Combination Of Goat Rumen And Mas Snails As Decomposer Bacteria In Manufacturing Empty Palm Bunch Compost

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***Abstract**.*

One effort to utilize EPOFB waste is by composting EPOFB. Cellulose can be broken down by the activity of microorganisms that are capable of hydrolyzing cellulose as an energy source, such as bacteria and fungi. One solution for managing EFB waste is to utilize cellulose decomposing organisms, which come from goldfish snails (pomacea canaliculata) and goat rumen (caprovis spp.). The aim of this research is to calculate the length of time for composting, observe the physical properties of the compost and test the nutrient elements N, P, K, C/N ratio and pH, compost from EFB using decomposer bacteria from golden snails combined with goat rumen at the P1 level and the P2 level. using commercial bioactivators. Fertilizer results at each level were compared with the Indonesian National Standard SNI No./140/10/2004. This research was carried out at the Agronomy Laboratory of the Plantation Plant Cultivation Study Program and Pilot Gardens of the Samarinda State Agricultural Polytechnic, from June to September 2023. The research results show the length of time for composting to compost empty oil palm bunch waste at P1 level using a golden snail decomposer combined with rumen goats and P2 used a commercial biodecomposer for 53 days. Based on the results of research on the physical properties of empty oil palm fruit bunch waste compost at levels P1 and P2, the temperature at the end was the same, namely 28ºC, while the color, odor and texture parameters were better at level P2, namely blackish brown, odorless and slightly grainy in texture. The research results at the P2 treatment level were better in terms of the element parameters N, P, K and C, namely, N = 1.0343%, P = 0.2554% and K = 32.58, which met SNI 19-7030-2004 standards.

Keywords: *Empty palm oil bunches, Bacterial isolates, Golden snails, Goat rumen, and Compost.*

I. INTRODUCTION

Based on BPS data for 2021, East Kalimantan has an oil palm plantation area of 1,312,095 ha with total production of up to 3,750,607 tons. The large area of oil palm plantations will of course produce a very large amount of waste, one of which is empty oil palm fruit bunches (EPOFB). EPOFB is composed of cellulose compounds which are quite high, reaching 35.66-57.75% [1] and contains high lignocellulose, namely around 81-89% [2]. The high cellulose content in EFB makes this material difficult to decompose and requires a relatively long time. One effort to utilize EPOFB waste is by composting EPOFB. However, the process of processing it into fertilizer requires a decomposer which can speed up the decomposition process. [3] reported that the EFB decomposition process can be accelerated by adding decomposers such as bacteria and fungi which have high capabilities in decomposing organic materials. Cellulose can be broken down by the activity of microorganisms that are able to hydrolyze cellulose as an energy source, such as bacteria and fungi [4]. One solution for managing EFB waste is to utilize cellulose decomposing organisms, derived from goldfish snails (*Pomacea canaliculata*) and goat rumen (*Caprovis spp.)*.Microorganisms from golden snails combined with goat rumen have the ability to decompose EFB waste into organic material.

Several studies have been carried out to explore the potential of these decomposing organisms in decomposing organic materials.Mas snail pests contain high levels of protein and fat so they have the potential to be a source of local microorganisms and are very good as decomposers in the composting process [5]. Local microorganisms (MOL) from golden snails contain *Aspergillus niger* which has the potential to produce cellulase enzymes which function to degrade cellulose [6], [7].Composting EPOFB made from decomposer from golden snails produces organic C of 26.9%, and a C/N ratio of 21.18 in accordance with the criteria of Minister of Agriculture Regulation Number 70/Permentan/SR.140/10/2011 [8]. Rumen fluid contains many bacteria, one of which is cellulolytic bacteria which have the ability to degrade cellulose [9]. The diversity and composition of abundant microbes such as bacteria, fungi and protozoa in goat rumen [10]. From the research results [11] shows the addition of 15% rumen in composting, has a C/N of 19.24%, this content meets SNI 19–7030–2004. [12] reported that providing the rumen in the composting process resulted in a C/N ratio of 13%.

The addition of cow rumen decomposer can produce compost nutrients, the respective values are 8.47 Carbon, 0.81 nitrogen, 0.36 phosphorus, and 0.81 potassium [13]. Research result [14] golden snail bioactivator combined with goat rumen produced 16 types of bacterial isolates. In this study, it was obtained that the highest producers of cellulase enzymes were isolates P106, P102, P104, P205 and P202, the highest producers of amylase and protease enzymes, P104.The aim of this research is to calculate the length of composting time, observe the physical properties of the compost and test the macro nutrients of compost from EFB using decomposer bacteria from golden snails combined with goat rumen. From several studies, microbes originating from golden snails combined with goat rumen have potential as decomposers of EFB waste because they contain cellulotic bacteria and produce amylase and protease enzymes which can also act as biological agents. Use of bacterial collection [14] from gold snails combined with goat rumen will be able to speed up the decomposition process of EFB waste so that it can be used as organic fertilizer. Apart from that, the use of microbes from golden snails combined with goat rumen in managing EFB waste can also help reduce negative impacts on the environment.

II. METHODS

2.1 Implementation Procedures

a. Collection of Empty Palm Oil Bunches (EPOFB)

EPOFB sampling will be carried out at the Pilot Garden of the Plantation Plant Cultivation Study Program, Samarinda State Agricultural Polytechnic. Samples were taken of 8 kg of EPOFB and put in sample plastic. Next, the EPOFB waste is taken to the laboratory for further stages.

b. Material Preparation and Enumeration

8 kg of EPOFB material was taken and then chopped into 2-4 cm pieces. The next step is to prepare 4 kg of bran, prepare golden snail isolate from a combination of goat rumen and commercial bioactivator.

c. Preparation of Commercial Isolates and Bioactivators

Preparation of decomposer bacterial suspension from golden snails combined with goat rumen using five isolates, namely P106, P102, P104, P202, P205. The isolates were then multiplied separately by streaking one full circle using a loop needle onto Tripthic Soya Agar (TSA) agar media and incubating for 48 hours. Next, suspend it in 50 ml of distilled water and shaker for 24 hours. The commercial bioactivator used is EM4, the bioactivator is first fermented, using 200 g of brown sugar with a fermentation time of 24 hours, 40 ml of bioactivator is used for 2 l of water [15].

d. Composting

The next step is in P1, mixing all the ingredients, namely 4 kg chopped EPOFB, 2 kg bran mixed until evenly mixed. Next, the results of the microbial suspension from golden snails combined with goat rumen were mixed into a 2l container of water. Mix the ingredients that contain microbes gently, little by little, until the mixture clumps and crumbles easily when touched. Meanwhile, in P2, mix all the chopped ingredients, 4 kg EPOFB, 2 kg bran. Next, mix the ingredients containing 2 l of commercial biodecomposer which has been fermented for 24 hours. The materials are stacked and covered using a tarpaulin that is thick and strong enough to suit the compost treatment with a total amount of 6 kg of material per level. Aeration, regulating air circulation, is carried out by turning the compost material over if the pile temperature is above 65 ^{o}C or below 45 ^{o}C, the pile is too wet or too dry. If the temperature is still 45–60 ^{o}C and humidity is 50%, it is not yet time to turn the compost pile [14]. Moisture measurements using a soil tester and composting will be carried out until the compost is finished.

2.2 Observation Parameters

a. Temperature Measurement

This measurement will be carried out every day at 15.00 WITA. The tool used is a stem thermometer. Temperature measurement is done by inserting a stick thermometer, a point that can represent the temperature of the pile in the middle of the compost pile.

b. Determination of Compost Color

This determination will be made every day at 15.00 WITA, determining the color of the compost is done by the sense of sight.

c. Determination of Compost Odor

This determination will be carried out every day at 15.00 WITA, carried out using the sense of smell. In this determination the compost is said to be mature if the compost no longer emits a rotten smell or resembles an earthy smell (no smell) indicating that the compost is mature.

d. Determination of Compost Texture

This determination will be made every day at 15.00 WITA, carried out using the sense of touch. In determining this texture, 2 categories are used, namely rough and smooth. The rough texture of the resulting compost is not destroyed and is still shaped like the starting material. Meanwhile, the fine texture is when the compost is clenched using your hands, it will clump and if pressed gently, it will easily crumble.

e. Measuring the pH (Degree of Acidity) of Compost

This measurement will be carried out every day at 15.00 WITA, taken by measuring the pH (degree of acidity) of the compost using a soil tester. The next stage in the finished compost sample unit from the two treatment levels will be a sample of 500 g of compost to be analyzed for organic N, P, K, C and C/N of compost in the laboratory of the East Kalimantan Agricultural Research Technology Center (BPTP). Data on the physical properties of the compost (temperature, color, odor, texture) as well as the results of the macro nutrient analysis of the EPOFB compost are presented descriptively and then compared with SNI No-19-7030-2004.

III. RESULT AND DISCUSSION

3.1 Result

Based on the results of observations of the physical properties of compost in the form of temperature, pH, color, smell and texture of compost in table 1.

Table 1. Results of Observations of Temperature, pH, Color, Odor and Texture in The Composting Process Of Empty Oil Palm Fruit Bunches

Days to	Parameter									
	Temperature		pH		Color		Smell		Texture	
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
1	49	52	5	5	Light brown	Light brown	Smelly	Smelly	Litter	Litter
2	49	51	5,2	5	Light brown	Light brown	Smelly	Smelly	Litter	Litter
3	48	50	5,2	5	Light brown	Light brown	Smelly	Smelly	Litter	Litter
4	48	49	5,2	5,2	Light brown	Light brown	Smelly	Smelly	Litter	Litter
5	47	49	5,2	5,2	Light brown	Light brown	Smelly	Smelly	Litter	Litter
6	47	48	5	5,2	Light brown	Light brown	Smelly	Smelly	Litter	Litter
7	47	48	5,3	5,4	Light brown	Light brown	Smelly	Smelly	Litter	Litter
8	46	46	5,5	5	Light brown	Light brown	Smelly	Smelly	Litter	Litter
9	46	46	5,5	5,4	Light brown	Light brown	Smelly	Smelly	Litter	Litter
10	45	45	5,5	5,4	Light brown	Light brown	Smelly	Smelly	Litter	Litter
11	44	45	5,8	5,5	Light brown	Light brown	Smelly	Smelly	Litter	Litter
12	45	45	5,4	5,5	Dark brown	Light brown	Smelly	Smelly	Litter	Litter
13	44	44	5,8	5,6	Dark brown	Light brown	Smelly	Smelly	Litter	Litter
14	43	44	5,8	5,8	Dark brown	Dark brown	Smelly	Smelly	Litter	Litter
15	42	43	6	5,8	Dark brown	Dark brown	Smelly	Smelly	Litter	Litter
16	42	42	6	6	Dark brown	Dark brown	Smelly	Smelly	A bit anxious	Litter
17	41	41	6	6	Dark brown	Dark brown	Less smelly	Smelly	A bit anxious	Litter
18	40	41	6,2	6,2	Dark brown	Dark brown	Less smelly	Smelly	A bit anxious	Litter
19	39	40	6,2	6,2	Dark brown	Dark brown	Less smelly	Smelly	A bit anxious	Litter
20	38	40	6,2	6	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	Litter
21	37	40	6,4	6,2	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	Litter
22	38	39	6,4	6,4	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
23	37	39	6,5	6,5	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
24	36	38	6,5	6,5	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
25	34	38	6,5	6,7	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
26	34	37	6	6,7	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
27	34	36	6,5	6,8	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
28	34	35	6,5	6,9	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
29	34	34	6,6	6,9	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
30	33	34	6,6	7	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
31	33	33	6,6	7	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
32	33	33	6,6	7	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
33	33	32	6,7	7	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
34	32	31	6,7	7,2	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
35	32	31	6,8	7,2	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
36	31	30	6,7	7,2	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
37	31	30	6,8	6,5	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
38	31	29	6,8	7,2	Dark brown	Dark brown	Less smelly	Less Smell	A bit anxious	A bit anxious
39	31	29	6,8	7,4	Dark brown	Dark brown	No smell	Less Smell	A bit anxious	A bit anxious
40	29	29	6,8	7,5	Dark brown	Dark brown	No smell	Less Smell	A bit anxious	A bit anxious
41	29	28	6,5	7,5	Dark brown	Dark brown	No smell	Less Smell	A bit anxious	A bit anxious
42	29	28	6,8	7,5	Blackish Brown	Dark brown	No smell	Less Smell	A bit anxious	A bit anxious
43	29	28	6,8	7,2	Blackish Brown	Dark brown	No smell	No smell	A bit anxious	A bit anxious
44	29	28	6,8	7,6	Blackish Brown	Dark brown	No smell	No smell	A bit anxious	A bit anxious
45	28	28	6,8	7,6	Blackish Brown	Dark brown	No smell	No smell	A bit anxious	A bit anxious
46	28	28	6,8	7,6	Blackish Brown	Blackish Brown	No smell	No smell	A bit anxious	A bit anxious
47	28	28	6,8	7,6	Blackish Brown	Blackish Brown	No smell	No smell	A bit anxious	A bit anxious
48	28	28	6,8	7,6	Blackish Brown	Blackish Brown	No smell	No smell	A bit anxious	A bit anxious
49	28	28	6,8	7,6	Blackish Brown	Blackish Brown	No smell	No smell	A bit anxious	A bit anxious
50	28	28	6,8	7,6	Blackish Brown	Blackish Brown	No smell	No smell	A bit anxious	A bit anxious
51	28	28	6,8	7,6	Blackish Brown	Blackish Brown	No smell	No smell	A bit anxious	A bit anxious
52	28	28	6,8	7,6	Blackish Brown	Blackish Brown	No smell	No smell	A bit anxious	A bit anxious
53	28	28	6,8	7,6	Blackish Brown	Blackish Brown	No smell	No smell	A bit anxious	A bit anxious

3.2 Discussion

a. Composting Time

Composting empty palm fruit bunches (EPOFB) waste at both levels P1 4 kg EPOFB waste, 2 kg bran and golden snail decomposer combined with goat rumen and P2 level 4 kg EPOFB waste, 2 kg bran and commercial biodecomposer, composting at both levels takes place for 53 days starting from 16 July 2023 to 5 September 2023, the speed of compost maturity is influenced by the materials that make up EFB waste, empty oil palm fruit bunch waste is composed of quite high levels of cellulose compounds, this is in line with research [16] reported that EFB contains 65% cellulose, 25.31% lignin, 33.5% hemicellulose and 86.3% holocellulose. According on [17] large piles of EFB, which is an organic material with a high cellulose content, mean that EFB waste takes a long time to decompose.

b. Physical Properties

1. Measuring Changes in Compost Temperature

In the composting process, it is necessary to observe the temperature of the compost to determine the maturity level of the compost and to determine whether the decomposition process is still ongoing. The following is an observation of the average temperature of compost every week (Figure 1).

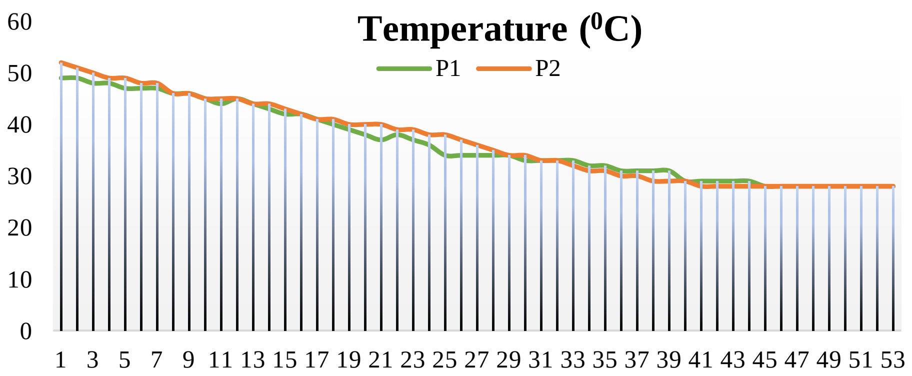

Fig 1. Compost Temperature Observation Data

During the decomposition process, microorganisms will produce nutrients and energy as heat so that the temperature increases. The heat produced will be used again by microorganisms to decompose the material and some will be wasted into the environment. Every time the decomposition process takes place, heat will be produced so that the temperature of the material will continue to increase, even to the thermophilic phase (40-60°C) [18]. In these conditions, microorganisms also experience changes starting from psychrophilic, mesophilic to thermophilic microorganisms. The thermophilic phase is the most optimal decomposition phase, organic material will decompose quickly and the temperature will return to the second mesophilic phase as the organic material content decreases as a substrate for microorganisms. Furthermore, when the organic material begins to decompose, the temperature will tend to remain constant and stabilize.Based on Figure 1, the P1 level on day 1, the initial temperature was 49ºC, then decreased gradually on day 7 to 47ºC. The temperature of the compost decreased until on the 44th day the temperature was stable, namely 28º C and on the 45th day at level P1 the temperature reached the highest temperature, namely 49ºC. In Figure P2 from table 1, the P2 level on day 1, the initial temperature is 52ºC, then decreases gradually on day 7 to 48ºC.

The temperature of the compost decreased until on the 40th day the temperature was stable, namely 28º C and on the 41st day at level P2 the temperature reached the highest temperature, namely 52ºC. According to [19] that thermophilic microorganisms live at temperatures of 45-60°C and are tasked with consuming carbohydrates and proteins so that the compost material can be degraded quickly and the microorganisms found in the thermophilic phase are Actinomycetes and thermophilic fungi which are capable of breaking down cellulose and hemicellulose. An increase in the initial temperature at each research level indicates the presence of microorganism activity in the decomposition process. The highest temperature at these two levels was at P2 using a commercial bioactivator, the temperature achieved was 52 ºC. This is according to opinion [20] that the initial temperature of composting increases due to the activity of microorganisms in decomposing organic material with oxygen, thereby producing energy in the form of heat, CO2 and water vapor. Heat stored in the pile will increase the temperature, after reaching the peak the temperature will decrease and stabilize until the composting process is complete.

2. Measurement of Daily pH Changes

In the composting process, it is necessary to observe the pH of the compost to determine the acid and alkaline levels in the compost and to determine whether the decomposition process is still ongoing. The following is an observation of the average pH of compost every week (Figure 2).

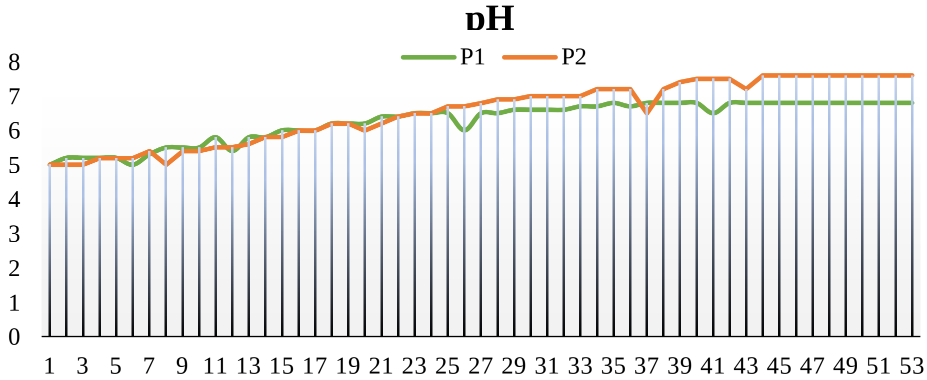

Fig 2. Compost pH Observation Data

Based on Figure 2, the P1 level of the average change in the pH value of the composting material shows that the pH value increases gradually in composting until around days 2-29. However, after stabilizing at a pH of 6.6-6.8, at the P2 level, the average change in the pH value of the composting material can be seen as the pH value gradually increasing in composting around days 4-37. However, it is stable on days 34-53 with a pH range of 7.2-7.6. The increase in pH occurs due to an increase in alkaline ammonium ions in the form of ammonia which is produced from biochemical reactions of elements containing nitrogen in limited quantities [21]. The final result of the compost meets the compost criteria according to SNI 19-7030-2004, namely the pH of the compost is in the range of 6.80-7.49. In the decomposition process of organic material, it depends on the length of the fermentation process, the longer the fermentation process takes, the more H+ ions there will be as a result of the activity of microorganisms decomposing organic material so that the pH becomes acidic [22]. In line with opinion [23] the longer fermentation time will increase the activity of microorganisms to use carbohydrates in the metabolic process and have an impact on increasing lactic acid. The more lactic acid produced, the lower or more acidic the pH will be.

3. Color Change Measurement

The color at the P1 treatment level, the initial color of the material is light brown, then the color changes to dark brown on the 12th to the 41st day and blackish brown on the 42nd to the 53rd day, while at the P2 treatment level the initial color of the material is colored. light brown then the color changed to dark brown on the 14th day and blackish brown like soil on the 46th day. The color changed to dark brown at the P1 treatment level and the P2 treatment level. At level P1 the color is dark brown on day 12 while P2 changes color on day 14. This color change is due to the activity of microorganisms in decomposing organic matter. This opinion is supported by research results [24] which states that the physical quality of the compost produced provides an illustration of the ability of each decomposer agent to decompose organic material.

Color changes occur due to the decomposition process by microorganisms which change organic materials with complex C chains into simple C forms [25]. In the composting process, organic material will be decomposed by microbial activity, namely microbes will take water, oxygen and nutrients from organic material, which will then decompose and release CO2 and O2 [26]. According on [27] ripe compost has a blackish brown color because mature compost has the same physical properties as soil and humus which are blackish brown and crumbly. This shows that the decomposition process by microbes in composting has been running.

4. Measurement of Smell Changes

The odor at the P1 level at the beginning is odorous then changes on the 17th day to become less odorous and on the 39th day odorless, while at the P2 level the odor of the starting material is odorous then changes on the 20th day to become less odorous. and on the 43rd day it became odorless. From these results it can be seen that the P1 level changes more quickly to become less odorous compared to the P2 level, the change to odorless occurs more quickly at the P1 level compared to the P2 level. It is thought that the change in odor occurs due to differences in the decomposer bacteria used in the composting process. changes in the composting process are also an indication that the composting process is running well.

The smell of compost that resembles the smell of soil indicates that the compost has matured and the activity of microorganisms is running well. The characteristic of mature compost is that the unpleasant odor disappears [25], [28]. In the decomposition process, microbes are able to break down nitrogen bonds in the form of ammonia into free nitrogen, and then the free nitrogen is used by bacteria as a building block for their body's proteins so that the smell of ammonia is reduced and disappears [29]. According on [30] Good compost is compost that has undergone weathering and is characterized by a color that is different from the color of the material from which it is made, odorless, low water content, and has the same temperature as room temperature. Changes in the physical properties of the compost, namely the color of the compost from brownish yellow to blackish brown, occur due to the decomposition process carried out by microbes.

5. Measurement of Texture Changes

At level P1, the initial texture of the material is still in the form of litter, then changes to slightly littered on the 16th to 57th day, while at level P2, the initial texture of the material is still in the form of litter, then changes to slightly littered on the 22nd to 24th day. 57th. From these results it can be seen that the P1 level changes the texture of the litter to slightly restless compared to the P2 treatment level. The change in texture is thought to be because the bacteria in the golden snail decomposer combined with the goat rumen are already working. This is in accordance with opinion [6] which states that the fine texture of compost occurs due to the decomposition of living microorganisms in the composting process. This opinion is also in accordance with the opinion [31] which states that the presence of degradation activity by Azotobacter bacteria in compost will cause changes in the texture of the compost. According to [32] which states that the physical quality of the compost produced provides an illustration of the ability of each decomposer agent to decompose organic material.

IV. CONCLUSION

The conclusions from this research are as follows:

1. Long time for composting to compost empty oil palm fruit bunch waste at P1 level using a gold snail decomposer combined with goat rumen and P2 using a commercial biodecomposer for 53 days
2. Based on the results of research on the physical properties of empty oil palm fruit bunch waste compost at levels P1 and P2, the temperature at the end was the same, namely 28ºC, while the color, odor and texture parameters were better at level P2, namely blackish brown, odorless and slightly grainy in texture.

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REFERENCES

[1] W. Emmanuela Maria, E. Kusumawati, A. Regiana, and D. R. Suminar, "Production Nanocellulose from Raw Materials for Oil Palm Empty Bunches (TKKS) with Hydrolysis and Freeze Drying Methods," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 742, no. 1, 2020, doi: 10.1088/1757-899X/742/1/012033.

[2] L.Elizabeth,E.M.Widyanti,B.Soeswanto, D. S. Wahyuni, and K.D.Pratiwi,"Comparison of Oil Palm Empty Fruit Bunch Delignification at Room and Mild Temperature," ***J.Tek. Kim. dan Lingkung.***,vol.6,no.2,pp.91–98, 2022.

[3] J. Supriatna, M. R. Setiawati, R. Sudirja, C. Suherman, and X. Bonneau, "Composting for a More Sustainable Palm Oil Waste Management: A Systematic Literature Review," ***Sci. World J.,*** vol. 2022, 2022, doi: 10.1155/2022/5073059.

[4] B. C. Behera, B. K. Sethi, R. R. Mishra, S. K. Dutta, and H. N. Thatoi, "Microbial cellulases – Diversity & biotechnology with reference to mangrove environment: A review," ***J. Genet. Eng. Biotechnol.***, vol. 15, no. 1, pp. 197–210, 2017, doi: 10.1016/j.jgeb.2016.12.001.

[5] N. Chimsung and C. Tantikitti, "Fermented golden apple snails as an alternative protein source in sex-reversed red tilapia (Oreochromis niloticus x O. mossambicus) diets," *Walailak Agric Technol Biol Sci*, vol. 11, no. 1, pp. 41–49, 2014.

[6] Rusmini, Daryono, R. R. Manullang, and A. Sadikin, Peningkatan Kualitas Bioaktivator Keong Mas Dengan Mikroorganisme. *Semin. Nas. Terap. Ris. Inov. Ke-6*, Vol. 6, No. 1, Pp. 1209–1215, 2020.

[7] Z. Abidin, R. Rusmini, R. R. Manullang, and D. Daryono, "Kualitas Mikroorganisme Lokal Dari Keong Mas Dengan Berbagai Jumlah Bahan Yang berbeda," *Agrosaintifika*, vol. 5, no. 1, pp. 31–38, 2022, doi: 10.32764/agrosaintifika.v5i1.3189.

[8] N. Z. Zahari, P. M. Tuah, N. H. C. Zulkifli, and F. N. Cleophas, "Composting of Oil Palm Empty Fruit Bunches by Microbial Inoculant," ***Int. J. Technol.***, vol. 14, no. 5, pp. 1081–1092, 2023, doi: 10.14716/ijtech.v14i5.5907.

[9] W. N. Sari, Safika, Darmawi, and Y. Fahrimal, "Isolation and identification of a cellulolytic Enterobacter from rumen of Aceh cattle," *Vet. World*, vol. 10, no. 12, pp. 1515–1520, 2017.

[10] S. Langda *et al.*, "Diversity and composition of rumen bacteria, fungi, and protozoa in goats and sheep living in the same high-altitude pasture," *Animals*, vol. 10, no. 2, 2020, doi: 10.3390/ani10020186.

[11] W. Pancapalaga, S. Suyatno, and D. Sedlacek, "The use of rumen contents as bio-activators for fermentation in goat manure fertilizer production," *E3S Web Conf.*, vol. 226, pp. 5–9, 2021, doi: 10.1051/e3sconf/202122600048.

[12] A. Napoleon, A. Hermawan, D. P. Sulistyani, M. L. Legowo, and ..., "Study of The Utilization of Ruminant Ruments as A Bioactivator For Palm Oil Frond Compost Quality," vol. 4, pp. 388–394, 2020, [Online]. Available: https://eprints.upnyk.ac.id/22775/%0Ahttp://eprints.upnyk.ac.id/22775/1/3. ABS-68.pdf

[13] I. Indasah and N. Fitriani, "Rotten Fruit and Cow Rumen as Local Microorganisms for Producing High-Quality Compost," ***Int. J. Integr. Eng.***, vol. 13, no. 3, pp. 9–19, 2021.

[14] Rusmini, Daryono, and L. Mudi, "Isolation and Characterization of Decomposer Bacterial Morphology of the Combination of Golden Apple Snail and Goat Rumen," 2022.

[15] N. E. A. Nasution and C. R. Rizka, "Production of liquid compost with EM4 bio activator volume variation from vegetable and fruit waste," ***META J. Sci. Technol. Educ.***, vol. 1, no. 1, pp. 87–99, 2022.

[16] S. Shinoj, R. V. B, S. Panigrahi, and M. Kochubabu, "Oil palm fiber (OPF) and its composites: A review," *Ind. Crops Prod.*, vol. 33, no. 1, pp. 7–22, 2011, doi: https://doi.org/10.1016/j.indcrop.2010.09.009.

[17] N. Hidayah and I. U. Wusko, "Characterization and Analysis of Oil Palm Empty Fruit Bunch (OPEFB) Waste of PT Kharisma Alam Persada South Borneo," *Maj. Obat Tradis.*, vol. 25, no. 3, pp. 154–160, 2020, doi: 10.22146/mot.52715.

[18] L. Y. Lim, C. P. C. Bong, and L. S. Chua, "Physicochemical profile of microbial-assisted composting on empty fruit bunches of oil palm trees," *Environ. Sci. Pollut. Res.*, vol. 22, pp. 19814–19822, 2015, doi: https://doi.org/10.1007/s11356-015-5156-5.

[19] M. Papale *et al.*, "Prokaryotic diversity of the composting thermophilic phase: The case of ground coffee compost," *Microorganisms*, vol. 9, no. 2, pp. 1–19, 2021, doi: 10.3390/microorganisms9020218.

[20] N. Yanqoritha, "Influence of Physico-Chemical and Bioactivators for Composting of Traditional Market Vegetable Waste," ***J. Penelit. Pendidik. IPA,*** vol. 9, no. 4, pp. 1696–1704, 2023, doi: 10.29303/jppipa.v9i4.3238.

[21] L. J. Hau *et al.*, "Mixed Composting of Palm Oil Empty Fruit Bunch (EFB) and Palm Oil Mill Effluent (POME) with Various Organics: An Analysis on Final Macronutrient Content and Physical Properties," *Waste and Biomass Valorization*, vol. 11, pp. 5539–5548, 2020, doi: https://doi.org/10.1007/s12649-020-00993-8.

[22] A. Sadeli, A. Wulandari, L. Sinuraya, E. Mirwandhono, and L. Hakim, "The comparative of activator effect and fermentation time on nutrient quality, physical quality (temperature, pH) in compost," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 977, no. 1, 2022, doi: 10.1088/1755-1315/977/1/012130.

[23] Z. Abidin *et al.*, "Utilization of Mole (Local Microorganism) of Mas Conch and Age of Seed on Rice Growth and Production," ***J. Agriment,*** vol. 7, no. 2, pp. 112–119, 2022, doi: 10.51967/jurnalagriment.v7i2.1755.

[24] A. Pujiyanti, S. Sulhadi, and M. P. Aji, "Quality of Biocompost Resulting from Biopore Holes Based on Light Intensity and Acidity Degree (pH)," ***J. Nat. Sci. Math. Res.,*** vol. 5, no. 2, pp. 43–48, 2019.

[25] S. Xie, H. T. Tran, M. Pu, and T. Zhang, "Transformation characteristics of organic matter and phosphorus in composting processes of agricultural organic waste: Research trends," *Mater. Sci. Energy Technol.*, vol. 6, pp. 331–342, 2023, doi: 10.1016/j.mset.2023.02.006.

[26] D. Hamilton, "Organic Matter Content of Wastewater and Manure," *Oklahoma Coop. Ext. Fact Sheets*, no. Figure 1, pp. 1760–1 to 4, 2012.

[27] Yuanita, "Making of Bokashi Fertilizer from Rice Straw (Oryza sativa L .) by Using the Activator Effective Microorganisms (EM4)," vol. 5, no. 10, pp. 1138–1142, 2020.

[28] F. Amery *et al.*, "Compost quality indicators," *Soilcom*, no. October, p. 23, 2020.

[29] M. Rofi'i, A. Susanti, and S. A. Zuhria, "The Formulation ' s Technique Using Microbes to the Speed Decomposition of Biomass Fertilizers," *AGARICUS Adv. Agric. Sci. Farming*, vol. 1, no. 1, 2021.

[30] I. N. Muliarta, N. L. P. P. Setianingsih, I. W. Sudiarta, D. A. D. Prawerti, I. K. Somariana, and I. K. S. Putra, "Training in Composting Efforts to Develop Economically Value Compost Products by Family Welfare Empowerment (FWE) Batuan Village, Sukawati District, Gianyar District, Bali," ***East Asian J. Multidiscip. Res.***, vol. 2, no. 7, pp. 2641–2654, 2023, doi: 10.55927/eajmr.v1i7.4828.

[31] Gusmawartati and P. R. Sari, "Cellulolytic Bacteria as Decomposers in Dry Empty Fruit Bunches Composting," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1188, no. 1, 2023, doi: 10.1088/1755-1315/1188/1/012002.

[32] Rusmini, R. R. Manullang, and Daryono, "Development of shrimp shells-based compost and plant-based pesticide using bio-activators from Golden Apple Snails and their effects on the kenaf plant growth and pest population," *Nusant. Biosci.*, vol. 9, no. 3, pp. 260–267, 2017, doi: 10.13057/nusbiosci/n090304.