Fabrication and Characterization of Microcapsules Containing Eel Fish Oil (*Anguilla marmorata* (Q.) GAIMARD)

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Abstract. Eel (*Anguilla marmorata* (Q.) Gaimard) oil consists of unsaturated fatty acids such as Omega-3 and Omega-6, which quickly oxidize to become rancid under the influence of oxygen be inhibited by microencapsulation by the spray drying method. This study was designed to identify the microcapsule characteristics of yellow eel oil extract by the spray drying method. Eel fish oil was yielded by the soxhletation method using diethyl ether as the solvent. Bentonite 3% was applied as an adsorbent for the purification step. Purified oil of the yellow eel phase was made in microcapsules with maltodextrin: Arabic gum coating ratio of 1:1 (F1), 2:1 (F2), and 1:2 (F3). The F1 had the highest yields (24.59%) and encapsulation efficiency (58.09%) for eel fish oil microcapsules. The moisture content of each formula met the requirement (2.71–7.06%). The yellow eel phase has a round morphology with a reasonably smooth to slightly rough surface. Eel fish oil could be formulated as microcapsules and applied as a nutritional supplement in the future.

Keywords: characterization · fish oil · microencapsulation · spray drying

1 Introduction

One of Sulawesi's native fish species is the eel (*Anguilla marmorata* (Q.) Gaimard). The population of eel is found in the Central Sulawesi Rivers, Poso Lake, and the mouth of the Palu Bay River [1]. The eel is a catadromous fish belonging to the *Anguilliformes* tribe and can migrate between freshwater and seawater. Eels have five stages of development, namely *Leptocephalus*, which is shaped like a leaf; glass eels with a clear or transparent appearance; elver in the form of seeds with skin color; yellow or young eels, mainly found in fresh, brackish, and seawater, and silver eels undergoing gonadal maturation [2]. According to Jamaluddin et al. (2018), the content of saturated, monounsaturated, and polyunsaturated fatty acids of yellow eel from the Palu River and Lake Poso are 2.766 g/100 g, and 0.275 g/100 g, 4.029 g/100 g, and 0.276 g/100 g, and 0.541 g/100 g and 0.102 g/100 g [3]. Polyunsaturated fatty acids (PUFA) have unsaturated double bonds in the acyl chain. Regarding human health and nutrition, omega-3 and omega-6 are two essential

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families of PUFAs. Omega-3 components are α-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA), whereas omega-6 consists of α-linoleic acid (LA), dihomo-γ-linolenic acid (DGLA), and arachidonic acid (AA) [4]. Due to their excellent dietary supply of essential fatty acids, particularly Polyunsaturated Fatty Acids (PUFA) like EPA (Eicosapentaenoic Acid) and DHA (Docosahexaenoic Acid), fish oil constitutes a functional food element. Numerous studies have suggested that taking fish oil supplements may benefit the heart, brain, and nervous system. However, fish oil has a strong odor and is readily oxidized if not preserved. Polyunsaturated Fatty Acids (PUFA) in fish oil undergo oxidative degradation, which reduces their nutritional value and causes the formation of sour flavors. Antioxidant addition and microencapsulation are typical methods for reducing oxidation [5].

The process of coating tiny solids, gases, and liquid capsules is known as microencapsulation. Microencapsulation guards against oxidation increases oil stability, lengthens the span of time, and releases the substance at predetermined rates under controlled circumstances [6]. Fish oil can be turned into a dry powder via microencapsulation, which allows the addition of omega-3 fatty acids to bread, infant formula, fast food, and other products. Spray drying is frequently employed in food and pharmaceutical industries, to turn liquid materials into dried powders, and it has been extensively utilized to create omega-3 PUFA microcapsules [7]. Compared to other drying techniques like freeze drying, extrusion, and complex coacervation, spray drying has some benefits, such as relatively low costs, the ability to work with heat-sensitive materials, easily accessible equipment, reliable efficiency, and the capability to manage the average particle size of the powders for spray dried emulsions [8]. In light of this background, eel fish oil is microencapsulated using a variety of binding agents to preserve its quality.

2 Materials and Methods

This research has three main stages: sample preparation, fish oil microencapsulation, and microcapsule characteristic evaluation. The eel (*Anguilla marmorata* (Q.) Gaimard) was washed, and the entrails, head, tail, and bones were dismissed. Furthermore, the samples were sliced into a few pieces and dried in an oven at 60 °C for 24 h. The powdered mixture was kept at room temperature [1]. Eel fish powder of 15 g and diethyl ether of 150 ml was put into a fat sleeve and a round bottom flask. Extraction was conducted at 60 °C for 5 h. After that, the solvent was evaporated. The sample was oven at 105 °C for ± 1 h, put in a desiccator to cool down, and weighed until constant. 3% of bentonite adsorbent was added into the extracted crude oil, stirred for 20 min at 29 °C, and centrifuged for 10 min at 6500 rpm at 10 °C to obtain pure oil [3].

The microencapsulation process was carried out by preparing three formulas consisting of several components, including maltodextrin and 25% Arabic gum coating in a ratio (1:1, 1:2, 2:1) (Table 1). The emulsifier formula and coating materials, as well as fish oil, were then stirred to form an emulsion using a homogenizer (100–300 rpm, 15 min). In the emulsion drying stage, the spray drying process was carried out with a flow rate of 10 mL/min at inlet and outlet temperatures of 125–145 °C and 70 °C, blower 0.35–0.42, and atomization 6 kPa [14]. The formed microcapsules were then collected in a container for further evaluation.

Table 1. Microencapsulated Formula of Eel Fish (*Anguilla marmorata* (Q.) Gaimard) Oil

No	Composition	Total Material (%)			
		F0	F1	F2	F3
1.	Eel Fish Oil Extract	15	15	15	15
2.	Maltodextrin	–	12.5	16.67	8.33
3.	Arabic Gum	–	12.5	8.33	16.67
4.	Tween 80	5	5	5	5
5.	CMC	0.5	0.5	0.5	0.5
6.	Aquadest	ad 100	ad 100	ad 100	ad 100

Description:
F0: Negative control without coating
F1: Maltodextrin 12.5% and Arabic gum 12.5% (1:1)
F2: Maltodextrin 16.67% and Arabic gum 8.33% (2:1)
F3: Maltodextrin 8.33% and Arabic gum 16.67% (1:2)

The last stage of the experiment was to evaluate the characteristics of the microcapsules, including the percent yield, water content, encapsulation efficiency, and shape and morphology. The test results were statistically analyzed using One-Way Analysis of Variance (ANOVA) with a 95% confidence limit ($P < 0.05$) using the Statistical Package for The Social Science (SPSS) version 20.

3 Results and Discussion

Eel (*Anguilla marmorata* (Q.) Gaimard) from the Palu River is rich in beneficial fish oil. Eel fish oil contains PUFA such as Omega-3 and Omega-6. However, the high content of unsaturated fatty acids in fish oil is leading to a decrease in the fish oil quality because it quickly oxidizes when exposed to oxygen. Therefore, eel fish oil becomes rancid and reduces its shelf life [9]. The microencapsulation process is one of the promising methods to prevent oxidation and damage of the fish oil quality due to environmental sensitivity, namely the coating of active ingredients. Microencapsulation is carried out using specific materials to improve the quality of fish oil [10]. The spray drying method is one of the methods that is widely used because it is more effective, flexible, and produces good quality powder microencapsulated products.

Yield is used to determine the efficiency and effectiveness of a process. The data on the average yield of the microcapsules are presented in Table 1. Table 1 showed that the highest average yield was produced by the formulation of a 1:2 ratio of maltodextrin and gum arabic, which was $26.51 \pm 0.02\%$. As reported by Bhandari et al., a successful spray drying method may be indicated by a product yield of more than 50% [11]. Several factors are involved in product results, one of which is the selection of wall materials. In F3, we used higher gum arabic concentration than maltodextrin. The highest yield in this research demonstrated that gum arabic is the most efficient wall material agent. Due to its higher molecular weight than maltodextrin, gum arabic has a higher glass transition

Table 2. Physical properties of microencapsulated eel fish oil.

Formula	Yield (%)	Moisture content (%)	Encapsulation efficiency (%)
F0	8.70 ± 0.13	2.71 ± 0.23	84.69 ± 5.14
F1	24.59 ± 4.11	6.51 ± 0.29	58.09 ± 3.83
F2	21.80 ± 4.00	7.06 ± 0.19	54.11 ± 0.13
F3	26.51 ± 2.99	6.60 ± 0.27	47.54 ± 2.38

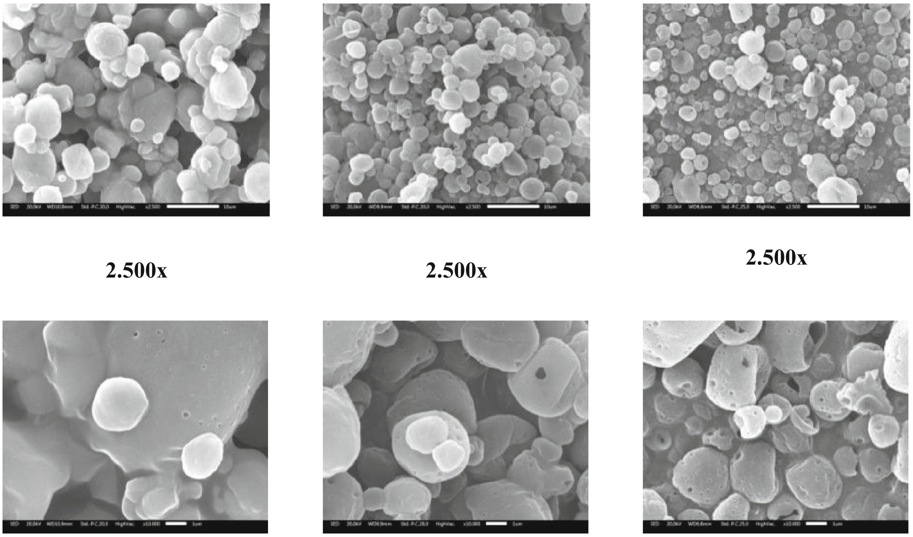
temperature [12]. The molecular weight and glass transition temperature are correlated [13].

The obtained encapsulated fish oil has a moisture content of 2.71 to 7.06%, which is very close to the moisture content percentage reported by Hasibuan et al. (2017) [10]. The moisture content in our study was higher than the highest moisture requirement for the majority of dry powders used in the food sector, between 3% and 4% [14]. It may be due to the composition of maltodextrin and gum Arabic as the wall material and the encapsulation method used for the research. In addition, the absence of a dehumidification accessory in the intake air of the spray drying process to control its relative humidity [15], a value above 5% was found.

The highest encapsulation efficiency value of eel fish oil was found in F1 at 58.09%. F1 was a balanced maltodextrin and gum arabic ratio formula. The formula shows a proportional balance between maltodextrin and gum arabic-coating material, resulting in higher efficiency. Akram et al. (2021) reported intermediate encapsulation efficiency using maltodextrin and gum Arabic in a similar ratio [16]. According to several studies, the type of material and its chemical properties, as well as those of the emulsion that is produced, have a substantial bearing on the durability of the microencapsulated contents [17].

The microcapsules' shape and morphology were determined using a Scanning Electron Microscope (SEM) with magnifications of 2,500x and 10,000x (Fig. 1). The three formulas of the microcapsules have almost the exact shape of a round, reasonably smooth, slightly rough surface. F1 indicated a round shape and a smoother surface. However, it has a non-uniform shape and slightly rough surface indentations caused by uneven shrinkage during drying and cooling. Furthermore, F3 showed almost all have a flattened shape, and some tend to shrink due to the ballooning event during the spray drying process and the microcapsules in a deflated form.

(a) **(b)** **(c)**



2.500x **2.500x** **2.500x**

10.000x **10.000x** **10.000x**

Fig. 1. SEM images of eel fish oil microcapsules produced by 3 different formulae: a) F1, b) F2, c) F3.

4 Conclusion

The extract of eel (Anguilla marmorata (Q.) Gaimard) oil can be made into microcapsules with various ratios of maltodextrin and gum arabic. F1 is the best formula because it produces the highest encapsulation efficiency value of 58.09%, respectively. The use of various coatings (maltodextrin: gum arabic) did not significantly affect the characteristics of the microcapsules of eel oil extract. Furthermore, eel fish oil can be applied as a nutritional supplement by the microencapsulation method.

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