponification value of soybean oil as 189 mg of KOH/g of oil. The values are comparable with some other oils like hemp seed oil (184–190 of KOH/g of oil) and *Moringa* oil (177.29–184.1 of KOH/g of oil) reported by (Anwar et al., 2006) and (Anwar et al., 2005b), respectively.

The unsaponifiable matter (0.6–0.74%) of the investigated soybean oils in this analysis was close to that of soybean oil 0.55–0.95% as reported by (Al-Kahtani, 1989) and that of *Moringa* oil (0.6–0.75%) (Anwar et al., 2005b), however, less than that of *Salicornia bigelovii* seed oil (1.4–1.78%) (Anwar et al., 2002).The statistical analysis revealed a significant variation in saponification value and unsaponifiable matter among varieties of soybean oil. The iodine value of the oils (119–128 g of I/100 g of oil)) was comparable with (128.4) that reported by (Kyenge et al., 2012) for soybean oil but significantly higher than Byriti oil (77.2 g of I/100 g of oil), mango kernel oil (40 g of I/100 g of oil), chili (*Capsicum anum*) oil (36 g of I/100 g of oil), olive oil (81.8 g of I/100 g of oil) but less than sunflower oil (130.2 g of I/100 g of oil) as reported by (Diaz et al., 2006).

It is well known that the iodine value is a measure of degree of unsaturation (double bond content) in vegetable oils principally oleic, linoleic and linolenic acids. High iodine value means that oil is highly unsaturated and could be used for edible purposes and or for industrial applications such as in paints varnishes, and emulsion formulations. The statistical analysis showed that iodine values of soybean oils were significantly ($p < 0.05$) varied within the varieties.

Free fatty acid contents of oil (0.39–0.67%) were higher than those already reported (0.07–0.32%) by (Al-Kahtani, 1989) for soybean oil, olive oil (0.28%) and sunflower (0.12%) (Diaz et al., 2006), crude palm olein (5.0%) and crude palm stearin (5.0%) (Rossell, 1991). A very low value of free fatty acid content as determined for soybean seed oil of different varieties in the present analysis is an indicative of good quality and hydrolysis status of the crude oil (McGinely, 1991).

The soybean oil from different varieties (Bovender Special, Foster and F-8827) also exhibited a good oxidative state as indicated by a low proxide values (1.8–2.64 meq/kg of oil) (Table 3). Peroxide value reflects the magnitude of primary oxidation products such as peroxides. Peroxide values of the investigated oils in the present analysis were less than the findings of (Al-Kahtani, 1989) who reported the peroxide value of soybean seed oils from Saudi Arabia to be in the range of 1.9–5.40%. Such differences can be attributed to ecological and genetic variations. The values were also lower than those of sunflower oil (7.9 meq/kg) and olive oil (10 meq/kg) reported by (Diaz et al., 2006). The specific extinctions at 232 and 270 nm, which represent the oxidative deterioration and purity of oils, were 1.51–1.91 and 0.40–0.65, respectively. A good oxidation state of soybean oils of different varieties

**Table 3** Oxidation state (±SD) of soybean seed oils.

| Constituent | Soybean variety | | |
|---|---|---|---|
| | Bovender special | Foster | F-8827 |
| Conjugated dienes $\varepsilon^{1\%}_{1cm}$ ($\lambda$232) | 1.50 ± 0.03$^{a}$ | 1.91 ± 0.03$^{b}$ | 1.87 ± 0.03$^{b}$ |
| Conjugated trienes $\varepsilon^{1\%}_{1cm}$ ($\lambda$270) | 0.60 ± 0.09$^{b}$ | 0.65 ± 0.02$^{b}$ | 0.41 ± 0.01$^{a}$ |
| Peroxide value (meq kg$^{-1}$ of oil) | 1.80 ± 0.09$^{a}$ | 1.98 ± 0.09$^{a}$ | 2.64 ± 0.12$^{b}$ |

Values are mean ± SD of three samples from each soybean variety, analyzed individually in triplicate.

**Table 4** Percentage (±SD) of fatty acids in soybean seed oils.

| Fatty acid (%) | Soybean variety | | |
|---|---|---|---|
| | Bovender special | Foster | F-8827 |
| Palmitic acid ($C_{16:0}$) | 11.0 ± 0.16$^{b}$ | 10.01 ± 0.14$^{a}$ | 13.50 ± 0.10$^{c}$ |
| Stearic acid ($C_{18:0}$) | 3.02 ± 0.06$^{a}$ | 3.90 ± 0.04$^{b}$ | 4.90 ± 0.07$^{c}$ |
| Oleic acid ($C_{18:1}$) | 22.6 ± 1.22$^{a}$ | 23.02 ± 1.05$^{a}$ | 24.0 ± 1.20$^{a}$ |
| Linoleic acid ($C_{18:2}$) | 51.05 ± 0.10$^{b}$ | 49.03 ± 0.10$^{a}$ | 53.0 ± 0.12$^{c}$ |
| Linolenic acid ($C_{18:3}$) | 7.02 ± 0.42$^{a}$ | 6.50 ± 0.44$^{a}$ | 8.00 ± 0.38$^{b}$ |

Values are mean ± SD of three samples from each soybean variety, analyzed individually in triplicate.

**Table 5** Concentration (±SD) of tocopherols (α, β and δ) in soybean seed oils.

| Tocopherol (mg/kg) | Soybean variety | | |
|---|---|---|---|
| | Bovender special | Foster | F-8827 |
| α | 90.7 ± 1.40[c] | 80.8 ± 2.0[b] | 66.5 ± 0.99[a] |
| γ | 987.2 ± 12.9[b] | 907.5 ± 4.5[a] | 1011.9 ± 10.2[c] |
| δ | 400.7 ± 6.7[a] | 411.5 ± 5.9[a] | 399.8 ± 5.21[a] |

Values are mean ± SD of three samples from each soybean variety, analyzed individually in triplicate.

in the present analysis might be ascribed to higher levels of tocopherol antioxidants which retarded lipid oxidation (Anwar, 2004).

The fatty acid composition of soybean oils from different varieties (Bovender special, Foster and F-8827) is given in Table 4. The contents of saturates such as palmitic acid ($C_{16}$:0) and stearic acid (C18:0) in the tested soybean oils ranged between 10.01–13.5% and 3.02–4.9%, respectively. These values were slightly lower than the findings of (Al-Kahtani, 1989) who investigated 9.18–12.54% and 4.33–5.23% for palmitic and stearic acids, respectively. The oils also contained an appreciable amount of oleic acid 22.6–24.0%. Linoleic acid (C18:2) was the predominant fatty acid with its content varying between 49.03% and 53.02%.The detected level of C18:2 of soybean oils is slightly lower than that investigated by (Al-Kahtani, 1989) who reported 47.81–58.04% linoleic acid for soybean seed oils from Saudi Arabia. The amount of another valuable polyunsaturated fatty acid namely linolenic acid (C18:3) varied from 6.50% to 8.00%.These amounts are quite comparable with the findings of (Al-Kahtani, 1989) 4.7–6.26% from Saudi Arabia. A small difference can be attributed to the genetic variability among the varieties and the ecological conditions of the countries. The composition of most of the fatty acids varied non-significantly ($p > 0.05$) among oils of the tested soybean varieties. The concentrations of major fatty acids, investigated in the present study were in close agreement with those reported by (Anjum, 1993) for soybean seed oils from Pakistan.

Soybean oil is a rich source of tocopherols (vitamin E) as reported by (Quek et al., 2007). The contents of tocopherols (α, γ and δ) in different varieties (Bovender special, Foster and F-8827) of soybean seed oils ranged from 66.50 to 90.74 mg/kg, 907.55–1011.87 mg/kg and 399.81–411.50 mg/kg, respectively (Table 5). The concentration of α tocopherol was slightly lower than that reported in the literature (152 mg/kg) while that of γ and δ tocopherols were higher than that given in the literature (494 and 182 mg/kg, respectively) according to (Gliszczyńska-Świgło et al., 2007) for some Polish soybean varieties. The variations may be due to the genetic and ecological variations.

The contents of α, γ, and δ in the present analysis were higher than that of hemp seed oil reported by (Anwar et al., 2006) but the content of α tocopherols was less than that of *S. bigelovi* and safflower oils by (Anwar et al., 2002). The content of α-tocopherols was less but γ and δ were higher than that of *Moringa* oil as studied by (Anwar et al., 2005b). Of the tocopherols, alpha homolog showed the highest vitamin-E activity, where as the δ-isomer exhibited potent antioxidant activity. The analysis revealed the soybean oil to be an exceptional source of δ-tocopherol.

## 4. Conclusion

The tested three varieties of soybean were found to be quite different on the basis of variation in most of the important physico-chemical characteristics. The difference may be attributed to their different genetic properties. Soybean variety F-8827 showed better nutritional status due to the higher quantity of essential fatty acids like linolenic acid and linoleic acid and tochopherols as compared to other two varieties selected. Data of this study might be useful for oil chemists and breeders for further investigations. At the same time it might be helpful for local soybean growers/farmers and oil producers for the selection of the appropriate soybean variety for cultivation and industrial processing.

## References


Albuquerque, M.L.S., Guedes, I., Alcantara Jr., P., Moreira, S.G.C., Barbosa Neto, N.M., Correa, D.S., Zilio, S.C., 2005. Characterization of Buriti (*Mauritia flexuosa* L.) oil by absorption and emission spectroscopies. J. Braz. Chem. Soc. 16, 1113–1117.

Al-Kahtani, H., 1989. Quality of soybean and their crude oils in Saudia Arabia. J. Amer. Oil Chem. Soc. 66 (1), 109–113.

Amos-Tautua, Martin, W.B., Adebayo, O.O., 2013. Physicochemical properties and fatty acid profiles of crude oil extracts from three vegetable seeds. Pak. J. Nutr. 12 (7), 647–650.

Anjum, J.I., 1993. Characterization of oil and oil cakes extracted from newly evolved soybean (Glysine max) varieties (Swat-84, Williams–82) (M.Sc. thesis). Department of Chemistry & Biochemistry, University of Agriculture Faisalabad, Pakistan.

Anonymous, 1994. Vegetable Soybean. Grow meat in your fields. Oil seeds Program, NARC, Pakistan Agricultural Research Council (PARC), Islamabad, Pakistan.

Anonymous, 2015. 16 Surprising Sources of Protein. <http://www.fitday.com/fitness-articles/fitness/16-surprising-sources-of-protein.html>. (Accessed on 09-02-2015).

Anwar, F., 2004. Analytical characterization of some non-conventional oil seed for their commercial exploitation (M. Phil. Thesis). National Center of Excellence in Analytical Chemistry. University of Sindh, Jamshoro, Pakistan.

Anwar, F., Anwer, T., Mahmood, Z., 2005a. Methodical characterization of rice (*Oryza sativa*) bran oil from Pakistan. Grasas Aceites 56, 125–134.

Anwar, F., Mohammad, N.A., Othman, F., Saari, N., 2011a. Inter-varietal variation in the composition of seeds and seed oils from winter melon [*Benincasa hispida* (Thunb.) Cogn.] fruit. Pak. J. Bot. 43, 2029–2037.

Anwar, F., Rashid, U., Mahmood, Z., Iqbal, T., Sherazi, T.H., 2011b. Inter-varietal variation in the composition of Okra (*Hibiscus esculentus* L.) seed oil. Pak. J. Bot. 43, 271–280.

Anwar, F., Bhanger, M.I., Nasir, M.K.A., Ismail, S., 2002. Analytical characterization of *Salicornia bigelovii* seed oil cultivated in Pakistan. J. Agric. Food Chem. 50, 4210–4214.

Anwar, F., Ashraf, M., Bhanger, M.I., 2005b. Interprovenance variation in the composition of *Moringa oleifera* oilseeds from Pakistan. J. Am. Oil Chem. Soc. 82, 45–51.

Anwar, F., Latif, S., Ashraf, M., 2006. Analytical characterization of hemp (*Cannabis sativa*) seed oil from different agro-ecological zones of Pakistan. J. Am. Oil Chem. Soc. 83, 323–329.

AOCS, 1997. Official and Recommended Practices of the AOCS, 5th ed. American Oil Chemist's Society Press, Champaign, USA.

AOAC, 1990. Official methods of the analysis of the Association of Official Analytical Chemists. 14th ed. Published by the AOACS Inc., North 19th street, suit 210 Arlington, Virginia, 22209, USA.

Barminas, J.T., James, M.K., Abubakar, U.M., 1999. Chemical composition of seeds and oil of *Xylopia aethiopica* grown in Nigeria. Plant Foods Hum. Nutr. 53, 193–198.

Clemente, T.E., Cahoon, E.B., 2009. Soybean oil: genetic approaches for modification of functionality and total content. Plant Physiol. 151 (3), 1030–1040.

Diaz, M.F., Hernandez, R., Martinez, G., Vidal, G., Gomez, M., Fernandez, H., Garces, R., 2006. Comparative study of ozonized olive oil and ozonized sunflower oil. J. Braz. Chem. Soc. 17, 403–407.

FAO, 2013. Trade and Market Division, Food Outlook: Oilseeds, Oils and Meals, < http://www.fao.org/fileadmin/templates/est/COMM_MARKETS_MONITORING/Oilcrops/Documents/Food_outlook_oilseeds/NOVEMBER_2013.pdf > (Accessed on 01-10-2014).

Gliszczyńska-Świgło, A., Sikorska, E., Khmelinskii, I., Sikorski, M., 2007. Tocopherol content in edible plant oils. Polish J. Food Nutr. Sci. 4 (A), 157–161.

Hudson, K., 2012. Soybean oil-quality variants identified by large-scale mutagenesis. Int. J. Agron. http://dx.doi.org/10.1155/2012/569817.

International Union of Pure and Applied Chemistry (IUPAC), 1987. Standard Methods for the Analysis of Oils, Fats and Derivatives, 7th revised and enlarged Ed., Paquot, C., Hautfenne, A., Eds., Blackwell Scientific Publications, London.

ISO, 1977. Oil seed Residue: determination of Total Ash. International Organization for Standardization, Geneva, Standard No. 749.

ISO, 1981. Animal Feeding Stuff: Determination of Nitrogen and calculation of Crude Protein Content, International Organization for Standardization, Geneva, Standard No. 5983.

Kyenge, B.A., Anhwange, J.T., Ageh, G., Igbum, O., 2012. Comparative analysis of soybean seed oil modified alkyd resin and epoxidized soybean seed oil modified alkyd resin. Int. J. Mod. Org. Chem. 1 (2), 66–71.

Ma, L., Li, B., Han, F., Yan, S., Wang, L., Sun, J., 2015. Evaluation of the chemical quality traits of soybean seeds, as related to sensory attributes of soymilk. Food Chem. 173, 694–701.

Maestri, D.M., Labuckas, D.O., Guzman, C.A., Giorda, L.M., 1998. Correlation between seed size, protein and oil contents, and fatty acid composition in soybean genotypes. Grasas Aceites 49, 450–453.

Mao, V., 1995, Biodiesel Kinetics: One-Phase Base-Catalyzed Methanolysis of Soybean Oii Using Tetrahydrofuran as Cosolvent (M.A.Sc. thesis). Department of Chemical Engineering and Applied Chemistry, University of Toronto, Canada.

McGinely, L. 1991. Analysis and quality control for processing and processed fats. In: Analysis of Oilseeds, Fats and Fatty Foods.

Messina, M.J., Loprinzi, C.L., 2001. Soy for breast cancer survivors: a critical review of the literature. J. Nutr. 131, 3095s–3108s.

Potter, S.M., Baum, J.A., Teng, H.Y., Stillman, R.J., Shay, N.F., Erdman, J.W., 1998. Soy protein and isoflavones: their effects on blood lipids and bone density in postmenopausal women. Am. J. Clin. Nutr. 68, 1375s–1379s.

Pritchard, J.L.R., 1991. Analysis and properties of oilseed. In: Rossell, J.B., Pritchard, J.L.R. (Eds.), Analysis of oilseeds, fat and fatty acid. Elsevier Applied Science, New York, pp. 39–102.

Quek, S.Y., Chu, B.S., Baharin, B.S., 2007. Commercial extraction of vitamin E from food sources. In: Preedy, V.R., Watson, R.R. (Eds.), The Encyclopedia of Vitamin E. Cromwell Press, Trowbridge, UK, pp. 140–152.

Rossell, J.B., 1991. Vegetable oils and fats. In: Rossell, J.B., Pritchard, J.L.R. (Eds.), Analysis of Oilseeds, Fats and Fatty Foods. Elsevier Applied Science Publishers, New York, USA, pp. 308–319.

Shahbaz, A., Hassan, F., 2000. Oil yield and fatty acid composition of spring sunflower. Pak. J. Biol. Sci. 3 (12), 2063–2064.

United States Department of Agriculture (USDA): World Agricultural Production. 2015. Circular Series WAP 8–15.

Vollmann, J., Fritz, C.N., Wagentrist, H., Ruckenbauer, P., 2000. Environmental and genetic variation of soybean seed protein content under Central European growing conditions. J. Sci. Food Agric. 80, 1300–1306.

Vrataric, M., Sudaric, A., Jankovic, M., 1994. Yield and quality of grain of some domestic and foreign soybean cultivars in agroecological conditions of eastern Slavonia. Prehrambeno-Tehnoloska I Biotehnoloska Revija 32, 157–161.

Wrolstad, R.E., 2003. Analysis of tocopherols and tocotrienols. In: Wrolstad, R.E. (Ed.), Current Protocols in Food Analytical Chemistry. John Wiley & Sons, U.K.

Yaklich, R.W., Vinyard, B., Camp, M., Douglass, S., 2002. Analysis of seed protein and oil from soybean Northern and Southern Region uniform tests. Crop Sci. 42, 1504–1515.

Yoshida, H., Kanrei, S., Tomiyama, Y., Mizushina, Y., 2006. Regional characterization of tocopherols and distribution of fatty acids within soybean seeds (*Glycine max* L.). J. Food Lipids 13, 12–26.

Younis, Y.M.H., Ghirmay, S., Al-Shihry, S.S., 2000. African *Cucurbita pepo* L.: properties of seed and variability in fatty acid composition of seed oil. Phytochemistry 54, 71–75.