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Research Article

PUMAKKAL FORMULA FOR MAKING SHRIMP POND WASTE FERTILISER

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Abstract
One way to decompose the pond waste sediment is to use the liquid nutrient culture media (NB) called Pumakkal as a starter formula. However, bioremediation in shrimp ponds paid less attention despite being massively promoted by the official government. East Lampung produced 11.6 million m^3 of liquid waste and 4.077 m^3 of sediment waste in shrimp ponds rich in organic matter. However, they will poison the pond if they are unchecked. This study investigated how *Pumakkal* decomposed shrimp pond waste with three parameters: macronutrients, micronutrients, and pH. The study employed laboratory experiments, and the research was a completely randomised design (CRD) with 15 factorial arrangements. The sample was 65 kg of shrimp pond waste and 65 litres of liquid waste. They were analysed with five treatment experiments: three treatments of liquid waste media (LW), sediment waste (SW), and mixed liquid and sediment waste (MLS). The results showed that the treatment of the CE 15 isolate (with MLS significantly improved ($p<0.05$) fertiliser quality. Bioremediation using Pumakkal CE is the best treatment with MLS, obtaining the fertiliser with the best macronutrient: Nitrogen (N) 1,3%, Phosphorus (P)2,3%, and Potassium (K) 2,3%; C-organic 23%, C/N ratio 29; micronutrient: Fe:155 ppm, Cu: 51 ppm, Zn: 72 ppm, Mn; 51 ppm, B; 25 ppm, and Mo: 8 ppm, and pH 5-6. The mixture of liquid and pond sediment waste produces the best fertiliser suitable for plant fertiliser users. The study implies that Pumakkal applies to decomposing harmful waste sediment to support the bioremediation program.

Keywords: Bioremediation, Nutrient levels, Pumakkal, Sediment and Wastewater from Shrimp Ponds

INTRODUCTION

In recent decades, studies in bioremediation have spread over the globe, including Indonesia. However, this issue should have paid more attention despite being massively promoted by the official government, particularly bioremediation in shrimp ponds. The current and previous studies are under a big umbrella of growth regulators in agriculture (Pérez-Álvarez et al., 2022). Prior studies such as

Bacillus Probiotics and Bioremediation (Kamilya & Devi, 2022) have connectivity in that the study anchored prebiotic bacteria, water quality, and aquaculture. Henceforth, the current study promoted "pumakkal," which is a trademark (Sutanto, 2019) with essential bioremediation called "Waste Organic Pollutants" (LCN)-(Sutanto, 2016). A backward report issued various variables such as evaluation of bioremediation with aquaculture sediments (Mandario et al., 2019), evaluation of bioremediation on water remediation in shrimp' pond (Shinde et al., 2023), and Probiotics and Bioremediation (Kamilya & Devi, 2022). Several variables of bioremediation are studied with attributes of water exchange shrimp ponds (Joseph et al., 2021) and active microbiological in bioremediation of earthen shrimp ponds (Colette et al., 2023). In short, these studies support the current study by providing scientific contributions to global remediation studies.

Indonesia's total shrimp production in the last five years has increased by 15.7%. Lampung Province is listed as the largest shrimp-producing area in Indonesia. Of the national shrimp production, which reached 348,100 tons, 45% was produced from the 2,175-hectare shrimp-producing area in Lampung region, producing a volume of 11.6 million m^3 of liquid waste and 4,077m^3 of sediment waste/harvest times (Yuka et al., 2020; Yuka et al., 2021). Pond wastewater contains organic matter such as BOD, DO, COD, TSS, phosphate, and high ammonia; 22-57% of the nitrogen that is put into the pond will be wasted with the liquid waste and pollute the pond (Nur Fatimah et al., 2018; Marliani, Siagian, 2022). Pond sediment solid waste has a high nutrient content such as N total 0,67%, P_2O_5 4,78%, K_2O 1%, C-organic 17,87%, pH 6,25, and water content 15,60% (Suryanto Suwoyo et al., 2017a). The fishery sector in Purworejo Village, Pasir Sakti District, and East Lampung Regency is dominated by 80% of the shrimp and fish pond industry. Vaname Shrimp Cultivation (*Litopenaeus vannamei*) has high productivity, resulting in high waste. The amount of sediment waste generated in shrimp ponds with a density of 1,250 fish/m^2 is 21,9 tons and a density of 1000 fish/m^2 by 20,3 tons (Mul Mulyani Sutedjo, 1990; Novizan, 2002). The problem with shrimp ponds is the accumulation of leftover feed, shrimp faeces, and micro-organisms, so liquid waste and sediment can reduce water quality and eventually disrupt the life processes of vannamei shrimp. Long-term liquid waste and sediment accumulation will reduce productivity, pond quality, and coastal ecosystems.

Liquid waste and shrimp pond sediments have yet to be utilised so far. Liquid and sediment waste have high organic matter content, potentially being used as a fertiliser through a bioremediation process using microbes to decompose organic matter. Bioremediation is an effort to improve the environment by involving the presence of organisms in nature. The process of waste treatment will be more accessible by utilising the activities of micro-organisms to break down the substances in the waste materials into simpler ones (Kusmiyarti, 2016; Ghosh et al., 2021). Bioremediation requires living agents in the form of plants, animals, and micro-organisms, including bacteria and fungi, to have the ability to decompose toxic compounds. Consortium Bacillus sp. and Pseudomonas sp., as well as Saccharomyces sp., Nitrosomonas sp., and Nitrosobacter sp., can reduce the concentration of organic matter in shrimp pond sediments up to 60% (Devaraja et al., 2002). These bacteria were also found in Pineapple Liquid Waste (Sutanto, 2010), indicating that there were 15 isolates of indigenous bacteria with different specifications for degrading organic matter such as carbohydrates, proteins, starch, and fats. Indigenous bacterial isolates known as Pumakkal can decompose organic matter through bioremediation, raising pH and producing CO2 and H2O that are safe for the aquatic environment (Sutanto, 2010; Sutanto, 2011). Organic matters in the shrimp pond contain nutrients and high organic matter that can be decomposed by Pumakal bacteria into simpler compounds and become organic fertiliser (Suryanto Suwoyo et al., 2017a; Suryanto Suwoyo et al., 2017b). For the effectiveness of Pumakkal indigenous bacterial isolates in degrading shrimp pond sediments, it is necessary to make five bacterial formulas (consortia) according to their hydrolytic abilities based on groups, quantities, and particular specifications including consortia A 3 isolate (CA), consortia B 6 isolate (CB), consortia C 9 isolatae (CC), consortia D 12 isolate (CD), and consortia E (CE) of 15 bacterial isolates. The 15 bacterial isolates used were *Bacillus licheniformis, Bacillus cereus, Bacillus cereus, Bacillus subtilis, Bacillus cereus, Bacillus subtilis, Acinetobacter baumannii, Acinetobacter baumannii, Klebsiella oxitoca, subtilis, Bacillus cereus, Pseudomonas pesudomallei, Actinobacillus iwoffii, Actinobacillus iwoffii,* and *Bacillus* that are firm to degrade protein, starch, and fat. Five formulas of Pumakkal will degrade shrimp pond sediments into fertilisers as measured by macronutrient and micronutrient parameters. Macronutrient parameters were Nitrogen (N), Phosphorus (P), Potassium (K), C-organic, and C/N. Micronutrient parameters were Fe, Cu, Zn, Mn, B, Mo, and pH 5-6; refer to RI Ministry of Agriculture Regulation Number: 261/KPTS/SR.310/M/4/2019 concerning minimum technical requirements for organic fertilisers, biological fertilisers, and soil conditioners (Kementan, 2019). The research benefit is using shrimp pond waste (liquid and sediment waste) as organic fertilisers using five Pumakkal bio-remediator formulas and fulfilling the Minister of Agriculture criteria.

The current study aims to investigate how *Pumakkal* (with 15 isolates) decomposed shrimp pond waste with three parameters: macronutrients, micronutrients, and pH. The study employed laboratory experiments, and the research was a completely randomised design (CRD) with a 5 x 3 factorial arrangement. The factorial employs 3 x 5 Factorial Bidirectional Variance Analysis, Variable X1 = Media Variation (X1.1= Liquid Waste; X1.2= Sediment Waste; X1.3= Mixture SPL Waste and Sediment), X2= Formula Pumakal (X2.1 = CO; X2.2= CA; X2.3= CB; X2.4= CC; X2.5= CD; X2.6= CE) and Variable Y= fertiliser quality: macronutrients: Nitrogen (N), Phosphorus (P), Potassium (K); C-organic and C/N ratio; micronutrients: Ferrum (Fe), Cuprum (Cu), Zinc (Zn), Manganese (Mn), Boron (B), and Molybdate (Mo), and Degree of acidity (pH). The study intends to solve the addressed problems. The problem with shrimp ponds is the accumulation of leftover feed, faeces, and micro-organisms. Consequently, the liquid waste and sediment can reduce water quality and eventually disrupt the life processes of Vannamei shrimp. Moreover, long-term liquid waste and sediment accumulation will reduce productivity, pond quality, and coastal ecosystems. Therefore, the researchers propose this research to solve the problems and novelty of the current study.

RESEARCH METHOD

The study employed a quantitative approach under factorial experimental design. The research employed five treatments (CO, CA, CB, CC, CD, and CE). The dependent variable was the Pumakkal isolate starter formula, while the dependent variable was shrimp pond waste from Pasir Sakti Lampung. After the rearing period (120 days), 65 kg of shrimp pond waste from Pasir Sakti Lampung was used, and 65 litres of liquid waste, five formulas of treatment experiments (CO, CA, CB, CC, CD, and CE); three treatments of liquid waste media (LW), sediment waste (SW), and mixed liquid and sediment waste (MLS) for in vitro and pilot plan scales. Liquid nutrient culture media (NB) manufactured Pumakkal isolate starter formula.

The study involved shrimp pond waste from Pasir Sakti Lampung. The subject was taken by purposive random sampling. The goal was to make the shrimp pond waste become organic fertiliser. There were two research stages, namely in vitro and a pilot plan according to procedures of Sutanto (2012) and Mekala et al. (2023) were used to test the ability of the Pumakkal formula to decompose liquid waste and shrimp pond sediments waste to be used as fertiliser according to the standard of Minister of Agriculture of Republic of Indonesia. *This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the University's Ethics Committee (December 22, 2022/No: 123/II.3.AU/F/UMM/2022).*

Preparation of the Pumakkal starter formula was conducted by using liquid nutrient media/Nutrient Broth (NB) according to the procedure of Abna et al. (2017) and Tantray et al. (2023). There are 5 Pumakkal formulas, each using 750 ml NB. The compositions of the five formulas (a) Consortia A (CA) with 3 isolates, namely bacterial isolates 2, 3, and 5 with the type of bacteria *Bacillus cereus, Bacillus cereus, and Bacillus cereus* to degrade fat, (b) Consortia B (CB) with 6 bacterial isolates, namely bacterial isolates 4, 5, 6, 7, 12, and 14 with the type of bacteria *Bacillus subtilis*, *Bacillus cereus*, *Bacillus subtilis*, *Acinetobacter*, *Pseudomonas pesudomallei*, and *Actinobacillus iwoffii* to degrade starch, (c) Consortia C (CC) with 9 bacterial isolates 1, 2, 3, 8, 10, 11, 12, 14, and 15 with the types of bacteria *Bacillus licheniformis*, *Bacillus cereus*, *Bacillus cereus*, *Acinetobacter baumannii*, *Bacillus subtilis*, *Bacillus cereus*, *Pseudomonas pesudomallei*, *Actinobacillus iwoffii*, and *Bacillus* are firm to degrade protein, (d) Consortia D (CD) with 12 bacterial isolates namely bacterial isolates 1, 2, 3, 7, 8, 9, 10, 11, 12, 13, 14, and 15 with the type of bacteria *Bacillus licheniformis, Bacillus cereus, Bacillus cereus*, *Acinetobacter baummanii*, *Acinetobacter baummanii*, *Klebsiella oxitoca*, *Bacillus subtilis*, *Bacillus cereus*, *Pseudomonas pesudomallei*, *Actinobacillus iwoffii*, *Actinobacillus iwoffii*, and *Bacillus* are firm to degrade protein and starch, and (e) Consortia E (CE) consisted of 15 bacterial isolates namely bacterial isolates 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15, with the type of bacteria *Bacillus licheniformis* , *Bacillus cereus*, *Bacillus cereus*, *Bacillus subtilis*, and *Bacillus* are firm to degrade protein, starch, and fat. The five Pumakkal formulas were used to degrade three media, namely liquid waste, sediment, and liquid/sediment mixture of shrimp ponds, each with a volume of 300 ml. Fermentations were conducted for 30 days, and the analyses of the parameters of macronutrients Nitrogen (N), Phosphorus (P), Potassium (K), organic carbon (C-organic), C/N ratio, micronutrients: Fe, Cu, Zn, Mn, B, Mo, and pH were conducted at the Chemistry Laboratory of the Muhammadiyah Malang, Malang. Data were analysed quantitatively using the Anova test and qualitatively to test the quality of fertiliser by comparing the Indonesian Ministry of Agriculture Regulation Number: 261/KPTS/SR.310/M/4/2019 (Decree of the Minister of Agriculture No. 261 of 2019 Concerning Guidelines for Organic Fertilizers, 2019).

Testing the effectiveness of the Pumakkal formula was followed by a pilot plant test with a volume of liquid waste, sediment, and mixture of 1 litre, controlled aeration, agitation for 30 days, treatment, and observation. The data employed laboratory analysis in Chemistry Laboratory Unievrsitas Muhammadiyah Malang, Indonesia. The expert laborants analysed the contents of shrimp pond waste to become organic fertilisers. Data analysis techniques with 3 x 5 Factorial Bidirectional Variance Analysis, Variable X1 = Media Variation (X1.1= Liquid Waste; X1.2= Sediment Waste; X1.3= Mixture SPL Waste and Sediment), X2= Formula Pumakal (X2.1 = CO; X2.2= CA; X2.3= CB; X2.4= CC; X2.5= CD; X2.6= CE) and Variable Y= fertiliser quality: macronutrients: Nitrogen (N), Phosphorus (P), Potassium (K); C-organic and C/N ratio; micronutrients: Ferrum (Fe), Cuprum (Cu), Zinc (Zn), Manganese (Mn), Boron (B), and Molybdate (Mo), and Degree of acidity (pH).

RESULTS AND DISCUSSION

The current study investigates how *Pumakkal* (with 15 isolates) decomposed shrimp pond waste with three parameters: macronutrients, micronutrients, and pH. The study employed laboratory experiments, and the research was a completely randomised design (CRD) with a 5 x 3 factorial arrangement and the results are recapped in table 1.

Table 1. Recap of Pumakkal Formula Test Data Analysis on Shrimp Pond Waste for making Liquid, Solid and Mixed Fertilizers

	Pumakkal Formula (CO, CA, CB, CC, CD and CE); Waste Shrimp (Liquid Waste (LW)), Sedimen Waste (SW) and Mix Liquid Sedimen (MLS)																	
	Control (0 Isolate)			Consortia A (3 Isolate)			Consortia B (6 Isolate)			Consortia C (9 Isolate)			Consortia D (12 Isolate)			Consortia E (15 Isolate)		
	LW CO	SW CO	MLS CO	LW CA	SW CA	MLS CA	LW CB	SW CB	MLS CB	LW CC	SW CC	MLS CC	LW CD	SW CD	MLS CD	LW CE	SW CE	MLS CE
Macronutrieat																		
Nitrogen (N) %	0.4a	0.5a	0.9ab	0.6a	0.8b	1ab	1.1a	1.1a	0.9b	1a	1.1a	1.2ab	1a	1.1a	1.1b	1.1a	1.2b	1.3ab
Photophorus (P) %	0.4a	0.7a	0.9ab	0.6a	1.5b	1.3b	0.3a	1.5b	1.3b	0.6a	1.7b	1.5ab	0.3a	1.8b	1.6ab	0.5a	2.3b	2ab
Potassium (K) %	0.2a	0.6b	0.8ab	0.5a	1.6b	1.3ab	0.3a	1.5b	1.4ab	0.5a	1.8b	1.5ab	0.4a	1.9b	1.6ab	0.5a	2.3b	2.1ab
C-Organic %	7a	11b	10ab	12a	16a	14ab	13a	18b	17b	11a	18b	18b	12a	20b	20b	14a	23b	21ab
C/N ratio	-	11a	10b	-	20a	15b	-	17a	17a	-	22a	20b	-	28a	27b	-	29a	26b
Micronutrient																		
Ferum (Fe) ppm	80a	85b	85b	92a	97b	100ab	100a	150b	150b	95a	100b	105ab	96a	98b	99ab	102a	150b	155ab
Cuprum (Cu) ppm	20a	25b	26ab	23a	30b	30b	28a	29	32b	33ab	40a	45b	29ab	40a	40a	32a	41b	61ab
Zink (Zn) ppm	23a	25a	25a	35a	30b	35a	33a	40b	44ab	56a	45b	50ab	60a	55ab	55ab	67a	55b	50ab
Mangan (Mn) ppm	20a	25b	26ab	30a	30a	32ab	45a	50b	50b	47a	58b	60ab	55a	60b	60b	60a	78b	72ab
Boron (B) ppm	4a	5b	5b	9a	9a	10b	10a	11b	12ab	13a	15b	16ab	12a	18b	20ab	14a	20b	25ab
Molibdat (Mo) ppm	1a	3b	3b	1.2a	5b	6ab	1.5a	5b	8ab	2.1a	8b	8b	2.3a	7b	8ab	2.5a	10b	8ab
Degree of acidity (pH)	41	3b	4a	5a	4b	5a	5a	5a	4b	5a	5a	4b	5a	5a	6b	5.5a	5b	6ab

Macronutrient Nitrogen (N)

The percentages of nitrogen (N) using the Pumakkal formula CO, CA, CB, CC, CD, and CE with liquid media waste (LW), sediment waste (SW), and mixed of liquid and sediment wastes (MLS) after 30 days of fermentation are presented in Figure 1. showing the percentages of nitrogen in the Pumakkal formula CA, CB, CC, CD, and CE in the media of liquid waste, sediment waste, and mixture of liquid and sediment wastes of shrimp ponds. Anova test results were significantly different ($p<0.05$). In the Pumakkal CE formula with 15 isolates and a mixture of liquid waste and shrimp pond sediment waste, the highest result was 1,3%. The percentage of nitrogen meets RI Minister of Agriculture Number: 261/KPTS/SR.310/M/4/2019; (N+P+K=2-6%).

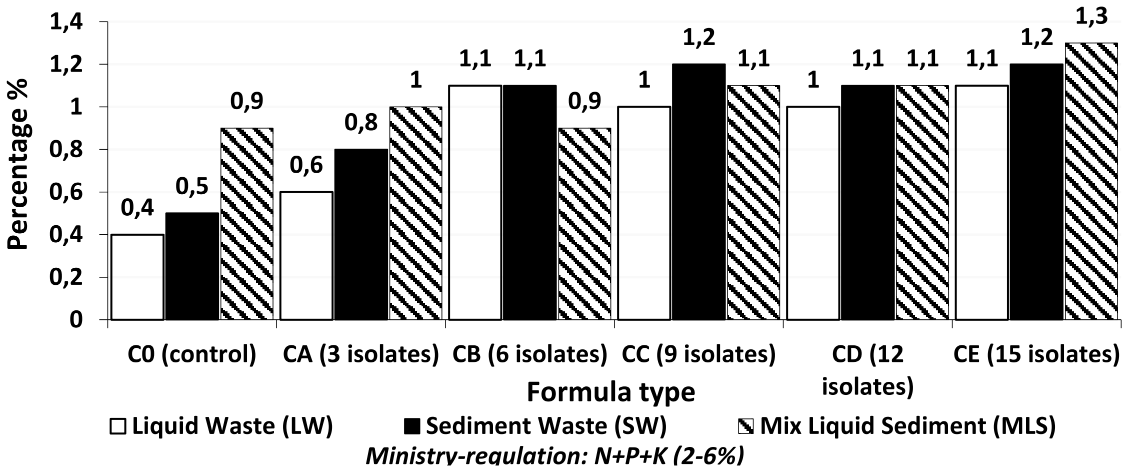


Figure 1. The average percentages of Nitrogen (N) using five Pumakkal formulas (CA, CB, CC, CD, and CE) and three media of liquid waste, sediment waste, and a mixture of shrimp pond liquid waste and sediment.

Comparison of the ability of the Pumakkal Formula from CO to CE showed an increase in the percentage of nitrogen CE and mixed media with the highest nitrogen content ($p<0.05$), and this result was due to the use of a Pumakkal fermenter and protein-rich shrimp pond waste (Paena et al., 2020; Hastuti, 2011). The highest percentage of nitrogen in the Pumakkal CE formula and mixed media and shrimp pond sediments is due to the decomposition of organic matter by bacteria *Bacillus licheniformis, Bacillus cereus, Acinetobacter baumannii*, *Bacillus subtilis*, *Pseudomonas pesudomallei*, and *Bacillus firmus* (Amara et al., 2012) as nitrifying bacteria that convert ammonia to nitrate at the end of the fermentation process. In addition, micro-organisms contribute to several single-cell proteins obtained during fermentation. After the decomposition process is complete, nitrogen will be rereleased as one of the components contained in the compost. Due to a breakdown, various types of nutrients, especially N, will be bound in the bodies of micro-organisms and will return after the micro-organisms die (*Sutedjo, 2019*). Nitrogen formation reaction (*Novizan*, 2007; Hastuti, 2011; Chen et al., 2021):

Protein Organic Ingredients $\xrightarrow{\text{Aminization Reaction}}$ Amino Acids
Amino Acid $\xrightarrow{\text{Ammonia Ammonification Reaction}}$ NH_3 and Ammonium NH_4+.

Ammonia nitrification reaction by bacteria *Nitrosomonas* and *Nitrococcus nitrate*. Aerobic conditions supplemented by a sufficient abundance of nitrifying bacteria (bacteria that help the process of breaking down ammonia into nitrites and nitrates) will produce an aquatic environment that is conducive and relatively safe from contaminants (Hastuti, 2011). The oxygen layer on the surface of the pond bottom is often conveyed to prevent most of the toxic metabolites from getting into the pond water because they are oxidised to non-toxic forms through biological activity when passing through the aerobic layer. Nitrite will be oxidised to nitrate, ferrous will be converted to ferric, and hydrogen sulfide (H2S) will be converted to sulfate. The five processes of the nitrogen biogeochemical cycle are ammonification, nitrification, nitrogen assimilation, denitrificati

on, and nitrogen fixation. Ammonification is the process of forming ammonia from organic matter. Ammonia can also be assimilated into amino acids and directly by diatom groups, cellular algae, and higher plants. Nitrification is an oxidation reaction forming nitrites or nitrates from ammonia. This process can take place both biologically and chemically.

Nitrogen assimilation utilises nitrogen to form amino acids in protoplasm by phytoplankton, algae, and bacteria. Ammonium and nitrite compounds are essential parts of the nitrogen cycle in nature. Denitrification is the reduction reaction of nitrate to nitrite, nitric oxide, and nitrogen gas. In contrast, nitrogen fixation is the fixation of nitrogen gas into ammonia and organic nitrogen (Dong et al., 2002). This process occurs in pond areas still in the coastal area so that it can involve a symbiosis of algae and bacteria (Effendi, 2003; Kusuma Pramushinta, 2018). In the biogeochemical cycle, there is oxidation and reduction of one inorganic nitrogen compound into another inorganic nitrogen compound. The concentrations of ammonium and nitrite compounds in sediments and waters are affected by nitrification and denitrification processes. Syahputra et al. (2011) said that there are three dissimilative nitrate reduction processes in bacteria, namely: denitrification, reduction of nitrate to ammonium, and dissimilative ammonium oxidation (anaerobic ammonia oxidation, anammox). Bacterial denitrification processes use nitrate compounds as the final electron acceptor to obtain energy in low oxygen or anaerobic conditions (Dodd et al., 1997; Richardson, 2000; Richardson et al., 2001); nitrite acts as an electron acceptor in the process of becoming nitrogen gas. Metabolism processes can form compounds between hydroxyl amines and hydrazine (Richardson et al., 2001; Hastuti, 2001). Nitrogen is an element needed by plants in vegetative growth and protein formation. If plants lack nitrogen, it will cause plants to become stunted, leaves to become yellow and fall, and root growth will be limited.

Total nitrogen (TN) consists of total ammonia nitrogen (TAN), and nitrite (NO_2) gives nitrate (NO_3). Nitrogen is generally divided into inorganic (NH_3, NH_4, NO_2, and NO_3) and organic (proteins, amino acids, and urea). Nitrogen sources in WWTPs are generally uneaten feed and shrimp faeces, which are transformed by phytoplankton and micro-organisms in assimilation, fixation, nitrification, ammonification, and denitrification. Enzymes that work to break down proteins are enzymes.

Proteases such as poly-peptidases, oligo-peptidases, and di-peptidases. Enzyme breaks down proteins into simpler peptides or amino acids. The amino acids then undergo trans-amination, deamination, decarboxylation, or dehydrogenation into simpler substances (Yuniati et al., 2015). The percentage of nitrogen from the fermentation of the CE Pumakkal formula (with 15 isolates) with mixed media of liquid waste and sediment produces organic fertiliser suitable for agriculture and plant fertilisers.

Macro Nutrient Phosphorus (P).

The percentages of phosphorus (P) using the Pumakkal formula CO, CA, CB, CC, CD, and CE with liquid media waste (LW), sediment waste (SW), and mixed liquid waste and sediment waste (MLS) after 30 days of fermentation are presented in Figure 2, showing the percentages of phosphorus in the CA treatment, CB, CC, CD, and CE in the media of liquid waste, sediment waste, and mixture of shrimp ponds Anova test results were significantly different ($p<0.05$). The Pumakkal CE formula with 15 isolates and sediment media and a mixture of shrimp ponds had the highest percentages of phosphorus, namely 2,3% and 2%. The percentage of phosphorus meets the requirement stated in the regulation in Republic of Indonesia Minister of Agriculture Number: 261/KPTS/SR.310/M/4/2019; (N+P+K=2-6%).

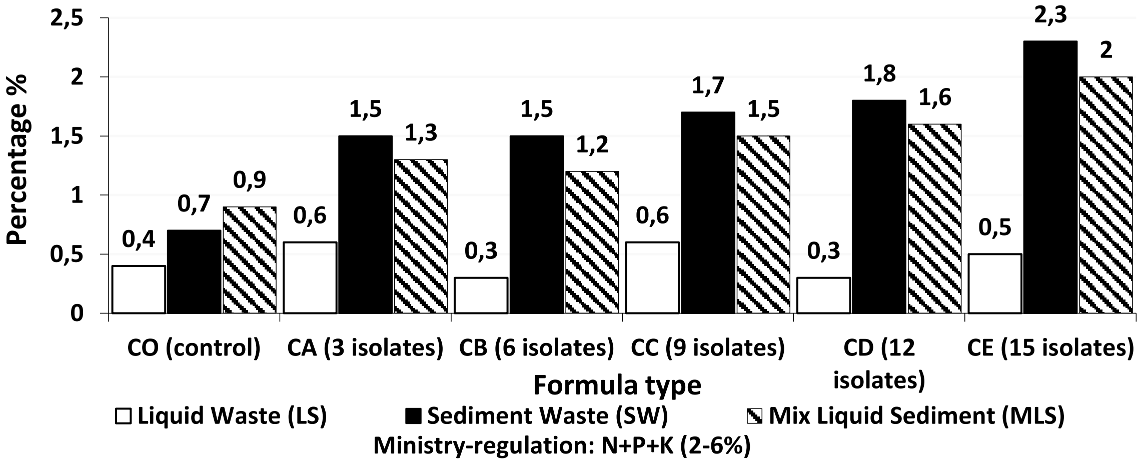


Figure 2. The average percentages of phosphorus (P) using five Pumakkal formulas (CA, CB, CC, CD, and CE) and three media of liquid waste (LW), sediment waste (SW), and a mixture of liquid waste and sediment waste (MLS) for shrimp ponds.

Comparison of the ability of the Pumakkal Formula from CO to CE showed an increase in the highest percentages of phosphorus in CE using mixed media ($p<0,05$). The highest percentage of phosphorus in the Pumakkal CE formula using mixed media for shrimp ponds is due to the decomposition of organic matter, exceptionally high protein by bacteria *Bacillus licheniformis*, *Bacillus cereus*, *Acinetobacter baummanii*, *Bacillus subtilis*, *Pseudomonas pesudomallei*, and *Bacillus firmus*.

Bacteria that play a role in the breakdown of phosphorus include *Bacillus, Pseudomonas, Aerobacter,* and *Xanthomonas*, and these micro-organisms dissolve phosphate so that plants can utilise it. Important micro-organisms involved in S oxidation are a group of bacteria belonging to the genus *Acidithiobacillus*, *Thiobacillus*, and heterotrophic bacteria including *Cytobacillus firmus*, *Enterobacter cloacae*, *Enterobacter ludwigii*, *Klebsiella oxytoca*, *Phytobacter diazotrophicus*, and *Pseudomonas stutzeri* (Williams & Kelly, 2013; Bünemann et al., 2018; Shinde et al., 2022). The characteristics of shrimp farming wastewater contain total organic matter (BOT), total suspended solids (TSS), total N, and PO_4 as sources of bacterial nutrition, and the potential for organic matter in large shrimp pond waste (Fahrur et al., 2016), retentions of N and P in vannamei shrimp culture are 22,27% and 9,79%, respectively, so that nutrients are wasted into the aquatic environment and each pond reaches 77,73% Nitrogen and 90.21% Phosphorus. Phosphorus input in vannamei shrimp ponds is 58,3%, consisting of 7,73% feed, 4.05% fertiliser, probiotic media <1%, the source of phosphorus in the pond is caused by 51% feed input, 26% erosion, and water flow by 10% (Hendarajat et al., 2007; Funge-Smith & Briggs, 1998). This can happen because phosphorus forms a complex with calcium under aerobic conditions, is insoluble, and precipitates in sediments so that algae cannot utilise it (Sudrajat & Bintoro, 2016). Orthophosphate can also be utilised directly by phytoplankton, while polyphosphate undergoes hydrolysis to form orthophosphate, which is influenced by pH and temperature. The polyphosphate change to orthophosphate occurs rapidly at high temperatures and low pH. The change of polyphosphate to orthophosphate in wastewater-containing bacteria occurs faster than in clean water (Sudrajat & Bintoro, 2016). The process of decomposing shrimp pond waste using the Pumakkal formula is due to the ability of bacteria to have the appropriate enzymes. The enzyme that works to decompose fat is lipase. Lipase enzymes can hydrolyse long-chain triglycerides into diglycerides, monoglycerides, glycerol, and fatty acids. Micro-organisms that produce lipase enzymes are widely used in waste treatment to decompose fats into harmless compounds. The lipase enzyme produced by micro-organisms is widely used for waste treatment to decompose fat (Arfiati, Lailiyah, Pratiwi, Alvateha, Aisyah, et al., 2021). The high percentage of phosphorus in the sediment and mixed waste added to shrimp comes from fat and protein, meeting the criteria of the Ministry of Agriculture, so fermented fertiliser using Pumakkal is suitable for use in agriculture. Plants use phosphorus to accelerate root growth, flower formation, fruit ripening, and grain production (Takahashi & Katoh, 2022).

Macro Nutrient Kalium (K).

The percentages of Potassium (K) using the Pumakkal formula CO, CA, CB, CC, CD, and CE with liquid media (LW), sediment waste (SW), and mixed (MLS) after 30 days of fermentation are presented in Figure 3. Pumakkal CE formula with 15 isolates and sediment waste and mixed liquid waste and sediment waste media for shrimp ponds produced the highest percentages of phosphorus at 2,3% and 2% ($p>0,05$). The percentage of phosphorus meets the levels stated in the regulation of the Republic of Indonesia Minister of Agriculture Number: 261/KPTS/SR.310/M/4/2019; (N+P+K=2-6%).

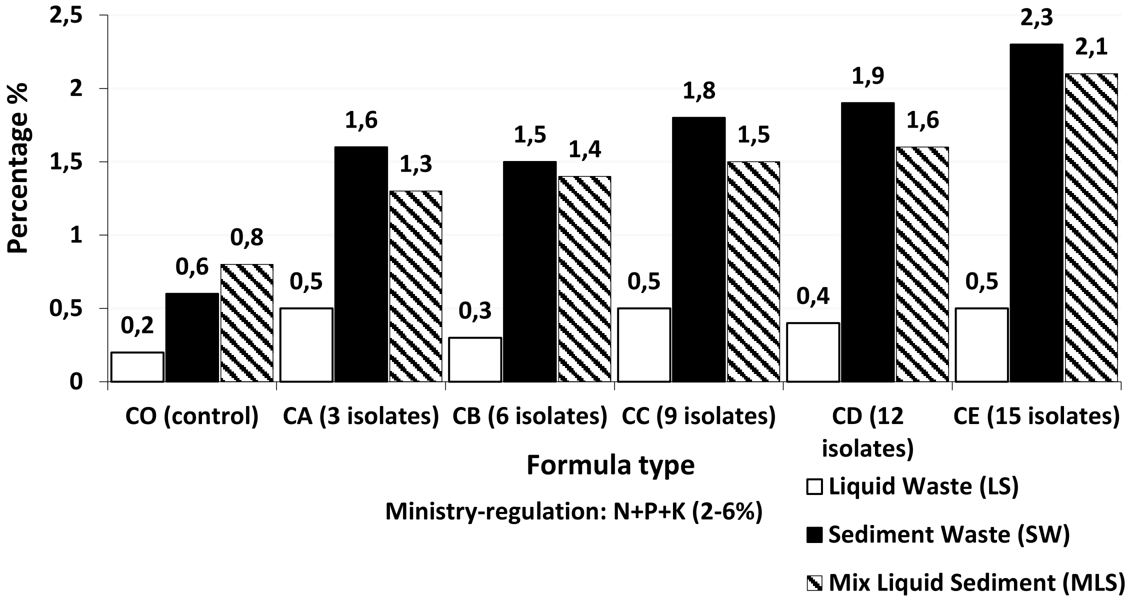


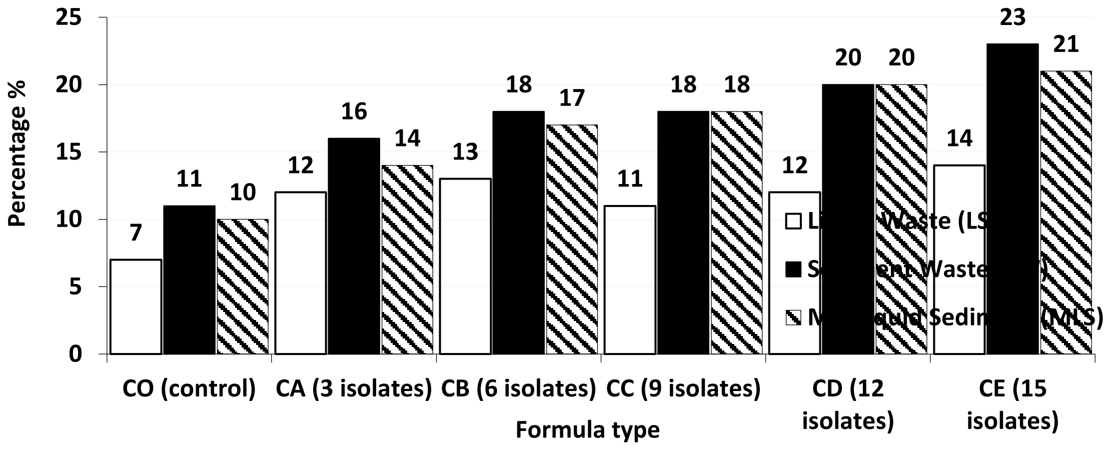
Figure 3. The average percentages of Potassium (K) using five Pumakkal formulas (CA, CB, CC, CD, and CE) and three media of liquid waste (LW), sediment waste (SW), and a mixture of liquid waste and sediment waste (MLS) of shrimp ponds.

The increased potassium levels were due to the decomposition process carried out by decomposer micro-organisms originating from Pumakkal. Microorganisms increase several nutrients, especially nitrogen, phosphorus, and potassium. These nutrients can return through the weathering of the remains of living things when the micro-organisms die (Serda et al., 2014). The decomposition of organic matter consists of primary decomposition and secondary decomposition. The primary decomposer is the mesofauna, which decomposes organic matter, such as Colembolla and Acarina, which crumble organic matter/litter into smaller sizes. Earthworms eat the remains of the crumbs, which are then excreted as faeces after going through digestion in the worm's body. Secondary decomposers are micro-organisms that decompose organic matter, such as *Trichoderma reesei, T. harzianum, T. koningii, Phanerochaeta crysosporium, Cellulomonas, Pseudomonas, Thermospora, Aspergillus niger, A. terreus, Penicillium,* and *Streptomyces*. The existence of soil fauna activity makes it easier for micro-organisms to utilise organic matter so that the mineralisation process runs faster and provides nutrients for plants better (Fan et al., 2022). Potassium in the compost is because much potassium comes from organic matter.

Organic materials can increase the cation exchange capacity. This is related to the negative charges originating from the –COOH and OH groups, which dissociate into COO^- and H^+ and O^- + H^+. This negative charge has the potential for humus to adsorb cations such as Ca, Mg, and K, which are bound with moderate strength to easily exchange or undergo a cation exchange process (Syafruddin et al., 2012). The macronutrient Kalium (K) catalyses proteins, cell division, and carbohydrates and activates enzymes (Kaya et al., 2014). If the plant is deficient in element K, then the process of photosynthesis decreases, while the process of plant respiration will increase. The functions of micronutrients include influencing oxidation and reduction processes, helping regulate acid levels, acting as a catalyst (stimulant), influencing osmotic value, helping growth, and affecting the absorption of nutrients (Sudarmi & Wartini, 2018). The high potassium content is due to the element Kalium (K), a catalyst for microbes or micro-organisms to speed up fermentation. In addition, the addition of bioactivators in the manufacture of liquid fertiliser also affects the high potassium levels in the fertiliser. If the fermentation process sprints and is accompanied by suitable supporting raw materials, the potassium content will also increase. Potassium in the 219compound potassium dioxide (K_2O), used by micro-organisms in the substrate material as a catalyst, will affect the presence of bacteria and their activity in the fermentation process (Andriawan et al., 2022). Kalium is bound and stored in the cells by bacteria and fungi. Potassium will be available if it is degraded again (Rahmawati et al., 2021). The highest percentage of potassium was found in the formula Pumakkal CE 15 isolates and pond sediment media at the level of 2,3%, which meets the criteria of the Minister of Agriculture as feasible for organic fertiliser.

Percentage of organic C.

The percentages of organic C using the formula Pumakkal CO, CA, CB, CC, CD, and CE with liquid waste (LW), sediment waste (SW), and mixed liquid waste and sediment waste (MLS) after 30 days of fermentation are presented in Figure 4. Pumakkal CE formula with 15 isolates and sediment waste and a mixture of shrimp ponds produce the highest percentage of organic C at the levels of 23% and 21% ($p< 0,05$) and meets the criteria of Minister of Agriculture Number: 261/KPTS/SR.310/M/4/2019 (minimum 10% liquid fertiliser and 15% solid).



Ministry Regulation*: *organic C liquid minimum 10% and sediment 15%

Figure 4. The average percentages of organic C using five Pumakkal formulas (CA, CB, CC, CD, and CE) and three media of liquid waste (LW), sediment waste (SW), and mixed liquid and sediment waste (MLS) of shrimp ponds.

The high levels of organic C are due to the use of Pumakkal as a starter for decomposer micro-organisms, among others, *Bacillus cereus* and *Bacillus subtilis*, which can break down organic compounds such as carbohydrates and proteins during the fermentation process into simpler compounds that plants can utilise. These micro-organisms use carbon to decompose organic matter during fermentation (*Pangkalan Data Kekayaan Intelektual*, 2017; Hieronymus Yulipriyanto, 2010). Reaction process

Organic ingredients + O_2 $\xrightarrow{\text{Aerobic Microbes}}$ H_2O + CO_2 + Nutrient+ humus + E, followed by an anaerobic process that takes place gradually. In the first stage, several facultative bacteria will decompose organic matter into fatty acids. In the second stage, the other microbial groups will convert fatty acids into ammonia, methane, carbon dioxide, and hydrogen. The heat generated in the anaerobic process is lower than the aerobic one. The following is a reaction that occurs under anaerobic conditions. With the following reaction:

Organic ingredients $\xrightarrow{\text{Anaerobic Microbes}}$ CH_4 + Nutrients+ Humus

The total organic C in liquid organic fertiliser is influenced by the method of decomposition of materials, the quality of the organic matter, and the activity of micro-organisms involved in the decomposition of organic matter. Carbon is a source of energy used by micro-organisms to fix nitrogen. There was a decrease in organic C content in the treatment of the Pumakkal CC and CD liquid waste formulas due to the use of carbon by microbes as food and an energy source in the decomposition process of organic matter. Microbes obtain/take energy to decompose organic matter from calories produced in biochemical reactions. For example, the conversion of carbohydrates to CO_2 and H_2O occurs continuously, so the carbon content in organic fertilisers decreases lower and lower. The increase in organic C levels again in the middle or at the end of the fermentation process is thought to be due to a decrease in the activity of micro-organisms, and some others die (Kusuma Pramushinta, 2018). The organic C content is an essential factor determining the quality of mineral soil. The higher the total organic C content, the better the mineral soil quality. Soil organic matter is important in improving soil physical properties, increasing soil biological activity, and increasing plant nutrient availability. Organic matter is a vital ingredient in creating soil fertility in physics, chemistry, and soil biology. The factors that affect the decomposition of organic matter can be grouped into three groups, namely 1) the nature of the plant type, plant age, and chemical composition; 2) soil, including aeration, temperature, humidity, acidity, and fertility, and 3) climatic factors, especially the influence of humidity and temperature (FAO, 1999). The minimum percentage of organic C fertiliser is 10% liquid fertiliser and 15% solid fertiliser, so the active carbon content contained in all treatments in this study meets the standards and is suitable for organic fertilisers.

Ratio of Carbon and Nitrogen (C/N).

C/N test results using the Pumakkal formula CO, CA, CB, CC, CD, and CE with sediment waste (SW) and mixed liquid and sediment wastes (MLS) are presented in Figure 5. The percentages of organic C in the CA, CB, CC, CD, and CE treatments, the Pumakkal CE formula with the 15 best isolates of sediment media, and CD 9 isolates of mixed media of shrimp ponds gave the highest C/N each at the levels of 29% and 27% ($p>0.05$). The Carbon and Nitrogen ratio meets RI Minister of Agriculture Number 261/KPTS/SR.310/M/4/2019 (minimum 25).

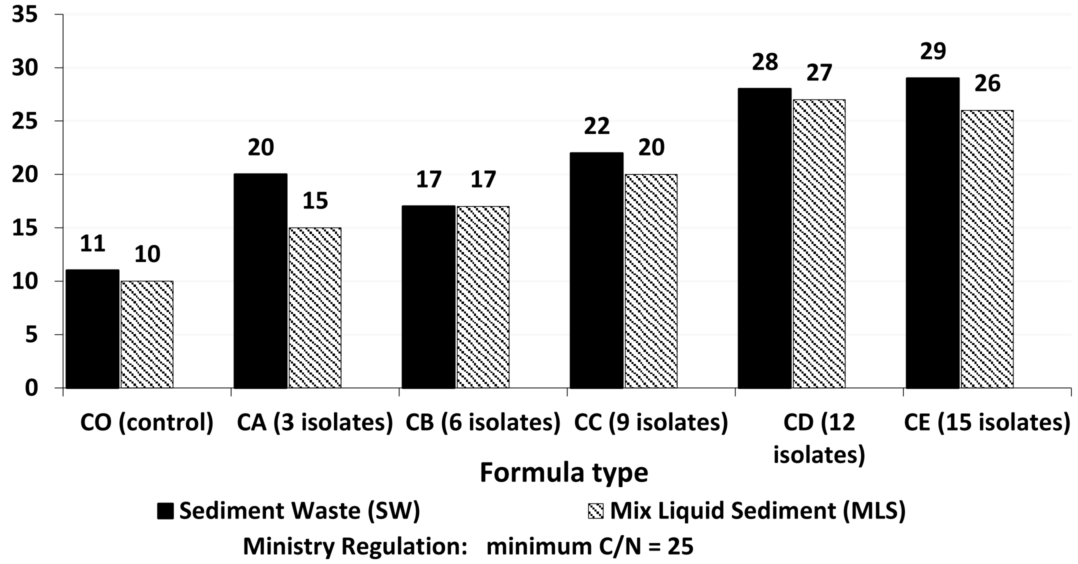


Figure 5. Average organic C/N using five Pumakkal formulas (CA, CB, CC, CD, and CE), two sedimentary waste media (SW), and a mixture of liquid waste and sediment waste (MLS) for shrimp ponds.

Composting (Aerobic Process) is decomposing organic waste/sediment waste easily decomposed into compost by micro-organisms. Factors influencing composting are C/N ratio = 20-40, micro-organisms, moisture content 50-55%, temperature 30-55°C, pH 5,5-8, aeration, and particle size. A C/N ratio of 25-35 is required (Purnomo et al., 2017) to compost sheep faeces with a low C/N ratio. Additional media is needed to increase the C/N ratio of the compost so that the composting process runs well and produces compost. The quality indicators of compost quality include the nutrient content of Nitrogen (N), Phosphorus (P_20_5), and Potassium (K_2O); compost quality standards based on SNI 19-7030-2004 contain a minimum of 0.40% Nitrogen (N), Phosphorus (P_20_5) 0,1%, and Potassium 0,20% (Tb. Benito et al., 2013). Optimal composting needs to pay attention to several influential environmental factors because this process is a biological process, and factors that affect the rate of composting include material size, C/N ratio, humidity and aeration, temperature, degree of acidity, and the micro-organisms involved. The size of the material used for the composting process will be better and faster if the raw material is smaller. The size of the raw material that is too small will cause the air voids to decrease so that the pile becomes more compressed than it was, and the supply of oxygen to the pile will decrease. If the oxygen supply is reduced, the micro-organisms in the waste compost cannot work optimally. The C/N ratio is the most important factor in the composting process. This is due to the composting process depending on the activities of micro-organisms that require carbon as an energy source and cell building and nitrogen to form cells. The value of C/N depends on the type of waste. A good composting process will produce an ideal C/N ratio of 20–40, but the best ratio is 30. If the C/N ratio is high, the activity of micro-organisms will decrease. In addition, several cycles of micro-organisms are needed to complete the degradation of the compost material so that the composting time will be longer and the compost produced will be of lower quality. If the C/N ratio is too low (less than 30), excess nitrogen (N), which is not used by micro-organisms cannot be assimilated and will be lost through volatilisation as ammonia or denitrified (Purnomo et al., 2017).

Microbes will use carbon and nitrogen for growth. Decomposing shrimp ponds involves Pumakkal microbes, so the C/N ratio is the ratio of carbon mass to nitrogen in a substance. In organic matter that is still new, it has a higher C/N ratio than the C/N ratio after the composting process. This means that composting is an effort to reduce the C/N ratio of organic matter so that it has a C/N ratio that can be absorbed by plants, which is at least 25. The C/N ratio contained in liquid fertiliser indicates the liquid fertiliser's maturity level; from this study's results, it is said that liquid organic fertiliser is immature because the fertiliser has not decomposed completely. When the C/N ratio is too high (a lot of C elements and a few N elements), the metabolism becomes inadequate, meaning there is carbon in the substrate that is not fully converted, so maximum methane yields will not be achieved. In the opposite case, a surplus of nitrogen can lead to the formation of excessive amounts of ammonia (NH_3), which, even in low concentrations, will inhibit bacterial growth (Kusuma Pramushinta, 2018). In addition, the low content of the C/N ratio of liquid organic fertiliser is also caused by the content and activity of micro-organisms. The longer the fermentation process, the lower the C/N ratio. This is because the C content in the material used to make liquid fertiliser has been greatly reduced. After all, it is used by micro-organisms as a food or energy source. At the same time, the nitrogen content has increased due to the decomposition process of liquid fertiliser ingredients by micro-organisms that produce ammonia and nitrogen, so the C/N ratio decreases (*Linda Trivana, 2018*). The C/N ratio of organic matter is the most important factor in making liquid fertiliser. This is because micro-organisms need carbon to provide energy (Yudi et al., 2023) and nitrogen which plays a role in maintaining and building their body cells (Yudi et al., 2023) and nitrogen which plays a role in maintaining and building their body cells (Yudi et al., 2023). A high C/N ratio will cause the fermentation process to run slowly due to the low nitrogen content. Conversely, if the C/N ratio is too low, it will cause ammonia to form, causing nitrogen to be lost in the air (Yudi et al., 2023). The C/N ratio can be used as an indicator of the fermentation process. The fermented fertiliser can be used if the total ratio between carbon and nitrogen is still 20% to 30%. The difference in C and N contents will determine the continuity of the liquid fertiliser fermentation process, affecting the quality of the liquid fertiliser produced (Pancapalaga, 2011). The results of the anaerobic bacterial organic waste decomposition produce CO_2, NH_4, NO_3, SO_4, and $H_2AFTER_4^{2-}$. There is a close relationship between the ratio of carbon and nitrogen to the decomposition rate of organic matter. Every 10 parts of C required 1 part to form plasma cells (Moriarty, 1997). A good range of C/N ratio for aquaculture is 10 to 15 (Tucker & Hargreaves, 2004). N fluctuations in ponds are influenced by the content of organic matter in ponds, which is still a lot and has not experienced an optimal decomposition process. Some nutrients settle at the bottom of the pond into organic sediments. Those that dissolve in water will be converted into inorganic nutrients used by seaweed and plankton, and some of the N evaporates into the air. Meanwhile, 60-80% of the total carbon content is estimated to be released in CO_2 under aerobic conditions. Types of organic matter will affect the quality and quantity of organic matter. Organic materials with a low C-N ratio (<25) will cause the decomposition process to sprint. Organic matter with a high C-N ratio (> 25) can cause immobilisation, formation of humus, accumulation of organic matter, and increased sulfur content. Increasing levels of lignin and polyphenols will inhibit the decomposition process of organic matter (Kismi et al., 2014). The ratio of carbon and nitrogen using Pumakkal CD and CE fermenters produces fertilisers 27 and 29, according to the requirements of the Ministry of Agriculture, and are suitable for agriculture.

Shrimp Pond Waste Micronutrients.

Percentages of Fe, Cu, Zn, Mn, B, and Mo were calculated using the formula Pumakkal CO, CA, CB, CC, CD, and CE with liquid media (LW). Figures 6, 7, and 8 Pumakkal CE formula with 15 isolates and the best shrimp pond mixed media (p>0.05), yielded Fe:155 (standard 90-900), Cu: 51 (standard 25-500), Zn: 72 (standard: 25-5000, Mn; 51 (standard 25-5000, B; 25 (standard: 12-250), and Mo: 8 (standard: 2-10) (p.0.05) comply with the regulation.

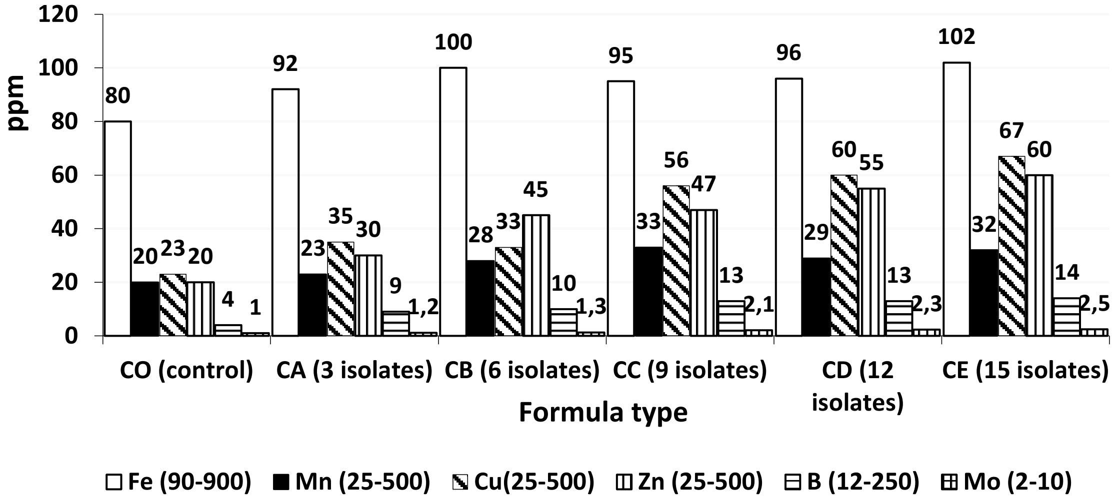


Figure 6. Fe, Cu, Zn, Mn, B, and Mo using five Pumakkal formulas (CA, CB, CC, CD, and CE) for shrimp pond wastewater.

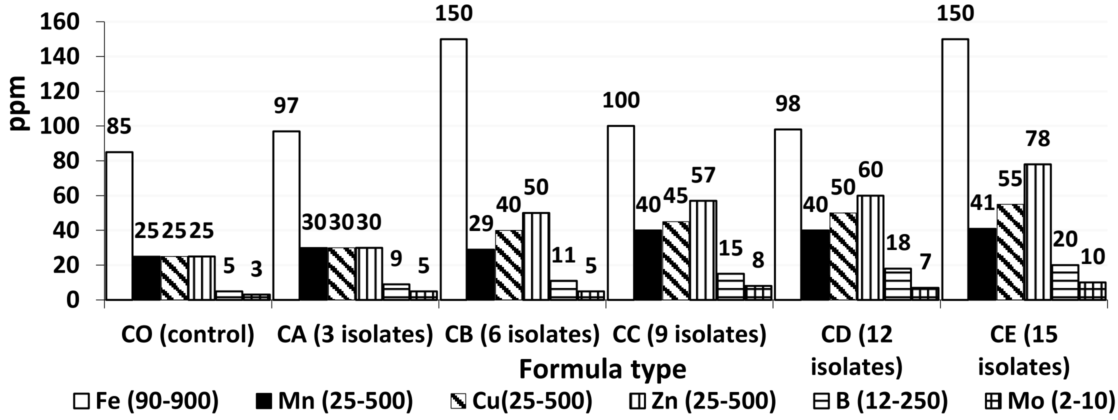


Figure 7. Fe, Cu, Zn, Mn, B, and Mo using five Pumakkal formulas (CA, CB, CC, CD, and CE) for shrimp pond liquid sediment media.

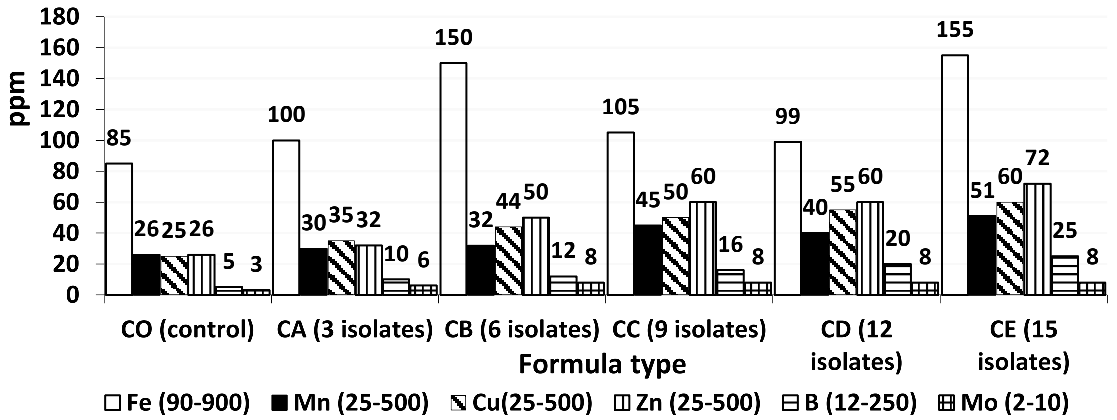


Figure 8. Fe, Cu, Zn, Mn, B, and Mo using five Pumakkal formulas (CA, CB, CC, CD, and CE) for mixed media for shrimp ponds.

Micronutrients are obtained from the decomposition of shrimp pond waste by Pumakkal microbes, namely bacteria *Bacillus licheniformis*, *Bacillus cereus*, *Acinetobacter baumannii*, *Bacillus subtilis*, *Pseudomonas pesudomallei*, *Bacillus firmus.* Bacteria that play a role in the revamp of phosphorus include *Bacillus*, *Pseudomonas*, *Aerobacter*, and *Xanthomonas.* Genus *Pseudomoas sp*., and *Bacillus sp.* have the greatest ability to dissolve insoluble phosphate into a soluble form in the soil (Tangguda et al., 2015). Bacteria species with a high ability to dissolve phosphates are *P. striata*, *P. rathonis*, *B. polymyxa*, and *B. Megaterium.* Saputra (2019) found that *Bacillus sp*. can reduce lipid levels by as much as 25% due to membrane-bound oxygenase enzymes produced by bacteria to increase direct contact between oil and bacteria so that bacteria can utilise the oil as a carbon source. **J**-types of bacteria of the genus *Bacillus* capable of degrading lipids are *B. polymixa*, *B. licheniformis*, *B. stearothermophilus*, *B. brevis*, and *B. coagulans*. *Alcaligenes sp.* and *Coryne bacterium sp*. are bioremediation agents (Tangguda & Prasetia, 2019). These micro-organisms produce enzymes that can change the structure of toxic pollutants to be less complex so that they become non-toxic and non-dangerous compounds (Priadie, 2012). Nitrification consists of two reactions, namely nitridation, which is the change from ammonia to nitrite which is carried out by the bacteria Nitrosomonas sp., and nitration, namely the change from nitrite to nitrate carried out by bacteria *Nitrobacter sp*. (Tangguda & Prasetia, 2019). Nitrifying bacteria in shrimp pond solid waste illustrates that nitrification can occur properly. The Pumakkal CE formula with the 15 best isolates of mixed media for shrimp ponds produced Fe:155 (90-900 standard), Cu: 51 (25-500 standard), Zn: 72 (25-5000 standard, Mn; 51 (25-5000 standard), B; 25 (standard: 12-250), and Mo: 8 (standard: 2-10) comply with RI Minister of Agriculture Number: 261/KPTS/SR.310/M/4/2019. In comparing the capabilities of the Pumakkal Formula from CO to CE, there was an increase in micronutrients, the type of sedimentary media and mixtures were significantly different ($p>0.05$), and the sediment media had high micronutrients.

Degree of Acidity (pH).

The results of the degree of acidity (pH) test using the Pumakkal formula CO, CA, CB, CC, CD, and CE with liquid media (LW), sediment (SW), and mixed (MLS) in Figure 9 show CE (15 isolates) and mixed media (MLS) the highest pH 5-6 ($p> 0,05$), meets the standard of Minister of Agriculture 4-9.

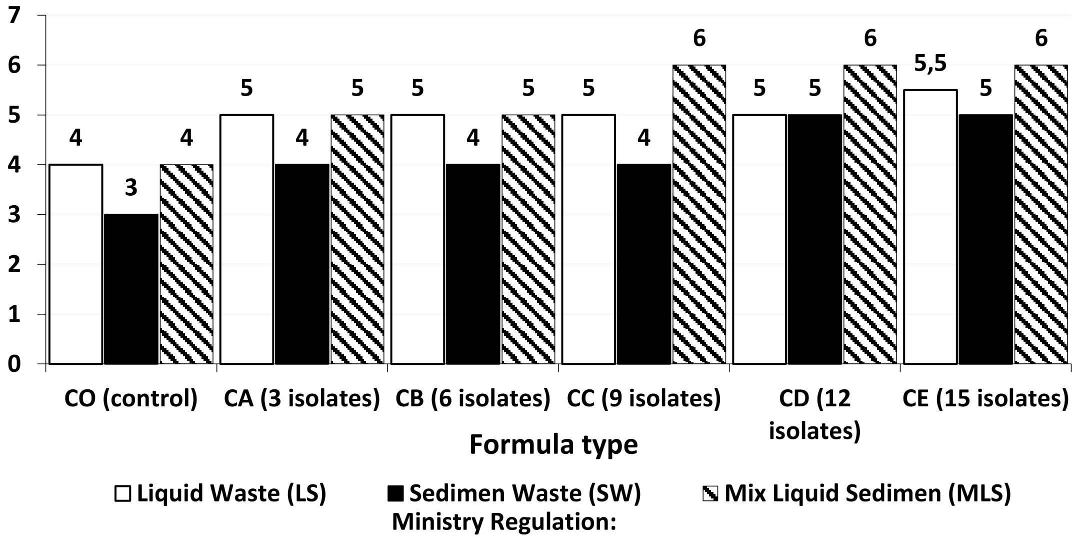


Figure 9. Ranges of pH using five Pumakkal formulas (CA, CB, CC, CD, and CE) and three media of liquid waste (LW), sediment waste (SW), and a mixture of liquid waste and sediment (MLS) for shrimp ponds.

The change in pH to neutral was caused by an acid-base reaction that formed between Pumakkal bio activators during the fermentation process with the following reaction:

$H^+ + OH^- \rightarrow H_2O$. Pumakkal bio-activator contains bacteria *Acinetobacter baumanni* and *Pseudomonas pseudomallei*, which can decompose organic acids in waste (*Pangkalan Data Kekayaan Intelektual*, 2017). The influence of pH on fertilisers is significant in determining plants' uptake of nutrient ions. Generally, plants will easily absorb nutrients at a pH of 6-7 because most of the nutrients will dissolve in water at that pH. If fertiliser is applied and causes the soil to become acidic, aluminium (Al) will be found, which can poison plants and bind phosphorus so that plants cannot absorb it.

In contrast, in alkaline conditions, many elements of Na (Sodium) and Mo (Molybdenum) can poison plants. pH conditions also determine the development of micro-organisms; at a pH of 5.5 – 7, fungi and bacteria that decompose organic matter will grow well (Maciej Serda et al., 2014). After harvesting and drying, the ponds will find shrimp droppings, leftover shrimp feed, and decaying shrimp as debris at the bottom of the pond. The residue will dry and can be used for shrimp biosolids. These biosolids are considered waste and are usually disposed of in landfills. These biosolids or shrimp pond residues are valuable sources of N, P, K, and other useful plant nutrients. The highest content in these biosolids is nitrogen (Dufault et al., 2013). The environmental impact of shrimp pond activities is closely related to managing wastewater and pond sludge that settles. The sludge from the pond has the potential to be reused and can also be used as organic fertiliser in the presence of high levels of nutrients and organic matter (Rahaman et al., 2013). Shrimp pond solid residue cannot be used alone as a complete fertiliser but must be used with commercial fertilisers. Pond solid residue has a very high organic matter, and soil minerals with low organic matter are expected to increase fertility, which may contribute to successive crops planted in the exact location (Dufault et al., 2013). Pumakkal, as a bioactivator, can decompose shrimp pond sediments into compost that meets the criteria of C, N, C/N, P. Ca, K, and pH content.

The pH level ranges from 6-7, and the optimum pH level for decomposing bacteria ranges from 5,5-7,5. In the hydrolysis and acidogenesis phases, the optimum is at pH 5,5-6,5; in the methanogenesis phase, the optimum is at pH 6,5-8,2 (Sari et al., 2016). The activity of acidic bacteria increases pH due to NH^{4+} binding to OH- to form NH_4OH, which is essential (*Pangkalan Data Kekayaan Intelektual*, 2017). The enzymes that decompose carbohydrates include starch-breaking enzymes such as amylase, invertase, lactase, and cellulase. Pectin-breaking enzymes include polygalacturonase and methyl pectin esterase (Arfiati, Lailiyah, Pratiwi, Alvateha, Dahria Aisyah et al., 2021). More feed given daily will increase the amount of sediment that settles and will trigger a decrease in sediment pH due to decomposition. At the beginning of the organic matter decomposition process for all treatments, the pH value decreased, and then the pH value increased.

The pH value drops at the beginning of decomposing organic matter due to the activity of bacteria that produce organic acids such as lactic acid, acetic acid, or pyruvic acid. The formation of these organic acids results from the decomposition of organic matter into lactic acid by the bacteria *Lactobacillus sp.* The emergence of other micro-organisms from the decomposed material causes the pH of the material to rise again after a few days (Siswati, 2015). The pH value, which increases again, can be caused by the biological activity of micro-organisms in breaking down organic nitrogen (Fitria et al., 2008). Micro-organisms will utilise organic pollutants through enzymes converted into simple compounds to help produce energy and nutrients used to build more (Abatenh et al., 2017; Singh et al., 2014). Bacteria will decompose complex organic compounds into more complex forms. Simple with enzymes. Organic compounds will be oxidised to CO_2, H_2O, $SMALL^{4+,}$ and new biomass. Using the Pumakkal bioremediation formula CE (15 isolates) can decompose macronutrients, micronutrients, and pH in wastewater, sediment, and pond mixtures so that they meet the requirements of the Minister of Agriculture and are suitable for use as plant fertilisers.

CONCLUSION

Five types of consortia pumakkal Application (CA, CB, CC, CD dan CE), the Pumakkal CE formula (15 isolates), and a mixture of shrimp pond sediments produced the macronutrients Nitrogen (N) 1,3%, Phosphorus 2,3%, and Potassium 2,3%; C-organic 23%, C/N ratio 29; micronutrients Fe:155 (90-900 standard), Cu: 51 (25-500 standard), Zn: 72 (25-5000 standard, Mn; 51 (25-5000 standard), B; 25 (standard: 12-250), and Mo: 8 (standard: 2-10) and the highest pH 5-6 ($p>0,05$) meet the RI Minister of Agriculture standard Number: 261/KPTS/SR.310/M/4/2019 and are suitable for agriculture.

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AUTHOR CONTRIBUTIONS

All authors have contributed to this article. The first and the third author are responsible for the whole manuscript. The fourth and fifth authors are responsible for reviewing the method and flows of discussion. In contrast, the second author is responsible for proofreading and crosschecking (in-text citation and list of references).

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

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