BIODIVERSITAS
Volume 24, Number 9, September 2023
Pages: 4862-4869

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d240928

The cooperation of microorganisms, bacteria, mold, yeast, and Actinomycetes consortium on decomposition of household organic waste in lowering C/N ratio

LILIS PRIHASTINI[1], ARI HANDONO RAMELAN[1,2,♥], PRABANG SETYONO[3], PRANOTO[4]

[1]Doctoral Program of Environmental Science, School of Postgraduate, Universitas Sebelas Maret. Jl. Ir. Sutami 36 A, Kentingan, Surakarta 57126, Central Java, Indonesia

[2]Department of Physics, Faculty of Mathematics and Natural Science, Universitas Sebelas Maret. Jl. Ir. Sutami 36 A, Kentingan, Surakarta, 57126, Central Java, Indonesia. Tel./Fax.: +62895327051144, ♥email: aramelan@mipa.uns.ac.id

[3]Department of Environmental Science, Faculty of Mathematics and Natural Science, Universitas Sebelas Maret. Jl. Ir. Sutami 36 A, Kentingan, Surakarta 57126, Central Java, Indonesia

[4]Department of Chemistry, Faculty of Mathematics and Natural Science, Universitas Sebelas Maret. Jl. Ir. Sutami 36 A, Kentingan, Surakarta 57126, Central Java, Indonesia

Manuscript received: 8 December 2022. Revision accepted: 24 September 2023.

Abstract. *Prihastini L, Ramelan AH, Setyono P, Pranoto. 2023. The cooperation of microorganisms, bacteria, mold, yeast, and* Actinomycetes *consortium on decomposition of household organic waste in lowering C/N ratio. Biodiversitas 24: 4862-4869.* This study aimed to investigate the effective management of household waste that can lead to environmental pollution when not appropriately managed. Composting has emerged as a promising, cost-effective, and sustainable solution to address the issue of organic waste management. Furthermore, this study identified the best bioinoculants with the ability to lower the C/N ratio on the decomposition of household organic waste. It was performed with Factorial Completely Randomized Design A×B, where the A factor was bioinoculant formulas (16 formulas) and the B was the decomposition period (0, 1, 2, 3, and 4 weeks). The decomposition process was conducted at the 0, 1st, 2nd, 3rd, and 4th weeks with the C/N ratio examination. The collected data were subjected to ANOVA testing and further analyzed using the Duncan test. The results showed the lowest C/N ratio with the addition of bioinoculant code A14 (14.87) and the highest C/N reduction percentage with the addition of bioinoculant code A14 (82.7%). The best bioinoculant was treatment with A14, namely the combination of the mold consortium, yeast, and Actinomycetes. However, treatment with the addition of A14 code bioinoculant was no different from A13 code since both have the same lowercase code (i). The A13 code treatment was not significantly different from A8 since both had the same lowercase code (h).

Keywords: Bioinoculant, C/N ratio, decomposition, household organic waste, microorganisms

INTRODUCTION

The high population density is directly proportional to the volume of waste produced. According to Moya et al. (2017), global municipal waste production is predicted to reach 2.2 billion tonnes annually by 2025. In 2021, Indonesia reported that national waste generation was 79,101.22 tons/day or 28,871,946.24 tons/year (SIPSN-KLHK 2021). It is worth noting that the waste came from households 40.96% and according to the type, 41.1% was food. Subsequently, the waste is disposed of in landfills, where more than 90% is disposed of in an unsanitary manner (Atalia et al. 2015). The landfill is the world's most widely used method of garbage disposal (El Barnossi et al. 2021). The landfill process is becoming problematic in Brazil (Liikanen et al. 2018) leading to an increase in the volume of waste piled up. More than 40% of urban waste is organic (Atalia et al. 2015), with Makassar City, Indonesia, producing 67.14% (Yunus et al. 2020). Meanwhile, in 2021, Madiun City produced household waste that was dominated by food at 81% (SIPSN-KLHK 2021). In Iraq, the composition of solid waste in religious activities is 57% organic in the form of food (Abdulredha et al. 2017). Even though microorganisms quickly decompose this type of waste, improper management can lead to environmental pollution (Zhao et al. 2017). Solid waste management practices produce volumes of waste that pose a public health and environmental threat (Abanyie et al. 2022). The decomposition of organic waste results in gases such as NH_3 and H_2S, which can cause respiratory problems and air pollution (Zhao et al. 2017). Piles of waste produce leachate which has the potential to cause groundwater contamination (Pande et al. 2015). Therefore, effective organic waste management practices are needed to reduce pollution and ensure a sustainable environment.

Composting is a viable alternative to conventional methods of processing organic waste, as it offers a promising, cost-effective, and sustainable solution to managing waste both at the household and centralized levels (Rastogi et al. 2020; Iacovidou and Zorpas 2022). This natural process, derived from microbial succession, results in the degradation and stabilization of organic matter (Rastogi et al. 2020). The conversion of solid waste into organic compost is a natural way to solve the escalating problem (Jain et al. 2017). However, the natural decomposition process is often slow, taking around 3-4 months to complete (Aminah et al. 2016). To expedite the process, microorganisms play a crucial role in accelerating waste degradation (Abdel-Rahman et al. 2016; Li et al. 2018). Adding microorganisms as bioinoculants can reduce composting time to 30-36 days (Hidayanti et al. 2013; Rastogi et al. 2020), making it an economical and environmentally friendly solution to dealing with large amounts of waste (Sharma et al. 2022).

Microorganisms such as bacteria and fungi are essential to composting (Zhao et al. 2017). These microorganisms secrete extracellular enzymes that aid in the degradation of organic matter (Wang et al. 2020). In particular, bacteria and fungi play crucial roles in litter decomposition (Ndibe and Onwumere 2019). Microorganisms have a soil ecosystem function, specifically in the decomposition of organic matter and the turnover of nutrients (de Menezes et al. 2017). Bacteria can accelerate substrate degradation and are responsible for most of the decomposition and heat generation in compost (Yu et al. 2019) and it is responsible for most of the decomposition and heat generation in compost (Ho et al. 2022). Fungi are microorganisms that can shorten the length of composting (Thapa 2018) and are the main players in the decomposition of waste (Voriskova and Baldrian 2013; Kj and Thippeswamy 2013). They can decompose lignin, cellulose, and hemicellulose in a litter (Schneider et al. 2012; Abubacker and Prince 2012; Osono 2020).

This study focuses on household organic waste management by using microorganisms as bioinoculants. Microorganisms used are consortiums of bacteria, mold, yeast, and Actinomycetes. Consortiums of microorganisms are more effective than single strains inoculants (Greff et al. 2022). This study employed 16 treatments with 16 bioinoculants isolated and identified from banana bunches. The city of Madiun is renowned for its pecel rice, which is delicately wrapped in banana leaves. As a result, the city drew inspiration from this cultural heritage and employed microorganisms derived from various parts of the banana tree to facilitate waste decomposition. Specifically, banana bunches were selected due to their exceptional durability and firm texture, making them an ideal component of the tree to tackle this endeavor. The texture of the banana bunch stem skin was hard and impermeable, and possessed certain strength and toughness that could protect the inner tissue (Guo et al. 2021). Juariah (2008) reported that the sap of Ambon banana bunches was able to inhibit the growth of fungi and bacteria. Furthermore, Maryati et al. (2020) reported that banana bunches have tannins, with antibacterial properties. The decomposition process lasted for 4 weeks, and the treatments were measured with 3C/N ratios, repeated 5 times at weeks 0, 1^{st}, 2^{nd}, 3^{rd}, and 4^{th}. The C/N ratio was used as an indicator of compost maturity (Badan Standardisasi Nasional 2004; Gong et al. 2017). This is also supported by other studies where the C/N ratio was a parameter reflecting the level of compost stability (Li et al. 2018; Yang et al. 2019). Therefore, this study aimed to determine the best bioinoculant for reducing the C/N ratio of household organic waste.

MATERIALS AND METHODS

Materials

The samples of household organic waste were obtained from communities in Banjarsari Village, Madiun District, Madiun Regency, East Java Province, Indonesia. The waste consisted of food and most leftover vegetable pieces and leaves. Organic waste was collected and then cut into pieces with a size of 1-3 cm and mixed.

Methods

This study was categorized as a true experimental design, where the factorial completely randomized design AxB was performed. The A factor explained the bioinoculant formulas coded as A0: control (without microorganism), A1: bacteria consortium, A2: mold consortium, A3: yeast consortium, A4: Actinomycetes, A5: mixture of bacteria consortium and mold, A6: mixture of bacteria consortium and yeast, A7: mixture of bacteria consortium and Actinomycetes, A8: mixture of mold consortium and yeast, A9: mixture of mold consortium and Actinomycetes, A10: mixture of yeast consortium and Actinomycetes, A11: mixture of bacteria consortium, mold, and yeast, A12: mixture of bacteria consortium, mold, and Actinomycetes, A13: mixture of bacteria consortium, yeast, and Actinomycetes, A14: mixture of mold consortium, yeast, and Actinomycetes, and A15: mixture of bacteria consortium, mold, yeast, and Actinomycetes. The B factor explained the decomposition period coded as B0: 0 weeks, B1: 1 week, B2: 2 weeks, B3: 3 weeks, and B4: 4 weeks.

Microorganisms

The bioinoculants added was a consortium of microorganisms, namely bacteria, mold, yeast, and Actinomycetes. The bacteria consisted of 5 genera of 8 species, namely the genus *Cellulomonas: C. cellulans*, genus *Cellvibrio*: *C. mixtus*, genus *Bacillus* includes *B. subtilis, B. licheniformis, B. polymyxa*, genus *Pseudomonas: P. fluorescent, P. putida,* genus *Micrococcus: M. luteus.* The mold consisted of 5 genera of 10 species, namely Genus *Aspergillus*, including *A. niger, A. penicillioides*, *A. oryzae*, genus *Rhizopus* was *R. nigricans, R. oryzae*, genus *Mucor: M. piriformis*, genus *Fusarium: F. chlamydosporium*, genus *Penicillium: P. citrinum*, *Penicillium chrysogenum*, and *Penicillium expansum* (Prihastini et al. 2021). The yeast consisted of 3 species, namely *Candida krusei*, *Saccharomyces bisporus*, and *Xeromyces bisporus.* Meanwhile, Actinomycetes included *Streptomyces erythreus.*

Bioinoculants

There were 16 bioinoculants used to decompose household organic waste, namely codes A0, A1, A2, A, A4, A5, A6, A7, A8, A9, A10, A11, A12, A13, A14, and A15. The dose of the microorganism consortium in all treatments was similar, which was 1% of the weight of the garbage. The sample size in each treatment was 5 kg of household organic waste divided into 5 polybags. The treatment was repeated 3 times, requiring 15 kg of household organic waste. Furthermore, bioinoculants had also added molasses and diluting water. The calculation of consortiums of microorganisms on the bioinoculants was based on the species. The density of microbial cell count was elaborated in Table 1, and the results of consortia are presented in Table 2.

The number of microbial consortia present in the bioinoculant formula was computed utilizing the isolate organisms described in the equation below:

$$Number\ of\ microorganism\ consortium\ (ml) = \frac{Number\ of\ each\ organism\ isolate}{Total\ number\ of\ microorganism\ isolates} \times 150\ ml$$

As an example, there were 8, 10, 3, and 1 isolate of bacteria, mold, yeast, and Actinomycetes, respectively. The process of calculating the bioinoculant formula for code A5, which comprises a blend of bacterial and mold consortia, is outlined below:

$$Number\ of\ bacteria\ consortium = \frac{8}{18} \times 150\ ml = 67\ ml$$

$$Number\ of\ mold\ consortium = \frac{10}{18} \times 150\ ml = 83\ ml$$

The process of bioinoculants mixing began with treatment 1, where a 1 kg sample was weighed 5 times and placed into 5 separate containers. Each container was then mixed with 62.5 mL of the bioinoculant code A0 and placed into a polybag labeled as A0. This process was repeated 3 times. The same process was repeated for treatment 2, whereas, 1 kg sample was weighed 5 times and placed into 5 separate containers.

Decomposition of organic waste

Bioinoculants mixing

The process of bioinoculants mixing began with treatment 1, where a 1 kg sample was weighed 5 times and placed into 5 separate containers. Each container was then mixed with 62.5 mL of the bioinoculant code A0 and placed into a polybag labeled as A0 while repeating the process 3 times. In each container, a bioinoculant code A1 of 62.5 mL was added, and the mixture was placed in a polybag coded A1 while repeating the process 3 times. After the completion of treatment, it would be continued from the 3rd to the 16th similarly. Once the bioinoculants had been mixed into all the completed treatments, the decomposition process could commence.

Table 1. The density of the microorganism population

Species	Total PlateCount (CFU/mL)
Cellulomonas cellulans	$7,2 \times 10^9$
Cellvibrio mixtus	$5,8 \times 10^9$
Bacillus subtilis	$9,2 \times 10^9$
Bacillus licheniformis	$8,9 \times 10^9$
Bacillus polymyxa	$8,6 \times 10^9$
Pseudomonas flourencens	$8,8 \times 10^9$
Pseudomonas putida	$7,9 \times 10^9$
Micrococcus luteus	$8,1 \times 10^9$
Aspergillus niger	$6,2 \times 10^7$
Aspergillus penicillioides	$5,4 \times 10^7$
Aspergillus oryzae	$4,9 \times 10^7$
Rhizopus nigricans	$4,2 \times 10^7$
Rhizopus oryzae	$3,6 \times 10^7$
Mucor piriformis	$4,1 \times 10^7$
Fusarium chlamydosporium	$4,1 \times 10^7$
Penicillium citrinum	$3,3 \times 10^7$
Penicilliun chrysogenum	$3,8 \times 10^7$
Penicillium expansum	$4,1 \times 10^7$
Candida krusei	$7,1 \times 10^8$
Saccharomyces bisporus	$7,9 \times 10^8$
Xeromyces bisporus	$6,2 \times 10^8$
Streptomyces erythreus	$4,6 \times 10^7$

Table 2. The number of consortiums of microorganisms on bioinoculants

Bioinoculants code	The consortium of microorganisms (mL)				Amount	Molasses (mL)	Water Diluent (mL)
	B	K	Kh	Act			
A0	0	0	0	0	0	37.5	900
A1	150	0	0	0	150	37.5	750
A2	0	150	0	0	150	37.5	750
A3	0	0	150	0	150	37.5	750
A4	0	0	0	150	150	37.5	750
A5	67	83	0	0	150	37.5	750
A6	109	0	41	0	150	37.5	750
A7	133	0	0	17	150	37.5	750
A8	0	115	35	0	150	37.5	750
A9	0	136	0	14	150	37.5	750
A10	0	0	113	37	150	37.5	750
A11	57	71	22	0	150	37.5	750
A12	63	79	0	8	150	37.5	750
A13	100	0	37	13	150	37.5	750
A14	0	107	32	11	150	37.5	750
A15	55	68	20	7	150	37.5	750

Note: B: consortium of bacteria, K: consortium of molds, Kh: consortium of yeast, Act: Actinomycetes

Decomposition process

The decomposition process was carried out for 4 weeks. To control the optimally running decomposition, temperature, pH, and humidity measurements were examined every 2 days, starting from the 0th, 2nd, 4th, and up to 4 weeks. During the process, moisture was maintained at around 40-60% by stirring and sprinkling water.

C/N ratio check

The C/N check was carried out at week 0 (zero), the beginning of the decomposition process, weeks 1st, 2nd, 3rd, and 4th. For the examination of the C/N ratio, the C analysis was conducted using the Ooxyidmetry/Gravimetric method while the N was performed using the Kjeldahl method.

Measurement of temperature, pH, and humidity

Temperature, pH, and humidity were checked once every 2 days during the decomposition process. The tools used for temperature measurement were an analog soil thermometer, while the pH and humidity were soil pH and moisture tester DM-15, Takemura Electric Works, LTD, Tokyo-Japan. A thermometer was inserted for a duration of 3 to 5 minutes, and the temperature was read from the scale of the. Furthermore, pH and humidity were measured using a soil tester by inserting the tool into the sample for 3 to 5 minutes, and the values were determined by observing the position of the needle.

Statistical analysis

The study on the decomposition of household organic waste was analyzed using ANOVA 2 factorials, where bioinoculants codes A0, A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12, A13, A14, and A15 were factors A and the decomposition period (weeks) were factors B. The ANOVA test demonstrated a significant difference, and subsequently, the Duncan Test (DMRT: Duncan's Multiple Range Test) was conducted at a confidence level of 95% to determine the degree of significance.

RESULTS AND DISCUSSION

C/N ratio

The decomposition results of household organic waste in the last week is shown in Figure 1. The analysis of the C/N ratio has become a widely recognized indicator of compost maturity. In this study, the examination of the C/N ratio concerning the decomposition of household organic waste showed that the treatment containing bioinoculant code A0 (without microorganisms as control) had the highest average during the 0 to 4th weeks. However, the group with the lowest average. According to Kepmentan (2019), solid organic fertilizer requires a C/N ratio parameter of 25. Table 3 indicates that during weeks 0 to 2, the average C/N ratio value in all treatments needs to meet the qualification criteria. During week 3, all treatments met the average C/N ratio value qualification criteria except for those with bioinoculant codes A0, A1, A6, A7, A10, and A11, where the average C/N ratio value exceeds 25. At week 4, the treatment with the addition of bioinoculant code A0 was not eligible, while other treatments met the criteria. The compost maturity is indicated by an average C/N ratio value of 10-20 (Badan Standarisasi Nasional 2004). Therefore, in week 3, only the treatment with the addition of bioinoculant code A13 is eligible. At week 4, the treatment becomes eligible by adding bioinoculant codes A3, A8, A9, A12, A13, A14, and A15. The price of the C/N land ratio is 10-12, hence, materials with a C/N ratio can be directly used (Damanhuri and Padmi 2010). During this week, the average, lowest, and closest ratio to the C/N soil was treated with bioinoculant code A14 at 14.87.

The decomposition of household organic waste with different combinations of bioinoculant formulas showed that from 1st week to 4th, A0-A15 experienced a decrease in the average C/N ratio. The pattern of decreasing the average C/N ratio is shown in Figure 2. During the composting period, the C/N ratio experiences a decrease owing to the usage of carbon as an energy source. The carbon is lost in the form of CO, while microbes use nitrogen for protein synthesis and the formation of body cells. Therefore, the carbon content diminishes, and the nitrogen increases, leading to a reduction in the C/N ratio (Andriany et al. 2018). This was observed in the same time frame.

Figure 1. The decomposition result of household organic waste in 4th week

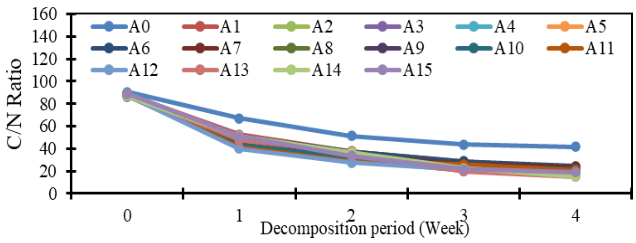

Figure 2. Chart of the average decrease pattern of the C/N week ratio 0 to week 4 on the decomposition of household organic waste

Table 3. Results of average C/N ratio on the decomposition of home organic waste on weeks 0 to 4

Bioinoculants code	Average C/N ratioweek-to-week				
	0	1	2	3	4
A0	90.40	67.17	51.31	43.73	41.48
A1	88.42	52.40	37.50	28.47	22.50
A2	87.83	47.07	34.10	24.65	21.38
A3	86.55	45.24	33.32	21.55	19.32
A4	89.55	45.81	35.31	22.50	20.33
A5	88.51	47.37	35.22	24.85	21.48
A6	87.17	51.33	37.37	28.60	24.32
A7	87.48	48.57	33.91	26.40	23.89
A8	87.80	41.35	30.30	20.22	16.37
A9	87.57	41.30	29.20	23.92	19.58
A10	88.07	43.58	31.47	25.48	21.32
A11	88.22	41.62	28.52	25.75	20.83
A12	87.27	39.97	27.73	21.17	18.41
A13	87.95	47.88	36.24	19.78	15.22
A14	86.63	51.18	36.83	22.90	14.87
A15	88.79	51.01	33.58	21.91	19.22

Note: A0: without microorganisms, A1: bacteria consortium, A2: mold consortium, A3: *yeast* consortium, A4: Actinomycetes, A5: mixture of bacteria consortium and mold, A6: mixture of bacteria consortium and yeast, A7: mixture of bacteria consortium and Actinomycetes, A8: mixture of mold consortium and yeast, A9: mixture of mold consortium and Actinomycetes, A10: mixture of yeast consortium and Actinomycetes, A11: mixture of bacteria consortium, mold, and yeast, A12: mixture of bacteria consortium, mold, and Actinomycetes, A13: mixture of bacteria consortium, yeast, and Actinomycetes, A14: mixture of mold consortium, yeast, and Actinomycetes, A15: mixture of bacteria consortium, mold, yeast, and Actinomycetes

Percentage average decrease in C/N ratio

The percentage decrease of the C/N ratio average from the 1st to 4th week in 16 treatments varied, and the smallest ratio was 54.1%. In the study, the treatment involved the application of a bioinoculant code A0 as well as a control treatment, which consisted of bioinoquinoclanes without microorganisms. The percentage decrease in the average C/N ratio was most prominent in the treatment that employed bioinoplasty code A14. This treatment used a mixed bioinoculants of the mold consortium, yeast, and Actinomycetes, resulting in a decrease of 82.8%.

Statistical test results

According to the ANOVA Test 2 factorials, the interaction between factors A and B yielded a significant p-value of 0.00, which is lower than the significance level (α) of 0.05. This indicates a significant difference between the treatments, and the Duncan Test was conducted.

The test results showed that the treatment with the addition of bioinoculant codes A0, A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A12, A13, A14, and A15 in each week followed by different capital letters namely A, B, C, D and E. Therefore, the average decrease in C/N ratios is significantly different each week. The treatment with the addition of bioinoculant code A11 in the initial 4 weeks resulted in significantly different average C/N ratios, denoted by distinct capital letters (A, B, C, and D). However, the average C/N ratio in week 3 did not differ significantly from week 2, as both were labeled with the same capital letter (C).

The Duncan Test results also showed that in week 0, the average C/N ratio did not differ significantly between the treatment with the addition of bioinoculants code A0 and those with A1, A2, A4, A5, A6, A7, A8, A9, A10, A11, A12, A13, and A15, receiving the same lowercase letter (a). However, the average C/N ratio in the treatment with the addition of bioinoculant codes A3 and A14 differed significantly from that in the other treatments, as indicated by a different lowercase letter (b). In weeks 1, 2, 3, and 4, the average C/N ratio with the addition of bioinoculants code A0 differed markedly from all treatments. At week 4, the average C/N ratio in adding bioinoculants code A14 did not differ from the treatment of code A13. However, it differed markedly from the treatment of adding bioinoculants code A8. The average C/N ratio with A13 is not significantly different from A14 and code A8, and Duncan's results are shown in Table 4.

Based on the Duncan Test in Table 4, the most effective bioinoculant for reducing C/N ratios and decomposing household organic waste is the A14 bioinoculant. Specifically, the A14 bioinoculant was not different from the A13 in week 4 since they were assigned the same lowercase letter, namely the letter (i). However, the treatment with bioinoculant code A13 is not different from A8 as it was assigned the same lowercase letter, namely the letter (h). During week 4, the A14 bioinoculant treatment had the lowest C/N ratio for mold, yeast, and Actinomycetes consortium.

The waste was predominantly vegetable residue and plants, which contained significant amounts of lignocellulose, including cellulose, hemicellulose, and lignin (Wang et al. 2020). Municipal waste contains lignocellulose consisting of cellulose, hemicellulose, and lignin (Gunjal et al. 2020). The household waste comprised leftovers of vegetables and leaves, which were rich in lignocellulose.

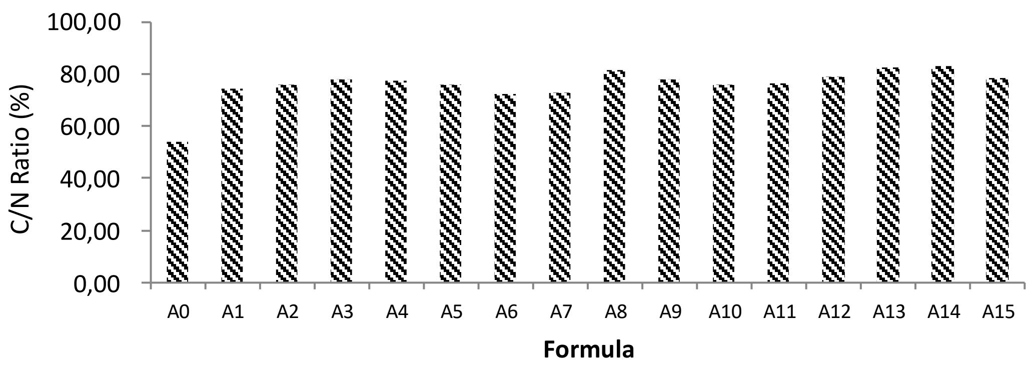

Figure 3. The average percentage decrease in C/N week to 0 ratio and 4th on the decomposition of household organic waste

Table 4. Duncan Test results in an average C/N ratio of 0 to 4 on the decomposition of household organic waste

Bioinoculants code	Average C/N week-to-week ratio				
	0	1	2	3	4
A0	90.40 Aa	67.17 Ba	51.31 Ca	43.73 Da	41.48 Ea
A1	88.42 Aab	52.40 Bb	37.50 Cb	28.47 Db	22.51 Ec
A2	87.83 Aab	47.07 Bcd	34.10 Ccde	24.65 Dcde	21.38 Ecd
A3	86.55 Ab	45.24 Be	33.32 Cde	21.55 Dghi	19.32 Dfg
A4	89.55 Aab	45.81 Bde	35.31 Cbcd	22.50 Dfg	20.33 Edef
A5	88.51 Aab	47.37 Bcd	35.22 Cbcd	24.85 Dcd	21.48 Ecd
A6	87.17 Aab	51.33 Bb	37.37 Cb	28.60 Db	24.32 Eb
A7	87.48 Aab	48.57 Bc	33.91 Cde	26.40 Dc	23.89 Eb
A8	87.80 Aab	41.35 Bg	30.30 Cfg	20.22 Dfi	16.37 Eh
A9	87.57 Aab	41.30 Bg	29.20 Cfg	23.92 Ddef	19.58 Eefg
A10	88.07 Aab	43.58 Bf	31.47 Cef	25.48 Dcd	21.32 Ecd
A11	88.22 Aab	41.62 Bg	28.52 Cg	25.75 Ccd	20.83 Dde
A12	87.27 Aab	39.97 Bg	27.73 Cg	21.17 Dghi	18.41 Eg
A13	87.95 Aab	47.88 Bc	36.24 Cbcd	19.78 Di	15.22 Ehi
A14	86.63 Ab	51.18 Bb	36.83 Cbc	22.90 Defg	14.87 Ei
A15	88.79 Aab	51.01 Bb	33.58 Cde	21.91 Dgh	19.22 Efg

Node: Numbers are presented in average (μ). Numbers followed by capital letters (showing horizontal interaction tests) and lowercase letters (showing vertical interaction tests) differing in the same column and row show a noticeable difference based on Duncan's Multiple Range Test's advanced tests at 95%

Mold is a multicellular fungus that forms filaments known as hyphae, while yeast is unicellular (Al-Enazi et al. 2018). Fungi play an essential role in lignocellulose degradation (Wang et al. 2020), and produce extracellular enzymes that play a role in decomposing lignin, cellulose, and other components in the garbage (Osono 2020). They are the main decomposers in reducing organic matter compared to other microorganisms (Krishna and Mohan 2017). Furthermore, fungi contribute the most to the degradation of lignocellulose during litter decomposition and decompose wheat straw better than bacteria and Actinomycetes (Singh and Upadhyay 2019).

The consortium of mold consists of species of *Aspergillus, Rhizopus, Fusarium, Mucor,* and *Penicillium. Aspergillus, Fusarium, Mucor,* and *Penicillium* are essential decomposers in composting activities. Meanwhile, *Aspergillus* and *Penicillium* are cellulitic fungi that can accelerate the composting process (Thapa 2018). They are a group of *Basidiomycetes* with the ability to decompose cellulose (Boswell 2020) and municipal solid waste (Jain et al. 2017). Actinomycetes are high-class or profiled bacteria used to degrade cellulose and plant litter (Krishna and Mohan 2017).

Results of measurements of temperature, humidity and pH

The process of litter decomposition is subject to environmental factors, including temperature, humidity, and pH affecting the process (Krishna and Mohan 2017; Ho et al. 2022). During the decomposition process of organic waste, pH, humidity, and temperature measurements were conducted in the sample to measure and control the variables in all treatments.

Composting is a multi-phase process that includes the mesophilic phase, where temperatures range from 20-45°C, the thermophilic phase ranging from 50-70°C, and the maturation phase, where temperatures return to the mesophilic range (Sharma et al. 2022). A temperature of 45-55°C is the optimum thermophilic phase for the composting process (Ho et al. 2022). Moreover, it has been observed that temperatures ranging between 50-55°C are conducive to the decomposition of garbage (Rastogi et al. 2020). In this study, temperature measurements during the decomposition of organic waste in all treatments ranged from 28-50°C. Specifically, the temperature at the onset of the decomposition process was around 28-30°C, then increased to approximately 50°C between the 3rd and 7th day before declining to 28°C The optimum humidity range for composting is between 50-60% (Rastogi et al. 2020; Ho et al. 2022). Meanwhile, the results of measuring waste humidity in all treatments ranged from 40-65%. The ideal pH value of composting ranges from 5.5-8.0 (Rastogi et al. 2020), and the optimum is 5.0-7.0 (Ho et al. 2022). The pH measurements for all treatments during the decomposition process ranged between 6.1-7.3. At the beginning of the process, the pH was relatively low, then increased toward the end. The ideal pH value of composting ranges from 5.5-8.0 (Rastogi et al. 2020), and the optimum is 5.0-7.0 (Ho et al. 2022). The pH measurements for all treatments during the decomposition process ranged between 6.1-7.3. At the beginning of the process, the pH was relatively low, then increased toward the end. Based on the measurement results, temperature, humidity and pH did not affect the decomposition process in all treatments.

In conclusion, the results showed that after a four-week decomposition process, the lowest C/N ratio value at week 4 was 14.87 in the treatment with the addition of bioinoculants code A14. The highest average percentage of C/N ratio reduction in treatment with the addition of bioinoculants code A14 was 82.8%. Duncan's test results showed that after 4 weeks of decomposition, the treatment with bioinoculant code A14 was not different from A13, however, the treatment with bioinoculant code A13 was not different from A8. Therefore, the best bioinoculant to decrease the C/N ratio on household organic waste is code A14, consisting of a consortium mixture of mold, yeast, and Actinomycetes.

ACKNOWLEDGEMENTS

The authors are grateful to the people of Banjarsari Village for their assistance and cooperation in collecting household organic waste. This work was financially supported by the Ministry of Health, Republic of Indonesia.

REFERENCES

Abanyie SK, Amuah EEY, Douti NB, Antwi MN, Fei-Baffoe B, Amadu CC. 2022. Sanitation and waste management practices and possible implications on groundwater quality in peri-urban areas, Doba and Nayagenia, northeastern Ghana. Environ Chall 8: 100546. DOI: 10.1016/j.envc.2022.100546.

Abdel-Rahman MA, Nour El-Din M, Refaat BM, Abdel-Shakour EH, Ewais EED, Alrefaey HMA. 2016. Biotechnological application of thermotolerant cellulose-decomposing bacteria in composting of rice straw. Ann Agric Sci 61 (1): 135-143. DOI: 10.1016/j.aoas.2015.11.006.

Abdulredha M, Khaddar RAL, Jordan D, Hashim K. 2017. The development of a waste management system in kerbala during major pilgrimage events: Determination of solid waste composition. Procedia Eng 196: 779-784. DOI: 10.1016/j.proeng.2017.08.007.

Abubacker MN, Prince M. 2012. Cellulose degradation potential of *Acacia dealbata* link. Leaf litter in virgin forest ecosystem of Ooty by microfungi in relation to CO2 release. Biosci Biotechnol Res Asia 9 (1): 451-456. DOI: 10.13005/bbra/1002.

Al-Enazi NM, Awaad AS, Al-Othman MR, Al-Anazi NK, Alqasoumi SI. 2018. Isolation, identification and anti-candidal activity of filamentous fungi from Saudi Arabia soil. Saudi Pharm J 26 (2): 253-257. DOI: 10.1016/j.jsps.2017.12.003.

Aminah S, Muttalib A, Norkhadijah S, Ismail S, Praveena SM. 2016. Application of Effective Microorganism (EM) in food waste composting: A review. Asia Pac Environ Occup Health J 2: 37-47.

Andriany A, Fahruddin F, Abdullah A. 2018. Pengaruh jenis bioaktivator terhadap laju dekomposisi seresah daun jati *Tectona grandis* L.f., di wilayah kampus Unhas Tamalanrea. Bioma: Jurnal Biologi Makassar 3 (2): 31-42. DOI: 10.20956/bioma.v3i2.5820. [Indonesian]

Atalia KR, Buha DM, Bhavsar KA, Shah NK. 2015. A Review on composting of municipal solid waste. J Environ Sci Toxicol Food Technol 9 (5): 20-29. DOI: 10.9790/2402-09512029.

Badan Standardisasi Nasional. 2004. Spesifikasi kompos dari sampah organik domestik. Badan Standardisasi Nasional, 12. [Indonesian]

Boswell J. 2020. The biological decomposition of cellulose. New Phytol 40 (1): 20-33. DOI: 10.1111/j.1469-8137.1941.tb07026.x.

Damanhuri E, Padmi T. 2010. Diktat Pengelolan Sampah. 1-97. https://fdokumen.com/document/diktatsampah-2010.html.

de Menezes AB, Richardson AE, Thrall PH. 2017. Linking fungal-bacterial co-occurrences to soil ecosystem function. Curr Opin Microbiol 37: 135-141. DOI: 10.1016/j.mib.2017.06.006.

El Barnossi A, Moussaid F, Iraqi Housseini A. 2021. Tangerine, banana and pomegranate peels valorisation for sustainable environment: A review. Biotechnol Rep 29: e00574. DOI: 10.1016/j.btre.2020.e00574.

Gong X, Li S, Sun X, Zhang L, Zhang T, Wei L. 2017. Maturation of green waste compost as affected by inoculation with the white-rot fungi *Trametes versicolor* and *Phanerochaete chrysosporium*. Environ Technol (United Kingdom) 38 (7): 872-879. DOI: 10.1080/09593330.2016.1214622.

Greff B, Szigeti J, Nagy Á, Lakatos E, Varga L. 2022. Influence of microbial inoculants on co-composting of lignocellulosic crop residues with farm animal manure: A review. J Environ Manag 302: 114088. DOI: 10.1016/j.jenvman.2021.114088.

Gunjal AB, Patil NN, Shinde SS. 2020. Ligninase in Degradation of Lignocellulosic Wastes. In: Enzymes in Degradation of the Lignocellulosic Wastes. DOI: 10.1007/978-3-030-44671-0_4.

Guo J, Fu H, Yang Z, Li J, Jiang Y, Jiang T, Liu E, Duan J. 2021. Research on the physical characteristic parameters of banana bunches for the design and development of postharvesting machinery and equipment. Agriculture (Switzerland) 11 (4): 1-25. DOI: 10.3390/agriculture11040362.

Hidayanti AK, Amalia N, Kirana P, Soetarto ES. 2013. Role of bacteria and mold as agent plant litter composting. 3rd International Conf on Chem, Biological and Env Sci (ICCEBS'2013), Kuala Lumpur, 8-9 January 2013.

Ho TTK, Tra VT, Le TH, Nguyen NKQ, Tran CS, Nguyen PT, Vo TDH, Thai VN, Bui XT. 2022. Compost to improve sustainable soil cultivation and crop productivity. Case Stud Chem Environ Eng 6: 100211. DOI: 10.1016/j.cscee.2022.100211.

Iacovidou E, Zorpas AA. 2022. Exploratory research on the adoption of composting for the management of biowaste in the Mediterranean island of Cyprus. Cleaner Circ Bioecon 1: 100007. DOI: 10.1016/j.clcb.2022.100007.

Jain A, Yadav S, Nigam VK, Sharma SR. 2017. Fungal-Mediated Solid Waste Management: A Review. Mycoremediation Environl Sustain 1: 153-170. DOI: 10.1007/978-3-319-68957-9_9.

Juariah S. 2008. Uji efektivitas getah tandan pisang ambon (*Musa paradisiaca* var.sapientum) terhadap pertumbuhan *Staphylococcus aureus*. Klinikal Sains: Jurnal Analis Kesehatan 5 (1): 10-15. [Indonesian]

Kepmentan. 2019. Persyaratan Teknis Minimal Pupuk Organik, Pupuk Hayati, dan Pembenah Tanah. In Keputusan Menteri Pertanian Republik Indonesia No 261 (pp. 1-18). http://psp.pertanian.go.id/index.php/page/publikasi/418.

Kj N, Thippeswamy B. 2013. Isolation and screening of potential cellulolytic fungi from Areca nut husk waste. Intl J Curr Sci 8: 125-132.

Krishna MP, Mohan M. 2017. Litter decomposition in forest ecosystems: A review. Energy Ecol Environ 2 (4): 236-249. DOI: 10.1007/s40974-017-0064-9.

Li Y, Gu J, Zhang SQ, Shi LX, Sun W, Qian X, Duan ML, Yin YN, Wang XJ. 2018. Effects of adding compound microbial inoculum on microbial community diversity and enzymatic activity during co-composting. Environ Eng Sci 35 (4): 270-278. DOI: 10.1089/ees.2016.0423.

Liikanen M, Havukainen J, Viana E, Horttanainen M. 2018. Steps towards more environmentally sustainable municipal solid waste management - A life cycle assessment study of São Paulo, Brazil. J Cleaner Prod 196: 150-162. DOI: 10.1016/j.jclepro.2018.06.005.

Maryati T, Pertiwiningrum A, Bachrudin Z, Yuliatmo R. 2020. The exploration of banana bunch as a new vegetable tanning agent. IOP Conf Ser: Mater Sci Eng 980 (1): 012019. DOI: 10.1088/1757-899X/980/1/012019.

Moya D, Aldás C, López G, Kaparaju P. 2017. Municipal solid waste as a valuable renewable energy resource: A worldwide opportunity of energy recovery by using Waste-To-Energy Technologies. Energy Procedia 134: 286-295. DOI: 10.1016/j.egypro.2017.09.618.

Ndibe TO, Onwumere GB. 2019. Molecular characterization of some bacteria and fungi associated with the decomposition of leaf litters of *Eucalyptus camaldulensis* and *Tectona grandis*. Niger J Biotechnol 36 (1): 222. DOI: 10.4314/njb.v36i1.28.

Osono T. 2020. Functional diversity of ligninolytic fungi associated with leaf litter decomposition. Ecol Res 35 (1): 30-43. DOI: 10.1111/1440-1703.12063.

Pande G, Sinha A, Agrawal S. 2015. Impacts of leachate percolation on ground water quality: A case study of Dhanbad city. Global Nest J 17 (1): 162-174. DOI: 10.30955/gnj.001377.

Prihastini L, Ramelan AH, Setyono P, Supriyanto A. 2021. Isolation and Identification of Mold in Banana Bunches and Their Potential as Bioinoculants to Accelerate Decomposition of Household Organic Waste. Proceedings of the 10th International Seminar and 12th Congress of Indonesian Society for Microbiol (ISISM 2019). Atlantis Press. DOI: 10.2991/absr.k.210810.013.

Rastogi M, Nandal M, Khosla B. 2020. Microbes as vital additives for solid waste composting. Heliyon 6 (2): e03343. DOI: 10.1016/j.heliyon.2020.e03343.

Schneider T, Keiblinger KM, Schmid E, Sterflinger-Gleixner K, Ellersdorfer G, Roschitzki B, Richter A, Eberl L, Zechmeister-Boltenstern S, Riedel K. 2012. Who is who in litter decomposition Metaproteomics reveals major microbial players and their biogeochemical functions. ISME J 6 (9): 1749-1762. DOI: 10.1038/ismej.2012.11.

Sharma P, Bano A, Singh SP, Dubey NK, Chandra R, Iqbal HMN. 2022. Recent advancements in microbial-assisted remediation strategies for toxic contaminants. Cleaner Chem Eng 2: 100020. DOI: 10.1016/j.clce.2022.100020.

Singh R, Upadhyay SK. 2019. A study on the plant litter decomposition using mycoflora for sustainable environment. Plantae Sci 2 (1): 11-14. DOI: 10.32439/ps.v2i1.11-14.

SIPSN-KLHK. 2021. Grafik Komposisi Sampah https://sipsn.menlhk.go.id/sipsn, diakses tanggal 28 Agustus 2022.

Jha SK, Thapa LB. 2018. Microfungi isolated from Water hyacinth (*Eichhornia crassipes*) compost. Bio Bull 4 (1): 43-47.

Voriskova J, Baldrian P. 2013. Fungal community on decomposing leaf litter undergoes rapid successional changes. ISME J 7 (3): 477-486. DOI: 10.1038/ismej.2012.116.

Wang W, Zhang Q, Sun X, Chen D, Insam H, Koide RT, Zhang S. 2020. Effects of mixed-species litter on bacterial and fungal lignocellulose degradation functions during litter decomposition. Soil Biol Biochem 141: 107690. DOI: 10.1016/j.soilbio.2019.107690.

Yang XC, Han ZZ, Ruan XY, Chai J, Jiang SW, Zheng R. 2019. Composting swine carcasses with nitrogen transformation microbial strains: Succession of microbial community and nitrogen functional genes. Sci Total Environ 688: 555-566. DOI: 10.1016/j.scitotenv.2019.06.283.

Yunus S, Muis R, Anggraini N, Ariani F. 2020. A multi-criteria decision analysis for composting technology in Makasar, Indonesia. J Mater Civil Eng 107 (4): 1-8. DOI: 10.35741/issn.0258-2724.55.4.1.

Yu XF, Borjigin Q, Gao JL, Wang ZG, Hu SP, Borjigin N, Wang Z, Sun JY, Han SC. 2019. Exploration of the key microbes and composition stability of microbial consortium GF-20 with efficiently decomposes corn stover at low temperatures. J Integr Agric 18 (8): 1893-1904. DOI: 10.1016/S2095-3119(19)62609-2.

Zhao K, Xu R, Zhang Y, Tang H, Zhou C, Cao A, Zhao G, Guo H. 2017. Development of a novel compound microbial agent for degradation of kitchen waste. Braz J Microbiol 48 (3): 442-450. DOI: 10.1016/j.bjm.2016.12.011 .