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Purification of Kurisi (*Nemipterus nematophorus*) Fish Oil Derived from Surimi Processing Products

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ABSTRACT

Kurisi fish oil is a promising omega–3 fatty acid source, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). In Indonesia, this oil is commonly obtained from a surimi processing industry product. It is predominantly utilized as an additive in animal feed due to its failure to meet the quality standards required for human consumption. Therefore, purification is essential to enhance its quality and broaden its potential applications as a food–grade oil. This study evaluated the effectiveness of two purification methods: (A) a three–step process involving degumming, neutralization, and bleaching; and (A+), which includes winterization following the A process. The study commenced with the characterization of crude kurisi fish oil, followed by applying both purification techniques. Quality parameters analyzed included free fatty acids (FFA), peroxide value (PV), acid value (AV), p–anisidine value (p–AnV), total oxidation value (totox), and fatty acid composition. The results indicated that both purification methods significantly reduced oxidative degradation indicators. Notably, the A+ method yielded the most favorable results, achieving a polyunsaturated fatty acid (PUFA) content of 33.69% and demonstrating superior oxidative stability. These findings suggest that the A+ purification method effectively enhances the quality of kurisi fish oil, supporting its potential use as a functional food ingredient.

Keywords: kurisi fish oil, omega–3, oxidation, fish oil purification, winterization

INTRODUCTION

Fish oil is a high-value commodity known for its high concentration of omega-3 fatty acids, including eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which promote cardiovascular, neurological, and immune system health. With rising public awareness of healthy lifestyles, the demand for fish oil for culinary and nutraceutical uses has increased dramatically. Imports continue to meet most of the Indonesia's need for fish oil. In 2023 and 2024, the import value of fish oil was USD 16.012 million (KKP 2024). From January to February 2021, fish oil imports totaled 1,476 t, worth USD 2.180 million (KKP 2024). These figures indicate that Indonesia continues to rely heavily on imported fish oil, implying that indigenous production has yet to meet national demand. In contrast, the country has significant potential for domestic fish oil production, particularly from surimi processing byproducts.

Kurisi (*Nemipterus nematophorus*) fish, is a promising native species related with surimi industrial byproducts, has demonstrated potential as a raw material for fish oil synthesis. This species has a total omega-3 fatty acid content of around 30.42%, with 9.25% EPA and 20.60% DHA (Kumar *et al*. 2017). Additionally, its high protein content (15−20%) and low lipid levels (< 5%) make it ideal for developing beneficial dietary ingredients like fish oil. However, fish oil derived from by-products of the canning, fishmeal, and surimi industries is frequently of poor quality and fails to meet international requirements. The high free fatty acid content and the presence of oxidation products limit its use as animal feed rather than human consumption (Maulana *et al*. 2018). As a result, improving the quality of fish oil requires an effective and standardized refining procedure.

Fish oil purification normally consists of many processes, including degumming, neutralization, and bleaching, and may be supplemented with other treatments such as winterization (Suseno *et al*. 2018). Degumming eliminates phospholipids, proteins, and carbohydrate residues that can reduce product quality. This procedure helps to eliminate gums that could cause undesired color and flavor changes in the finished product (Sanchez *et al*. 2016). Neutralization removes free fatty acids, which have an unfavorable effect on flavor and oxidative stability, by reacting them with sodium hydroxide (NaOH) to produce soap, which is then separated. The bleaching process decolorizes the oil and eliminates impurities including heavy metals and oxidation byproducts. These refinement stages reduce phospholipids, free fatty acids, colors, metals, and oxidation chemicals that degrade oil quality (Sanchez *et al*. 2016).

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Fish oil quality is usually analyzed using the International Fish Oil Standards (IFOS), which set the following limits: FFA ≤ 1.50%, PV ≤ 5.00 mEq/kg, *p*-anisidine (*p*-AnV) ≤ 20.00 mEq/kg, and total oxidation value (totox) ≤ 19.50 mEq/kg. Oils that do not meet the IFOS requirements are considered unacceptable for food and cosmetic purposes (IFOS 2022). Thus, the purpose of this study was to determine the most efficient purification approach for reducing oxidation parameters, as well as to assess the efficacy of refining methods in enhancing the quality of fish oil derived from kurisi fish by-products from the surimi industry to meet IFOS criteria.

METHODS

Materials and Tools

The major ingredients in this study were kurisi fish oil (crude oil and after cooking fractions) and omega-3. The chemical reagents used were vitamin E (Blackmores), synthetic adsorbent (Magnesol), distilled water, 95% ethanol, phenolphthalein indicator (Merck), sodium hydroxide (NaOH) solution, potassium hydroxide (KOH) solution, potassium iodide (KI) solution, sodium thiosulfate ($Na_2S_2O_3$) solution, starch solution (Merck), glacial acetic acid (Merck), chloroform (Merck), sodium sulfate (Na_2SO_4) (Merck), iso-octane (Merck), *p*-anisidine (Merck), phenolphthalein solution, aluminum foil, and nylon mesh.

The equipment used included measuring cylinders, pipettes, beakers, Erlenmeyer flasks (Herma), filters, rulers, burettes, hot plate, oven (DHG 9053A), glass stirring rods, sample spoons, electric stove, spatulas, pans, Duran bottles, vials, magnetic stirrer (Corning PC-420 D), digital scale (SF-400 C), aluminum foil, test tubes, UV-VIS spectrophotometer (Agilent 8453), magnetic stirrer, 96-well microplates, microscope, 40-µm cell strainer, 15 mL tubes, centrifuge, incubator, hemocytometer, latex beads, and cover slips.

Procedures

This investigation was divided into three stages: initial characterization of the fish oil, primary refining, and enhanced purification utilizing the winterization procedure. Kurisi fish oil I (crude oil) and fish oil II (after cooking) were utilized as samples, both generated from surimi industry byproducts. The first stage entailed characterizing the unprocessed fish oil, with an emphasis on oxidative quality metrics such as free fatty acid (FFA) concentration, peroxide value (PV), *p*-anisidine value (*p*-AnV), acid value (AV), and total oxidation (totox). In addition, fatty acid profiling was used to assess the content of fatty acids in the fish oil sample.

Primary purification involved three steps: degumming, neutralization, and bleaching. To degum the fish oil, a 5% NaCl solution and 30% water were mixed and homogenized for 10 min at 50 °C using a magnetic stirrer. The sample was neutralized by adding a 12 °Bé NaOH solution, stirring for 10 min at 50 °C, then centrifuging at 10,000 rpm and 27 °C for 10 min to separate soap residues. To bleach, we added 5% Magnesol adsorbent, stir at 50°C for 20 min, then centrifuged at 4,000 rpm and 10°C for 25 min. After completing all purification stages, the samples were re-analyzed for the same oxidative parameters that were assessed during the first characterization.

If oxidation levels remained over permissible limits, an advanced purification stage was carried out using the winterization process. This technique was designed to eliminate saturated fatty components that crystallize at low temperatures. The best-performing oil from the initial purification underwent a temperature-controlled winterization procedure. The oil was winterized by centrifuging at 10,000 rpm at 4°C for 15 min. The winterized samples were then tested for FFA, PV, AV, *p*-AnV, and totox levels to determine the efficacy of the purification process.

The influence of various purification processes on the properties of kurisi fish oil was assessed using a factorial fully randomized design (CRD) with two variables: purification technique and fish oil type. Statistical studies were conducted on oxidation-related parameters such as FFA, PV, AV, *p*-AnV, and totox. The fatty acid profile data was analyzed using descriptive statistics. All data were processed with Microsoft Excel 2021 and SPSS 26.0.

RESULTS AND DISCUSSION

Oxidative Characteristics of Crude Fish Oil

The crude fish oil samples analyzed in this study were kurisi fish oil I and II, produced from surimi manufacturing byproducts. Prior to purification, the oil was characterized by evaluating oxidative parameters such as free fatty acids (FFA), peroxide value (PV), *p*-anisidine (*p*-AnV), acid value (AV), and total oxidation value (totox) (Suseno *et al*. 2019). The reference quality standard was the International Fish Oil Standards (IFOS), which defines the following maximum limits: FFA ≤ 1.5%, PV ≤ 5.0 mEq/kg, AV ≤ 3.0 mEq/kg, *p*-AnV ≤ 20.0 mEq/kg, and totox ≤ 26.0 mEq/kg.

As indicated in Table 1, neither crude fish oil sample satisfied the IFOS criteria for FFA, PV, or AV characteristics. Kurisi fish oil I had an FFA concentration of 2.23 ± 0.05%, whereas oil II had 2.30 ± 0.10%, both surpassing the allowed limit. Elevated FFA levels indicate hydrolytic breakdown, which occurs when triglycerides break down into free fatty acids and glycerol. This process is often caused by water, high temperatures, or enzymatic activity during processing or storage (Insani *et al*. 2017). PV of 5.40 ± 0.10 mEq/kg (oil I) and 5.23 ± 0.11 mEq/kg (oil II) indicate

higher levels of primary oxidation than the IFOS threshold. These results indicate an accumulation of hydroperoxides caused by lipid oxidation, which could be altered by temperature and storage time. High PV suggests increased oxidative degradation, which reduces oil quality (Suanti *et al*. 2017). The acid value (AV) of both samples exceeded the maximum limit, with 4.66 ± 0.05 mEq/kg (oil I) and 5.81 ± 0.02 mEq/kg (oil II). Elevated AV levels are associated with higher free fatty acid content, indicating lipid degradation caused by oxidation or hydrolysis, which contributes to rancidity (Mo *et al*. 2018).

Both samples had acceptable *p*-anisidine values of 8.73 ± 0.27 mEq/kg (oil I) and 7.16 ± 0.14 mEq/kg (oil II), indicating minimal secondary oxidative degradation. The totox levels were within the IFOS standard, at 19.53 ± 0.35 mEq/kg (oil I) and 17.63 ± 0.34 mEq/kg (oil II). Despite acceptable *p*-AnV and totox values, the excess of important parameters such as FFA, PV, and AV suggest that both crude fish oil samples are of poor quality and unfit for direct consumption, needing further purification.

Fatty Acid Profile of Crude Oil

A fatty acid profile study was performed to determine the levels of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA) in kurisi fish oil I and II. According to Table 2, palmitic acid was the predominant fatty acid in both samples (13.56% and 18.83%, respectively), followed by docosahexaenoic acid (DHA; 10.56% and 18.15%), eicosapentaenoic acid (EPA; 10.74% and 10.73%), and oleic acid (11.29% and 7.43%) in fish oil I and II.

EPA and DHA gave considerable contributions to the oil's PUFA content. This discovery is similar with the findings of Ramesh *et al*. (2016), that palmitic acid, stearic acid, EPA, and DHA dominate the fatty acid profile of the *Nemipterus nematophorus* species. Kurisi fish have a high PUFA content, indicating that their

Table 1 Oxidation parameters of crude Kurisi fish oil I and II before purification

Parameter	Kurisi I	Kurisi II	IFOS (2014)
Free fatty acid (FFA) (%)	2.23 ± 0.05	2.30 ± 0.1	≤ 1.50
Peroxide value (PV) (mEq/kg)	5.40 ± 0.1	5.23 ± 0.11	≤ 5.00
Acid value (AV) (mEq/kg)	4.66 ± 0.05	5.81 ± 0.02	≤ 3.00
p–Anisidine value (*p*–AnV) (mEq/kg)	8.73 ± 0.27	7.16 ± 0.14	≤ 20.00
Total oxidation (Totox) (mEq/kg)	19.53 ± 0.35	17.63 ± 0.34	≤ 26.00

Table 2 Fatty acid profile of crude kurisi fish oil

Fatty acid	Kurisi I (%)	Kurisi II (%)
Butryric acid C4:0	0.10	0.06
Lauric acid C12:0	0.05	0.10
Myristic acid C14:0	4.26	3.47
Pentadecanoic acid C15:0	0.42	0.96
Palmitic acid C16:0	13.56	18.83
Heptadecanoic acid C17:0	0.53	1.29
Stearic acid C18:0	3.22	7.37
Arachidic acid C20:0	0.19	0.45
Behenic acid C22:0	0.09	0.29
Total SFA	22.42	32.82
Myristoleic acid C14:1	0.07	0.09
Palmitoleic acid C16:1	3.60	5.21
cis-10–Heptadecanoic acid C17:1	0.19	0.37
Oleic acid C18:1n9c	11.29	7.43
Elaidic acid C18:1n9t	0.09	0.12
Erucic acid C22:1n9	8.12	0.04
Nervonic acid C24:1	0.63	0.31
Total MUFA	23.99	13.57
Linoleic acid C18:2n6c	1.20	1.07
Linolelaidic acid C18:2n9t	0.05	0.28
Linolenic acid C18:3n3	0.59	0.79
γ-Linolenic acid C18:3n6	0.06	0.14
cis-1,14-Eicosadienoic acid C20:2	0.26	0.22
Methyl ester of *cis*–11,14,17-eicosatrienoic acid C20:3n3	0.62	0.16
cis-8,11,14-Eicosatrienoic acid C20:3n6	0.08	0.11
Arachidonic acid C20:4n6	0.72	2.04
Eicosapentaenoic acid (EPA) C20:5n3	10.74	10.73
Docosahexaenoic acid (DHA) C22:6n3	10.56	18.15
Total PUFA	24.88	33.69
Total identified fatty acids	71.26	80.06

tissue is highly nutritious. Environmental temperature also has an impact on fatty acid content in fish, as unsaturation increases with lower temperatures. A high PUFA composition, particularly in terms of EPA and DHA, implies good nutritional quality because of their proven benefits to cognitive function, cardiovascular health, and anti-inflammatory activity. Furthermore, the high concentration of MUFA, particularly oleic acid, contributes to the oil's oxidative stability and provides health benefits such as increased HDL cholesterol and decreased LDL levels. However, a high concentration of MUFA may diminish the proportion of omega-3 fatty acids, which are essential for proper neurological function (Josef *et al*. 2019).

Meanwhile, fish oil II has a higher saturated fatty acid (SFA) content (33.82%) than fish oil I (22.42%), which may improve the oil's oxidative stability. However, it may affect its viscosity and melting point. Species, nutrition, and environmental factors are thought to all have a substantial impact on fatty acid composition differences. Fish oil's oxidative susceptibility is also heavily affected by its fatty acid composition. SFA, which lack double bonds, are more resistant to oxidation, but unsaturated fatty acids (MUFA and PUFA) are more vulnerable to oxidative breakdown due to their double bonds. Hydroperoxides are generated when unsaturated fatty acids combine with free oxygen, signaling the start of oil breakdown (Suseno *et al*. 2020). As a result of their multiple double bonds, PUFA-rich oils are very vulnerable to oxidation and require proper storage conditions.

Quality of Oil After Purification (A): Degumming–Neutralization–Bleaching

Fish oil purification tries to remove impurities that may impair oil quality (Suseno *et al*. 2020). In this study, oxidation characteristics were used to assess the efficacy of the purification method (A) on the quality of fish oil types 1 and 2. Fish oil type I was extracted directly from raw kurisi fish, exhibited a considerable reduction in oxidation parameters after the purifying procedure (Table 3). The FFA content was reduced to 1.43% and the PV to 4.40 mEq/kg, meeting IFOS criteria of ≤ 1.50% and ≤ 5.00 mEq/kg, respectively. The AV was lowered to 3.47 mEq/kg, slightly higher than the IFOS maximum threshold (≤ 3.00 mEq/kg). Meanwhile, the *p*-AnV fell to 6.72 mEq/kg, while the totox dropped to 15.52 mEq/kg, both considerably below the IFOS limits. These decreases reflect a suppression of primary and secondary oxidation, implying increased oil stability. Overall, the purification procedure significantly reduced oxidative deterioration and improved the quality of fish oil type I to meet international standards.

Kurisi fish oil type II, generated from kurisi fish that were thermally processed (rendering) prior to oil extraction, which may have increased oxidative deterioration, also improved significantly following purification. The FFA and PV levels reduced to 1.33% and 4.20 mEq/kg, respectively, meeting the IFOS requirements. Although the AV value dropped to 4.14 mEq/kg, it still surpassed the IFOS threshold. The *p*-AnV declined to 6.69 mEq/kg, whereas totox fell to 15.02 mEq/kg, indicating less secondary oxidation and higher oil quality. Overall, purification procedure A (degumming, neutralization, and bleaching) was effective in lowering oxidation parameters in both types of kurisi fish oil, as demonstrated by decreases in FFA, PV, *p*-AnV, and totox values, all of which met IFOS criteria.

Quality of Oil After Purification (A+): Winterization Method

The winterization procedure purifies kurisi fish oil by removing unwanted components such as saturated fats and waxes. According to Martins *et al*. (2021), conventional refining predominantly reduces peroxide values and free fatty acids, while having little effect on the fatty acid profile. Winterization is an excellent supplementary procedure for further purifying the oil by removing turbidity-causing fractions at low temperatures. Table 4 presents the oxidation parameter analysis after advanced purification (A+) for fish oil types I and II.

Kurisi fish oil sample I, categorized as crude oil, was obtained by direct extraction of raw fish material. Prior

Table 3 Oxidation parameters of kurisi fish oil I and II after purification A

Parameter	Kurisi I	Kurisi II	IFOS (2014)
Free fatty acid (FFA) (%)	1.43 ± 0.15	1.33 ± 0.15	≤ 1.50
Peroxide value (PV) (mEq/kg)	4.40 ± 0.1	4.20 ± 0.1	≤ 5.00
Acid value (AV) (mEq/kg)	3.47 ± 0.05	4.14 ± 0.08	≤ 3.00
p-Anisidine value (*p*-AnV) (mEq/kg)	6.72 ± 0.07	6.69 ± 0.14	≤ 20.00
Total oxidation (Totox) (mEq/kg)	15.52 ± 0.22	15.02 ± 0.29	≤ 26.00

Table 4 Oxidation parameters of kurisi fish oil I and II after purification A+

Parameter	Kurisi I	Kurisi II	IFOS (2014)
Free fatty acid (FFA) (%)	0.7 ± 0.1	0.8 ± 0.1	≤ 1.50
Peroxide value (PV) (mEq/kg)	3.2 ± 0.1	3.3 ± 0.1	≤ 5.00
Acid value (AV) (mEq/kg)	2.4 ± 0.17	2.8 ± 0.1	≤ 3.00
p-Anisidine value (*p*-AnV) (mEq/kg)	4.48 ± 0.36	5.36 ± 0.21	≤ 20.00
Total oxidation (Totox) (mEq/kg)	10.88 ± 0.43	11.96 ± 0.32	≤ 26.00

to purification, oxidation parameters such FFA, PV, and AV had comparatively high levels. After the initial purification stage (A), which included degumming, neutralization, and bleaching, there was a considerable drop in FFA and PV levels. However, the AV exceeded the maximum limit defined by the IFOS (≤ 3.00 mEq/kg), requiring additional purification through winterization.

Following the enhanced purification phase (A+), all quality criteria for Kurisi I oil met IFOS standards. The FFA decreased to 0.7 ± 0.1%, PV to 3.2 ± 0.1 mEq/kg, and AV to 2.4 ± 0.17 mEq/kg, demonstrating increased stability against hydrolysis and primary oxidation. The *p*-AnV of 4.48 ± 0.36 mEq/kg and totox value of 10.88 ± 0.43 mEq/kg were within acceptable limits, indicating a low presence of secondary oxidative chemicals and improved oxidative stability (Wael *et al*. 2018). These findings support the effectiveness of winterization in lowering residual oxidative chemicals and enhancing overall oil quality.

Fish oil sample II was produced from thermally processed materials (after cooking), hence it underwent more severe deterioration. Initial oxidation measurements also showed increased levels. Following the initial purification phase (A), FFA and PV were reduced to 1.33% and 4.20 mEq/kg, respectively, but AV remained above the IFOS threshold. As a result, winterization was undertaken to improve the oil quality even further. Following winterization of (A+), the FFA decreased at 0.8 ± 0.1%, PV to 3.3 ± 0.1 mEq/kg, and AV to 2.8 ± 0.1 mEq/kg. The *p*-AnV was 5.36 ± 0.21 mEq/kg, while the totox was 11.96 ± 0.32 mEq/kg, showing significant increase in oxidative quality and aldehyde elimination.

The low *p*-AnV indicates increased stability against secondary oxidative reactions, which is crucial for sustaining the sensory and functional quality of fish oil (Wang *et al.* 2019). All measured values met IFOS criteria, indicating that the winterization process efficiently reduced primary and secondary oxidation. These findings are consistent with Wang *et al*.'s (2019) publication, that winterization at 5°C dramatically lowered FFA and PV levels in fish oil. Furthermore, winterization eliminates pro-oxidant chemicals and non-polar contaminants that were not removed by conventional purifying methods.

Comparative Analysis of the Quality of Oil Before and After Purification

The quality of kurisi fish oil was assessed by comparing five major oxidative parameters: FFA concentration, AV, PV, *p*-AnV, and totox. These metrics are essential markers for determining fish oil stability and quality. The purification techniques used in this investigation included stage A (degumming, neutralization, and bleaching), followed by stage A+, which involved winterization under low temperatures. Table 5 compares the oxidation parameter values for Kurisi fish oil I and II obtained using each purification process.

During storage and processing, lipase enzymes or oxidation events hydrolyze triglycerides, resulting in the formation of free fatty acids. Kurisi fish oil I and II had initial FFA values of 2.23 ± 0.05% and 2.3 ± 0.10%, respectively. After purification stage A, FFA levels dropped to 1.43 ± 0.15% and 1.33 ± 0.15%. Purification through method A+ decreased FFA to 0.7 ± 0.1% for Kurisi I and 0.8 ± 0.1% for Kurisi II, all below the IFOS maximum threshold, demonstrating effective removal of pro-oxidant components and residual free fatty acids.

PV is an indicator used to determine the degree of primary oxidation in oils or fats. PV measures the concentration of peroxide compounds produced during lipid oxidation because of interactions with oxygen. Higher PV levels imply more intense oxidation, which could lead to rancidity and reduced oil quality. The initial PVs were 5.40 ± 0.1 mEq/kg (Kurisi I) and 5.23 ± 0.11 mEq/kg (Kurisi II), close to the IFOS upper limit. Following purification stage A, PVs reduced to 4.40 ± 0.1 and 4.20 ± 0.1 mEq/kg, respectively. Winterization (A+) resulted in PVs of 3.20 ± 0.1 mEq/kg (Kurisi I) and

Table 5 Result of oxidation parameter analysis for each purification method

Parameter	Purification Stage	Kurisi I	Kurisi II	IFOS
Free Fatty Acid (%)	0	2.23 ± 0.05	2.3 ± 0.1	≤ 1.5
	A	1.43 ± 0.15	1.33 ± 0.15	≤ 1.5
	A+	0.7 ± 0.1	0.8 ± 0.1	≤ 1.5
Peroxide Value (mEq/kg)	0	5.40 ± 0.1	5.23 ± 0.11	≤ 5
	A	4.40 ± 0.1	4.20 ± 0.1	≤ 5
	A+	3.20 ± 0.1	3.30 ± 0.1	≤ 5
AV (mEq/kg)	0	4.66 ± 0.05	5.81 ± 0.02	≤ 3
	A	3.47 ± 0.05	4.14 ± 0.08	≤ 3
	A+	2.40 ± 0.17	2.80 ± 0.1	≤ 3
p–Anisidine Value (mEq/kg)	0	8.73 ± 0.27	7.16 ± 0.14	≤ 20
	A	6.72 ± 0.07	6.69 ± 0.14	≤ 20
	A+	4.48 ± 0.36	5.36 ± 0.21	≤ 20
Totox (mEq/kg)	0	19.53 ± 0.35	17.63 ± 0.34	≤ 26
	A	15.52 ± 0.22	15.02 ± 0.23	≤ 26
	A+	10.88 ± 0.43	11.96 ± 0.32	≤ 26

3.30 ± 0.1 mEq/kg (Kurisi II), meeting IFOS criteria. This reduction demonstrates the efficacy of winterization in reducing hydroperoxide generation and improving oil stability.

AV refers to the amount of free fatty acids in fish oil, which normally rises owing to lipid hydrolysis and oxidization. High AV levels suggest substantial fat breakdown. The initial AVs of Kurisi I and Kurisi II were 4.66 ± 0.05 and 5.81 ± 0.02 mEq/kg, indicating lipid breakdown prior to purification. After purification stage A, AVs reduced to 3.47 ± 0.05 (Kurisi I) and 4.14 ± 0.08 mEq/kg (Kurisi II), showing successful removal of hydrolyzed products. However, Kurisi II's AV remained slightly above the IFOS limit. Following purification (A+), AVs were lowered to 2.40 ± 0.17 and 2.80 ± 0.1 mEq/kg, meeting IFOS criteria.

The *p*-AnV measures secondary oxidation in oils. Elevated *p*-AnV suggests additional degradation and a decrease in the oil's sensory and nutritional quality (Yoshiara 2023). Kurisi I and II showed moderate secondary oxidation, with initial *p*-AnV of 8.73 ± 0.27 and 7.16 ± 0.14 mEq/kg, respectively. After purification stage A, the values reduced to 6.72 ± 0.07 (Kurisi I) and 6.69 ± 0.14 mEq/kg (Kurisi II), indicating successful elimination of secondary oxidation products. Advanced purification (A+) lowered *p*-AnV to 4.48 ± 0.36 and 5.36 ± 0.21 mEq/kg. This reduction emphasizes the need of winterization in eliminating non-triglyceride components and polar prooxidants.

The totox value, calculated as the sum of PV and twice the *p*-AnV, represents the oil's total oxidative state. It offers a full assessment of an oil's oxidative stability at both the primary and secondary stages. Kurisi I and II had initial totox values of 19.53 ± 0.35 and 17.63 ± 0.34 mEq/kg, respectively. Following the purification stage A, totox levels decreased dramatically to 15.52 ± 0.22 (Kurisi I) and 15.02 ± 0.23 mEq/kg (Kurisi II), showing a decrease in oxidative and pro-oxidative chemicals. Winterization (A+) resulted in excellent purification, dropping totox levels to 10.88 ± 0.43 and 11.96 ± 0.32 mEq/kg for Kurisi I and II. All final totox readings were significantly lower than the IFOS standard, confirming the overall efficacy of the purification procedure in improving oxidative stability.

CONCLUSION

The crude kurisi fish oils (Kurisi I and II) were initially characterized, and most of the samples had oxidative parameter values that exceeded the IFOS quality standards, such as free fatty acid (FFA) content, peroxide value (PV), acid value (AV), *p*-anisidine value (p-AnV), and total oxidation value. Palmitic acid dominated the fatty acid profile, and the presence of EPA and DHA increased the oil's sensitivity to oxidation. Purification (A): The degumming−neutralization−bleaching successfully lowered almost all oxidative indices in fish oil samples. However, several parameters, such as AV, remained slightly above the IFOS threshold. Further purification (A+): winterization resulted in a further reduction in all oxidative indices, ensuring full conformity with international quality requirements. As a result, the purification (A+) method via winterization is the most effective technique for reducing oxidation levels and improving the quality of kurisi fish oil, a byproduct of the surimi industry that can be used as a raw material in food products and other value-added applications.

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