

ASSESSMENT OF FATTY ACID AND VITAMIN E PROFILES IN EDIBLE OILS IN MALAYSIA

RADHIKA LOGANATHAN¹ and TENG KIM-TIU^{1*}

ABSTRACT

Cooking oil plays a pivotal role in our daily diet. The present investigation was designed to characterise the fatty acid composition and eight homologs of vitamin E in a total of 52 locally available vegetable oils [types: pure oils (n=10) and blended oils (n=6)] in Putrajaya, Malaysia. The analyses were performed by gas chromatography for fatty acid composition, the acetic acid-isooctane method for peroxide value (PV), and high-performance liquid chromatography (HPLC) for vitamin E profiling. Following multivariate discriminant analysis, the oils were categorised into two groups. Most studies and oil standards have reported only part of eight vitamin E homologs, therefore this current study is novel as it provides the complete vitamin E profiling of the tested oils. There was no major discrepancy found between the assayed values and packaging labels on the fatty acid composition, trans-fat, and vitamin E content. The PV and trans-fats were within the recommended range, indicating good quality compliance. Fatty acid and vitamin E content were within standard oil specifications. These observations implied that the oil manufacturers and retailers in Malaysia had good acquiescence to international standards and local regulations. This study provides consumers with technical insights in oil selection, based on the functionality needed.

Keywords: blended oils, edible oils, fatty acid composition, peroxide value, vitamin E.

Received: 12 November 2021; **Accepted:** 22 February 2022; **Published online:** 14 April 2022.

INTRODUCTION

The total world consumption for oils and fats in the year 2020 was 234.8 million tonnes (Oil World Annual, 2020). Palm oil (32.2%) was the most widely consumed amongst the 17 listed major oils and fats (Oil World Annual, 2020). This is followed by soybean oil (24.1%), rapeseed oil (10.5%), sunflower oil (9.0%), tallow (4.2%), butter (3.7%), palm kernel oil (3.4%), lard (3.3%), cotton oil (2.0%), corn oil (1.8%), groundnut oil (1.7%), olive oil (1.5%), coconut oil (1.2%), fish oil (0.4%), sesame oil (0.4%), linseed oil (0.4%) and lastly castor oil (0.3%) (Oil World Annual, 2020).

Cooking oil is an essential part of our daily diet preparation. Fats and oils are made up of triglycerides which consist of a glycerol backbone

esterified with three fatty acids (Figure 1). Fats and oils play a pivotal role in maintaining good health and they provide more calories per gram (9 kcal g⁻¹) than any other nutrients (Chowdhury *et al.*, 2007). Fatty acids are grouped into three broad categories namely saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) depending on the number of double bonds (Chowdhury *et al.*, 2007). The World Health Organization (WHO) recommends 20.0%-35.0% energy (E) total fat from total energy intake for adults (WHO, 2008). Intake of SFA and *trans*-fats are recommended to be <10.0% and <1.0% respectively of total energy intake. The acceptable range for total PUFA (n-6 and n-3 fatty acids) consumption is 6.0%-11.0% E from total energy intake of which n-3 fatty acid intake ranges between 0.5%-2.0% energy [$>0.5\%$ E alpha-linolenic acid (ALA) plus eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (0.25-2.00 g/day)], whereas n-6 fatty acids (linoleic acid, LA) intake ranges between 2.5%-9.0% E (Elmadfa

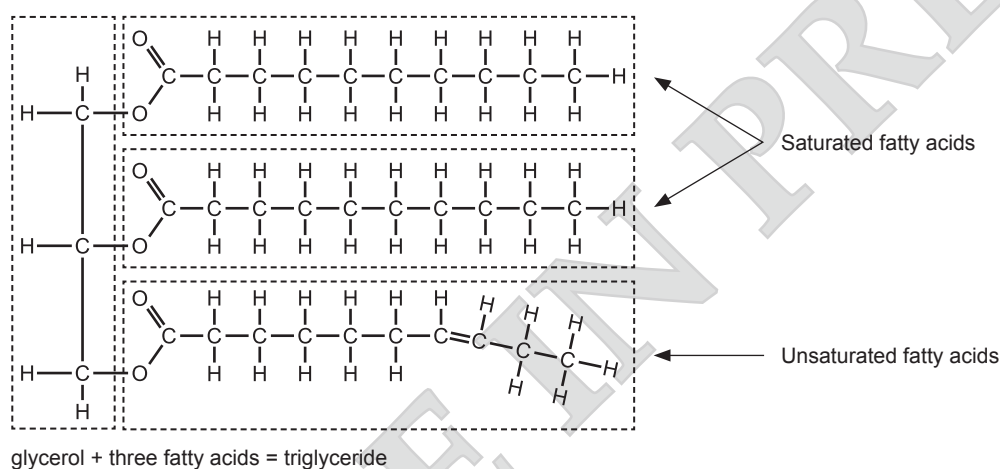
¹ Malaysian Palm Oil Board,
6 Persiaran Institusi, Bandar Baru Bangi,
43000 Kajang, Selangor, Malaysia

* Corresponding author e-mail: kimtiu@mpob.gov.my

and Kornsteiner, 2009; WHO, 2008). Wallingford *et al.* (2004) reported that the fatty acid profile of edible oils in China is often incompletely and incorrectly labelled. There are some literature on the characterisation of fatty acids in commercial oils in China (Haiyan *et al.*, 2007; Wallingford *et al.*, 2004), India (Dorni *et al.*, 2018), the Spanish market (Rueda *et al.*, 2014), Iran (Piravi-Vanak *et al.*, 2009) and Bangladesh (Chowdhury *et al.*, 2007). However, none were found in the Malaysian setting.

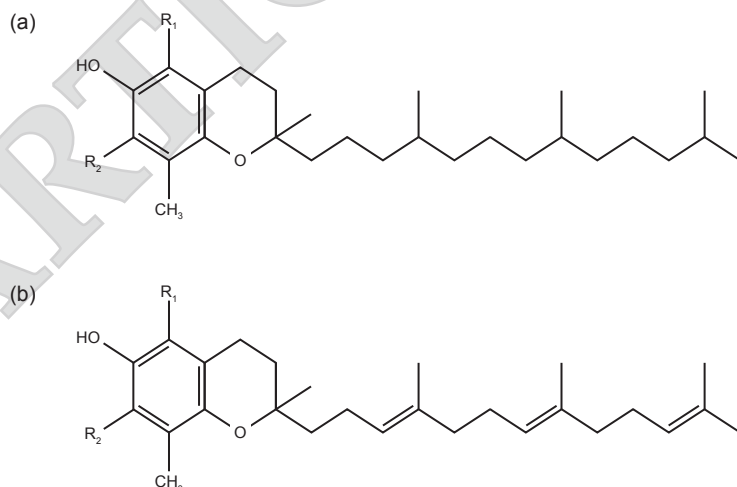
Vitamin E or tocopherols is a fat-soluble vitamin that is found abundantly in oilseeds and nuts (Aksoz *et al.*, 2020). Vitamin E is a family of eight similar homologs that exists naturally as two families namely tocopherols and tocotrienols (*Figure 2*). Each

vitamin E family exists naturally in four isoforms namely alpha, beta, delta and gamma (Loganathan *et al.*, 2021). Vitamin E is a potent antioxidant with lipoperoxyl radical scavenging activities which could protect the oils against oxidative deterioration (Loganathan *et al.*, 2020a; 2020b). Besides, the content of vitamin E in oil reflects the oil quality (Wen *et al.*, 2020). Most studies (Aksoz *et al.*, 2020; Gliszczynska-Swiglo *et al.*, 2007; Matthaus *et al.*, 2016; Petersen *et al.*, 2012) and standards (Codex Alimentarius, 1999; 2001; 2019) have reported only part of eight vitamin E homologs, and more attention has been given to tocopherols as compared to tocotrienols. Therefore, there is a gap of knowledge in understanding the complete vitamin E profiling.



Source: Lichtenstein (2013).

Figure 1. Molecular structure of a triglyceride.



Homologs	R ₁	R ₂
Alpha	CH ₃	CH ₃
Beta	CH ₃	H
Gamma	H	CH ₃
Delta	H	H

Source: Fu *et al.* (2014).

Figure 2. Molecular structure of (a) tocopherols and (b) tocotrienols with homologs determined based on the presence and position of methyl group(s) as side chains at R1 and R2 on the chromanol ring.

Fats and oils emanate a great deal of variation and uniqueness by nature in their fatty acid compositions, phytonutrient contents, and physiological properties. The aims of this work were to (1) characterise the fatty acid present and vitamin E content of locally available vegetable oils; (2) study the quality of oils on the shelf in terms of peroxide value (PV); (3) determine the accuracy of the packaging labels to the assayed values.

MATERIALS AND METHODS

Edible Oil Samples

Edible oil samples of 11 different varieties: palm oil (five samples), canola oil (five samples), sunflower oil (nine samples), corn oil (seven samples), soybean oil (four samples), olive oil (11 samples), rice bran oil (one sample), avocado oil (one sample), grapeseed oil (one sample), rapeseed oil (one sample), and blended oils (13 samples) were purchased from the local supermarket around Putrajaya, Malaysia area between October to November 2015. Oils were transferred into six dark amber bottles, blanketed with nitrogen, and stored at -20°C for subsequent analyses. All labels on oil samples were tabulated and analysed alongside.

Chemicals and Reagents

Tocopherol and tocotrienol homologs (alpha, beta, gamma and delta) were purchased from Davos Life Sciences Pte. Ltd. (Singapore); 2,2,5,7,8-pentamethyl-6-hydroxychromane (PMC) from Wako (Osaka, Japan); AOCS oil reference mixture RM-6 from Supelco (Bellefonte, USA); High-Performance Liquid Chromatography (HPLC) gradient grade methanol, 1-propanol, *n*-hexane, toluene and dioxane from Merck (Darmstadt, Germany); potassium hydrogen carbonate, glacial acetic acid, potassium iodide, sodium chloride isooctane, starch, sodium thiosulphate from System ChemAR (Shah Alam, Malaysia).

Preparation of Fatty Acid Methyl Ester (FAME)

The fatty acid composition of the test fats was determined by converting fatty acids of triglyceride to FAME according to AOCS Official Method Ch 1-91 (The American Oil Chemists' Society, 2017c).

Fatty Acid Composition Analysis by Gas Chromatography (GC)

Analysis of fatty acid composition was carried out according to AOCS Official Method Ce 1a-13 (The American Oil Chemists' Society, 2017b) on GC

Perkin Elmer Autosystem Model, USA. The GC was fitted with the SGE Capillary BPX70 column from SGE Analytical Science Pty. Ltd. (Milton Keynes, United Kingdom). The identification of fatty acids was based on AOCS oil reference mixture RM-6. The results were expressed as relative percentages of wet weight.

Vitamin E Analysis by HPLC

Vitamin E content was analysed by normal phase HPLC Agilent model 1100 series, the US with fluorescence detector. The mean recovery of internal standard, namely 2,2,5,7,8-pentamethyl-6-hydroxy-Chromane (PMC) was 93.07% ± 0.72%. The chromatographic analysis of the compounds was conducted on Phenomenex® Luna 5 µM Silica analytical column (250 mm x 4.6 mm i.d) and a mobile phase of hexane/dioxane/isopropyl alcohol (970:25:5) at a flow rate of 1.0 mL per min. Identification and quantification of the components were done by comparison of the peak areas with those pure standards. Values are presented as mg kg⁻¹ of wet weight.

Peroxide Value (PV)

Analysis of PV was performed with reference to the AOCS Official Method Cd 8b-90 (The American Oil Chemists' Society, 2017a). Briefly, an oil sample weighing 5.0 g was placed in the conical flask and 50.0 mL of acetic acid/iso-octane solution (3:2) was added. The sample was stirred until it has been well dissolved before the addition of 0.5 mL of saturated potassium iodide. The solution was shaken thoroughly and thereafter, immediately, with 30.0 mL of distilled water and 0.5 mL of starch solution. The sample was titrated with 0.1 M sodium thiosulphate until the blue colour disappears. PV of the oil samples was measured in milliequivalent of peroxide per kg of oil sample (wet weight).

Data Presentation

All analytical determinations were performed at minimum in duplicates and presented as the mean values ± standard deviation. One-way analysis of variance ANOVA followed by Tukey's *post hoc* test was applied to assess the differences between oils ($p < 0.05$). Cluster analyses were performed by multivariate statistical classification methods. Following hierarchical cluster analysis, discriminant analysis was applied to analyse differences among the oil groups. Statistical analysis was conducted using GraphPad Prism version 9.3.1 and SPSS version 11.5.

RESULTS AND DISCUSSION

All assayed samples had fatty acid profiles that fall within standard database values (Codex Alimentarius, 1999; 2001; 2019) and corresponded closely with the total fatty acid content of the packaging label. The fatty acid composition of the oils is shown in *Table 1* and *Figure 3*. Heat map visualisation in *Figure 4* provides a direct intuitive visualisation of the different contents of total SFA, total MUFA, and total PUFA in assayed edible oils by category.

Following cluster analysis depicted in *Figure 5*, the oils can be classified into two main groups namely high MUFA: high oleic sunflower (85.00%) > olive > avocado > rapeseed > canola > red palm olein and canola blend/canola and sunflower blend > palm olein/palm olein, peanut and sesame blend > soybean, palm olein and canola blend (38.00%); and high PUFA [grapeseed (71.95%) > sunflower > soybean > olive and sunflower blend > corn oil > corn, soybean, and canola blend (50.47%)] oils.

Within the MUFA group, the oils were further classified into five sub-classes (*Figure 5*). The first subclass had an equal composition of MUFA (45.11%-45.41%) and SFA (42.54%-43.42%). Palm olein is a member of the first subclass. Palm olein is derived from the mesocarp of the fruit of the oil palm, *Elaeis guineensis* (Kushairi *et al.*, 2019). Olein fractions are widely used as cooking oils and suitable as a heavy-duty frying oil. There are two main grades of palm olein, namely single-fractionated palm olein and double-fractionated palm olein (Ahmad Tarmizi and Siew, 2008). All five tested palm olein were found to be of double fractionated grade. The tertiary blend of palm olein, peanut, and sesame oil (n=3) had an almost similar fatty acid composition to that of palm olein. The second subclass had MUFA concentrations ranging from 51.91%-64.06%. Low erucic acid canola and rapeseed oils classified in this group were derived from a variety of rapeseed cultivars of the plant family *Brassicaceae* (Codex Alimentarius, 1999; Matthaus *et al.*, 2016). Similar to Matthaus *et al.* (2016), we too find these oils consisted mainly of oleic (C18:1) (51.80%-63.80%), linoleic (C18:2 N6C) (18.60%-25.30%), and n-3 fatty acid (C18:3N3, 8.00%-11.20%). The binary blend of high MUFA canola oil with high PUFA sunflower oil (n=4) as well as the blend of MUFA rich oils namely red palm olein and canola oil (n=1) also belongs to this group. These unique blends resulted in low SFA content (9.23%-18.18%) but high MUFA (51.91%-54.14%) and PUFA (27.68%-38.87%) profiles. High oleic sunflower oil is the only member of subclass three with distinctly high MUFA content. High oleic acid sunflower oil is produced from high oleic acid oil-bearing seeds of the same plant (*Helianthus annuus* L.) (Codex Alimentarius, 1999). Following previous

bibliographic data (Chowdhury *et al.*, 2007; Petersen *et al.*, 2012), the fractions corresponded almost entirely to C18:1N9C (84.53%). Olive and avocado oils were classified under sub-class four. Olive oil is the oil obtained from the fruit of the long-lived olive tree (*Olea europaea* L.) (Codex Alimentarius, 2001). We have evaluated three types of olive oils, namely extra virgin (n=3), extra light (n=2) and refined/pure (n=5). All three types of olive oil had similar fatty acid compositions and this was in agreement with data from the literature (Piravi-Vanak *et al.*, 2009) and standards (Codex Alimentarius, 2001; International Olive Council, 2006). Another member of this subclass namely avocado oil is an edible oil extracted from the fruit of *Persea Americana* (Haytowitz *et al.*, 2011). Similar to the current study, Haiyan *et al.* (2007) also reported avocado oil had an almost similar fatty acid composition to that of canola/rapeseed oil, with predominantly MUFA (C18:1N9C). Avocado oil can be distinguished from other tested oil with a notable presence of C16:1 (7.80%), of which a similar observation was also reported in the literature (Rueda *et al.*, 2014). A tertiary blend of soybean, palm olein, and canola oils was classified as subclass five. This blend had SFA (30.44%): MUFA (37.82%): PUFA (31.74%) content at a 1:1:1 ratio.

PUFA group, on the other hand, can be further divided into two big clusters. Sunflower, soybean, corn, binary blended oil (olive and sunflower), and tertiary blended oil (corn, soybean, and canola) were classified as one group (sub-class six). These oils have almost similar fatty acid composition (PUFA: 50.47%-62.49%, MUFA: 23.93%-37.06%, and SFA: 10.65%-15.71%). Sunflower (*Helianthus annuus* L.) is an annual crop that belongs to the family Asteraceae or Compositae (Codex Alimentarius, 1999). Sunflower oil is extracted from the sunflower seeds. Corn oil is a by-product from the wet or dry milling of maize germ (the embryos of *Zea mays*) (Jovanović *et al.*, 2005). The primary product from this milling is starch (Jovanović *et al.*, 2005). Soybean oil is derived from soybeans (*Glycine max* (L.) Merr.) that belong to the nitrogen-fixing leguminous plant (Codex Alimentarius, 1999). Soybean oil can be distinguished from the other members of the subclass as it had the highest levels of C18:3N3 (5.50%-7.10%) (Chowdhury *et al.*, 2007; Haiyan *et al.*, 2007). Grapeseed oil was classified as a separate subclass (no.7) under the PUFA group. Grapeseed oil is derived from the seeds of the grapes (*Vitis vinifera* L.) (Codex Alimentarius, 1999). Grapeseed oil is a winery industry by-product (Martin *et al.*, 2020) and was found to have the highest PUFA content (72.00%) in the form of C18:2N6C as compared to other tested oils.

Most oil groups had no *trans*-fatty acid (C18:2N6T- linolelaidic acid) except for sunflower, corn, soybean, binary blends of canola and

sunflower oil, and tertiary blends of soybean, palm olein, and canola oils (Table 1). A slight variation was found between the assayed samples values as compared to packaging labels for canola oil (samples 6-9), sunflower oil (samples 11-17), and soybean oil (sample 27).

The original American Heart Association (AHA) Step I Diet fat recommended 30% E from dietary fat and fatty acid balance, SFA: MUFA: PUFA at 1:1:1 (Krauss *et al.*, 2000), corresponding to soybean, palm olein, and canola blended oil. Currently, the AHA recommends slightly less SFA (<10% of calories), up to 10% from PUFA, and as much as 15% from MUFA (Krauss *et al.*, 2000). Raising the dietary PUFA/SFA ratio has been recommended to reduce cardiovascular disease event risk and improve glycaemic control (Kang *et al.*, 2005). WHO recommended PUFA/SFA ratio above 0.4 (Coskuntuna *et al.*, 2015). Nevertheless, a high dietary PUFA/SFA ratio increases oxidative stress since PUFA are highly prone to lipid peroxidation (Kang *et al.*, 2005). Only olive oil, avocado oil, and tertiary blended oil (soybean, palm olein, and canola oil) had a desirable PUFA/SFA ratio of 0.4-1.0. Palm olein had a lower than ideal PUFA/SFA ratio (>0.4). Whereas sunflower oil (5.90), grapeseed oil (8.83), and binary blended olive and sunflower oil (5.59) had a very high ratio of PUFA/SFA content. Edible oils are usually blended to contain a better proportion of SFAs, MUFAs, PUFAs, and essential fatty acids. The downside of blended oils was that the ratio of blending was not written on any of the labels. It was interesting to note that the same type of blended oil carried similar fatty acid composition, implying a similar ratio of blending, although the manufacturers were different.

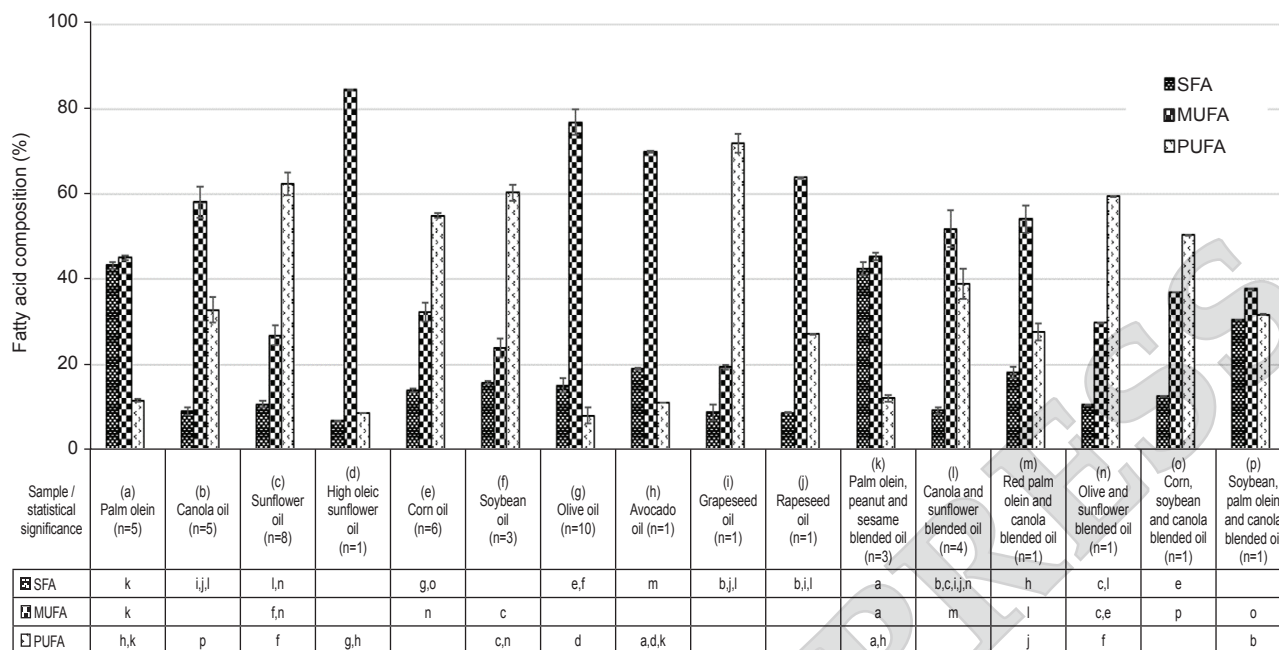
The primary oxidation products are usually measured with a PV test. Peroxides are intermediate oxidation products of oil, that lead to the formation of a complex mixture of volatile compounds *i.e.* aldehydes, ketones, hydrocarbons, alcohols, and esters (Loganathan *et al.*, 2020a; 2020b). Peroxides form in oils, especially at undesirable storage conditions such as elevated temperatures as well as exposure to oxygen and/or light (Loganathan *et al.*, 2020a; 2020b). The acceptable range of PV in refined palm oil is less than 10 meq O₂ kg⁻¹. PVs of all the oil samples were within the recommended range (<10 meq O₂ kg⁻¹) except for sample no. 6 (Table 1).

All assayed samples had almost similar total vitamin E and its homologs content (Table 2 and Figure 6) as compared to standard database values (Codex Alimentarius, 1999; 2001; 2019). Additional to Codex Alimentarius standards' data, we also report beta-tocotrienol content in the assayed oils. Only 30 companies reported on vitamin E content in their packaging labels, whereby 50% of these labels (n=15) had vitamin E content within the assayed range (with ± 30% deviation), 14 were under-

TABLE 1. MAIN FATTY ACIDS (%) AND PV, WET WEIGHT BASIS IN ASSAYED EDIBLE OILS

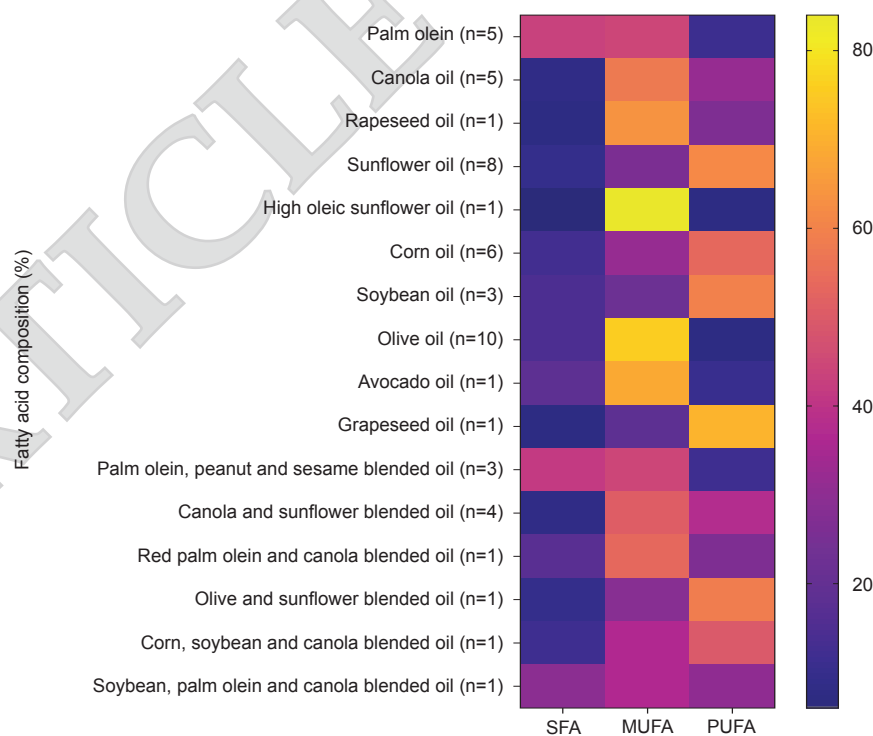
Sample	C16:0 (Palmitic)	C18:0 (Stearic)	C18:1n9C (Oleic)	C18:2n6C (Linoleic)	C18:2n6T (Linolelaidic)	C18:3n3 (Alpha linolenic)	PV (meq O ₂ kg ⁻¹)
(a) Palm olein (n=5)	37.93 ± 0.77 ^k	3.9 ± 0.09 ^{cknp}	44.93 ± 0.58 ^k	11.03 ± 0.38 ^{hk}	ND ^{bcd,de,gh,ijkl,mno}	0.54 ± 0.05 ^{cd,de,gh,ijkl}	1.57 ± 0.85 ^{dikm}
(b) Canola oil (n=5)	5.1 ± 0.57 ^{hij}	2.15 ± 0.18 ^{de,el}	56.87 ± 3.65 ^m	22.57 ± 2.27	ND ^{abc,de,gh,ijkl,mno}	9.2 ± 0.98 ^l	5.2 ± 2.42 ^{d,ef,hij,lop}
(c) Sunflower oil (n=8)	6.22 ± 0.22 ^{l,ln}	3.59 ± 0.19 ^{a,ap,k}	26.02 ± 1.75 ^t	61.42 ± 2.79	0.05 ± 0.14 ^{ab,de,gh,ijkl,mno}	0.38 ± 0.34 ^{ad,de,gh,ijkl}	10.67 ± 0.73 ⁿ
(d) High oleic sunflower oil (n=1)	3.87 ± 0 ^l	2.37 ± 0.01 ^{beg,il,mno}	84.53 ± 0.01	7.79 ± 0.02 ^g	ND ^{abc,de,gh,ijkl,mno}	ND ^{abc,de,gh,ijkl}	3.67 ± 0.22 ^{bc,ef,h,ijkl,mno,p}
(e) Corn oil (n=6)	11.19 ± 0.18 ^{fg}	2.05 ± 0.1 ^{bd,dl}	30.94 ± 0.48 ⁿ	53.54 ± 0.47 ^f	0.06 ± 0.07 ^{abc,de,gh,ijkl,mno}	1.25 ± 0.4 ^{ag}	3.07 ± 0.81 ^{ad,h,ijkl,mno,p}
(f) Soybean oil (n=3)	10.52 ± 0.28 ^e	4.43 ± 0.27 ^k	23.66 ± 2.1 ^c	52.39 ± 1.1 ^e	0.29 ± 0.44 ^p	6.15 ± 0.74 ^l	5.49 ± 2.09 ^{bd,hij,lop}
(g) Olive oil (n=10)	11.69 ± 1.45 ^e	2.85 ± 0.52 ^{d,il,mno}	75.66 ± 3.12	7.24 ± 1.85 ^d	ND ^{abc,de,gh,ijkl,mno}	0.6 ± 0.18 ^{ac,de,gh,ijkl}	7.96 ± 2.48 ⁿ
(h) Avocado oil (n=1)	18.15 ± 0.01	0.77 ± 0.19	62.07 ± 0.23 ^l	10.5 ± 0.01 ^{ak}	ND ^{abc,de,gh,ijkl,mno}	0.18 ± 0.28 ^{ac,de,gh,ijkl}	3.77 ± 0.36
(i) Grapeseed oil (n=1)	5.87 ± 0.89 ^{bcd,ln}	2.78 ± 1.12 ^{de,lmno}	19.16 ± 0.34	71.85 ± 2.39	ND ^{abc,de,gh,ijkl,mno}	0.1 ± 0.09 ^{abc,de,gh,ijkl}	3.17 ± 0.08 ^{b,de,ef,h,ijkl,mno,p}
(j) Rapeseed oil (n=1)	4.39 ± 0 ^{bd,il}	1.61 ± 0 ^e	63.84 ± 0.04 ^b	18.24 ± 0.02 ^m	ND ^{abc,de,gh,ijkl,mno}	8.68 ± 0.03 ^b	4.33 ± 0.29 ^{b,de,ef,h,lop}
(k) Palm olein, peanut and sesame blended oil (n=3)	36.89 ± 1.41 ^a	3.96 ± 0.14 ^{ac,ef,np}	45.16 ± 0.73 ^a	11.46 ± 0.79 ^{ab,h}	ND ^{abc,de,gh,ijkl,mno}	0.54 ± 0.11 ^{ac,de,gh,ijkl}	2.11 ± 1.59 ^{ad,ef,h,lm}
(l) Canola and sunflower blended oil (n=4)	5.29 ± 0.39 ^{bcd,aj}	2.46 ± 0.21 ^{bd,ef,lmno}	51.58 ± 4.35 ^m	31.06 ± 3.82	0.07 ± 0.07 ^{abc,de,gh,ijkl,mno}	6.69 ± 0.92 ^{lm}	4.47 ± 1.1 ^{b,de,ef,h,lop}
(m) Red palm olein and canola blended oil (n=1)	13.99 ± 0.99	2.81 ± 0.19 ^{de,gl,lo}	53.95 ± 3.32 ^{bl}	19.31 ± 1.37 ^l	ND ^{abc,de,gh,ijkl,mno}	7.37 ± 0.5 ^l	1.93 ± 0.22 ^{ade,h,kl}
(n) Olive and sunflower blended oil (n=1)	6.87 ± 0.01 ^{ci}	3.66 ± 0.01 ^{ack,p}	29.76 ± 0.01 ^e	58.66 ± 0.02	ND ^{abc,de,gh,ijkl,mno,p}	0.33 ± 0.02 ^{ac,de,gh,ijkl}	8.8 ± 0.39 ^{eg}
(o) Corn, soybean and canola blended oil (n=1)	8.84 ± 0	2.85 ± 0 ^{d,gl,lm}	36.36 ± 0 ^p	44.53 ± 0.05	ND ^{abc,de,gh,ijkl,mno}	5.07 ± 0	5.03 ± 0.36 ^{bd,ef,h,ijkl,p}
(p) Soybean, palm olein and canola blended oil (n=1)	25.7 ± 0.03	3.79 ± 0.03 ^{ack,n}	37.69 ± 0.02 ^o	28.06 ± 0	0.32 ± 0.01 ^t	2.85 ± 0.01	4.4 ± 0.14 ^{b,de,ef,h,lop}

Note: Values are mean value ± SD. Analyses were done in replicates for fatty acid composition (%) and triplicates for PVs. Data was measured by one-way analysis of variance (ANOVA) with Tukey post hoc test. Statistical differences (p<0.05) were found between test oils except those indicated by the alphabet to represent the sample of each row. ND - not detected.



Note: Values are mean value \pm SD. Analyses were done in replicates for fatty acid composition (%). Data was measured by one-way analysis of variance (ANOVA) with Tukey *post hoc* test. Statistical differences ($p < 0.05$) were found between test oils except those indicated by the alphabet to represent the sample of each column.
 SFA - saturated fatty acids; MUFA - monounsaturated fatty acids; and PUFA - polyunsaturated fatty acids.

Figure 3. Total SFA, total MUFA, and total PUFA wet weight basis in assayed edible oils by category.



Note: Yellow (■) indicates fatty acids distributed at high concentration and blue (■) indicates fatty acids distributed at a low concentration).
 SFA (saturated fatty acids), MUFA (monounsaturated fatty acids), and PUFA (polyunsaturated fatty acids).

Figure 4: Heatmap explains the different contents of total SFA, total MUFA, and total PUFA wet weight basis in assayed edible oils by category.

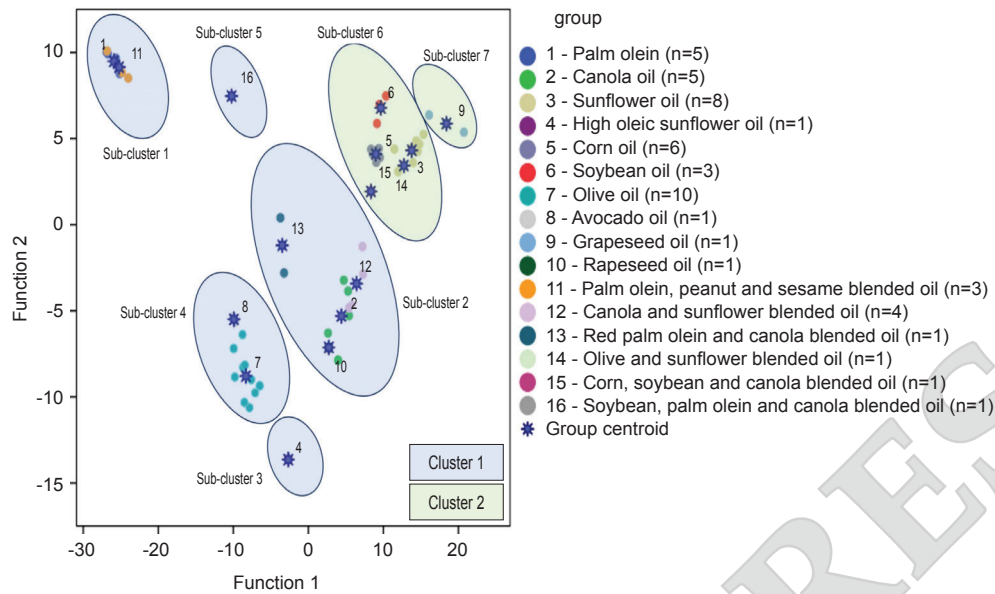


Figure 5. Classification of assayed edible oils with canonical discriminant analysis.

reported, and one over-reported. The present study shows that total vitamin E, total tocopherols, total tocotrienols, and vitamin E homologs of the assayed samples varied a wide range in assayed edible oils (Table 2 and Figure 6).

As depicted in Figure 6 and Table 2, the total vitamin E in the assayed oils were compared and listed in decreasing order: palm olein and peanut blended oil (780 mg kg^{-1})/palm olein (769 mg kg^{-1})/soybean oil (736 mg kg^{-1}) > corn oil (642 mg kg^{-1})/soybean, palm olein and canola blended oil (673 mg kg^{-1})/corn, soybean, and canola blended oil (671 mg kg^{-1})/red palm olein and canola blended oil (581 mg kg^{-1}) > sunflower oil (511 mg kg^{-1})/rapeseed oil (486 mg kg^{-1})/canola and sunflower blended oil (481 mg kg^{-1})/grapeseed oil (448 mg kg^{-1}) > olive and sunflower oil (375 mg kg^{-1}) > olive oil (186 mg kg^{-1}) > avocado oil (89 mg kg^{-1}).

The heat map in Figure 6 provides a clearer visual representation of the hierarchical concentrations of vitamin E homologs, total tocopherols, total tocotrienols, and total vitamin E in assayed edible oils by category. In accordance with previous findings, alpha-tocopherol was found to be the most abundant form of vitamin E in the studied vegetable oils and blends (Aksoz *et al.*, 2020; Gliszczynska-Swiglo *et al.*, 2007; Wen *et al.*, 2020). The richest alpha-tocopherol source in the current pool of samples was sunflower oil (429 mg kg^{-1}). Whereas, beta-tocopherol was found in low quantities in vegetable oils (Gliszczynska-Swiglo *et al.*, 2007). Palm olein, grapeseed, and blended oils with palm olein (palm olein, peanut, and sesame blended oil; soybean, palm olein and canola blended

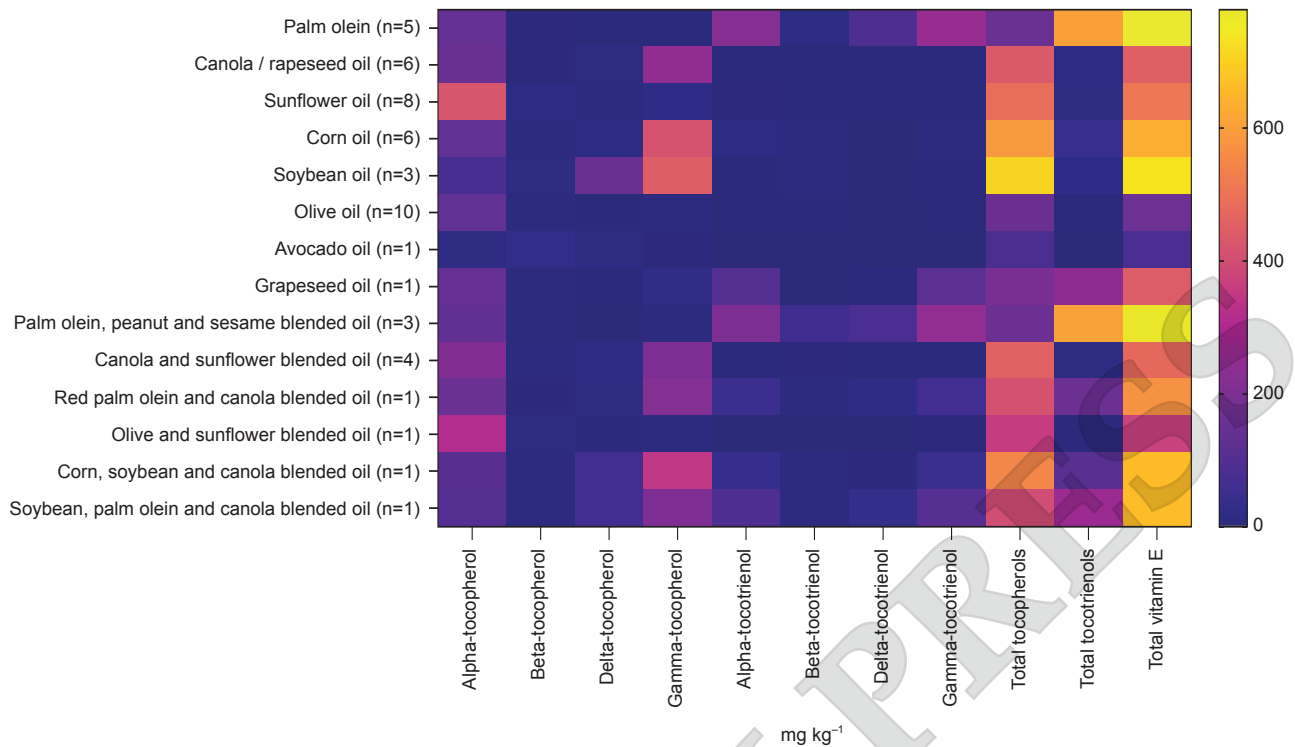
oil; red palm olein and canola blended oil; and corn, soybean, and canola blended oil) were unique as it were the only oils bearing tocotrienols mainly in the forms of alpha, delta and gamma. Inferior to the current study, most studies have reported (delta- and gamma-) tocopherols together due to lack of separation (Aksoz *et al.*, 2020; Gliszczynska-Swiglo *et al.*, 2007). Soybean oil was found to be another rich source of vitamin E ($549.2\text{--}862.3 \text{ mg/kg}$), mainly in the form of tocopherols: gamma (61.8%), delta (21.6%), and alpha (10.9%). Research conducted by Wen *et al.*, (2020) reported higher concentrations of vitamin E in soybean oil 1053 mg kg^{-1} with almost similar concentrations of tocopherols: gamma 64.0%, delta 25.0%, and alpha 11.0% (Wen *et al.*, 2020). Grapeseed oil had a balanced composition of tocopherols (45.2%) and tocotrienols (55.8%). Sunflower oil, olive oil, and their blend (sunflower and olive blended oil) resulted in more than 96.0% of tocopherols mainly in the form of alpha-tocopherol (>81.0%). Similar to Matthauss *et al.* (2016), we too report that corn oil, canola oil, and rapeseed oil can be distinguished from other analysed oils as they consist of only alpha- and gamma-tocopherols. Similar to the current study, Petersen *et al.* (2012) also observed that high oleic sunflower oil and sunflower oil possess comparable vitamin E content and composition. Corn, soybean, and canola blended oil display fairly high vitamin E content, mostly in the form of tocopherols: gamma (52.6%), alpha (17.7%), delta (10.2%), and trace amounts of gamma (7.7%) and alpha (6.8%) tocotrienols. Vitamin E content was lowest in avocado oil (88.8 mg kg^{-1}) as compared to other assayed samples.

TABLE 2. HOMOLOGS AND TOTAL TOCOPHEROLS AND TOCOTRIENOLS WET WEIGHT BASIS IN ASSAYED EDIBLE OILS BY CATEGORY

Tocopherols (mg kg ⁻¹)	Alpha	Beta	Delta	Gamma	Total
(a) Palm olein (n=5)	144.19 ± 6.08 ^{b,d,f,h,j,l,n}	9.81 ± 0.28 ^{b,f,h,j,l}	1.36 ± 2.15 ^{c,f,h,j,m}	5.08 ± 2.7 ^{c,f,g,h,j,m}	160.45 ± 9.92 ^{f,h,j}
(b) Canola oil (n=5)	155.54 ± 11.08 ^{a,d,f,h,j,l}	9.83 ± 0.27 ^{a,d,h,j,l}	18.65 ± 3.5 ^{c,d,g,i,k,l,m}	249.48 ± 20.59 ^{i,k,l,o}	433.5 ± 26.36 ^{c,i,k,l,o}
(c) Sunflower oil (n=10)	429.51 ± 49.67	23.45 ± 1.98	11.3 ± 5.79 ^{a,b,g,h,i,l,m}	27.33 ± 16.59 ^{a,f,g,h,j,m}	491.58 ± 66.45 ^{b,i,k,n}
(d) Corn oil (n=6)	136.34 ± 12.61 ^{a,b,f,h,j,l,n}	12.84 ± 0.34 ^{k,o}	23.97 ± 2 ^{b,g,k,l}	419.81 ± 81.87 ^e	592.95 ± 91.01 ⁿ
(e) Soybean oil (n=3)	80.04 ± 13.3	17.61 ± 1.12	158.25 ± 23.63	453.97 ± 51.48 ^d	709.87 ± 78.44
(f) Olive oil (n=10)	136.32 ± 20.36 ^{a,b,d,h,j,l}	10.47 ± 0.51 ^{a,b,h,j,l}	0.34 ± 1.06 ^{a,b,h,j,m}	15.57 ± 3.05 ^{a,c,g,h,j,m}	162.69 ± 21.6 ^{a,b,j}
(g) Avocado oil (n=1)	18.77 ± 0.23	39.72 ± 0.11	20.54 ± 0.03 ^{b,c,d,i,k,l}	9.75 ± 0.04 ^{a,c,f,h,j,m}	88.77 ± 0.41
(h) Grapeseed oil (n=1)	149.26 ± 1.39 ^{a,b,d,f,i,j,k,l}	10.94 ± 0.01 ^{a,b,f,j}	7.67 ± 0.08 ^{a,c,f,i,j,m}	32.58 ± 0.19 ^{a,c,f,g,j,m}	200.44 ± 1.66 ^{a,f,j}
(i) Rapeseed oil (n=1)	170.46 ± 0.94 ^{b,h,l}	9.58 ± 0.01 ^{a,b,f,j,l}	12.57 ± 0.01 ^{b,c,g,h,l,m}	266.77 ± 1.3 ^{b,l}	459.38 ± 2.26 ^{b,c,k,l,o}
(j) Palm olein, peanut and sesame blended oil (n=3)	143.2 ± 5.61 ^{a,b,d,f,h,j,l,n}	10.57 ± 1.06 ^{a,b,t,h,i,l}	0 ± 0 ^{a,t,h,m}	13.26 ± 2.8 ^{a,c,f,g,h,m}	167.02 ± 6.18 ^{a,t,h}
(k) Canola and sunflower blended oil (n=4)	218.28 ± 18.48	12.85 ± 0.72 ^{d,n,o}	24.39 ± 7.27 ^{b,d,g,l}	204.34 ± 52.15 ^{b,i,o}	459.86 ± 40.48 ^{b,c,i,l,o}
(l) Red palm olein and canola blended oil (n=1)	161.47 ± 0.71 ^{a,b,d,f,h,i,j}	9.71 ± 0.03 ^{a,b,f,i,j}	20.07 ± 0.17 ^{b,c,d,g,i,k}	224.24 ± 0.16 ^{b,i,k,o}	415.49 ± 0.4 ^{b,i,k,m,o}
(m) Olive and sunflower blended oil (n=1)	320.51 ± 1.19	21.21 ± 0.01	8.26 ± 0.01 ^{a,b,c,f,h,i,j}	15.53 ± 0.05 ^{a,c,f,g,h,j}	365.52 ± 1.16 ^o
(n) Corn, soybean and canola blended oil (n=1)	118.91 ± 0.62 ^{a,d,f,j,o}	13.95 ± 0.04 ^{d,k,o}	68.58 ± 0.09 ^o	350.69 ± 2.03	552.13 ± 2.6 ^{c,d}
(o) Soybean, palm olein and canola blended oil (n=1)	109.88 ± 0.86 ^o	13.85 ± 0.07 ^{d,k,o}	68.11 ± 0.43 ⁿ	209.37 ± 2.8 ^{b,k,l}	401.22 ± 1.44 ^{b,i,k,l,m}

Tocotrienols (mg kg ⁻¹)	Alpha	Beta	Delta	Gamma	Total
(a) Palm olein (n=5)	226.88 ± 8.47	22.74 ± 1.22 ^o	95.32 ± 6.36	263.77 ± 12.22 ^l	608.72 ± 24.57 ^l
(b) Canola oil (n=5)	6.98 ± 3.57 ^{c,e,f,g,i,k,m}	4.91 ± 3.44 ^{c,d,f,g,h,k,l,m}	1.46 ± 2.31 ^{b,d,e,f,g,k,m}	8 ± 1.46 ^{c,d,e,f,g,i,k,m}	21.35 ± 6.96 ^{c,e,f,i,k,m}
(c) Sunflower oil (n=10)	9.57 ± 5.5 ^{b,e,f,i,k}	1.87 ± 3.7 ^{b,f,g,h,i,m}	0.78 ± 2.34 ^{b,c,d,e,f,g,k,m}	6.88 ± 3.91 ^{b,d,e,f,g,i,k,m}	19.09 ± 9.72 ^{b,e,f,i,k,m}
(d) Corn oil (n=6)	22.36 ± 1.36	11.3 ± 1.12 ^{b,e,k,l,n,o}	0 ± 0 ^{b,c,e,f,g,k,m}	15.78 ± 1.81 ^{b,c,i,k,m}	49.44 ± 3.99
(e) Soybean oil (n=3)	5.44 ± 0.22 ^{b,c,f,g,i,k,m}	14.58 ± 1.68 ^{q,k,l,n,o}	0 ± 0 ^{b,c,d,f,g,k,m}	6.21 ± 2.69 ^{b,c,f,g,i,k,m}	26.23 ± 4.41 ^{b,c,i,k,m}
(f) Olive oil (n=10)	3 ± 4.2 ^{b,c,e,g,i,k,m}	1.27 ± 2.87 ^{b,c,g,h,i,m}	0 ± 0 ^{b,c,d,e,g,k,m}	1.28 ± 2.89 ^{b,c,e,g,i,k,m}	5.54 ± 7.37 ^{b,c,g,k,m}
(g) Avocado oil (n=1)	0 ± 0 ^{b,e,f,k,m}	0 ± 0 ^{b,c,f,g,h,m}	0 ± 0 ^{b,c,d,e,f,k,m}	0 ± 0 ^{b,c,e,f,i,k,m}	0 ± 0 ^{f,m}
(h) Grapeseed oil (n=1)	110.97 ± 1.04	0 ± 0 ^{b,c,f,g,i,m}	8.9 ± 0.02 ^{i,n}	127.7 ± 1.04	247.58 ± 2.06
(i) Rapeseed oil (n=1)	10.25 ± 0.18 ^{b,c,e,f,k}	0 ± 0 ^{b,c,f,g,h,m}	7.45 ± 0.02 ^{h,n}	8.49 ± 0.06 ^{b,c,d,e,f,g,l,m}	26.19 ± 0.26 ^{b,c,e,k,m}
(j) Palm olein, peanut and sesame blended oil (n=3)	207.09 ± 18.04	64.39 ± 16.03	87.25 ± 7.05	254.68 ± 18.06 ^a	613.41 ± 29.19 ^a
(k) Canola and sunflower blended oil (n=4)	1.25 ± 2.17 ^{b,c,e,f,g,i,m}	9.41 ± 0.64 ^{b,d,e,l,n,o}	1.81 ± 3.13 ^{b,c,d,e,f,g,m}	8.71 ± 0.36 ^{b,c,d,g,e,f,i,m}	21.17 ± 5.25 ^{b,c,e,f,i,m}
(l) Red palm olein and canola blended oil (n=1)	56.95 ± 1.26	11.49 ± 0.65 ^{b,d,e,k,n,o}	28.23 ± 0.17	69.07 ± 0.25	165.74 ± 0.68
(m) Olive and sunflower blended oil (n=1)	0 ± 0 ^{b,e,f,g,k}	0 ± 0 ^{b,c,f,g,h,i}	0 ± 0 ^{b,c,d,e,f,g,k}	9.21 ± 0.07 ^{b,c,d,e,f,g,i,k}	9.21 ± 0.07 ^{b,c,e,f,g,i,k}
(n) Corn, soybean and canola blended oil (n=1)	45.6 ± 0.04	12.56 ± 0.92 ^{d,e,k,l,o}	9.34 ± 0 ^{h,i}	51.24 ± 0.17	118.75 ± 1.13
(o) Soybean, palm olein and canola blended oil (n=1)	98.54 ± 0.72	15.97 ± 0.02 ^{a,d,e,k,l,n}	40.56 ± 1.69	116.24 ± 0.83	271.31 ± 3.22

Note: Values are mean value ± SD. Analyses were done in replicates for vitamin E analysis. Data was measured by one-way analysis of variance (ANOVA) with Tukey *post hoc* test. Statistical differences ($p < 0.05$) were found between test oils except those indicated by the alphabet to represent the sample of each column.



Note: Yellow (■) indicates fatty acids distributed at high concentration and blue (■) indicates fatty acids distributed at a low concentration). SFA (saturated fatty acids), MUFA (monounsaturated fatty acids), and PUFA (polyunsaturated fatty acids).

Figure 6: Heatmap explains the different contents of vitamin E homologs, total tocopherols, total tocotrienols and total vitamin E (tocols) wet weight basis in assayed edible oils by category.

Antioxidants are intentionally added at times to improve the oxidative stability of oils (Loganathan *et al.*, 2020b). All the oils used in the current study were in their natural form and none were fortified. The recommended dietary allowance (RDA) for Vitamin E by the Institute of Medicine National Academies (Russell *et al.*, 2001) is 15 mg day⁻¹. All the oils except for olive and avocado oils could fulfil the required daily intake of vitamin E. In general, vitamin E deficiency is very rare in healthy people as vitamin E is found in a variety of foods (Aksoz *et al.*, 2020).

Limitations of the current study were erucic acid (C22:1n9 cis), elaidic acid (C18:1n9t) and stereospecific analysis of fatty acids were not analysed. There could be a little variation in fatty acid composition and vitamin E content within the same type/cultivar of oil. This could be due to variations in oilseed/plant, the degree of fruit ripeness/plant maturity, the geographical location of plantations, climatic conditions, oil extraction and processing method, storage conditions, and analytical method (Aksoz *et al.*, 2020; Loganathan *et al.*, 2017; Matthaus *et al.*, 2016; Wen *et al.*, 2020).

It's important to have a healthy balance of the fatty acids in our diets. Each oil has a different fatty acid profile and unique uses in meal preparations. This can be attained by choosing the

right commercially available blended oil. Another option is using a combination of edible oils. For example, in a meal, sesame oil can be used to season rice porridge, sunflower oil to sauté green leaves, palm olein to deep fry chicken fillets, and olive oil to prepare the salad dressing. Regardless of how healthy or how balanced it is, whatever is consumed in excess is deleterious to health. Hence, appropriate calorie intake and a balanced diet are important.

CONCLUSION

By analysing the pattern of fatty acid and vitamin E profiles, the current study provides novel evidence that edible oils in the Malaysian market are of good quality and appropriately labelled. We did not find any discrepancy in the fatty acid composition labelling in any of the samples assayed. Although vitamin E content was underreported on a few labels of the assayed samples, however, all assayed samples had almost similar fatty acid and vitamin E profiles as compared to standard oil specifications. The PVs were also within the recommended range, indicating good quality compliance. These observations implied that the oil manufacturers had good acquiescence to international standards and local regulations. In

addition to that, consumers in Malaysia can be assured that the edible oils on the market shelves are well maintained during processing, delivery, and storage. Current reporting on complete vitamin E profiling is important as the functional property of each homolog varies. This study offers a clear understanding of the characterisation of fatty acid and vitamin E profiles which could serve as a benchmark for the oil industry and dietary nutrition. Besides, this study will be helpful for consumers to select suitable edible oils for various cooking methods.

ACKNOWLEDGEMENT

The authors would like to thank the Director-General of MPOB for the permission to publish the study. Sincere acknowledgement to research assistants (Fatmawati, Noraqmar and Ghazali) and intern student (Aida Farzana-UiTM) for the assistance in laboratory analysis.

REFERENCES

- Ahmad Tarmizi, A H and Siew, W L (2008). Quality assessment of palm products upon prolonged heat treatment. *J. Oleo Sci.*, 57 (12): 639-48.
- Aksoz, E; Korkut, O; Aksit, D and Gokbulut, C (2020). Vitamin E (α -, β + γ - and δ -tocopherol) levels in plant oils. *Flavour Fragr. J.*, 35 (5): 504-510.
- Chowdhury, K; Banu, L A; Khan, S and Latif, A (2007). Studies on the fatty acid composition of edible oil. *Bangladesh J. Sci. Ind. Res.*, 42 (3): 311-316.
- Codex Alimentarius (1999). *Codex standard for named vegetable oils*. Food and Agriculture Organization of the United Nations. World Health Organization.
- Codex Alimentarius (2001). *Codex standard for olive oil, virgin and refined, and for refined olive-pomace oil*. Food and Agriculture Organization of the United Nations. World Health Organization.
- Codex Alimentarius (2019). *Proposed Draft Version to the Standard for Named Vegetable Oils (CXS 210-1999): Inclusion of Walnut oil, Almond oil, Hazelnut oil, Pistachio oil, Flaxseed oil and Avocado oil*, Food and Agriculture Organization of the United Nations. World Health Organization.
- Coskuntuna, L; Gecgel, U; Yilmaz, I; Gecgel, U and Dulger, G C (2015). Investigating fatty acid composition of samples were homogenized various meat and offal products from Turkey. *J. Am. Oil Chem. Soc.*, 92 (5): 659-665.
- Dorni, C; Sharma, P; Saikia, G and Longvah, T (2018). Fatty acid profile of edible oils and fats consumed in India. *Food Chem.*, 238: 9-15.
- Elmadfa, I and Kornsteiner, M (2009). Fats and fatty acid requirements for adults. *Ann. Nutr. Metab.*, 55 (1/3): 56-75.
- Fu, J Y; Che, H L; Tan, D M Y and Teng, K T (2014). Bioavailability of tocotrienols: Evidence in human studies. *Nutr. Metab. (Lond)*, 11 (1): 1-10.
- Gliszczynska-Swiglo, A; Sikorska, E; Khmelinskii, I and Sikorski, M (2007). Tocopherol content in edible plant oils. *Pol. J. Food Nutr. Sci.*, 57 (4 [A]): 157-161.
- Haiyan, Z; Bedgood Jr, D R; Bishop, A G; Prenzler, P D and Robards, K (2007). Endogenous biophenol, fatty acid and volatile profiles of selected oils. *Food Chem.*, 100 (4): 1544-1551.
- Haytowitz, D; Lemar, L; Pehrsson, P; Exler, J; Patterson, K; Thomas, R; Nickle, M; Williams, J; Showell, B and Khan, M (2011). USDA national nutrient database for standard reference, release 24. US Department of Agriculture, Washington DC, USA.
- International Olive Council (2006). *Global Method for the Detection of Extraneous Oils in Olive Oils*. International Olive Council (IOC), Madrid, Spain.
- Jovanović, P L; Dokić, L P and Marić, B J (2005). Fatty acid composition of maize germ oil from high-oil hybrids wet-milling processing. *Acta Period. Technol.*, 36: 43-50.
- Kang, M J; Shin, M S; Park, J N and Lee, S S (2005). The effects of polyunsaturated: Saturated fatty acids ratios and peroxidisability index values of dietary fats on serum lipid profiles and hepatic enzyme activities in rats. *Bri. J. Nutr.*, 94 (4): 526-532.
- Krauss, R M; Eckel, R H; Howard, B; Appel, L J; Daniels, S R; Deckelbaum, R J; Erdman Jr, J W; Kris-Etherton, P; Goldberg, I J and Kotchen, T A (2000). AHA dietary guidelines: Revision 2000: A statement for healthcare professionals from the Nutrition Committee of the American Heart Association. *Circulation*, 102 (18): 2284-2299.
- Kushairi, A; Ong-Abdullah, M; Nambiappan, B; Hishamuddin, E; Bidin, M; Ghazali, R; Subramaniam, V; Sundram, S and Parveez, G K A (2019). Oil palm economic performance in

- Malaysia and R&D progress in 2018. *J. Oil Palm Res.*, 31 (2): 165-194.
- Lichtenstein, A (2013). Fats and oils. *Reference Module in Biomedical Sciences Encyclopedia of Human Nutrition*. 3rd edition. Academic Press, Elsevier Ltd., Waltham, MA, USA. p. 201-208.
- Loganathan, R; Selvaduray, K R; Nesaretnam, K and Radhakrishnan, A (2021). Palm tocotrienols cause cleavage of poly-(ADP)-ribose polymerase enzyme and down-regulation of cyclooxygenase-2 protein level in human breast cancer cells. *J. Oil Palm Res.*, 33 (1): 119-128.
- Loganathan, R; Subramaniam, K M; Radhakrishnan, A K; Choo, Y-M and Teng, K-T (2017). Health-promoting effects of red palm oil: Evidence from animal and human studies. *Nutr. Rev.*, 75 (2): 98-113.
- Loganathan, R; Tarmizi, A H A; Vethakkan, S R and Teng, K T (2020a). Retention of carotenes and vitamin E, and physico-chemical changes occurring upon heating red palm olein using deep-fat fryer, microwave oven and conventional oven. *J. Oleo. Sci.*, 69 (3): 167-183.
- Loganathan, R; Tarmizi, A H A; Vethakkan, S R and Teng, K T (2020b). Storage stability assessment of red palm olein in comparison to palm olein. *J. Oleo. Sci.*, 69 (10): 1163-1179.
- Martin, M E; Grao-Cruces, E; Millan-Linares, M C and Montserrat-De La Paz, S (2020). Grape (*Vitis vinifera* L.) seed oil: A functional food from the winemaking industry. *Foods*, 9 (10): 1360.
- Matthaus, B; Özcan, M M and Al Juhaimi, F (2016). Some rape/canola seed oils: Fatty acid composition and tocopherols. *Z. Naturforsch., C, J. Biosci.*, 71 (3-4): 73-77.
- Oil World Annual (2020). *ISTA Mielke GmbH*. Hamburg, Germany.
- Petersen, K D; Kleeberg, K K; Jahreis, G and Fritsche, J (2012). Assessment of the oxidative stability of conventional and high-oleic sunflower oil by means of solid-phase microextraction-gas chromatography. *Int. J. Food Sci. Nutr.*, 63 (2): 160-169.
- Piravi-Vanak, Z; Ghavami, M; Ezzatpanah, H; Arab, J; Safafar, H and Ghasemi, J B (2009). Evaluation of authenticity of Iranian olive oil by fatty acid and triacylglycerol profiles. *J Am. Oil Chem. Soc.*, 86 (9): 827-833.
- Rueda, A; Seiquer, I; Olalla, M; Giménez, R; Lara, L and Cabrera-Vique, C (2014). Characterization of fatty acid profile of argan oil and other edible vegetable oils by gas chromatography and discriminant analysis. *J. Chem.*, 2014. DOI: 10.1155/2014/843908.
- Russell, R; Beard, J L; Cousins, R J; Dunn, J T; Ferland, G; Hambidge, K; Lynch, S; Penland, J; Ross, A and Stoecker, B (2001). Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. A Report of the Panel on Micronutrients, Subcommittees on Upper Reference Levels of Nutrients and of Interpretation and Uses of Dietary Reference Intakes, and the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes Food and Nutrition Board Institute of Medicine.
- The American Oil Chemists' Society (2017a). AOCs Official Method Cd 8b-90: Peroxide Value Acetic Acid-Isooctane Method, Official Methods and Recommended Practices of the AOCs. 7th edition. American Oil Chemists Society Press, Champaign. AOCs Press.
- The American Oil Chemists' Society (2017b). AOCs Official Method Ce 1a-13: Determination of Fatty acids in Edible Oils and Fats by Capillary GLC, Official Methods and Recommended Practices of the AOCs. 7th edition. American Oil Chemists Society Press, Champaign. AOCs Press.
- The American Oil Chemists' Society (2017c). AOCs Official Method Ch 1-91: Preparation of Methyl Esters of Long-Chain Fatty Acids, Official Methods and Recommended Practices of the AOCs. 7th edition. American Oil Chemists Society Press, Champaign. AOCs Press.
- Wallingford, J C; Yuhas, R; Du, S; Zhai, F and Popkin, B M (2004). Fatty acids in Chinese edible oils: value of direct analysis as a basis for labeling. *Food Nutr. Bull.*, 25 (4): 330-336.
- Wen, Y; Xu, L; Xue, C; Jiang, X and Wei, Z (2020). Assessing the impact of oil types and grades on tocopherol and tocotrienol contents in vegetable oils with chemometric methods. *Molecules*, 25 (21): 5076.
- WHO (2008). *Interim summary of conclusions and dietary recommendations on total fat and fatty acids*. Joint FAO/WHO expert consultation on fats and fatty acids in human nutrition.