International Food Research Journal 20(1): 357-361 (2013)
Journal homepage: *http://www.ifrj.upm.edu.my*

Simultaneous quantitative analysis of red fruit oil and sesame oil using FTIR spectroscopy and multivariate calibrations

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Article history

Received: 24 April 2012
Received in revised form: 26 May 2012
Accepted:27 May 2012

Keywords

FTIR spectroscopy
sesame oil
red fruit oil
multivariate calibrations

Abstract

Sesame oil (SeO) and red fruit oil (RFO) share several similarities, especially in color properties. Both SeO and RFO are red in color. The objective of this study was to analyze SeO and RFO simultaneously using FTIR spectroscopy and multivariate calibrations of partial least square and principle component regressions. Some frequency regions and spectral treatments were optimized. The selection of the spectral treatment, frequency region and multivariate calibrations types was based on the ability to provide the highest values of coefficient of determination (R^2) and the lowest values of errors, either in calibration or prediction. Based on these criteria, FTIR spectra using normal mode and partial least square, regression at frequency regions of 1200 – 1000 cm^{-1} was suitable for determination of SeO and RFO simultaneously. The developed method is rapid at one minute per sample, sensitive, and considered as a green analytical technique since the use of chemicals and reagents are minimized.

Introduction

Red fruit (*Pandanus conoideus* Lam) is an important fruit mainly grown in Papua province of Indonesia. This fruit is consumed daily as diet. The extract of red fruit and its oil are believed to be functional oil due to its capability to provide some biological activities such as antioxidant (Rohman *et al*., 2010) and anti-carcinogenic activity. This oil is red in color which is similar to that of sesame oil. Several active compounds have been identified in red fruit oil such as beta-carotene and tocopherol (Rohman *et al*., 2012). In addition, in the local market, red fruit oil has higher priced-value than common plant oils like palm, soybean, and corn oils. Consequently, RFO can be target of adulteration with those plant oils (Rohman *et al*., 2011).

Since human civilization, sesame seed and its oil have been utilized as an important food components due to the beneficial effects to human health such as antioxidants (Park *et al*., 2010a ; Elleuch *et al*., 2012), lowering platelet aggregation (Reena *et al*., 2010), preventing atherosclerosis in LDL knockout mice (Bhaskaran *et al*., 2006), and reducing serum cholesterol (Chen *et al*., 2005). Namiki (2007) has reviewed several nutraceutical aspects of sesame oil. Sesame has several active compounds like tocopherols, phytosterols, resveratrol, lignans, and flavonoids (Lee *et al*., 2009) contributing to above biological activities.

Several instrumental techniques have been used for analysis of sesame oil (SeO), especially for detection and quantification of adulterants in SeO. Such methods are gas chromatography and high performance liquid chromatography through analyses of fatty acid and triacylglycerol compositions respectively (Lee *et al*., 2001; Park *et al*., 2010b), liquid chromatography-mass spectrometry (LC-MS) (Wang *et al*., 2009), electronic nose (Hai and Wang, 2006). These methods are time consuming and requiring skillful operators. Besides, the above methods generally determined specific components present in SeO rather than analysis of SeO and RFO as a whole matter. FTR spectroscopy in combination with chemometrics techniques provide some advantageous in term of analysis of sample as a whole. Therefore, in this study, FTIR spectroscopy coupled with chemometrics of multivariate calibrations was explored for simultaneous determination of SeO and RFO.

In recent years, FTIR spectroscopy has been proven to be a powerful technique for determination

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of edible oils, as indicated by several publications. Recently, Rohman and Che Man (2012) have reviewed the application of FTIR spectroscopy combined with chemometrics for quantitative analysis of plant oils and animal fats present in other oil. The uses of FTIR spectroscopy in combination with multivariate calibrations for simultaneous analysis could be elaborated to analyze two functional food oils namely extra virgin olive oil and virgin coconut oil (Rohman and Che Man, 2011a). However, using literature searching there is no report available in relation to application of this technique for analysis of SeO and RFO simultaneously. The developed method can be extended for purity determination of SeO and RFO may be subjected to be adulterated with other oils.

Materials and Methods

Materials

Red fruit oil was obtained from red fruit which collected from Papua Province, Indonesia, extracted by liquid-liquid extraction using hexane as oil extracting solvent. Red fruit was slashed into small pieces using a conventional cutter and subsequently subjected to commercial blender containing ethanol. The extracts were further macerated by methanol for 4 days and partitioned using hexane. The hexane extracts containing red fruit oil were evaporated at 60^{o}C until the hexane residue is removed. The oil obtained was further used for analysis of FTIR spectra and fatty acid composition. Sesame oil (SeO) was bought from super market near Yogyakarta. SeO used for this study was the mixture of three commercial oils in order to compensate any variation preset among oils. Standard of fatty acid methyl esters was purchased from Sigma (Alldrich, USA). Solvents and reagents used were of pro analytical grade bought from E. Merck (Darmstat, Germany).

Fatty acid analysis

The fatty acid composition of red fruit oil and sesame oil was determined using gas chromatography coupled with flame ionization detector operated at 200 ^{o}C. For qualitative analysis, the retention time of each fatty acids was compared to that in standard fatty acid methyl esters (FAME). Quantitative analysis of each fatty acids was performed with the internal normalization technique, as described in Rohman and Che Man (2011b). The column, carrier gas and other conditions of gas chromatograph were adjusted to similar with in our previous report (Rohman *et al*., 2012).

FTIR Analysis

For calibration samples, 33 samples of red fruit oil (RFO) in the mixture with sesame oil (SeO) was made. RFO was mixed with SeO in the concentration level of 0 – 100 %. For validation samples, 29 samples of RFO mixed with SeO was also made. FTIR spectra of all samples i.e. pure SeO, pure RFO, and the mixture of both oils with different concentrations were scanned using a FTIR spectrometer ABB MB3000 FTIR spectrometer (Clairet Scientific, Northampton, UK) equipped with detector of deuterated triglycine sulphate (DTGS) and beam splitter of Germanium on KBr substrat. FTIR spectra were scanned using a resolution of 4 cm^{-1}, number of scanning of 32 in the wavenumbers of 400–4000 cm^{-1}. Spectra were analyzed with the software of Horizon MB® version 3.0.13.1 (ABB, Canada). The samples were placed in direct contact with ZnSe crystal of attenuated total reflectance at controlled room temperature (20^{o}C).

Data analysis

Quantitative analysis of RFO and SeO was carried using partial least square (PLS) and principle component regression (PCR) using spectral absorbance as predictor. PLS and PCR were done using Horizon MB FTIR software version 3.0.13.1 (ABB, Canada). The leave-one-out cross-validation procedure was used to verify the calibration model. The values of root mean square error of calibration (RMSEC) and coefficient of determination (R^2) were used as the validity criteria for calibration model. The predictive ability of PLS calibration model was further used to calculate the validation samples.

Results and Discussion

Fatty acid composition of red fruit oil and sesame oil as determined using gas chromatography was shown in table 1. Oleic acid is the main components composed of red fruit oil, while oleic and linoleic (C18:2) acids are major fatty acids composed of sesame oil. The specification of the used of sesame oil in this study was in agreement with that in Codex, as shown in the similar profile of fatty acids composed of the used sesame oil with that specified in Codex Alimentarius ranges (2001).

FTIR spectra in mid infrared region (4000 – 650 cm^{-1}) of red fruit oil and sesame oil were shown in Figure 1. Both spectra exhibited FTIR spectral

Table 1. Fatty acid composition of red fruit oil and sesame oil

Fatty acids	Fatty acid composition (%)		
	Red fruit oil	Sesame oil	Sesame oil in Codex
Myristic acid (C14:0)	0.08 ± 0.01	0.02 ± 0.00	nd–0.1
palmitic acid (C16:0)	20.08 ± 0.07	10.00 ± 0.07	7.9–12
Palmitoleic acid (C16:1)	0.15 ± 0.01	0.14 ± 0.00	0.1–0.12
Stearic acid (C18:0)	0.17 ± 0.01	7.27 ± 1.09	4.8–6.1
Oleic acid (C18:1)	67.90 ± 0.13	33.69 ± 0.12	35.9–42.3
Linoleic acid (C18:2)	8.95 ± 0.14	46.95 ± 0.16	41.5–47.9
Eicosanoic acid (C20:0)	0.16 ± 0.00	0.36 ± 0.00	0.3–0.6
C18:3 (linolenic acid)	0.14 ± 0.01	0.64 ± 0.01	0.3–0.4
Eicosanoic acid (C20:1)	0.02 ± 0.00	0.15 ± 0.00	0.1–0.5

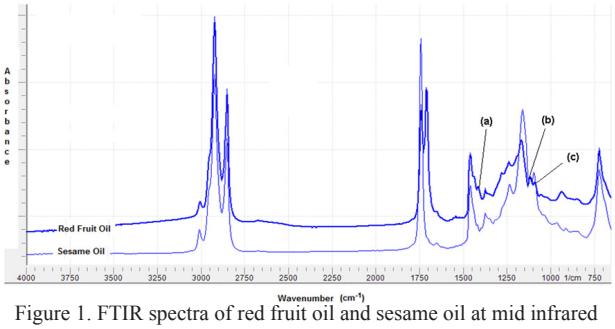

Figure 1. FTIR spectra of red fruit oil and sesame oil at mid infrared region (4000 – 650 cm^{-1})

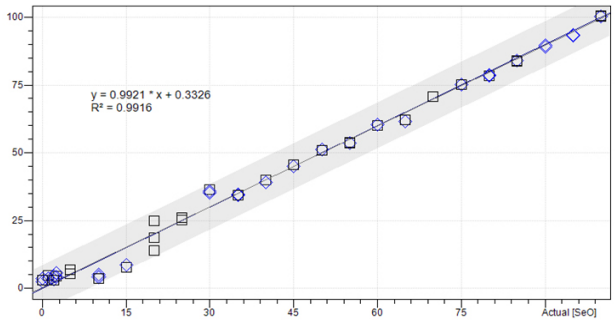

Figure 2. The relationship between actual and FTIR predicted value of sesame oil in PLS calibration model at frequency region of 1200 – 1000 cm^{-1}

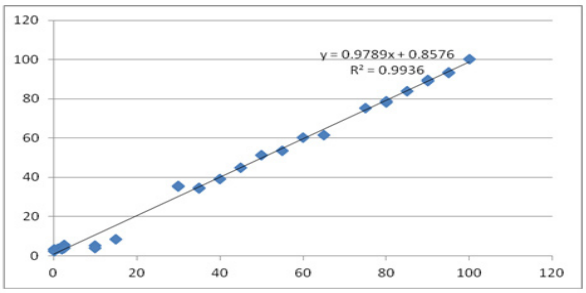

Figure 3. The relationship between actual and FTIR predicted value of sesame oil in PLS prediction model at frequency region of 1200 – 1000 cm^{-1}

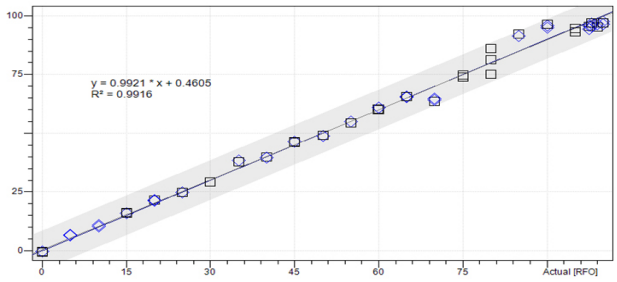

Figure 4. The relationship between actual and FTIR predicted value of red fruit oil in PLS calibration model at frequency region of 1200 – 1000 cm^{-1}

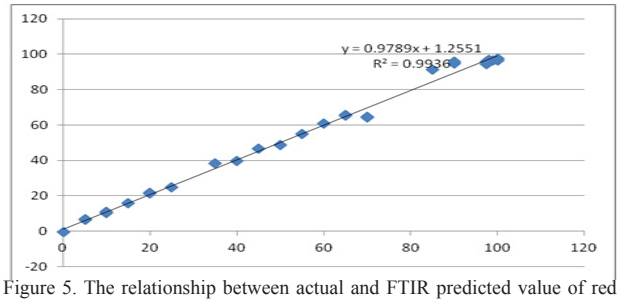

Figure 5. The relationship between actual and FTIR predicted value of red fruit oil in PLS prediction model at frequency region of 1200 – 1000 cm^{-1}

characteristics of edible fats and oils. For qualitative analysis, FTIR spectra can be potential means for differentiation of edible fats and oils. This based on fact that FTIR spectra are taken into account as fingerprint spectra meaning that no two fats and oils having the same FTIR spectra in terms of the sum of peak and shoulder, the intensities of each peaks and sholders, and the exact frequencies of maximum absorptions either in shoulder or in peak (Vlachos *et al*., 2006).

Both spectra revealed same profiles in terms of the number of peaks; however, using detailed investigation both oils can be distinguished from its FTIR spectra, especially in fingerprint region (1500 – 650 cm^{-1}). FTIR spectra of RFO can be differentiated from sesame oil in which in which the peak intensities at frequency regions of 1413 cm^{-1} (a), 1117 cm^{-1} (b), and 1097 cm^{-1} (c) were slightly different. Peak at 1416 cm^{-1} corresponds to Rocking vibrations of CH bonds of cis-disubstituted olefins; meanwhile frequencies of 1118 and 1097 cm^{-1} were coming from ether linkage absorptions in TAG (Rohman and Che Man, 2010). The functional groups responsible to the peak and shoulder absorptions in FTIR spectra of red fruit oil and sesame oil can be seen in our previous reports (Rohman *et al*., 2011; Rohman and Che Man, 2011b). The variations of FTIR spectra among three oils, especially at selected frequency regions marked with (a), (b), and (c), were further optimized for simultaneous quantitative analysis of red fruit oil and sesame oil.

Quantitative Analysis

For simultaneous quantitative analysis of red fruit oil and sesame oil, two multivariate calibrations namely partial least square (PLS) regression and principle component regression (PCR) were used. PLS calibration is relied on its ability to exploit spectral information from wide range spectral frequencies and to correlate spectral changes as a function of the changes in the level of analytes of interest (red fruit oil and sesame oil) (Syahariza *et al*., 2005). PLS calibration model was developed based on the calibration standard that included the different weighted amounts of analytes. Meanwhile, PCR exploit the combination of linear regression and principal component regression (Che Man *et al*., 2010).

Based on the differences in FTIR spectra of red fruit oil and sesame oil marked with (a), (b), and (c), for frequency regions namely the whole spectra region (4000 – 650 cm^{-1}), 1780-1680 cm^{-1}, 1200-1000 cm^{-1} and the combined frequency regions of 1780-1680 and 1200-1000 cm^{-1} were investigated. Besides,

Table 2. The performance of multivariate calibration for analysis of sesame oil

Frequency region (cm^{-1})	Multivariate calibration	Spectra	Calibration			Validation		
			Equation	R^2	RMSEC	Equation	R^2	RMSEP
4000-650	PLS	normal	y = 0.9869x + 0.5450	0.9907	1.7161	y = 0.9794x + 1.1724	0.9927	1.4430
	PLS	1st der	y = 0.9899x + 0.4688	0.9882	1.8234	y = 0.9784x + 1.6006	0.9906	3.5507
	PLS	2nd der	y = 0.9891x + 0.5117	0.9871	1.8654	y = 0.9774x + 1.7147	0.9898	3.9335
	PCR	normal	y = 0.9865x + 0.5582	0.9906	1.7221	y = 0.9795x + 1.2080	0.9926	1.6495
	PCR	1st der	y = 0.9899x + 0.4689	0.9882	1.8246	y = 0.9784x + 1.6067	0.9906	3.5741
	PCR	2nd der	y = 0.9890x + 0.5142	0.9870	1.8680	y = 0.9807x + 1.5836	0.9898	4.0051
1780-1680	PLS	normal	y = 0.9911x + 0.4066	0.9897	1.7622	y = 0.9826x + 1.3744	0.9917	3.3274
	PLS	1st der	y = 0.9893x + 0.5049	0.9868	1.8748	y = 0.9784x + 1.7372	0.9895	4.2766
	PLS	2nd der	y = 0.9883x + 0.5571	0.9853	1.9248	y = 0.9771x + 1.8684	0.9885	4.6981
	PCR	normal	y = 0.9911x + 0.4087	0.9897	1.7622	y = 0.9864x + 1.2170	0.9917	3.3720
	PCR	1st der	y = 0.9893x + 0.5064	0.9868	1.8762	y = 0.9783x + 1.7417	0.9895	4.3048
	PCR	2nd der	y = 0.9883x + 0.5558	0.9852	1.9282	y = 0.9766x + 1.9056	0.9884	4.7881
1200-1000	PLS	normal	y = 0.9921x + 0.3326	0.9916	1.6767	y = 0.9789x + 0.8576	0.9936	0.4104
	PLS	1st der	y = 0.9910x + 0.4055	0.9894	1.7766	y = 0.9760x + 1.6034	0.9916	2.9859
	PLS	2nd der	y = 0.9909x + 0.4124	0.9893	1.7801	y = 0.9749x + 1.7294	0.9916	3.4089
	PCR	normal	y = 0.9920x + 0.3425	0.9916	1.6760	y = 0.9789x + 0.8578	0.9936	0.4096
	PCR	1st der	y = 0.9912x + 0.4020	0.9894	1.7765	y = 0.9760x + 1.6037	0.9915	2.9861
	PCR	2nd der	y = 0.9908x + 0.4181	0.9893	1.7803	y = 0.9749x + 1.7299	0.9916	3.4095
1780-1680 and 1200-1000	PLS	normal	y = 0.9918x + 0.3651	0.9908	1.7121	y = 0.9818x + 1.1838	0.9927	2.0828
	PLS	1st der	y = 0.9895x + 0.4939	0.9871	1.8643	y = 0.9782x + 1.7233	0.9898	4.1833
	PLS	2nd der	y = 0.9885x + 0.5461	0.9856	1.9146	y = 0.9770x + 1.8575	0.9888	4.6264
	PCR	normal	y = 0.9921x + 0.3505	0.9908	1.7150	y = 0.9818x + 1.1848	0.9927	2.0871
	PCR	1st der	y = 0.9895x + 0.4986	0.9871	1.8651	y = 0.9782x + 1.7273	0.9897	4.1986
	PCR	2nd der	y = 0.9884x + 0.5491	0.9856	1.9169	y = 0.9767x + 1.8837	0.9887	4.6932

Table 3. The performance of multivariate calibration for analysis of red fruit oil

Frequency region (cm^{-1})	Multivariate calibration	Spectra	Calibration			Validation		
			Equation	R^2	RMSEC	Equation	R^2	RMSEP
4000-650	PLS	normal	y = 0.9869x + 0.7650	0.9907	1.7161	y = 0.9794x + 0.8874	0.9927	1.4427
	PLS	1st der	y = 0.9899x + 0.5396	0.9882	1.8234	y = 0.9784x + 0.5579	0.9906	3.5507
	PLS	2nd der	y = 0.9891x + 0.5793	0.9871	1.8654	y = 0.9774x + 0.5441	0.9898	3.9335
	PCR	normal	y = 0.9865x + 0.7937	0.9906	1.7221	y = 0.9795x + 0.8469	0.9926	1.5644
	PCR	1st der	y = 0.9899x + 0.5409	0.9882	1.8246	y = 0.9781x + 0.5639	0.9906	3.6214
	PCR	2nd der	y = 0.9890x + 0.5828	0.9870	1.8680	y = 0.9807x + 0.3485	0.9898	4.0051
1780-1680	PLS	normal	y = 0.9911x + 0.4793	0.9897	1.7622	y = 0.9826x + 0.3639	0.9917	3.3274
	PLS	1st der	y = 0.9893x + 0.5628	0.9868	1.8748	y = 0.9784x + 0.4260	0.9895	4.2879
	PLS	2nd der	y = 0.9883x + 0.6127	0.9853	1.9248	y = 0.9771x + 0.4225	0.9885	4.6981
	PCR	normal	y = 0.9911x + 0.4773	0.9897	1.7622	y = 0.9864x + 0.1463	0.9917	3.3720
	PCR	1st der	y = 0.9893x + 0.5647	0.9868	1.8762	y = 0.9783x + 0.4247	0.9895	4.3048
	PCR	2nd der	y = 0.9883x + 0.6150	0.9852	1.9282	y = 0.9770x + 0.4209	0.9885	4.7249
1200-1000	PLS	normal	y = 0.9921x + 0.4605	0.9916	1.6767	y = 0.9789x + 1.2551	0.9936	0.4104
	PLS	1st der	y = 0.9910x + 0.4934	0.9894	1.7766	y = 0.9760x + 0.7949	0.9916	2.9859
	PLS	2nd der	y = 0.9909x + 0.4973	0.9893	1.7801	y = 0.9749x + 0.7795	0.9916	3.4089
	PCR	normal	y = 0.9920x + 0.4624	0.9916	1.6760	y = 0.9789x + 1.2550	0.9936	0.4096
	PCR	1st der	y = 0.9912x + 0.4820	0.9894	1.7765	y = 0.9760x + 0.7953	0.9915	2.9861
	PCR	2nd der	y = 0.9908x + 0.4978	0.9893	1.7803	y = 0.9749x + 0.7800	0.9916	3.4095
1780-1680 and 1200-1000	PLS	normal	y = 0.9918x + 0.4502	0.9908	1.7121	y = 0.9818x + 0.6372	0.9927	2.0828
	PLS	1st der	y = 0.9895x + 0.5533	0.9871	1.8643	y = 0.9780x + 0.4587	0.9897	4.2246
	PLS	2nd der	y = 0.9885x + 0.6025	0.9856	1.9146	y = 0.9770x + 0.4384	0.9888	4.6264
	PCR	normal	y = 0.9921x + 0.4375	0.9908	1.7150	y = 0.9818x + 0.6367	0.9927	2.0871
	PCR	1st der	y = 0.9895x + 0.5537	0.9871	1.8651	y = 0.9782x + 0.4504	0.9897	4.1986
	PCR	2nd der	y = 0.9884x + 0.6101	0.9856	1.9169	y = 0.9770x + 0.4368	0.9887	4.6513

the optimization was also performed on FTIR spectra either in normal spectra or in its derivative spectra (first and second derivatives). The selection of frequency regions and FTIR spectral treatment was based on the highest values of R^2 and the lowest values of RMSEC obtained during developing PLS calibration model.

Table 2 and 3 showed the performance of PLS and PCR calibrations for determination of sesame oil and red fruit oil simultaneously in terms of R^2 and root mean square error of calibration (RMSEC) values. It is known that PLS using normal spectra and at frequency region of 1200-1000 cm^{-1} was preferred for quantification of both oils due to its ability to provide the highest value of R^2 and the lowest value of RMSEC.

Figure 2 exhibited the partial least square regression model for the relationship between actual and FTIR predicted values of sesame oil 1200-1000 cm^{-1} showing the close relationship. Furthermore, this calibration model was further used for computing the levels of sesame oil in prediction samples. Figure 3 revealed the prediction model for the relationship between actual value of sesame oil and predicted value. Figure 4 and 5 exhibited the regression linear obtained for the relationship between actual value of red fruit oil (x-axis) and FTIR predicted value of red fruit oil (y-axis) in calibration and prediction samples, respectively.

Conclusion

Based on these results, it can be deduced that FTIR spectroscopy in combination with multivariate calibrations is promising technique for simultaneous determination of red fruit oil and sesame oil. FTIR spectra using normal mode at frequency regions of 1200 – 1000 cm^{-1} was suitable for such determination.

Acknowledgement

The authors thank to Universitas Gadjah Mada for the financial support during this study through competitive grant

References

Bhaskaran, S., Santanam, N. and Parthasarathy, S. 2006. The dietary prevention of atherosclerosis in LDL knockout mice: combined effects of components of sesame oil that go beyond plasma lipid lowering. Atherosclerosis Supplements 7(3): 473.

Che Man, Y.B., Syahariza, Z.A. and Rohman, A. 2010. Chapter 1. Fourier transform infrared (FTIR) spectroscopy: development, techniques, and application in the analyses of fats and oils, in Fourier Transform Infrared Spectroscopy edited by Oliver J. Ress, Nova Science Publishers, New York: USA.). pp 1 – 26.

Chen, P.R., Chien, K.L., Su, T.C., Chang, C.J., Liu, T-L., Cheng, H. and Tsai, C. 2005. Dietary sesame reduces serum cholesterol and enhances antioxidant capacity in hypercholesterolemia. Nutrition Research 25(6): 559-567.

Codex Alimentarius Commision, 2001. 2nd Edn., Revised. Codex Standard for Named vegetable Oils, CX-Stan 210-1999.

Elleuch, M., Bedigian, D., Besbes, S., Blecker, C. and Attia, H. 2012. Dietary fibre characteristics and antioxidant activity of sesame seed coats (testae). International Journal of Food Properties 15(1): 25-37.

Hai, Z. and Wang, J. 2006. Electronic nose and data analysis for detection of maize oil adulteration in sesame oil. Sensors and Actuators B: Chemical 119(2): 449-455

Lee, S. W., Jeung, M. K., Park, M. H., Lee, S. Y. and Lee, J. H. 2009. Effects of roasting conditions of sesame seeds on the oxidative stability of pressed oil during thermal oxidation. Food Chemistry 118: 681–685.

Lee, D-S., Lee, E-S., Kim, H-J., Kim, S-O. and Kim, K. 2001. Reversed phase liquid chromatographic determination of triacylglycerol composition in sesame oils and the chemometric detection of adulteration. Analytica Chimica Acta 429 (2): 321-330.

Namiki, M. 2007. Nutraceutical functions of sesame: a review. Critical Reviews in Food Science and Nutrition 47(7): 651-673.

Park, S-H., Ryu, S-N., Bu, Y., Kim, H., Simon, J.E. and Kim, K-S. 2010a. Antioxidant components as potential neuroprotective agents in sesame (*Sesamum indicum* L.). Food Reviews International 26(2): 103-121.

Park, Y.W., Chang, P.S. and Lee, J. 2010b. Application of triacylglycerol and fatty acid analyses to discriminate blended sesame oil with soybean oil. Food Chemistry 123(2): 377-383.

Rohman, A., Riyanto, S. and Che Man, Y.B. 2012. Characterization of red fruit (*Pandanus conoideus* Lam) oil. International Food Research Journal: 19(2): 563-567.

Rohman, A. and Che Man, Y.B.. 2012. Authentication of functional food oils Fourier transformed infrared spectroscopy. Applied Spectroscopy Reviews 47(1): 1-13.

Rohman, A., Che Man, Y.B. and Riyanto, S. 2011. Authentication Analysis of Red Fruit (*Pandanus conoideus* Lam) oil using FTIR spectroscopy in combination with chemometrics. Phytochemical Analysis. 22(5): 462 – 467.

Rohman, A. and Che Man, Y.B.. 2011a. Simultaneous quantitative analysis of two functional food oils, extra virgin olive oil and virgin coconut oil using ftir spectroscopy and multivariate calibration. International Food Research Journal. 18(4): 1231-1235.

Rohman, A. and Che Man, Y.B. 2011b. Application of gas chromatography and FTIR spectroscopy for anaysis of palm oil in adulterated sesame oil. European Journal of Lipid Science and Technology 133: 522 – 527.

Rohman A., Riyanto, S., Yuniarti, N. Saputra, W.R., Utami, R. and Mulatsih, W. 2010. Antioxidant activity, total phenolic, and total flavonoid of extracts and fractions of red fruit (*Pandanus conoideus* Lam). International Food Research Journal 17: 97-106.

Rohman, A. and Che Man, Y. B. 2010. Fourier transform infrared (FTIR) spectroscopy for analysis of extra virgin olive oil adulterated with palm oil. Food Research International 43: 886 – 892.

Reena, M.B., Krishnakantha, T.P. and Lokesh, B.R. 2010. Lowering of platelet aggregation and serum eicosanoid levels in rats fed with a diet containing coconut oil blends with rice bran oil or sesame oil. Prostaglandins, Leukotrienes and Essential Fatty Acids 83 (3): 151-160.

Syahariza, Z. A., Che Man, Y. B., Selamat, J. and Bakar, J. 2005. Detection of lard adulteration in cake formulation by Fourier transforminfrared (FTIR) spectroscopy. Food Chemistry 92: 365−371.

Vlachos, N., Skopelitis, Y., Psaroudaki, M., Konstantinidou, V., Chatzilazarou, A. and Tegou, E. 2006. Applications of Fourier transform-infrared spectroscopy to edible oils. Analytica Chimica Acta 573–574: 459–465.

Wang, X., Peng, Y., Li, M. and Rustum, A.M. 2009. Use of high resolution LC–MSn analysis in conjunction with mechanism-based stress studies: Identification of asarinin, an impurity from sesame oil in an animal health product. Journal of Pharmaceutical and Biomedical Analysis 50 (5): 1015-1021.