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Polyunsaturated versus saturated index as a reference for determining the quality of edible seed oils extracted from locally cultivated oil seeds of Ethiopia

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ABSTRACT: Consumption of edible oils is increasing tremendously regardless of their high prices. As a result, the global production of vegetable oils has also been growing constantly. This may be related to global population growth and associated increasing demands of the consumers. In this particular work, ten crude food seed oils of Ethiopian origin were extracted in our lab and analyzed for their chemical composition by gas chromatography mass spectroscopy (GC-MS). To check their food quality, P/S index of all laboratory extracted seed oils were compared. The fatty acids (FAS) concentrations of the oils were determined using decanoic acid methyl ester as internal standard and linoleic acid ethyl ester as a reference. The analysis results indicate that the P/S index for standard crude oils were 8.19 for safflower (SFF), 2.58 for sesame (SES), 4.37 for Niger (NIG), 5.50 for Linseed (LNS), 2.04 for peanut (PNT), 5.13 for Ethiopian mustard (ETM) 4.25 for sunflower (SUF), 0.09 for palm (PAL), 3.14 for soybean (SOB), and 1.56 for cotton (COT). The maximum and minimum P/S index were obtained for SFF oil (8.19) and PAL oil (0.09), respectively. Analysis of the mixtures of commercial LNS and PAL oils indicate the improvement of the food quality of the PAL seed oil by mixing them in an appropriate ratio.

Keywords/Phrases: Seed oil, GC-MS, P/S index, food quality

INTRODUCTION

Vegetable oils are fats that have been extracted from plants seeds and used for cooking, as a fuel and as an ingredient for soaps and personal care products. Edible seed oils are known for their complex mixtures of different organic compounds such as triglycerides, free fatty acids, phospholipids, and fat-soluble vitamins among others that provide many nutritious and functional components for human health (Technical Committee of the Institute of Shortening and Edible Oils, 2004; Mc Donald *et al*., 2010; Salah and Nofal, 2021). Triglycerides are the major components of vegetable edible oils which cover 95–98% of the total composition, where glycerol is attached to three identical or different fatty acids that account for their structural variations. Some of them are saturated (SFAS) while others are monounsaturated (MUFAS) and polyunsaturated fatty acids (PUFAS). Naturally, unsaturated fatty acids in edible oils contain *cis* double bond (Alimentarius, 1999; Technical Committee of the Institute of Shortening and Edible Oils, 2004; Chowdhury *et al*., 2007; Young *et al*., 2012; Syed, 2016; USDA, 2021).

SFAs have the capacity to stick tightly to cell membranes (Te Morenga and Montez, 2017) and those with carbon number 12 (C- 12) (**1**), carbon number 14 (C-14) (**2**), and carbon number 16 (C-16) (**3**) increase low-density serum lipoprotein (LDL) (bad cholesterol (Nicolosi, 1997). In the contrary, stearic acid (**4**) (C-18) has no impact on LDL (Grande *et al*., 1970; Mensink 2005). Consumption of MUFAS beyond the recommended limit may lead to diastolic and systolic blood pressure, and coronary heart disease (CHD) (Jakobsen *et al*., 2009) and intake of partially hydrogenated vegetable oils enhance CHD risk factors (Nestel *et al*., 1992; Kummerow, 2009).

Global production of vegetable oils has been growing constantly due to population growth and associated increasing demands of the consumers. Global oilseed consumption is forecasted to rise 3% in 2021/22 (Syed, 2016).

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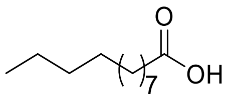
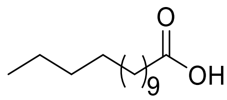
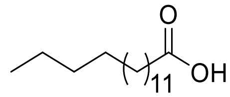


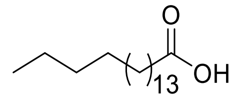
Lauric acid (C12:0)
(**1**)



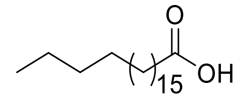
Myristic acid (C14:0)
(**2**)



Palmitic acid (C16:O)
(**3**)

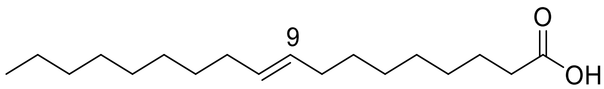


Stearic acid (C18:0)
(**4**)

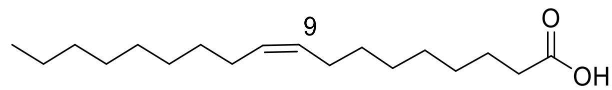


Arachidic acid(C20:0)
(**5**)

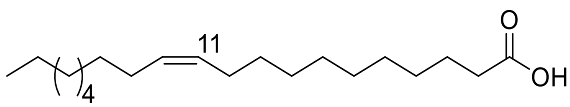
Saturated fatty acids (SFAs)



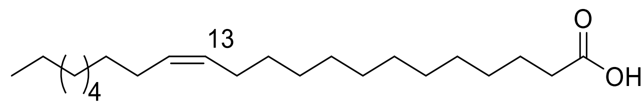
Elaidicacid (C18:1n-9)
(**6**)



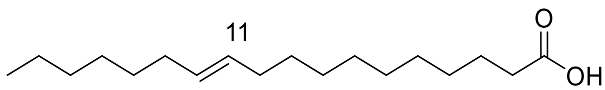
Oleic acid acid (C18:1n-9)
(**7**)



Gondoic acid(C20:1 n-9)
(**8**)

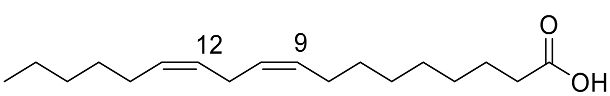


Erucic acid (C22:1n-9)
(**9**)

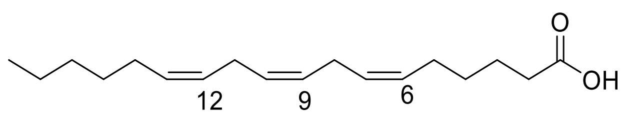


Vacenic acid (C18:1n-7)
(**10**)

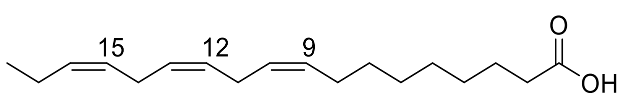
Monounssaturated fatty acids (MUFAs)



Linoleic acid (18:2n-6)
(**11**)



Gamma-Linolenic acid (C18:3n-6)
(**12**)



Alpah-Linolenic acid (C18:3n-3)
(**13**)

Pollyunsaturated fatty acid (PUFAs)

Figure 1: Common fatty acids (SFA, MUFA and PUFA) with their chemical structures. 'n' stands for the position of the first double bond from omega side (Young et al., 2012).

Butter (milk fats) contains fatty acids such as myristic (**2**), palmitic (**3**), stearic (**4**), and oleic (**7**) acids. The content of the FAs are highly affected by geographical areas, the breed type, and physiological factors of the animals (Ozcan *et al*., 2016; Zhao *et al*. 2018). *Cis*-oleic acid (**7**) (C18:1, n-9), is the principal FA in butter used as a source of energy and believed to be beneficial in decreasing levels of the low-density lipoprotein (LDL) (bad cholesterol) in blood (Grundy, 1994).

Adulteration of oils and butters is one of the problems that contribute towards lowering their individual quality. This may include admixing of useless or cheap items to useful edible items so as to increase the amount and get more profit by compromising the quality (Bell and Gillatt, 1994). Cold pressed oils and refined oils or more expensive oils and fats can be replaced by the capitalist with cheap oils (Jee, 2002) to increase the profit. It is difficult to check adulteration without careful experimentation that requires advanced techniques. In this regard, attempts are made to use the ratio of major fatty acids as points of comparison and drawing conclusions (Sharma and Singhal, 1996; Fsaha and Estifanos, 2016; Yadav, 2018). Hence, this study was aimed at investigating the fatty acid compositions of locally marketed edible seed oils and analyzing their food quality.

Experimental

Sample Collection

The ten edible oil seed samples namely safflower (SFF), sesame (SES), Niger (NIG), Ethiopian mustard (ETM), Linseed (LNS), peanut (PNT), sunflower (SUF), palm (PAL), soybean (SOB), and cotton (COT) were purchased from different market places in Addis Ababa, Ethiopia. Commercially available PAL and LNS oils were also purchased from the local markets.

Extraction of Oils

The oil seeds were carefully sorted out from their impurities, and ground using an electrical grinder until it forms uniform fine powder. From each sample, 50g ground oil seed was weighed on an electronic balance and placed in a thimble and carefully placed in a Soxhlet extractor. Hexane (150 mL) was added into a distilling flask (250 mL) which was fitted to the Soxhlet extractor and a condenser. The flask was heated at a refluxing temperature on heating mantle for 4h, and the mixture containing the seed oil was filtered and concentrated using a rotary evaporator. The crude seed oil was weighed, labeled, and stored in a refrigerator until further use.

Preparation of Fatty Acid Methyl Esters (FAMEs)

The seed oil (1g) transferred into 50 mL round bottom flask was warmed up for 10 minutes at 50 °C using water bath. After adding 6.0 mL of methanolic 2% KOH solution and fitting the round bottom flask to a condenser the whole content was heated at 70 °C for 1h using water bath under continuous stirring and then the round bottom flask was allowed to cool to room temperature. Saturated sodium chloride solution (2 mL) was added to the cooled mixture and transferred into a separatory funnel followed by addition of 30 mL hexane. The organic layer was separated and dried over anhydrous sodium sulphate and concentrated on a rotary evaporator, weighed, labeled and stored in a refrigerator until analyzed by GC-MS (Sampath, 2009; Fsaha and Estifanos, 2016). All the FAME samples were processed in triplicate.

Solvents, Reagents and GC-MS Analysis

All solvents and reagents used were of analytical grade which were purchased from Fisher Scientific (UK). The fatty acids decanoic acid methyl ester (internal standard) and linoleic acid ethyl ester (reference) were purchased from Sigma-Aldrich, (Germany). Samples were analyzed using GC-MS, Agilent Technologies 7820A GC and 5977E MSD systems equipped with auto sampler at Addis Ababa University. Chromatographic separations were carried out using DB-1701 column with 30 m length, 0.25 mm internal diameter and 0.25 µm column phase thickness. Injection mode was split-less, helium was a carrier gas and 1µl sample was injected to the inlet heated to 275°C. Initial oven temperature was 100 °C with 2 min hold time then heated to 220 °C with ramp 15°C/min and 3°C/min to 240°C. Each sample was prepared and injected in triplicate and the results were expressed as mean ± standard deviation (M ± STD) (Fsaha and Estifanos, 2016).

Preparation of Decanoic Acid Methyl Ester as Internal Standard

Esterification of decanoic acid was carried out using Fischer esterification technique (Fsaha and Estifanos, 2016). One gram decanoic acid was weighed and dissolved in 10 mL methanol followed by careful addition of 1 mL conc. H_2SO_4 to the mixture in 50 mL round bottom flask. The mixture was heated at 70 °C for 1h in water bath. The mixture was then allowed to cool to room temperature. The product was diluted with 30 mL deionized water and transferred into a separatory funnel and extracted with chloroform (3 × 30 mL). The organic phase was rinsed with 30 mL $NaHCO_3$ solution and water. The resulting decanoic acid methyl ester was dried over anhydrous sodium sulphate and concentrated on a rotary evaporator. Decanoic acid methyl ester (5 ppm) was added into each sample before GC-MS analysis as an internal standard (Rouessac and Rouessac, 2000).

Preparation of Mixtures of Palm and Linseed Oils at Different Ratios

The P/S indices of different mixtures (see below) of commercially available PAL and LNS oils were calculated. Pure PAL, pure LNS, PAL/LNS mixed ratios (80:20, 60:40, 50:50, 40:60, and 20:80) were prepared and analyzed using GC-MS with the same experimental conditions as stated above.

RESULTS AND DISCUSSION

Since the quality of seed oils can be assessed by comparing their P/S indexes the concentration of each FA present in each seed oil was determined by GC-MS using an internal standard method. The FA concentrations of the samples were calculated by the formula presented as follows.

$$\frac{K_1}{K_{IS}}(RRF) = \frac{C_1 A_{IS}}{C_{IS} A_1}$$

Where K_1= response factor of reference (Linoleic acid ethyl ester), K_{IS}= response factor of internal standard (Decanoic acid methyl ester), C_{IS}= concentration of internal standard, A_{IS}=peak area of internal standard, A_1=peak area of the reference, C_1= concentration of the reference, RRF=Relative Response Factor.

$$C_i = \frac{C_{IS} \times RRF \times A_i}{A_{IS}}$$

Where C_i= concentration of individual FAME, and A_i= Peak area of the FAME.

$$\%W/W = \frac{C_i \times 100}{mass\ of\ sample\ taken}$$

Based on the GC-MS analysis report and using the above equations, the following results were obtained. The normalized fatty acid (FA) concentrations and P/S index values of the analyzed samples are shown in the Tables below.

Table 1: Percent relative concentrations of fatty acids of the experimental seed oils.

	Mean ± SD									
	SFA					MUFA			PUFA	
Type of oil with its code*	**C12:0 Dodecanoic/ Lauric acid**	**C14:0 Tetradecanoic/ Myristic acid**	**C16:0 Hexadecanoic/ Palmtic acid**	**C18:0 Octadecanoic/ Stearic acid**	**C20:0 Arachidic acid/ Eicosanoic acid**	**C18:1 9-Octadecenoic/ Oleic acid**	**C20:1 11-Eicosenoic acid/ Gondoic**	**C22:1 13-Docosenoic/ Erucic**	**C18:2 9,12-Octadienoic/ Linoleic acid**	**C18:3 9,12,15-Octadecatrienoic/ Linolenic acid**
SF	-	-	6.97 ± 0.16	3.00 ± 0.25	-	9.10 ± 0.86	-	-	80.94 ± 0.63	-
SUF	-	-	6.76 ± 0.64	7.47 ± 0.46	-	21.47 ± 0.41	-	3.82 ± 0.02	60.48 ± 0.59	-
SES	-	-	12.02 ± 0.57	5.73 ± 0.03	-	36.36 ± 0.46	-	-	45.89 ± 0.23	-
NIG	-	-	8.93 ± 0.30	8.30 ± 0.26	-	7.43 ± 0.44	-	-	75.34 ± 0.51	-
LND	-	-	5.97 ± 0.55	7.05 ± 0.50	-	15.30 ± 0.91	-	-	15.19 ± 0.65	56.48 ± 0.65
PNT	-	-	9.12 ± 0.44	4.98 ± 0.32	1.39 ± 0.14	52.89 ± 0.42	-	-	31.62 ± 0.28	-
ETM	-	-	11.66 ± 0.33	-	-	12.35 ± 0.29	16.17 ± 0.75	-	36.40 ± 0.63	23.42 ± 0.37
PAL	17.67 ± 0.60	9.89 ± 0.32	27.33 ± 0.01	4.22 ± 0.07	-	35.46 ± 0.54	-	-	5.43 ± 0.18	-
SOB	-	-	11.34 ± 0.6	6.72 ± 0.03	-	25.12 ± 0.05	-	-	50.78 ± 0.41	6.04 ± 0.35
COT	-	1.77 ± 0.07	27.94 ± 0.6	4.25 ± 0.09	-	15.86 ± 0.57	-	-	51.95 ± 0.15	-

Where SFF (safflower), SES (sesame), NIG (Niger), LND (linseed), PNT (peanut), ETM (Ethiopian mustard), SUF (sunflower), PAL (palm), SOB (soybean), COT (cotton)

The analysis results shows that palmitic acid (**3**) was the major saturated fatty acid (SFA) (except in SUF and LNS) followed by stearic acid (**4**), except in PAL oil where lauric acid (**1**) was the second highest. In addition, less common SFAS such as arachidic (**5**) (in PNT), **1** and myristic (**2**) (in PAL) and **2** (in COT) were detected. Oleic acid (**7**) was the major MUFA in all analyzed oils except in ETM in which gondoic acid (**8**) was the higher one. Erucic acid (**9**) was only detected in SUF oil. Linoleic acid (**11**) was the major PUFA in all analyzed oil samples except in LNS where linolenic acid (**12**) was the major component. Besides, significant amount of **12** was detected in ETM and SOB oils. Interestingly stearic acid (**4**) was not detected in PNT oil.

The relationship between PUFA and SFA explained in terms of P/S index is a crucial tool to determine the nutritional quality of edible oils where oils with P/S index values greater than one can be considered to have nutritional value for human body and beneficiary for heart health (Kostik *et al*., 2013). In the analyzed locally grown seed oil samples, the P/S indices range from 0.9 to 8.12 and PAL (0.09) recorded the lowest whereas SFF measured the highest value (**Error! Reference source not found.**).

Table 2: Total fatty acids and P/S index values of the experimental seed oils measured.

Type of oil	Mean ± SD			
	SFA ± SD	MUFA ± SD	PUFA ± SD	P/S indices
SF	9.97 ± 0.21	9.10 ± 0.86	80.94 ± 0.63	8.12
SUF	14.23 ± 0.55	25.29 ± 0.25	60.48 ± 0.59	4.25
SES	17.75 ± 0.30	36.36 ± 0.46	45.89 ± 0.23	2.58
NIG	17.23 ± 0.34	7.43 ± 0.44	75.34 ± 0.51	4.37
LND	13.03 ± 0.40	15.30 ± 0.91	71.67 ± 0.65	5.50
PNT	15.49 ± 0.33	52.89 ± 0.42	31.62 ± 0.28	2.04
ETM	11.66 ± 0.33	28.52 ± 0.52	59.82 ± 0.50	5.13
PAL	59.11 ± 0.25	35.46 ± 0.54	5.43 ± 0.18	0.09
SOB	18.06 ± 0.02	25.12 ± 0.05	56.82 ± 0.38	3.14
COT	33.96 ± 0.38	15.86 ± 0.57	51.95 ± 0.15	1.53

The result of the study of each edible oil is discussed below.

A. *Safflower*

The analysis report showed that safflower (SF) crude oil contains maximum amount of linoleic (**11**) followed by oleic (**7**), palmitic (**3**), and stearic (**4**) acids with 80.94% ± 0.63, 9.10% ± 0.86, 6.97% ± 0.16 and 3.00% ± 0.25, respectively. These findings were in agreement with Codex report (Alimentarius, 1999). The total FA profile indicates that the oil has 80.94% ± 0.63 PUFA, 9.10% ± 0.86 MUFA, and 9.97% ± 0.21 SFA. SF oil has relatively higher content of PUFA (linoleic acid) and low content of SFA. The P/S index was calculated to be 8.12 which is the highest. The high content of linoleic acid (**11**) makes the oil preferable for salad, (https://www.hsph.harvard.edu) and for mass consumption.

B. *Sunflower*

In the sunflower oil (SUF), linoleic acid (**11**) was a major component followed by oleic (**7**), stearic (**4**), palmitic (**3**) and erucic (**9**) acids with the percentage of 60.48% ± 0.59, 2.47% ± 0.41, 7.47% ± 0.46, 6.76% ± 0.64 and 3.82% ± 0.02, respectively. Of the total FA content, 60.48% ± 0.59 was PUFA, 25.29% ± 0.25 was MUFA, and 14.23% ± 0.55 was SFA. The P/S index is calculated to be 4.25 which is one of the highest.

C. *Sesame oil*

The analysis of sesame oil (SES) showed that linoleic acid (**11**) was the major component with 45.89% ± 0.23, followed by oleic acid (**7**) with 36.36% ± 0.46, and then palmitic acid (**3**) with 12.02% ± 0.58 and stearic acid (**4**) with 5.73% ± 0.03. From the total FA profile, concentration of PUFAS was45.89% ± 0.23, while MUFAS was 36.36% ±0.46, and SFAS was 17.75% ±0.3. The P/S index was found to be 2.58. The higher content of PUFA and its P/S index suggests sesame oil is advisable for cooking purposes and might not cause heart related problems (Bharti *et al*., 2017).

D. Niger oil

The Niger oil (NIG) analysis showed that it contains highest amount of linoleic acid (**11**) followed by palmitic (**3**), stearic (**4**) and oleic (**7**) acids with concentrations 75.34% ± 0.55, 8.93 % ± 0.30, 8.30% ± 0.26 and 7.43% ± 0.44, respectively, which has a close agreement with Getinet's report (Getnet and T/Wold, 2006). The total FA composition showed relatively high amount of PUFA with the percentage of 75.34% ± 0.55 followed by SFA with 17.23% ± 0.28, and MUFA with 7.43 % ± 0.44. The P/S index calculated was 4.37. The higher P/S index value, which has a direct relation with high concentration of PUFA and lower concentration of SFA, makes the Niger oil one of the best choices for consumption as it increases the level of good cholesterol and decreases bad cholesterol in the blood.

E.Linseed oil

The fatty acids of linseed (LNSD) oil is composed of linolenic acid (**12**) as a major component followed by oleic (**7**), linoleic **11**), stearic (**4**) and palmitic (**3**) acids with the concentrations of 56.48% ±0.65, 15.30% ±0.91, 15.19% ± 0.65, 7.05% ± 0.50 and 5.97% ±0.0.55, respectively. The total FAs content was 71.67% ±0.65 PUFA, 15.30% ±0.91 MUFA and 13.03% ±0.53 SFA. The calculated P/S index was 5.5 which is in close agreement with Kostik *et al.*, 2013 report. Linseed oil contains high amount of linolenic (omeg-3) (**12**). The higher content of PUFA and the corresponding P/S index value show that linseed oil may play an important role in the regulation of biological functions, prevention and treatment of heart related disease and inflammations (Shapiro and Could, 2003). At the same time, increase in linolenic acid (**12**) concentration may increase oxidation of the double bonds which in turn increases instability of the oil (El-Beltagi *et al.*, 2007).

F.Peanut oil

Peanut (PNT) oil is less common and less consumable in Ethiopia. The analysis report of the Lab extracted peanut oil (PNT) revealed that the oil has high content of oleic acid (**7**) followed by linolenic (**12**), palmitic (**3**), stearic (**4**) and arachidic (**5**) acids with concentrations of 52.89% ± 0.42, 31.62% ± 0.28, 9.12% ± 0.44, 4.98% ± 0.32, and 1.39% ± 0.14, respectively. This finding is in close agreement with the report of Kostik *et al.*, 2013. Of the total fatty acid content MUFA accounts for 52.89% ± 0.42 while PUFS and SFA were31.62% ± 0.28 and 15.49% ± 0.30, respectively. The P/S index was calculated and found to be 2.04.

G. Ethiopian mustard

The Lab extracted ETM oil contains linoleic acid (**11**) as a major component followed by linolenic (**12**), gondoic (**8**), oleic (**7**), and palmitic (**3**) acids with the percentage of 36.40% ± 0.63, 23.42% ± 0.37, 16.17% ± 0.75, 12.35% ± 0.29 and 11.66% ± 0.33, respectively. The total FA contents are 59.82% ± 0.50 PUFA, 28.52% ± 0.52 MUFA, 11.66% ± 0.33 SFA. P/S index of the oil was found to be 5.13. This value is one of the highest among the analyzed oils which indicated that the oil is richer in PUFA.

H. Palm oil

The FA profile of palm oil (PAL) was 35.46% ± 0.54 oleic (**7**), 27.33% ± 0.01 palmitic (**3**), 17.62% ± 0.60 lauric (**1**), 9.89% ± 0.32 myristic (**2**), 5.43% ± 0.18 linoleic (**11**) and 4.22% ± 0.07 stearic (**4**) acids. The total FA composition is59.11% ± 0.25 SFA, 35.46% ± 0.54 MUFA and5.43% ± 0.18 PUFA. The P/S index was found to be 0.09 which is consistent with Kostik *et al.*, 2013 report.This shows that the oil has low amount of PUFA and relatively higher level of SFA. High amount of SFA makes the oil to be resistant to oxidative deterioration (Maszewska *et al.*, 2018).

I. Soybean oil

The analysis report of the soybean oil (SO) showed, linoleic acid (**11**) as a major component followed by oleic (**7**), palmitic (**3**), stearic (**4**) and linolenic (**12**) acids with the concentration of 50.78% ± 0.41, 25.12% ± 0.05, 11.34% ± 0.06, 6.72% ± 0.03, and 6.04% ± 0.35, respectively. The total amount of PUFA, MUFA, SFA are

56.82% ± 0.38, 25.12% ± 0.05, and 18.06% ± 0.02, respectively. The calculated P/S index value was 3.14. This finding was consistent with the CODEX (Alimentarius, 1999) report except slight differences in linoleic acid (**11**) amount.

J. Cottonseed oil

The fatty acids composition analysis of cotton seed oil (COT) showed linoleic acid (**11**) (51.95% ± 0.15) followed by palmitic acid (**3**) (27.94% ± 0.60), oleic acid (**7**) (15.86% ± 0.57), stearic acid (**4**) (4.25% ± 0.09) and myristic acid (**2**) (1.77% ± 0.07). The result is closely related to FAO/WHO standard report with a small variation (Alimentarius, 1999). The total FA content was measured to be 51.95% ± 0.15 PUFA, 33.96% ± 0.38 SFA, and 15.86% ± 0.57 MUFA. The P/S index was found to be 1.56, one of the lowest compared to others.

The analysis of mixtures of PAL and LNS oils showed increase in P/S indices, compared to pure PAL oil, as the ratio of LND:PAL oil increases. At the ratio 50:50 of the two oils P/S index slightly goes above 1. Currently the PAL oil price is lower than other oils which makes it affordable oil in, especially, the low-income countries. As a recommendation, it can be suggested that PAL oil can be used by mixing it up with other oils which contain relatively high amount of PUFAS. **Error! Reference source not found.** shows the mixed ratio of PAL and LNSD oils and their corresponding P/S indices.

Table 3: Total fatty acids and P/S index values of the commercial seed oils

Type of oil with its code	% SFA	% PUSFA	P/S indexes
PAL	45.12	12.53	0.28
LND	12.86	72.80	5.66
P80L20	39.56	21.97	0.56
P60L40	36.85	29.32	0.80
P50L50	30.71	40.46	1.32
P40L60	27.78	46.16	1.66
P20L80	19.28	61.38	3.18

Where PAL (palm), LND (linseed), P80L20 (palm 80% and linseed 20%), P60L40 (palm 60% and linseed 40%), P50L50 (palm 50% and linseed 50%), P40L60 (palm 40% and linseed 60%), P20L80 (palm 20% and linseed 80%).

Below are the details of the two samples and their mixed ratios.

Table 4: Percent relative concentrations and P/S indices of fatty acids of commercial PAL and LNS oils and their mixtures.

PAL

PK	RT	Area	FAMEs	Area %	% SFA	% PUSFA	P/S index
2	8.3118	12607112	Dodecanoic acid, methyl ester	0.149645	45.12 (PKs 2, 4, 6, and 10)	12.53 (PK 9)	0.28
4	9.8481	108972840	Tetradecanoic acid, methyl ester	1.293496			
6	11.4171	3090410347	Hexadecanoic acid, methyl ester	36.68284			
8	13.2902	3568255955	9-Octadecenoic acid, methyl ester, (Z)-	42.35482			
9	13.3524	1055460830	9,12-Octadecadienoic acid (Z,Z)-, methyl ester	12.52821			
10	13.4306	588968360	Methyl stearate	6.990992			
	Total Area	8424675444		100			

LNS

PK	RT	Area	FAMEs	Area %	% SFA	% PUSFA	P/S index
1	11.4232	394566044	Hexadecanoic acid, methyl ester	5.888444	12.86 (PKs 1 and 4)	72.80 (PKs 3 and 5)	5.66
2	13.2967	960873109	9-Octadecenoic acid, methyl ester, (Z)-	14.33993			
3	13.3595	1069547935	9,12-Octadecadienoic acid (Z,Z)-, methyl ester	15.96177			
4	13.4441	466996174	Methyl stearate	6.969381			
5	13.5651	3808700769	9,12,15-Octadecatrienoic acid, methyl ester, (Z,Z,Z)-	56.84048			
	Total Area	6700684031		100			

P80L20

PK	RT	Area	FAMEs	Area %	% SFA	% PUSFA	P/S index
2	8.3209	9490554	Dodecanoic acid, methyl ester	0.110286	39.56 (PKs 2, 4, 6, and 10)	21.97 (PKs 9 and 11)	0.56
4	9.8565	62934204	Tetradecanoic acid, methyl ester	0.731336			
6	11.4231	2782622807	Hexadecanoic acid, methyl ester	32.33587			
8	13.2986	3309774746	9-Octadecenoic acid, methyl ester, (Z)-	38.46171			
9	13.3598	1137044989	9,12-Octadecadienoic acid (Z,Z)-, methyl ester	13.2132			
10	13.4391	549552803	Methyl stearate	6.386158			
11	13.559	753954819	9,12,15-Octadecatrienoic acid, methyl ester, (Z,Z,Z)-	8.761441			
	Total Area	8605374922		100			

P60L40

PK	RT	Area	FAMEs	Area %	% SFA	% PUSFA	P/S index
2	8.3118	6415945	Dodecanoic acid, methyl ester	0.09057	36.85 (PKs 2, 4, 6, and 10)	29.32 (PKs 9 and 11)	0.80
4	9.85	44323912	Tetradecanoic acid, methyl ester	0.625694			
6	11.4147	2124898385	Hexadecanoic acid, methyl ester	29.99591			
8	13.2878	2396561010	9-Octadecenoic acid, methyl ester, (Z)-	33.8308			
9	13.3506	961207277	9,12-Octadecadienoic acid (Z,Z)-, methyl ester	13.56878			
10	13.4316	434547218	Methyl stearate	6.13424			
11	13.5506	1116007628	9,12,15-Octadecatrienoic acid, methyl ester, (Z,Z,Z)-	15.754			
	Total Area	7083961375		100			

P50L50

PK	RT	Area	FAMEs	Area %	% SFA	% PUSFA	P/S index
1	8.3154	7162407	Dodecanoic acid, methyl ester	0.09175	30.71 (PKs 1, 3, 5, and 8)	40.46 (PKs 7 and 9)	1.32
3	9.8537	25496020	Tetradecanoic acid, methyl ester	0.326604			
5	11.416	1863208965	Hexadecanoic acid, methyl ester	23.86768			
6	13.288	2249375179	9-Octadecenoic acid, methyl ester, (Z)-	28.81446			
7	13.3518	1094573978	9,12-Octadecadienoic acid (Z,Z)-, methyl ester	14.02147			
8	13.4346	501457554	Methyl stearate	6.423663			
9	13.5523	2065137402	9,12,15-Octadecatrienoic acid, methyl ester, (Z,Z,Z)-	26.45438			
	Total Area	7806411505		100			

P40L60

PK	RT	Area	FAMEs	Area %	% SFA	% PUSFA	P/S index
2	8.3119	4591618	Dodecanoic acid, methyl ester	0.057013	27.78 (PKs 2, 4, 7, and 11)	46.16 (PKs 10 and 12)	1.66
4	9.8509	29874515	Tetradecanoic acid, methyl ester	0.370942			
7	11.4139	1685602272	Hexadecanoic acid, methyl ester	20.92956			
9	13.2871	2098932517	9-Octadecenoic acid, methyl ester, (Z)-	26.06174			
10	13.3499	1156242666	9,12-Octadecadienoic acid (Z,Z)-, methyl ester	14.35668			
11	13.4333	517283469	Methyl stearate	6.422935			
12	13.5518	2561166020	9,12,15-Octadecatrienoic acid, methyl ester, (Z,Z,Z)-	31.80114			
	Total Area	8053693077		100			

P20L80

PK	RT	Area	FAMEs	Area %	% SFA	% PUSFA	P/S index
2	8.322	2136367	Dodecanoic acid, methyl ester	0.028373	19.28 (PKs 2, 5, 9 and 16)	61.38 (PKs 15 and 17)	3.18
5	9.85	15885067	Tetradecanoic acid, methyl ester	0.210972			
9	11.413	930952546	Hexadecanoic acid, methyl ester	12.3641			
14	13.285	1456082739	9-Octadecenoic acid, methyl ester, (E)-	19.33842			
15	13.35	1138935033	9,12-Octadecadienoic acid (Z,Z)-, methyl ester	15.12634			
16	13.433	502752123	Methyl stearate	6.677115			
17	13.552	3482737119	9,12,15-Octadecatrienoic acid, methyl ester, (Z,Z,Z)-	46.25468			
	Total Area	7529480994		100			

CONCLUSIONS

The analysis of fatty acid concentrations of seed oils in terms of P/S indices showed values greater than one except for palm oil which clearly showed that the oils are rich in PUFA ranging from 32 to 81%. The poor quality of PAL oil (low P/S) was found better (higher P/S) when the oil was mixed in lower proportions (40:60 and 20:80) with LNS oil. In the meantime, P/S data analysis of equal proportion of the oils demonstrated the possibility of using PAL together with locally available seed oils for consumption due to their role in improving its food quality (P/S).

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