www.ijarp.com ISSN 2456-9992 Page: 01-15

International Journal Advanced Research Publications

Research Article

Volume: 02
Issue: 06

THE USE OF MACKEREL OIL (RASTRELIGER SP.) FOR OMEGA-3 FORTIFICATION IN ICE CREAM

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Article Received: 3 May 2026, Article Revised: 23 May 2026, Published on: 13 June 2026

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Doi: https://doi-doi.org/101555/ijarp.1288

ABSTRACT

Mackerel (*Rastrelliger*sp.) hasa highpotentialasasourceofoilrichin omega-3. Ice cream is a frozen product with a sweet flavor that is commonly consumed as a dessert.As consumer demand for functional foods that promote health continues to rise, various efforts have been made to substitute raw materialstoenhancethenutritionalvalueoficecream.Oneinnovationthatcanbeapplied is the production of ice cream containing omega-3 fatty acids through the addition of mackerel oil.This study aimed to determine the characteristics of ice cream with added mackerel oil and identify the optimal formulation for adding mackerel oil to ice cream and the resulting omega-3 content.An *experimental laboratory* study with a Complete Randomized Design (CRD) was used.The treatments used in this study were the addition of mackerel oil at concentrations of 0% (EM0), 1% (EM1), 3% (EM3), and 5% (EM5). Hedonic test analysis used *the Kruskal-Wallis test*, followed by *the Mann-Whitney test*. Testing of *overrun,* melting point, emulsion stability, viscosity, and fat content used ANOVA (*Analysis of Variance*) and the Honest Significant Difference (HSD) test. The best treatmentwas EM5, with a 5% addition of mackerel oil, which yielded a hedonic score of$7.55 < \mu < 7.71$, *overrun of* 28.15%, melting time of 15.01 min, emulsion stability of 82.47%, viscosity of 2,495 cP, and fat contentof6.59%.Icecreamtreated with EM1 contained no omega-3 fatty acids,whereas the EM5 treatment yielded 1.27% omega-3, consisting of 0.85% EPA and 0.42% DHA.

KEYWORDS: Icecream, mackerel, fishoil, emulsion, omega-3.

1. INTRODUCTION

Mackerel (*Rastrelliger*sp.) is found in almost all of Indonesia's waters. The amount of mackerel fish catches in 2021 increased to 375,534.32 tons [1]. Mackerel is a small pelagic fish with high nutritional content capable of meeting most health requirements, one of which is omega-3. The omega-3 fatty acid content in raw mackerel consists of alpha-linolenic acid (ALA) at 1.21%, eicosapentaenoic acid (EPA) at 5.20%, and docosahexaenoic acid (DHA) at 17.87% [2].Fish oil is rich in omega-3, omega-6, and omega-9 polyunsaturated fatty acids (PUFAs).Omega-3 can be added to various food products by extracting fish oil. The omega-3 fatty acids most commonly found in fish oil are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The omega-3 content in mackerel oil is 20.84% [3].

The omega-3 fatty acids most commonly found in fish oil are EPA and docosahexaenoic acid (DHA).Omega-3s offer health benefits for humans, including supporting brain, heart, and nervous system function, and lowering cholesterol levels. The daily omega-3 intake for children ranges from 0.7 to 0.9 g, whereas the recommended intake for adults is 1.0 to 1.6 g per day [4]. Theseomega-3intakerequirementscanbeachievedbytakingfishoilsupplements.Mackerel (*Rastrelliger kanagurta*) has a high potential for producing oil with a high omega-3 content. Mackerel oil (*Rastrelliger kanagurta*) contains 16.38% fatty acids per 100 grams of sample [3].

Ice cream is a frozen product with a sweet taste that is often consumed as a dessert.In recent years, ingredient substitutions have been made to improve the nutritional value of ice creams.This substitution is expected to provide good nutrition, categorize the product as a functional food, and improve sensory acceptance.However, commercially available ice cream currently remains low in fatty acids, such as omega-3.One approach is to produce ice cream containing omega-3 fatty acids by adding fish oil to it.

The composition of ice cream ingredients influences the nutritional content and quality of the final product. Ice cream ingredients include milk, cream, stabilizers, emulsifiers, sweeteners, and flavor enhancers. To improve the quality and nutritional value of ice cream, modifications and the addition of various natural ingredients such as fruits have been implemented in recent years.Icecream is currently being diversified by adding agricultural products, such as yellow squash, green beans,papaya, edamame, and grape juice [5]. The purpose of adding these ingredients is to improve the nutritional and sensory value of ice cream and provide health benefits.

The addition of fish oil to food products using a mixture of anchovy, catfish, and tuna oils has been studied [6].The optimal concentration was 15 g, yielding 46.21% SFA, 38.43% MUFA, and 3.3% PUFA.In this study, the objective of using mackerel oil at different concentrations in ice cream was to determine the characteristics of the resulting ice cream and to identify the optimal formulation of mackerel oil in relation to the chemical, physical, and hedonic characteristics of the ice cream.

2. MATERIALSANDMETHODS

2.1. PreparationofRawMaterials

The raw material, mackerel (*Rastrelliger* sp.), was obtained from a local fish market in Rejomulyo, SemarangCity,Indonesia.Thefish werefresh,approximately15cminlength,andweighedbetween70and80 g.The chemicals used, such as 3% bentonite, 7% citric acid, NaCl, HCl, and others in the extraction process and fish oil testing, were obtained from Toko Kimia Indrasari, Semarang, Indonesia.The ingredients for making the ice cream were obtained from a local supermarket in Semarang City.

2.2. Productionofmackereloil

Crude mackerel fish oil was produced using the dry rendering method [7]followed by degumming [8] and *bleaching* [9] to producehigher-qualityfishoil.Theresultingoilwascentrifugedat 7000rpmfor10min toseparate the oil from the bentonite solids.The final product of this centrifugation process is pure fish oil,which is then stored in glass bottles in *a freezer* at -20°C to maintain the oil quality.

2.3. Ice Cream Production

The process of making ice cream using ice cream maker equipment according to the procedure [10]. The ice cream base was prepared by mixing cow's milk, granulated sugar, egg yolks, and cornstarch, and heating the mixture to 85°C. The mixture was allowed to cool to 40°C, after which skim milk and *whipping cream* were added, and the mixture washomogenized using *a mixer*at maximum speed. The mixturewaschilled for 12 hours at -23°C.The frozen mixture was churned in an *ice cream maker* (ICM) for 30 min, and mackerel oil was added as a treatment at concentrations of 0% (EM0) as a control, 1% (EM1), 3% (EM3), and5% (EM5).The mixture was then packaged and placed in *a freezer* for 24 h to solidify the ice cream.

2.4. Hedonic Test

The evaluation was based on consumer preference using the hedonic testevaluationsheet, according to theGuidelinesfor Sensory Testingof FisheryProducts [11]. The ice cream hedonic testused a1–9 numerical scale, with a score of 9indicating the high estrating of liking.

2.5. Overrun

The *overrun* test was conducted by weighing 100 g of the ice cream mixture before freezing and weighing it again after freezing [12]. This was performed because of the possibility of volume expansion during freezing.The *overrun* value was calculated using the following formula: (mixture weight – frozen ice cream weight) ÷ mixture weight × 100%.

2.6. Melting Point

Melting point testing was conducted by freezing 5 g of ice cream in *a freezer* for 24 h [13]. The frozen ice cream was placed in a Petri dish at room temperature or incubator temperature (±37°C) and observed until all the ice cream melted completely.The melting time was measured in minutes, recorded, and analyzed statistically.

2.7. Emulsion Stability

Emulsion stability testing was conducted method by weighing a 5-g sample and placing it in an oven at 45°C for 1 h, then transferring it to a cooler at a temperature below 0°C for 1 h [14].The sample was returned to the 45°C oven for 1 h and allowed to reach a constant weight.Emulsion stability was calculated using the following formula: (weight of remaining phase) ÷ (total weight of ice cream emulsion) × 100%.

2.8. Viscosity

Viscosity testing based was performed using a *Brookfield viscometer* [15].A 100-ml sample was placed in a 250-ml beaker. Spindle 4 was installed and set to the appropriate speed, and then dippedinto the ice cream. The viscosity of the sample was read on the scale of the instrument after stability was achieved.

2.9. Fat Content

FatcontenttestingwasperformedusingtheSoxhletextraction method [16].

2.10. Fatty Acid Determination

Fatty acid including omega-3 testing wasperformed with an Agilent Technologies7890B Gas Chromatography (GC) instrument [17].

2.11. Data Analysis

Data were analyzed using the SPSS software. Parametric data underwent normality tests, homogeneity tests, *Analysis of Variance* (ANOVA), and the Honest Significant Difference (HSD) test, while non-parametric data underwent the *Kruskal-Wallis* test followed by the *Mann-Whitney* test.

3. RESULTS AND DISCUSSION

3.1. HedonicTestResults

The results of the hedonic tests are presented in Table 1.The appearance of the ice cream scored between 7.23 and 7.43, indicating that the appearance of the ice cream in all the treatments was acceptable to the panelists.The ice cream was pale yellow in color and contained fine ice crystals.This appearance is due to its ingredients, such as milk, sugar, cornstarch, and eggs.The fish oil used has a yellowish color, which does not alter the appearance of the ice cream.The color of ice cream is influenced by its ingredients, such as sugar, eggs, and milk, which result in a pale yellowish-white color [18].

Table1. Results of the Hedonic Test for Ice Cream with Added Mackerel Oil.

Parameter	Treatment of Mackerel Oil Addition			
	EM0	EM1	EM3	EM5
Appearance	7.23±0.57^{a}	7.27±0.64^{a}	7.30±0.53^{a}	7.43±0.50^{a}
Taste	7.20±0.61^{a}	7.27±0.64^{a}	7.33±0.61^{a}	7.33±0.48^{a}
Aroma	7.17±0.83^{a}	7.37±0.76^{a}	7.57±0.50^{ab}	7.77±0.50^{b}
Texture	7.07±0.64^{a}	7.33±0.66^{ab}	7.53±0.51^{b}	8.00±0.37^{c}
Confidenceinterval	7.01<μ<7.32	7.16<μ<7.46	7.35<μ<7.51	7.55<μ<7.71

Note:EM0(Icecreamwith0%fishoilasacontrol),EM1(Icecreamwith1%fishoil),EM3(Ice cream with 3% fish oil), and EM5 (Ice cream with 5% fish oil).Each value is reported as themean± SD of three replicates. Values in thesamecolumn with different superscriptsare significantly different ($p < 0.05$).

The taste test results ranged from 7.27 to 7.33, indicating that the ice cream with all treatments wasacceptable to the panelists. The ice cream had a dominant milky flavor and sweetness from sugar, and the addition of mackerelfish oildid not result in *any aftertastes* or a neutral taste. This is because the fishy taste of fish oil was masked by milk and sugar. The resulting ice cream flavor wassweet, asitwasmadewith added sugar [19].Thesweetness of ice cream comesfrom carbohydrate components consisting of sucrose, which is then broken down into glucose and fructose, which are sweet.The taste influences consumer preference for ice cream and is considered the primary determining factor [20]. The flavors of ice cream on the market are highly diverse; therefore, discernment and creativity are required to blendflavors that appeal to consumers.

The aroma test results ranged from 7.30 to 7.53, indicating that the ice cream with all treatments was acceptable to the panelists.The dominant aromas of the ice cream were milk and vanilla.Although fish oil has a fishy odor, when added to ice cream, it did not have a noticeable effect because it was overpoweredby the milk and vanilla aromas derived from *the* *whipping cream*.Serving temperature can also influence consumer preferences for aroma so that cold temperatures can affect the preferences of panelists [21]. Thelonger the ice cream remained outside *thefreezer*, the stronger thearoma intensity produced by the ice cream.The aroma of the ice cream was derived from the milk, sugar, and strawberries used.

The texture test results yielded values ranging from 7.43 to 8.00, indicating that the ice cream with all treatmentswasacceptabletothe panelists.Thetexturescoresindicatedthatthe ice cream became more porous with increasing fish oil content compared to the control.This is because of the formation of ice crystals during freezing.Ice cream with 5% fish oil was preferred by the panelists, as the ice cream without fish oil addition resulted in a very dense and sticky texture, making it less preferred by consumers.The texture of ice cream is influenced by the composition of the ingredient mixture, such as milk, sugar, and stabilizers[22].Milk fat provides a *creamy* texture and prolongs the melting time.The texture of ice cream is influenced by the composition of the ingredients and processing methods [23]. Milk fat helps create a soft texture, aids in maintaining the shape and density, and provides good melting properties.Skim milk can increase the solids content in ice cream, making it thicker and serving as a source of protein [24]. Protein helps stabilize the fat emulsion after homogenization, enhances flavor, aids in foaming, and improves and stabilizes waterholding capacity, factors that influence ice cream viscosity and result in a soft texture

3.2. Overruncharacteristics

Theadditionofmackereloilatdifferentconcentrationstoicecreamresultedinsignificantdifferences ($p<0.05$) in *overrun* values.Theresultsof theicecream *overrun* tests areshown in Table2.Thetable shows that the overrun test results ranged from 20.75%–28.15%.The results of the overrun test obtained were higher than the results of previous research, that found *overrun* values with the addition of palm oil ranging from 16.19% to 20.58% [25].The increase in *the overrun* values was due to the decrease in the viscosity of the mixture, thereby enhancing the ability of the mixture to form air pockets.When the viscosity of the mixture increases, the free water bound in the mixture can lower the surface tension, making it easier for air to penetrate the surface of the mixture [26], this resultedin ahighericecream *overrun*.Ice cream produced in factories has *an overrun* of 70–80%, whereas homemade ice cream has *an overrun* of 35–50% [27].

Table2.Resultsofphysicalcharacteristictestsonicecreamsupplementedwithmackereloil.

Treatment	Overrun(%)	MeltingPoint (Minutes)	EmulsionStability(%)	Viscosity(cP)
EM0	20.75±0.36^{a}	19.68±0.79^{c}	83.07±1.38^{a}	3.492±6.08^{d}

EM1	23.39±1.41[b]	17.61±0.37[b]	82.89±0.96[a]	3.172±3.06[c]
EM3	25.63±0.54[c]	15.61±0.76[a]	82.81±0.84[a]	2.957±4.36[b]
EM5	28.15±0.54[d]	15.01±0.60[a]	82.47±0.71[a]	2.495±4.62[a]

Note: EM0 (Ice cream with 0% fish oil as a control), EM1 (Ice cream with 1% fish oil), EM3 (Ice cream with 3% fish oil), and EM5 (Ice cream with 5% fish oil).Each value is expressed as the mean ± SD of three replicates. Values in thesamecolumn with different superscriptsare significantly different (p < 0.05).

*Overrun*isalsoinfluencedbythetypeandconcentrationofthe stabilizer.Theuseofcornstarchasa stabilizer can produce a uniform texture with small ice crystals and does not affect the taste of ice cream.A higher cornstarch concentration resulted in a better texture, which is related to the amylose and amylopectin content, which can form a firm gel.Starch can be used asa stabilizer, but its application (*swelling)* remains limited because of its insolubility in water and limited expansion capacity [28]. The physical property of overrun and the expansion volume of ice creamcan also be influenced by the fat content of the ingredients [29].

3.3. Resultsofthemeltingpointcharacteristictest

The results of the ice cream melting time tests, as shown in Table 2, indicate that adding fish oil at different concentrations to ice cream produced a significant difference ($p<0.05$) in melting time.The melting time of ice cream with fish oil added at concentrations of 0%, 1%, 3%, and 5% ranged from 15.01 to 19.68 min, indicating that all treatments fell within the range of good melting time.Ice cream melting time tended to decrease with increasing fish oil content.These results are consistent with the results of previous research which found that ice cream with added virgin coconut oil had lower melting resistance than control ice cream [30].This can be attributed to the presence of unsaturated fatty acids in the oil.Unsaturated fatty acids in the oil remain liquid at room temperature, thus affecting the melting time of the ice cream.Fatty acids containing more than two double bonds are commonly foundin fish oil and remain liquid at room temperature and even at low temperatures [31].This is because they have a lower melting point than *Monounsaturated Fatty Acids* (MUFA) or *Saturated Fatty Acids* (SFA).The ideal ice cream melting time is 15–20 min at room temperature [32].

3.4. EmulsionStabilityTestResults

Theadditionoffishoilatdifferentconcentrationstoicecreamdidnotresultinasignificantdifference ($p<0.05$) in emulsion stability (Table 2).This indicates that variations in the concentration of mackerel fish oil did not affect the emulsion stability of the ice cream in this study.The factor influencing emulsion stability was the use of an egg yolk *emulsifier* at the same concentration.The previous research reported that varying the milk fat to virgin coconut oil

(VCO) ratio did not significantly affect the emulsion stability of the resulting ice cream [30]. This is because the addition of an emulsifier during ice cream production helps to bind fat globules and water.Emulsion stability in ice cream approaches 100%; therefore, the emulsion stability in ice cream is increasingly good.The volume ratio between the two phases affects the type and stability of the emulsion [33]. The correct ratio produces a stable emulsion.An emulsion stability value approaching 100% indicates a good emulsion.

Emulsion stability is influenced by temperature, mixing time and duration, fat particle size and viscosity.Smaller fat particles helpmaintain emulsion stability by increasingthe viscosity of the mixture, inhibiting movement between droplets, and helping maintain emulsion stability.

3.5. ViscosityTestResults

The results of the ice cream viscosity tests, as shown in Table 2, indicate that adding fish oil at different concentrations to the ice cream resulted in a significant difference ($p<0.05$) in viscosity.The viscosity test results ranged from 2.495–3.492 cP.Currently, there is no established standard for the viscosity of substituted ice cream. However, the average viscosity of the ice cream in this study was higher than that reported in previous research that average viscosity values for ice cream with different vegetable oil substitutions ranged from 1,319.67 cP to 1,651.67 cP.[34].

The viscosity decreased as fish oil was added, owing to a reduction in the total solid content of the ice cream, which in turn reduced its thickness.Viscosity can decrease due to the ingredients mixed into the mixture; the more liquid added, the lower the viscosity, whereas the more solids added, the higher the viscosity [29]. A high fat content can increase the viscosity of the mixture; however, if the fat content is too high, the ice cream viscosity may become excessively high and disrupt the texture of the ice cream.Viscosity is influenced by temperature, pressure, solvent, and solutionconcentration.Temperatureaffectsthe internalmovementwithin thesystem; higher temperaturesreduce the viscosity because the particle movement is greater[35].This is supported in previous research thattemperature significantly affects viscosity [36]. The higher the temperature, the lower the viscosity; conversely, the lower the temperature, the higher the viscosity of the preparation.The higher the total solids, the higher the viscosity of the ice cream.This is because the total solids can also trap and bind water [37].

3.6. FatContentTestResults

Adding mackerel oil at different concentrations to ice cream resulted in a significant difference ($p<0.05$) in fat content. The results of the ice cream fat content test are shown in

Table 3.

Table3.Results of chemical analysis off at contentinice cream with added mackerel oil concentration.

Treatment	Fat Content (%)
EM0	7.58 ± 0.05^{c}
EM1	7.18 ± 0.05^{b}
EM3	6.75 ± 0.03^{a}
EM5	6.59 ± 0.14^{a}

Note: EM0 (Ice cream with 0% fish oil as a control), EM1 (Ice cream with 1% fish oil), EM3 (Ice cream with 3% fish oil), and EM5 (Ice cream with 5% fish oil).Each value is reported as themean± SD of three replicates. Values in thesamecolumn with different superscriptsare significantly different ($p < 0.05$).

The test results for the fat content of the ice cream ranged from 6.59%–7.58%.The fat content met the SNI standard requirement of a minimum of 5%.The fat content decreased with the addition of fish oil. Thedecrease in fat content is suspected to becausedby fatcrystallization dueto differencesinfatcomposition,one of which is a lower melting point. The type of fat used in ice cream with different melting points affects the stability of fat crystals, causing the separation of fat and water phases.This is because fat settles or separates during storage, resulting in a lower measured fat content in theice cream.The lowfat content in ice cream is caused by fat crystallization during the ice cream production process, which forms *fat globules* with a three-dimensional structure [38].This structure can trap water and air, thereby decreasing the fat content of the ice cream.Anotherfactorcausingthedecreaseinfatcontentis the addition of fish oil, which reduces the total solids in ice cream, thereby increasing the water content.Thedifferences in water content among the treatments were due to the varying amounts of fish oil added [39].

3.7. FattyAcidProfile

The addition of fish oil at different concentrations resulted in significant differences in the fatty acid composition. Fatty acid profiling revealed 18 types of fatty acids, consisting of 10 types of SFAs (*Saturated FattyAcids*), 3 typesof MUFAs(*MonounsaturatedFattyAcids*), and5 typesof PUFAs(*Polyunsaturated Fatty Acids)*. The percentages of SFA, MUFA, and PUFA in the 0% treatment (EM0) were 41.84 %, 39.76%, and 18.41 %, respectively.The percentages of SFA, MUFA, and PUFA in the 5% treatment (EM5) were 34.08 %, 40.81%, and 24.08 %, respectively.The addition offish oil changed the fatty acid composition of the ice cream.The percentageof SFA in the ice cream decreased with the addition of fish oil, whereas the percentages of MUFA and PUFA increased. The previous researchreported that ice cream without the addition of fish oil microcapsules had SFA, MUFA, and PUFA contents of 65.2 %, 28.52%, and 0.933 %, respectively, whereas ice cream with a 15 g/kg addition had SFA, MUFA, and PUFA contents of 46.21%, 38.43%, and 3.347 %, respectively [6].This is because fish oil contains various fatty acids.The fattyacidsinfishconsistofsaturatedfattyacids(15–25%),monounsaturatedfattyacids (35–60%), and polyunsaturated fatty acids (25–40%) [40].

Table 4. Fatty acid profile of ice cream with added mackerel oil.

TypeofFattyAcid	FattyAcidContent(%)	
	0%	5%
SFA		
C4:0(ButanoicAcid)	1.00	0.45
C6:0(HexanoicAcid)	0.47	0.19
C8:0(CaprylicAcid)	2.24	1.72
C10:0(Capricacid)	2.77	1.02
C12:0(LauricAcid)	21.75	15.62
C14:0(MyristicAcid)	9.59	6.72
C17:0(Heptadecanoicacid)	1.15	0.88
C20:0(Arachidicacid)	2.87	1.72
C21:0(Henicosanoic acid)	-	4.34
C24:0(LignocericAcid)	-	1.42
∑SFA	41.84	34.08
MUFA		
C16:1(Palmitoleic acid)	26.80	27.23
C18:1(OleicAcid)	12.96	13.66
C24:1(NervonicAcid)	-	0.92
∑MUFA	39.76	40.81
PUFA		
C18:2(Linoleicacid)	18.41	20.45
C20:2(Eicosadienoic acid)	-	1.37
C 20:3(Eicosatrienoic acid)	-	0.99
C 20:5(Eicosapentaenoicacid)	-	0.85
C22:6(Docosahexaenoic Acid)	-	0.42
∑PUFA	18.41	24.08
Omega-3	-	1.27
Omega-6	-	2.36
Omega-9	12.96	14.58

Ice cream with added fish oil showed an increase in omega-3 content.Ice cream with 0% fish oil contained no omega-3 fatty acids, whereas the EM5 treatment yielded 1.27% omega-3 fatty acids, consisting of 0.85% EPA and 0.42% DHA. The omega-3 content in the ice cream in this study was higher than that reported in the previous research where the omega-3 content in ice cream with 0% chiaoil addition was undetectable, and the 5% addition yielded

0.12% EPA and 0.11% DHA [41].The omega-3 content in previous research reported that without the addition of microencapsulated fish oil consisted of ALA 0.189% and ETE 0.034%, with DHA and EPA undetected [6]. Addition at a concentration of 15 g/kg yielded ALA, ETE, EPA, and DHA at 1.164 %, 1.620%, 0.090%, and 0.007 %, respectively. The omega-3 content of the ice cream increased with the addition of fish oil.

Fish oil is rich in omega-3 fatty acids [42]. The EPA and DHA content in fish oil possesses unique characteristics that distinguish marine animal fats from terrestrial animal fats.Omega-3 fatty acids are essential for overall health.Adults require 1.0–1.6 g of omega-3 per day. Omega-3 can protect the body against cardiovascular disease and cancer and support brain function and development.A high intake of omega-3 fatty acids has beneficial effects on health, particularly on heart function, brain health, and the nervous system [43].

4. CONCLUSION

The use of mackerel oil in ice cream significantly affected the characteristics of the resulting ice cream, as determined by hedonic tests of aroma and texture, overrun, melting point, viscosity, fat content, and omega-3 content.However, no significant differences were observed in emulsion stability, appearance, or taste.Based on the results of all test parameters, the best formulation was the use of 5% mackerel oil (EM5), which yielded an omega-3 content of 1.27%, comprising 0.85% EPA and 0.42% DHA.

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