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Utilization of maggot (*Heermetia illucens*) as raw material for feed on the physical quality of fish feed

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Abstract

Objective: The aim of this research is to determine the use of maggot (*Heermetia illucens*) as a raw material for feed on the physical quality of fish feed.

Material and method: This research was carried out in September-November 2023. The experimental design in this research was to make maggot caterpillar flour, fish meal, corn flour and tapioca flour, then formulated using the trial and error method. The treatments tried included treatment A with 45% fish meal, 35% maggot meal, treatment B with 50% fish meal and 30% maggot meal, treatment C with 55% fish meal and 25% maggot meal and treatment K with 0% fish meal and maggot meal. 80%. All treatments each added 16% corn flour and 4% tapioca flour as feed adhesive. Physical test analysis includes tests for feed hardness, solubility and feed color.

Results: The results of the research show that regarding the solubility of the feed, maggot can be used as an ingredient in making feed because it has good attractiveness for the test fish, even though commercial feed shows better results. Regarding solubility, feed made from maggots has good solubility, even treatments B and C showed better results than the control treatment. The hardness level of the feed is better than the control treatment, which means that the fish can use the feed well because it has a low hardness level and suits the fish's needs.

Conclusion: The use of Maggot (*Heermetia illucens*) as a feed ingredient can be used as a raw material for feed because it can have a positive influence on the physical quality of fish feed such as the attractiveness of the feed to fish, the solubility of the feed, the hardness level of the feed, and the color of the feed.

Keywords: Utilization; Maggots; Fish feed; Physical quality of feed

1 Introduction

Nowadays, development in the fisheries sector is faced with the problem of feed requirements which is an important component in fish cultivation. Nowadays, development in the fisheries sector is faced with the problem of feed requirements which is an important component in fish cultivation. Feed as a production component takes up 60-70% of total production costs (Zaman, 2017). The problem often faced in fish cultivation is the high price of feed so that production costs are quite high (Fitriani et al., 2023). Because the price of fish feed is relatively expensive, innovative and alternative feed is needed that is relatively cheap, easy to obtain and contains good nutrition, to reduce the use of pelleted feed (Murni, 2013).

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Fish food can be divided into two, namely natural food and artificial food. Natural feed is feed that is obtained directly in nature, while artificial feed is feed that is deliberately made and mixed into feed based on the desired feed formulation. Artificial feed is made by humans from various kinds of raw materials that contain high nutritional value according to the needs of fish and in its making it great attention is paid to the characteristics and size (Djarijah, 2001). Artificial feed has a high selling price for farmers and causes a decrease in water quality such as reducing oxygen levels in the water and producing ammonia which is a toxic compound for fish (Fahmi, 2015).

Fish feed is a mixture of various feed ingredients, both plants and animals, which are processed in such a way that they are easy to consume and digest and are also a source of nutrition for fish that can produce energy for living activities (Wulandari, 2015). According to Abdiguna (2013), fish feed is a component that plays an important role in the success of cultivation activities because the content of quality feed that suits the fish's needs will determine the growth and development of the fish. Fish growth can run optimally if the amount of feed, feed quality and nutritional content are met properly (Zaenuri et al., 2014).

The development of commercial feeds for aquatic organisms has traditionally depended on fishmeal as a protein source (Wang et al., 2019). However, the reduced availability of fishmeal and the increasing price of fishmeal have encouraged research to look for substitutes for this protein source. According to Belghit et al. (2019), the choice of ingredients and formulation of fish feed can influence the environmental impact on the aquaculture industry. Finding suitable and sustainable nutrition as a substitute for fish meal and fat is the focus of current research where possible alternative sources of feed ingredients come from plant products, animal waste

In making fish food, it turns out that you not only need the right raw material formulation, both in terms of the type of raw material and the nutritional composition, what is no less important is the quality of the fish food after being spread into the water. Many feeds have been successfully made with adequate nutritional quality, but they sink quickly, easily disintegrate and decompose in water, even though not all of them are eaten by the fish. As a result, the feed given becomes no longer effective and efficient (Mulia et al., 2017). The physical form of fish food is greatly influenced by the type of material used, printer size, amount of water, pressure, post-processing method, and use of adhesive to produce fish food with a strong, compact and sturdy structure so that it does not break easily (Jahan et al., 2006).

Attention to insects as feed ingredients for land and aquatic animals continues to develop and grow throughout the years as shown by the increasing number of journals about feed ingredients derived from insect ingredients. Insects used as food can provide a solution to overcome the problem of protein deficiency (Wang et al., 2019). Maggots are organisms that originate from Black Soldier Fly (BSF) larvae. Maggots have a fairly high nutritional content (40%-50%), do not carry disease agents, do not require high technology to obtain them, and are relatively cheap (Hem et al., 2006 *in* Ediwarman, 2008). Meanwhile, according to Azir et al (2017), maggots contain 41.22% protein, this is because maggots have storage organs called trophocytes which function to store the nutrient content found in the culture media they eat. Maggots also function as an alternative feed for fish which can be given in fresh form (Subaima et al., 2010).

Maggot larvae are considered an important natural ingredient for use in feed. This species has long been used as a protein source for animal feed, mainly due to its ability to convert food waste such as vegetables, fruit, industrial waste and animal tissues into high quality protein. In recent years, research on the production of maggot larvae as feed has increased (Wang and Shelomi, 2017). The advantage of using maggots as a promising alternative source of protein is that this organism has the ability to convert organic matter, and only requires a small amount of land and water. Maggot (Hermetia illunces) is an organism that originates from black soldier fly eggs and is a putrefactive organism because it consumes organic materials to grow (Silmina et al., 2014 and Mokolensang et al., 2018).

The advantage of the black soldier fly maggot is that it has a chewy texture and has the ability to produce natural enzymes which can increase the fish's digestibility of feed. Maggots have a high protein content, namely 42.1% (Mudeng, et al., 2018 and Li et al., 2019). The high level of nutrition in maggots, their use which does not compete with humans and their easy-to-make growing media show good potential as natural fish food. It is hoped that maggots can be the answer to the problem of cheap feed availability that is easy to provide, does not cause damage to water quality and can increase the fish's immune system (Fahmi, 2015). This research aims to determine the effect of using Maggot (*Heermetia illucens*) as a feed ingredient on the physical quality of fish feed.

2 Material and method

2.1. Research Design and Treatment

The experimental design in this research was to make maggot caterpillar flour, fish meal, corn flour and tapioca tape, then formulated using the trial and error method. This method is used for small-scale feed production using the Pearson Square program. After that, a physical test of the feed is carried out, namely fish attractiveness, feed hardness, solubility and color.

The treatments tried were Treatment A 45% fish meal, 35% maggot flour, 16% corn flour, and 4% tapioca flour. Treatment B 50% fish meal, 30% maggot flour, 16% corn flour, and 4% tapioca flour. Treatment C 55% fish meal, 25% maggot flour, 16% corn flour, and 4% tapioca flour. Meanwhile, the Control treatment (K) was 0% fish meal, 80% maggot flour, 16% corn flour, and 4% tapioca flour. The design used in this research was a Completely Randomized Design (CRD) which consisted of 4 treatments, each treatment was repeated 3 times to obtain 12 experimental units (Table 1).

Table 1 Research Design

C2	**C1**	**KO**
KO	C3	A1
B2	A2	B1
B3	KO	A3

2.2. Place and time of research

This research was carried out at the Agricultural Technology Education Laboratory, Faculty of Engineering, Universitas Negeri Makassar, Indonesia. The research was carried out in September-December 2023. As part of the research, maggot (Hermetia illucens) was reared for 1 month, then maggot processing (drying and starvation) for 3 weeks, while the feed making and drying process was carried out in 4 treatments, namely for 3 weeks. , then physical tests were carried out for 2 weeks including tests for feed attractiveness, feed hardness, solubility and feed color.

2.3. Media Preparation Stage and Rearing Maggots

The stages in maggot rearing which refer to research by Fauzi & Sari (2018) are preparing all the materials and tools that will be used as maggot rearing media consisting of commercial fish pellets, coconut fiber, bran, basin and spoon, crushing the commercial fish pellets until they are half coarse, then add water little by little until the pellets become moist, put the commercial fish pellets into the rearing basin, put coconut fiber in the rearing basin right above the commercial fish pellets, and sprinkle bran on the edge of the basin right above the commercial fish pellets.

The stages in maggot maintenance that refer to research by Fauzi & Sari (2018), namely that the maggot is placed in a basin (maintenance medium). The maggots that are reared are 3 days old after hatching and their size is around 5 mm. Provide maggot food once a day in the form of fish waste, and add water to the maggot rearing medium little by little if the rearing medium is dry. The following are several stages in collecting maggots according to Fauzi & Sari (2018), namely preparing the equipment that will be used in the maggot harvesting/collecting process, including 3 basins, 2 1 × 1 meter wire filters and spoons, first separating the remaining -remaining fish waste found in maggot rearing media. When the rearing media is clean of maggot food remains, the maggots usually gather in the corners of the basin, scoop up the maggots using a large spoon, then move them to another basin.

2.4. Cleaning, Drying and Making Maggot Flour

Several stages in cleaning maggots which refer to the research of Putra et al., (2022), namely maggots that are still mixed with the rearing media are filtered using a wire filter, so that the rearing media (loose pellets) can pass through the filter through the filter holes, maggots that have collected and divided into 4 containers to facilitate the process of killing the maggots, before the maggots are doused with hot water (turned off), the maggots are washed first, the process of killing the maggots is using boiling water which is then poured into the container containing the maggots, after that wait until the maggots are completely dead.

Stages in drying maggot maggots which refer to the research of Saleh et al. (2023), namely preparing 4 plastic gutters which are then lined with plastic, inserting maggots into the gutter, then putting them in a drying room. After that, wait for the maggots to dry completely, around 5 days or depending on the weather.

The stages in cleaning maggots which refer to research by Pardosi (2022) are preparing the equipment that will be used in the process of sifting maggots, including a stone mortar, 2 basins, a spoon and a sieve, putting the dried maggots into the mortar then pounding them until smooth, pouring the maggots. has been ground into a sieve, then the maggot is filtered, moving the maggot flour to a place far from the reach of water or damp places.

2.5. Fish Meal, Binder and Corn Flour

The fishmeal used in making feed is obtained commercially in Makassar City stores. The steps for making a binder/adhesive from tapioca flour according to Prihanka & Nuwa (2018) are weighing the tapioca flour, putting it in a container, then adding hot water, stirring the mixture until it forms white gelatin, cooling it first before using it and mixing it into the feed mixture little by little. A little. The stage for making corn flour is to buy corn commercially and then blend the corn until it becomes corn flour.

2.6. Formulation and Making of Fish Feed

The initial stage of feed formulation is preparing the materials and tools that will be used to determine the amount of ingredient composition in each feed treatment. The materials and tools used to determine the composition of ingredients in each feed treatment are scales, containers, spoons and plastic bags. Research treatment as in Table 2.

Table 2 Research Treatment

Materials	**Treatments**			
	Control/K (%)	**A (%)**	**B (%)**	**C (%)**
Fish flour	0	45	50	55
Maggot Flour	80	35	30	25
Cornstarch	16	16	16	16
Tapioca flour	4	4	4	4
Amounts	100	100	100	100

The stages of making feed are first preparing the tools and materials that will be used in making feed, putting maggot meal, corn meal and fish meal into a container according to a predetermined ratio, mixing all the ingredients until evenly mixed, pour water little by little until smooth, pour water into a container containing tapioca flour according to the specified ratio, heat the tapioca flour solution until the temperature reaches 100°C (boils), then stir until cooked (forms gel), Add the binder gel/adhesive made from tapioca flour into the feed mixture, then stir until evenly mixed and smooth, add it into the pellet press little by little, if the feed that comes out of the pellet press is shaped like crumbles/pellets, then the feed is ready to dry.

2.7. Data Collection and Analysis

The data collection technique used in this research is by systematically observing and recording the research subjects. Data was collected through several tests, namely physical tests which included attractiveness, feed solubility, feed hardness and feed color.

The stage in testing attractiveness (Aslamyah and Fujaya, 2011) is by dropping 10 g of feed into a basin containing tilapia fish with a distance between the pellet and the fish value of 30 cm. The time it takes for the tilapia to eat the pellets is calculated using a stopwatch. The time used by the tilapia to eat the pellets is the result of an attractiveness test using units of minutes.

Measuring the solubility of fish food is in accordance with the opinion of Kurniasari, et al., (2022), solubility or breaking speed is the length of time it takes for the pellets to become soft or disintegrate in water. A total of 10 pellets of the same size are put into a measuring cup filled with water. To determine whether the test pellet is soft or not, press it with your index finger. This observation was carried out by pressing the pellet every 5 minutes.

The feed hardness level test was measured by inserting 5 g of feed into a paralon pipe with a height of 1 m. Then the feed is weighed with weights weighing 500 g. The feed that has been weighed is then sieved using a 0.5 mm cyclone. The level of hardness is calculated in terms of the percentage of feed that is not crushed. The impact resistance formula is as follows (Aslamyah & Karim, 2012):

$$\text{Feed Hardness (\%)} = \frac{B - A}{B} \text{ x } 100\ \%$$

Information::
A : Whole pellet weight after dropping
B : Whole pellet weight before dropping

The color of the feed is the color of the feed after the fish feed has been made, then the color is observed, including the control feed which is a comparison feed obtained commercially.

The data analysis technique used in research to analyze research data is quantitative descriptive analysis

3 Results

Physical testing is a way of initial evaluation of feed, by examining its physical condition. The quality of artificial feed for fish is not only determined by its nutritional content which is sufficient for the needs of fish growth and development, however, it is also determined by its physical properties, for example the buoyancy and stability of the feed in water, as well as several other important physical properties of the feed (Mulia and Maryanto, 2014).

3.1. Attractiveness of Fish Food

Figure 1 shows that the attractiveness of the feed tested on tilapia fish means that the fish are slower to respond to treatment C fish feed with a value of 17.06 seconds, which means that in only 17.06 seconds, The tilapia has approached and consumed the feed provided. The next best treatment is treatment A, namely 14.04 seconds, treatment B, namely 9.03 seconds and the control treatment, which is fish food obtained commercially, has the lowest feed attractiveness, namely 7.07 seconds, which means that the control feed is still better than the feed, artificial fish in this study.

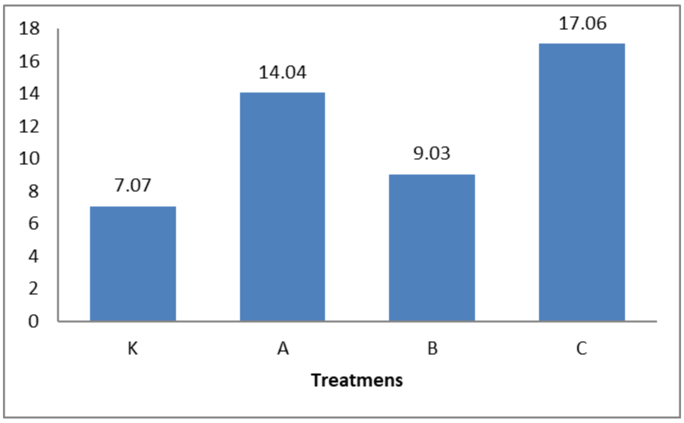

Figure 1 Attractiveness of Fish Food (seconds)

3.2. Solubility of Fish Feed

Figure 2 shows that the fish food that dissolves the fastest in water is treatment A, namely 240 minutes, followed by the control treatment, namely 243 minutes, treatment B, namely 244 minutes and the treatment that dissolves the slowest in water is treatment C, namely 254 minutes. The faster the food dissolves in water, the more difficult it is for the fish to use it properly because before it can be used by the fish, the food has already dissolved in water. However, based on the solubility aspect of the feed, the feed that dissolves the fastest is the feed in treatment A, namely 240 minutes or 4 hours. Based on several theories, it is stated that the solubility of feed or feed stability in water should be no less than 2 hours or 120 minutes.

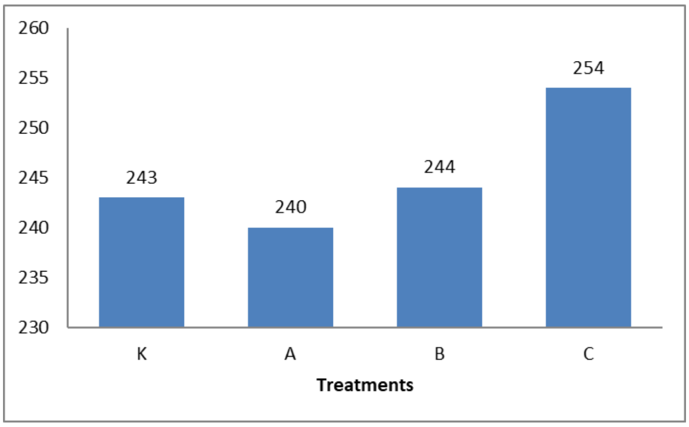

Figure 2 Solubility of Fish Food (minutes)

3.3. Fish Feed Hardness Level

Based on Figure 3, it shows that the highest level of feed hardness occurred in the control treatment, namely 47.70%, followed by treatment B, namely 27.84%, treatment A, namely 19.21% and the lowest in treatment C, namely 13.62%. The level of hardness in fish feed will affect the solubility of the feed and the level of feed utilization by the fish.

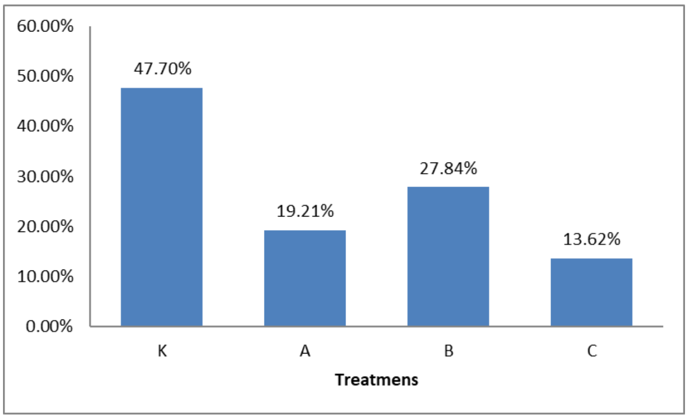

Figure 3 Fish Food Hardness Level (%)

3.4. Fish Food Color

Based on Figure 4, it shows that the color of the feed made in the study was almost the same for all treatments, namely brown. The color of the feed is very important because it is related to the level of feed utilization by fish, especially feed intended for fish that utilize the visual aspect to find food in water.

	
Treatment K	Treatment A

	
Treatment B	Treatment C

Figure 4 Fish Food Color

4 Discussion

4.1. The Attraction of Fish Food

Feed striking time or feed attractiveness is closely related to the level of attractiveness or aroma of the feed. Saade et al. (2013) stated that the more pungent the test food was, the quicker the test fish responded with interest by approaching the food to consume it. The time required for the test animal to first eat the test pellet is expressed as the attractiveness of the pellet in minutes (Saade et al., 2010). The higher the attractiveness of a feed, the faster the feed will be consumed before it disintegrates in the water.

4.2. Solubility of Fish Feed

Feed stability in water is the level of feed resistance in water or how long it takes for the feed to become soft and disintegrate (Aslamyah and Karim, 2012). The effect of binders on the water stability characteristics of pellets (pellet resistance in water) shows a relatively high value compared to without using binders (Krisnan and Ginting, 2009). If the feed is too hard it is difficult for the fish to swallow and if it is in the form of a paste, the pellets will crumble easily, causing wastage of feed and water spoilage. An efficient binder, if very expensive, will make the final cost of feed production uneconomical (Zaman, 2017).

Feed unit density is similar to feed mass density, but the measurement method is different. The density of a feed unit is the ratio of mass (g) to the total volume (cm3) of pellet units whose mass is weighed (Fallahi, 2012). According to Tumuluru and Sokhansanj (2008) *in* Fallahi (2012) observed that screw speed, barrel temperature, pellet dimensions, and feed moisture content significantly influence the feed unit density value. This research carried out unit density without paying attention to how the feed making machine works, but rather observing the optimal level of fermentation and cutting when making pellets.

The buoyancy of the feed is to determine how long the fish pellets stay above the water surface so that they can be utilized optimally by the fish when the feed is put into the water (Mulia and Maryanto, 2014). The buoyancy and integrity of food in the water is important because: (1) food that floats and is not easily destroyed makes it easier to observe that fish are full and feeding should be stopped (Jauncey et al., 2007); (2) minimizing waste and pond water pollution due to crushed and inedible food waste (Jauncey et al., 2007). Determination of pellet buoyancy was carried out to differentiate pellet categories, namely (a) very good with buoyancy > 30 minutes; (b) good at 15-30 minutes of buoyancy; (c) moderate buoyancy 5-15 minutes; and (d) not good at buoyancy < 5 minutes (Irma, 2008). The fermentation process can provide buoyancy and other physical properties such as integrity in water that are beneficial for fish farmers.

Hydrophobicity is the level of rejection of water molecules (Rianto et al., 2011). This test can help explain the buoyancy, water absorption and water stability of fish pellets. It can be said that hydrophobicity influences the nature of the surface exposed to water, including whether it is hydrophilic or hydrophobic. Mudjiman (2008) states that the buoyancy of feed is related to the specific gravity of the feed. The greater the specific gravity of the feed compared to the specific gravity of water (specific gravity of water = 1), the faster the feed in question sinks, if the specific gravity of the feed is around 1 then the feed will float, whereas if the specific gravity of the feed is less than 1 the feed will float. This shows that feed A, B and C have a specific gravity of more than 1 and the floating condition experienced by the feed is due to the presence of oxygen trapped in the feed, as well as the sinking speed of the pellets, indicating that the specific gravity of the feed is more than 1 so that the pellets immediately sink. without flying first.

4.3. Fish Food Hardness Level

Ingredients that contain high starch can act as binders, for example cassava flour, corn flour, rice flour, wheat, tapioca flour, molasses, cassava flour, and other ingredients (Susilawati et al., 2012). Density is the mass of particles that occupy a certain unit volume (Wirakartakusumah, 1992). Density is used to determine the compactness and texture of feed. A compact feed texture will be resistant to the effects of the pressing process so that the bonds between the particles that make up the feed become very strong and the space between the particles of the feed material is not filled with air cavities (Krisnan and Ginting, 2009). Feed density (g/cm^3) is calculated by comparing the mass (g) with the feed volume (cm3) as explained by USDA (1999).

Water absorption is the ability of an object to absorb water from the surrounding environment (Krisnan and Ginting, 2009). Feed that has a high water absorption capacity will cause the feed to become soft and become destroyed when exposed to water, so it is said to not withstand long periods of storage (Zaman, 2017). Generally, the water content of feed rations will increase as the storage time increases (Prabowo, 2003 *in* Krisnan and Ginting, 2009).

4.4. Fish Food Color

The color of the feed really depends on the type of raw material used (Aslamyah and Karim, 2012). Cahyadi (2006) states that there are three functions of flavor, namely as a flavoring agent (delicious), maintaining deliciousness and strengthening acceptability. According to Rusadi (2011), the food is made according to the fish's wishes, so that fish that smell the fish food are attracted to consuming the food or what is commonly known as the fish's receptivity to the fish food that is made.

5 Conclusion

Maggot (*Heermetia illucens*) can be used as a raw material for feed because it can have a positive influence on the physical quality of fish feed. Regarding the solubility of feed, maggot can be used as an ingredient in making feed because it has good attractiveness for test fish, even though commercial feed shows better results. Regarding solubility, feed made from maggots has good solubility, even treatments B and C showed better results than the control treatment. The hardness level of the feed is better than the control treatment, which means that the fish can use the feed well because it has a low hardness level and suits the fish's needs.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

In this research there is no conflict of interest

The all authors declare that they have no conflicts of interest related to this study.

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