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Quality Characteristics of Massage Oil Produced from Tuna Skin Waste (Thunnus sp.) Enriched with Lemongrass and Bajakah Wood

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A B S T R A C T

Tuna skin waste is an underutilized by-product of tuna processing, although it contains lipid and collagen-rich fractions that may be transformed into value-added topical products. This study evaluated the sensory acceptance and chemical quality of massage oil produced from tuna skin waste (Thunnus sp.) with the addition of lemongrass and bajakah wood extracts. The research was conducted from 11 March to 15 April 2025 at the Biochemical Testing Laboratory for Fishery Product Processing and Storage, State Agricultural Polytechnic of Pangkajene Islands. Tuna skin oil was extracted by maceration, purified by heating, alkaline treatment, washing, bleaching, and centrifugation, and then formulated with lemongrass and bajakah extract at a 70:15:15 ratio. Product quality was assessed using a 30-panelist organoleptic test and chemical analyses of free fatty acids, peroxide value, and iodine value in duplicate. The product achieved mean sensory scores of 3.90 for color, 4.15 for aroma, and 4.10 for texture, indicating neutral-to-liked acceptance. The mean free fatty acid content was 1.14%, equivalent to approximately 2.27 mg KOH/g when expressed as acid value assuming oleic acid conversion. The peroxide value was 3.24 mEq O_2/kg, while the iodine value was 33.03 g I_2/100 g. These results indicate that the formulated oil had acceptable sensory quality and moderate chemical stability, although its low iodine value suggests limited unsaturation compared with highly unsaturated fish oils

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INTRODUCTION

Fish processing industries generate substantial quantities of organic by-products, including heads, bones, viscera, and skin. In tuna processing, skin waste is often treated as a low-value residue, even though it contains structural proteins, lipids, and bioactive fractions that can be redirected into higher-value products. Fish-industry waste management has been widely discussed because untreated residues can create environmental burdens, while recovered by-products can supply ingredients for feed, collagen, oil, pigments, chitosan, and cosmetic applications (Arvanitoyannis & Kassaveti, 2008; Jayathilakan et al., 2012). In the Indonesian fisheries context, tuna is economically important as both an export commodity and a local food resource, and its processing has expanded into diverse products such as nuggets, meatballs, sausages, risoles, and dumplings. However, the growth of processed tuna products also increases solid residues that can create odor and environmental problems when they are not rapidly handled or converted into useful materials (Setyowati & Rahayu, 2018).

The utilization of fishery by-products has become an important strategy for reducing organic waste and improving resource efficiency in fish-processing systems. Marine by-products can be processed into value-added protein and lipid fractions, and the feasibility of this approach depends on appropriate handling, extraction, stabilization, and product design (Rustad et al., 2011). Tuna skin is particularly attractive because previous studies have shown that yellowfin tuna skin can be a source of gelatin and collagenous material with functional properties comparable to mammalian gelatin under optimized extraction conditions (Cho et al., 2005; Estaca et al., 2009). The lipid fraction is also relevant because marine oils are associated with omega-3 polyunsaturated fatty acids, especially eicosapentaenoic acid and docosahexaenoic acid, which are recognized as important bioactive lipid classes in fish oil research (Shahidi & Ambigaipalan, 2018). Although these components are commonly discussed in relation to food and nutraceutical products, the physical lubricity and bioactive potential of fish-derived oil also create opportunities for non-food applications, including topical oils and massage preparations.

One limitation of fish-derived topical oil is the characteristic fishy odor that can reduce consumer acceptance. Aromatic plant materials are therefore relevant as sensory modifiers and functional ingredients. Lemongrass (Cymbopogon citratus) is widely recognized for its citrus-like aroma and volatile oil fraction rich in terpenoid compounds, particularly citral-related constituents, which supports its use in fragrance, food flavoring, and traditional preparations (Avoseh et al., 2015; Boukhatem et al., 2014). In the source manuscript, lemongrass was selected because its essential oil fraction, reported at around 0.4%, may help reduce fishy odor in fish-based products and improve aroma acceptability (Purba et al., 2020). The addition of lemongrass was therefore expected to enhance the sensory profile of tuna skin oil by providing a stronger and more pleasant aromatic note.

Bajakah wood is another locally valued plant material, particularly associated with traditional uses in Kalimantan. The plant has been empirically used by Dayak communities as a medicinal resource and is reported to contain phytochemical groups such as flavonoids, alkaloids, and steroids (Iskandar & Warsidah, 2020). Flavonoids are widely distributed plant secondary metabolites and are frequently discussed for antioxidant and inflammation-modulating activities, which provides a conceptual basis for incorporating bajakah-derived extract into topical oil formulations (Ginwala et al., 2019; Panche et al., 2016). However, because this study did not directly test pharmacological endpoints, bajakah was treated as a natural additive supporting the local-material identity of the product rather than as evidence of therapeutic efficacy.

Quality assessment of a topical oil product requires both sensory and chemical evaluation. Organoleptic testing reflects product acceptability through direct human perception of color, aroma, and texture, while chemical indicators describe hydrolysis, oxidation, and unsaturation. Free fatty acid content is a hydrolytic quality indicator because increasing free fatty acids indicate triglyceride breakdown and may contribute to off-odors or reduced stability (Nurjanah et al., 2020). Peroxide value measures primary lipid oxidation products and is therefore frequently used to evaluate rancidity development in oil systems (Andhikawati, 2020; Choe & Min, 2006). Iodine value indicates the degree of unsaturation, with higher values reflecting more carbon–carbon double bonds and generally greater susceptibility to oxidation (Shahidi & Zhong, 2010; Siahaan, 2021).

The central problem addressed by this research is whether tuna skin waste can be converted into a sensory-acceptable and chemically stable massage oil after enrichment with lemongrass and bajakah wood. Topical oil studies emphasize that oils used on skin should not be evaluated solely by perceived naturalness, because spreadability, skin feel, barrier compatibility, oxidative stability, and safety are also important for product development (Lin et al., 2018; Vaughn et al., 2018). The study was developed from the assumption that lemongrass improves aroma and consumer acceptance, while bajakah wood contributes to the perceived functional value of the product. The research focused on a single formulation ratio of tuna skin oil, lemongrass extract, and bajakah extract, and assessed quality through organoleptic responses, free fatty acid content, peroxide value, and iodine value. The objective was to analyze the quality characteristics of massage oil from tuna skin waste (Thunnus sp.) with the addition of lemongrass and bajakah wood, thereby contributing preliminary evidence for the valorization of fisheries waste into topical oil products.

LITERATURE REVIEW

Valorization of Fish Processing By-products and Tuna Skin

Fish-processing by-products have shifted from being regarded only as disposal burdens to being recognized as renewable feedstocks for a circular bioeconomy. Reviews of fish-industry waste emphasize that heads, bones, viscera, skin, scales, and trimmings can generate environmental problems when they are discarded, but the same materials may also be transformed into fish oil, collagen, gelatin, enzymes, protein hydrolysates, pigments, and other value-added products (Arvanitoyannis & Kassaveti, 2008; Jayathilakan et al., 2012; Rustad et al., 2011). This conceptual shift is relevant for tuna-processing systems because the expansion of fish-based food products increases residual biomass that needs to be stabilized, recovered, or converted into usable materials rather than treated as low-value waste.

Recent literature further strengthens this circular-bioeconomy rationale by showing that fish waste can represent a substantial fraction of processed biomass. Coppola et al. (2021) reported that fish-processing waste may vary from approximately 20% to 80% depending on species and processing intensity, while skin and fins may account for around 1–3% of processing discards. The same review identifies fish by-products as sources of proteins, fatty acids, minerals, collagen, peptides, chitin, and oil with potential application in food, pharmaceutical, cosmetic, and biotechnological sectors. Therefore, the use of tuna skin waste as the base material for massage oil aligns with a broader research trend that seeks to convert marine residues into higher-value products.

Tuna skin is especially relevant because it contains structural proteins and lipid fractions that can be separated for different applications. Studies on yellowfin tuna skin gelatin showed that tuna skin can yield gelatin with functional properties comparable to mammalian gelatins under appropriate extraction conditions (Cho et al., 2005). Comparative work on bovine-hide and tuna-skin gelatin also demonstrated that tuna-skin gelatin can form films with distinct physicochemical properties, supporting the broader view that tuna skin has material functionality beyond waste disposal (Estaca et al., 2009). Reviews of collagen and gelatin from alternative sources further describe fish-derived collagen as a promising biomaterial for food, biomedical, and cosmetic applications, although extraction method, molecular weight, and thermal stability strongly influence its final quality (Gómez-Guillén et al., 2011).

Fish-Derived Oil and Topical Oil Functionality

The lipid fraction of fish-processing by-products is also scientifically important because marine oils may contain long-chain polyunsaturated fatty acids, particularly eicosapentaenoic acid and docosahexaenoic acid. These compounds are widely discussed in fish-oil literature because of their biological relevance and nutritional value (Shahidi & Ambigaipalan, 2018). In the context of a massage oil, however, the value of fish-derived oil should not be framed only through nutritional identity. Topical oil development requires attention to lubricity, spreadability, odor, color, skin feel, and chemical stability, because these properties directly shape user acceptance and product feasibility.

Topical oil literature indicates that oils applied to the skin may support barrier function, hydration, and skin feel depending on their fatty acid profile and minor bioactive constituents. Lin et al. (2018) reviewed the biological influence of plant oils on the skin and emphasized that topical oils may affect inflammation, antioxidant response, wound healing, and barrier repair. Vaughn et al. (2018) similarly discussed natural oils as topical agents that may support skin-barrier repair, while also showing that the effect of an oil depends on composition, processing, purity, and safety. These studies provide a useful framework for interpreting tuna skin oil as a topical base: its sensory and chemical quality must be evaluated before any functional or therapeutic claim is proposed.

A major limitation of marine oils is oxidative instability. Fish oils are vulnerable to oxidation because unsaturated fatty acids contain multiple double bonds that can react with oxygen, particularly under heat, light, metal contamination, or prolonged storage (Choe & Min, 2006; Shahidi & Zhong, 2010). Boran et al. (2006) also showed that storage temperature and time influence fish-oil quality, confirming that oxidative stability is essential for maintaining acceptable odor and chemical quality. For topical products, oxidation is not only a chemical issue but also a sensory issue because rancidity can reduce aroma acceptability and consumer confidence.

Lemongrass and Bajakah Wood as Natural Additives

The addition of aromatic plant material is a practical strategy for improving the sensory profile of fish-derived topical oil. Lemongrass (Cymbopogon citratus) is widely recognized for its citrus-like aroma and volatile terpenoid fraction. Avoseh et al. (2015) reviewed Cymbopogon species and highlighted their ethnopharmacological, phytochemical, and pharmacological relevance, while Boukhatem et al. (2014) described lemongrass essential oil as a citral-rich oil with anti-inflammatory and antifungal potential. In the present formulation, lemongrass is most appropriately interpreted as an aroma-improving additive because the study evaluated sensory acceptance rather than biological activity. The previous report that lemongrass extract may improve aroma in fish-based products also supports its practical use as an odor modifier (Purba et al., 2020).

Bajakah wood provides a different type of value because it contributes local ethnobotanical identity to the formulation. Indonesian literature describes bajakah as a medicinal plant associated with traditional uses in Kalimantan and reports phytochemical groups such as flavonoids, alkaloids, and steroids (Iskandar & Warsidah, 2020). Flavonoids are broadly recognized as plant secondary metabolites with antioxidant and inflammation-modulating potential (Ginwala et al., 2019; Panche et al., 2016). Nevertheless, the biological relevance of bajakah in a massage-oil matrix remains formulation-specific and should be validated experimentally. Therefore, the literature supports bajakah as a plausible natural additive, but not as evidence for therapeutic efficacy in the absence of antioxidant, antimicrobial, anti-inflammatory, or dermal-safety assays on the final product.

Quality Indicators for Fish-Derived Massage Oil

Preliminary quality evaluation of fish-derived massage oil requires both sensory and chemical indicators. Organoleptic parameters such as color, aroma, and texture represent direct user perception, whereas free fatty acid content, peroxide value, and iodine value describe hydrolysis, primary oxidation, and unsaturation. Free fatty acid content increases when triglycerides undergo hydrolysis; therefore, it is commonly used as an indicator of oil deterioration, raw-material quality, and storage stability (Nurjanah et al., 2020). Acid value provides a related expression of acidity and is often used as a comparative quality index for oils, including fish oils under national or industrial standards (BSN, 1992).

Peroxide value is central to evaluating the early stage of lipid oxidation because hydroperoxides are primary oxidation products that form before secondary aldehydes and ketones become dominant (Choe & Min, 2006; Shahidi & Zhong, 2010). A low peroxide value indicates limited primary oxidation at the time of analysis, although it does not fully describe later oxidation products. Iodine value complements peroxide and free fatty acid measurements by indicating the degree of unsaturation in the oil. Higher iodine values generally reflect more carbon–carbon double bonds, while lower values suggest lower unsaturation or possible reduction of unsaturated components during processing (Siahaan, 2021). Together, these indicators provide a basic but informative quality profile for determining whether tuna skin oil enriched with lemongrass and bajakah wood is chemically suitable for further topical product development.

Taken together, the literature indicates that tuna skin waste has realistic potential as a raw material for value-added topical oil because it contains recoverable marine lipid and collagen-associated fractions, while lemongrass and bajakah wood may improve sensory identity and local-material value. However, the same literature also indicates that fish-derived topical products require careful evaluation of hydrolytic quality, oxidation, unsaturation, sensory acceptability, safety, and stability. This review therefore provides the scientific basis for assessing the formulated tuna skin massage oil through organoleptic scores, free fatty acid content, peroxide value, and iodine value in the following sections.

METHODOLOGY

Study Site and Research Design

The study was conducted from 11 March to 15 April 2025 at the Biochemical Testing Laboratory for Fishery Product Processing and Storage, Department of Agricultural Technology, State Agricultural Polytechnic of Pangkajene Islands. The research used a laboratory experimental design with a quantitative descriptive approach. The product was prepared from tuna skin waste and natural plant additives, followed by organoleptic testing and chemical analyses. Each chemical test was performed in two repetitions, and the results were summarized as replicate values and means.

The formulation evaluated in the sensory stage used a 70:15:15 ratio, referring to the relative proportion of tuna skin oil, lemongrass extract, and bajakah extract reported in the source manuscript. Organoleptic quality was evaluated by 30 panelists using color, aroma, and texture parameters. The sensory scores were interpreted descriptively using a hedonic scale in which higher scores indicated better acceptance.

Materials and Equipment

The primary raw material was tuna skin waste (Thunnus sp.), while ethanol and water were used in the extraction process. Lemongrass, powdered bajakah wood, and chloroform were used in the extraction of aromatic and plant-derived fractions. Materials for oil purification included crude fish oil, citric acid, sodium hydroxide, bentonite, and distilled water.

Equipment for tuna skin oil extraction included a large jar, analytical balance, oven, Erlenmeyer flasks, beakers, hot plate, filter paper, funnel, knife, cutting board, and containers. Equipment for lemongrass and bajakah extraction included cutting tools, tripod, Bunsen burner, Erlenmeyer flask, funnel, separating funnel, distillation flask, condenser, hot plate, beaker, and vertical cooler. Oil purification used a hot plate, beakers, thermometer, stirring rod, centrifuge, centrifuge tubes, droppers, and tube rack.

Extraction of Crude Tuna Skin Oil

Tuna skin was washed with running water until clean, cut into small pieces, and weighed. The cleaned pieces were arranged on trays and dried in an oven at 74°C until dry. The dried material was then transferred into a container for maceration. Ethanol and distilled water were added at a 1:5 ratio, and the container was tightly closed and left for 3–5 days. After maceration, the liquid fraction was separated from the skin residue and filtered one to two times. The filtrate was evaporated using a rotary evaporator at 100°C to remove the solvent and obtain crude tuna skin oil.

Purification of Tuna Skin Oil

Crude tuna skin oil was heated at 70°C for 1 min with stirring and then cooled to room temperature. The oil was transferred into centrifuge tubes and centrifuged at 2,600 rpm and 20°C for 10 min. Sodium hydroxide solution, reported as 12.6 g in the source procedure, was added to the oil, followed by heating at 65°C for 20 min with stirring. The oil was cooled again and centrifuged at 2,600 rpm and 20°C for 20 min.

The separated oil was washed three times using distilled water. Bentonite was then added as a bleaching adsorbent, and the mixture was heated on a hot plate at 100°C for 20 min with stirring. The oil was finally separated by centrifugation at 6,500 rpm and 10°C for 10 min to obtain purified tuna skin oil. This sequence was intended to reduce impurities, soap residues, polar compounds, and suspended solids in the crude extract.

Extraction of Lemongrass and Bajakah Fractions

Lemongrass was washed, cut into small pieces, placed in a distillation flask, and mixed with distilled water. The flask was heated using a Bunsen burner, and the vapor was condensed using a condenser. The distillate was transferred into a 250 mL separating funnel, mixed with 8 mL chloroform, homogenized, and allowed to stand briefly. The solvent and extract fractions were separated, and the extract-solvent phase was heated on a hot plate until the solvent evaporated and the lemongrass oil fraction remained.

For bajakah extraction, powdered bajakah wood was placed in a distillation flask and mixed with distilled water. The flask was heated using a Bunsen burner and vapor was condensed through the condenser. The extract was transferred into a 250 mL separating funnel, mixed with 8 mL chloroform, homogenized, and allowed to separate. The extract-solvent fraction was evaporated on a hot plate until the remaining oil-like extract was obtained.

Quality Analysis

The formulated oil was analyzed using organoleptic and chemical parameters. Organoleptic analysis evaluated color, aroma, and texture because these attributes are directly related to consumer acceptance and topical usability. Chemical quality was evaluated using free fatty acids, peroxide value, and iodine value. These indices are commonly used to describe hydrolytic degradation, primary oxidation, and unsaturation in oils; therefore, they are appropriate preliminary markers for assessing the stability of fish-derived oil before more advanced analyses such as fatty acid profiling, p-anisidine value, total oxidation value, or accelerated shelf-life testing are performed (Choe & Min, 2006; Shahidi & Zhong, 2010).

RESEARCH RESULT

Organoleptic Quality

organoleptic test indicated that the formulated massage oil was generally accepted by panelists. The mean score for color was 3.90, which corresponded to a neutral response, while aroma and texture achieved mean scores of 4.15 and 4.10, respectively, indicating liked responses. These results suggest that the 70:15:15 formulation of tuna skin oil, lemongrass extract, and bajakah extract produced a product with acceptable sensory characteristics. The higher aroma score supports the formulation rationale because lemongrass essential oil is known for citrus-like volatile constituents that can improve odor perception in natural formulations (Avoseh et al., 2015; Boukhatem et al., 2014).

Table 1. Mean organoleptic scores of tuna skin massage oil formulated with lemongrass and bajakah wood.

No.	Parameter	Mean score	Descriptive category
1	Color	3.90	Neutral
2	Aroma	4.15	Liked
3	Texture	4.10	Liked

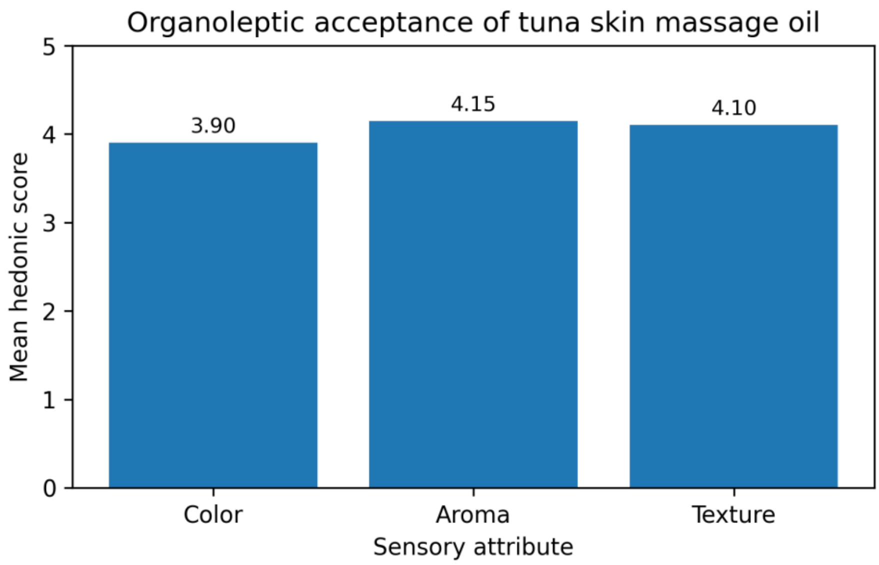

Figure 1. Organoleptic acceptance of massage oil from tuna skin waste with lemongrass and bajakah wood enrichment

Chemical Quality Indicators

Chemical analysis showed that the formulated oil had a mean free fatty acid content of 1.14%, with replicate values of 1.18% and 1.09%. Assuming the free fatty acid percentage was expressed as oleic acid, this value corresponded to an estimated acid value of approximately 2.27 mg KOH/g. The mean peroxide value was 3.24 mEq O_2/kg, with replicate values of 3.28 and 3.19 mEq O_2/kg. The iodine value was 33.03 g I_2/100 g, with replicate values of 33.10 and 32.29 g I_2/100 g. Because fish oils may be susceptible to oxidation due to unsaturated fatty acid fractions, the low peroxide value in this study suggests limited primary oxidation at the point of analysis, while the low iodine value suggests relatively low unsaturation or possible alteration during extraction and purification (Choe & Min, 2006; Shahidi & Zhong, 2010).

Table 2. Chemical quality of tuna skin massage oil enriched with lemongrass and bajakah wood

	Parameter	Unit	Replicate 1	Replicate 2	Mean
1	Free fatty acids	%	1.18	1.09	1.14
2	Estimated acid value*	mg KOH/g	2.35	2.17	2.27
3	Peroxide value	mEq O_2/kg	3.28	3.19	3.24
4	Iodine value	g I_2/100 g	33.10	32.29	33.03

*Estimated from free fatty acid values assuming expression as oleic acid; acid value ≈ free fatty acids (%) × 1.99.

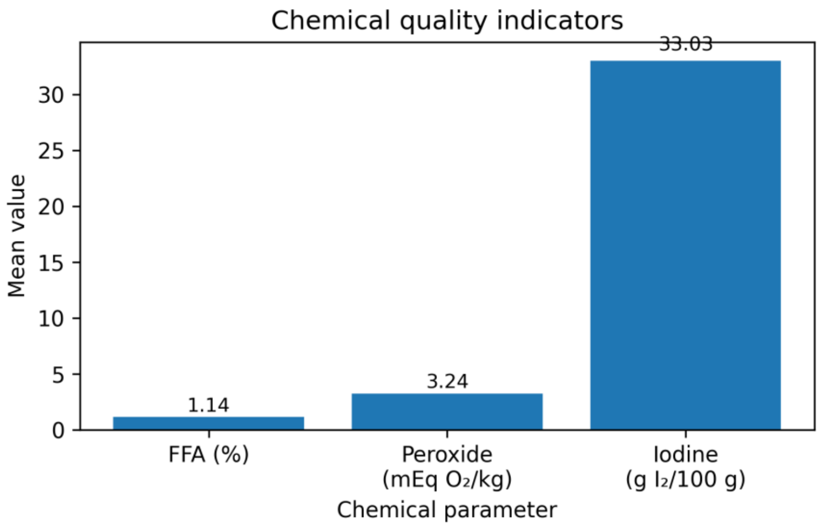

Figure 2. Mean chemical quality indicators of the formulated tuna skin massage oil.

DISCUSSION

Sensory Acceptance of the Formulated Oil

The sensory results demonstrate that tuna skin waste can be converted into a topical oil formulation with acceptable consumer-oriented properties. Color received a mean score of 3.90, indicating a neutral response. This suggests that the product color did not strongly attract or reject panelists. Color is important in oil-based products because visual appearance often influences the first judgment of cleanliness, naturalness, and quality. The result is promising because the raw material was a fish-processing residue, which could otherwise be associated with darkening, turbidity, or undesirable appearance if extraction and purification are poorly controlled. The finding is consistent with broader valorization literature showing that fish-processing residues can be transformed into value-added materials when processing conditions are controlled (Jayathilakan et al., 2012; Rustad et al., 2011). This interpretation is further supported by recent circular-bioeconomy literature, which emphasizes that fish waste can supply high-value fractions such as oil, collagen, enzymes, and bioactive peptides instead of remaining an environmental burden (Coppola et al., 2021).

Aroma was the strongest sensory attribute, with a mean score of 4.15. This result is consistent with the formulation rationale because lemongrass was included to reduce or mask fishy odor. The citrus-like volatile profile of lemongrass essential oil has been associated with citral-rich terpenoid constituents and antimicrobial or anti-inflammatory potential in previous studies, although the present work measured sensory response rather than bioactivity (Avoseh et al., 2015; Boukhatem et al., 2014). The liked response for aroma indicates that the 15% lemongrass fraction was sufficient to improve the odor profile of the fish-derived oil under the conditions of this experiment. However, aroma intensity should be optimized carefully because excessive essential oil concentration may cause irritation or overpowering odor in topical products. This caution is consistent with dermatological reviews of natural oils, which emphasize that topical acceptability must be interpreted together with ingredient composition, processing method, and possible irritation risk (Lin et al., 2018; Vaughn et al., 2018).

The texture score of 4.10 indicates that panelists perceived the oil as acceptable for topical use. A suitable massage oil should spread easily, feel smooth on the skin, and avoid excessive stickiness. The favorable texture score suggests that the purified fish oil base and plant-derived fractions produced a formulation that could be evenly applied and perceived as comfortable. Topical oil literature also emphasizes that oils used on skin may influence barrier function and user perception, but product safety and skin compatibility must be verified before claims are extended beyond acceptability (Lin et al., 2018; Vaughn et al., 2018). Therefore, the sensory result supports product feasibility, while further irritation, stability, and dermal safety testing remain necessary.

Hydrolytic and Oxidative Quality

The free fatty acid content of 1.14% provides an estimate of hydrolytic degradation in the oil. Free fatty acids are produced when triglycerides undergo hydrolysis, and their accumulation may increase acidity, reduce stability, and contribute to off-odors. When expressed as an estimated acid value, the result was approximately 2.27 mg KOH/g, which is below the 3 mg KOH/g value commonly used in the source manuscript as a comparative SNI threshold. The controlled acid value suggests that washing, alkaline treatment, bleaching, and centrifugation were able to reduce hydrolytic degradation indicators. Nevertheless, because hydrolysis is affected by raw material freshness, moisture, endogenous enzymes, temperature, and storage duration, future studies should include controlled storage experiments and replicate batches (Boran et al., 2006; Choe & Min, 2006; Nurjanah et al., 2020).

The peroxide value of 3.24 mEq O_2/kg indicates that primary oxidation products were present at a relatively low level. Peroxide value is a sensitive early indicator of lipid oxidation, particularly in oils containing unsaturated fatty acids. Marine oils require careful stabilization because polyunsaturated fatty acids, including EPA and DHA, are prone to oxidation when exposed to oxygen, heat, light, and pro-oxidant metals (Shahidi & Ambigaipalan, 2018; Shahidi & Zhong, 2010). The value observed in this study suggests that the oil had not undergone severe primary oxidation at the time of measurement. This is important for a topical product because oxidation can produce rancid odor, reduce consumer acceptance, and alter the perceived freshness of the formulation. Fish-oil storage studies also show that peroxide value and related quality indices can change with storage temperature and time, supporting the need for accelerated stability testing before product scaling (Boran et al., 2006).

The iodine value of 33.03 g I_2/100 g was comparatively low for a fish oil-based product. Iodine value reflects the number of double bonds in oil molecules and is therefore associated with the level of unsaturation. Fish oils are commonly valued because they can contain long-chain omega-3 polyunsaturated fatty acids, but higher unsaturation also increases oxidative vulnerability (Shahidi & Ambigaipalan, 2018; Shahidi & Zhong, 2010). A lower iodine value may indicate that the extracted oil fraction contained fewer highly unsaturated components, that unsaturated fractions were reduced during processing, or that the formulation was diluted by plant-derived fractions. For topical massage oil, lower unsaturation can improve oxidative stability, but it may reduce the nutritional identity associated with fish oil.

The low iodine value may also reflect processing conditions. The extraction involved drying at 74°C, solvent maceration, evaporation at 100°C, alkaline treatment at 65°C, bleaching at 100°C, and centrifugation. These steps may help purify oil but can also expose unsaturated compounds to heat and oxygen. Edible-oil oxidation studies show that heat, oxygen exposure, metals, and unsaturation level interact to accelerate oxidative changes (Choe & Min, 2006; Shahidi & Zhong, 2010). In fish-oil systems, storage temperature and processing history are also important determinants of quality deterioration, which reinforces the need to control both extraction and post-production handling (Boran et al., 2006). In this context, the iodine value should not be interpreted as a negative result alone. Instead, it indicates that the product may be more chemically stable for topical use but needs fatty acid profiling to determine whether EPA, DHA, or other unsaturated fatty acids were retained.

Value Addition from Tuna Skin Waste

The study provides preliminary evidence that tuna skin waste can be used as a raw material for a value-added topical oil. This is relevant for fish-processing sustainability because untreated skin waste may create odor and disposal problems, whereas recovered oil and collagenous fractions can support circular-economy product development. Previous reviews have emphasized that fish-processing by-products can be converted into higher-value products, including oils, collagen, gelatin, animal feed, pigments, and cosmetic ingredients (Arvanitoyannis & Kassaveti, 2008; Jayathilakan et al., 2012). More recent marine by-product literature similarly reports that fish-processing operations can generate substantial by-product streams and that these materials contain commercially relevant compounds such as lipids, collagen, peptides, enzymes, and minerals (Coppola et al., 2021). Studies on tuna-skin gelatin further show that tuna skin has functional material potential beyond waste disposal (Cho et al., 2005; Estaca et al., 2009). Therefore, the present formulation aligns with the broader scientific direction of converting marine by-products into usable materials.

The collagen-related fraction of tuna skin also has scientific relevance even though this study focused on the oil phase. Fish collagen and gelatin have been reviewed as alternative biomaterials with functional and bioactive properties for food, pharmaceutical, biomedical, and cosmetic applications (Gómez-Guillén et al., 2011). This connection strengthens the resource-efficiency argument: tuna skin should not be viewed only as a lipid source, but as a multiphase by-product in which oil recovery could be combined with collagenous-material utilization in future process designs.

The use of lemongrass and bajakah also strengthens the local-material identity of the product. Lemongrass contributes aroma and sensory appeal, while bajakah provides an ethnobotanical identity linked to Kalimantan. The relevance of bajakah in this study should be interpreted cautiously because no antioxidant, anti-inflammatory, wound-healing, or antimicrobial assay was conducted. Therefore, the product should be described as a natural massage oil with acceptable sensory and chemical characteristics, not as a therapeutic oil. Literature on flavonoids, plant oils, and topical natural oils supports the plausibility of antioxidant and skin-related functions, but direct evidence must be generated for the exact formulation before any bioactivity claim is made (Ginwala et al., 2019; Lin et al., 2018; Panche et al., 2016; Vaughn et al., 2018).

Several methodological limitations should be addressed in future research. The study used a single formulation ratio and did not compare different concentrations of tuna skin oil, lemongrass, or bajakah. Chemical analyses were performed in duplicate only, and the study did not include fatty acid composition, microbial safety, dermal irritation, accelerated stability, p-anisidine value, or total oxidation value. Future studies should also standardize extraction yield, quantify citral or major lemongrass volatiles, characterize bajakah phytochemicals, and evaluate product stability under controlled storage. Because fish skin and other marine by-products can simultaneously support lipid, collagen, and gelatin valorization, subsequent work should also consider whether oil extraction can be integrated with collagen or gelatin recovery to improve resource efficiency (Coppola et al., 2021; Gómez-Guillén et al., 2011). These additional tests are necessary to move from preliminary laboratory feasibility toward a standardized topical oil product supported by stronger chemical and safety evidence.

CONCLUSIONS AND RECOMMENDATIONS

The formulation of massage oil from tuna skin waste (Thunnus sp.) with lemongrass and bajakah wood enrichment produced a product with acceptable sensory quality and measurable chemical stability. Organoleptic evaluation by 30 panelists showed a neutral response for color (3.90) and liked responses for aroma (4.15) and texture (4.10), indicating that the addition of aromatic and plant-based ingredients improved product acceptability, particularly in aroma and topical feel. Chemical analysis showed a free fatty acid content of 1.14%, corresponding to an estimated acid value of 2.27 mg KOH/g when calculated as oleic acid, a peroxide value of 3.24 mEq O_2/kg, and an iodine value of 33.03 g I_2/100 g. These findings suggest that the oil had controlled hydrolytic and oxidative quality, while the low iodine value indicates relatively low unsaturation and potentially improved resistance to oxidation for non-food topical use. The study contributes preliminary evidence for the valorization of tuna skin waste into a value-added massage oil product using locally available natural additives. Further research should optimize the formulation, validate shelf life, determine fatty acid composition, evaluate dermal safety, and test antioxidant or anti-inflammatory activity before therapeutic claims or commercial application are proposed.

ADVANCED RESEARCH

Future studies should optimize the formulation ratio of tuna skin oil, lemongrass extract, and bajakah extract across multiple batches and storage conditions. Further work should determine fatty acid composition, p-anisidine value, total oxidation value, microbial safety, dermal irritation, accelerated shelf life, and direct antioxidant or anti-inflammatory activity before broader topical or commercial claims are proposed.

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