Optimization of Liquid Organic Fertilizer Production from Tofu Liquid Waste Using EM-4 Activator and Additional Ingredients of Rice Washing Water and Goat Urine

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ABSTRACT

Liquid organic fertilizer is organic fertilizer in liquid form which is partly or wholly derived from organic compounds such as plant, animal and industrial waste, either in solid or liquid form. The nutrients contained in it are in the form of a very fine solution so that it is easily absorbed by plants, even the leaves or stems. Organic fertilizer is one solution to restore soil minerals physically, chemically and biologically from the bad effects of synthetic fertilizers. The benefits of liquid organic fertilizer include providing nutrients for plants, improving soil structure, suppressing bacteria that can be detrimental to the soil, and continuous use of soil will improve the physical, chemical and biological properties of the soil as a result being conducive to the environment. In the fermentation process, the role of microbes greatly determines the product produced. The aim of this research is to determine the potential of liquid waste. in the form of liquid organic fertilizer with the addition of goat urine and rice washing water with variations of 15 mL and 30 mL to increase micro and micro nutrients with the bacterial activator EM-4 through a fermentation process. The results of the optimum organic fertilizer content show that the Biological Oxygen Requirement is 969,549 ppm, the Chemical Oxygen Requirement is 14,801.04 ppm and the Total Suspended Solids is 5.360 ppm. Optimal macro nutrient results show Nitrogen 0.2527%, phosphorus 0.1359%, potassium 0.15435%. And the highest degree of acidity (pH) is 4.415. on the first day.

1. Introduction

Tofu is one of the food industries that produce protein sources with essential ingredients from soybeans which are very popular with the people of Indonesia. On the other hand, this industry produces liquid waste that has the potential to pollute the environment and is one of the industries that produce organic waste. Tofu is one of the most commonly consumed side dishes in Indonesia. Tofu contains a lot of protein and vitamins needed by the body This number is considerably higher than per capita consumption of beef and chicken. Tofu can also serve as snacks and for some people, tofu is also considered as the side dishes are eaten with the staple food [1].

Tofu is consumed practically all over Indonesia, although the consumption level still varies from one province to another. Waste obtained from byproducts of tempe making, if not properly managed and only directly discharged into the waters will greatly disrupt the surrounding environment because

it can damage the quality of groundwater, causing unpleasant odor, and trigger the growth of various bacteria Pathogens [2].

The industrial revolution followed by green revolution caused increase in yield per unit area in agricultural production, but they also caused increase in synthetic fertilizers and pesticides used in agriculture. To reduce and eliminate the adverse effects of synthetic fertilizers and pesticides on human health and environment, new agricultural practices have been developed in the so-called organic agriculture, ecological agriculture or sustainable agriculture. The increasing demand for organic fertilizers, organic farming and organic foods are becoming more popular globally due to the foremost public concern on food safety and security. Most of the multifaceted environmental and health issues are associated with excessive use of chemical fertilizers i.e., deterioration of soil, loss of soil fertility, loss of organic matter, increased soil acidity, reduction of biodiversity, contamination of groundwater [3].

Tofu wastewater that is simply thrown into the environment will cause odor problems, reduce the nutrient content in the soil, and pollute the water. One effort to overcome this is by utilizing tofu industry liquid waste into liquid compost. Liquid compost fertilizer is one of the ingredients comes from plants and goes through an engineering process to improve physical, chemical and biological properties soil properties [4].

The liquid waste generated from the home-based tofu industry contains various organic compounds such as 40-60% protein, 25-50% carbohydrates, and 10% fat, therefore if this liquid waste is discharged directly into waters such as rivers or lakes, the water contained in it become polluted matter will affect the high nitrogen, phosphorus, and sulfur in water. The liquid waste produced from this tofu has the potential to be developed into liquid fertilizer. Tofu liquid waste has various nutrients and can be used as a new alternative fertilizer that can be applied for plant growth [5]. The use of inorganic fertilizers continuously causes the fertilizer function to be ineffective. This is due to the residual effects of these chemicals which can cause soil biological ecosystems to become unbalanced and can have an impact on the soil, plants and the environment. One way to reduce the use of inorganic fertilizers is to combine them with organic fertilizers [6].

Table 1. Liquid organic fertilizer standards

Parameter	Unit	Technical Requirements	Information
C-Organic	%	>-4	C-Organic content
N,P,K	%	<2	If > 2% is suspected to contain inorganic chemicals
Pantogen Microba	cfu/g	<102	Salmonella must be negative because of the level of danger
Functional	cfu/g	-	Bacterial activity level
pH	-	4-8	A pH that is too acidic/alkaline is not good for the soil

Liquid organic fertilizer provides essential plant nutrients and microorganisms that assist in the decomposition of organic matter. Nitrogen (N), phosphorous (P), and potassium (K) are the three most important macronutrients for plant development. These macronutrients aid in increasing the production, growth, and freshness of a variety of crops. As a consequence, the nutritional levels in these fertilizers are meticulously calibrated to assure consistency, and as a consequence, they have won many farmers' hearts. As compared to the control and prototype fertilizers, organic liquid fertilizer not only boosts the bioorganic fertility of crops but also speeds up their maturity and nutritional quality [7].

Effective Microorganism Solution (EM4) is a material in the form of a fermenting liquid and consists of four main groups, namely photosynthetic bacteria, *Lactobacillus sp*, *Streptomyces sp*, and

yeast (yeast). In addition to accelerating the fermentation process, EM4 can add soil nutrients by pouring it on the ground and spraying it directly on the leaves of the plants [8]. The alternative choices of main ingredients for producing liquid organic fertilizer are shown in Table 2, and alternative ingredients for enriching POC nutrients are shown in Table 3.

This research was conducted due to wastewater problem from the tofu manufacturing industry, that has not handled appropriately. The wastewater has caused a very foul odor, polluted ecosystems, polluted groundwater, and of course, and could affect community health.

Table 2. Alternative choice of main ingredients for making Liquid organic fertilizer

The main ingredient	Nutrient content	Reference
Goat urine	N 1,7%, P 0,003%, K 1,45%, Ca 0,014%, Mg 0,04%	[9]
Bat feces	N 7-17%, P 8-15%, K 1,5-2,5%	[10]
Industrial waste water	Sugar 13,59 g/l, proteins 1,24 g/l, N total 753,5 mg/l, P total 103,5 mg/l	[11]
Tempe industrial waste water	N 0,05%, P 0,048%, K 0,02%	[10]
Tapioca industrial waste water	N 3,06 g/l, P 0,31 g/l, K 3,2 g/l, Ca 0,24 g/l, Mg 1,59 g/l, Na 0,39 g/l	[12]
Cow pen waste water	C organik 34%, N total 0,23%, total P 0,13% C/N 14,5	[13]
Pig pen waste water	N 2,25-3,1 g/l, P 2,58-3,41 g/l, K 1,07-1,31 g/l, Mn 0,03-0,04 g/l, Cu 0,06-0,08 g/l	[14]

Table 3. Alternative ingredients for enriching POC nutrients

Nutrient enrichment ingredients	N (CP)	P	K	Ca	Mg	Reference
Tithonia	2,5-3,5	0,25-0,38	2,5-4.1	0,25	0	[15]
Krinyu	1,8-2,9	0,13-0,50	1,01-2,60	0	0	[16]
Badotan	(24,5)	0,38	0,139	0,22	0,11	[17]
Asystasia gangetica	(15,5-25)	1,1-1,7	0	1,8-2,0	0,68-0,85	[18]
Sugarcane leaves	1,12	0,08	2,45	0	0	[19]
Cocoa pod shell	0,91	0,2	3, 18	0,67	0,29	[20]
Coffee skin pulp	1,91	0,28	3,61	0	0	[20]
Coffee husk ash	0	1,03	5,29	0,76	0,38	[20]
Coir ash	0	0,27	19,85	27,93	0	[21]

2. Research Methodology

2.1. Materials

The main material in this experiment was tofu liquid waste obtained from the tofu industry in the Ngestiharjo Kasihan Bantul, Indonesia. Additional materials were goat urine that was obtained from local goat farm, rice washing water which was prepared by washing 200 g of rice with 1 liter of water and collected the washing water, and EM-4 commercial starter that was bought from agriculture shop.

2.2. ExSperimental Method

The pretreatment was conducted for tofu liquid waste and rice washing water by filtration process using fiter paper before used in the experiment. The research was initiated by mixing 100 ml of tofu liquid waste, 5 ml of effective microorganism 4 (EM-4) starter [22] 5 ml of goat urine, and various volume of rice washing liquid (0, 15, 30 ml) until homogenuous condition. The mixture was then filled in the bottle and closed tightly. The bottle was placed in the room at the ambient temeperature for fermentation process. Fermentation process was conducted for various time (0, 7 and 14 days). After fermentation completed, the fermentation product was considered as liquid organic fertilizer. The liquid organic fertilizer was analyzed to determine its contents. The research procedure are presented in the Figure 1.

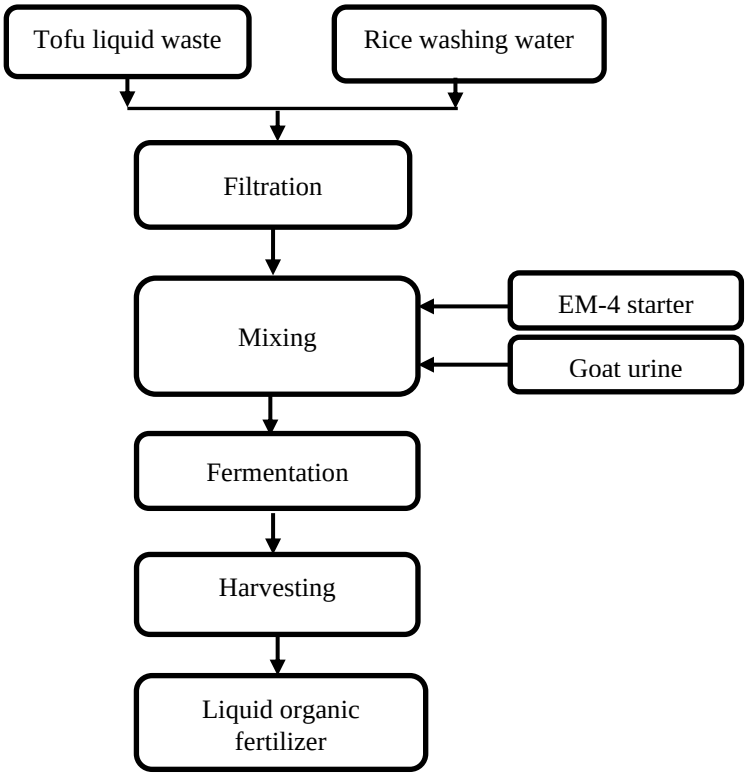

Fig. 1. Research Flow Chart

2.3. Sample analysis

Samples of liquid organic fertilizer was prepared for analysis of charatcteristics and composition. Analysis of BOD, COD and TSS content as well as pH is carried out by measuring the content values using laboratory tests. The 100 ml of the liquid organic fertilizer was taken to analyze the N, P, K content of each fertilizer. Nitrogen levels are determined using a Nitrogen Analyzer, potassium levels are determined using an atomic absorption spectrophotometer (AAS) and phosphorus levels are determined using a UV-Vis spectrophotometer. Liquid organic fertilizer is also checked for acidity levels using a pH meter.

3. Results and Discussion

3.1. Biological Oxygen Demand (BOD)

The biological oxygen demand (BOD) is the amount of oxygen required by microorganisms to oxidize organic compounds in waste. These organic pollutants which are quite high will experience decomposition due to bacterial activity. This activity will use up a certain amount of oxygen. The more organic substances contained in the waste water, the higher the oxygen demand will be, so the dissolved oxygen in the waste water will be lower. The BOD value of liquid organic fertilizer for

various volume of rice washing water (0, 15, and 30 ml) and various fermentation times (0, 7, and 14 days) are depicted in the Figure 2.

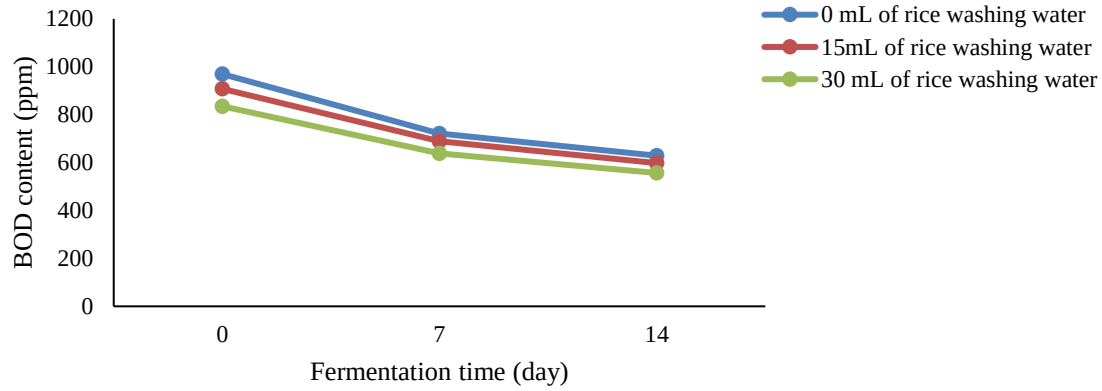

Fig.2. Biological Oxygen Demand (BOD) value at various fermentation conditions

Fig. 2 shows the results of the difference in BOD levels before and after fermentation process. The biggest decrease was in the second treatment, BOD levels fell from 969.549 ppm to 720.843 ppm on the seventh day and on the fourteenth day it was 628.842 ppm for 0 mL washing water parameters. While higher volume of rice washing water added results in the higher BOD level measured. The results showed that BOD levels decreased on the first day of treatment and the following days. This process of decreasing BOD levels is caused by EM-4 bacteria which are in the sediment. The process of reducing BOD levels has begun in equalization due to the deposition of suspended organic substance particles.

3.2. Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) is the amount of oxygen needed in the process of chemically oxidizing/decomposing organic objects. Figure 3 shows that there are differences in COD levels before and after fermentation. The difference in COD levels in the first treatment, where from the first day to the seventh treatment day it decreased. COD levels decreased from 14801.04 ppm to 13183.44 ppm for 0 ml of rice washing water, and the decrease also take place at all variations in volume of rice washing water.

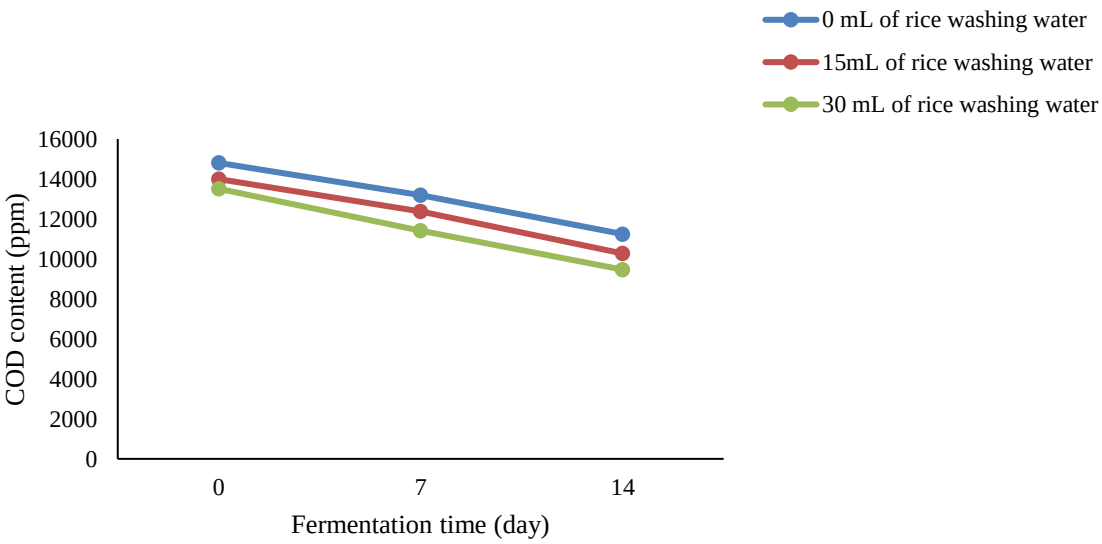

Fig. 3. Chemical Oxygen Demand (COD) value at various fermentation conditions

The decrease in COD levels began to take place from the first day of treatment after the fermentation operated with a constant reduction efficiency. The low reduction is due to ongoing processing by microorganisms, because microorganisms need time to grow. The decline is only influenced by the deposition of organic material in sedimentation.

3.3. Total Suspend Solid (TSS)

Total Suspended Solids (TSS) are the solids that cause air turbidity, not dissolved and cannot settle directly. Solids Suspended consists of particles that are larger in size and weight small portions of sediment, such as cells of microorganisms, clay, etc. Determination of suspended solids (TSS) is useful for determining the strength of domestic wastewater pollution. Liquid waste quality standards are the permitted level limits for polluting substances or materials to be discharged from pollutant sources into water at water sources so that it does not result in exceeding the water quality standards. The TSS of the various conditons are presented in the Figure 4.

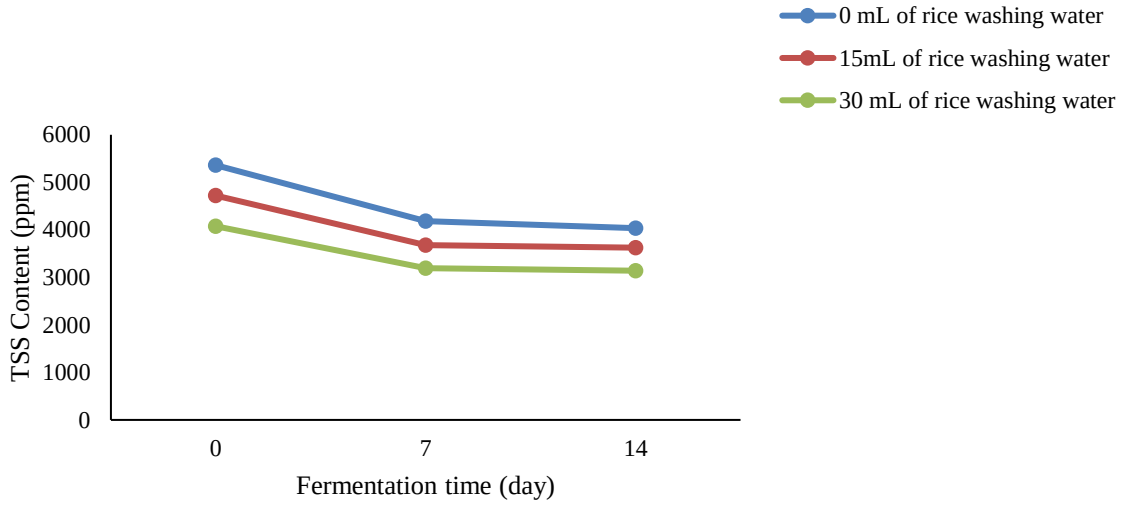

Fig. 4. Total Suspended Solid (TSS) value at various fermentation conditions

Based on the Figure 4, the TSS level examination results show a high average levels of 3140 - 5360 ppm. The value of TSS concentration experiences a decline trend with increasing fermentation time. For sample without rice washing water on day 0, TSS concentration was the highest (5360 ppm, and decreased on day 7 with value of 4185 ppm. The TSS concentration on the day 14 was 4035 ppm. The decrease trend also took place for sample with 15 and 30 ml of rice washing water. The process of decreasing concentration TSS results in reduced efficiency the good one. The efficiency value increases over time increasing

3.4. Determination of N Levels

Organic nitrogen and ammonia nitrogen can be determined using the Kjeldahl method, so that the concentration of both can be further expressed as Total Kjeldahl Nitrogen (TKN). Figure 5 presents the nitrogen level for various conditions.

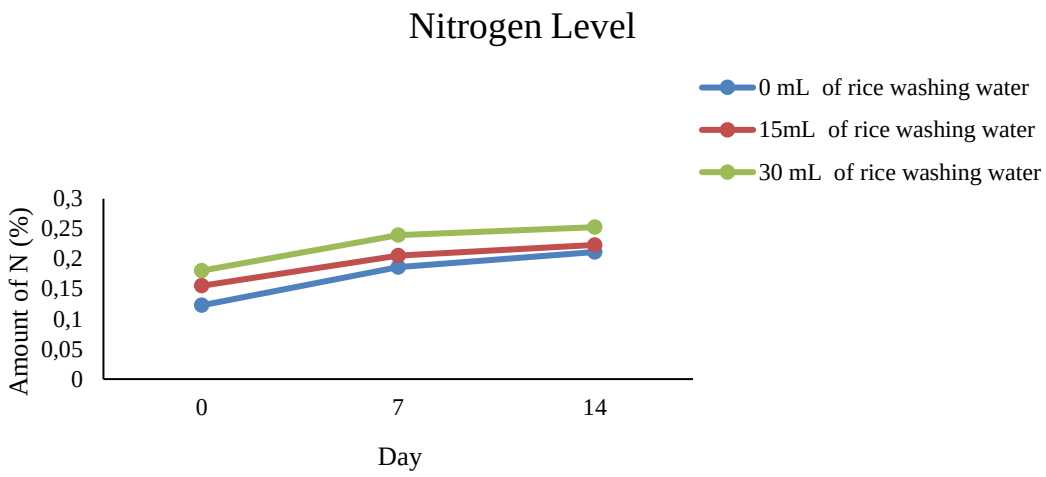

Fig. 5. Nitrogen (N) concentration at various fermentation conditions

From the Figure 5, it can be seen that the fermentation process using EM-4 was able to increase N levels, with the results obtained that sample 1 contained a total N content of 0.1803%, sample 2 contained 0.23945%, sample 3 contained 0.2527%, and the highest N content was found in sample 3, namely the sample fermented with 5 ml of EM-4, for 14 days. namely containing a total N content of 0.2527%, this price is sufficient to meet the standard requirements for liquid organic fertilizer which has a threshold requirement of <2. Rice washing water can enhance the nitrogen (N) content in liquid organic fertilizer.

A higher N ratio will cause the rate of fermentation in liquid fertilizers to decrease. Liquid fertilizer that has a higher N ratio can cause the concentration of nitrogen in the soil is reduced because the activity of soil organisms tend to spend nitrogen for its growth [23]. Nitrogen besides stimulates plant growth, too gives green color to leaves. That the darker green color of the leaves on corn plants, the higher the amount of nitrogen absorbed by plants [24].

3.5. Determination of Phosphor levels

Phosphorus (P) is an essential plant nutrient. There are no other elements that can replace its function in plants, so plants must get or contain enough P for normal growth. Figure 6 shows phosphor (P) level for various conditions of fermentation.

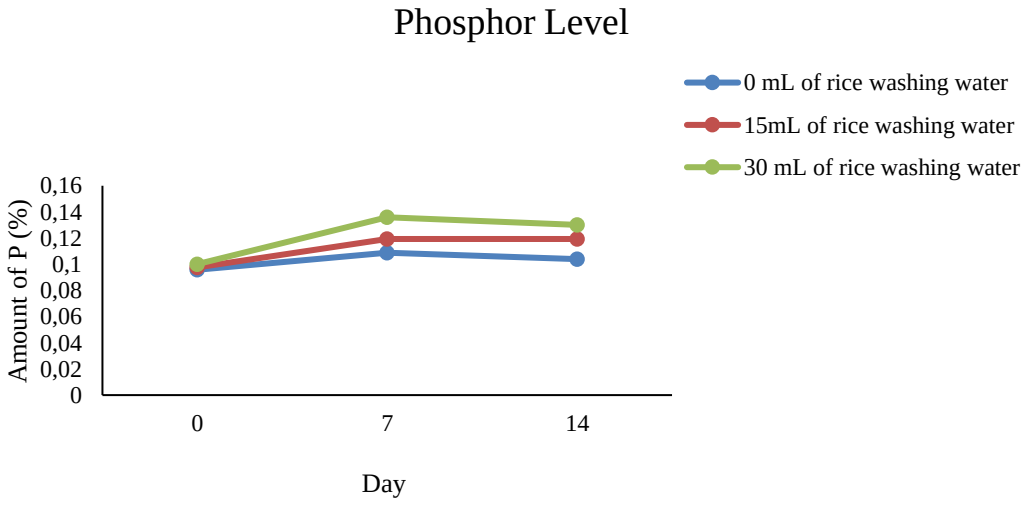

Fig. 6. Phospor (P) concentration at various fermentation conditions

From the Figure 6, showed that sample 1 contained phosphate (P) levels of 0.1001%, sample 2 of 0.1359%, sample 3 of 0,1301%. From the results obtained, it can be concluded that the samples

that experienced the addition of EM-4 experienced an increase in P levels. This shows that EM-4 has sufficient phosphate content for plant needs, which of course does not exceed the standard level of liquid organic fertilizer, which is < 2 %. The increase in P-potential depends on the amount of phosphorus that comes from fertilizer into the soil, the higher the dose of phosphorus, the phosphorus content in the soil will increase. Phosphorus in the soil is present in the form of H_2PO^{4-}, HPO_4^{2-}, and PO_4^{3-}, and in the form of bonds with metal ions such as Fe, Mn ions. Phosphorus is expressed in its oxidative form, P_2O_5, which then reacts to produce phosphoric acid (H_3PO_4). The resulting phosphoric acid reacts with OH^- and forms H_2PO_4 ions. The H_2PO_4 ions will form bonds with metal ions such as Mn and Fe [6].

3.6. Determination of potassium (K) levels in samples

Potassium (K) plays a role in the formation of proteins and carbohydrates, hardening the woody parts of plants, improving the quality of seeds and fruit and increasing plant resistance to pest and disease attacks. Potassium is vital in the process of photosynthesis. If K^+ ion deficiency then the process of photosynthesis will decrease, but the respiration of plants will increase. This causes the process of formation of parts of the plant will be reduced which in the end the formation and production of plants will also be reduced [23]. Figure 7 presents the potassium (K) level for various conditions.

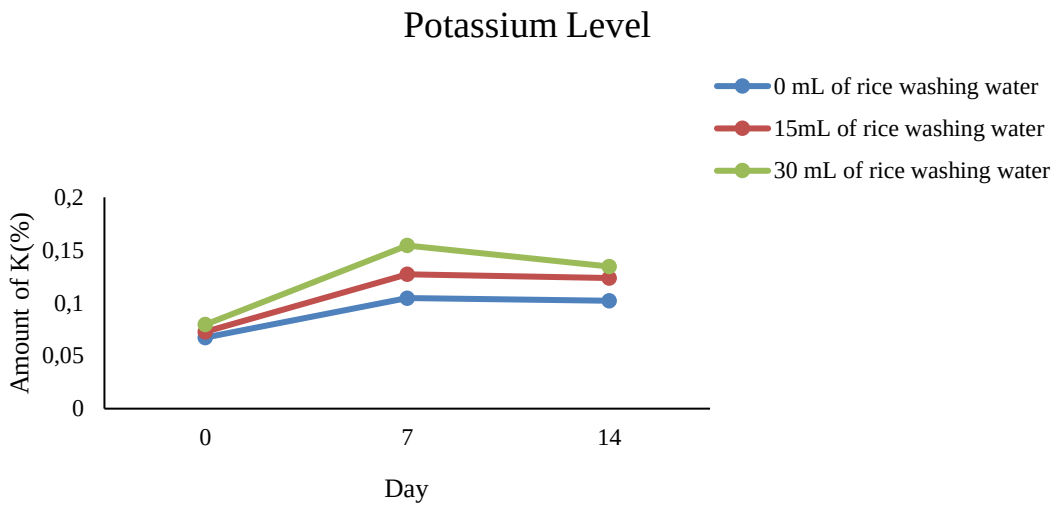

Fig. 7. Potassium (K) concentration at various fermentation conditions

The Figure 7 shows that K content increases with increasing fermentation time (days). The fermentation process with EM-4 can increase potassium (K) levels. and the highest potassium content was found at 14 days of fermentation and 30 ml of rice washing water. Even though this content has reached the standard, namely less than 2% in accordance with the standard provisions for liquid organic fertilizer, the potassium content value should still be maximized to reach a value of < 2%, therefore research needs to be carried out. to increase the K content itself so that the element K content in this liquid fertilizer will be of good quality.

3.7. Determination of pH Values

The pH determination aimed to check quality of liquid organic fertilizer in comparison with standard quality. It determines how this liquid organic fertilizer complies with the standards that have been set. Figure 8 presents the pH level for various conditions.

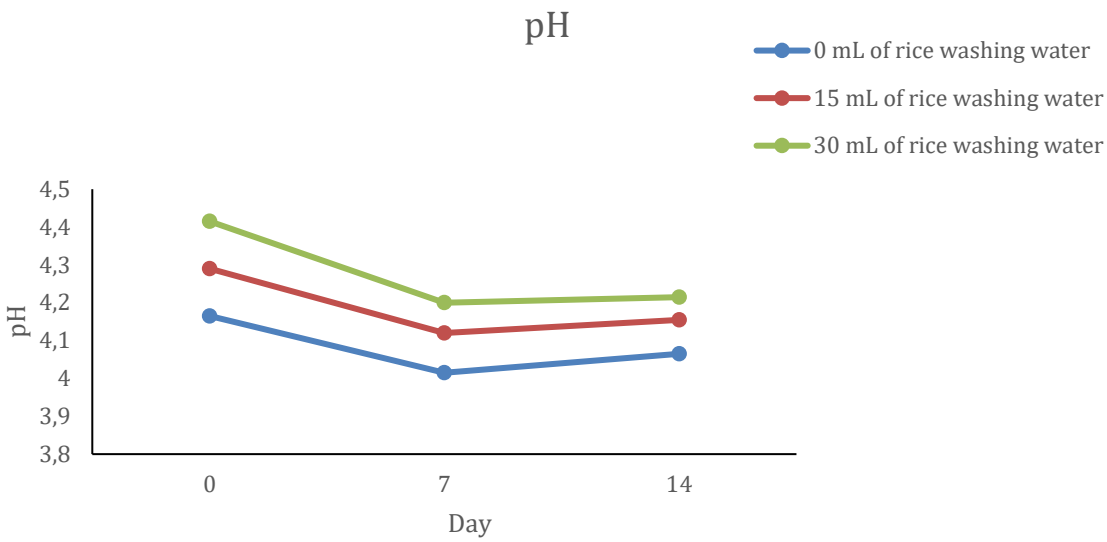

Fig. 8. The pH value at various fermentation conditions

The optimal degree of acidity (pH) of the media environment greatly influences the biological waste processing process, states that microorganisms require a pH between 6.5 - 9. From Figure 8, the pH range during fermentation met the Quality Standards Organic Fertilizer, pH between 4-8 according to The Regulation of Minister of Agriculture, of Indonesia Number 28, 2009 (Permentan/OT.140/2/2009). Increased fertilizer pH is caused by the activity of microorganisms in decomposers which provides input of OH ions from the decomposition process fertilizer material, thereby supporting the increase in alkalinity which in turn increases the organic pH value [19].

4. Conclusion

Tofu liquid waste can be used as raw material for producing liquid organic fertilizer with additional material i.e. goat urine and rice washing water using the fermentation method with EM-4 activator. The optimal volume comparison was found in sample with 15 ml of rice washing water, 5 ml of urine goat and 5 ml of EM-4. The nutrient content are N of 0.2542%, P of 0.1302%, and K of 0.1360%. The largest pH content obtained in liquid organic fertilizer is pH 4.415. The fermentation time and volume of EM-4 bioactivator, rice washing water and goat urine greatly influence the levels of macro nutrients (N, P, K).

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