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Identification of Morphological and Growth Characteristics of *Eisenia foetida* in Mushroom Media Waste

Ana Mardiana[1], Baiq Mirawati[1], Hunaepi[2], Desi Ratnasari[3*], Hilda Aqua Kusuma Wardhani[3], and Ahmad Aris Arifin[4]

[1]Program Studi Pendidikan Biologi, Fakultas Sains Teknik dan Terapan, Universitas Pendidikan Mandalika, Nusa Tenggara Barat, Indonesia
[2]Program Studi Pendidikan Profesi Guru, Universitas Pendidikan Mandalika, Nusa Tenggara Barat, Indonesia
[3]Program Studi Pendidikan Biologi, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Kapuas Siantang, Kalimantan Barat, Indonesia; e-mail: desiratnasari@unka.ac.id
[4]Program Studi Pendidikan IPA, Pascasarjana, Universitas Mataram, Nusa Tenggara Barat, Indonesia

ABSTRAK

Penelitian ini bertujuan untuk mengetahui karakteristik morfologi dan pertumbuhan *Eisenia foetida* sebagai respons terhadap media limbah jamur. Dua jenis media limbah jamur yang digunakan adalah limbah media jamur jerami dan limbah baglog jamur tiram. Desain penelitian ini bersifat eksperimen, menggunakan metode kuantitatif dan analisis statistik deskriptif. Penelitian ini mengamati parameter seperti panjang tubuh, berat tubuh, warna kulit, populasi, dan biomassa *Eisenia foetida*. Hasil penelitian menunjukkan adanya perbedaan signifikan dalam pertumbuhan dan karakteristik morfologi *Eisenia foetida* di antara berbagai perlakuan media. Media limbah jamur tiram dengan komposisi yang lebih tinggi (80%) menghasilkan pertumbuhan yang lebih baik dalam hal berat tubuh dan biomassa dibandingkan dengan media limbah jamur jerami. Secara spesifik, perlakuan dengan 80% limbah jamur tiram dan 20% limbah jamur jerami (P3) menunjukkan rata-rata berat tubuh tertinggi (17,13 g). Kesimpulannya, limbah media jamur, khususnya limbah baglog jamur tiram, mendukung perkembangan morfologi dan pertumbuhan optimal Eisenia foetida. Temuan ini menunjukkan bahwa limbah jamur tiram dapat digunakan secara efektif sebagai media untuk budidaya *Eisenia foetida*, memberikan solusi ramah lingkungan untuk pengelolaan limbah organik. Rekomendasi untuk penelitian selanjutnya termasuk mengeksplorasi jenis limbah organik lainnya sebagai media potensial untuk budidaya *Eisenia foetida* dan melakukan studi jangka panjang untuk mengevaluasi keberlanjutan media tersebut.

***Kata Kunci**:* Morfologi, Eisenia foetida, Limbah Media Jamur

ABSTRACT

This study aims to determine the morphological and growth characteristics of *Eisenia foetida* in response to mushroom waste media. Two types of mushroom waste media were used: straw mushroom media waste and oyster mushroom baglog waste. The research design was experimental, using quantitative methods and descriptive statistical analysis. The study observed parameters such as body length, body weight, skin color, population, and biomass of *Eisenia foetida*. The results showed significant differences in the growth and morphological characteristics of *Eisenia foetida* among the various media treatments. The oyster mushroom waste media with higher composition (80%) yielded better growth in terms of body weight and biomass compared to the straw mushroom waste media. Specifically, the treatment with 80% oyster mushroom waste and 20% straw mushroom waste (P3) showed the highest average body weight (17.13 g). In conclusion, mushroom media waste, especially oyster mushroom baglog waste, supports the optimal morphological development and growth of *Eisenia foetida*. These findings suggest that oyster mushroom waste can be effectively utilized as a medium for cultivating *Eisenia foetida*, providing an environmentally friendly solution to organic waste management. Recommendations for future research include exploring other types of organic waste as potential media for *Eisenia foetida* cultivation and conducting long-term studies to evaluate the sustainability of such media.

Keywords: Morphology, Eisenia foetida, Mushroom Media Waste

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1. INTRODUCTION

Earthworm *Eisenia foetida* is an organism that plays a crucial role in soil ecosystems. They can quickly decompose organic matter into fertile soil (Purba et al., 2022; Zhao et al., 2022). These earthworms have various advantages and use, including medicine in the beauty sector, animal feed, fish feed, and plant fertilizer (casting). Therefore, the development of earthworm cultivation is one of the solutions to utilize organic waste, which is a source of environmental pollution, as earthworms can act as natural biodegraders of waste (Popoola, 2022; Singh & Sinha, 2022).

Previous research by Patnaik et al. (2022) and Fadilah et al. (2017) has shown that to address organic waste, one way is to utilize detritivore organisms such as the earthworm Lumbricus rubellus. The cultivation of earthworms is also important because it can produce fresh earthworms as feed for broodstock shrimp, earthworm meal as a substitute for fish meal, and vermicompost which can be used as natural feed (Hs et al., 2022; Sharma & Garg, 2023). One species of earthworm that has many benefits is Eisenia foetida (Sharma & Garg, 2023). These earthworms can be used as a source of protein-rich feed for livestock such as poultry, fish, and shrimp (Musyoka et al., 2019). Additionally, earthworms can reduce soil density, surface runoff, erosion, and provide nutrients for plants through their castings. Therefore, increasing the growth of *Eisenia foetidais* is important for maintaining soil quality (Pangestika, 2016).

Market organic waste can be used as a medium for cultivating *Eisenia foetida* to increase cocoon and biomass production. However, market organic waste cannot be used purely but must be mixed with other wastes that contain crude fiber and high protein such as rice straw, cow feces, horse feces, and goat feces (Mashur, 2020; Mashur et al., 2021; Suthar, 2009; Vodounnou et al., 2016). The highwater content and low crude fiber content in market wastelead to poor media aeration, which can cause the death of the worms.

The growth and morphology of *Eisenia foetida* are influenced by the availability of nutrients in the media and feed. Organic materials such as wood sawdust, corn flour, rice bran, rice straw, and compost can be used as growth media for earthworms (Febrita' et al., 2015; Sharma & Garg, 2018). In this study, two types of mushroom waste, namely straw mushroom media waste and oyster mushroom baglog waste, were used as media for cultivating *Eisenia foetida*. Straw mushroom media waste made from rice straw can be an alternative source of nutrition for *Eisenia foetida*. Rice straw is a waste that has not been widely used by the community and can cause problems. Additionally, rice straw waste has good potential to be managed, one of which is to be used as a medium for growing earthworms (Setiawan et al., 2021).

Oyster mushroom baglog waste has the potential as a source of nutrition for earthworms. Oyster mushroom baglog is made from various mixtures of ingredients such as corn flour, rice bran, lime, sawdust, and water. Fermented oyster mushroom baglog waste with microbial bioactivator (EM4) can also be used as a growth medium for *Eisenia foetida* because it still contains nutrients. Mushroom media waste has a nutritional content of 5.3701% with a carbon (C) value of 36.23% and nitrogen (N) of 0.49%. Thus, mushroom media waste can be used as a growth medium for earthworms (Tanjung, 2017).

Earthworm cultivation has promising prospects in addressing environmental issues and providing an alternative protein-rich feed source. However, the success of earthworm cultivation highly depends on the appropriate selection of media. Different media will yield different results in terms of the growth and morphology of earthworms. Therefore, this study is essential to identify the morphological and growth characteristics of *Eisenia foetida* in mushroom waste media.

In addition to media, environmental factors such as humidity, temperature, and pH also play a vital role in earthworm growth. According to Firmansyah (2017), humidity is necessary to keep the earthworm's skin functioning normally to sustain its life. This study was conducted by watering the media every three days to maintain stable media moisture. Watering was not done daily to avoid excessive media moisture, which can cause the media pH to become acidic because the gases trapped in the media interact with organic compounds, thus inhibiting the growth of earthworms (Roslim et al., 2013).

According to Brata (2010) and Nurwati (2011), the growth of earthworms heavily depends on the type and amount of feed they consume. Earthworms that consume nitrogen-rich feed will experience rapid growth. Earthworms can utilize organic matter from litter or plant parts for their growth. In this study, two types of mushroom waste, namely straw mushroom media waste and oyster mushroom baglog waste, were used as media for cultivating *Eisenia foetida*. Rice straw contains cellulose, hemicellulose, and lignin, which are beneficial for nutrition in earthworm feed, allowing the growth of *Eisenia foetida* to develop well (Putra, 2022).

Furthermore, according to Ciptono (2022), the worm's body consists of segments with longitudinal and circular muscles for movement. Contractions of the longitudinal muscles make the earthworm's body elongate and shorten, while circular muscle contractions make the earthworm's body expand and contract. Therefore, measuring the length of the worm is done when the worm is stationary or about to move to get a body length close to its actual body length.

According to Liberty et al. (2022), the increase in the body length of earthworms in mushroom waste media is due to the nutrient content that supports the growth of new segments in the posterior part of the earthworms. Moreover, protein is an essential nutrient for earthworms because it serves as an energy source and a building material for new tissues

that continuously form in the earthworm's body during adulthood. Organic materials influence the growth in length and body weight of earthworms.

Based on the above background, this study aims to identify the morphological and growth characteristics of *Eisenia foetida* in mushroom waste media, with observational parameters including body length, body weight, skin color, population, and biomass. The results of this study are expected to provide valuable information for the development of earthworm cultivation and the utilization of organic waste as an effective growth medium.

2. METHODS

2.1. Types of Research

The type of research used in this study is experimental research which can be interpreted as a research method used to seek certain treatments for others under controlled conditions. The experiment referred to in this study uses a quantitative method (Lidia et al., 2018).

2.2. Research Design

The design in this study used a completely randomized design (CRD). Completely Randomized Design is the simplest research design and is commonly used in laboratory research, with relatively homogeneous experimental units such as environmental conditions, tools, materials, and media. In this case, the limitation of the research problem is assumed that all *Eisenia foetida worms* have a homogeneous size at the age of 14 days. To determine the number of repetitions used in this study using the general formula:

$$t\,(n-1) \geq 15$$

information :
t = Number of treatments in the study
r = Number of replicate treatments

Table 1. Research Treatment

Research Treatment	
P_{01}	Oyster mushroom waste 100%
P_{02}	Mushroom waste 100%
P_1	Oyster mushroom waste 30% (300 grams) + straw mushroom waste 70% (700 grams)
P_2	Oyster mushroom waste 50% (500 grams) + straw mushroom waste 50% (500 grams)
P_3	Oyster mushroom waste 80% (800 gram) % + waste mushroom 20% (200 gram)

2.3. Population and Sample

The population in this study were earthworms of the type *Eisenia foetida*. The sample in this study was the earthworm type *Eisenia foetida* by observing the morphological characteristics with the required number of worms of 150 earthworms with each replication containing 5 earthworms.

2.4. Time and Place of Research

This research was conducted in the Greenhouse and Biological Laboratory of Universitas Pendidikan Mandalika (UNDIKMA). The research time starts from March 24 to May 10, 2023.

2.5. Research Instruments

Research instruments are tools and materials that will be used to collect data. In this study, the instruments used were:

Table 2. Tools Used in Research

Tool	Function
Ruler	As a measure of length
Bucket	As a media mixing container
Gloves	As a hand protector to keep it clean
Spraying	To water the media
Poly bag	As a medium for the growth of earthworms
Digital scales	To measure a weight or load
Tweezers	To clamp the worm when taking it for observation
Measuring cup	To measure the volume of a solution or liquid
Erlenmeyer pumpkin	Become a container of EM4 solution material
Petri dish	For weighing worm samples and as a container for worms before being transferred to worm growing media
Label	To label the media
Bag	As a storage media fermentation
Mobile	For documentation
Books and stationery	To record the results of observations

Table 3. Materials Used in Research

Material	Function
The earthworm *Eisenia foetida*	Main research material
Mushroom waste	As a medium
Bagloq oyster mushrooms	As a medium
EM4	Media fermentation material, serves to increase livestock appetite
Brown sugar	Gives a sweet taste and a source of energy.
Water	Mixing in the fermented solution, watering the medium for growing earthworms

2.6. Data Collection Technique

In data collection techniques, research will be carried out in the laboratory. Before this research is carried out, there are several things that need to be prepared including preparation of the place to suit the research, preparation of tools and materials to be used during the research.

Several media mixtures were used during the observation process, in the form of 5 treatments, with 2 as controls, and with each treatment 6 repetitions, so that the total media used was 30 media. The types of treatment media used were, 1) oyster mushroom waste, 2) straw mushroom waste. The procedure in the research is as follows:

a. The process of fermentation of mushroom media waste , Fermentation of mushroom media waste using EM4 microorganisms, the stages are as follows:
   1) Oyster mushroom baglog waste fermentation
      Baglog oyster mushroom waste weighing 15.6 kg was put into a bucket, added 104 ml of EM4 solution and 104 ml of brown sugar, then added 10 liters of 400 ml of water into the

fermentation container. After all the ingredients are put into the fermentation container, then the fermented solution is poured over the oyster mushroom waste, and stirred until evenly distributed, then put into a sack and tied tightly so that it is airtight and dark. The material is fermented for 14 days.

2) Straw mushroom media waste fermentation
Second fermentation 15 kg of straw mushroom waste was put into a bucket, 99.9 ml of EM4 solution and 99.9 ml of brown sugar were added, then 10 liters of water was added to the fermentation container. After all the ingredients are put into the fermentation container, then the fermentation solution is poured over the straw mushroom waste, then stirred until evenly distributed, then put in a sack and tied tightly so that it is airtight and dark. The material is fermented for 14 days.

b. *Eisenia foetida* worm rearing media
1) Before spreading *Eisenia foetida worms* on the media, polybags as maintenance containers were filled with 100% oyster mushroom baglog waste fermentation as control 1 for 6 replications.
2) Filling polybags with 100% fermented straw mushroom waste as control 2 for 6 replications.
3) Fill the maintenance container according to the predetermined treatment, namely: P_1 : 30% oyster mushroom waste + 70% straw mushroom waste, P_2 : 50% oyster mushroom waste + 50% edible mushroom waste, P_3 : 80% oyster mushroom waste + waste straw mushroom 20% for 6 repetitions.

c. Planting earthworms. Each media is put into a polybag. earthworms put into the media each 5 worms earthworms above the surface of the media.

d. Watering the media is done once every 3 days, with the aim of keeping the worm growing media moist.

e. Observations were made on the first day of the study and on the 30th day covering the morphological characters of earthworms, body length (cm), skin color, body weight, Biomass and population calculations.

2.7. Data Analysis Technique

The data analysis technique used in this study was an experimental technique in the form of descriptive statistics consisting of 3 treatments, 2 controls, 6 replications, so that the total media used was 30 media. Parameters measured:

a. Morphological Observation Parameters

Table 4. Research Parameters

No.	Research Parameters
1.	Body Length(cm)
2.	body weight(g)
3.	Skin color
4.	Population
5.	Biomass

b. Worm Biomass Growth Eisenia *foetida worms*

Biomass growth of Eisenia foetida worms is calculated using the Weatherley formula in astutik (2016), namely:

W = Wt – Wo
Information:
W = Absolute growth (g)
Wo = Biomass at the start of the study (g/time of maintenance)
Wt = Biomass at the end of the study (g)

c. Eisenia foetida worm population

Calculation of the population of Eisenia foetida worms was calculated using the population formula according to Sagita et al., (2014):

$$K = \frac{\text{jumlah cacing tanah}}{\text{jumlah unit sampel}}$$

information :
K = Population density of earthworms (individuals/m^2)

3. RESULTS AND DISCUSSION

This research was carried out at the UNDIKMA Laboratory and Greenhouse starting from Friday, March 24 to Wednesday, April 10, 2023. In this study, experiments were carried out to see the effect of mushroom media waste on the growth and morphology of the earthworm Eisenia foetida with parameters of observing body length, *body* weight, skin color, population and biomass. To observe the results of the parameters that have been determined in this study using 5 kinds of treatment, namely: P_{01} (100% Oyster Mushroom Waste), P_{02} (100% Straw Mushroom Waste), P_1 (30% Oyster Mushroom Waste + 70% Oyster Mushroom Waste %), P_2 (50% Oyster Mushroom Waste + 50% Straw Mushroom Waste), P_3 (80% Oyster Mushroom Waste + 20% Straw Mushroom Waste). With each repetition in each treatment, namely 6 repetitions, so that a total of 30 growth media for the earthworm *Eisenia foetida.*

3.1. Worm Body Length

The results of the analysis of the average body length of worms are presented in Table 5.

Table 5. Results of Descriptive Statistics on the Length of *Eisenia foetida worms*

Treatment	Minimum	Maximum	Means	std. Deviation
P_{01}	6.08	9.42	7.75	2,357
P_{02}	5.50	10.92	8.2	3.83
P_1	7.50	11.50	9.5	2.82
P_2	8.67	12.33	10.5	2.59
P_3	6.17	11.33	8.75	3.65
Valid N (listwise)				

The body length measurements of *Eisenia foetida* varied significantly across different mushroom waste media treatments. In treatment P 01 (100% Oyster Mushroom Waste), the body length ranged from 6.08

cm to 9.42 cm, with an average length of 7.75 cm and a standard deviation of 2.357, indicating significant variation. For treatment P 02 (100% Straw Mushroom Waste), the body length ranged from 5.50 cm to 10.92 cm, with an average of 8.2 cm and a standard deviation of 3.83, showing substantial variability. Treatment P 1 (30% Oyster Mushroom Waste+70% Straw Mushroom Waste) exhibited a body length range from 7.50 cm to 11.50 cm, with an average of 9.5 cm and a standard deviation of 2.82, indicating moderate variability. In treatment P 2 (50% Oyster Mushroom Waste + 50% Straw Mushroom Waste), the body length ranged from 8.67 cm to 12.33 cm, with an average of 10.5 cm and the least variability (standard deviation of 2.59), suggesting more consistent growth. Lastly, treatment P 3 (80% Oyster Mushroom Waste+20% Straw Mushroom Waste) had a body length range from 6.17 cm to 11.33 cm, with an average of 8.75 cm and a standard deviation of 3.65, indicating considerable variability. Overall, treatment P 2, with a balanced composition of 50% oyster mushroom waste and 50% straw mushroom waste, provided the optimal conditions for the growth of *Eisenia foetida*, resulting in the highest average body length and the most consistent growth. Other treatments showed varying degrees of effectiveness, reflecting the different nutritional and physical properties of the media compositions.

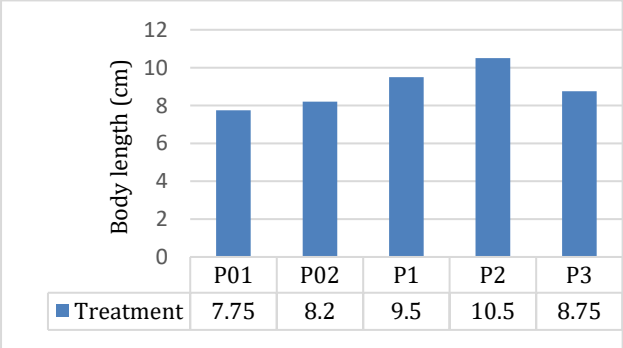

Figure 1. Body Length of the Earthworm *Eisenia foetida*

Figure 1 shows the average body length of the earthworm *Eisenia foetida* under five different mushroom waste media treatments. Treatment P01, which used 100% oyster mushroom waste, resulted in an average body length of 7.75 cm. Treatment P02, which used 100% straw mushroom waste, showed an increase in average body length to 8.2 cm. In Treatment P1, where the media consisted of 30% oyster mushroom waste and 70% straw mushroom waste, the earthworms achieved an average body length of 9.5 cm. Treatment P2, with a media composition of 50% oyster mushroom waste and 50% straw mushroom waste, produced the highest average body length of 10.5 cm. Meanwhile, Treatment P3, consisting of 80% oyster mushroom waste and 20% straw mushroom waste, showed an average body length of 8.75 cm.

From the diagram, it is evident that variations in the composition of mushroom waste media significantly affect the growth in body length of *Eisenia foetida*. Treatment P2 showed the most optimal results with the highest average body length. This may be due to the better balance of nutrients in the media with a 50% mix of oyster mushroom waste and 50% straw mushroom waste, providing ideal conditions for earthworm growth. In contrast, treatments with single-type waste media compositions (P01 and P02) showed lower average body lengths.

Treatments P1 and P3, with different proportions of mixed waste, showed better results than single composition treatments, but still lower than Treatment P2. Treatment P1, with 30% oyster mushroom waste and 70% straw mushroom waste, resulted in a relatively high average body length, though not as high as Treatment P2. Meanwhile, Treatment P3, with 80% oyster mushroom waste and 20% straw mushroom waste, had an average body length lower than P2 but higher than P01 and P02. Overall, these results indicate that a balanced combination of mushroom waste media is more effective in supporting the optimal growth of *Eisenia foetida*.

3.2. Body Weight

Worm body weight is a measurement of body weight in each medium that has 5 earthworms. The results of the analysis of the average worm body weight are presented in Table 6.

Table 6. Results of Descriptive Statistics on the Body Weight of *Eisenia foetida worms*

Treatment	Minimum	Maximum	Means	std. Deviation
P_{01}	7.00	24.49	15.74	12.36
P_{02}	2.95	26.70	14.82	16.79
P_{1}	4.64	25.50	15.06	14.75
P_{2}	4.70	25.68	15.18	14.83
P_{3}	8.58	25.70	17.13	12.10
Valid N (listwise)				

Table 6 shows the average body weight measurements of *Eisenia foetida* earthworms across five different mushroom waste media treatments. In Treatment P 01 (100% Oyster Mushroom Waste), the body weight of the earthworms ranged from 7.00 g to 24.49 g, with an average weight of 15.74 g and a standard deviation of 12.36. Treatment P 02 (100% Straw Mushroom Waste) showed body weights ranging from 2.95 g to 26.70 g, with an average of 14.82 g and a standard deviation of 16.79, indicating significant variation.

Treatment P 1, which used a mix of 30% oyster mushroom waste and 70% straw mushroom waste, resulted in body weights ranging from 4.64 g to 25.50 g, with an average of 15.06 g and a standard deviation of 14.75. Treatment P 2, with a media composition of 50% oyster mushroom waste and 50% straw

mushroom waste, showed body weights ranging from 4.70 g to 25.68 g, with an average of 15.18 g and a standard deviation of 14.83. Treatment P 3, consisting of 80% oyster mushroom waste and 20% straw mushroom waste, produced the best results with an average body weight of 17.13 g, ranging from 8.58 g to 25.70 g and a standard deviation of 12.10.

From this data, it is evident that the composition of mushroom waste media significantly affects the body weight growth of *Eisenia foetida*. Treatment P 3 demonstrated the most optimal results, with the highest average body weight and lower variation compared to other treatments. This indicates that a media composition of 80% oyster mushroom waste and 20% straw mushroom waste provides a more balanced and conducive environment for earthworm growth. In contrast, Treatment P 02 exhibited very high variation in body weight, possibly indicating unstable media conditions for earthworm growth.

Other treatments, such as P 1 and P 2, showed more consistent results but still lower than P 3. Therefore, a balanced combination of oyster mushroom waste and straw mushroom waste provides more optimal conditions for the body weight growth of *Eisenia foetida*. Overall, this study highlights the importance of selecting the appropriate media to support the optimal growth and development of earthworms.

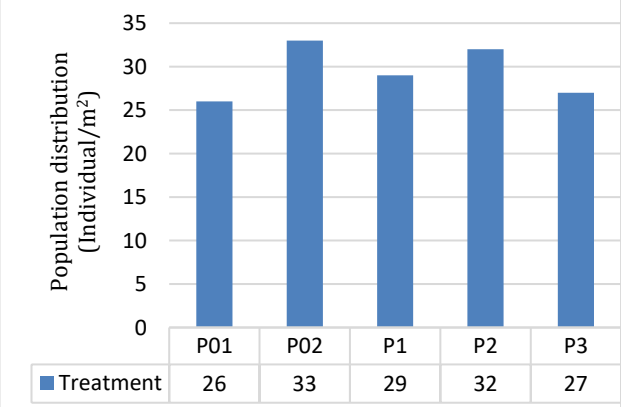

Figure 2. Population Distribution of Eisenia foetida

Figure 2 shows the population density of *Eisenia foetida* earthworms under five different mushroom waste media treatments. Population density is measured in the number of individuals per square meter (individuals/m^2). In Treatment P01 (100% Oyster Mushroom Waste), the population density of earthworms is 26 individuals/m^2. Treatment P02 (100% Straw Mushroom Waste) shows the highest population density of 33 individuals/m^2. In Treatment P1, with a media composition of 30% oyster mushroom waste and 70% straw mushroom waste, the population density is 29 individuals/m^2. Treatment P2, with a media composition of 50% oyster mushroom waste and 50% straw mushroom waste, has a population density of 32 individuals/m^2. Meanwhile, Treatment P3, consisting of 80% oyster mushroom waste and 20% straw mushroom waste, shows a population density of 27 individuals/m^2.

From this data, it is evident that the composition of mushroom waste media affects the population density of *Eisenia foetida* earthworms. Treatment P02, with 100% straw mushroom waste, resulted in the highest population density, possibly due to the more optimal availability of nutrients in this media. Conversely, Treatment P01, with 100% oyster mushroom waste, showed the lowest population density, which may be due to less supportive media conditions compared to other treatments.

Treatment P2, with a balanced mix of 50% oyster mushroom waste and 50% straw mushroom waste, also showed a high population density of 32 individuals/m^2, nearly equal to Treatment P02. Treatments P1 and P3 showed varying results, with population densities of 29 individuals/m^2 and 27 individuals/m^2, respectively. This indicates that while mixed media provide better conditions than single media, an optimal mix ratio is still necessary to achieve maximum results.

These results emphasize the importance of selecting the right composition and proportion of mushroom waste media to support optimal population density of *Eisenia foetida* earthworms. Media containing straw mushroom waste appear to be more effective in supporting earthworm populations compared to oyster mushroom waste alone.

3.3. Skin color

The skin color of the worms in each medium was observed on the last day of the study. The results of observing the color of the worm's skin are presented in Figure 3.

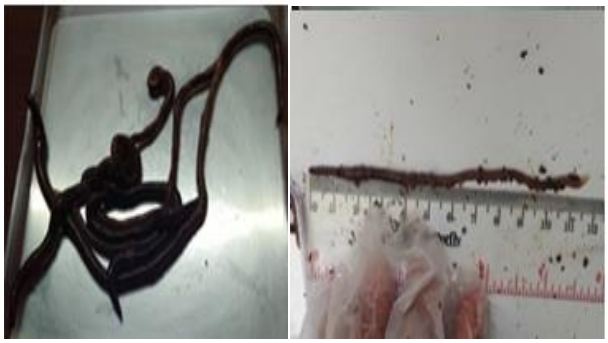

Figure 3. Earthworm *Eisenia foetida*

The earthworm *Eisenia foetida* has a red-black dorsal (top) section, a darker colored mouth on the front (anterior), and an orange or brighter anus at the end of the tail (posterior).

3.4. Population

The population observed was the earthworm population (tail), using the hand sorting method and using the formula for calculating the population according to Sagita et al., (2014). The results of calculating the number of earthworms for each treatment are presented in Table 7.

Table 7. Population of *Eisenia foetida* Per Media (Polybag)

Treatment	2nd test						Total
	U1	U2	U3	U4	U5	U6	
P_{01}	4	3	4	5	5	5	26
P_{02}	5	5	8	5	5	5	33
P_1	5	5	5	4	5	5	29
P_2	5	7	5	5	5	5	32
P_3	5	3	5	5	4	5	27
Total							147
K (individuals/m^2)							5

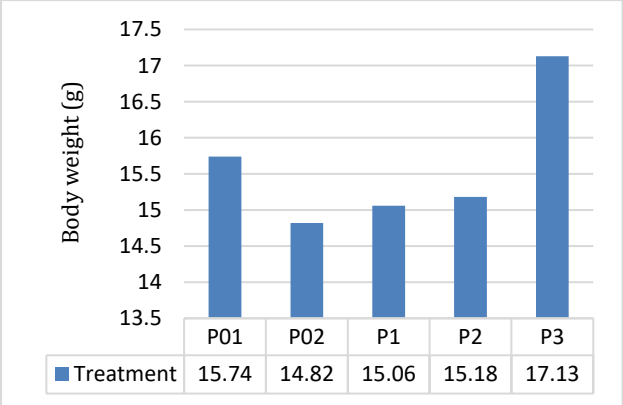

Figure 4. Body Weight of *Eisenia foetida* Earthworms

Table 7 and Figure 4 illustrate the average body weight and population density of *Eisenia foetida* earthworms across different mushroom waste media treatments. The average body weight of the earthworms is measured in grams (g) for five different treatments. In Treatment P01 (100% Oyster Mushroom Waste), the average body weight is 15.74 g. Treatment P02 (100% Straw Mushroom Waste) shows the lowest average body weight of 14.82 g. In Treatment P1, consisting of 30% oyster mushroom waste and 70% straw mushroom waste, the average body weight is 15.06 g. Treatment P2, with a media composition of 50% oyster mushroom waste and 50% straw mushroom waste, has an average body weight of 15.18 g. Treatment P3, consisting of 80% oyster mushroom waste and 20% straw mushroom waste, shows the highest average body weight of 17.13 g.

The table shows the population density of *Eisenia foetida* earthworms in five different mushroom waste media treatments, measured in individuals per square meter (individuals/m^2). In Treatment P01, the population density is 26 individuals/m^2. Treatment P02 shows the highest population density with 33 individuals/m^2. In Treatment P1, the population density is 29 individuals/m^2. Treatment P2 has a population density of 32 individuals/m^2. Treatment P3 shows a population density of 27 individuals/m^2. The total population density across all treatments is 147 individuals/m^2, with an average density of 5 individuals/m^2.

From these data, it is evident that the composition of mushroom waste media affects both the body weight and population density of *Eisenia foetida* earthworms. Treatment P3 demonstrates the most optimal results in terms of average body weight, while Treatment P02 shows the highest population density. This indicates that a higher proportion of oyster mushroom waste provides better conditions for body weight growth, whereas media with straw mushroom waste is more effective for population density. The variation in these results underscores the importance of selecting the appropriate media composition to support the optimal growth and population of *Eisenia foetida* earthworms.

3.5. Biomass

Biomass of earthworms was analyzed from the results of calculating the initial and final biomass of the research in each treatment. The results of the analysis of earthworm biomass are presented in Figure 5.

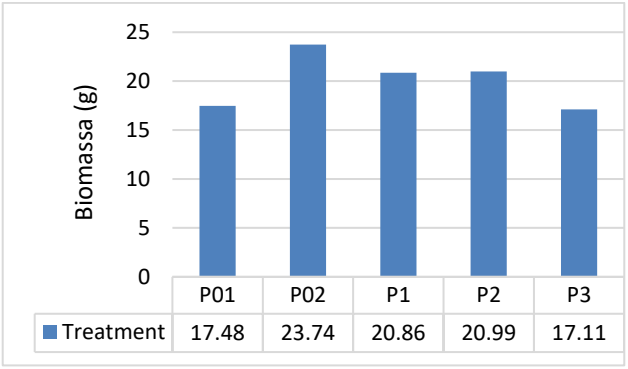

Figure 5. Growth of *Eisenia foetida* Worm Biomass

Figure 5 shows that the growth of *Eisenia foetida worm biomass* at P_{01} (100% Oyster Mushroom Waste) was an average of 17.48 g. P_{02} (100% Straw Mushroom Waste) with an average of 23.74 g. P_1 (Oyster Mushroom Waste 30% + Straw Mushroom Waste 70%), namely an average of 20.86 g. P_2 (50% Oyster Mushroom Waste + 50% Straw Mushroom Waste) is an average of 20.99g. P_3 (80% Oyster Mushroom Waste + 20% Straw Mushroom Waste) which is an average of 17.11 g.

The growth and morphology of earthworms is strongly influenced by media humidity (Firmansyah, 2017) states that moisture is needed to keep the earthworm's skin functioning normally to sustain its life. Therefore, in this study watering was carried out 1 time in 3 days, to be precise in the afternoon, to keep the media moist. Watering was not done every day in this study to reduce excessive media moisture, which is not good for the growth of earthworms. Excessive media humidity can cause the pH of the media to become acidic, because the gases trapped in the media will interact with the organic compounds in it, thereby inhibiting the growth of earthworms (Roslim et al., 2013)

According to (Brata, 2010; Nurwati, 2011) The growth of earthworms is very dependent on the type and amount of feed they consume. Earthworms that consume nitrogen-rich feed will experience rapid growth. Earthworms can utilize organic matter from litter, or plant parts for their growth.

The development of the morphological characteristics of the earthworm *Eisenia foetida* was observed starting at the age of 14 days which were homogeneous in each medium of 5 earthworms and at the age of 44 days. Observations were reviewed from several variables including body length, body weight, skin color, population and biomass. Each variable is explained as follows:

a. Eisenia foetida Worm Body Length

The growth in length *of Eisenia foetida* experienced the highest growth in the $P_{2\ \text{treatment medium}}$ (50% Oyster Mushroom Waste + 50% Straw Mushroom Waste), with an average of 10.5 cm. Meanwhile, the lowest increase occurred in the $P_{01\ \text{treatment medium}}$ (100% Oyster Mushroom Waste), with an average of 7.75 cm.

The highest growth in length occurred in media with 50% straw mushroom waste composition compared to media using only oyster mushroom waste. This is due to the fact that the basic ingredient of straw mushroom waste is rice straw which is known to contain 37.71% cellulose, 21.99% hemicellulose and 16.62% lignin. This content is good for nutrition in earthworm feed, so that the growth of *Eisenia foetida worms* develops well (Putra, 2022) .

According to (Ciptono, 2022) The worm's body consists of segments, with longitudinal and circular muscles for the movement of the earthworm. Contractions of the longitudinal muscles make the earthworm's body elongate and shorten, while circular muscle contractions make the earthworm's body expand and contract. Therefore, measuring the length of the worm is done when the worm is stationary or when it is about to move in order to get a body length that is close to its original body length.

According to (Liberty et al., 2022) suggested that the increase in the body length of earthworms in mushroom waste media was due to the nutrient content which was able to provide the growth of new segments in the posterior part of the earthworms. In addition, protein is a food substance that is very important for the body of earthworms, because this substance, apart from being a source of energy as well as a building substance, protein is a material for forming new tissues that always occur in the body of earthworms when they enter adulthood. Organic materials will have an effect on the growth of the length and body weight of earthworms.

b. Body Weight

The growth of *Eisenia foetida* experienced the highest increase in earthworm weight in the $P_{3\text{treatment medium}}$ (80% Oyster Mushroom Waste + 20% Straw Mushroom Waste), with an average weight of 17.13 g. Meanwhile, the lowest increase in worm body weight occurred in the $P_{02\ \text{treatment medium}}$ (100% straw mushroom waste), with an average weight of 14.82 g.

According to (Garg & Gupta, 2011) worm body weight gain is an indication of worm growth that obtains sufficient nutrition from the media and environmental conditions suitable for earthworm growth, conversely a decrease in worm body weight indicates a lack of nutrition for worm growth and unsuitable environmental conditions.

This is caused by the level of preference of earthworms for the type of food. As it is known that earthworms most preferred organic food comes from leaf litter (fallen leaves), livestock manure (Febrita' et al., 2015). Menuru (Mega, 2014) in baglog oyster mushroom waste contains organic material composition in the form of sawdust, rice bran, corn bran which can fulfill the nutrients in the food so that the weight growth of the worm's body develops properly.

According to (Rusniyati et al., 2021) in the results of his research, he stated that the body weight of earthworms is strongly influenced by the condition of the media and the availability of nutrients in the growth medium of earthworms. So it must be ensured that the growth media used contains good nutrition for the growth of earthworms. In general, what can be used as earthworm feed ingredients to support nutrition in the media is in the form of organic wastes, such as vegetable waste, sawdust, remaining mushroom media, forage waste, livestock manure, midribs, leaves, banana cobs, rice straw waste and dregs. know.

The availability of feed in the media greatly affects the physiological activity of earthworms. Nitrogen content and the amount of different media composition greatly affect the physiological development of earthworms. In addition, the development of earthworms can be influenced by the frequency of watering, thus in this study watering was done every 3 days to keep the media humidity stable. According to (Harmatang & Sitti, 2014) stated that 85% of the earthworm's body weight is water, so it is very important to keep the rearing medium moist. In addition, moisture is needed to keep the worm's skin functioning normally.

c. *Eisenia foetida* Worm Skin Color

Based on the results of the study, *the Eisenia foetida* worm has a red-black dorsal (top) section, a darker colored mouth in the front (anterior), and at the end of the tail (posterior) an orange or brighter anus. The initial color of the earthworm *Eisenia foetida's skin* is red, but after 30 days, the skin color changes slightly to a more intense blackish red. Changes in earthworm skin color can be caused by media humidity and worm age.

According to (Setiawan et al., 2021) humidity is very necessary to keep worm skin functioning normally. Humidity that is too high or too wet will cause earthworms to turn pale and eventually die. Conversely, media humidity that is too low or dry can also cause earthworms to stop eating and eventually cause the death of earthworms.

Based on the results of the study (Vianingrum, 2017) the general characteristics of the *Eisenia foetida* worm are that it has a flat tail tip, the dorsal (top) part

is blackish red, the ventral (bottom) part is reddish white and the tip of the tail is orange.

According to (Edwards & Lofty, 1977) in general, the male genital organs consist of two pairs of testicles, which are located on the 10th and 11th segments, while the female genital organs, namely the ovaries, are located on the 13th segment. After adulthood, there will be thickening of the epithelium at certain segment positions to form the clitellum (uterine tube or uterus). The clitellum can be darker or lighter in color than the rest of the body.

d. Biomass

Earthworm biomass in different media compositions has a different weight between one treatment and another. This is due to the presence of food for earthworms. The highest biomass was found in the treatment medium P_{02} (100% edible mushroom waste) with an average of 23.74 g, while the lowest biomass was found in the $P_{3\text{treatment medium}}$ (80% oyster mushroom waste + 20% edible mushroom waste) with an average 17.11 g. The highest growth in biomass was obtained from the treatment of straw mushroom waste feed due to the fact that the amount of food for these earthworms is more abundant in rice straw, it is known that rice straw contains as much as 18.06% protein, while oyster mushrooms contain as much as 8.53% protein. Earthworms really need protein for their growth process (Sarungu et al., 2020).

Based on research results (Mashur, 2020) states that the nutrients needed by soil worms are protein, fat, carbohydrates, vitamins, minerals, and water. Deficiency and excess of protein can reduce the growth rate of earthworms. This is because protein in feed is a source of energy needed for the formation of body proteins so that the growth of earthworms develops properly.

Based on research results (Anita, 2021), it is also said that biomass growth is affected by the nutrient content such as protein in the rearing medium. Therefore, the availability of food sources in the straw mushroom waste medium is sufficient for the proper growth and development of earthworms, thereby increasing the biomass of *Eisenia foetida worms* .

Apart from being influenced by nutrients in food, the growth of *Eisenia foetida worm biomass* is also influenced by other factors such as container capacity and environment. Even though the capacity of the container area in each treatment medium is the same, they have different qualities because the amount of composition in each treatment is different.

e. Population

Eisenia foetida worm population according to (Sagita et al., 2014) using the hand sorting method or taking soil mesofauna which is done directly (manually) at predetermined sample point locations. The distribution of the population in the treatment medium P_{02} (100% straw mushroom waste) had the highest population of 33 individuals, and the lowest population distribution in the treatment medium P_{01} (100% oyster mushroom waste) was 26 individuals. The difference in the number of distribution of earthworm populations is due to the earthworm *Eisenia foetida* preferring straw mushroom waste media because there are more food nutrients in the media. So it can be said that at every 1 m2 distance there are 5 earthworms that live in the media.

According to (Muksin & Anasaga, 2021) stated that earthworms are soil biota that are often found in land and have a beneficial role in the soil ecosystem. Population density and biomass of earthworms are highly dependent on soil physical-chemical factors and the availability of sufficient food for earthworms. In different physical and chemical soil media, of course the density of earthworms is also different.

According to (Ibrahim, 2015) The life of earthworms is also determined by pH. The acidity of the media greatly affects the population and activity of earthworms so that it becomes a limiting factor for their distribution and species. In general, earthworms grow well at an optimum pH of around 6-7.2. Earthworms are very sensitive to soil acidity, therefore pH is a limiting factor in determining the number of species that can live in a particular soil.

4. CONCLUSION

Eisenia foetida worms have different characteristics and growth in body length, body weight, skin color, population and biomass in each treatment medium. Mushroom media waste with the same composition treatment is very good for the morphological development of earthworms. As for the development of earthworm growth, the composition of oyster mushroom waste is better than that of straw mushroom waste.

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