Food Research 8 (3) : 424 - 431 (June 2024)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

RESEARCH PAPER

Analysis of lard in cod liver oil emulsion using FTIR spectroscopy combined principal component analysis

[1,2,*]Zilhadia Zilhadia, [1,2]Anggraeni, Y., [3]Apriyanti, Y.F., [1,2]Mustafidah, M. and [4]Jaswir, I.

[1]*Department of Pharmacy, Faculty of Health Sciences, Syarif Hidayatullah State Islamic University, Jakarta, 15412 Indonesia*
[2]*Halal Science Center, Syarif Hidayatullah State Islamic University, Jakarta, 15412 Indonesia*
[3]*Students of Pharmacy Department, Faculty of Health Sciences, Syarif Hidayatullah State Islamic University, Jakarta, 15412 Indonesia*
[4]*International Institute for Halal Research and Training, International Islamic University Malaysia, Selangor, 53100, Malaysia*

Article history:
Received: 20 May 2022
Received in revised form: 9 August 2022
Accepted: 21 May 2023
Available Online: 16 June 2024

Keywords:
Lard,
Cod liver oil,
FTIR spectroscopy,
Principal component analysis

DOI:
https://doi.org/10.26656/fr.2017.8(3).329

Abstract

Cod liver oil (CLO) contains essential fatty acids and has a high price in the market. Therefore, CLO can be targeted for adulteration to increase economic profits. One of the substances used for adulteration of CLO is lard. This study aimed to analyze the spectral profile of lard and CLO in cod liver oil emulsion using Fourier transform infrared (FTIR) spectroscopy combined with principal component analysis (PCA). Lard and CLO were mixed with a range of concentrations of 0-100% used as the control. CLO emulsions were made with a composition of lard and CLO in concentrations similar to those of the control. To analyze the lard and CLO spectrum, lard and CLO were extracted from the emulsion using liquid-liquid extraction, and then the oil extracted from the emulsion was analyzed using FTIR spectroscopy and PCA. Fourier transform infrared spectrum absorption at region 1117–1098 cm^{-1} is specific to identifying the different spectrums of CLO and lard. The results of PCA showed that clustering between similar oil content and a combination of FTIR and PCA is effective in distinguishing the spectrum of lard and CLO in cod liver oil emulsion.

1. Introduction

Health supplements are products that are used to complete nutritional needs and then maintain and improve the health functions in our bodies (Dominguez and Barbagallo, 2018). The benefit of consuming health supplements is to prevent disease, increase appetite and improve cognitive capability and child growth (Durmuş, 2019). Fish oil is one of the health supplements as the main source of lipid with essential omega-3 unsaturated fatty acid, predominantly eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) (Ali, 2017). Consumption of omega-3 fatty acids can prevent many diseases, especially cardiovascular disorders, by reducing risk factors such as heart arrhythmias, blood pressure, triglyceride concentrations, and platelet aggregation (Sun *et al*., 2019). The two types of cod fish are the Pacific cod (*Gadus macrocephalus* Tilesius) and Atlantic cod (*Gadus morhua L.*) (Rohman, 2017). Unfortunately, these two types of cod fish have very little fat, making them produce minimum CLO (less than 1%). The price of CLO is very expensive, and adulteration is potential using a material of a low price (Gao *et al*., 2021). Mustafidah *et al*. (2021) examined the authenticity of milkfish oil which could be adulterated with palm oil and corn oil. Meanwhile, Rohman *et al*. (2017) studied the authentication method for CLO mixed with lard.

From the Islamic point of view, pork and its derivates are haram ingredients which cannot be used in food. Allah SWT says in the holy Qur'an Surah Al-Baqarah verse 173 "He has forbidden you to eat dead meat, blood, the flesh of swine, and that on which any name other than Allah has been invoked; but if someone is compelled by absolute necessary, intending neither to sin nor to transgress, he shall incur no sin. Surely Allah is Forgiving and Merciful." Therefore, the products containing substrate from lard and its derivates are prohibited from being used by Muslims and Judaism. In the last decade, methods for authenticating lard and dogs for adulterants received increasing attention as a rapid detection for halal tests (Zilhadia *et al*., 2018). Previous researchers distinguished lard from other edible oils

*Corresponding author.
Email: *zilhadia@uinjkt.ac.id*

eISSN: 2550-2166 /
Published by Rynnye Lyan Resources

using gas chromatography-mass spectrophotometry (GC-MS) (Giese *et al*., 2019). Gas chromatography-mass spectrophotometry is an expensive, higher technology with a more complex analytical method. On the other hand, FTIR spectroscopy is one of the methods developed to identify the presence of a mixture of lard in a food or supplement. FTIR is inexpensive and simple with a short analysis time, and it does not require many solvents, making it greener chemistry (Rohman *et al*., 2019).

Among the physicochemical methods, FTIR spectroscopy combined with chemometrics such as principal component analysis (PCA), partial least square (PLS) regression, and principal component regression (PCR), is the most common method applied for a prediction of the adulteration level of fish oil due to its nature as a fingerprint analytical technique (Rohman, 2019). PCA is an application of chemometrics used as a tool for exploratory analysis using algorithms and data reduction techniques to exploit linear structures (Syifa *et al*., 2020). The output is treated as the principal component (PC) which is a linear transformation (axis) of the original data set and calculated based on the coefficient among variables. The grouping by PCA can be directly seen in the resulting quadrant, making it easier for researchers to analyze (Giese *et al*., 2019).

FTIR spectroscopy in combination with chemometrics has been used for the authentication of virgin coconut oil from grape seed oil and soybean oil (Rohman, Che Man and Ali, 2019), corn and soybean oils in red fruit oil (Setyaningrum *et al*., 2013); authentication of Patin fish oil (Putri *et al*., 2019), authentication of cod liver oil (Rohman *et al*., 2017), authentication of pumpkin seed oil from sesame oil (Irnawati *et al*., 2019) and authentication of milkfish oil (Mustafidah *et al*., 2021), patin fish oil (Putri *et al*., 2020) and gabus fish oil (Irnawati *et al*., 2021) using edible oil. However, there has been no publication reporting the application of FTIR spectroscopy coupled with chemometrics for the emulsion of fish oil and lard oil. The goal of this research was to perform an authentication of fish oil emulsion adulterated with lard oil using FTIR spectroscopy combined with PCA.

2. Materials and methods

2.1 Materials

The pork fat was obtained from PD. Dharmajaya, Kapuk, Jakarta Barat Indonesia and cod liver oil were from PT. Brataco.

2.2 Preparation of lard oil

Lard was extracted from 2 kg of pork fat by putting it in a beaker glass and heating it at 90°C for 2 h until it melted. The melted fat was filtered using a fabric, and sodium sulphate was added to withdraw the water. The sample was then centrifugated using a centrifuge at 3000 rpm for 20 mins, and then the sediment was separated and the lard was ready to use.

2.3 Preparation of binary mixtures lard oil and fish oil

CLO and lard were mixed in a binary mixture with concentration ranges of 0-100% v/v of oils (Table 1). All samples were analyzed using FTIR (Jasco, 6100) measurement based on their FTIR spectra at wavenumbers of 4000-650 cm^{-1} by co-adding 32 scans with a resolution of 4 cm^{-1}. These spectra were recorded as absorbance values at each data point.

Table 1. Concentration of mixtures between lard and CLO for standard.

Composition of lard oil and CLO	Standard					
	S1	S2	S3	S4	S5	S6
Lard oil (%)	0	20	40	60	80	100
CLO (%)	100	80	60	40	20	0

2.4 Simulation formula for emulsions of fish oil

The formulation of CLO emulsion was prepared based on the Indonesian Formulary, consisting of 30 g CLO, 15 g Arabic gum, 15 g glycerin, 2 mg sunset yellow, and 3 drops of oleum cinnamomic (Table 2). Some modifications in the composition of CLO can be seen in Table 3.

Table 2. Formulation of CLO emulsion based on Formularium Indonesia.

Materials	Total
Mixture of Oil (refer to Table 3)	30 g
Arabic Gum	15 g
Glycerin	15 g
Sunset Yellow	2 mg
Oleum Cinnamomic	3 drops

Table 3. Formula of CLO and lard in emulsions.

Composition of lard and CLO	Formula					
	F1	F2	F3	F4	F5	F6
Lard (%)	0	6	12	18	24	30
CLO (%)	30	24	18	12	6	0

The emulsion preparation used the dry gum method, in which CLO and Arabic gum were stirred in a mortar to obtain a homogenous mixture. Then, 20 mL distilled water was added followed by stirring for approximately 3 minutes to produce a primary emulsion as well as by the addition of glycerin and sunset yellow. Oleum cinnamomic and distilled water were then added to yield a final volume of 100 mL.

https://doi.org/10.26656/fr.2017.8(3).329

2.5 Fat extraction

The fat extraction used the liquid-liquid extraction method (Lukitaningsih *et al*., 2012), where 10 g emulsion, 5 mL hydrochloric acid, and 20 mL water were vigorously shaken. The resulting filtrate was then transferred to a separatory funnel and extracted using 2×15 mL chloroform. The extract were combined in a 250-mL round-bottom flask and evaporated using a vacuum rotary evaporator at 40°C to completely remove the chloroform. The yielded lipid extract was further examined using an FTIR spectrometer.

2.6 Data analysis

The FTIR spectrum results data was processed using chemometrics with The Unscrambler 10.3 software. The selected menu was the principal component analysis (PCA) where data interpretation was done by reducing a variable to produce a new variable. The new variable became the main component. The 13 points selected in this analysis were the absorbance at wavelengths of 3009, 2924, 2854, 1743, 1657, 1465, 1377, 1215, 1163, 1117, 1099, and 1032 cm^{-1}

3. Results and discussion

3.1 Lard extraction

The lard was extracted from pork fat using dry rendering at 95°C for 2 hrs until the fat was melted. Sodium sulphate was added to withdraw water from the lard. The lard was made in our laboratorium because no lard has a certificate of analysis in the market. The lard extracted showed good transparency (Figure 1). Lard contains triglyceride which consists of long-chain saturated fatty acids. Palmitic acid and linoleic acid are the dominant ingredients in saturated fatty acid lard (Rohman *et al*., 2012).

Figure 1. Organoleptic of lard extracted from pork fat.

3.2 Extraction of lard and cod liver oil from emulsion

This research used six emulsion formulas (Table 3) with different compositions in a range of concentrations of CLO and lard. The homogeneity evaluation involving a creaming rate test was performed in sedimentation tubes after the emulsions were left for 15 mins. Emulsions that only contain CLO as the oil phase have a lower viscosity compared to other emulsions added with lard. The higher the lard concentration, the higher the viscosity of the emulsion. The results of this study are consistent with the findings by Lukitaningsih *et al*. (2012). Then, an oil extraction process was carried out for the 6 formulas of CLO emulsion made. The extraction method used to obtain oil from the formula is the liquid-liquid extraction method. Liquid-liquid extraction is used because this method is considered the most appropriate for extracting oil in emulsions (Lukitaningsih *et al*. 2012). Lard and CLO will separate from the water layer because they dilute in chloroform. The chloroform was separated from lard and CLO by using a rotary evaporator at 40°C to obtain lard oil and CLO in pure oil, and then analysis was performed using an FTIR spectrometer.

3.3 FTIR spectra analysis

The first step of analysis is to compare the lard spectra obtained with the lard spectra found in other studies to ensure the correctness of the existing spectra shown in Figure 2. The lard spectra were very similar to the spectra of lard obtained by other researchers. Lard has a specific spectrum because there is higher overlapping at 1117 than 1098 cm^{-1}. Based on the result of FTIR spectroscopy, the FTIR spectra of oil show a spectrum pattern that is almost the same in the area of 3010-450 cm^{-1} (Rohman *et al*., 2011).

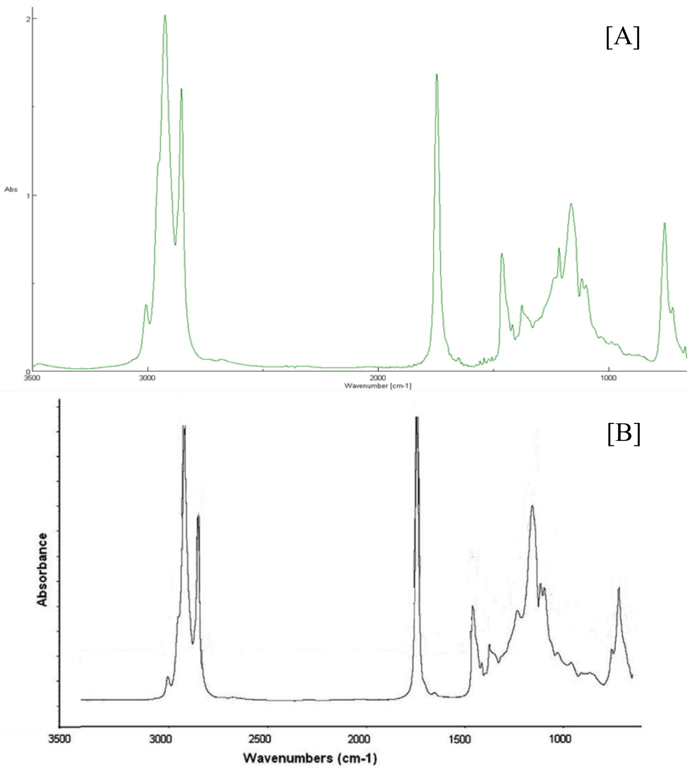

Figure 2. The Specific spectrum of lard (sample) [A] and (control) [B].

https://doi.org/10.26656/fr.2017.8(3).329

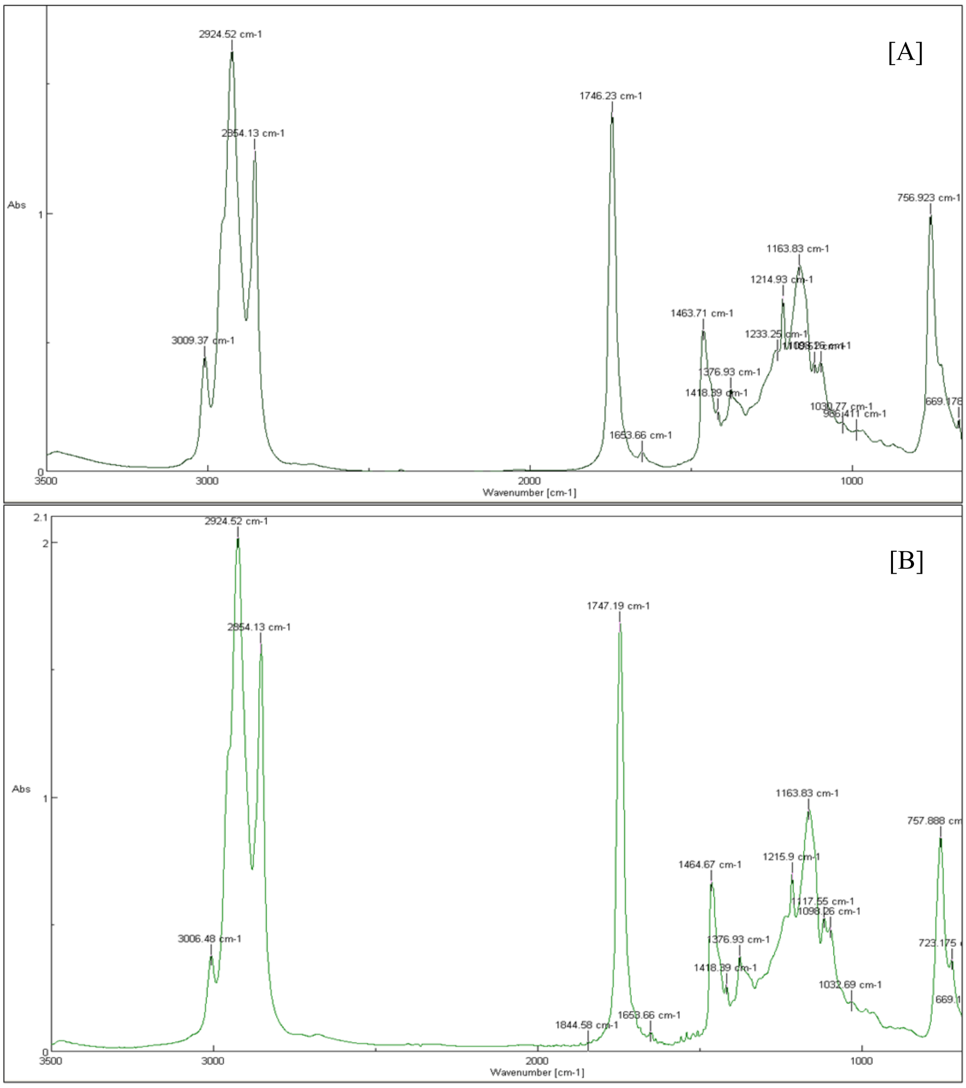

Figure 3. Spectrum lard [A] and CLO [B].

Figure 3 shows FTIR spectra of Lard and CLO in the middle infrared region (4000-400 cm^{-1}). Each peak in the FTIR spectra corresponds to a functional group responsible for IR absorption. Although both spectra appear very similar, they reveal slight differences in terms of band intensities and the exact frequencies due to the different compositions. The peak of CLO in the area of 3009.37 is a stretching vibration of the vinylic (C=CH) trans and CIS (Nandiyanto *et al.*, 2019). The same peak also appears in the spectra of lard at the area of 3006.48 cm^{-1} with the lower intensity of CLO. However, the peak in the area of 3010-2855 cm^{-1} is unspecific, making it useless for further analysis. In general, FTIR spectra show a significant difference in the absorption at 1117-1098 cm^{-1}. Both absorptions show an overlap between saturated fatty acid and oleic acid. Lard has a higher absorption intensity at 1117 cm^{-1}. This indicates differences in the saturated fatty acids and unsaturated fatty acids of lard and CLO. The range of wavenumber at 1117-1098 cm^{-1} absorption becomes a specific absorption difference between lard and CLO.

Furthermore, a mixture of lard and CLO (shown in Table 3) was determined as a standard to be compared with the oil mixture of extraction from the emulsion. The spectrum results of the oil mixture in certain concentrations can be seen in Figure 4. The wavenumber 1117 cm^{-1}–1098 cm^{-1} absorption area shows the peak characteristics, where the intensity of 1117 cm^{-1} decreases along with the decreasing lard concentration. Figure 4 shows that each wavenumber corresponds to the functional groups presenting in lard and CLO. The peaks at 1117–1098 cm^{-1} come from -C-O stretching (Che Man *et al.*, 2011). The spectrum of the oil mixture extracted from the emulsion can be seen in Figure 5. The spectrum of lard and CLO extracted from the emulsion looks very similar to that of the mixture of lard and CLO standard. Afterwards, the data of intensity and wavenumber of each peak was fed to PCA for the grouping of oil.

3.4 Data analysis using principal component analysis

In this study, the absorbance at the whole mid infrared region (4000-650 cm^{-1}) was used to obtain more information extracted from the FTIR spectra (Che Man *et al.*, 2011). The spectral peaks are identified at various wavenumbers to determine the types of vibrations and functional groups that sustain vibrations in the oil. The determination of the wavenumbers is based on the peak of the wavenumber in the functional group (Nandiyanto

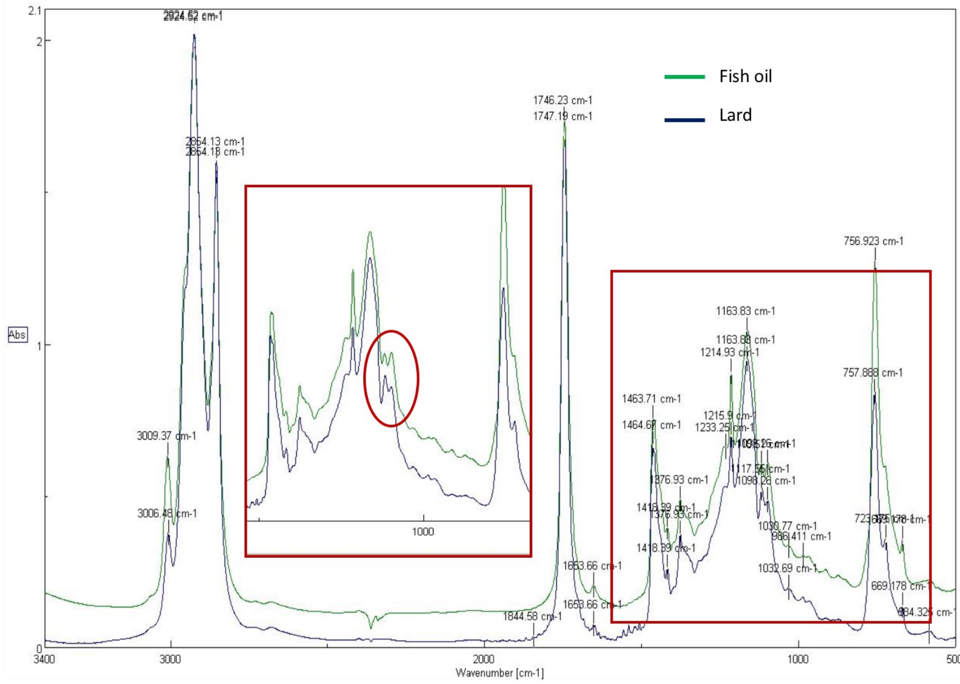

Figure 4. The spectrum of mixtures between lard (green) and CLO (blue).

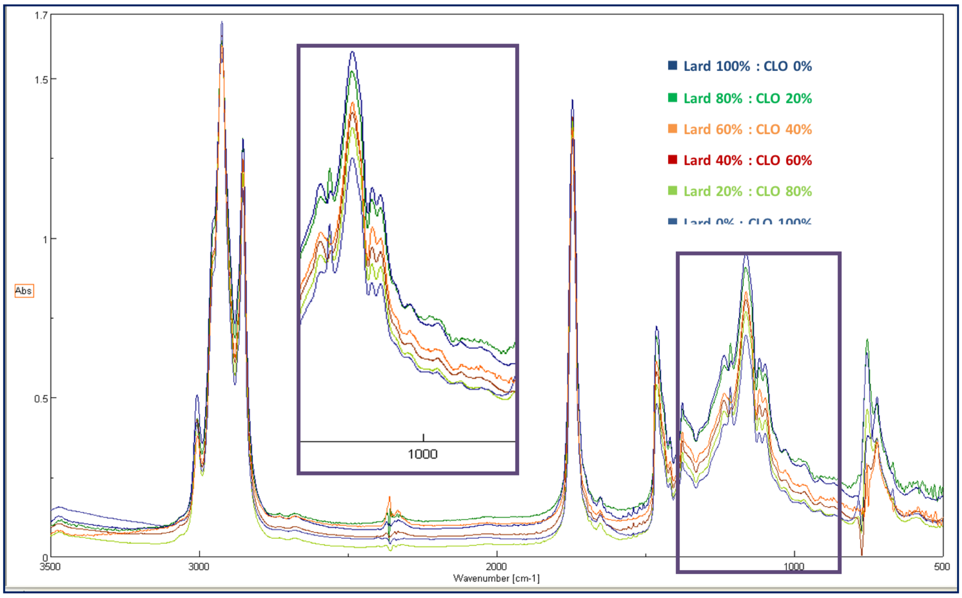

Figure 5. The spectrum of mixtures between fish oil and lard oil in emulsions.

et al., 2019).

In this research, thirteen wavenumber points were selected in the 3009-668 cm^{-1} area. The absorbance at 13 wavenumbers was chosen to avoid errors due to the large and varied number of spectroscopy data. The peak at 3009 cm^{-1} is from [*cis*=C-H (stretching)], at 2924 cm^{-1} from [-CH2, asymmetric stretching], at 2854 cm^{-1} from [-CH2, symmetric stretching], at 1743 cm^{-1} from [-C=O (ester), stretching], at 1657 cm^{-1} from [*cis* -C=C, stretching], at 1465 cm^{-1} from [-CH2, bending], at 1377 cm^{-1} from [-CH3, bending], at 1215, 1163, 1117, 1099, and 1032 cm^{-1} from [-C-O, stretching] and from ester linkage, and at 966 cm^{-1} from [-*trans* H-C=CH- out of plane] (Putri *et al*., 2019; Mustafidah *et al*., 2021).

The classification of CLO emulsion with and without lard in each formula using PCA is among the unsupervised pattern recognition techniques (Lukitaningsih *et al*., 2012). The absorbance value of the CLO and lard mixtures as a standard is shown in Table 4 while the absorbance value of CLO and lard extracted from the emulsion is shown in Table 5. Both were analyzed using PCA. The results of PCA analysis are in the form of score plot and loadings plot. The results of the score plot in Figure 6 indicate that there are four quadrants which can distinguish the mixture of CLO and lard in the emulsion and standard. The lard is in a different quadrant from CLO. From Figure 6, we can also understand that the increasing concentrations of lard (0%, 20%, 40%, 60, 80%) lead to closer values to the 100% lard standard. In addition, the point of lard extracted from the emulsion has the same quadrant as the lard standard. Meanwhile, the point of CLO and lard from Formula 1 has a different quadrant from F6.

Table 4. Absorbance value of lard and CLO standard.

Wavenumber (cm^{-1})	Standard (combination of lard and CLO)					
	S1	S2	S3	S4	S5	S6
3009	0.44138	0.44216	0.41613	0.38073	0.36723	0.37724
2924	1.62434	1.55115	1.53794	1.67841	1.65601	2.01697
2854	1.24381	1.21662	1.18661	1.27923	1.31351	1.60019
1743	1.38768	1.34466	1.31217	1.40285	1.40132	1.68414
1657	0.07595	0.10181	0.09203	0.08582	0.06948	0.07890
1465	0.54569	0.54895	0.55092	0.55752	0.56733	0.66780
1377	0.31827	0.33296	0.33296	0.32929	0.32535	0.37573
1215	0.67801	0.57730	0.49888	0.54980	0.57781	0.69993
1163	0.79519	0.79069	0.77900	0.80188	0.81269	0.94782
1117	0.41887	0.43692	0.44377	0.44908	0.45197	0.52427
1099	0.42147	0.43249	0.43638	0.43295	0.42933	0.48460
1032	0.18721	0.20863	0.20562	0.20318	0.18771	0.19610
966	0.15621	0.17278	0.17044	0.16624	0.14819	0.15347

Table 5. The absorbance value of lard and CLO extracted from emulsions.

Wavenumber (cm^{-1})	Formula emulsion lard and CLO					
	S1	S2	S3	S4	S5	S6
3009	0.47080	0.41286	0.40519	0.35897	0.33136	0.37876
2924	2.17108	1.61782	1.53678	1.11514	1.23336	1.60217
2854	1.46230	1.20457	1.17311	0.92434	1.00359	1.24543
1743	1.67659	1.36560	1.29876	1.01098	1.05232	1.33589
1657	0.07694	0.10641	0.12877	0.13337	0.14267	0.14561
1465	0.54917	0.53931	0.54489	0.50971	0.52898	0.61407
1377	0.29978	0.32759	0.34177	0.34008	0.35459	0.39180
1215	0.61954	0.50507	0.43990	0.44486	0.51231	0.51221
1163	0.83950	0.76813	0.75777	0.67445	0.69405	0.83020
1117	0.42506	0.43511	0.44884	0.43972	0.45333	0.52502
1099	0.42374	0.42798	0.43775	0.42669	0.43801	0.49757
1032	0.17963	0.21747	0.22721	0.23722	0.25776	0.27169
966	0.13074	0.17912	0.19187	0.20521	0.23502	0.22734

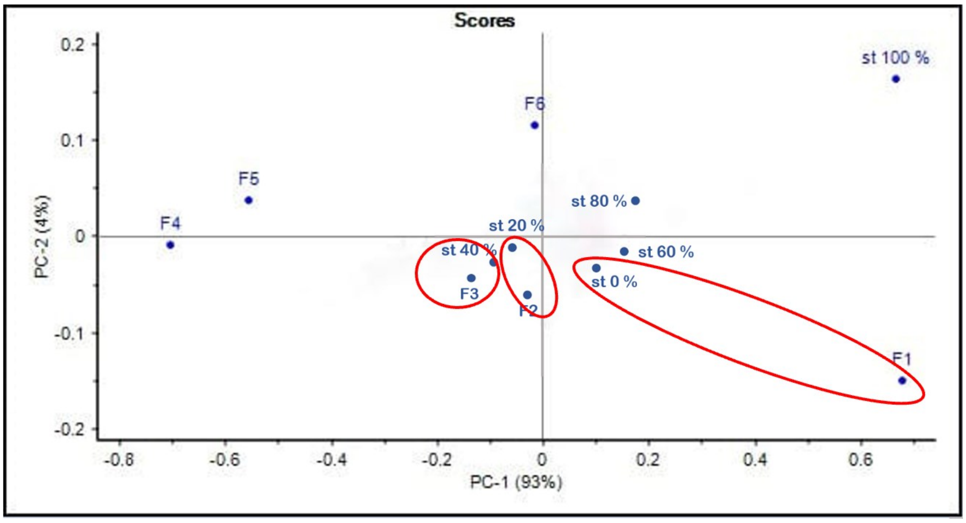

Figure 6. The result of PCA score plot “combination between standard mixtures of lard oil and fish oil (st 0%, st 20%, st 40%, st 60%, st 80%, st 100%) with PCA scores of mixtures fish oil and lard oil in emulsions (F1, F2, F3, F4, F5 and F6).

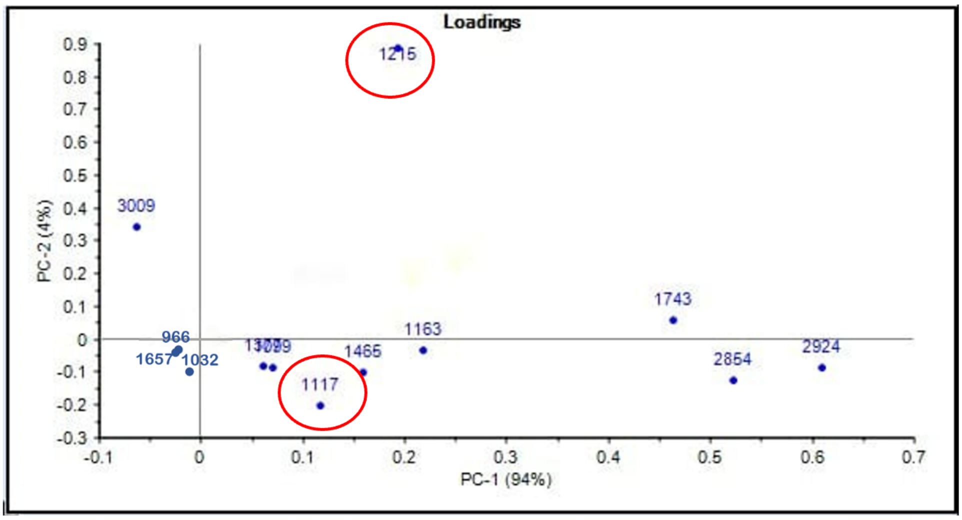

Figure 7. Loadings score result.

The loadings plot (Figure 7) is used to determine the absorbance value in FTIR which greatly influences the grouping between CLO and lard. The absorbance value can be symbolized by blue dots that spread around the center line. The further away the point from the center line, the more influential the absorbance point on the grouping. The absorbance value which is strongly influential on the grouping of CLO and lard is in wavenumber 1215 and 1117 cm^{-1}. The combination of FTIR fingerprint and PCA has been able to distinguish CLO and lard extracted from the emulsion successfully. FTIR combined chemometrics, especially PCA is an accurate and precise tool for predicting the adulteration of lard in CLO emulsion. This method is extensively used for species identification, discrimination, and authentication from the origin (Ikhsan *et al*., 2021).

4. Conclusion

FTIR combined PCA was able to classify the CLO and lard in emulsion based on their FTIR spectra at the selected fingerprint regions. This method can be applied to other preparations with the same base material, such as cosmetic creams, medicinal creams and pastes. This method is relatively simple and inexpensive, and since it does not use many chemical solvents, it supports green chemistry.

Conflict of interest

The authors declare no conflict of interest.

References

Ali, S.R. (2017). Effect of varying levels of lipid on growth performance, survival and body composition of Milkfish (*Chanos chanos*). *International Journal of Fisheries and Aquatic Studies,* 5(4), 30–34.

Dominguez, R.L.J. and Barbagallo, M. (2018). Not All Fats are Unhealthy. In Sánchez-Villegas, A. and Sánchez-Tainta, A. (Eds.) The Prevention of Cardiovascular Disease Through The Mediterranean Diet, p. 35–58. USA: Academic Press. https://doi.org/10.1016/B978-0-12-811259-5.00003-2

Durmuş, M. (2019). Fish Oil for Human Health: Omega-3 Fatty acid profiles of marine seafood species. *Food Science and Technology,* 39(Suppl. 2), 454–461. https://doi.org/10.1590/fst.21318

Gao, B., Xu, S., Han, L. and Liu, X. (2021). FT-IR-based quantitative analysis strategy for target adulterant in fish oil multiply adulterated with terrestrial animal lipid. *Food Chemistry*, 343, 128420. https://doi.org/10.1016/j.foodchem.2020.128420

Giese, E., Rohn, S. and Fritsche, J. (2019). Chemometric tools for the authentication of cod liver oil based on nuclear magnetic resonance and infrared spectroscopy data. *Analytical and Bioanalytical Chemistry,* 411(26), 6931–6942. https://doi.org/10.1007/s00216-019-02063-yvano

Ikhsan, A.N., Mustafidah, M., Syifa, F. and Rohman, A. (2021). Implementation of chemometrics as a Solution to detecting and preventing falsification of herbal medicines in Southeast Asia: A review. *Journal of Applied Pharmaceutical Science,* 11(9), 139–148. https://doi.org/10.7324/JAPS.2021.110917

Irnawati, Riyanto, S., Martono, S. and Rohman, A. (2019). The Employment of FTIR spectroscopy and chemometrics for authentication of pumpkin seed oil from sesame oil. *Food Research,* 4(1), 42–48. https://doi.org/10.26656/fr.2017.4(1).198

Irnawati., Riyanto, S. and Rohman, A. (2021). Adulteration of Gabus (*Channa striata*) fish oil with corn oil and palm oil: the use of FTIR spectra and chemometrics. *Food Research,* 5(2), 184-190. https://doi.org/10.26656/FR.2017.5(2).368

Lukitaningsih, E., Sa'adah, M., Purwanto. and Rohman, A. (2012). Quantitative analysis of lard in cosmetic lotion formulation using FTIR Spectroscopy and

Partial Least Square Calibration. *Journal of the American Oil Chemists' Society*, 89(8), 1537-1543. https://doi.org/10.1007/s11746-012-2052-8

Che Man, Y.B., Rohman, A. and Mansor, T.S.T. (2011). Differentiation of lard from other edible fats and oils by means of Fourier Transform Infrared Spectroscopy and Chemometrics. *Journal of the American Oil Chemists' Society,* 88(2) 187-192. https://doi.org/10.1007/S11746-010-1659-X

Mustafidah, M., Irnawati, Lukitaningsih, E. and Rohman, A. (2021). Authentication analysis of milkfish fish oil using the combination of FTIR spectroscopy and Chemometrics. *Food Research,* 5 (2), 272–278. https://doi.org/10.26656/fr.2017.5 (2).607

Nandiyanto, A.B.D., Ragadhita, R. and Oktiani, R. (2019). How to Read and interpret FTIR Spectroscope of organic material. *Indonesian Journal of Science and Technology,* 4(1), 97–118. http://dx.doi.org/10.17509/ijost.v4i1.15806

Putri, A.R., Rohman, A. and Riyanto, S. (2019). Authentication of Patin (*Pangasius micronemus*) fish oil adulterated with Palm oil using FTIR Spectroscopy combined with Chemometrics. *International Journal of Applied Pharmaceutics,* 11 (3), 195–199. https://doi.org/10.22159/ ijap.2019v11i3.30947

Putri, A.R., Rohman, A., Riyanto, S. and Setyaningsih, W. (2020). Authentication of Patin Fish Oil (*Pangasius micronemus*) using FTIR Spectroscopy Combined with Chemometrics. *Indonesian Journal of Chemometrics and Pharmaceutical Analysis*, 1(1), 22-27. https://doi.org/10.22146/ijcpa.487

Rohman, A., Che Man, Y.B., Hashim, P. and Ismail, A. (2011). FTIR spectroscopy combined with chemometrics for analysis of lard adulteration in some vegetable oils. *CYTA - Journal of Food*, 9(2), 96–101. https:// doi.org/10.1080/19476331003774639

Rohman, A., Kuwat, T., Retno, S., Sismindari., Yuny, E. and Tridjoko, W. (2012). Fourier Transform Infrared Spectroscopy applied for rapid analysis of lard in palm oil. *International Food Research Journal*, 19 (3), 1161–1165.

Rohman, A. (2017). Physico-chemical properties, biological activities and authentication of cod liver oil. *Journal of Food and Pharmaceutical Sciences,* 5 (1), 1-7.

Rohman, A., Widyanintyas, R. and Amalia, F. (2017). Authentication of COD liver oil from selected edible oils using FTIR Spectrophotometry and Chemometrics. *International Food Research Journal,* 24(4), 1362–1367.

Rohman, A. (2019). The Employment of Fourier Transform Infrared Spectroscopy Coupled with Chemometrics Techniques for traceability and authentication of meat and meat products. *Journal of Advanced Veterinary and Animal Research,* 6(1), 9–17. https://doi.org/10.5455/javar.2019.f306

Rohman, A., Che Man, Y.B. and Ali, M.E. (2019). The Authentication of Virgin Coconut Oil from Grape seed oil and Soybean oil using FTIR Spectroscopy and Chemometrics. *International Journal of Applied Pharmaceutics,* 11(2), 259–263. https:// doi.org/10.22159/ijap.2019v11i2.31758

Rohman, A., Irnawati., Erwanto, Y., Lukitaningsih, E., Rafi, M., Fadzilah, N., Windarsih, A., Sulaiman, A. and Zakaria, Z. (2019). Virgin Coconut Oil: extraction, physicochemical properties, biological activities and its authentication analysis. *Food Reviews International,* 37(1), 46-66. https:// doi.org/10.1080/87559129.2019.1687515

Setyaningrum, D.L., Riyanto, S. and Rohman, A. (2013). Analysis of Corn and Soybean Oils in Red Fruit Oil using FTIR Spectroscopy in Combination with Partial Least Square. *International Food Research Journal,* 20(4), 1977–1981.

Sun, L., Goh, H.J., Govindharajulu, P., Leow, M.K.S. and Henry, C.J. (2019). Differential effects of monounsaturated and polyunsaturated fats on satiety and gut hormone responses in healthy subjects. *Foods,* 3(8), 120634. https://doi.org/10.3390/ foods8120634

Syifa, F., Irnawati., Riyanta, A.B. and Rohman, A. (2020). Authentication analysis of snakehead fish oil using combination of FTIR spectra and chemometrics. *International Journal of Pharmaceutical Research,* 13(1), 160–167. https:// doi.org/10.31838/ijpr/2021.13.01.025

Zilhadia, Yahdiana, H., Irwandi, J. and Effionora, A. (2018). Characterization and functional properties of gelatin extracted from goatskin. *International Food Research Journal,* 25(1), 275–281.

