JEE Journal of Ecological Engineering

Journal of Ecological Engineering, 2025, 26(3), 177–186
https://doi.org/10.12911/22998993/199649
ISSN 2299–8993, License CC-BY 4.0

Received: 2024.12.02
Accepted: 2025.01.15
Published: 2025.02.01

Processing milk waste as additional material in biodegradation of food waste, tofu dregs, goat manure using black soldier fly larvae composting

Mirna Apriani[1*], Vivin Setiani[1], Ulvi Pri Astuti[1], Dewi Cahya Rahmawati[1], Debby Zintya Hayati[1]

[1] Waste Treatment Engineering Study Program, Politeknik Perkapalan Negeri Surabaya, Kampus ITS Sukolilo, Surabaya 60111, Indonesia

* Corresponding author's e-mail: mirna.apriani@ppns.ac.id

ABSTRACT

The aims of the study are to investigate compost quality (physic and chemistry) using black soldier fly (BSF) larvae composting compared with Indonesia standard (SNI) and assess whether compost quality is affected by the research variation. This study was conducted by research variations are raw material composition, addition of milk waste and vegetable waste local microorganism. The twelve reactors (larvero) have a dimension of 50 cm (length) × 40 cm (width) × 15 cm (height). This study uses mixtures of food waste added with various variable, including waste milk (WM), tofu dregs (TD), goat manure (GM) and self-made bioactivator of local organism (MoL). Total substrate of each larvero was 10 kg, added every third day and monitored ambient temperature, pH and water content. Carbon to nitrogen, phosphorus and potassium was measured in the final compos result. The result show all variable accordance with the Indonesia standard (SNI). However, the highest moisture content of 50–54% from TD added needs particular maintenance work challenging using advanced natural drying. WM treatment using BSF larvae composting with all variation research also resulting compost meet the SNI. Based on statistical analysis report, research variation that have an influence on the overall compost quality are MW and MoL addition.

Keywords: larvero, local organism, natural drying, SNI.

INTRODUCTION

Ministry of Environment and Forestry (2024) reported that Indonesia as a developing country produce 31 million tons/year of waste, with the largest composition of food waste (40.8%) and majority source of waste generation comes from domestics (49.5%). At present, waste management still relies on direct disposal to landfill, potentially causing landfill lifespan to be shorter that planned time period. As reported by Ministry of National Development Planning (2023), approximately 72% of waste ends up in landfill and 17% leaks to environment. If there is no land available to extend the landfill, one by one of landfill will soon be full and have to close. The waste recycling rate in landfill only reached 11%, represent is far from the ideal requirement for reducing waste to landfill. Developing countries most commonly using landfilling as final disposal and for organic fraction (Elkhalifa et al., 2019). Meanwhile, landfill impact on climate change is ten times greater than anaerobic digestion, composting and incineration. Landfill method will significantly consider to global environmental problems (Gao et al., 2017). Composting is an effective way to reduce the volume of organic waste and can enriched with other waste may be a good organic fertilizer (Kazemi et al., 2017). Recycling organic waste, apart from becoming compost, can also produce useful products such as processing food waste into bioplastic (Apriani et al., 2022, Vaverkova and Adamcova, 2015, Rahmatullah, 2024).

The fishery industry is economically important in many countries including Spain, China, India (Kazemi et al., 2017) also in Indonesia as a maritime country. Processing of fish from catching and raising activity leads to high amounts of waste, which are of global concern (Choe et al., 2020). The amount of fish waste (FW) is equivalent to the fish consumed. At present, FW is discarded by landfill or ocean dumping (Karim et al., 2015). FW has potential for fertilizers or energy production (Toppe et al., 2018). Composting is an aerobic biological decomposition of organic matter into a humus-like product. Composting of FW is an effective way to reduce the volume of waste FW, and compost enriched with FW may be a good organic fertilizer (Kazemi et al., 2017). However, success of FW composting is based on the addition of raw material to provide carbon sources for microorganisms. FW may be a useful substrate to decrease C/N when treating waste material rich in C. Addition of raw material such as animal litter can support reduce volume of FW became compost (Busato et al., 2018). Therefore, the selection of appropriate additives to promote organic material degradation is necessary to improve the composting efficiency and product quality.

The goat population in Indonesia has the highest value after cattle, which is 18,560,835 (BPS, 2023). This has great potential also for manure produced from goat farms. Goat manure (GM) can be used as an organic source of fertilizer raw materials to fertilize agricultural soil. Composting is an environmentally friendly method of managing livestock manure (Lin et al., 2018). GM contains 46.58% organic C, 1.34% N, 0.54% P_2O_5, and 1.56% K_2O (Tivana and Pradana). GM was potential as compost substrate rich in carbon, therefore may be useful as addition with FW composting to improve C/N.

Tofu dregs (TD) are the byproduct of tofu processing, enriched with mineral, carbohydrates and amino acids are easily decomposed. However, utilization rate of TD is relatively low, resulting in serious environmental pollution and nutrient waste (Ortiz-Cornejo et al., 2017). TD can effectively increase enzymes functional in macromolecular organic substances degradation (Zhang and Sun, 2018). Therefore, it is the reason to explore composting process by addition of TD.

Waste milk (WM) is produced from dairy industry as unsuitable milk for human consumption (Ma et al., 2022). WM usually contains pathogenic, harmful pathogens and antibiotic residues, can be environmental hazard (Aust et al., 2013; Brunton et al., 2012). Treatment of WM to prevent environmental damage can be apply composting to ensure safe disposal (Anusha and Paul, 2015; Desai et al., 2016). As reported by Lalman et al., 2004, level of WM protein is the highest among fat and lactose, in the range 210–560 mg/L. Therefore, the addition of WM was expected to improve quality of compost protein produced.

Composting process commonly use some of commercial or traditional bio-activators. Bio-activators is able to accelerate organic fertilizer maturity in decomposition or composting process of organic material (Aslanzadeh et al., 2020; Sutrisno et al., 2020; Wikurendra et al., 2022). Traditional bio-activator is a self-made bio-activator of local microorganisms (MoL). MoL is a collection of microorganisms that can be bred as a starter in composting. On the basis of the ingredients, there are two local microorganism that can be made, tapai and local microorganism stale rice as well as various local microorganism made from other ingredients (Indasah et al., 2018).

MATERIALS AND METHODS

Study site

The research study site was located in the campus of the Politeknik Perkapalan Negeri Surabaya (*Shipbuilding Institute* of *Polytechnic Surabaya)* in Surabaya, Indonesia. This experiment was conducted in compost house, under a constructed shelter roof of corrugated metal sheet and supported by natural ventilation.

Preparation of substrate and bio-activator

Materials of substrate consists of goat manure, tofu dregs, fish waste and milk waste. Raw materials were grinded to help larvae consume feeding, because larva's mouthpart is too small to break down large substrate (Dortmans et al., 2017). The grinding has possibility to increase substrate's surface area, which supports the homogenizes and growth of beneficial microbes to promote nutrient availability consistency (Boaru et al., 2019). Total substrate of each reactor was 10 kg with every 3 days feeding. Feeding regime every 3 days in the previous experiment promote the best compost quality based on Indonesia standard (Priastuti et al., 2022). Bio-activator were used from vegetable waste traditional bio-activators. The research variables were conducted based on combination shown in Table 1.

Table 1. Research variations on each larvero

Larvero (L)	Substrate variation				MoL
	GM (%)	TD (%)	FW (%)	MW (mL)	(mL)
1	100	-	-	-	-
2	100	-	-	-	30
3	100	-	-	200	-
4	100	-	-	200	30
5	30	70	-	-	-
6	30	70	-	-	30
7	30	70	-	200	-
8	30	70	-	200	30
9	30	-	70	-	-
10	30	-	70	-	30
11	30	-	70	200	-
12	30	-	70	200	30

Note: GM – goat manure, TD – tofu dregs, FW – fish waste, MW – milk waste.

Preparation of larvero

The design of larvero in this experiment based on inspiration from currently available in website, journals and market with slightly modification. Larvero was used as larvae feeding and growing (Dortmans et al., 2017; Amrul et al., 2022). The dimensions of larvero based on the calculation of waste production and density of each experiment variation. Twelve [50 (length) cm × 40 (width) cm × 15 (height) cm] wood containers were chosen to perform the composting.

Analytical method

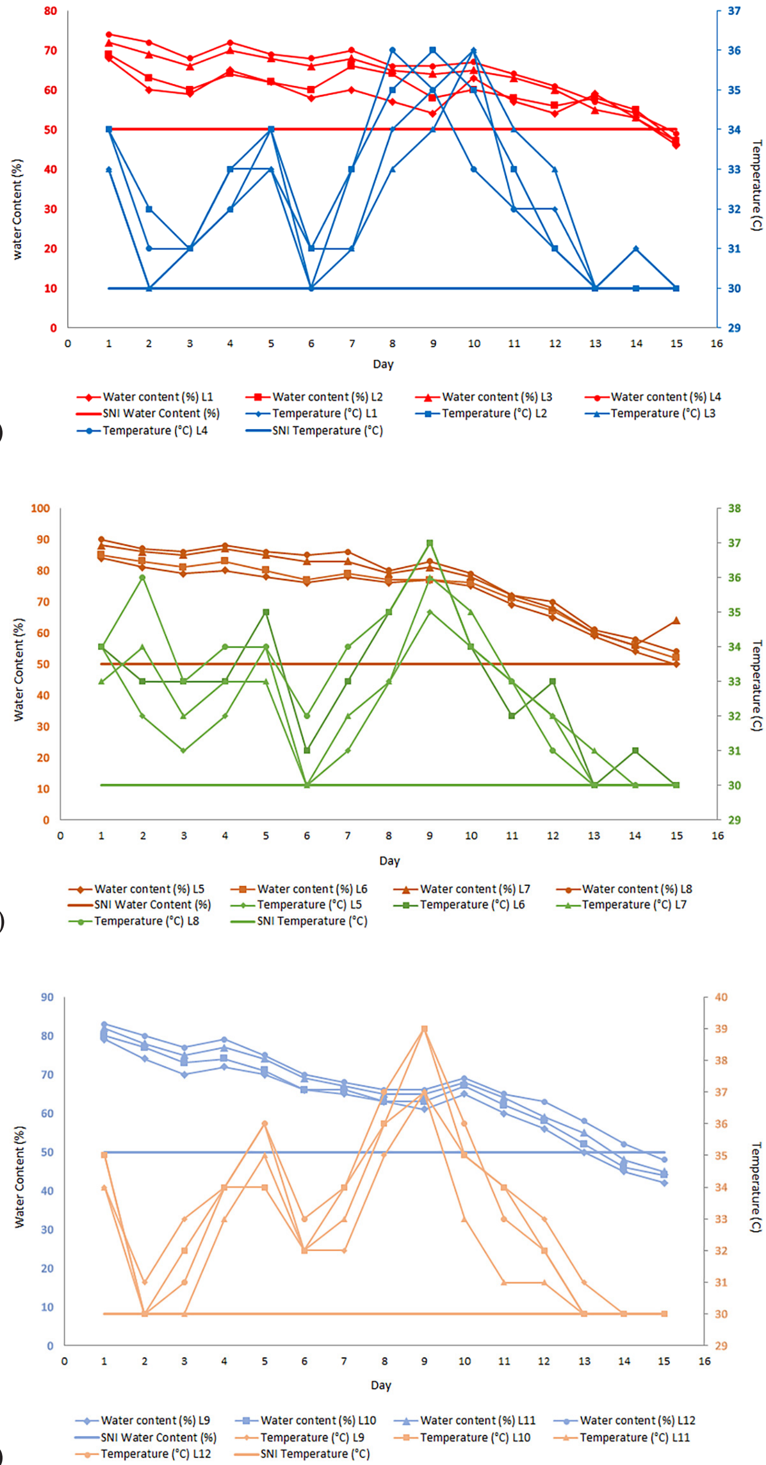
Temperature and water content were monitored using soil meter tester each day. C-organic was considered by gravimetry method. Nitrogen, phosphorous and potassium were determined by Kjeldahl, Spectrophotometry and AAS methods respectively. Statistical analysis using MANOVA test, starting normality and homogeneity test. Three combination experiment variation assessed the differences in physicochemical properties. MANOVA were applied by statistical mean differences were considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

Changes of water content and temperature

Changes of water content and temperature are displayed based on the type of compost material with experiment variations in the addition of milk waste and local microorganism. Figure 1 shows the changes of water content and temperature during BSF composting process for all variation. Figure 1a represents monitoring result for 100% GM material with variation milk waste and MoL addition. At beginning process, water content range is 68–74%, while temperature is 33–34 °C. As shown in Figure 1a, water content was decreased among all variation, L1 decreased from 68 to 46%, L2 69–47%, L3 72–47% and L4 74–49%. Temperature was opposite with water content, starting from 33 °C (L1, L3) – 34 °C (L2, L4), increasing until reaching 36 °C then decreasing to 30 °C for all reactor. Monitoring result for 30% GM and 70% TD composting reported in Figure 1b. Water content starting from 84% (L5), 85%(L6), 88% (L7) and 90% (L8) was decrease until 50% (L5), 52% (L6) and 54% (L7, L8). Temperature was decrease from 33 °C (L7) – 34 °C (L5, L6, L8) to 30 °C (L5, L7), 31 °C (L6), 32 °C (L8) within 6 days. Figure 1c shows water content and temperature daily measurement for 30% GM and 70% FW variation. Water content was decreased from 79% (L9), 80% (L10), 82% (L11), 83% (L12) to 42% (L9), 44% (L10), 45% (L11), 48% (L12). While temperature decreased from 34 °C (L9, L11) – 35 °C (L10, L12) until 32 °C (L9, L10, L11) – 33 °C (L12), then increase reaching 37 °C (L9, L11) – 39 °C (l10, L12) and finally decline at 30 °C for all variation.

Water content is one of the environment conditions has essential role in bioconversion (Banks et al., 2014). From Figure 1a-c, the lowest and the highest water content of raw material were 68%



a) b) c)

Figure 1. a) Water content and temperature monitoring in L1-L4, b) Water content and temperature monitoring in L5-L8, c) Water content and temperature monitoring in L9-L12

and 90%, respectively. The optimal range of water content is 70–80%, with the lower limit is 40–55% (Dortmans et al., 2021; Bortolini et al., 2020). In this experiment, water content was adequate with the ideal condition except of TD. Water content of TD reached more than 80% because physical characteristic influenced by raw material that contains more water. Microorganisms and larvae metabolic activities influenced by water content because have a role to supply oxygen indirectly (Bernal et al., 2009) and potential causing environmental odour and nutrient leachate (Dortmans, 2015). Bioconversion process of all experiment variation resulting, the lowest and the highest water content of compost were 42% and

54%, have met with the Indonesia standard for compost quality. L5-L8 using TD as raw material has the highest water content among GM and FW. Based on analysis of initial characteristics, water content of TD was around 88%, the highest compared to water content of FW (75%) and GM (11%). This is the reason that compost produced from materials using TD mixture has the highest water content. Composting process using TD can produce compost with water content 50–54% after drying in compost house three days before harvesting. As reported by Aja and Al-Kayiem (2014), composting process with water content more than 60% required post-treatment such as advanced drying. Compost drying was conducted to meet compost quality standard. This aims to avoid odours and sticky compost making it difficult to handle. Dortmans (2015) reported that the high moisture of raw material caused foul-smelling and sticky.

The changes of temperature during composting process recorded in mesophilic with ranged between 33 °C and 39 °C, slightly above the ambient temperature (Figure 1a–c). The higher temperature during process indicate biodegradation was undergone (ˇCiˇcková, 2015). The increasing of temperature caused by microorganisms released heat to metabolism of organic matter from raw material (Pandebesie et al., 2022). The study has shown that temperature could rise up to 39 °C (mesophilic phase). As reported by Waqas et al., (2023), combination of actinomycetes, fungi and bacteria metabolism C-abundant rapidly in raw material during mesophilic phase. Aerobic process in tolerable temperature with range 15 °C and 40 °C will produce heat. During mesophilic phase, rapid composting by larvae occurs to convert raw material with higher air circulation to prevent temperature in constant condition (Pang et al., 2020).

Physical qualities based on Indonesia standard (SNI) regarding compost quality apart from temperature and water content, are colour and odour. Final result after harvesting reported compost has black soil colour and earthly aromatic flavour. There was indicating that compost already reached its maturity (Diener et al., 2011). Figure 1a–c shows that the final measurement of compost water content meets SNI as depicted by the red line (maximum 50%). In line with the temperature which is also in accordance with SNI, maximum 30 °C (blue line).

The pH during process was daily monitored which is represent in Figure 2a, b and c shown similar trend for all experiment variation. The initial pH was starting from 6.4–6.8, decreasing until 4.6–4.9 and increasing reached 7.0 in 15th day measurement. The lowest pH occurred on days 7, similar with previous study (Ahmad et al., 2023). The increasing of pH was representing the process reaching curing phase (Bernal et al., 2009). The changes of pH 4.6–4.9 become 7 indicated maturing stage was occurring before harvesting (Wei et al., 2007). The pH of compost from all research variations was within the range of quality requirements, namely 6.8–7.5 as depicted by the red and blue line.

Analysis of carbon to nitrogen ratio

Final carbon to nitrogen ratio of compost resulting from all research variation shown in Figure 3. The study showed C/N ranged between 10 and 20, the highest was 20 (L5) and the lowest was 10 (L12). All of the experiment variation met the compost quality based on Indonesia standard (black and red line). The reduction carbon in composting process which caused by microorganism and larvae activity metabolism. This activity was resulting CO_2 (Sarpong et al., 2018). Meanwhile, increasing of nitrogen probably caused by larvae activities and nitrification process by bacteria (Bernal et al., 2009). C/N value of 15 and below is highly recommended for agronomic. C/N value less than 20 is suitable for plants, mineralize of organic nitrogen to inorganic (Pan et al., 2012).

Analysis of phosphorous

The study showed phosphorus ranged between 0.13–0.40% (Figure 4). Raw material used GM, TD and FW with all variation was proper with Indonesia standard (minimum 0,10%). The highest phosphorus produced by variation 100% GM with MW and MoL addition. Livestock manure is a potential phosphorus sources reached 70–80% which is appropriate for agriculture propose (Karunanithi et al., 2015). During composting process, only small part of organic phosphorus can be degraded by microorganism. Phytic acid is the main component of organic phosphorus which is found in livestock manure (Xie et al., 2023). This is the reason why compost resulting from 100% GM raw material reached the highest phosphorus among TD and FW.

Analysis of potassium

Figure 5 represented final measurement of potassium for L1-L12. The highest potassium was

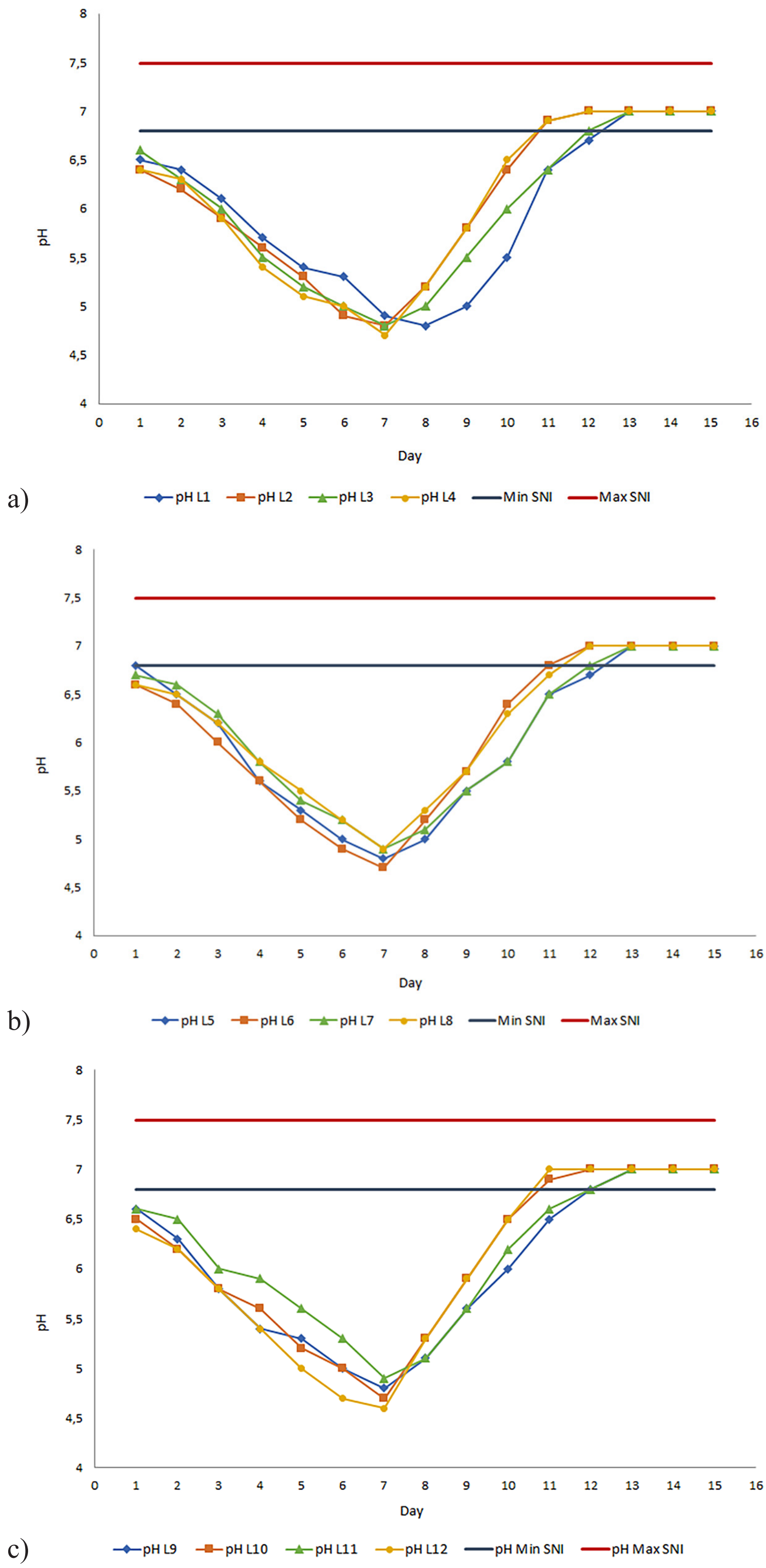


Figure 2. a) pH measurement in L1-L4, b) pH measurement in L5-L8, c) pH measurement in L9-L12

0.38% (L2 and L4) using 100% GM added by MW and MoL. Potassium could be resulted from recycling from manure compost (Nguyen et al., 2024). Meanwhile the lowest K was 0.21% (L6) which used variation raw material 30% GM and 70% TW. According previous study decreased potassium might be caused by loss of potassium salts through excessive leaching (Sommer 2001).

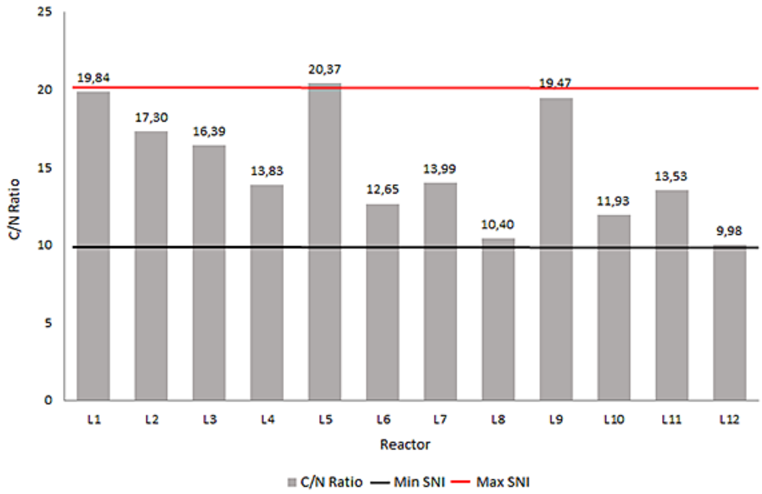


Figure 3. Carbon to nitrogen ratio compared with standard

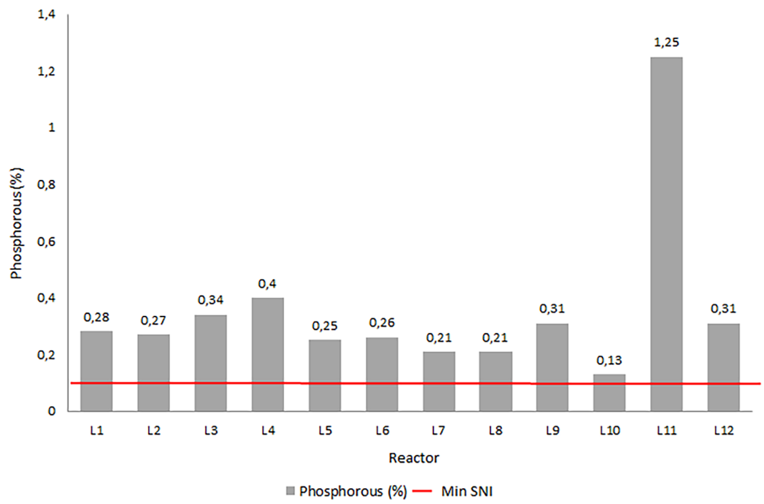


Figure 4. Phosphorous analysis compared with standard

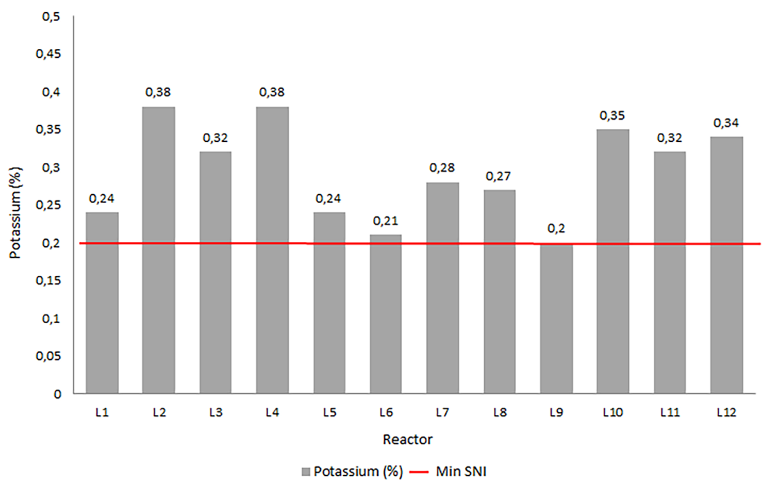


Figure 5. Potassium analysis compared with standard

Water content of L6 reported had high water content reached 80%, it probably causing excessive leaching. Raw material of compost using 30% GM and 70% FW had water content less than TW reached potassium ranged between 0.30% and 0.35%. However, all reactors can produce

Table 2. MANOVA test

Variation	Sig. number	Sig. limited	Hypotesis	Conclusion
Raw material	0.160	> 0.05	H_0 Accepted	Raw material had no effect
MW addition	0.040	< 0.05	H_0 Rejected	MW addition had effet
MoL addition	0.042	< 0.05	H_0 Rejected	MoL addition had effect
Raw material*WM addition*MoL addition	0.132	> 0.05	H_0 Accepted	All variation combined has no effect

compost that has a potassium value in accordance with SNI (red line).

Statistical analysis

Multivariate Analysis of Variance (MANOVA) with normality and homogeneity test were conducted to examine the effect of research variation on compost quality. Based on normality test using Kolmogorov-Smirnov method for raw material composition, MW addition and MoL addition versus compost quality reported all sig number > 0.05. It indicated the data was normal. Continuing homogeneity test using Levene method sig number ranged between 0.070 and 0.971 (> 0.05) shown the data is homogenous. The requirement data before MANOVA had been achieved. MANOVA conducted with the null hypothesis for assumes that the mean of the treatment combination is equal (no treatment effect of the compost quality).

H_0 – the mean of variation is identical (no variation effects for compost quality)

H_1 – the mean of variation had effect for compost quality

Mean value to evaluate effect of raw material variation, MoL and WM addition to compost quality shown in Table 2. Based on statistical analysis, research variation that have an influence on the overall compost quality are MW and MoL addition.

The analysis of the physicochemical properties showed that in this study, all the treatment met the compost maturity based on Indonesia standard. However, this study also examined which variation give effect to compost quality. The significant value of research variation (< 0.05) showed by MW and MoL addition than those raw material and all combination. From the results of statistical analysis, it was found that the research variation that had an influence on compost quality was the addition of WM and MoL. It supported by data from Figure 3, the lowest C/N resulted by L5 (no WM and MoL addition) and the highest C/N founded in L12 (WM and MoL addition).

WM addition can be successfully support to improve C/N because high protein contains (Lalman et al., 2004). In line with research conducted by Naveen Desai et al., 2026, which shows that MW can be successfully treated into compost. Composting process that decomposed organic material use nitrogen to build cell structure that can be supported by MW addition. MoL addition can be supported composting in acceleration of organic decomposition. MoL has a basis fuction as a starter in composting (Wikurendra et al., 2022).

The limitation of using compost produced from this research is still required to detail chemical and microbiological tests. The use of compost in soil improvement still requires inorganic fertilizer. Meanwhile, the advantage of the research results is provides a preliminary practice that WM can be processed using BSF larvae composting which is easy to operate, requires a relatively short time, around 15 days and the results meet compost quality standards in Indonesia.

CONCLUSIONS

Waste milk, food waste, tofu dregs and goat manure can be successfully converted and decomposed into useful friendly fertilizer with standard limit in Indonesia. Water content, temperature and pH were monitored every day have met the standard limits. However special management is required regarding water content that is too high causing by tofu dregs in compost material. This is in line with C:N ratio, phosphorous and potassium which also meets compost quality standard for all larvero. MW and MoL addition that have an influence on the overall compost quality based on Indonesia standard. WM has the potential to be processed using compost and can be an additional material that influences the quality of compost.

Acknowledgements

The authors are grateful to Indonesia government, for the financial support granted to conduct the research.

REFERENCES

1. Elkhalifa S., Al-Ansari T., Mackey H.R., McKay G. (2019). Food waste to biochars through pyrolysis: A review. *Resour. Conserv. Recycl., 144*, 310–320.
2. Gao A., Tian Z., Wang Z., Wennersten R., Sun Q. (2017). Comparison between the technologies for food waste treatment. Energy Proc 105:3915–3921. https://doi.org/10.1016/J.EGYPRO.2017.03.811
3. Ungyong C., Mustafa A.M., Lin H., Choe U., Sheng K. (2020). Anaerobic co-digestion of fish processing waste with a liquid fraction of hydrothermal carbonization of bamboo residue, *Bioresource Technology, 297*, https://doi.org/10.1016/j.biortech.2019.122542.
4. Karim N.U., Lee M.F.M.A., Arshad A.M. (2015). The effectiveness of fish silage as organic fertilizer on post-harvest quality of Pak choy (*Brassica rapa* L. subsp. *chinensis*). *Eur. Int. J. Sci. Technol. 4*, 163–174.
5. Toppe J., Olsen R.L., Peñarubia O.R. (2018). Production and utilization of fish silage. a manual on how to turn fish waste into profit and a valuable feed ingredient or fertilizer. FAO, Rome, 28.
6. Kazemi K., Zhang B., Lye L.M., Zhu Z. (2017). Evaluation of state and evolution of marine fish waste composting by enzyme activities. *Can. J. Civ. Eng. 44*, 348–357.
7. Apriani M., Cahyono L., Utomo A.P., Nugraha A.T., Cahya Ningrum A.D. (2022). Preliminary investigation of bioplastics from durian seed starch recovery using PEG 400 for reducing marine debris. *Journal of Ecological Engineering*. *23*(2), 12–17. https://doi.org/10.12911/22998993/144824
8. Vaverková M.D., Adamcová D. (2015). Biodegrability of bioplastic materials in a controlled composting environment. *Journal of Ecological Engineering.16*(3), 155–160. https://doi.org/10.12911/22998993/2949
9. Rahmatullah R., Putri R.W., Komariah L.N., et al. (2024). The effect of plasticizer type and concentration on cellulose acetate-based bioplastic from durian skin. *Journal of Ecological Engineering. 25*(11), 70–82. https://doi.org/10.12911/22998993/192677
10. Busato J.G., de Carvalho C.M., Zandonadi D.B., Sodré F.F., Mol A.R., de Oliveira A.L., Navarro R.D. (2018). Recycling of wastes from fish beneficiation by composting: chemical characteristics of the compost and efficiency of their humic acids in stimulating the growth of lettuce. *Environ. Sci. Pollut. Res. 25*, 35811–35820.
11. Trivana L., Pradhana, A.Y. (June 2017). Optimalisasi waktu pengomposan dan kualitas pupuk kandang dari kotoran kambing dan debu sabut kelapa dengan bioaktivator PROMI dan orgadec. *Jurnal Sain Veteriner*, [S.l.], 35(1), 136–144 https://doi.org/10.22146/jsv.29301
12. Ortiz-Cornejo N.L., Romero-Salas E.A., Navarro-Noya Y.E., González-Zúñiga J.C., Ramirez-Villanueva D.A., Vásquez-Murrieta M.S., Verhulst N., Govaerts B., Dendooven L., Luna-Guido M., (2017). Incorporation of bean plant residue in soil with different agricultural practices and its effect on the soil bacteria. *Appl. Soil Ecol 119*, 417–427.
13. Zhang L., Sun X. (2018). Effects of bean dregs and crab shell powder additives on the composting of green waste. *Bioresour. Technol 260*, 283–293.
14. Ma Y., Khan M.Z., Xiao J., Alugongo G.M., Chen X., Li S., Wang Y. and Cao Z. (2022). An overview of waste milk feeding effect on growth performance, metabolism, antioxidant status and immunity of dairy calves. *Front. Vet. Sci. 9*, 898295. https://doi.org/10.3389/fvets.2022.898295
15. Aust V., Knappstein K., Kunz H.J., Kaspar H., Wallmann J., Kaske M. (2013). Feeding untreated and pasteurized waste milk and bulk milk to calves: effects on calf performance, health status and antibiotic resistance of faecal bacteria. *J Anim Physiol Anim Nutr (Berl). 97*, 1091–103. https://doi.org/10.1111/jpn.12019
16. Brunton L.A., Duncan D., Coldham N.G., Snow L.C., Jones J.R. (2012). A survey of antimicrobial usage on dairy farms and waste milk feeding practices in England and Wales. *Veterinary Record. 171*, 296. https://doi.org/10.1136/vr.100924
17. Anusha S., Paul P. (2015). Stabilization of sludge from AAVIN dairy processing plant (Chennai) using vermicomposting, *J. Chem. Pharma. Res. 7*(3), 846–851.
18. Desai N., Tanksali A., Soraganvi V.S. (2016). Vermicomposting – Solution for Milk Sludge, *Procedia Environmental Sciences, 35*, 441–449, https://doi.org/10.1016/j.proenv.2016.07.027
19. Dortmans, B., Diener, S., Bart, V. and Zurbrügg, C. (2017). Black soldier fly biowaste processing: a step-by-step guide. eawag.
20. Boaru A., Vig A., Ladoşi D., Păpuc T., Struți D., Georgescu B. (2019). The use of various oviposition structures for the black soldier fly, *Hermetia illucens* L. (Diptera: Stratiomydae) in improving the reproductive process in captivity. *Adv. Agric. Bot., 11*, 12–20.
21. Astuti U.P., Setiani V., Apriani M., Dewi T.U., and Sulistiyo N. (2022). Tanjung Perak Port solid waste composting using black soldier fly method. *Jurnal Presipitasi: Media Komunikasi dan Pengembangan*

Teknik Lingkungan, 19(3), 578–588. https://doi.org/10.14710/presipitasi.v19i3.578-588

22. Amrul N.F., Ahmad, I.K., Basri, N.E.A., Suja, F., Jalil, N.A.A., Azman, N.A. (2022). A review of organic waste treatment using black soldier fly (*Hermetia illucens*). *Sustainability, 14*, 4565. https://doi.org/10.3390/su14084565
23. Banks I.J., Gibson W.T., Cameron M.M. (2014). Growth rates of black soldier fly larvae fed on fresh human faeces and their implication for improving sanitation. *Trop. Med. Int. Health 19*(1), 14–22.
24. Aja O.C., Al-Kayiem H.H. 2014. Review of municipal solid waste management options in Malaysia, with an emphasis on sustainable waste-to-energy options. *J Mater Cycles Waste 16*(4), 693–710. https://doi.org/10.1007/s10163-013-0220-z
25. Bernal M.P., Alburquerque J.A., Moral R. (2009). Composting of animal manures and chemical criteria for compost maturity assessment. A review. *Bioresour Technol 100*(22), 5444–5453. https://doi.org/10.1016/j.biort ech.2008.11.027
26. Dortmans B. (2015). *Valorisation of Organic Waste—Effect of the Feeding Regime on Process Parameters in a Continuous Black Soldier Fly Larvae Composting System.* Master's Thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden, 38.
27. ˇCiˇcková H., Newton G.L., Lacy R.C., Kozánek M. (2015). The use of fly larvae for organic waste treatment. *Waste Manag. 35*, 68–80.
28. Pandebesie E.S., Warmadewanthi I., Wilujeng S.A., and Simamora M.S. (2022). Changes of nitrogen and organic compound during co-composting of disposable diaper and vegetable wastes on aerobic process. *Journal of Ecological Engineering, 23*(4), 228–234. https://doi.org/10.12911/22998993/144944
29. Waqas M., Hashim S., Humphries U.W., Ahmad S., Noor R., Shoaib M., Naseem A., Hlaing P.T., Lin H.A. (2023). Composting processes for agricultural waste management: A comprehensive review. *Processes*. *11*(3), 731. https://doi.org/10.3390/pr11030731
30. Pang W., Hou D., Chen J., Nowar E., Li Z., Hu R., Tomberlin J.K., Yu Z., Li Q., Wang S. (2020). Reducing greenhouse gas emissions and enhancing carbon and nitrogen conversion in food wastes by the black soldier fly. *J. Environ. Manag. 260*, 110066. https://doi.org/10.1016/j.jenvman.2020.110066
31. Ahmad I.K., Peng N.T., Amrul N.F., Basri N.E.A., Jalil N.A.A., Azman N.A. (2023). Potential application of black soldier fly larva bins in treating food waste. *Insects*. *14*(5), 434. https://doi.org/10.3390/insects14050434
32. Wei Z., Xi B., Zhao Y., Wang S., Liu H., Jiang Y. (2007). Effect of inoculating microbes in municipal solid waste composting on characteristics of humic acid, *Chemosphere, 68*(2), 368–374, https://doi.org/10.1016/j.chemosphere.2006.12.067
33. Diener S., Solano N.M.S., Roa Gutiérrez F. et al. (2011). Biological treatment of municipal organic waste using black soldier fly larvae. *Waste Biomass Valor 2*, 357–363 https://doi.org/10.1007/s12649-011-9079-1
34. Sarpong D., Oduro-Kwarteng S., Gyasi S.F., Buamah R., Donkor E., Yaw E., Botchway, E., Acquah S. (2018). Biodegradation of heterogeneous mixture of organic fraction of municipal solid waste by black soldier fly larvae (*Hermetia Illucens*) under the tropical climate conditions. *International Journal of Innovative Science, Engineering & Technology, 5*, 243–254.
35. Pan I., Dam B., Sen S.K. (2012). Composting of common organic wastes using microbial inoculants. 3 Biotech 2, 127–134. https://doi.org/10.1007/s13205-011-0033-5
36. Karunanithi R., Szogi A.A., Bolan N., Naidu R., Loganathan P., Hunt P.G., Krishnamoorthy S. (2015). Phosphorus recovery and reuse from waste streams *Adv. Agron., 131*, 173–250. https://doi.org/10.1016/bs.agron.2014.12.005
37. Xie S., Tran H.-T., Pu M., Zhang T. (2023). Transformation characteristics of organic matter and phosphorus in composting processes of agricultural organic waste: Research trends, *Materials Science for Energy Technologies, 6*, 331–342. https://doi.org/10.1016/j.mset.2023.02.006
38. Nguyen T.T., Sasaki Y., Nasukawa H., Katahira M. (2024). Recycling potassium from cow manure compost can replace potassium fertilizers in paddy rice production systems, *Science of The Total Environment, 912*, https://doi.org/10.1016/j.scitotenv.2023.168823
39. Sommer S.G. (2001). Effect of composting on nutrient loss and nitrogen availability of cattle deep litter. *Eur J Agron 14*, 123–133. https://doi.org/10.1016/S1161-0301(00)00087-3
40. Desai N., Tanksali A., Soraganvi V.S. (2016) Vermicomposting – solution for milk sludge, *Procedia Environmental Sciences, 35*, 441–449, https://doi.org/10.1016/j.proenv.2016.07.027
41. Wikurendra E.A., Nurika G., Herdiani N., Lukiyono Y.T. (2022). Evaluation of the commercial bio-activator and a traditional bio-activator on compost using Takakura method. *Journal of Ecological Engineering, 23*(6), 278–285. https://doi.org/10.12911/22998993/149303
42. Aslanzadeh S., Kho K., Sitepu I. (2020). An Evaluation of the Effect of Takakura and Effective Microorganisms (EM) as Bio Activators on the Final Compost Quality *IOP Conf. Ser.: Mater. Sci. Eng. 742,* 012017. https://doi.org/10.1088/1757-899X/742/1/012017