BCSIR

Available online at www.banglajol.info/index.php/BJSIR

Bangladesh J. Sci. Ind. Res. **60(1)**, 63-72, 2025

BANGLADESH JOURNAL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

ISSN. 0304-9809

Comparison of *trans* fatty acid content in commonly consumed seed oils and commercially refined counterparts

M. A. Kabir[1,3], S. A. Lisa[1], M. M. Alam[1], M. K. Hossain[2], S. N. Islam[3] and N. Shaheen[3]*

[1]*Institute of Food Science and Technology (IFST), Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka-1205, Bangladesh*

[2]*BCSIR Laboratories Dhaka, Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka-1205, Bangladesh*

[3]*Institute of Nutrition and Food Science, University of Dhaka*

ARTICLE INFO

Received: 15 January 2025

Revised: 23 February 2025

Accepted: 02 March 2025

eISSN 2224-7157/

DOI: https://doi.org/10.3329/bjsir.v60i1.79017

Abstract

Conventional seed oils and their commercially refined counterparts may contain different levels of *trans* fatty acids (TFA) due to refining and high heat treatment during deodorization. To identify and quantify TFA content in five commonly consumed marketed refined vegetable oils namely refined soybean oil (RSO), refined palm oil (RPO), mustard oil (MO), refined rice bran oil (RRBO), and refined sunflower oil (RSuO) were analyzed. To identify the potential source of TFA, seed extract and crude extract of the studied oil were also analyzed. Among the 57 analyzed samples, the highest TFA was found in RRBO 4.35±3.88% followed by RSO 3.50±1.54%. RSuO and RPO contained TFA within the recommended level of the World Health Organization whereas TFA was below the detection limit in MO. Very little TFA was observed in crude palm oil, rice bran, and soybean seed extracted oil, while no TFA was found in mustard and sunflower seed extracted oil.

Keywords: *Trans* fatty acids; Seed oil; Refined oil; Heat treatment; Gas Chromatography

Introduction

Trans fats also referred to as *trans* fatty acids (TFAs), can be defined as the geometric isomers of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) having at least one carbon-carbon double bond at opposite positioned hydrogens (Iqbal, 2014). MUFAs and PUFAs are suggested to be consumed in replacement of saturated fatty acids (SFA) due to their positive effects in lowering Low-density lipoprotein cholesterol (LDL) from plasma (Lada and Rudel, 2003). However, edible oils that abound with PUFA, are more susceptible to producing TFA during industrial processing like partial hydrogenation. Although some TFAs come from the bacterial *trans*-formation of unsaturated fatty acids in the rumen of ruminants (Dhaka *et al*. 2011), most of the TFAs are produced industrially through hydrogenation or refining process (Destaillats and Angers, 2005; Dhaka *et al*. 2011; Puprasit *et al*. 2020; Sarwar *et al*. 2024). The heat treatment during the cooking procedure or deep frying has also caused the translocation of hydrogen atoms attached to double bond leads the conversion of *cis* to *trans* fatty acids in oil (Bhardwaj *et al*. 2016; Tsuzuki *et al*. 2010).

TFAs engender deleterious effects on the human body by increasing insulin levels, triglycerides, and LDL and reducing high-density lipoproteins (HDL)(Katan *et al*. 1995). The structural transformation from cis to *trans* fatty acids influences physicochemical properties like the increment of melting point, which leads to detrimental effects on physiological properties in the human body (Oteng and Kersten, 2020). The melting points of elaidic acid (C18:1n9t),

*Corresponding author's e-mail: nazmashaheen@du.ac.bd

oleic acid (C18:1n9c), and stearic acid (C18:0) are, respectively, 42, -5, and 70 °C which suggests that just like saturated fat *trans*-fat remains solid at room temperature as well as human body temperature (Song *et al*. 2015). Therefore, TFAs have a great influence in elevating the risk of coronary heart disease as well as endangering the brain cell membrane and neurons, which ultimately undermine mental performance (Ginter and Simko, 2016). A high-TFA diet has been linked to negative alterations in the plasma lipoprotein profile, including a drop in high-density lipoproteins (HDL) and an increase in low-density lipoproteins (LDL), according to many clinical investigations (Brouwer *et al*. 2010; de Roos *et al*. 2001; Garshick *et al*. 2014). Research has indicated that TFAs may deleteriously affect atherosclerosis's inflammatory process by elevating inflammatory cytokines. Considering the noxious effect of TFA on human health, the World Health Organization (WHO) recommended limiting 2 g of industrially produced TFAs per 100 g of total fat in all foods (WHO, 2018). Edible vegetable oil, an important component of the human diet, provides the energy and fatty acids essential for the human body and increases digestion followed by absorption of fat-soluble vitamins (Zhao *et al*. 2021). The worldwide consumption of vegetable oil has increased to almost 222 million metric tons in the year 2023/24, indicating that people are more avid to consume vegetable oil as a healthier alternative than animal fat due to the abundance of unsaturated fatty acids (Shahbandeh, 2024). However, TFAs consumption is also increasing with the rise of vegetable oil consumption since a significant amount of TFA is formed during different refining stages, especially at the deodorization step (Tasan and Demirci, 2003). In a recent study in Bangladesh, Sarwar *et al*. (2024) found an elevated amount of TFAs in locally available refined branded and non-branded soybean oil. Although refining vegetable oil at high temperatures is a possible cause of producing TFA (Pipoyan *et al*. 2021; Xie *et al*. 2019), some previous studies showed the presence of TFA in non-refined seed oils (Brühl, 1996; Dixit and Das, 2012; Fritsche and Steinhart, 1998) arising the questions about the natural occurrence of TFA in oilseeds.

In Bangladesh, there are several packaged and labeled refined vegetable oils available under various brand names; of these, 39% are soybean oil, 20% are rice bran oil, 19% are sunflower oil, 18% are palm oil, and 79% of the oils that are available in the market are locally refined (GAIN and icddrb, 2017). Although the scenario of TFA in soybean and palm oil of the Bangladeshi market is conspicuous in Sarwar *et al*. (2024), the condition of other vegetable oils is prevaricating till now. Apart from that, the presence of the individual isomers of *trans* oleic, *trans* linoleic, and *trans* linolenic should be assessed in both the seed oils and their processed counterparts which was reported by multiple studies (Dixit and Das, 2012; Li *et al*. 2012; Tsuzuki *et al*. 2008). Considering the above-mentioned risk of *trans* fatty acid in human health and since it was not done before in the Bangladesh perspective to the author's best knowledge, the assessment of the TFAs content along with the individual isomers in seed has become imperative for the indigenous seed oils. The main objective of this study is to assess the presence of TFAs in solvent-extracted oils in the laboratory from locally available oilseed (soybean, sunflower, rice bran, mustard, and palm) that naturally occurred and give conclusive evidence of TFAs abundance in their refined counterparts.

Materials and methods

Standard materials and reagents

The mix standard used for fatty acid analysis was Supelco 37 component FAME mix (Supelco, Bellefonte, PA, USA) and for the *trans*-fatty acid analysis were elaidic acid (C18:1), Linoleic acid methyl ester mix (C18:2 isomers) and Linolenic acid methyl ester mix (C18:3 isomers) (Supelco, Bellefonte, PA, USA). All other used chemicals of high purity were obtained from Merck (Darmstadt, Germany).

Oilseed and refined oil sample collection

The seed sample consists of sunflower seed (Heliathus annuus), Soybean seed (Glycine max), and mustard seed (Brassica juncea). All the seeds and rice bran were collected from the local market (New-market, Dhaka) of the capital city of the country where the seeds were sourced from various parts of Bangladesh. The crude Palm oil (CPO) samples were collected from the refinery before processing. The refined soybean oil (RSO), refined sunflower oil (RSuO), Refined rice bran oil (RRBO), refined palm oil (RPO), and mustard oil (MO) (branded and non-branded) were collected from the same market and a departmental store.

Oil extraction from seed

Soybean seed extracted oil (SSEO), sunflower seed extracted oil (SuSEO), rice bran extracted oil (RBEO), and mustard seed extract oil (MSEO) were prepared by cold extraction procedure using petroleum ether. All the seeds were ground into powder and soaked in petroleum ether overnight. Oil was obtained from the dried filtration of the seed-petroleum

mixture. Temperature was strictly maintained below 80°C in every step to avoid TFA formation in the extracted oil.

Effect of processing on TFAs in processed edible oils

To understand the effect of processing on TFA in refined oil, all the extracted and crude oil samples (SSEO, SuSEO, RBEO, MSEO, and CPO) and refined samples (RSO, RSuO, RRBO, RPO, and MO) were subjected to an attenuated total reflectance Fourier transform infrared spectrophotometry (ATR-FTIR) to see the presence of *trans* fatty acid in seed and processed oil. Then the fatty acid content was analyzed by gas chromatography (GC) in processed oils and compared with their corresponding seed extract.

ATR-FTIR conditions

FTIR analyses were conducted using a Thermo Fisher Nicolet™ iS™ 5 FTIR Spectrometer from MA, USA, equipped with OMNIC software and operated in ATR mode. Spectra were obtained across the wavenumber range of 4000 to 500 cm^{-1} at a 4 cm^{-1} resolution, adhering to an established industrial standard. Air served as the reference background material during the measurements.

FAME Preparation

Fatty acids in oils were esterified to converted into FAMEs by following ISO 12966-2:2017(E) with slight modification as described by Lisa *et.al.* (2024) (Lisa *et al*. 2024). About 50 mg of the oil sample was transferred into a test tube containing 2 mL of isooctane and shaken vigorously. With the solution, 2 M methanolic KOH (0.1 mL) was added, and properly shaken for 1 minute, 2 mL saturated sodium chloride was added and kept for 2 minutes for phase separation. Then clear portion was passed through an anhydrous sodium sulfate column and collected into a 2 mL vial for GC analysis.

Gas Chromatography Instrumentation

Identification and quantification of FAMEs of the oils were conducted using Thermo Fisher Scientific Gas Chromatography (Trace 1300, MA, USA) equipped with flame ionized detector (FID), autosampler and a highly polar fused silica capillary column (Rt-2560, Restek, Bellefonte, PA, USA) (100 m × 0.25 mm i.d × 0.20 µm film thickness) was used for fatty acid methyl ester separation. The initial oven temperature was 150°C with 10 min holding time. The temperature was then increased to 200°C at a rate of 5°C/min and 10 minutes held at this temperature. After that, the temperature increased at 10°C/min to 240°C and held for 20 minutes. Split injection mode was used for this analysis and split ratio was 20:1, injection temperature and detector temperature were 250°C. The identification and quantification of separated peaks were performed by using reference standards (Figure 1).

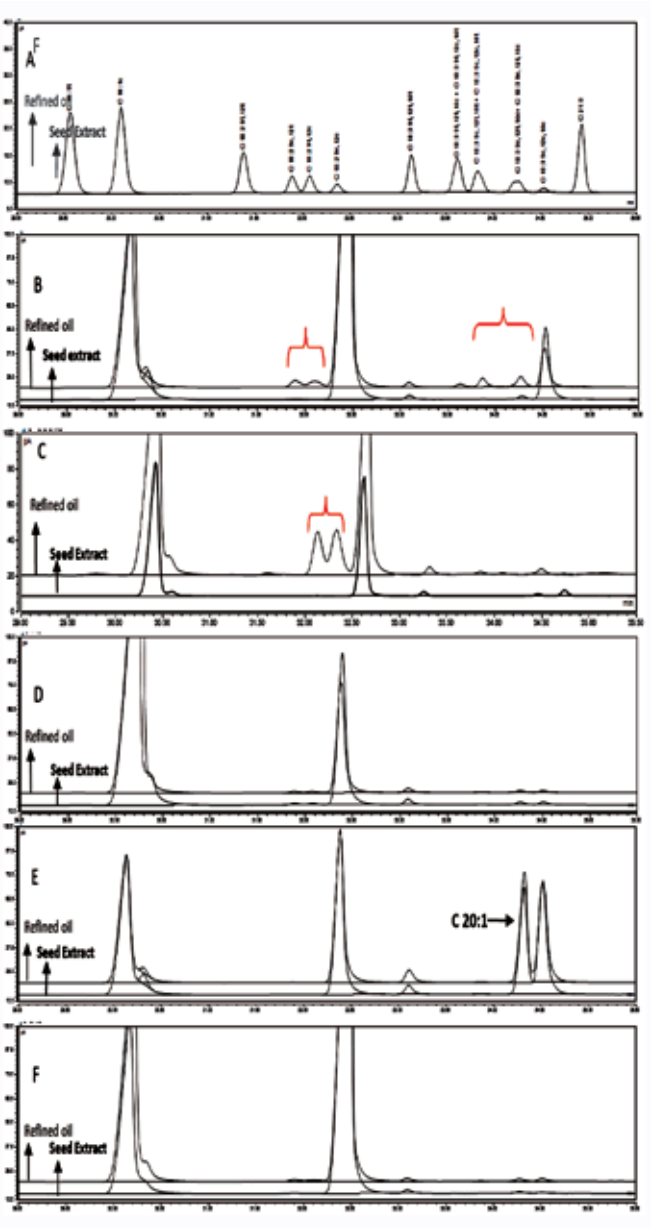

Fig. 1. Standard chromatograms of 18 isomers (A) and the chromatograms of the seed extracted oil and their refined counterparts; (B) Soybean oil, (C) Rice bran oil, (D) Palm oil, (E) Mustard oil, (F) Sunflower oil

Statistical Analysis

All the analyses were conducted in triplicate (n=3), and values were reported as mean ± standard deviations (SD). Independent sample t-test was used to compare mean values and $p < 0.05$ was considered as statistically significant. Statistical analysis was performed by using Statistical Package of Social Sciences (SPSS) version 25 (IBM, NY, USA).

Results and discussion

Analysis of TFAs in seed extract and processed oil using ATR-FTIR

The infrared spectra of seed extract and refined oil are shown in Figure 2. The absorbance band was assigned in the mid-IR spectrum (500-4000 cm^{-1}) as it is widely used for oil sample analysis (Jamwal *et al*. 2021). The spectrum is

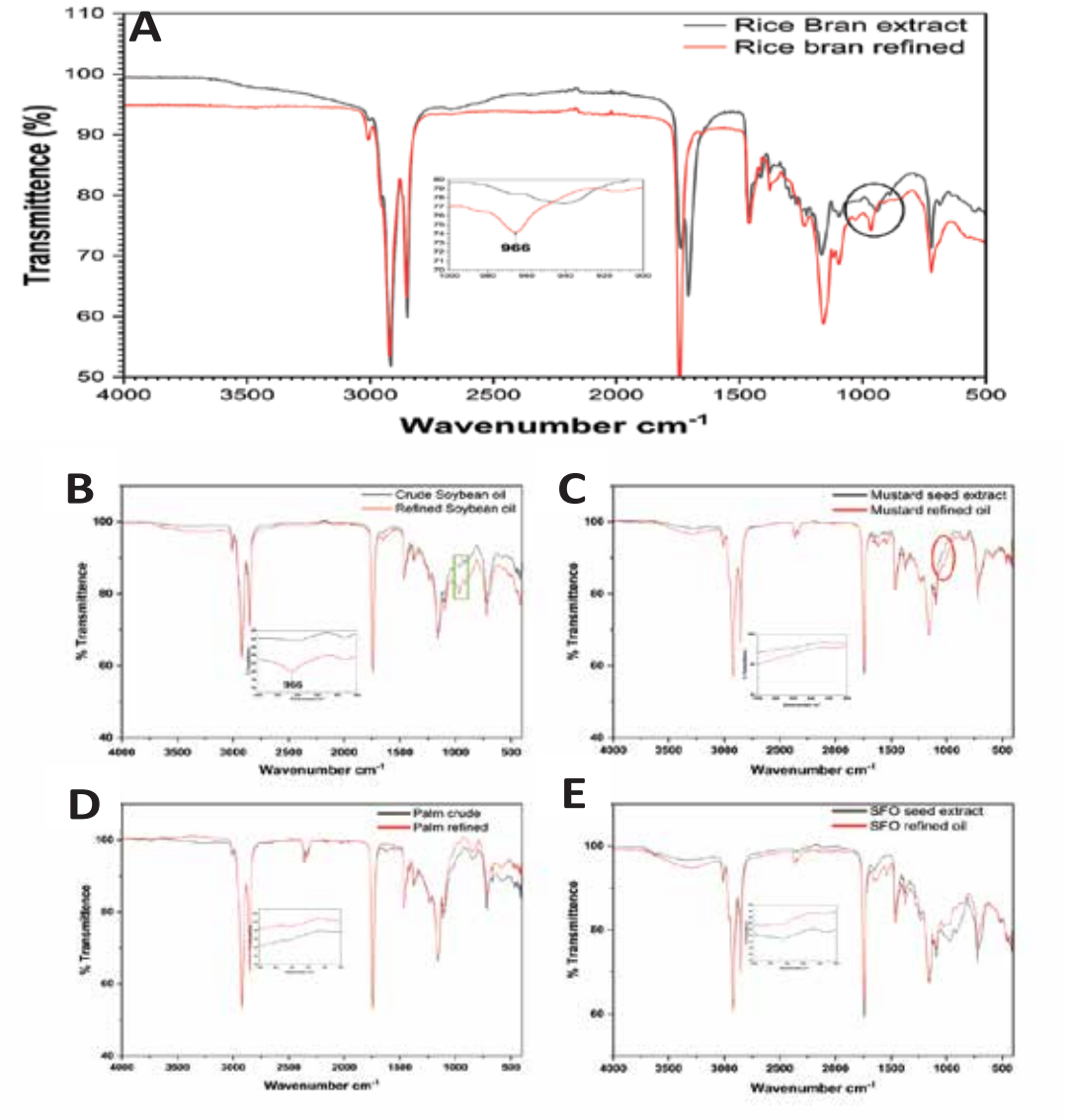

Fig. 2. Infrared spectra of seed extract and refined oil, A. Rice Bran, B. Soybean, C. Mustard oil D. Palm oil E. Sunflower oil; Prominent peak at 966 cm^{-1} was observed Rice bran oil and soybean oil indicating the trans figuration of C-H group at C-C double bond

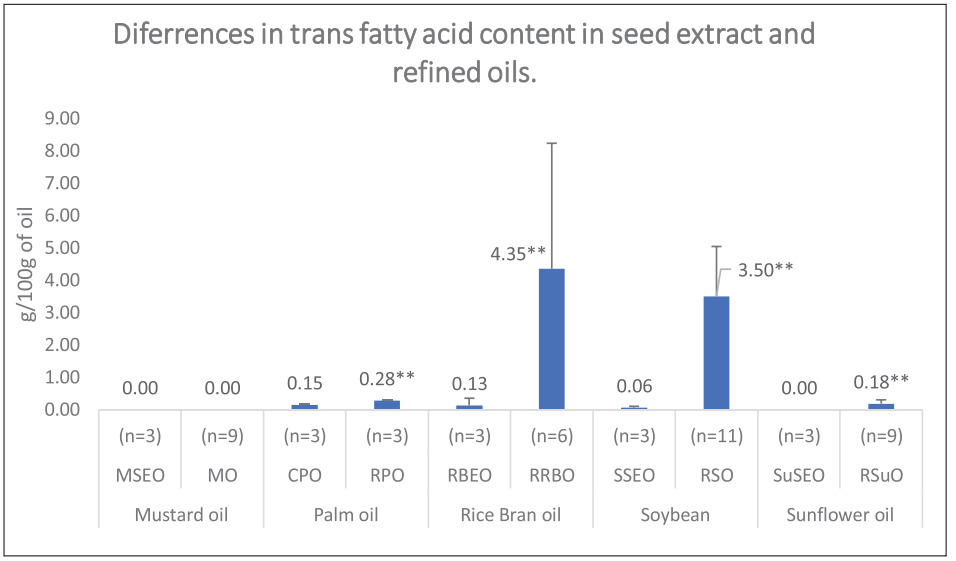

Fig. 3. Differences in *trans* fatty acid content in seed extract and refined oils

mainly divided into four regions and all the regions have identical peaks of corresponding seed extract and refined oil (Bunaciu *et al*. 2022; Guillén and Goicoechea, 2007; Li *et al*. 2012; Rohman and Che Man, 2012). The fingerprint region (600-1500 cm^{-1}) is unique and specific for each oil. In this region, the *trans* configuration of the unsaturated fatty acids' isomer is expected to absorb 960-970 cm^{-1} (Coates, 2000). That means prominent peaks will be observed if there is any *trans* fatty acid present in the oil. The enlarged form of the spectra of this region of each refined and their corresponding seed extract was as shown in the inset of Figure 3 A. Rice Bran, B. Soybean, C. Mustard D. Palm E. Sunflower oil. A prominent peak was observed at 966 cm^{-1} in RRBO (inset A) whereas no visible peak was observed in its corresponding seed extract by cold-pressed. Moreover, there were no peaks on both sides of the 966 cm^{-1} peak which indicated the *trans* formed in the RRBO was non-conjugated trans fatty acids (Christy, 2009). In RSO (inset B) the prominent peak was at 963 cm^{-1} and the seed extract had no such peaks in that band. Although Li *et al*. reported the *trans* band at 966 cm^{-1} in processed soybean oil which was increased in size with the increasing heat (Li *et al*. 2012), analyzed peak of the current study is well within the range. In Sunflower oil (inset C) both processed and seed extract have no prominent peaks in the reference region which was alike to previous reported studies (Guillén and Goicoechea, 2007; Ozulku *et al*. 2017).

Comparison of TFAs content in seed extract and refined oils

All the seed samples were collected from three different sources and analyzed separately. All the seeds are fundamentally different from each other, so their fatty acid content will differ from each other. The source of oils or the technological procedure used in their refining determines the variation in their fatty acid profile (Orsavova *et al*. 2015). The fatty acid composition of SSEO, SuSEO, RBEO, MSEO, CPO, RSO, RSuO, RRBO, RPO, and MO are presented in Table 1. In the present experiment, very little amount of TFA was observed in RBEO (0.13 ± 0.22), SSEO (0.06 ± 0.04), and CPO (0.15 ± 0.01) while no TFA was found in MSEO and SuSEO. Among the refined oils, RRBO showed the highest TFA content having 4.35 ± 3.88% followed by RSO with 3.50 ± 1.54% TFAs. Refined SuO and PO contained very little amount of TFA, 0.23% and 0.28% respectively. TFA content in RRBO is about double that of the previous studies (Cui *et al*. 2017; Mishra and Sharma, 2014), but total TFA content in RSO is comparable with Hou *et al*. (2012) and Dixit and Das, (2012) who found 3.11% and 3.25% TFAs in RSO respectively The most common TFA was nonconjugated *trans* linoleic acid (9c12t; 9t12c) found in all the refined oils except mustard oil. *Trans* linoleic acid was the main contributor to total TFAs content, and the content was 3.63 ± 1.81 for RRBO, 1.51±0.51 for RSO, and 0.15±0.1 for RPO, this result is similar to the previous studies where *trans* linoleic acid was also found as

Table 1. Effect of processing techniques on TFAs in processed edible oils (g/100g of oil)[a]

Fatty acids	Mustard oil		Palm oil		Rice Bran oil		Soybean		Sunflower oil	
	MSEO (n=3)	MO (n=9)	CPO (n=3)	RPO (n=3)	RBEO (n=3)	RRBO (n=6)	SSEO (n=3)	RSO (n=11)	SuSEO (n=3)	RSuO (n=9)
C 16:0	3.29 ± 0.30	3.39 ± 1.86	37.79 ± 0.42	37.96 ± 0.89	20.07 ± 0.86	19.30 ± 0.73	11.52 ± 0.37	10.92 ± 0.30*	6.13 ± 0.03	6.15 ± 0.40
C 16:1	0.18 ± 0.03	0.17 ± 0.03	0.14 ± 0.03	0.16 ± 0.01	0.13 ± 0.12	0.19 ± 0.01	0.12 ± 0.01	0.09 ± 0.02*	nd	0.13 ± 0.04**
C 18:0	1.30 ± 0.27	1.51 ± 0.37	4.42 ± 0.16	4.22 ± 0.17	2.34 ± 0.41	1.97 ± 0.20	3.48 ± 0.06	4.47 ± 0.19***	4.72 ± 0.02	3.41 ± 0.21***
C 18:1 9c	22.44 ± 8.22	23.89 ± 8.51	43.68 ± 0.58	43.28 ± 0.24	41.81 ± 1.58	39.93 ± 2.82	26.70 ± 0.24	23.20 ± 0.83***	23.56 ± 0.06	35.00 ± 6.27*
C 18:1 11c	1.00 ± 0.25	1.47 ± 0.44	1.53 ± 0.15	1.12 ± 0.01**	1.13 ± 0.18	1.29 ± 0.10	1.79 ± 0.38	1.65 ± 0.09	nd	1.03 ± 0.12***
C 18:2 9t, 12t	nd	nd	nd	nd	nd	0.04 ± 0.02	nd	nd	nd	nd
C 18:2 9t, 12c	nd	nd	0.08 ± 0.01	0.15 ± 0.01***	0.08 ± 0.14	1.79 ± 1.01	0.06 ± 0.04	0.78 ± 0.38**	nd	0.12 ± 0.06**
C 18:2 9c, 12t	nd	nd	0.07 ± 0.01	0.13 ± 0.01***	nd	1.84 ± 1.96	nd	0.73 ± 0.38**	nd	0.05 ± 0.07
C 18:2 9c, 12c	13.97 ± 0.29	15.20 ± 3.17	10.70 ± 0.94	10.62 ± 0.72	29.79 ± 1.58	29.81 ± 1.86	48.63 ± 0.56	50.02 ± 1.16	62.97 ± 0.04	52.14 ± 6.35*
C 20:0	0.71 ± 0.07	0.86 ± 0.11	0.40 ± 0.02	0.39 ± 0.01	0.86 ± 0.08	0.72 ± 0.07*	0.31 ± 0.01	0.39 ± 0.13	0.30 ± 0.02	0.26 ± 0.02*
C 18:3 9t, 12t, 15c + 18:3 9t, 12c, 15t	nd	nd	nd	nd	nd	0.16 ± 0.07**	nd	0.20 ± 0.17	nd	nd
C 18:3 9c, 12t, 15t + 18:3 9c, 12c, 15t	nd	nd	nd	nd	0.02 ± 0.01	0.24 ± 0.06**	nd	0.89 ± 0.30	nd	nd
C 18:3 9t, 12c, 15c	nd	nd	nd	nd	nd	0.24 ± 0.07***	nd	0.90 ± 0.33	nd	nd
C 20:1	10.91 ± 2.03	6.90 ± 2.55*	0.18 ± 0.01	0.19 ± 0.01	0.50 ± 0.09	0.52 ± 0.06	0.22 ± 0.01	0.22 ± 0.01	nd	0.15 ± 0.01***
C 18:3 ALA	9.58 ± 0.90	8.07 ± 0.79*	0.17 ± 0.01	0.20 ± 0.04	1.22 ± 0.26	0.54 ± 0.33*	6.08 ± 0.16	4.15 ± 0.83**	nd	0.09 ± 0.06*
C 22:0	0.44 ± 0.13	0.76 ± 0.17*	nd	0.08 ± 0.01***	0.30 ± 0.05	0.24 ± 0.03	0.31 ± 0.02	0.48 ± 0.04***	0.87 ± 0.01	0.76 ± 0.05**
C 22:1	33.23 ± 9.29	34.76 ± 10.02	nd	nd	nd	nd	nd	nd	nd	nd
C 24:0	0.20 ± 0.05	0.31 ± 0.07	nd	0.05 ± 0.05	0.39 ± 0.06	0.35 ± 0.06	0.13 ± 0.01	0.17 ± 0.06	0.28 ± 0.00	0.27 ± 0.02
Σ cis-UFAs	92.89 ± 0.58	90.80 ± 2.08	56.40 ± 0.56	55.61 ± 1.00	74.58 ± 0.60	72.50 ± 3.36	83.58 ± 0.08	79.46 ± 1.66**	86.53 ± 0.02	88.56 ± 0.73**
Σ trans-UFAs	nd	nd	0.15 ± 0.01	0.28 ± 0.01**	0.13 ± 0.22	4.35 ± 3.88***	0.06 ± 0.04	3.50 ± 1.54***	nd	0.18 ± 0.12*
Σ SFAs	5.98 ± 0.36	6.89 ± 2.08	43.42 ± 0.57	43.63 ± 1.00	24.43 ± 1.54	22.90 ± 0.70	15.91 ± 0.21	16.61 ± 0.50**	12.30 ± 0.04	10.96 ± 0.51**
Σ MUFAs	68.76 ± 1.34	67.17 ± 4.58	45.53 ± 0.39	44.77 ± 0.26*	43.60 ± 1.49	42.00 ± 2.89	28.87 ± 0.65	25.20 ± 0.85***	23.56 ± 0.06	36.32 ± 6.37**
Σ PUFAs	24.13 ± 1.06	23.68 ± 2.87	10.87 ± 0.95	11.12 ± 0.75	31.11 ± 1.97	34.89 ± 3.54	54.77 ± 0.75	57.76 ± 1.28**	62.97 ± 0.04	52.42 ± 6.37*
Total FAs	98.83 ± 0.90	98.74 ± 0.56	99.82 ± 0.01	99.52 ± 0.04	99.13 ± 1.18	99.75 ± 0.21	99.55 ± 0.31	99.56 ± 0.14	98.83 ± 0.02	99.70 ± 0.23

Note: [a] **n** represents the number of samples; Analysis of each sample was conducted in triplicate and values are reported as mean ± standard deviations (SD); **nd** = not detected; * value is significant at $p < 0.05$ level; ** value is significant at $p < 0.01$ level; *** value is significant at $p < 0.001$.

main contributor of total TFA in SO and PO (Fang *et al*. 2023; Hou *et al*. 2012; Sarwar *et al*. 2024). The other TFA found in this experiment was *trans* linolenic acid which found RRBO (0.64±0.21) and RSO (1.99±0.91). The presence of *trans* linolenic acid in RSO was also described by Hou *et al*. (2012) and Fang *et al*. (2023) on the other hand, Sarwar *et al*. 2024 did not discuss the presence of it in their study Sarwar *et al*. (2024). However, elaidic (C 18:1 9t), the most described *trans* fatty acid was not identified in any of the seed extract or refined oil samples in the present study.

In Figure 3, the comparison of *trans* fatty acids in seed oil and their refined counterparts has been shown. The figure clearly shows that the refined oils contain more *trans* fatty acids than the seed-extracted oils, while the abundance of *trans* fatty acids is maximum in RRBO followed by RSO.

CPO had the highest saturated fatty acid (SFA) content (43.86%) with a considerable portion of palmitic acid (38.10%). With a major content of 34.01% erucic acid, MSEO had the highest level of monounsaturated fatty acids (MUFA) at 66.45%. The polyunsaturated fatty acid (PUFA) content of SuSEO was highest (62.97%), whereas oleic acid was only less than one-fourth of total fatty acid (23.57%). These results were consistent with some earlier research findings (Mancini *et al*. 2015; Schwarzinger *et al*. 2022).

Palmitic acid (C16:0), stearic acid (C18:0), oleic acid (C18:1), linoleic acid (C18:2), and linolenic acid (C18:2) are the most prominent fatty acids found in all types of oil which follow the specification mentioned in codex standard for vegetable oil (CODEX STAN 210, 1999). Furthermore, the findings of fatty acids in this investigation aligned with the findings of earlier research (Chotimarkorn and Silalai, 2008; Petraru *et al*. 2021).

Among the five studied oils, sunflower oil is imported in refined form and no treatment is applied in Bangladesh. In contrast, soybean oil and palm oil are imported as crude form, and refining and purification are performed in Bangladesh. On the other hand, rice bran oil is extracted and refined inside the country and mustard oil is extracted by mechanical pressing without any chemical treatment.

In this experiment seed oils were collected by cold extraction involving heat treatment less than 80°C, hence, very little amount of TFAs was found in seed extract indicating that naturally plant seeds contain negligible TFAs. A high level of TFAs found in RRBO and RSO was certainly generated during the refining stages, besides, no TFA in MO and a small amount in RPO and RSuO indicate processing without heat treatment and careful refining limits the TFA content within the recommended level (Bruhl, 1996).

Conclusion

In conclusion, it can be said that, naturally, a small amount of *trans* fatty acid is present in oil extracted from seeds by the physical procedure which increased several folds in rice bran oil and soybean oil during refining whereas, palm oil and sunflower oil showed less increment. As no heat treatment in the case of mustard oil extraction in Bangladesh, TFAs in commercial mustard oil are similar to seed extract oil. In the case of rice bran oil and soybean oil, high heat treatment is involved during refining which is considered the main cause of the TFAs formation. Hence, further study is needed to find out the potential stage where TFA is formed and heat treatment should be adjusted accordingly to control TFA in its acceptable limit.

Acknowledgment

The authors would like to thank the Chairman of BCSIR and the Director of IFST for logistic support.

References

Bhardwaj S, Passi SJ, Misra A, Pant KK, Anwar K, Pandey, R and Kardam V (2016), Effect of heating/reheating of fats/oils, as used by Asian Indians, on trans fatty acid formation, Food Chemistry **212:** 663-670. https://doi.org/10.1016/j.foodchem.2016. 06.021

Brouwer IA, Wanders AJ and Katan MB (2010), Effect of animal and industrial trans fatty acids on HDL and LDL cholesterol levels in humans–a quantitative review, *PloS one* **5**(3): e9434. https://journals.plos.org/plosone/article/file?id=10.1371/-journal.pone.0009434andtype=printable

Brühl L (1996), Determination of trans fatty acids in cold pressed oils and in dried seeds, *Lipid/Fett* **98**(11): 380-383. https://doi.org/ https://doi.org/10.1002/lipi.19960981107

Bunaciu AA, Fleschin S and Aboul-Enein HY (2022), Detection of sunflower oils adulteration by ATR-FTIR spectra, *Chemical Papers* **76**(9): 5533-5539. https://doi.org/ 10.1007/ s11696-022-02245-6

Chotimarkorn C and Silalai N (2008), Addition of rice bran oil to soybean oil during frying increases the oxidative stability of the fried dough from rice flour during storage, *Food Research International* **41**(3): 308-317. https:// doi.org/https:// doi.org/10.1016/j.-foodres. 2007.12.007

Christy AA (2009), Thermally induced isomerization of trilinolein and trilinoelaidin at 250 C: analysis of products by gas chromatography and infrared spectroscopy, *Lipids* **44**(12): 1105-1112. https://link.springer.com/article/10.1007/s11745-009-3363-x

Coates J (2000), Interpretation of infrared spectra, a practical approach, Encyclopedia of analytical chemistry, 12, 10815-10837. https://doi.org/ https://doi.org/10.1002/9780470027318.a5606

CODEX STAN 210. (1999). CODEX Standard for Named Vegetable Oils, Volume 8-2001 (Vol. 8-2001). Codex Alimentarius Org.

Cui Y, Hao P, Liu B and Meng X (2017), Effect of traditional Chinese cooking methods on fatty acid profiles of vegetable oils, *Food Chemistry* **233:** 77-84. https://doi.org/https://doi.org/10.1016/j.foodchem.2017.04.084

de Roos NM, Bots ML and Katan MB (2001), Replacement of dietary saturated fatty acids by trans fatty acids lowers serum HDL cholesterol and impairs endothelial function in healthy men and women, *Arterioscle-rosis, thrombosis and vascular biology* **21**(7): 1233-1237. https://www.ahajournals.org/doi/pdf/10.1161/hq0701.092161?download=true

Destaillats F and Angers P (2005), Thermally induced formation of conjugated isomers of linoleic acid, *European Journal of Lipid Science and Technology* **107**(3): 167-172. https://doi.org/ https://-doi.org/10.1002/ejlt.200401088

Dhaka V, Gulia N, Ahlawat KS and Khatkar BS (2011), Trans fats-sources, health risks and alternative approach - A review, *J Food Sci Technol* **48**(5): 534-541. https:// doi.org/ 10. 1007/s13197-010-0225-8

Dixit S and Das M (2012), Fatty Acid Composition Including Trans-Fatty Acids in Edible Oils and Fats: Probable Intake in Indian Population, *Journal of Food Science* **77**(10): T188-T199. https://ift.onlinelibrary.wiley. com/doi/ 10.1111/ j.1750- 3841. 2012. 02875.x

Fang H, Cao M, Zhang X, Wang K, Deng T, Lin J, Liu R, Wang X and Liu A (2023), The assessment of trans fatty acid composition in edible oil of different brands and regions in China in 2021, *Journal of Food Composition and Analysis* **121:** 105394. https://-doi.org/https://doi.org/10.1016/j.jfca.2023.105394

Fritsche J and Steinhart H (1998), Analysis, occurrence, and physiological properties of trans fatty acids (TFA) with particular emphasis on conjugated linoleic acid isomers (CLA)–a review, *Lipid/Fett* **100**(6): 190-210. https://doi.org/https://doi.org/10.1002/(SICI) 1521-4133 (199806) 100: 6<190: :AID -LIPI190> 3.0.CO;2-5

GAIN and icddrb (2017), Assessment of Presence of Edible Oil Brands in Bangladesh and their vitamin A content. https://www.gainhealth.org/sites/default/-files/ publications /documents/ assessment-of-presence-of-edible-oil-brands-in-bangladesh-2017.pdf

Garshick M, Mochari-Greenberger H and Mosca L (2014), Reduction in dietary trans fat intake is associated with decreased LDL particle number in a primary prevention population, *Nutrition, Metabolism and Cardiovascular Diseases* **24**(1): 100-106. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3943937/pdf/nihms495153.pdf

Ginter E, and Simko V (2016), New data on harmful effects of trans-fatty acids, *Bratisl Lek Listy* **117**(5): 251-253. https://doi.org/10.4149/bll_2016_048

Guillén MD and Goicoechea E (2007), Detection of primary and secondary oxidation products by Fourier transform infrared spectroscopy (FTIR) and 1H nuclear magnetic resonance (NMR) in sunflower oil during storage, *Journal of agricultural and food chemistry* **55**(26): 10729-10736. https://doi.org/ 10.1021/jf071712c

Hou J-C, Wang F, Wang Y-T, Xu J and Zhang C-W (2012), Assessment of trans fatty acids in edible oils in China, *Food Control* **25**(1): 211-215. https://-doi.org/https://doi.org/10.1016/j.foodcont.2011.10.044

Iqbal MP (2014), Trans fatty acids - A risk factor for cardiovascular disease, *Pak J Med Sci.* **30**(1): 194-197. https://doi.org/10.12669/pjms.301.4525

Jamwal R, Amit, Kumari S, Sharma S, Kelly S, Cannavan A and Singh DK (2021), Recent trends in the use of FTIR spectroscopy integrated with chemometrics for the detection of edible oil adulteration, *Vibrational Spectroscopy* **113:** 103222. https://doi.org/https://-doi.org/10.1016/j.vibspec.2021.103222

Katan MB, Zock PL and Mensink RP (1995), Trans fatty acids and their effects on lipoproteins in humans, *Annu Rev Nutr* **15:** 473-493. https://-doi.org/10.1146/annurev.nu.15.070195.002353

Lada AT and Rudel LL (2003), Dietary monounsaturated versus polyunsaturated fatty acids: which is really better for protection from coronary heart disease? *Curr Opin Lipidol* **14**(1): 41-46. https://-doi.org/10.1097/00041433-200302000-00008

Li A, Ha Y, Wang F, Li W and Li Q (2012), Determination of thermally induced trans-fatty acids in soybean oil by attenuated total reflectance fourier transform infrared spectroscopy and gas chromatography analysis, *Journal of agricultural and food chemistry* **60**(42): 10709-10713. https:// pubs.acs.org/doi/10.1021/jf3033599

Lisa SA, Alam MM, Bristy SA, Rahim A and Kabir MA (2024), Qualitative Enhancement and trans-Fat Depletion of Different Used Frying Oils with Adsorbents, *ACS Food Science and Technology.* https://-doi.org/10.1021/acsfoodscitech.4c00110

Mancini A, Imperlini E, Nigro E, Montagnese C, Daniele A, Orrù S and Buono P (2015), Biological and Nutritional Properties of Palm Oil and Palmitic Acid: Effects on Health, *Molecules* **20**(9): 17339-17361. https://www.mdpi.com/1420-3049/20/9/17339

Mishra R and Sharma HK (2014), Effect of frying conditions on the physico-chemical properties of rice bran oil and its blended oil, *Journal of Food Science and Technology* **51**(6): 1076-1084. https://doi.org/10.1007/ s13197-011-0602-y

Orsavova J, Misurcova L, Ambrozova JV, Vicha R and Mlcek J (2015), Fatty Acids Composition of Vegetable Oils and Its Contribution to Dietary Energy Intake and Dependence of Cardiovascular Mortality on Dietary Intake of Fatty Acids, *Int J Mol Sci,* **16**(6): 12871-12890. https://doi.org/ 10.3390/ijms 160612871

Oteng AB and Kersten S (2020), Mechanisms of Action of trans Fatty Acids, *Adv Nutr* **11**(3): 697-708. https://-doi.org/10.1093/advances/nmz125

Ozulku G, Yildirim RM, Toker OS, Karasu S and Durak MZ (2017), Rapid detection of adulteration of cold pressed sesame oil adultered with hazelnut, canola, and sunflower oils using ATR-FTIR spectroscopy combined with chemometric, *Food Control* **82**: 212-216. https://doi.org/https://doi.org/10.1016/j.-foodcont.2017.06.034

Petraru A, Ursachi F and Amariei S (2021), Nutritional Characteristics Assessment of Sunflower Seeds, Oil and Cake. Perspective of Using Sunflower Oilcakes as a Functional Ingredient, *Plants (Basel)* **10**(11): https://doi.org/10.3390/plants10112487

Pipoyan D, Stepanyan S, Stepanyan S, Beglaryan M, Costantini L, Molinari R and Merendino N (2021), The Effect of Trans Fatty Acids on Human Health: Regulation and Consumption Patterns, *Foods.* **10**(10): 2452. https:// doi.org/10.3390/ foods 10102452

Puprasit K, Wongsawaeng D, Ngaosuwan K, Kiatkittipong, W and Assabumrungrat S (2020), Non-thermal dielectric barrier discharge plasma hydrogenation for production of margarine with low trans-fatty acid formation, *Innovative Food Science and Emerging Technologies* **66:** 102511. https://doi.org/https://-doi.org/10.1016/j.ifset.2020.102511

Rohman A and Che Man Y (2012), Quantification and classification of corn and sunflower oils as adulterants in olive oil using chemometrics and FTIR spectra. *The Scientific World Journal* 2012. https://-doi.org/10.1100/2012/250795

Sarwar S, Shaheen N, Ashraf MM, Bahar N, Akter F, Hossain MM, Mridha MK, Kaja, MAM, Rasul SSB, and Khondker R (2024), Fatty acid profile emphasizing trans-fatty acids in commercially available soybean and palm oils and its probable intake in Bangladesh, *Food Chemistry Advances* **4:** 100611.

https://doi.org/https://doi.org/10.1016/j.focha.2024.100611

Schwarzinger B, Feichtinger M, Blank-Landeshammer B, Weghuber J and Schwarzinger C (2022), Quick determination of erucic acid in mustard oils and seeds, *Journal of Analytical and Applied Pyrolysis* **164:** 105523. https://doi.org/https://doi.org/10.1016/j.jaap.2022.105523

Shahbandeh M (2024), Production of major vegetable oils worldwide from 2012/13 to 2022/2023, by type. In (Vol. 2023): Statista.

Song J, Park J, Jung J, Lee C, Gim SY, Ka H, Yi B, Kim M J, Kim CI and Lee J (2015), Analysis of Trans Fat in Edible Oils with Cooking Process, *Toxicol Res*, **31**(3): 307-312. https://doi.org/10.5487/ tr.2015.31.3.307

Tasan M and Demirci M (2003), Trans FA in sunflower oil at different steps of refining, *Journal of the American Oil Chemists' Society* **80**(8): 825-828. https://doi.org/10.1007/s11746-003-0779-9

Tsuzuki W, Matsuoka A and Ushida K (2010), Formation of trans fatty acids in edible oils during the frying and heating process, *Food Chemistry* **123**(4): 976-982. https://doi.org/https://doi.org/10.1016/j.foodchem.2010.05.048

Tsuzuki W, Nagata R, Yunoki R, Nakajima M and Nagata T (2008), cis/trans-Isomerisation of triolein, trilinolein and trilinolenin induced by heat treatment, *Food Chemistry* **108**(1): 75-80. https://doi.org/https://doi.org/10.1016/j.foodchem.2007.10.047

WHO (2018): Guidelines: Saturated fatty acid and trans-fatty acid intake for adults and children, World Health Organization.

Xie D, Zhou H and Jiang X (2019), Effect of chemical refining on the levels of bioactive components and hazardous substances in soybean oil, *Journal of Food Measurement and Characterization* **13**(2): 1423-1430. https://doi.org/10. 1007/s11694-019-00058-y

Zhao X, Xiang X, Huang J, Ma Y, Sun J and Zhu D (2021), Studying the Evaluation Model of the Nutritional Quality of Edible Vegetable Oil Based on Dietary Nutrient Reference Intake, *ACS Omega* **6**(10): 6691-6698. https://doi.org/ 10.1021 /acsomega.0c05544