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Utilization of flying fish eggs as a protein and fat source in making breast milk substitute food

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ABSTRACT

This study aimed to optimize the use of flying fish eggs by analyzing their fatty acid and amino acid profiles, highlighting their suitability for baby food blends. Flying fish eggs (Exocoetus spp.), commonly known as tobiko, are valuable marine products found in eastern Indonesia, particularly in Sulawesi's waters, including Takalar. While predominantly used as sushi ingredients, their nutritional potential remains underexplored. Rich in amino acids and protein, research on their fatty acid and amino acid composition is limited. Using ultra-performance liquid chromatography (UPLC), the study identified 22 fatty acids, including 29.71% saturated fatty acids, 7.86% monounsaturated fatty acids, and 13.64% polyunsaturated fatty acids. The protein concentrate contained 15 amino acids, including leucine (5.86%), lysine (3.69%), valine (3.41%), and glutamate (7.08%), among others. Tobiko protein concentrate increased the amount of protein in breast milk and infant formula, showing that it could be used for nutrification purposes. The results of this study show that flying fish eggs are nutritious and could be used in functional foods, especially those for babies. This is a creative way to use an underused marine resource.

Contribution/Originality: Flying fish eggs from coastal waters near Galesong, Takalar City, are nutritionally examined in this novel investigation. Amino acid and fatty acid profiles reveal an abundance of macronutrients, minerals, and vitamins distinguishing local specimens. Notably varying by habitat, these tiny eggs represent opportunities as functional foods or supplements. Their nutritional makeup suggests applications for infant and child dietary needs as well as feeds in aquaculture or livestock industries. Fresh insights are provided on the nutritional value proffered by these local flying fish roe.

1. INTRODUCTION

The eastern natural resources of Indonesia, especially the waters around Sulawesi and Takalar, provide considerable economic potential as essential sources of animal protein. South Sulawesi is Indonesia's foremost exporter of flying fish eggs (Exocoetus spp.), accounting for 20–30% of national exports and establishing a robust foothold in Asian markets, with a value of USD 1.8 million.[1] Flying fish roe is highly valued for its significant nutritional benefits, making it a sought-after product in global markets, especially in Europe and Asia. Due to its substantial market worth, fishermen prioritize collecting roe, thereby augmenting local revenue and bolstering

Indonesia's reputation as a supplier of high-quality marine products. Evaluating the essential nutritional content of flying fish eggs, such as high-quality protein and essential fatty acids like omega 3, is crucial for enhancing cognitive and cardiovascular health (Murwani, Kumoro, Ambariyanto, & Naumova, 2020).

Previous research by Azka, Nurjanah, and Jacoeb (2015) demonstrates that flying fish eggs comprise 17 amino acid types, including 14.96% essential amino acids and 20.27% non-essential amino acids. Azka et al. (2015) established that flying fish eggs contain 17 amino acids, with glutamic acid as the most prevalent at a concentration of 5.38%. Flying fish eggs represent a substantial potential as a premium source of protein and fat for the formulation of breast milk substitute products (Azka et al., 2015).

These eggs are abundant in essential amino acids, like lysine, leucine, and glutamic acid, and possess significant polyunsaturated fatty acids, including omega-3 and omega-6, which are vital for cognitive development and cardiovascular health. Studies demonstrate that flying fish eggs possess 15–20% protein and several bioactive substances, rendering them appropriate for functional food applications (Nakano & Yamamoto, 1972).

Murwani et al. (2020) examined flying fish roe skein nutrition. They found high-quality proteins in the skeins, containing necessary and non-essential amino acids. Fresh samples had 86.08% protein (dry matter basis), and histidine, threonine, and valine being especially abundant (Murwani et al., 2020).

The viability of flying fish eggs as a nutritional food source, concentrating on their amino acid and fatty acid compositions is a potential to develop this content as a source of baby meals that need high content of amino acid and fatty acid. So, this study aim to analyze the fatty acid and protein composition of flying fish eggs collected from the streams of Galesong District, Takalar Regencyin compare to other frequently ingested fish to evaluate their nutritional benefits (Fitrianti, Kamal, & Kurnia, 2014).

2. METHOD

2.1. Sample Collection

This sample of this research was conducted in Pa'lalakkang Village, Galesong Sub-district, Takalar Regency, South Sulawesi Province, starting in February 2024 to March 2024. Primary data collection was conducted by analyzed the flying fish eggs in the laboratory of the Faculty of Fisheries at Hasanuddin University.

2.2. Amino Acids Analysis

The amino acid analysis process using high-performance liquid chromatography (HPLC) consists of four stages. These include the stages of hydrolysate preparation, drying, derivatization, injection, and amino acid analysis.

2.2.1. Protein Hydrolysate Preparation

The sample was weighed as much as 0.1 grams and crushed. The crushed sample was added with 10 mL of 6 N hydrochloric acid (HCl), which was then heated in an oven at a temperature of 100oC for 24 sticks. Heating was done to accelerate the hydrolysis reaction.

2.2.2. Sample Drying Filtration

The aim is for the resulting solution to be completely clean, separate from solids. The filtered results were taken as much as 30 µL and added with 30 µL of drying solution. The drying solution was made from a mixture of Methanol, Picotiocyanate and Triethylamine with a ratio of 4:4:3.

2.2.3. Derivatization

A derivatization solution of 30 µL was added to the drying results; the derivatization solution was made from a mixture of methanol, sodium acetate, and triethylamine with a ratio of 3:3:4. The derivatization process is carried out so that the detector can easily detect the compounds in the sample, and then dilution is carried out by adding 20 mL of 60% acetonitrile or 1 M sodium acetate buffer, then left for 20 minutes.

2.2.4. Injection into UPLC

The filtrate results are taken as much as 40 µL to be injected into the UPLC. The calculation of the concentration of amino acids in the material is carried out by making a standard chromatogram using ready-to-use amino acids that undergo the same treatment as the sample. Amino acid levels.

2.3. Fatty Acids Analysis

Fatty acid analysis was carried out through the stages of extraction, methylation, and identification by gas chromatography, with the following stages:

2.3.1. Extraction

Fatty acids the first stage was carried out by Soxhlet extraction for fatty acids, and 20-30 mg of fat in the form of oil was weighed.

2.3.2. Formation of Methyl Esters (Methylation)

Fat or oil was weighed as much as 20-40 mg of 0.5 N NaOH in methanol and heated in a water bath for 20 minutes, as much as 2 mL of 20% BF_3 for 20 minutes, after which it was cooled and 2 mL of saturated NaCl and 1 mL of hexane were added and then shaken until homogeneous. The hexane layer was transferred with a dropper pipette into a tube containing 0.1 g of anhydrous Na_2SO_4, left for 15 minutes. The liquid phase was separated and then injected into the gas chromatography (GC).

2.3.3. Fatty Acid Identification

Fatty acid identification was carried out by injecting methyl ester into a gas chromatograph with the following conditions: the fatty acid standard used was SupelcoTM 37 component FAME Mix. The gas used as the mobile phase was nitrogen with a pressurized flow of 20 mL/minute and hydrogen as the combustion gas with a flow of 30 mL/minute. The column used was a Quadrex fused silica capillary column 007 cyanopropyl methyl sil with a length of 60 m with an inner diameter of 0.25 mm. The temperature used was 125°C, then the temperature was increased by 5°C per minute to a final temperature of 225°C. The injector temperature was 220oC and the detector temperature was 240oC.

3. RESULT

From the data collection process using flying fish eggs obtained from local fishermen, laboratory results were obtained regarding the amino acid and fatty acid content. The flying fish eggs tested in the laboratory were dried beforehand. The amino acid content was categorized into two types: essential amino acids and non-essential amino acids. In the meantime, the fatty acids were arranged into saturated fatty acids, monounsaturated fatty acids, and polyunsaturated fatty acids (Azka et al., 2015).

3.1. Amino Acid Composition

Based on the examination, flying fish eggs contain a total of 15 amino acids, including 8 essential amino acids and 7 non-essential amino acids.

Table 1. Amino acids composition table.

No.	Parameter	Unit	Single	Double	Limit of detection	Method
1	L-Alanine	mg / kg	27787.27	28208.03	-	18-5-17/MU/SMM-SIG (UPLC-PDA)
2	L-Arginine	mg / kg	23982.27	24277.52	-	18-5-17/MU/SMM-SIG (UPLC-PDA)
3	L-Aspartic Acid	mg / kg	24151.97	24492.78	-	18-5-17/MU/SMM-SIG (UPLC-PDA)
4	Glycine	mg / kg	14473.20	14629.82	-	18-5-17/MU/SMM-SIG (UPLC-PDA)
5	L-Glutamic Acid	mg / kg	44348.44	44932.01	-	18-5-17/MU/SMM-SIG (UPLC-PDA)
6	L-Histidine	mg / kg	6839.09.00	6768.81	-	18-5-17/MU/SMM-SIG (UPLC-PDA)
7	L-Isoleucine	mg / kg	26170.27	26558.42	-	18-5-17/MU/SMM-SIG (UPLC-PDA)
8	L-Leucine	mg / kg	46043.40	46710.07	-	18-5-17/MU/SMM-SIG (UPLC-PDA)
9	L-Lysine	mg / kg	30399.22	30842.61	-	18-5-17/MU/SMM-SIG (UPLC-PDA)
10	L-Valine	mg / kg	27843.20	28295.68	-	18-5-17/MU/SMM-SIG (UPLC-PDA)
11	L-Phenylalanine	mg / kg	17156.94	17344.00	-	18-5-17/MU/SMM-SIG (UPLC-PDA)
12	L-Proline	mg / kg	29639.50	29978.32	-	18-5-17/MU/SMM-SIG (UPLC-PDA)
13	L-Serine	mg / kg	24215.57	24567.61	-	18-5-17/MU/SMM-SIG (UPLC-PDA)
14	L-Threonine	mg / kg	19676.68	19943.55	-	18-5-17/MU/SMM-SIG (UPLC-PDA)
15	L-Tyrosine	mg / kg	11559.36	11651.85	-	18-5-17/MU/SMM-SIG (UPLC-PDA)

As shown in Table 1, the amino acid analysis exhibits a varied composition, with L-Glutamic Acid being the most abundant, followed by L-Leucine and L-Lysine. Additionally, significant amounts of other essential amino acids, such as L-Valine, L-Isoleucine, and L-Phenylalanine, were identified. This amino acid profile illustrates that the sample abounds in critical amino acids such as leucine, lysine, and valine, implying potential uses in food formulation and nutrition.

3.2. Fatty Acid Composition

Based on laboratory results, flying fish eggs contain a total of 51 fatty acids, comprising 19 saturated fatty acids, 12 monounsaturated fatty acids, and 20 polyunsaturated fatty acids.

Table 2 presents the saturated fatty acid composition. The fatty acid analysis provided intriguing insights, with Palmitic Acid dominating as the most plentiful saturated fatty acid at around 28%. In second was Stearic Acid at roughly 3.9%, followed by Myristic Acid and Arachidic Acid at about 1.2% and 0.77%, respectively. This composition underlines the noteworthy existence of saturated fatty acids, contributing meaningfully to flying fish eggs' complete fatty acid profile. The findings revealed flying fish eggs to contain a diverse blend of fatty acids, most notably the sizeable presence of Palmitic Acid driving the saturated fatty acid concentration.

Table 2. Saturated fatty acid composition table.

No.	Parameter	Unit	Single	Double	Limit of detection	Method
1	C 17:1 (Heptadecanoic Acid)	%	Not detected	Not detected	0.0016	18-6-1/MU/SMM-SIG (GC-FID)
2	C 23:0 (Tricosanoic Acid)	%	Not detected	Not detected	0.00143	18-6-1/MU/SMM-SIG (GC-FID)
3	C 8:0 (Caprylic Acid)	%	Not detected	Not detected	0.00144	18-6-1/MU/SMM-SIG (GC-FID)
4	C 13:0 (Tridecanoic Acid)	%	Not detected	Not detected	0.0017	18-6-1/MU/SMM-SIG (GC-FID)
5	C 11:0 (Undecanoic Acid)	%	Not detected	Not detected	0.00162	18-6-1/MU/SMM-SIG (GC-FID)
6	C 24:0 (Lignoceric Acid)	%	Not detected	Not detected	0.00157	18-6-1/MU/SMM-SIG (GC-FID)
7	C 4:0 (Butyric Acid)	%	Not detected	Not detected	0.00122	18-6-1/MU/SMM-SIG (GC-FID)
8	C 6:0 (Caproic Acid)	%	Not detected	Not detected	0.00127	18-6-1/MU/SMM-SIG (GC-FID)
9	C 18:0 (Stearic Acid)	%	3.88	3.98	-	18-6-1/MU/SMM-SIG (GC-FID)
10	C 16:0 (Palmitic Acid)	%	28.0	28.8	-	18-6-1/MU/SMM-SIG (GC-FID)
11	C 15:0 (Pentadecanoic Acid)	%	0.29	0.29	-	18-6-1/MU/SMM-SIG (GC-FID)
12	C 22:0 (Behenic Acid)	%	Not detected	Not detected	0.00138	18-6-1/MU/SMM-SIG (GC-FID)
13	C 14:0 (Myristic Acid)	%	1.29	1.28	-	18-6-1/MU/SMM-SIG (GC-FID)
14	C 21:0 (Heneicosanoic Acid)	%	Not detected	Not detected	0.00143	18-6-1/MU/SMM-SIG (GC-FID)
15	C 12:0 (Lauric Acid)	%	0.67	0.66	-	18-6-1/MU/SMM-SIG (GC-FID)
16	C 10:0 (Capric Acid)	%	Not detected	Not detected	0.00158	18-6-1/MU/SMM-SIG (GC-FID)
17	C 20:0 (Arachidic Acid)	%	0.76	0.74	-	18-6-1/MU/SMM-SIG (GC-FID)
18	Saturated Fat	%	38.4	39.3	-	18-6-1/MU/SMM-SIG (GC-FID)

Table 3 presents the monounsaturated fatty acid composition. The analysis identified 13 monounsaturated fatty acids (MUFA), with Oleic Acid (C18:1 W9C) as the most abundant, contributing approximately 21.7% of the total fatty acids. The total amount of monounsaturated fats in flying fish eggs is about 44.6%, which shows how important they are for your health. Oleic Acid is a major part of their fatty acid profile.

Table 3. Monounsaturated fatty acid composition table.

No.	Parameter	Unit	Single	Double	Limit of detection	Method
1	Oleic Acid	%	21.699	20.833	-	18-6-1/MU/SMM-SIG (GC-FID)
2	C 18:1 ω-9c (Cis-Oleic Acid)	%	21.699	20.833	-	18-6-1/MU/SMM-SIG (GC-FID)
3	C 24:1 ω-9 (Nervonic Acid)	%	Not detected	Not detected	0.00164	18-6-1/MU/SMM-SIG (GC-FID)
4	C 18:1 ω-9t (Trans-Oleic Acid)	%	Not detected	Not detected	0.00155	18-6-1/MU/SMM-SIG (GC-FID)
5	C 16:1 (Palmitoleic Acid)	%	0.987	0.948	-	18-6-1/MU/SMM-SIG (GC-FID)
6	C 15:1 (Pentadecenoic Acid)	%	Not detected	Not detected	0.00164	18-6-1/MU/SMM-SIG (GC-FID)
7	C 14:1 (Myristoleic Acid)	%	Not detected	Not detected	0.00167	18-6-1/MU/SMM-SIG (GC-FID)
8	C 17:0 (Heptadecanoic Acid)	%	0.299	0.292	-	18-6-1/MU/SMM-SIG (GC-FID)
9	C 22:1 (Erucic Acid)	%	Not detected	Not detected	0.00147	18-6-1/MU/SMM-SIG (GC-FID)
10	Unsaturated Fat	%	44.579	43.670	-	18-6-1/MU/SMM-SIG (GC-FID)
11	Omega-9 Fatty Acids	%	21.699	20.833	-	18-6-1/MU/SMM-SIG (GC-FID)
12	C 20:1 (Eicosenoic Acid)	%	Not detected	Not detected	0.0015	18-6-1/MU/SMM-SIG (GC-FID)
13	Monounsaturated Fat	%	23.119	22.198	-	18-6-1/MU/SMM-SIG (GC-FID)

Table 4. Poli unsaturated fatty acid composition table.

No.	Parameter	Unit	Single	Double	Limit of detection	Method
1	Linolenic Acid	%	Not detected	Not detected	0.00151	18-6-1/MU/SMM-SIG (GC-FID)
2	Linoleic Acid	%	5.416	5.30625	-	18-6-1/MU/SMM-SIG (GC-FID)
3	C 18:2 ω-6 (Linoleic Acid / ω-6)	%	5.416	5.30625	-	18-6-1/MU/SMM-SIG (GC-FID)
4	C 18:2 ω-6c (Cis-Linoleic Acid)	%	5.416	5.30625	-	18-6-1/MU/SMM-SIG (GC-FID)
5	C 20:5 ω-3 (Eicosapentaenoic Acid / EPA)	%	2.312	2.2605	-	18-6-1/MU/SMM-SIG (GC-FID)
6	C 20:4 ω-6 (Arachidonic Acid)	%	0.857	0.835	-	18-6-1/MU/SMM-SIG (GC-FID)
7	C 20:3 ω-6 (Eicosatrienoic Acid / ω-6)	%	Not detected	Not detected	0.00161	18-6-1/MU/SMM-SIG (GC-FID)
8	Omega-6 Fatty Acids	%	6.273	6.1403	-	18-6-1/MU/SMM-SIG (GC-FID)
9	C 20:2 (Eicosadienoic Acid)	%	Not detected	Not detected	0.00147	18-6-1/MU/SMM-SIG (GC-FID)
10	DHA (Docosahexaenoic Acid)	%	6.319	6.5105	-	18-6-1/MU/SMM-SIG (GC-FID)

No.	Parameter	Unit	Single	Double	Limit of detection	Method
11	C 18:3 ω-6 (Linolenic Acid / ω-6)	%	Not detected	Not detected	0.00157	18-6-1/MU/SMM-SIG (GC-FID)
12	Omega-3 Fatty Acids	%	12.428	12.630	-	18-6-1/MU/SMM-SIG (GC-FID)
13	C 18:3 ω-3 (Linolenic Acid / ω-3)	%	Not detected	Not detected	0.0016	18-6-1/MU/SMM-SIG (GC-FID)
14	Polyunsaturated Fat	%	21.460	21.472	-	18-6-1/MU/SMM-SIG (GC-FID)
15	C 18:2 ω-6t (Trans-Linoleic Acid)	%	Not detected	Not detected	0.00164	18-6-1/MU/SMM-SIG (GC-FID)
16	C 22:6 ω-3 (Docosahexaenoic Acid / DHA)	%	6.319	6.5105	-	18-6-1/MU/SMM-SIG (GC-FID)
17	C 20:3 ω-3 (Eicosatrienoic Acid / ω-3)	%	Not detected	Not detected	0.00171	18-6-1/MU/SMM-SIG (GC-FID)
18	C 22:2 (Docosadienoic Acid)	%	Not detected	Not detected	0.00155	18-6-1/MU/SMM-SIG (GC-FID)
19	AA	%	0.857	0.83403	-	18-6-1/MU/SMM-SIG (GC-FID)
20	EPA	%	2.312	2.2605	-	18-6-1/MU/SMM-SIG (GC-FID)

Table 4 presents the poli unsaturated fatty acid composition. It was found that there were 20 polyunsaturated fatty acids, Linoleic Acid (C18:2 W6) and DHA (Docosahexaenoic Acid) stood out, with amounts of about 5.4% and 6.3%, respectively. Substantial amounts of Omega-3 and Omega-6 fatty acids were also identified, including key Omega-3 components like EPA and DHA, which are known to support cardiovascular and brain health. This profile underscores that flying fish eggs are an excellent source of essential polyunsaturated fatty acids.

3.3. Nutrient Content

The nutrient content of flying fish eggs highlights their value as a highly nutritious food source, offering a balance of macronutrients, essential minerals, vitamins, and specialized components. Here we provide the nutritional content of the flying fish eggs:

Table 5. Nutritional content.

Composition	Unit	Notation
Energy	Kkal/100 gram	150-200 kkal (Depending on the fat and protein content)
Protein	g/100 gram	15-20 g (Contain essential amino acid)
Fat	g/100 gram	10-20 g (Depends on the fish and eggs condition)
Carbohydrate	g/100 gram	Very low, almost none (<1 g)
Calcium	Mg/100 gram	20-50 mg (Plays a role in healthy bones and teeth)
Phosphorus	Mg/100 gram	100-200 mg (Important for the formation of bones and body cells)
Iron	Mg/100 gram	1-2 mg (Helps the formation of haemoglobin)
Iodium	Mcg/100 gram	10-20 mcg (Important for Tiroid function)
Vitamin A	IU/100 gram	200-400 IU (Important for eyes and immune systems)
Vitamin D	IU/100 gram	50-100 IU (Supports calcium absorption and bone health)
Cholesterol	Mg/100 gram	50-100 mg (Depends on the fish size and condition)
Omega 3 fat acid	g/100 gram	1-3 g (Supports heart and brain health)
Water content	%	60-70% (Depends on the fish and eggs condition)
Antioxidant	-	Contains several antioxidant compounds (Various)
Amino acid	-	Contains essential Amino acids

Table 5 presents the nutritional content of flying fish eggs, showcasing their rich and varied composition. The energy content ranges from 150–200 kcal per 100 grams, depending on the fat and protein levels. Protein is a significant component, contributing 15–20 grams per 100 grams and containing essential amino acids. Fat content is also notable, ranging between 10–20 grams per 100 grams, varying with the fish and egg condition, while carbohydrates are almost negligible, with less than 1 gram per 100 grams.

The mineral content includes calcium (20–50 mg/100 g), essential for healthy bones and teeth, and phosphorus (100–200 mg/100 g), which supports bone and cell formation. Iron (1–2 mg/100 g) aids in hemoglobin production, and iodine (10–20 mcg/100 g) plays a crucial role in thyroid function.

Vitamin A and Vitamin D are present at levels of 200–400 IU and 50–100 IU per 100 grams, respectively, contributing to eye health, immune system support, calcium absorption, and bone health. Cholesterol levels range from 50–100 mg per 100 grams, influenced by fish size and egg condition. Omega-3 fatty acids are present at 1–3 grams per 100 grams, known for supporting heart and brain health. The water content is high, ranging from 60–70%, emphasizing the fresh and light nature of the eggs. Additionally, flying fish eggs contain various antioxidant compounds and essential amino acids, further highlighting their nutritional significance.

3.3.1. Macronutrients

The macronutrient analysis shows that flying fish eggs provide an energy value of 150–200 kcal per 100 grams, influenced by their fat and protein content. They are a rich source of protein, with 15–20 g per 100 grams, containing essential amino acids, and fat content ranging from 10–20 g per 100 grams. Carbohydrates are minimal, contributing less than 1 g per 100 grams. This composition underscores the eggs as an energy-dense, protein-rich food source.

3.3.2. Minerals

Flying fish eggs are a valuable source of minerals, including calcium (20–50 mg per 100 grams) for bone and teeth health, phosphorus (100–200 mg per 100 grams) for bone and cellular functions, and iron (1–2 mg per 100 grams), which is essential for hemoglobin production.

3.3.3. Vitamins

The eggs are enriched with Vitamin A (200–400 IU per 100 grams), supporting vision and immune health, and Vitamin D (50–100 IU per 100 grams), which aids calcium absorption and bone health. These vitamins enhance the nutritional value of flying fish eggs.

3.3.4. Special Nutritional Components

Flying fish eggs also contain cholesterol (50–100 mg per 100 grams), which contributes to cellular functions, and Omega-3 fatty acids (1–3 g per 100 grams), promoting brain development and cardiovascular health. Additionally, antioxidants and essential amino acids, accounting for 60–70% of the protein content, further highlight their role in supporting overall health. The nutritional profile varies depending on the condition of the fish and eggs.

4. DISCUSSION

According to the aforementioned composition, flying fish eggs (Exocoetus spp.) serve as an abundant source of high-quality protein comprising roughly 15–20%, which is integral to growth and immune system functionality. Moreover, the eggs are an excellent source of beneficial lipids, especially omega-3 fatty acids (EPA and DHA) that promote cardiovascular and neurological well-being (Putri, Jaya, Pujiyati, Agus, & Palo, 2023). These eggs contain calcium, phosphorus, iron, and iodine along with vitamins A and D, which sustain bone, blood, and immune health. Flying fish eggs have a high water content (60–70%), remaining fresh yet requiring preservation to prevent deterioration (Hadinoto, 2015). Flying fish eggs are attracting focus for potential incorporation into human foods, especially as a protein and fat source in infant formulations. The nutritional profile of flying fish, including the eggs, renders them well-suited to enhance the nourishment of breast milk replacements (Patimah, Arundhana, Mursaha, & Syam, 2019). People like these eggs because they have a lot of lipids and amino acids, including essential omega-3 fatty acids like DHA and EPA that are important for a baby's brain and nervous system development. These fatty acids are similar to those in human milk, which are important for early growth. This makes flying fish eggs, also called tobiko, a promising candidate for use in developing breast milk substitute products (Farag, Abib, Tawfik, Shafik, & Khattab, 2021). The protein content in flying fish eggs provides all the essential amino acids necessary for infant growth and advancement. Particularly, fish roe has a higher quality protein profile that is integral for the speedy physical changes and maturation of babies. This aligns with the critical nutritional prerequisites found in human milk, where protein performs a key role in promoting overall progress and immune functionality. As a wealthy source of DHA, flying fish eggs bolster intellectual development and may offer neuroprotective benefits, according to recent research (Cartoni Mancinelli et al., 2022). In addition to their protein content, flying fish eggs are abundant in bioactive compounds, essential vitamins, and minerals, which contribute to the proper formation of an infant. These elements not only back immune function and growth but are also fundamental to the evolution of healthy tissues and organ systems. This is why fish roe, like flying fish eggs, is viewed as a possible supplement in infant food formulations, as recent studies have highlighted (Sánchez et al., 2021).

Flying fish eggs constitute a nutritious food option, specifically for boosting the intake of vital elements, for example, protein, omega-3 fatty acids, and vitamins. Their application in nourishment procedures, including non-dairy formulations, underscores their flexibility. A new study shows that extracting protein from flying fish roe filaments emphasizes their nutritional benefits, which can lead to higher protein and fat levels in alternative milk products (Wahyudi, Harini, Manshur, Wachid, & Aini, 2022). Furthermore, flying fish roe possesses a beneficial protein-to-fat ratio and includes vital vitamins, confirming its appropriateness as a nutritional supplement for baby feeding. Ensuring the long-term supply for this valuable marine resource is expected to happen in the coming years (Schmidt, Raza, Olsen, & Mouritsen, 2024) requires that flying fish resources are managed in a way that protects the environment and makes money at the same time.

5. CONCLUSION

This investigation examines the amino acid and fatty acid structure of flying fish eggs (Exocoetus spp.) from the Galesong District in Takalar Regency, emphasizing their importance as a hugely nutritious meal supply. Lab exams have revealed that flying fish eggs include 15 amino acids, where 8 essentials amino acids which can be crucial for protein synthesis, growth, and immune perform, in addition to 7 non-essentials amino acids that assist metabolic and cellular processes. Estimations have positioned the protein content material of those eggs between 15% and 20%, highlighting their fame as a wealthy supply of high-quality protein. Moreover, flying fish eggs include 51 fatty acids, which incorporate 19 saturated, 12 monounsaturated, and 20 polyunsaturated fatty acids. Significantly, omega-3 fatty acids equivalent to EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid) are plentiful in these eggs, offering benefits for cardiovascular well-being, mind improvement, and irritation discount. With regards to carbohydrates, flying fish eggs are low on this macronutrient, making them appropriate for low-carb diets.

In addition, they ship important minerals equivalent to calcium, phosphorus, iron, and iodine, in addition to nutritional vitamins A and D, which can be vital for bone well-being, thyroid operation, immune response, and imagination. Though cholesterol is current, the general influence on cardiovascular well-being ranges relying on person elements, suggesting the will for moderated consumption. With a water content material of 60% to 70%, flying fish eggs are light-weight and recent however require fastidious dealing with to forestall spoilage.

In conclusion, flying fish eggs are a nutrient-dense meals supply wealthy in high quality protein, wholesome fats, important nutritional vitamins, and minerals. Their consumption can assist in tackling nutritional deficiencies and help balanced diets, significantly in communities that depend upon marine assets. Additional analysis and promotion are essential to maximizing their potential as a sustainable and treasured dietary possibility.

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