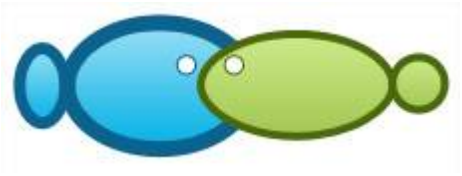

Effect of temperature and time on fat recovery from the by-products of striped catfish (*Pangasianodon hypophthalmus*) using organic solvents

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Abstract. The effect of temperature and time on fat recovery from striped catfish (*Pangasianodon hypophthalmus*) by-products using organic solvents was examined to determine the optimal extraction parameters. A high recovery efficiency (61.1%) was found for fat samples extracted at 50°C. The acid index and fat colour were 2.81 mg KOH g^{-1} and b* = 11.0, respectively, and the fatty acid composition of the fat was the highest with an EPA (eicosapentaenoic acid) content of 0.15%. The efficiency of fat extraction at 25 min was high (66.8%), and the acid index and fat colour were 2.92 mg KOH g^{-1} and b* = 8.33, respectively. Additionally, the fatty acid of EPA and DHA (docosahexaenoic acid) accounted for the highest contents of 0.15% and 0.57%, respectively. The results confirmed that the optimal conditions for extracting fat from striped catfish by-products with an organic solvent are 50°C for 25 min.
Key Words: extraction temperature, extraction time, fat recovery, fatty acid content.

Introduction. Striped catfish (*Pangasianodon hypophthalmus*) is one of the main aquaculture species in the Mekong Delta of Viet Nam. The fillet of this fish has been exported to over 138 countries and territories (VASEP 2022). The production and export value were 1.7 million tons and US$ 2.4 billion in 2002, respectively (VASEP 2022). The fillet is the main product of striped catfish processing. The fillet percent is from 28.9 to 38.5% of the fish biomass, while by-products, such as the head, viscera, skin, bone, and flesh meat, are 61.5 to 71.1% of the biomass (Huong & Thu 2013). Generally, the by-products contain many nutrients, especially fish oil; thus, the development of methods for the proper use of by-products would enhance the value of striped catfish.

Dung et al (2011) reported that the lipids in striped catfish by-products contain a high ratio of unsaturated fatty acids in the total fatty acids (47.3%), such as oleic acid (39.5%) and linoleic acid (7.83%). Studies have investigated the development of extraction methods for omega-3 fatty acids from the by-products of striped catfish using isopropanol and hexane (Trang et al 2015). The composition and characteristics of fatty acids in striped catfish as a function of fish size (4-10 g, 30-40, and 100-200 g) have been studied by Nguyen & Anh (2013), who found differences in total fatty acids for different fish sizes, such as 6.3 g, 5.7 g, and 2.12 g per 100 g wet weight, respectively. Palmitic acid and oleic acid were 23.3% and 28.6% of total fatty acids in fish of 100-200 g (Nguyen & Anh 2013). However, the extraction process for the recovery of total fatty acids was dependent on many factors, including the type of solvent, extraction method and equipment used for rotary evaporation (Zhang et al 2018). Until now, there have been no documented studies on the effects of temperature and time on the recovery of fatty acids from by-products of striped catfish using organic solvents. This paper reports the recovery of oil in terms of quantity and quality from the by-products at different times and temperatures using organic solvents.

Material and Method

Time and location. The study was conducted from May 2022 to February 2023 at the College of Aquaculture and Fisheries, Can Tho University.

Materials. The flesh meat of striped catfish was collected from Bien Dong Company (Tra Noc Industrial Zone 2, O Mon District, Can Tho City, Viet Nam). The collected materials were kept in ice during transportation from the processing plant to the laboratory. The bone of the samples was removed, and the samples were cleaned with chilled water. Then, the samples were placed in a polyethylene (PE) bag at 100 g per bag and stored at -20°C until use. NaOH, n-hexane (C_6H_{14}), isopropanol (C_3H_8O), sodium sulphate (Na_2SO_4), phenolphthalein, and Kali hydroxide (KOH) were used for the extraction.

Experimental design

Effects of temperature on the fatty acid recovery from the flesh meat of striped catfish. The experiments consisted of four different temperature treatments, 25, 50, 70 and 90°C, with three replications. The flesh meat was defrosted and homogenised using a crusher. A 10-g sample was placed into 100 mL of isopropanol:hexane solvent at a ratio of 4:6 (Minh et al 2023) and gently mixed by stirring. The solution was kept at different temperatures for 35 min (Suseno et al 2015). The separation of liquid and solid was achieved using Whatman 47-mm-diameter paper. Then, the solid portion was used for extraction one more time. Then, 40 g of Na_2SO_4 was added to all collected solutions, and it was covered by Parafilm and kept in the refrigerator overnight. The Whatman paper was used to filter the solution again. Then, we collected the oil mixture using rotary evaporation for 2 h. The collected fatty acid solution was removed from the solvents by using a nitrogen gas presser. The percentage of oil recovery was calculated, and the acid index, fat colour and composition of the fatty acid were analysed. Based on this result, the optimal temperature was selected for the next experiment.

Effects of extraction time on the fatty acid recovery from flesh meat of striped catfish. The experiments consisted of four different extraction time treatments, 15, 25, 35 and 45 min, with three replications. The samples were prepared as described in the section above. The optimal temperature (50°C) in the first experiment was chosen for this experiment. Samples (10 g each) were placed into 100 mL of isopropanol:hexane solvent at a ratio of 4:6 (Minh et al 2023) and extracted for specific times. The continuous extraction process was described in the section above. The same parameters mentioned above were analysed.

Sample analysis. The lipid content in the flesh meat was analysed using the Soxhlet method (AOAC 2000). Samples of 30 g each were dried for 2 days at 60°C, and then, a 0.5 g dried sample was continuously dried for 1 day at 105°C. Then, the sample was weighed and analysed using the Soxhlet method for 8 h. Samples were re-dried at 105°C within 1 day and re-weighed.

The lipid content (%) was calculated using the formula: $m_{lipid} = \frac{(P1 - P2)}{G} \times 100$, where P_1 is the filter paper + sample weight before Soxhlet, P_2 is the filter paper + sample weight after Soxhlet, and G is the weight of buffer chemical (g). The lipid recovery efficiency (%) was calculated based on the weight of samples compared to the lipid extracted using the formula: $H\ (\%) = \frac{X}{Y} \times 100$, where X is the extracted oil, and Y is the lipid content in the sample.

Acid value (AV): weight of KOH (mg) required for neutralizing the free fatty acid in 1 g of lipid. A 1-g lipid sample was mixed with 50 mL of 96% ethanol and 50 mL of 77% ether and then neutralised with 0.1 N KOH, using 0.5 mL of phenolphthalein solution as the indicator. The solution sample was titrated with 0.1 N KOH until a permanent pink colour appeared within 15 s. The acid value of the oil (mg KOH/g of sample) was

calculated according to the method described by Iberahim & Tan (2020), AV = $\frac{5.610 \times a}{P}$, where a is the standard alkaline, and P is the amount of lipid sample.

The colour of the oil sample was analysed using the AOCS Official Method Cc 13e-92 using a colourimeter (PCE - CSM 2 China) with the CIE-D65 colour system. The results were based on *L** (from lightness to darkness), *a** (redness to greenness), and b* (yellowness to blueness) (Sae-leaw & Benjakul 2015).

The fatty acid composition was determined using the AOAC Official Method 920.39 (AOAC 2016). An Agilent 6890N gas chromatograph (Agilent Technologies, Santa Clara, CA, USA) was used in combination with an Agilent 7683 B autoinjector and a flame ionisation detector. Helium was used as the carrier gas at a flow rate of 1.6 mL min^{-1}. The individual fatty acids were separated according to their different migration rates using a Varian CP7419 capillary column (50 m × 250 µm × 0.25 µm; Agilent Technologies, Santa Clara, CA, USA). After maintaining the temperature at 60°C for 1 min, the column was temperature-programmed to increase at 30°C/min to 130°C, 1.3°C/min to 195°C, and 30°C/min to 240°C, where it was maintained for 10 min. The temperature of the injector was 240°C, and the temperature of the detector was 250°C.

Statistical analysis. Microsoft Excel 2016 was used for the descriptive statistical analysis, including the determination of the standard deviation (SD) and mean (M). One-way analysis of variance (ANOVA) and Duncan's post hoc tests were used to test for significant differences among treatments (at the 95% significance level) using SPSS 20.0.

Results and discussion

Lipid content in the flesh meat of striped catfish. The lipid content in the flesh meat of striped catfish fluctuated from 41 to 42.5% wet weight (n = 3). This level was higher than that found by Reddy (2016) (11.3%). The flesh meat used in this study included the lipids in the abdomen of the fish, which made the lipid content high. In addition, the variation of lipids in the striped catfish depends on the husbandry conditions, such as feed, water environment and culture period (Dao et al 2020). The lipid content in the striped catfish was higher than those in herring (*Sardinella gibbosa*) (6.77%) (Chrisolite et al 2016), yellowfin tuna (*Thunnus albacares*) (11.1%) (Binh & Kieu 2019) and salmon (*Salmo salar*) (20.0%) (Luan & Tuyen 2018).

Effects of temperature on the lipid content in the flesh meat of striped catfish. Temperature is an important factor that directly affects the lipid recovery of flesh meat. The lipid recovery was the highest at 70°C (68.0%) and the lowest at 25°C (57.9%). The acid value was significant among the treatments (Table 1).

The lipid recovery increased with increasing temperature but decreased at 90°C. Suseno et al (2015) explained that this was due to the oxidative process. Wu & Bechtel (2008) reported that physical factors can affect the oil extraction ratio from fish owing to high temperatures that destroy the lipids. The advantage of high temperature is the stimulation of the diffusion of the buffer into the material, which decreases the viscosity of the material and thus increases lipid recovery (Man et al 2011; Lanh et al 2016). However, the protein in the material was denatured with no reversal at 90-100°C and became hard and condensed; thus, the release of oil was inhibited (Ahern & Klibanov 1985). In this study, the lipid recovery from the flesh of striped catfish was higher at 70°C (68%) than at temperature of 25°C (56.2%) (Minh et al 2023). The recovered lipids from other species were also high at high temperatures, such as 6.44% (70°C) from the waste from tilapia (*Oreochromis niloticus*) processing (Suseno et al 2015), skipjack tuna (*Katsuwonus pelamis*) at 4.8% (85°C) (Chantachum et al 2000), and algae *Schizochytrium mangrovei* PQ6 at 68.2% (70-75°C) (Hien et al 2013).

In this study, the acid value of the lipid products varied with increased extraction temperature. When the temperature was increased from 25 to 90°C, the acid value was the highest at 50°C (2.81 mg KOH g^{-1}) and the lowest at 25°C (2.17 mg KOH g^{-1}). Hydrolysis of lipids produces free fatty acids and glycerol, where the extraction process occurs in water (Estiasih 2009). Water evaporation due to heating process may reduce oil

hydrolysis; and a decrease in the acid value of the oil extracted at 70 to 90°C because of the decreased water content in the oil products (Suseno et al 2015). The acid value indicates the formation of free fatty acids upon oil extraction (Panagan et al 2011). According to Luyen & Phung (2009), the acid value indicates the free fatty acids in the oil. The higher amount of free fatty acids means that the acid value is high, leading to oxidation reactions occurring easily, which seriously affects consumer health (Luyen & Phung 2009). According to the International Fish Oil and Fish Meal Standard (IFFO 2017), the acid value in fish oil must be less than 3 mg KOH g^{-1}.

The colour of the oil is also important; the differences in the colour of lipids extracted from striped catfish meat at different temperatures are presented in Table 1. The results show that the colour of the oil was affected by extraction temperature, where the yellow transition (b*) means a significant change depending on the change in the extraction temperature from 25 to 50°C (11.4 to 11.0) and from 70 to 90°C (13.2 to 13.0). Moreover, the luminance (L*) decreased from 25 to 90°C (from 44.4 to 39.2). The oil extracted from the flesh meat of striped catfish had a light yellow or creamy yellow colour, which may be due to the high content of saturated fats derived from stearic acid and palmitic acid, small amounts of caffeine and theobromine (Liendo et al 1997). According to another study, the (b*) value is directly correlated with the trans-β-carotene content (O'Callaghan et al 2016). The colour of the oil depends on vitamin A, carotene and other pigments in the oil (Kontkanen et al 2011). In addition, during heating, aldehydes in fish oil may be oxidised, such as 2-hexenal and acetaldehydes, which react by condensing the aldol and dehydrating to form crotonaldehyde and 2-(1-butenyl). 2,4-Octadienal is the main component in the early stages of browning (Fujimoto & Kaneda 1973).

Table 1

Lipid recovery, acid value and colour for flesh meat as a function of different extraction temperatures

Temperature (°C)	*Lipid content (%)*	*Acid value (mg KOH g^{-1})*	*Colour (L*)*	*Colour (b*)*
25	57.9±0.92^{a}	2.17±0.01^{a}	44.4±0.9^{d}	11.4±1.16^{b}
50	61.1±0.92^{b}	2.81±0.29^{d}	41.0±1.7^{c}	11.0±0.82^{a}
70	68.0±2.40^{d}	2.47±0.27^{c}	39.7±0.4^{b}	13.2±1.04^{d}
90	66.8±1.15^{c}	2.22±0.03^{b}	39.2±0.4^{a}	13.0±0.60^{c}

The data show the average values (mean±STD, n = 3), and the columns with different letters (a, b, c, d) indicate the significance level at 95%.

The fatty acid composition of oil extracted from the flesh meat of catfish is shown in Table 2. The extracted oil from the flesh meat was rich in saturated fatty acids (SFA). Specifically, in this study, the total SFA was the highest at 25°C (44.7%) and the lowest at 50°C (41.6%) (Table 2). As a comparison, the high percentage of total SFA in fat extracted from *Pangasius* meat in another study (41.6%) was similar to that extracted from striped catfish meat at room temperature (26-30°C) in this study (Minh et al 2023). In addition, palmitic fatty acid (C16:0) had the highest total SFA recovery in the flesh meat of striped catfish (from 29.4 to 32.4%) depending on the extraction temperatures. The same results have been found for channel catfish (*Ictalurus punctatus*) with a palmitic acid content in SFA of approximately 19.2% (Sathivel et al 2002) and for the fillet of striped catfish at 29.3% (Ho & Paul 2009). The temperatures for extraction of palmitic acid from the flesh meat of striped catfish were higher than those used for the head of skipjack tuna (85°C, 27.9%) (Chantachum et al 2000), the waste of tilapia (70°C, 21.4%) (Suseno et al 2015) and flesh meat at room temperature (26-30°C, 28.8%) (Minh et al 2023).

The total monounsaturated fatty acid (MUFA) content ranged from 37.7 to 41.3%, depending on the extraction temperature. Among them, oleic acid (C18:ln9) is a MUFA commonly compared to others. Oleic acid plays an important role in preventing cardiovascular diseases caused by cholesterol accumulation and has high moisture

stability, preventing oxidation-induced transformation (Frankel & Huang 1994; Mounts et al 1994). Specifically, our study determined the oleic acid content in the flesh meat at different extracted temperatures; the oleic acid was the highest (38.9%) at 70°C and the lowest (35.5%) at 25°C. For comparison, the oleic acid extracted from skipjack tuna head at 85°C was 14.1% (Chantachum et al 2000), and that from tilapia by-products at 70°C was 12.74% (Suseno et al 2015). However, the oleic acid content from striped catfish flesh meat at room temperature (26-30°C) by using isopropanol:hexan (41.3%) was higher than the oleic content in this study (Minh et al 2023). Steiner-Asiedu et al (1991) reported that the correlation between oleic acid content and temperature depends on the living environment of the fish. Furthermore, the oleic acid content is higher in freshwater fish than in marine fish (Ho & Paul 2009). The total polyunsaturated fatty acid (PUFA) content in oil from striped flesh meat was 13.4% at 90°C. Linoleic acid (C18:2n6) is the main PUFA in fat from flesh meat, and the content ranged from 10.9 to 11.1%. The linoleic acid content in striped catfish flesh meat was 1.60% higher than those in skipjack tuna head fat extracted at 85°C (Chantachum et al 2000), in by-products of tilapia extracted at 70°C (7.61%), and in striped catfish flesh meat extracted at room temperature (26-30°C) (9.81%) (Minh et al 2023).

Table 2

Fatty acid composition of oil extracted from the flesh meat of catfish at different temperatures

Fatty acid	*% of total fatty acid content*			
	25°C	*50°C*	*70°C*	*90°C*
	Saturated fatty acids (SFA)			
C14:0	4.51	3.43	3.62	4.30
C16:0	32.4	29.4	29.5	31.3
C18:0	7.78	8.69	8.62	7.73
ΣSFA	44.7	41.6	41. 8	43.3
	Monounsaturated fatty acids (MUFA)			
C16:1n7	1.10	1.00	0.98	1.10
C18:1n9	35.5	38.2	38.9	36.6
C20:1n9	1.09	1.39	1.37	1.16
ΣMUFA	37.7	40.6	41.3	38.8
	Polyunsaturated fatty acids (PUFA)			
C18:2n6	10.9	11.1	10.9	11.1
C20:4n6	0.23	0.27	0.27	0.22
C18:3n3	0.77	0.78	0.82	0.76
C20:4n3	0.49	0.47	0.46	0.49
C20:5n3 (EPA)	0.12	0.15	0.11	0.14
C22:6n3 (DHA)	0.47	0.55	0.44	0.64
ΣPUFA	13.1	13.3	13.0	13.4
Omega-3 fatty acid	1.85	1.95	1.83	2.03
Omega-6 fatty acid	11.2	11.4	11.2	11.4

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; DHA: docosahexaenoic acid; EPA: eicosapentaenoic acid.

The highest EPA content was 0.15% at extraction temperatures of 50°C and DHA contents was 0.64% in the sample extracted at 90°C. In the oil extracted from striped catfish waste, EPA and DHA contents were low, similar to those in oil extracted from striped catfish fillets (EPA and DHA at 0.31% and 4.47%, respectively) (Ho & Paul 2009). According to Huong (2012), EPA and DHA are essential fatty acids for humans, where DHA has an important role in the development of nerve tissue, and EPA contributes to reducing cholesterol in the blood and preventing heart disease. In this study, the levels of EPA and DHA were higher than those extracted previously at room temperature (26-30°C) from the same material (EPA at 0.094% and DHA at 0.29%) (Minh et al 2023). However, the contents of EPA and DHA extracted from striped catfish flesh meat were lower than

those in skipjack tuna head fat extracted at 85°C (EPA at 0.1% and DHA at 25.5%) (Chantachum et al 2000) and in tilapia by-product fat extracted at 70°C (EPA at 1.03% and DHA at 2.84%) (Suseno et al 2015). The omega-3 fatty acids were highest (2.03%) at 90°C with omega-6 fatty acids at 11.4% at 50°C. EPA and DHA have double bonds that are easily oxidised. These can react strongly when exposed to high temperatures. Furthermore, high temperatures can cause fatty acid hydrolysis, leading to a change in composition. In addition, temperature has a significant effect on the total oxidation value of the oil. Higher extraction temperatures will result in oils with higher toxic values, according to Suseno et al (2015). Moreover, fat from striped catfish meat always has lower EPA and DHA contents than marine fish; the EPA content in striped catfish (0.76 mg per 100 g) to that in Atlantic salmon (*S. salar*) (61.1 mg per 100 g) (Ho & Paul 2009). Freshwater fish has lower levels of EPA and DHA than marine fishes (Haard 1992) because, in seawater, there are omega-3 fatty acids from plankton (Steffens 1997). In our analysis, we found that in fat extracted from fish meat at different temperatures, the fatty acid contents were different. Thus, if fish oil with a high omega-3 content is needed, one should choose an extraction temperature of 90°C (2.03%), and if a high content of omega-6 fatty acids is required, the extraction temperature should be 50°C (11.4%).

To summarize, an extraction temperature of 50°C led to effective results in which the EPA and DHA contents were the highest, and the total omega-3 and omega-6 fatty acids were also quite high.

Effects of time on the lipid content in flesh meat of striped catfish. Table 3 provides the efficiencies of lipid extraction from the flesh meat of striped catfish at different times, similar to that presented for the different temperatures. Specifically, we show the extraction efficiencies at four different times, with the highest efficiency at 35 min (67.2%) and the lowest at 15 min (63.2%). The efficiency increased with increasing extraction time, and extraction at 15 min resulted in the lowest efficiency because of incomplete separation of adipocytes (Suseno et al 2015). However, at a longer time (45 min), evaporation of the solvent will occur, and some unsaturated fatty acids converted; thus, the efficiency decreased (Quynh et al 2020). According to Lanh et al (2016), the extraction time depends on factors, such as the raw material, solvent and temperature, and the longer the extraction time, the higher the essential oil yield (Bin 2005). However, when the extraction time is too long, it will affect the quality and consume considerable energy for the heating process. If the extraction time is too short or too long, it affects the efficiency of the extraction. If the extraction time is short, it will not be sufficient for the solvent to diffuse into the material (Negi et al 2011). Conversely, a long extraction time will reduce enzyme activity (Ghildyal et al 1991). Thus, the extraction time should be sufficient to separate lipid-containing adipocytes to achieve the highest yield of extracted lipids (Estiasih 2009).

Table 3

Lipid recovery, acid value and colour in flesh meat at different extraction times

Time (min)	*Lipid content (%)*	*Acid value (mg KOH g^{-1})*	*Colour (L*)*	*Colour (b*)*
15	63.2 ± 0.9^{a}	2.23 ± 0.0^{a}	31.6 ± 3.0^{a}	4.64 ± 0.2^{a}
25	65.8 ± 0.9^{b}	2.92 ± 0.2^{c}	34.5 ± 0.1^{ab}	8.33 ± 0.3^{b}
35	67.2 ± 0.2^{c}	2.21 ± 0.0^{a}	37.2 ± 0.3^{b}	10.6 ± 0.0^{c}
45	66.6 ± 0.1^{bc}	2.77 ± 0.0^{b}	33.3 ± 0.4^{ab}	11.3 ± 0.7^{c}

Data showing the averages (mean±STD, n = 3); the columns with different letters (a, b, c, d) indicate the significance level at 95%.

In addition to the extraction efficiency, the acid value is also an important indicator used to evaluate the quality of fat from processing by-products of striped catfish. The acid content changed with an increase in extraction time, specifically, from 15 to 45 min; the acid index was the highest (2.92 mg KOH g^{-1}) at 25 min and the lowest (2.21 mg KOH g^{-1})

at 35 min. In this study, the acid value reached the criteria of the International Fish Oil Standard (IFOS) (2011): it was less than 2.25 mg KOH g^{-1}.

Besides the criteria used to evaluate fatty acid quality, extraction recovery, acid value and colour index are also important. The differences in the colour of fat extracted from the flesh meat at different heating times are presented in Table 3. The extraction time affected the fat colour, the yellow transition (b*) was a significant difference among the extraction times. Specifically, the (b*) value increased with increasing extraction time from 15 to 45 min (from 4.64 to 11.3). Moreover, the brightness (L*) increased from 31.6 to 37.2 from 15 to 35 min, respectively, and decreased to 33.3 at 45 min. The lowest (b*) level was at 15 min because this time was not enough for the solvent to diffuse into the material, leading to a low extracted fat content (Dong et al 2021). The yellow conversion (b*) value increased, which meant that the fat concentration increased.

Table 4 shows that the total SFA content after four different extraction times ranged from 40.5 to 42.3%. Palmitic fatty acid (C16:0) accounted for the highest level of total SFA extracted from the flesh meat (28.6 to 30.4%), depending on the extraction time.

Table 4

Fatty acid composition of oil extracted from the flesh meat of catfish at different heating times

Fatty acid	*% of total fatty acids*			
	15 min	*25 min*	*35 min*	*45 min*
Saturated fatty acids (SFA)				
C14:0	3.22	3.45	3.14	3.74
C16:0	29.1	29.5	28.6	30.4
C18:0	9.38	8.13	8.81	8.25
ΣSFA	41.7	41.1	40.5	42.3
Monounsaturated fatty acids (MUFA)				
C16:1n7	0.89	1.01	0.92	103
C18:1n9	40.1	38.4	39.7	38.3
C20:1n9	1.32	1.45	1.35	1.23
ΣMUFA	42.3	40.8	42.0	40.6
Polyunsaturated fatty acids (PUFA)				
C18:2n6	10.3	11.7	10.9	11.1
C20:4n6	0.22	0.23	0.22	0.24
C18:3n3	0.73	0.86	0.81	0.78
C20:4n3	0.43	0.53	0.46	0.49
C20:5n3 (EPA)	0.14	0.15	0.12	0.12
C22:6n3(DHA)	0.41	0.57	0.44	0.56
ΣFUFA	12.2	14.1	13.0	13.3
Omega-3 fatty acid	1.71	2.11	1.83	195
Omega-6 fatty acid	10.5	11.9	11.2	11.3

SFA: Saturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids; DHA: Docosahexaenoic acid; EPA: Eicosapentaenoic acid.

The total MUFA content ranged from 40.6 to 42.3%, depending on the heating time, where oleic acid (C18:1n9) reached the highest content at 15 min (40.1%) and the lowest content at 45 min (38.3%). Polyunsaturated fatty acids (PUFA) in fat from the meat of striped catfish were at the highest content of 14.1% at 25 min in which linoleic acid (C18:2n6) was the main PUFA and varied from 10.3 to 11.7%.

EPA (0.15%) and DHA (0.57%) content in the fatty acid extracted from the flesh meat were the highest at an extraction time of 25 min. The total amount of omega-3 (2.11%) and omega-6 (11.9%) fatty acids were also the highest upon extraction at 25 min. Separation time for extraction has no significant effect on the contents of fish oil. However, if separated at high temperature for a long time, hydroperoxide decomposes, leading to the formation of secondary oxidation products (Estiasih 2009; Suseno et al 2015). We showed that the fatty acid extracted from flesh meat at different times also

resulted in different fatty acids. The fish oil contained high levels of omega-3 and omega-6 fatty acids with an extraction time of 25 min.

Conclusions. We observed a high fat recovery yield, the lowest acid value, the highest EPA and DHA contents and the highest contents of omega-3 and omega-6 fatty acids from stripped catfish flesh meat at an extraction temperature of 50°C for 25 min. A high recovery efficiency was also found for fat extracted at 50°C.

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Conflict of interest. The authors declare that there is no conflict of interest.

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