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Determination of fatty acid content in krill oil commercial supplements by GC/FID technique

GC/FID tekniğiyle krill yağı ticari takviyelerindeki yağ asidi içeriğinin belirlenmesi

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Abstract

Krill oil has recently gained attention as a popular dietary supplement due to its high bioavailability and the presence of potent antioxidants such as astaxanthin. In this study, the fatty acid profiles of different commercial krill oil supplements (KOs) were determined using the Gas Chromatography-Flame Ionization Detector (GC-FID) technique. Based on the results, the total saturated fatty acids (SFA) ranged from 11.70% to 51.59%, monounsaturated fatty acids (MUFA) from 32.13% to 52.50%, and polyunsaturated fatty acids (PUFA) from 9.22% to 55.17%. The predominant fatty acids identified were palmitic acid (C16:0), linoleic acid (C18:2 ω−6), oleic acid (C18:1 ω−9), docosahexaenoic acid (DHA, C22:6) and eicosapentaenoic acid (EPA, C20:5). Additionally, very low levels of trans fatty acids (0.28–3.96%) were observed across all samples. The findings demonstrate that the fatty acid composition of KOs varies significantly depending on the source of raw materials and the specific production parameters employed. This research provides valuable data for the nutritional classification and commercial development potential of krill oil supplements.

Keywords: Krill oil, Fatty acid profile, GC-FID

Öz

Krill yağı, yüksek biyoyararlanımı ve astaksantin gibi güçlü antioksidanların varlığı nedeniyle son zamanlarda popüler bir besin takviyesi olarak dikkat çekmiştir. Bu çalışmada, farklı ticari krill yağı takviyelerinin (KOs) yağ asidi profilleri Gaz Kromatografisi-Alev İyonizasyon Dedektörü (GC-FID) tekniği kullanılarak belirlenmiştir. Sonuçlara göre, toplam doymuş yağ asitleri (SFA) %11.70 ile %51.59 arasında, tekli doymamış yağ asitleri (MUFA) %32.13 ile %52.50 arasında ve çoklu doymamış yağ asitleri (PUFA) %9.22 ile %55.17 arasında değişim göstermiştir. Belirlenen başlıca yağ asitleri palmitik asit (C16:0), oleik asit (C18:1 ω−9), linoleik asit (C18:2 ω−6), eikosapentaenoik asit (EPA, C20:5) ve dokosaheksaenoik asit (DHA, C22:6) 'den oluşmaktadır. Ayrıca, tüm örneklerde çok düşük miktarlarda trans yağ asidi (%0.28–3.96) tespit edilmiştir. Elde edilen bulgular, ticari krill yağı ürünlerinin yağ asidi bileşiminin, hammadde kaynağına ve kullanılan spesifik üretim parametrelerine bağlı olarak önemli ölçüde değiştiğini göstermektedir. Bu araştırma, krill yağı takviyelerinin besin sınıflandırması ve ticari geliştirme potansiyeli için önemli veriler sağlamaktadır.

Anahtar kelimeler: Krill yağı, Yağ asidi profili, GC-FID

1 Introduction

Krill is a small marine crustacean with a total dry weight of 65% protein, with lipid content varying from 12% to 50% according as age, time and species from capture to freezing [1-4]. Antarctic krill is mostly found in the Atlantic region of the Southern Ocean (ASO). Due to its high biological value and enormous abundance, krill is a valuable resource for global fisheries [5-8]. Krill oils are obtained from commercially available Antarctic krill (Euphausia Superba). Recently, krill oil has gained attention for its profile and concentration of phospholipids (PLs) and long-chain omega-3 polyunsaturated fatty acids (n-3 LCPUFAs) [1, 9]. Krill oil is valuable as a dietary supplement because it contains high concentrations of long-chain (C20) n-3 PUFA: EPA (13.8-20.3%) and DHA (5.6-17.4%) [7, 8]. Krill oil, similar to fish oil, is rich in EPA and DHA [9]. Unlike fish oil, most of the EPA and DHA in krill oil is in the form of phospholipids [9, 10]. The presence of EPA and DHA in phospholipid form in krill oil provides better oxidative stability and bioavailability than fish oil [9, 11, 12]. A publication by Ulven and Holven highlighted the higher bioavailability of n-3 fatty acids in krill oil compared to fish oil [13]. Since most of the fatty acids in krill oil are bound as phospholipids instead of TG, it is assumed that the high bioavailability may be due to the emulsifying properties of phospholipids and thus increased lipase activity [14, 15]. It also contains significant amounts of astaxanthin (natural antioxidant) in the form of diesters and monoesters [1, 9, 16, 17]. Astaxanthin in its esterified form has been reported to exhibit superior antioxidant activity compared to free astaxanthin, owing to its enhanced stability and functional efficacy across a wide range of conditions [9, 18]. Additionally, the presence of this powerful antioxidant in krill oil may provide protection to EPA and DHA [9]. Omega-3 fatty acids are known to have positive effects on cardiovascular diseases due to their capacity to increase HDL cholesterol and reduce cardiac arrhythmias, plasma triglycerides (TAG), and blood pressure

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[1, 8, 19-21]. In addition, positive effects have been reported against some neurological diseases and insulin resistance [22, 23]. Due to its numerous health benefits and advantages, krill oil is increasingly used as a dietary supplement [9].

Numerous studies have investigated the health-related effects of krill oil, including its antioxidant capacity, anti-inflammatory properties, and potential benefits for cardiovascular health. In Türkiye, the majority of studies on krill oil have focused on these biological and clinical aspects, particularly the bioavailability of omega-3 fatty acids and their physiological effects. Despite this growing body of research, there is a notable lack of studies examining the compositional quality of commercially available krill oil products. Specifically, comprehensive and comparative analyses of fatty acid profiles, brand-based evaluations, and verification of label accuracy for krill oil supplements marketed in Türkiye remain limited. This represents a significant research gap, as variations in fatty acid composition can directly affect both the nutritional value and bioavailability of these products. In this context, the present study aims to analyze and compare the fatty acid profiles of different commercially available krill oil supplements using GC/FID methodology. By reporting the distribution of SFA, MUFA, and PUFA components, this study seeks to contribute to the existing literature by providing a clearer understanding of the compositional characteristics and quality variations of krill oil products available in the Turkish market.

2 Materials and methods

2.1 Krill oil samples

KOs were bought, in capsule or softgel form, from an online vendor in April 2025. These samples were deposited at 4 °C until GC analysis.

2.2 Instrumentation and chemicals

High purity chemicals (potassium hydroxide, n–hexane, anhydrous, methanol and sodium sulphate) were supplied from VWR Chemicals BDH Inc. (West Chester, Pennsylvania, US) and Sigma–Aldrich Inc. (Zwijndrecht, The Netherlands). The reference material of fatty acid methyl esters (FAMEs) (C4–C24, wt.%, mixture) was purchased from Sigma–Aldrich Inc. (Zwijndrecht, The Netherlands). An Agilent 7890A GC device with B.03.02–2008 Chemstation software and 5975C model FID (Santa Clara, CA, USA) were used for analysis.

2.3 GC–FID analysis

Before the GC–FID analysis, 0.1 g of KO was mixed with n–hexane (10 mL); later, 0.1 mL of the 2N KOH (potassium hydroxide) solution in methanol (base–catalyzation reagent) was poured into this solution and they were blended for about 2 min. Afterwards, this solution was centrifugated for 10 min and 5000 rpm, and the superior supernatant was poured into vials for the GC analysis.

For the GC analysis, high-purity helium and hydrogen were employed as the carrier and make-up gases, respectively. Separation was achieved using a highly polar capillary column (100 m × 0.25 mm i.d., 0.20 µm film thickness; Agilent HP–88 cyanopropyl, Santa Clara, CA, USA). The oven temperature was initially maintained at 45 °C for 4 min, then increased to 175 °C at a rate of 13 °C/min and held for 27 min. Subsequently, the temperature was raised to 215 °C at 4 °C/min and maintained for 35 min. The injector and detector temperatures were set at 250 °C. Fatty acid methyl esters (FAMEs) of KO were injected at a volume of 1.0 µL with a split ratio of 100:1. Fatty acids were identified by comparing their retention times (tR) with those of authenticated reference standards, and the results were expressed as percentages of total fatty acids. GC–FID method parameters applied for fatty acid profile analyses are given in detail in Table 1.

Table 1. GC–FID method parameters applied for fatty acid profile analyses [24-26]

Applied GC–FID Analysis Method Parameters			
Sample derivatization procedure	Preparation of methyl ester derivatives. At the end of the processes, the upper phase, that is, the fatty acids converted into methyl ester derivatives, were taken and placed in the GC vial and injected into the device with an automatic injector.		
Injection	1 µL (maximum amount of the syringe) ; split ratio of 100:1		
Injection block temperature	250°C		
Column	Agilent HP–88 capillary GC column (88% Cyanopropyaryl–polysiloxane) (100 m×0.25 mm×0.20 µm)		
Column Temperature Program	–	45°C	4 min
	13°C /min	175°C	27 min
	4°C/min	215°C	35 min
Analysis time	**86 min**		
Mobile phase	High purity Helium gas		
Flow rate	1 mL/min		
Detector	Flame ionization detector 250°C. H_2 flow rate 45 mL/min. Air flow rate 450 mL/min. Makeup gas Helium		

3 Results and discussion

The fatty acid profiles of the analyzed KOs are shown in Table 2. The total contents of MUFAs, PUFAs, and SFAs are expressed as percentages (%, g fatty acid/100 g KO). The analyzed KOs were showed a predominance of C14:0, C16:1, C16:0, C18:0, cis–C18:2, cis–C18:1, C22:6 and C20:5 fatty acids and are generally characterized by high PUFAs content (9.22%–55.17%).

All samples content very low values for trans fatty acid content (0.28–3.96%). In conclusion, analyzed krill oil samples exhibited ∑MUFA, ∑PUFA, and ∑SFA contents ranging from 32.13–52.50%, 9.22–55.17%, and 11.70–51.59%, respectively (Table 2). Table 2 shows that KOs (KO1-KO10) were divided into distinct groups in terms of fatty acid composition, nutritional values and characteristic structures. Samples KO2, KO3, and KO8 exhibit similar characteristics, particularly in terms of linoleic acid (C18:2 ω−6) content. Oil in this group have high linoleic acid percentages, ranging from approximately 39.66% to 53.64%. Furthermore, these samples have quite high total PUFA content (44.46% – 55.17%), while their SFA content remains low at 11.70% – 19.33%. Samples coded KO4, KO6, and KO10 have a sharply different high saturated fatty acid composition from the others. In these samples, SFA ratios range from 48.77% to 51.59%, with palmitic acid (C16:0) being the main source of these values, varying between 27.07% and 30.24%. This profile indicates that these oils exhibit a more stable structure. Oleic acid (C18:1 ω−9) stands out as one of the most common components among all samples examined. Samples such as KO7 and KO9 were noteworthy for their total MUFA ratios, ranging from 43.08% to 52.50%. In particular KO9 is characterized as a high source of omega-9 with its oleic acid ratio of 30.48%. Unlike other KO samples, it is noteworthy that KO4 and KO10 samples contained significant amounts of EPA (4.65%-4.91%), and KO1 and KO10 samples also contained significant amounts of DHA (6.81%-2.21%). In conclusion, these fundamental differences in the composition of the oils stem from variations in the type of raw material, growing conditions, and production techniques. These data, when compared with similar studies in literature, allow for the classification of the commercial and nutritional value of the samples.

Lee et al. [8] investigated the levels of omega-3 PUFAs, particularly EPA and DHA, along with the overall fatty acid composition of 20 commercially available krill oil supplements. The relative proportions of DHA and EPA ranged from 14.2% to 34.8% (w/w). Although all products were labeled as containing 100% krill oil as the raw material, four samples exhibited deviations from the characteristic fatty acid profile of typical krill oil, particularly with respect to palmitic acid (C16:0), myristic acid (C14:0), palmitoleic acid (C16:1), eicosenoic acid (C20:1, n-9) and linoleic acid (C18:2, n-6). Similarly, Srigley and Orr-Tokle [27] assessed the lipid composition of 22 commercial krill oil (CKO) supplements available in the United States market. Their findings revealed that ten products (45%) contained substantial levels of fatty acid ethyl esters (FAEEs), ranging from 41% to 75% (w/w). These concentrations were markedly higher than the FAEE levels (<3%, w/w) reported in krill oil supplied directly by the manufacturer.

Figure 1 presents the GC/FID chromatograms obtained for the KO2 and KO3 samples. The complete chromatograms illustrate the distribution of all fatty acids present in the samples in both cis and trans forms. The clear peak separation observed throughout the profiles reflects the combined effect of the highly polar HP-88 cyanopropyl capillary column and the optimized oven temperature program. Under these chromatographic conditions, unsaturated fatty acids with a carbon chain length of X elute within a characteristic retention window bounded by the corresponding saturated fatty acids, namely CX:0 and CX+2:0.

The assignment of individual fatty acids, including positional and geometric isomers, was achieved by comparing retention times with authentic reference standards and supported by previously reported data. The values of retention time (tR) of fatty acids determined by the GC method were summarized in Table 2. Overall, the chromatograms reveal comparable fatty acid patterns for KO2 and KO3, while differences in peak intensities indicate variations in the relative abundance of specific components between the two krill oil samples.

4 Conclusions

In this study, the content and composition of key fatty acids (MUFAs, PUFAs, and SFAs) in commercially available krill oil (KO) supplements were comprehensively evaluated using the GC/FID method. The results revealed a wide range of variations among samples, with ∑MUFAs ranging from 32.13% to 52.50%, ∑PUFAs from 9.22% to 55.17%, and ∑SFAs from 11.70% to 51.59%. These findings demonstrate significant variability in the fatty acid profiles of krill oil products available on the market, indicating potential differences in raw material quality, processing conditions, and formulation practices. Such variability may directly influence the nutritional value, bioavailability, and overall efficacy of these supplements. Given these variations, regular and systematic monitoring of krill oil supplements is essential to ensure product quality, safety, and compliance with label claims. Independent analytical verification should be encouraged to enhance transparency and to support informed decision-making by both consumers and regulatory authorities. Furthermore, the results of this study highlight the need for more comprehensive and standardized analyses of commercially available dietary supplements in Türkiye. Establishing quality benchmarks and conducting comparative product evaluations will be critical for improving consumer trust and supporting the sustainable growth of the krill oil market. Overall, this study provides valuable insights into the compositional characteristics of krill oil supplements and is expected to serve as a useful reference for future research on high value-added food products and dietary supplements.

Table 2. Fatty acid composition analysis results (%)

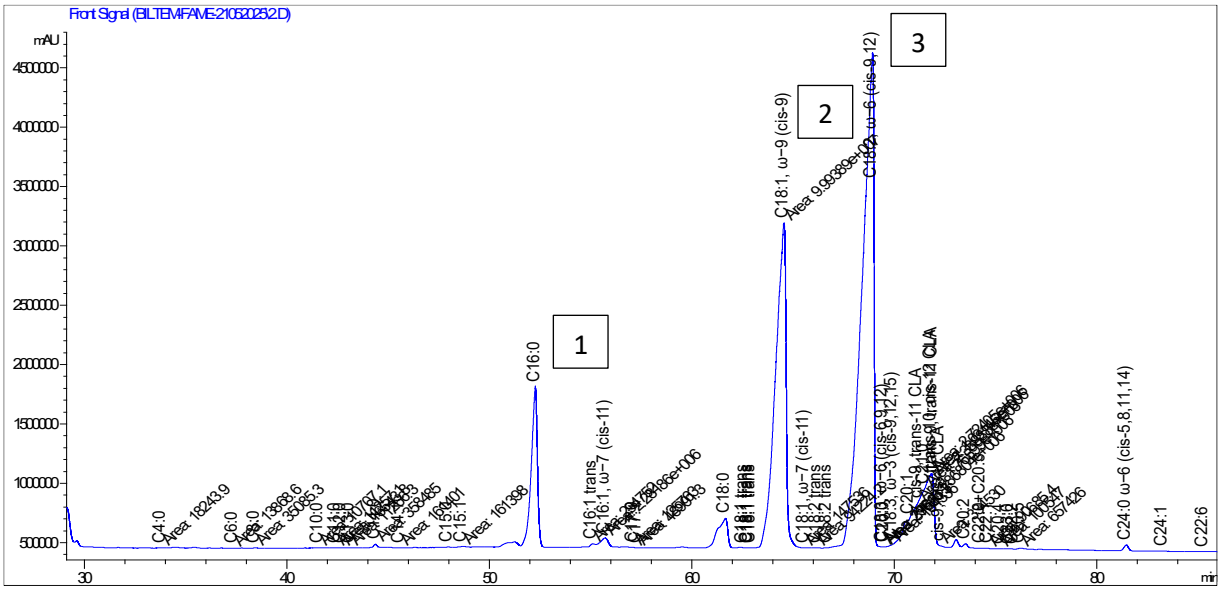
t_R (min)	Fatty acid. % (w/w)	KO1	KO2	KO3	KO4	KO5
33.804	butanoic acid (C4:0)	0.008 ±0.001	0.006 ±0.001	0.008 ±0.001	0.011 ±0.001	0.004 ±0.001
37.424	hexanoic acid (C6:0)	0.015 ±0.001	0.004 ±0.001	0.009 ±0.001	0.011 ±0.001	0.004 ±0.001
38.73	octanoic acid (C8:0)	0.014 ±0.001	0.011 ±0.001	0.005 ±0.001	0.430 ±0.001	0.005 ±0.001
41.223	decanoic acid (C10:0)	0.071 ±0.001	0.003 ±0.001	0.008 ±0.001	0.099 ±0.001	0.003 ±0.001
41.838	undecylic acid (C11:0)	0.094 ±0.001	0.003 ±0.001	0.111 ±0.001	0.014 ±0.001	0.015 ±0.001
42.733	dodecanoic acid (C12:0)	0.032 ±0.001	0.005 ±0.001	0.005 ±0.001	0.032 ±0.001	0.002 ±0.001
43.451	tridecylic acid (C13:0)	0.176 ±0.001	0.003 ±0.001	0.004 ±0.001	0.009 ±0.001	0.012 ±0.001
44.502	myristic acid (C14:0)	6.843 ±0.01	0.110 ±0.001	0.113 ±0.001	17.800 ±0.02	3.275 ±0.01
45.249	myristic acid. n9 (C14:1)	0.033 ±0.001	0.050 ±0.001	0.007 ±0.001	0.025 ±0.001	0.044 ±0.001
47.188	pentadecanoic acid (C15:0)	0.094 ±0.001	0.012 ±0.001	0.024 ±0.001	0.277 ±0.001	0.041 ±0.001
48.939	ginkgolic acid (C15:1)	0.056 ±0.001	0.05 ±0.001	0.028 ±0.001	0.018 ±0.001	0.009 ±0.001
52.514	palmitic acid (C16:0)	23.871 ±0.02	8.656 ±0.01	6.992 ±0.01	30.235 ±0.02	5.508 ±0.01
54.667	C16:1 trans	0.640 ±0.001	0.090 ±0.001	0.033 ±0.001	0.295 ±0.001	0.054 ±0.001
55.384	palmitoleic acid (cis–11) (C16:1. ω−7)	10.873 ±0.02	0.700 ±0.001	0.350 ±0.001	11.524 ±0.02	9.059 ±0.02
56.415	heptadecanoic acid (C17:0)	0.141 ±0.001	0.039 ±0.001	0.005 ±0.001	0.215 ±0.001	0.213 ±0.001
56.937	heptadecanoleic acid (C17:1)	1.762 ±0.001	0.015 ±0.001	0.081 ±0.001	0.086 ±0.001	0.116 ±0.001
61.496	stearic acid (C18:0)	5.862 ±0.01	2.624 ±0.001	3.861 ±0.01	1.633 ±0.001	3.229 ±0.01
62.643	C18:1 trans	0.582 ±0.001	0.022 ±0.001	0.051 ±0.001	0.490 ±0.001	0.090 ±0.001
64.415	oleic acid (cis–9) (C18:1. ω−9)	31.591 ±0.02	30.67 ±0.02	31.89 ±0.02	23.863 ±0.02	29 ±0.02
65.048	oleic acid (cis–11) (C18:1. ω−7)	0.816 ±0.001	0.045 ±0.001	0.061 ±0.001	0.657 ±0.001	8.375 ±0.01
66.686	C18:2 trans	0.635 ±0.001	0.067 ±0.001	0.071 ±0.001	0.376 ±0.001	0.087 ±0.001
68.037	linoleic acid (cis–9.12) (C18:2. ω−6)	2.516 ±0.001	52.760 ±0.02	53.642 ±0.02	2.858 ±0.001	34.690 ±0.02
68.979	linolenic acid (cis–6.9.12) (C18:3. ω−6)	0.403 ±0.001	0.009 ±0.001	0.104 ±0.001	0.132 ±0.001	1.004 ±0.001
69.763	arachidic acid (C20:0)	0.154 ±0.001	0.012 ±0.001	0.028 ±0.001	0.059 ±0.001	0.006 ±0.001
70.013	linolenic acid (cis–9.12.15) (C18:3. ω−3)	0.013 ±0.001	0.050 ±0.001	0.010 ±0.001	0.076 ±0.001	0.021 ±0.001
70.615	eicosenoic acid (C20:1)	0.227 ±0.001	0.573 ±0.001	0.318 ±0.001	0.173 ±0.001	0.032 ±0.001
70.998	cis–9. trans–11 CLA	0.259 ±0.001	0.542 ±0.001	0.075 ±0.001	0.400 ±0.001	0.347 ±0.001
71.51	heneicosylic acid (C21:0)	0.012 ±0.001	0.718 ±0.001	0.007 ±0.001	0.375 ±0.001	0.649 ±0.001
71.789	trans–10. cis–12 CLA	0.008 ±0.001	0.836 ±0.001	0.005 ±0.001	0.305 ±0.001	0.061 ±0.001
71.832	trans–9. trans–11 CLA	0.009 ±0.001	0.317 ±0.001	0.004 ±0.001	0.007 ±0.001	0.008 ±0.001
72.325	cis–9. cis–11 CLA	0.082 ±0.001	0.103 ±0.001	0.041 ±0.001	0.006 ±0.001	0.165 ±0.001
72.971	eicosadienoic acid (C20:2)	1.313 ±0.001	0.301 ±0.001	0.380 ±0.001	0.864 ±0.001	0.070 ±0.001
74.107	behenic acid+eicosatrienoic acid (C22:0+C20:3)	0.356 ±0.001	0.022 ±0.001	0.142 ±0.001	0.347 ±0.001	0.574 ±0.001
74.509	erucic acid (C22:1)	0.074 ±0.001	0.028 ±0.001	0.050 ±0.001	0.046 ±0.001	0.032 ±0.001
74.861	lignoceric acid (C20:4)	0.123 ±0.001	0.031 ±0.001	0.034 ±0.001	0.072 ±0.001	0.213 ±0.001
75.657	trikosylik acid (C23:0)	0.074 ±0.001	0.021 ±0.001	0.019 ±0.001	0.005 ±0.001	0.116 ±0.001
75.952	C22:2 (cis–13.16–doco. acid)	0.024 ±0.001	0.012 ±0.001	0.013 ±0.001	0.005 ±0.001	0.016 ±0.001
76.533	eicosapentaenoic acid (C20:5) (EPA)	3.090 ±0.01	0.202 ±0.001	0.595 ±0.001	4.909 ±0.01	2.469 ±0.001
81.699	ligno. acid ω−6 (cis–5.8.11.14) (C24:0)	0.078 ±0.001	0.264 ±0.001	0.358 ±0.001	0.040 ±0.001	0.254 ±0.001
84.534	nervonic acid (C24:1)	0.170 ±0.001	0.003 ±0.001	0.067 ±0.001	0.045 ±0.001	0.106 ±0.001
85.399	docosahexaenoic acid (C22:6) (DHA)	6.806 ±0.01	0.010 ±0.001	0.392 ±0.001	1.173 ±0.001	0.024 ±0.001
	∑SFAs	37.895	12.513	11.699	51.592	13.910
	∑MUFAs	45.602	32.134	32.852	36.437	46.773
	∑PUFAs	14.288	53.375	55.170	10.089	38.507
	∑trans FAs	2.215	1.977	0.280	1.879	0.812

t_R; retention time, FAs; fatty acids, MUFAs; monounsaturated fatty acids, PUFAs; polyunsaturated fatty acids, SFAs; saturated fatty acids

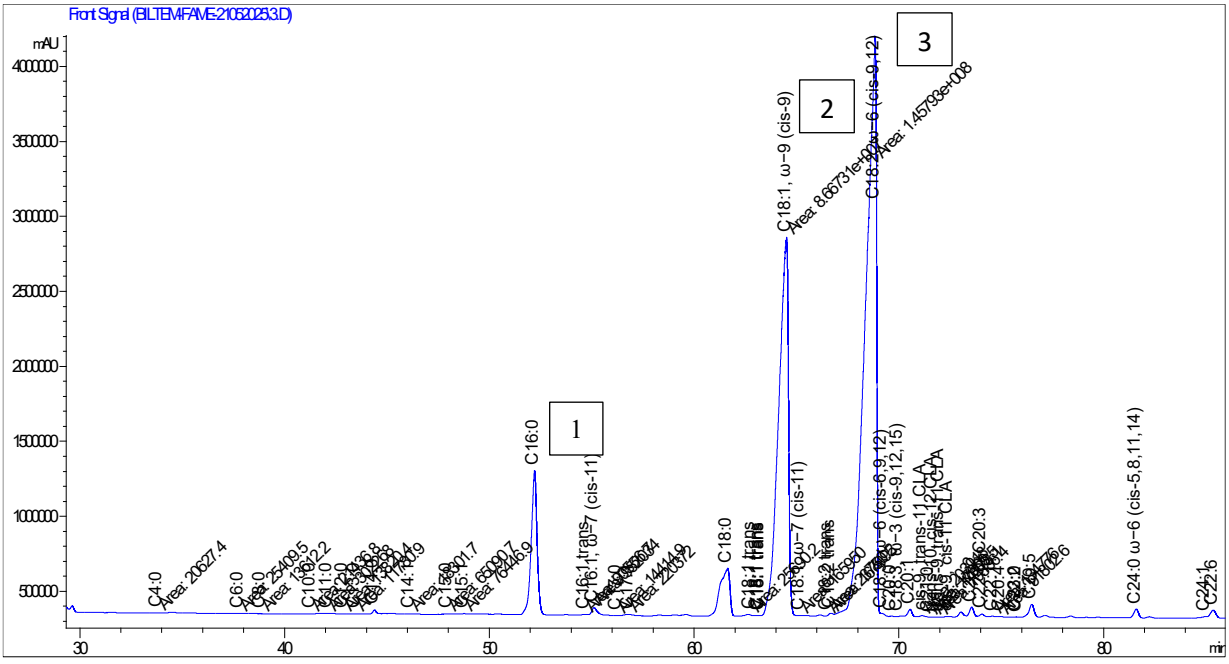
Table 2. (Continue) Fatty acid composition analysis results (%)

t_R (min)	Fatty acid. % (w/w)	KO6	KO7	KO8	KO9	KO10
33.804	butanoic acid (C4:0)	0.388 ±0.001	0.127 ±0.001	0.396 ±0.001	0.013 ±0.001	0.065 ±0.001
37.424	hexanoic acid (C6:0)	0.022 ±0.001	0.015 ±0.001	0.043 ±0.001	0.017 ±0.001	0.015 ±0.001
38.73	octanoic acid (C8:0)	0.399 ±0.001	0.175 ±0.001	0.048 ±0.001	0.016 ±0.001	0.450 ±0.001
41.223	decanoic acid (C10:0)	0.097 ±0.001	0.031 ±0.001	0.024 ±0.001	0.012 ±0.001	0.098 ±0.001
41.838	undecylic acid (C11:0)	0.009 ±0.001	0.031 ±0.001	0.022 ±0.001	0.053 ±0.001	0.006 ±0.001
42.733	dodecanoic acid (C12:0)	0.135 ±0.001	0.047 ±0.001	0.04 ±0.001	0.037 ±0.001	0.052 ±0.001
43.451	tridecylic acid (C13:0)	0.027 ±0.001	0.025 ±0.001	0.017 ±0.001	0.039 ±0.001	0.034 ±0.001
44.502	myristic acid (C14:0)	17.341 ±0.02	7.249 ±0.01	2.633 ±0.001	3.298 ±0.01	18.054 ±0.02
45.249	myristic acid. n9 (C14:1)	0.236 ±0.001	0.163 ±0.001	0.139 ±0.001	0.049 ±0.001	0.162 ±0.001
47.188	pentadecanoic acid (C15:0)	0.302 ±0.001	0.308 ±0.001	0.175 ±0.001	0.039 ±0.001	0.350 ±0.001
48.939	ginkgolic acid (C15:1)	0.036 ±0.001	0.502 ±0.001	0.041 ±0.001	0.002 ±0.001	0.003 ±0.001
52.514	palmitic acid (C16:0)	30.372 ±0.02	16.348 ±0.02	11.192 ±0.02	8.189 ±0.01	27.070 ±0.02
54.667	C16:1 trans	0.322 ±0.001	0.106 ±0.001	0.060 ±0.001	0.040 ±0.001	0.288 ±0.001
55.384	palmitoleic acid (cis–11) (C16:1. ω−7)	11.454 ±0.02	19.955 ±0.02	3.994 ±0.01	7.287 ±0.01	16.419 ±0.02
56.415	heptadecanoic acid (C17:0)	0.146 ±0.001	0.317 ±0.001	0.098 ±0.001	0.198 ±0.001	0.104 ±0.001
56.937	heptadecanoleic acid (C17:1)	0.082 ±0.001	0.508 ±0.001	0.234 ±0.001	0.108 ±0.001	0.061 ±0.001
61.496	stearic acid (C18:0)	1.659 ±0.001	2.842 ±0.001	3.256 ±0.001	2.728 ±0.001	1.797 ±0.001
62.643	C18:1 trans	0.441 ±0.001	1.296 ±0.001	0.293 ±0.001	0.125 ±0.001	0.674 ±0.001
64.415	oleic acid (cis–9) (C18:1. ω−9)	24.019 ±0.02	14.323 ±0.02	26.848 ±0.02	30.481 ±0.02	22.327 ±0.02
65.048	oleic acid (cis–11) (C18:1. ω−7)	0.730 ±0.001	15.447 ±0.02	0.553 ±0.001	4.611 ±0.01	0.678 ±0.001
66.686	C18:2 trans	0.810 ±0.001	0.512 ±0.001	0.405 ±0.001	0.188 ±0.001	0.253 ±0.001
68.037	linoleic acid (cis–9.12) (C18:2. ω−6)	2.323 ±0.001	4.901 ±0.01	39.657 ±0.02	27.351 ±0.02	2.024 ±0.001
68.979	linolenic acid (cis–6.9.12) (C18:3. ω−6)	0.137 ±0.001	1.962 ±0.001	0.141 ±0.001	9.929 ±0.01	0.119 ±0.001
69.763	arachidic acid (C20:0)	0.083 ±0.001	0.046 ±0.001	0.048 ±0.001	1.032 ±0.001	0.043 ±0.001
70.013	linolenic acid (cis–9.12.15) (C18:3. ω−3)	0.078 ±0.001	0.097 ±0.001	0.009 ±0.001	0.013 ±0.001	0.004 ±0.001
70.615	eicosenoic acid (C20:1)	0.264 ±0.001	0.337 ±0.001	0.345 ±0.001	0.217 ±0.001	0.029 ±0.001
70.998	cis–9. trans–11 CLA	0.362 ±0.001	0.599 ±0.001	0.448 ±0.001	0.223 ±0.001	0.091 ±0.001
71.51	heneicosylic acid (C21:0)	0.022 ±0.001	0.688 ±0.001	0.918 ±0.001	0.162 ±0.001	0.116 ±0.001
71.789	trans–10. cis–12 CLA	0.017 ±0.001	0.836 ±0.001	0.664 ±0.001	0.009 ±0.001	0.016 ±0.001
71.832	trans–9. trans–11 CLA	0.173 ±0.001	0.048 ±0.001	0.083 ±0.001	0.007 ±0.001	0.077 ±0.001
72.325	cis–9. cis–11 CLA	0.274 ±0.001	0.521 ±0.001	2.006 ±0.001	0.255 ±0.001	0.218 ±0.001
72.971	eicosadienoic acid (C20:2)	0.894 ±0.001	0.730 ±0.001	2.188 ±0.001	0.384 ±0.001	0.613 ±0.001
74.107	behenic acid+eicosatrienoic acid (C22:0+C20:3)	0.350 ±0.001	1.536 ±0.001	0.153 ±0.001	0.449 ±0.001	0.347 ±0.001
74.509	erucic acid (C22:1)	0.114 ±0.001	0.831 ±0.001	0.093 ±0.001	0.222 ±0.001	0.217 ±0.001
74.861	lignoceric acid (C20:4)	0.126 ±0.001	0.839 ±0.001	0.228 ±0.001	0.307 ±0.001	0.044 ±0.001
75.657	trikosylik acid (C23:0)	0.005 ±0.001	0.666 ±0.001	0.012 ±0.001	0.063 ±0.001	0.131 ±0.001
75.952	C22:2 (cis–13.16–doco. acid)	0.005 ±0.001	0.201 ±0.001	0.024 ±0.001	0.013 ±0.001	0.016 ±0.001
76.533	eicosapentaenoic acid (C20:5) (EPA)	4.630 ±0.01	2.943 ±0.001	0.859 ±0.001	1.204 ±0.001	4.655 ±0.01
81.699	ligno. acid ω−6 (cis–5.8.11.14) (C24:0)	0.044 ±0.001	0.007 ±0.001	0.251 ±0.001	0.322 ±0.001	0.038 ±0.001
84.534	nervonic acid (C24:1)	0.039 ±0.001	0.437 ±0.001	0.003 ±0.001	0.101 ±0.001	0.051 ±0.001
85.399	docosahexaenoic acid (C22:6) (DHA)	1.032 ±0.001	1.450 ±0.001	1.356 ±0.001	0.203 ±0.001	2.211 ±0.001
	∑SFAs	51.401	30.458	19.326	16.667	48.770
	∑MUFAs	36.974	52.503	32.250	43.078	39.947
	∑PUFAs	9.225	13.123	44.462	39.404	9.686
	∑trans FAs	2.399	3.918	3.959	0.847	1.617

t_R; retention time, FAs; fatty acids, MUFAs; monounsaturated fatty acids, PUFAs; polyunsaturated fatty acids, SFAs; saturated fatty acids



(a) GC/FID chromatogram of KO2



(b) GC/FID chromatogram of KO3

Figure 1. GC/FID chromatogram for the fatty acid analysis of KOs (KO2 and KO3 samples)
1; palmitic acid, 2; oleic acid, 3; linoleic acid

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Conflict of interest

The author declares that there are no conflicts of interest related to the publication of this article.

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