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THE EFFECT OF ENCAPSULATOR MACHINE SPEED ON COMPOSITE MICROCAPSULE SIZE

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Abstract

Microencapsulation is a process that converts solid or liquid materials into capsule form which aims to protect and maintain active ingredients from environmental influences such as humidity, high temperature, light exposure, or oxidation processes. Microcapsule formation can be done using the cross-link method. Microcapsule size is affected by the stirring speed of the encapsulator machine. During microencapsulation of fish meal with eggs and gelatin using the crosslink method, the stirring speed is 3000 rpm, 3500 rpm, 4000 rpm, 4500 rpm, and 5000 rpm. In the microencapsulation process of fish meal with eggs and gelatin, the smallest average diameter at a speed of 5000 rpm, which is 18.220 ± 3.3 µm and has a yield of 26% while the largest diameter at a speed of 3000 rpm, which is 33.53 ± 4.8 µm and has a yield of 28.4%. Based on the results of the Tukey SPSS test, the speeds of 3000 rpm (33.53 ± 4.8 µm), 3500 rpm (30.25 ± 4.4 µm), 4000 rpm (26.30 ± 3.5 µm), 4500 rpm (22.50 ± 4.1 µm), and 5000 rpm (18.220 ± 3.3 µm) were very significantly different ($P < 0.05$) in each treatment.

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Introduction

Feed is a factor that influences the success of fish farming efforts (Simanjuntak *et al.*, 2017). Generally, feed circulating on the market is in the form of pellets (Sukardi *et al.*, 2014). Fish in the larval stage require quality feed with the right feeding frequency to support growth after the yolk runs out. The provision of feed in cultivation activities can be considered several factors, such as quantity, quality of feed, and size of feed (Nuraini *et al.*, 2019). The size factor of feed in fish larval cultivation activities is a factor that affects the level of life of fish larvae (Sukardi *et al.*, 2014).

The solution to overcome this is to make the right feed, namely feed with a micro size that is in accordance with the opening of the fish larvae (Prasetya *et al.*, 2016). Microcapsules are particles with a size of 0.2-5000 µm which have two main parts, namely the matrix or wall and the active ingredient inside which is called the core material . The core material of microcapsules can be solid, liquid, and gas (Arshady, 1990). Microcapsules can generally have sizes ranging from several micrometers or several millimeters (Sri *et al.,* 2012). Composites can be defined as a combination of two or more matrix materials that have different properties. (Setyawan *et al.,* 2012). The combination of matrix materials will produce better material properties compared to those of the constituent components (Widiarta *et al.,* 2017).

In the process of making microcapsules, the shape and size of microcapsules can be influenced by several factors, one of which is the stirring speed in the microencapsulation process (Djajadisastra & Novitasari, 2004). According to Jayanudin *et al.,* (2018), increasing the stirring speed in the microencapsulation process can reduce the size of the microcapsules formed. This study will study the effect of stirring speed on the encapsulator machine on the size and characteristics of the resulting composite microcapsules.

Materials and Methods

Time and Location

This research was conducted using experimental and observational methods, involving core materials and matrices tested. The research conducted from August to December 2023 at the Feed Technology Laboratory, Fisheries and Marine Sciences Faculty, Jenderal Soedirman University.

Research Procedures

The treatments used was the stirring speed in the formation of microcapsules as follows: (A) 3000 rpm, (B) 3500 rpm, (C) 4000 rpm, (D) 4500 rpm, and (E) 5000 rpm. The treatment was based on trialling and error. The difference in speed below 500 rpm does not make a significant difference. A slight increase in speed did not show significant results on microcapsule particle size (Sukardi *et al.,* 2024). The materials used are grouped into tools and materials. The tools used are an encapsulator machine, thermogun, tachometer, binocular microscope, stereo microscope, and a Euromex CMEX 3 DC-3000C camera. The materials used in the study as feed formulation components consist of fish meal as the core ingredient, whole shelled free-range chicken eggs and gelatin used as matrix materials, and water, tween 80, and fish oil as additional ingredients. The materials used in the study for data analysis are the total weight of the materials used, the final weight of the microcapsule feed after drying, buoyancy, size, and shape of the microcapsules.

The encapsulation process using the cross-linking emulsion technique used is a modification referring to Arshady (1990), fish meal is measured based on the total proportion of the formulation. Gelatin powder is dissolved in water. Additional ingredients such as tween 80, water, and fish oil are weighed according to the specified formulation. Tween 80 is used to help dispersion and stabilization in the formulation. Water is added as a solvent for the gelatin solution and as a medium for mixing other ingredients. Fish oil is used to increase the nutritional content of microcapsule feed. The Encapsulation Process with the Cross-linking Emulsion Method consists of three stages (1) Droplet formation stage: the initial stage of mixing two hydrophilic and hydrophobic phases which will produce small granules; (2) Cross-link polymer stage: the droplet hardening stage which aims to increase the stability of the microcapsules and protect the core material inside; (3) Product recovery stage: the final stage in making microcapsules which aims to allow the microcapsules to be stable after heating before the next process.

The main parameter in this study was the diameter of the microcapsules taken from 60 microcapsules randomly using a stereo microscope with a magnification of 20x. Supporting parameters consisted of yield, water content, buoyancy, and microcapsule characteristics.

Yield

The yield formula refers to Xiao et al. (2007):

$$Yield = \frac{W_c}{W_0} \times 100\%$$

Where:

Wc = final weight of the microcapsules/weight of the microcapsules after drying (gram)

W0 = initial weight of the microcapsules/weight of the wet microcapsules (before drying) (gram)

Water Content

The water content formula refers to Sah et al. (1995) :

$$Water\ Content = \frac{W_1 - W_2}{W_2} \times 100\%$$

Where:

W_1 = final weight of the microcapsules/weight of the microcapsules after drying (gram)

W_2 = initial weight of the microcapsules/weight of the wet microcapsules (before drying) (gram)

Buoyancy

The buoyancy test refers to Safitri *et al.*, (2020), dropping 0.5 grams of microcapsule feed into 250 ml of distilled water, then the time required for the feed to reach the bottom of the water is calculated. Buoyancy can be expressed in units of time such as seconds, minutes, and hours (Fahrizal & Ratna, 2020; Hutagalung *et al.*, 2022).

Characteristics of Microcapsules

The characteristics of the microcapsules were observed directly and using the aid of a binocular microscope equipped with a Euromex CMEX 3 DC-3000C camera with a magnification of 400x. The characteristics observed consisted of color, aroma, and shape of the microcapsules. Data processing was carried out on SPSS software using analysis of variance or ANOVA, which then if there was a significant ($P < 0.05$) further testing would be carried out using the Tukey test.

Results and Discussion

Microcapsule Diameter

The results of observations on the size of the microcapsules showed that the size of the microcapsules was influenced by the stirring speed of the encapsulator machine. The increasing speed caused the size of the microcapsules to become smaller. The results of the analysis showed that the size of the microcapsules at speeds of 3000 rpm, 3500 rpm, 4000 rpm, 4500 rpm, and 5000 rpm, respectively, were 33.53 ± 4.8 µm, 30.25 ± 4.4 µm, 26.30 ± 3.5 µm, 22.50 ± 4.1 µm, and 18.22 ± 3.3 µm (Figure 1). Significantly different results ($P < 0.05$) were shown in each treatment with the largest microcapsule size at the lowest speed (P1: 3000 rpm) and the smallest microcapsule size at the highest speed (P5: 5000 rpm).

The formation of droplets into small particles is enabled by high speed, while at low speeds, the droplets tend to merge and

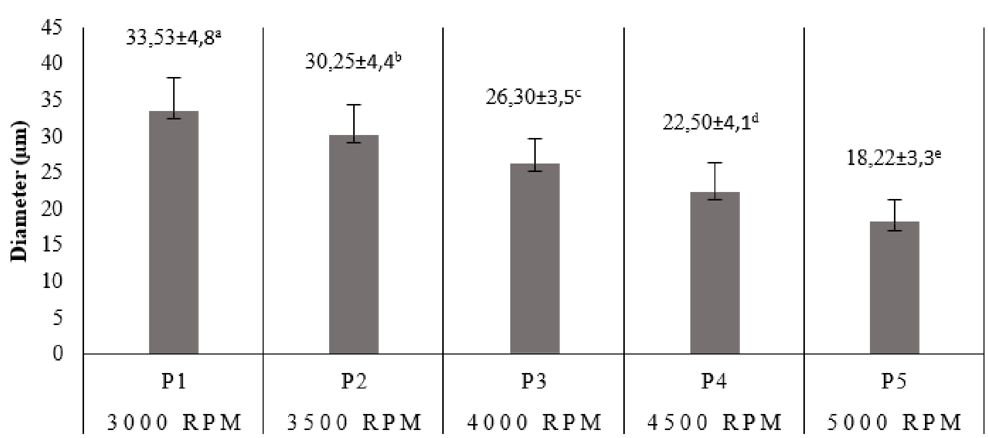

Figure 1. Microcapsule Diameter

create larger droplets during the encapsulation process (Berchane *et al.,* 2006; Jayanudin *et al.,* 2018). Generally, natural feeds that are often used in larval maintenance are microalgae and rotifers. Salmia et al. (2021) stated that the size of rotifers that can be used as natural feed ranges from 5-200 µm. Microalgae as natural feed generally have a size ranging from 2-20 µm (Iba *et al.,* 2019; Nirwawan *et al.,* 2019). Based on the size of the natural feed used, the microcapsule feed produced in all treatments can be used as a substitute for natural rotifer feed. Sukardi *et al.,* 2024, stated that different speeds produced different average microcapsule diameters. At 500 rpm, the diameter of the microcapsules produced tended to be larger than the diameter of the microcapsules produced at 1300 rpm. However, a slight increase in speed (200 rpm) did not show significant results on the particle size of the microcapsules formed. Different stirring speeds will affect the density of inclusion particles and the thickness of the polymer layer.

Other important things to consider in production are yield, water content, and buoyancy. Yield is an important assessment in the application of treatment (Dewatisari *et al.,* 2018). These parameters are used as a percentage to measure how efficient and effective treatment is used (Hasrini *et al.,* 2017).

Yield Microcapsules

The calculation results showed that the yield of microcapsules at speeds of 3000 rpm, 3500 rpm, 4000 rpm, 4500 rpm, and 5000 rpm, respectively, were 28.96%, 28.78%, 29.34%, 29.41%, and 31.09% (Figure 2), with the highest yield at the highest speed treatment (P5: 5000 rpm). The higher the yield, the more efficient the treatment applied (Hasrini *et al.,* 2017). High speed is thought to increase more solutes or

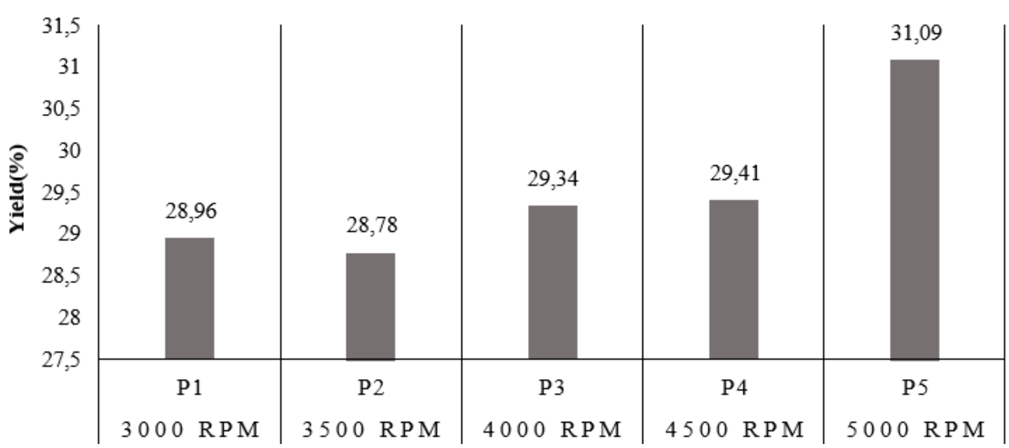

Figure 2. Yield Microcapsule

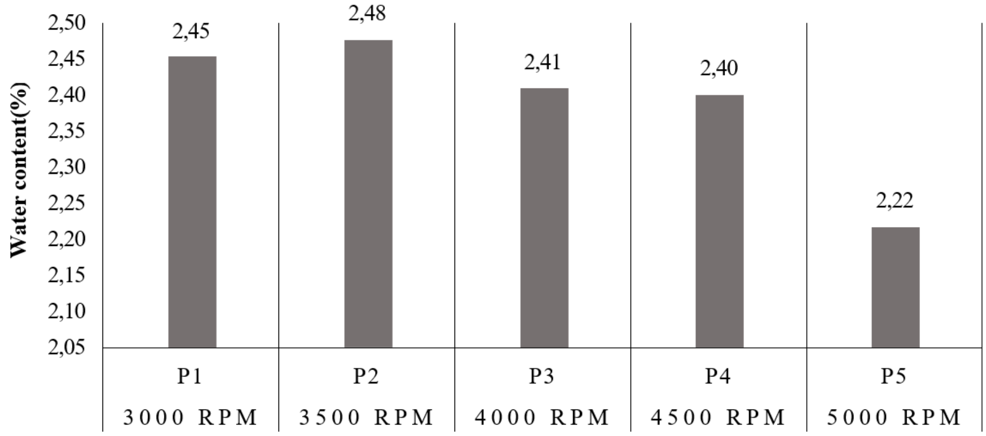

Figure 3. Water Content Microcapsule

solids that are adsorbed. Stirring at high speed affects the mass transfer of components that are eventually trapped in the matrix. Fluid turbulence enhanced by high stirring speeds increases the interaction between the ingredients and the solvent, accelerating the mass transfer of these components (Amalia *et al.,* 2022). The increase in yield that occurs with rising speed can be linked to an enhancement in adsorption capacity. High speeds allow for more solute or solid materials to be adsorbed. Additionally, at high speeds accompanied by heating, water evaporates more easily, causing the microcapsule liquid to become thicker. This thicker liquid contains more solute or solid materials compared to the water within it, while thinner liquids have the opposite composition. Several variables that influence the yield of microcapsules include the total weight of the microcapsules and the amount of water contained in the emulsion (Sofyaningsih & Iswahyudi, 2018).

Water Content

Water content is the percentage of water content in the feed. The water content will determine how and how long to store the feed. Feed that contains more water will mold faster due to high humidity (Wahyuningsih *et al.,* 2017).

The calculation results showed that the water content of the microcapsules at speeds of 3000 rpm, 3500 rpm, 4000 rpm, 4500 rpm, and 5000 rpm, respectively, were 2.45%, 2.48%, 2.41%, 2.40%, and 2.22% (Figure 3), with the lowest water content at the highest speed (P5: 5000 rpm). Stirring contributes to accelerating the water evaporation process. The stirring speed affects the evaporation rate during the heating process. The higher the stirring speed, the faster the evaporation rate, which results in lower water content (Dewi *et al.,* 2014). The optimal microcapsule product has an ideal water content between 2-6%. The selection of coating materials plays a role in regulating the water content in the microcapsules (Reineccius, 2004). Based on the reference, the moisture content produced in this study shows that the moisture content of microcapsules is still in a good range, ranging from 2.22-2.48%.

Buoyancy Microcapsule

Buoyancy is the ability of feed to float, which is determined by the time required for the feed from when it is spread until it sinks to the bottom of the pond (Armen *et al.,* 2022).

The calculation results showed that the buoyancy of microcapsules at speeds of 3000 rpm, 3500 rpm, 4000 rpm, 4500 rpm, and 5000 rpm, respectively, were 29.78 minutes (1787 seconds), 25.02 minutes (1501 seconds), 34.75 minutes (2085 seconds), 31.10 minutes (1866 seconds). and 36.25 minutes (2175 seconds). The results of the analysis did not show a significant difference (P>0.05) in all treatments. It is believed that this is a result of ingredients and formulations being the same. However, it can be seen in (Figure 4). the buoyancy at the highest speed (P5:5000 rpm) has a longer time compared to the buoyancy at the lowest speed (P1:3000 rpm). According to Firmansyah et al. (2014), increasing the stirring speed will cause the bonds between particles to become denser and stronger so it will be increasingly difficult for the feed to absorb water.

Providing floating feed in cultivation activities has various advantages compared to sinking feed. Providing floating feed will increase the digestibility of feed by fish. Additionally, floating feed will last longer in water, allowing nutrients to be utilized more effectively. The more feed eaten by fish, the better the water quality in the cultivation pond will be because there is not much leftover feed that will pollute the water

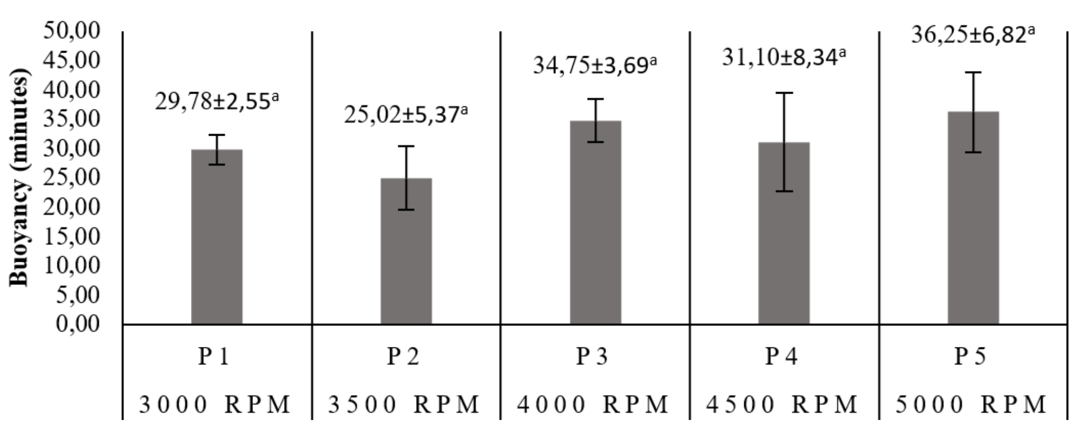

Figure 4. Buoyancy Microcapsule

quality (Agriandini *et al.,* 2024; Hakim *et al.,* 2020; Rizky *et al.,* 2022).

The characteristics of microcapsules can be influenced by the encapsulation process. (Gibbs *et al.,* 1999). The shape of microcapsules can generally be divided into 2, namely: regular (round) and irregular (irregular) (Pahlevi *et al.,* 2008).

In this study, the color produced after mixing the microcapsule materials changed according to the color of the core material used. Pahlevi et al. (2008) in Sukardi et al. (2014) stated that the color of the microcapsules can be influenced by the original color of the core material used. Likewise, the aroma produced follows the aroma of the core material used but is not as strong as before the core material undergoes the encapsulation process.

In storage for two weeks at room temperature, microcapsules produced a stronger aroma. The release of aroma from microcapsules is influenced by the surface structure and the level of porosity of the microcapsules. Meanwhile, the release of core material is influenced by the characteristics of the core material, the ratio of core to encapsulation material, the nature of the encapsulation material, and the interactions between these components. The porosity of the wall material also plays a crucial role in regulating the rate of vapor release from the core material contained inside (Choudhury *et al.,* 2021; Zhao *et al.,* 2019).

Conclusion

The results showed that the smallest microcapsule size was at the highest speed, namely 18.22 ± 3.3 µm, while the largest diameter was at the lowest speed, namely 33.53 ± 4.8 µm. The stirring speed affected the yield, water content, and buoyancy of the microcapsules, but did not affect the characteristics (smell, shape, and color) of the microcapsules.

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