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Utilization of Tofu Liquid Waste as Liquid Organic Fertilizer Using the Fermentation Method with Activator Effective Microorganisms 4 (EM-4): A Review

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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 residues. The nutrients contained are in the form of a very fine solution so that they are 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. Liquid fertilizer is obtained from a solid fermentation process first, then followed by a liquid anaerobic fermentation and extraction process. In the fermentation process, the role of microbes greatly determines the product produced. Tofu liquid waste is resulted from cooking residue of boiled soybeans and the water from the remaining tofu tends to be thrown into the surrounding environment. Tofu liquid waste contains organic ingredients, namely carbohydrates reaching 20-50%, protein 40-60%, and 10% fat. It is known that this tofu waste can be used as liquid organic fertilizer by fermentation. Tofu liquid waste contains organic substances, namely carbohydrates, proteins and fats, which can be used as liquid organic fertilizer. These substances must first be decomposed into simpler elements by a fermentation process so that they can be absorbed by plants. Effective Microorganisms-4 as inoculants to increase microbial diversity in soil and can control unpleasant odors, accelerate the decomposition process, maximize the decomposition process, increase nutrient content, reduce the growth of pathogenic microorganisms, improve the physical, chemical and biological structure of the soil and bioremediation.

1. INTRODUCTION

The tofu industry is one of the food industries that produce the source of protein with basic ingredients from soybeans. The tofu industry is very popular in Indonesian society. Industries grow rapidly in line with the increase in population. On the other hand, this industry produces liquid waste that has the potential to pollute the environment [1]. Tofu industries produce solid and liquid organic waste [2]. Industrial development has grown rapidly, especially the home industries that directly support public daily life. Most home industries do not pay attention to regulations of factory locations based on the business sectors and also on waste disposal systems [3].

The tofu industry produces tofu liquid waste. When the tofu liquid waste treatment is not carried out and tofu liquid waste is directly discharged into a river, it will affect the physical and chemical properties of the water. It finally affects the aquatic life. Most micro businesses are unaware of the environmental impacts of liquid waste disposal due to a lack of knowledge on the tofu liquid waste treatment and its impact on the environment [4]. To deal with tofu liquid waste, the tofu liquid waste can be processed to produce an organic liquid fertilizer. Tofu liquid waste has a large potential to produce liquid fertilizer. The tofu liquid waste contains the nutrients needed by plants [5].

Organic fertilizers contain the macronutrients, N, P, and K that are very necessary for the growth of plants. The organic fertilizer does not aim to replace the role of chemical fertilizers but as a complementary to chemical fertilizers. The combination of organic fertilizer and chemical fertilizer will be more optimal and more efficient to be used together. Organic fertilizer can reduce the negative impact of chemical fertilizers and improve the physical, biological, and chemical properties of soil simultaneously [6]. Table 1 presents the standard liquid organic fertilizer.

Table 1. Standard liquid organic fertilizer [7]

Parameter	Unit	Technical Requirements	Information
C-Organic	%	> 4	C Organic content
N, P, K	%	< 2	If > 2% is suspected to contain inorganic chemicals
Pathogen Microbe	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

The harmful effects of organic wastes originating from plant residues, agro-industrial waste, animal waste, and humans can be avoided by converting organic wastes to liquid organic fertilizer. Liquid organic fertilizer can be made from liquid organic materials or liquid organic waste, by composting it and adding a composting activator. Liquid organic fertilizer has the advantage of being environmentally friendly, and not damaging soil and plants. Utilization of organic waste as fertilizer can help improve the structure and quality of soil because it contains nutrients (NPK)[8]. Organic liquid fertilizer is able to loosen the surface layer of soil (topsoil), increasing the population of microorganisms, and increasing the absorption and storage capacity of water, which therefore soil fertility increases. The use of organic fertilizer provides the benefit of increasing the availability of the main anions for growth plants such as nitrates, phosphates, sulfates, borates, and chlorides, increasing the availability of micronutrients for plant needs, and improving physical properties, chemistry, and soil biology [9].

Tofu industries produce much liquid waste that can contaminate the environment. On the other hand, tofu liquid waste contains nutrients that are needed by plants for growing up. However, the tofu liquid waste cannot be applied directly as fertilizer. Tofu liquid waste needs to be processed to convert to a liquid organic fertilizer. Many aspects of tofu liquid waste need to be explored to convert it to liquid organic fertilizer and its applications. This paper studies the characteristics of tofu liquid waste, its conversion to liquid organic fertilizer, and its application to plants.

2. TOFU LIQUID WASTE

The tofu industry produces liquid waste and when it is discharged into water, it will affect the physical and chemical properties of the water. It also has an effect on aquatic life. Tofu liquid waste is a by-product of the tofu-making process in the form of tofu liquid waste. The resulting tofu liquid waste still contains a lot of organic substances, such as proteins, carbohydrates, fats and dissolved substances containing suspended solids. The largest amounts of organic substances are protein, carbohydrate, and fat with a percentage of 40-60% protein, 20-50% carbohydrates and 10% fat. The presence of high levels of organic material causes microbes to become active and biologically decompose the organic material into organic acid compounds [4].

Industrial waste has two main characteristics, namely physical and chemical characteristics. Physical characteristics comprise total solids, suspended solids, temperature, color, and odor. Chemical characteristics comprise organic materials, inorganic materials, and gases. The exhaust temperature of the tofu industry comes from the soybean cooking process. The temperature of tofu liquid waste is generally higher than the ambient temperature of water about 40-46 °C. Rising temperatures in the aquatic environment will affect biological life, the solubility of oxygen and other gases, air density, viscosity and surface tension.

The effort to reuse tofu liquid water has been carried out, for example for agricultural activities. The existence of several elements in tofu industrial liquid waste such as N, P and K in certain amounts are required by plants for their growth, but if the amount is excessive, it will have a negative impact. The right concentration of tofu liquid waste can be used as liquid fertilizer for land and plants, where the concentration of tofu wastewater is 15% providing the most optimal results. Tofu liquid waste has a high organic content. Proteins in liquid waste, if it is decomposed by soil microbes, will release N compounds which will ultimately be absorbed by plant roots. The tofu liquid waste has the potential to be used as organic fertilizer. Utilization of various waste for organic fertilizer is one effort to overcome the environmental pollution problem, with its high organic matter, waste can act as an organic source of food by microbial growth [10].

The production of tofu comprises several steps of the process. Tofu liquid waste results from almost every step of the process. The detailed sources of tofu liquid waste are presented in Table 2.

Table 2. Tofu Industry Liquid Waste 100 Kg of Soybean Raw Material[10]

Process	Clean water consumption (Liters)	Liquid waste generated (Liters)	Information
Enduring	250	200	The nature of waste is not hazardous
Washing	400	400	-
Milling	400	300	-
Boiling	200	0	-
Screening 1	200	100	High-temperature waste
Clumping	-	100	-
Screening 2	-	100	The nature of waste is polluting
Cutting	-	0	-
Total	1,450	1,200	

Tofu liquid waste is the remaining water from the clumping of tofu that is produced during the tofu production. The residue like uncoagulated proteins and other water-soluble substances will be present in the tofu liquid waste. The organic materials contents in the tofu liquid waste are generally very high. The organic compounds in the liquid waste can be proteins, carbohydrates, fats and oils. Among these compounds, protein and fat are the largest in quantity. Protein reaches 40-60%, carbohydrates 25-50% and fat 10%. The higher quantity and the more types of organic materials in the liquid waste, it will be more difficult to treat. Some substances in the tofu liquid waste are difficult to break down by microorganisms. The largest component of tofu liquid waste is protein (total N) about 226.06 - 434.78 mg/l, so the dumping of tofu liquid waste into the environment like into the river will increase the total nitrogen. The gases commonly found in tofu waste are nitrogen (N), oxygen (O_2), hydrogen sulfide (H_2S), ammonia (NH_3), carbon dioxide (CO_2), and methane (CH_4). These gases come from the decomposition of organic materials contained in wastewater [11].

2.1 Characteristics of Tofu Liquid Waste

In general, the characteristics of liquid waste can be classified into physical, chemical and biological properties. However, commonly industrial liquid waste parameters only consist of physical and chemical characteristics. The parameters used to indicate the character of tofu industrial liquid waste are physical parameters such as turbidity, temperature, solids, odor and others, and chemical parameters that are divided into organic chemistry and inorganic chemistry [12].

Nitrogen

Tofu liquid waste contains proteins as a source of nitrogen (N). Nitrogen is the main supporting nutrient element vegetative growth of plants. This element plays a role in the formation of cells and tissues in plants, such as roots, stems, leaves and the beginning of flower formation. In the presence of nitrogen, the leaves will run function well in the process of photosynthesis. The results of perfect photosynthesis will affect leaf growth, a greater number of leaves, strands wide and looks shiny. In flowers, the result of photosynthesis the perfect one makes it bloom perfectly and brighter in color [13].

Phosphorus

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 phosphorus for normal growth. The important functions of phosphorus in plants are in the processes of photosynthesis, respiration, energy transfer and storage, cell division and concentration, and other processes in plants. Potassium plays a role in facilitating all processes that occur inside the plant. Phosphorus is needed by plants for growth vegetative, such as root formation (especially plants young), formation of cell nuclei and cell division, stimulates flowering, and seed formation, as well Strengthens plant resistance to attack disease. Root growth is also greatly influenced by adequate availability of phosphorus. Number of roots Many plants can absorb water together with more nutrients. Phosphorus is very influential in the flowering process and fruit and seed production. Phosphorus is one of the essential elements found in the tofu liquid waste [13].

Potassium

Tofu liquid waste contains potassium (K) in a certain amount. Potassium is the second most abundant element after nitrogen in plants. The levels are 4-6 times higher than P, Ca, Mg and S. Potassium is absorbed in the form of monovalent potassium cations and no potassium transformation occurs in plants. The main form in plants is the monovalent K cation. This action is unique to plant cells. Element Potassium is very abundant and has a low hydration energy so it does not cause polarization of water molecules. So, this element minimally interferes with the solvent phase of the chloroplast. Potassium deficiency can inhibit plant growth, the leaves appear curly and shiny. It can also cause weak leaf stalks so they droop easily and the seed coat wrinkles. Potassium will strengthen tissue so that leaves, flowers, and fruit do not easily fall out. Potassium also has a profound effect on protein formation and cell division. The role of potassium can be seen in the vegetative growth of plants, such as stem stiffness, leaf color, number of shoots, and lots of roots [11].

Acidity (pH)

The acidity needs to be maintained to adjust to optimum conditions of microbial growth. Optimum fermentation takes place at pH 5.5-8. Very good condition acid at the beginning of the fermentation process, as a result of the activity of acid-producing microbes. Along with the growth of other microbes, as the material decomposes, the pH of the material will rise [14].

Tofu liquid waste has characteristics that are appropriate for raw materials of liquid organic fertilizer. Based on chemical characteristics, they show the rich nutrients that are needed by plants. Many other sources also have similar content of nutrients that can be utilized as the raw material of liquid organic fertilizer. They have similar nutrient content with tofu liquid waste. Table 3 presents various wastes that are possible to be the source of nutrients for liquid organic fertilizer.

Table 3. Alternative nutrients source of the main ingredients for producing liquid organic fertilizer

Source of nutrients	Nutrient content	Reference
Cow feces	N: 0.53-0.65%; P: 0.15-0.35%, K: 0.3-0.41% K	[15]
Goat feces	N:1.28%; P: 0.9%; K: 0.93, Ca: 0.59%; Mg: 0.19%	[15]
Goat urine	N: 1.7%; P: 0.003%; K: 1.45%, Ca: 0.014%; Mg: 0.04%	[16]
Sheep urine	N: 2.2%; P: 0.005%; K: 2.4%; Ca: 0.009%; Mg: 0,08%	[16]
Bat feces	N: 7-17%; P: 8-15%; K: 1.5-2.5%	[17]
Sugar industrial wastewater	Sugar:13.59 g/l; proteins: 1.24 g/l; N total: 753.5 mg/l; P total: 103.5 mg/l	[18]
Tempe industrial wastewater	N: 0.05%; P: 0.048%; K: 0.02%	[17]
Tapioca industrial wastewater	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	[19]
Cowpen wastewater	C organic: 34%; N total: 0.23%; P total: 0.13%; C/N: 14,5	[20]
Pigpen wastewater	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	[21]
Pigpen wastewater	N: 1.65%; P: 0.18%; K: 0.27%	[22]

2.2 Tofu Industrial Wastewater Parameters

Tofu wastewater has an unpleasant odor. One of the efforts that will be taken is to add other organic materials to reduce the odor produced by liquid organic fertilizer made from tofu liquid waste [23]. Tofu industry liquid waste is a source of environmental pollution. The resulting pollution load causes serious disruption, especially for waters around the tofu industry. Considering that the origins of liquid waste from the process are different, their characteristics are also different. For liquid waste that comes from washing and soaking the contamination value is not so high so can still be thrown directly into the river. Meanwhile, for liquid waste originating from the cooking process, the contamination value is quite high, so it must be processed first before being thrown into the water. When liquid waste from industrial activities is not treated first, it can disrupt the life of aquatic biota [4].

In general, the tofu factory's liquid waste is directly discharged into the river via channels. If the debit of the river is high enough and the dilution is sufficient, then the waste water does not cause problems. But if the environmental supporting capacity is exceeded, then there will be a lot of liquid wastes containing organic materials that will undergo a decomposition process by microorganisms that can pollute the environment. Tofu

liquid waste parameters that are usually measured are temperature, pH, total suspended solids (TSS), and biological oxygen demand (BOD and chemical oxygen demand COD) [24].

Temperature

Temperature tofu industrial liquid waste tends to be acidic, in this acidic condition substances will be released that are easy to evaporate. This causes the liquid waste from the tofu industry to emit a foul smell. pH is very influential in the wastewater treatment process. The fermentation process will not be separated from the influence of temperature and pH. The optimum temperature for fermentation is around 30 – 50 ^{o}C [12].

Total Suspended Solid

Total suspended solid (TSS) is used to determine liquid waste concentration, process efficiency, and process unit load. Measurement varying the residue concentration is necessary to ensure stability control process. TSS or suspended solids, namely materials that float and do not dissolve in the air. Suspended solids are very closely related to the level of air turbidity. Turbidity describes the determined optical properties of air based on the amount of light absorbed and emitted by the ingredients contained therein air. Turbidity is caused by the presence of materials suspended and dissolved organic and inorganic substances, or suspended solids, namely materials that float and do not dissolve in the air. Suspended solids are very closely related to the level of air turbidity. Turbidity describes the determined optical properties of air based on the amount of light absorbed and emitted by the ingredients contained therein air. Turbidity is caused by the presence of materials suspended and dissolved organic and inorganic substances. The higher the suspended material content, the water becomes increasingly cloudy [2].

Biological Oxygen Demand

Biological oxygen demand (BOD) is a parameter used to assess the amount of dissolved organic substances and shows the amount of oxygen required by microbial activity to decompose organic substances biologically in tofu industrial liquid waste containing high levels of dissolved organic substances. BOD is the parameter used to assess the amount of dissolved organic substances as well as shows the amount of oxygen required by microbial activity in decomposing organic substances biologically in liquid waste. Tofu industrial liquid waste contains high levels of dissolved organic matter [2].

Chemical Oxygen Demand

Chemical oxygen demand (COD) is the amount of oxygen needed so that waste materials in water can be oxidized through chemical reactions. If the content of organic and inorganic compounds is large enough, the dissolved oxygen in the water can reach zero so that aquatic plants, fish, and other aquatic animals that need oxygen cannot live. The COD or chemical oxygen requirement is a certain amount of oxygen necessary for the waste material contained within water that can be oxidized through chemical reactions. If it contains organic compounds and inorganics are large enough, then the dissolved oxygen in water can reach zero so that aquatic plants, fish, and other aquatic animals that need oxygen do not allow life [2].

3. FERMENTATION PROCESS

Fermentation is a process of chemical changes in organic substrates through the activity of enzymes produced by microorganisms. The fermentation process requires a starter as a microbe that will be grown in the substrate. A starter is a microbial population in physiological numbers and conditions that is ready to be inoculated into the fermentation medium. The utilization of fermented vegetable waste in the form of organic acids can be used as a biological preservative or as a fermentation starter. Fermentation is the process of breaking down organic compounds into simple compounds involving microorganisms. Fermentation is all kinds of metabolic processes (enzymes, microorganisms via oxidation, reduction, hydrolysis, or other chemical reactions) that carry out chemical changes in an organic substrate to produce a final product [25].

The fermentation process that occurs in organic waste will convert organic N into nitrate compounds so that it can be absorbed by plants. Reactions that occur in the fermentation process to obtain nitrogen nutrients

$$\text{Energy Protein} + E \rightarrow ATP + NADP + NH_3 + \text{Energy} \quad (1)$$

$$NH_3 + 3O_2 \rightarrow 2HNO_2 + 2H_2O + \text{Energy} \quad (2)$$

The reaction forms the element NO_3^- which will still be absorbed by plants

$$2HNO_2 + O_2 \rightarrow 2HNO_3 + 2H_2O + \text{Energy} \quad (3)$$

Meanwhile, to obtain phosphate, the phosphate-solubilizing bacteria (pseudomonas sp.) utilizes adenosine triphosphate (ATP) which was previously formed at the beginning of the fermentation process

$$\text{ATP + Glucose} \rightarrow \text{ADP + Glucose 6 – Phosphate} \quad (4)$$

$$\text{Glucose 6 – Phosphate + } H_2O \rightarrow \text{Glucose + Phosphate} \quad (5)$$

The principle of this fermentation is that organic waste material is destroyed by microbes in a certain temperature range and conditions, namely fermentation. There are two types of bacteria involved, namely facultative bacteria which convert cellulose into glucose during the initial decomposition process, and obligate bacteria which respond in the final decomposition process of organic materials which produce very useful materials and alternative rural energy. The fermentation process of microorganisms grows and develops actively and changes the fermented material into the desired product, to increase the effectiveness of the fermentation process, several factors must be considered, including fermentation temperature, initial pH of fermentation, inoculum, substrate, and the nutrient content of the medium [12].

4. TOFU INDUSTRIAL LIQUID WASTE PROCESSING

The tofu liquid waste comes from soybean cooking locations, soybean washing, process, equipment washing, and floors. The characteristics of the liquid waste produced are in the form of suspended solid organic materials (skin, mucous membranes, and other organic materials). The cloudy white color of liquid waste comes from the disposal of soaking water and peeling of soybean skins which still contain a lot of starch, and also comes from water used to wash process equipment, kitchen equipment, and other equipment. Odors arise due to the activity of microorganisms that decompose organic substances or from chemical reactions that occur and produce certain gases [26]. Fig. 1 presents the integrated concept for tofu liquid waste treatment

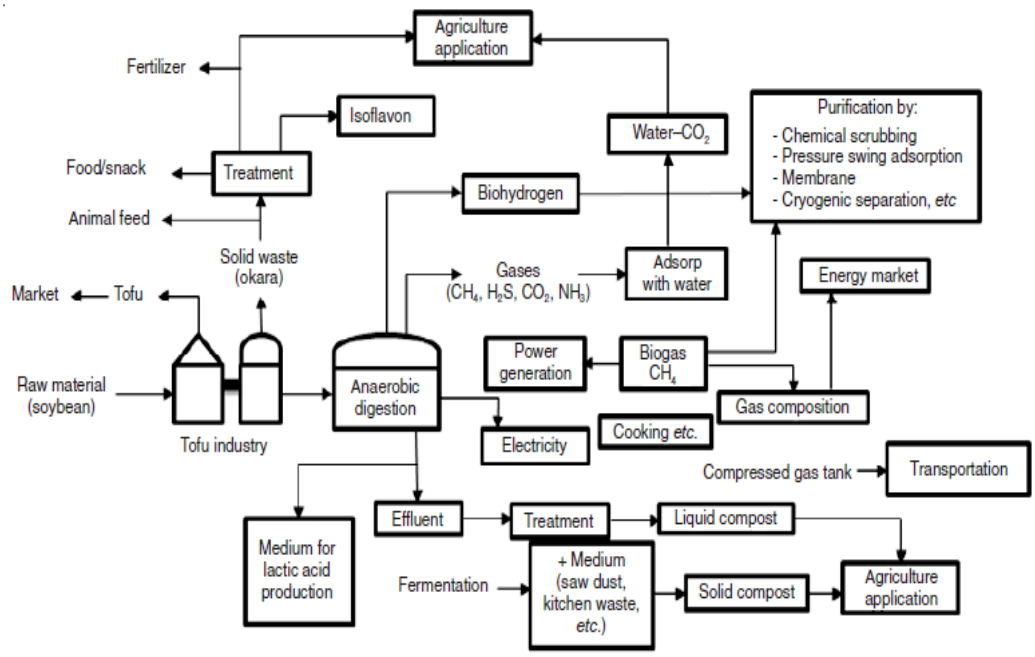

Figure. 1. Integrated concept for tofu liquid waste treatment in the tofu industry

The selection of a liquid waste treatment system is based on the nature and character of the water tofu waste itself. The nature and characteristics of liquid waste are determined in this matter when selecting a wastewater treatment system, especially on wastewater quality including the parameters pH, COD (Chemical Oxygen Demand), BOD (Biological Oxygen Demand), and TSS (Total Suspended Solid). Looking at the characteristics of tofu liquid waste above, this is a sufficient alternative The appropriate method to treat waste water is with a biological process. This method is relatively simple and has no serious side effects. For the characteristics of industrial waste, you know Two things that need to be considered are characteristics of physics and chemistry. Physical characteristics include total solids, temperature, color, and odor. Characteristic Chemicals include

organic materials, inorganic materials, and gas. The organic ingredients contained in tofu industry waste in general are very high. Organic compounds in water These wastes can be protein, carbohydrates, fats, and oils [2].

4.1 Anaerobic Liquid Waste Processing

Anaerobic processes are essentially processes that occur due to the activity of microbes that occur when there is no free oxygen. Anaerobic processes can be used to process various types of biodegradable waste, including the food industries liquid wastes. The anaerobic biological process is one of tofu liquid waste treatment systems that has widely applied. The considerations are easy, cheap, and has good results. Anaerobic biological processes are one of the liquid waste treatment systems by utilize microorganisms that work in anaerobic conditions. Gathering Microorganisms, generally bacteria, are involved in the transformation of complex compounds organic to methane. Moreover, there is a synergistic interaction between various things a group of bacteria that play a role in the decomposition of waste. A group of non-methanogenic bacteria that are responsible for the hydrolysis process and fermentation consists of facultative and obligate anaerobic bacteria. Microorganisms that isolated from anaerobic digesters were *Clostridium spp., Peptococcus anaerobus, Bifidobacterium spp., Desulphovibrio spp., Corynebacterium spp., Lactobacillus, Actonomyces, Staphylococcus, and Escherichia coli* [27]. The roles of metabolic bacteria in an anaerobic system are presented in Fig. 2.

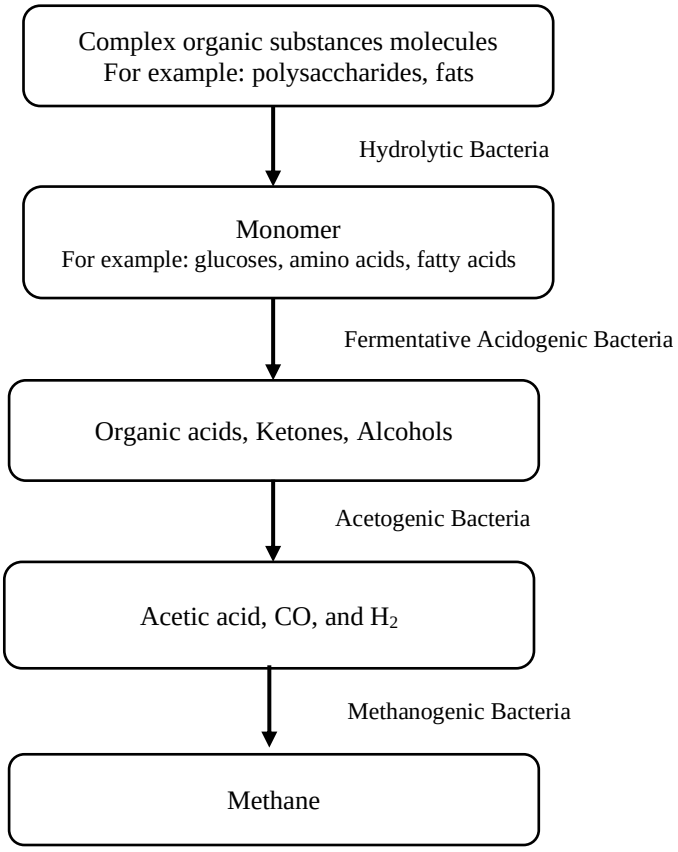

Figure. 2. Metabolic Bacteria in Anaerobic Systems [28]

There are three basic stages included in the overall waste processing by anaerobic oxidation, namely: hydrolysis, acidogenesis, and methanogenesis [11]. Every stage has a unique role in waste processing. Final product of fermentation is mostly methane compound.

Hydrolysis

During the hydrolysis process, fermentation bacteria change complex organic matter insoluble molecules, such as cellulose, into soluble molecules, such as fatty acids, amino acids, and sugars. Complex polymer materials are hydrolyzed to become monomers, for example: cellulose becomes sugar or alcohol. Molecules This monomer can be directly utilized by the next group of bacteria. Hydrolysis of complex molecules is catalyzed by extracellular

enzymes such as cellulase, protease, and lipase. However, the anaerobic decomposition process is very slow and is limited in the decomposition of cellulolytic waste containing lignin.

Acidogenesis

In the fermentation process (acidogenesis), acidogenic (acid-forming) bacteria convert sugars, amino acids, and fatty acids into organic acids (acetic acid, propionate, butyrate, lactate, formate) alcohols and ketones (ethanol, methanol, glycerol, and acetone), acetate, CO_2 and H_2. The main product of this fermentation process is acetate. The results of this fermentation vary depending on the type of bacteria and culture conditions such as pH and temperature.

Methanogenesis

The methanogenesis process is carried out by a group of microorganisms known as methanogenic bacteria. There are two groups of methanogenic bacteria involved in the methane production process. The first group, acetic acid methanogens, splits acetate into methane and carbon dioxide. The second group, hydrogen utilizes methanogens, namely using hydrogen as an electron donor and CO_2 as an electron acceptor to produce methane. Bacteria in the process anaerobic, namely acetogenic bacteria, are also able to use CO_2 to oxidize and acetic acid form. Where acetic acid is converted to methane. About 72% of the methane produced in anaerobic digesters is formed from acetate.

4.2 Aerobic System Liquid Waste Processing

The aerobic biological processes are processes that continue to degrade the remaining organic compound content of wastewater after the anaerobic process. Aerobic handling systems are used as a deterrent to the emergence of odor problems during waste handling, to meet waste requirements, and to stabilize waste before it is channeled to receiving bodies. Aerobic waste processing is a process where there is dissolved oxygen. Oxidation of organic materials uses oxygen molecules as an electron acceptor The final process is the main process that produces chemical energy for microorganisms in this process. Microbes that use oxygen as the final electron acceptor are aerobic microorganisms. Waste processing using an aerobic system which is widely used by other people activated sludge system, rotating biological plate (Rotating Biological Contactor -RBC), and oxidation ditch (Oxidation Ditch) [27].

4.3 Anaerobic-Aerobic Combination System Waste Processing

In general, the combinations of processes are divided into two stages. The first stage is the anaerobic digestion process. The second stage is the further process: anaerobic-aerobic biofilter system [11].

Anaerobic digestion

Waste resulting from the tofu production process is collected through the waste channel and then channeled to the control tank for separate solid waste. Next, the waste flows into an anaerobic digestion tank. In the anaerobic digestion tank, there are organic pollutants in the waste will be broken down by microorganisms anaerobically, producing hydrogen gas sulfide and methane which can be used as fuel. At the process stage Firstly, the efficiency of reducing COD values in waste can reach 80-90%. Water This initial stage of processing is then processed with further processing using the system anaerobic-aerobic combination using a biofilter.

Advanced processing

The waste processing process with a biofilter process anaerobic-aerobic consists of several parts, namely the initial settling tank, biofilter anaerobic, aerobic biofilter, final settling tank, and if necessary equipped with tank chlorination. Waste originating from the anaerobic decomposition process (processing stage first) flowed into the initial settling tank, to settle mud and sand particles and other impurities. Apart from being a settling tank, it also functions as a tank flow controller, as well as a tank for decomposing organic compounds in solid form, a sludge decomposer, and a sludge collector.

5. EFFECTIVE MICROORGANISM-4

Effective microorganism-4 (EM-4) solution is a mixed culture containing fermentation microorganisms that have been selected and are very numerous, around 80 genera. There are five main groups contained in EM-4, namely photosynthetic bacteria (Rhodopseudomonas sp), lactic acid bacteria (lactobacillus sp), Streptomyces sp., yeast, Actinomycetes sp. In EM-4, some microorganisms work effectively to add nutrients if the organic materials

contet is sufficient. These organic materials are food ingredients that contain nitrogen (N), phosphorus (P), and potassium (K) which will be decomposed by the microbes in EM-4. Each species of microorganism has its specific role. Photosynthetic bacteria are the most important implementers of EM-4 activities because they support the activities of other microorganisms and physiological conditions that are ready to be inoculated in fermentation media [6]. The EM-4 is a material that helps speed up the process of making fertilizer organic and improve its quality. The EM-4 is also useful in improving the structure. The soil texture becomes better and provides nutrients that plants need. Thus the use of EM-4 will make plants more fertile, healthy, and relatively resistant to pest and disease attacks [29]. The roles of EM-4 on the growth of plants are presented in Fig. 3.

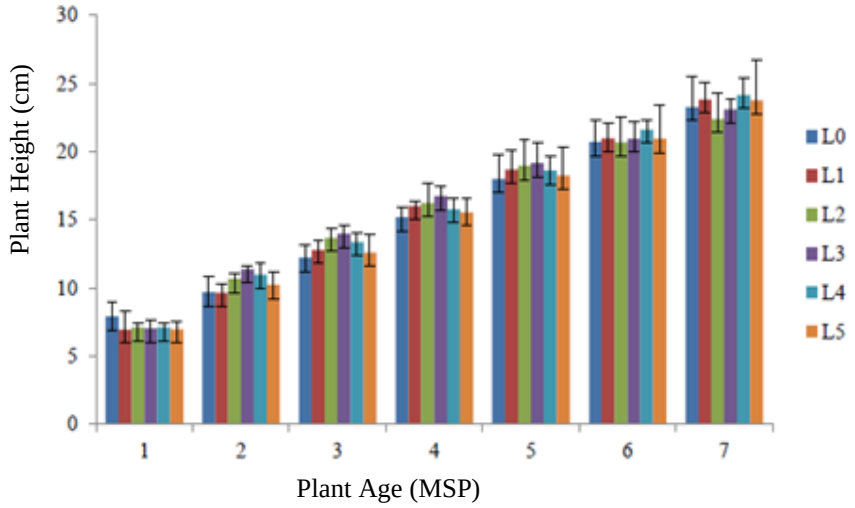

Fig. 3. Effect of incubation time for tofu liquid waste with EM-4 on plant height

The EM-4 is a mixed culture of beneficial natural microorganisms, which can be applied as an inoculant to increase microbial diversity in soil. The content of EM-4 consists of aerobic and anaerobic microorganisms consisting of five families, 10 genera and more than 80 species including lactic acid bacteria which function to produce lactic acid and degrade lignin and cellulose (*Lactobacillus plantarum, Lactobacillus casei and Streptococcus lactis*); photosynthetic bacteria function to degrade chemical compounds (waste), synthesize nucleic acids, amino acids, sugars, antioxidants, and bioactive compounds as well as carbon dioxide and nitrogen fixation (*Rhodopseudomonas palustris* and *Rhodobacter sphaeroides*); yeast that has function to decompose organic compounds aerobically and anaerobically (Saccharomyces cerevisiae and Candida utilis); actinomycetes that has function to degrade organic phosphorus compounds and have antimicrobial activity in soil (*Streptomyces albus subsp. albus and Streptomyces griseus*); fungi that has function to decompose organic compounds into alcohols, esters, and antimicrobial compounds (*Aspergillus oryzae* and *Mucor hiemalis*) and other microorganisms that mixed at a pH below 3.5 [30].

The effectiveness of EM-4 does not come from microorganisms' own functions, but rather their combination and synergy when used together. The EM-4 plays a role in helping speed up the process of making organic fertilizer. The content of microorganisms has a good influence on the quality of fertilizer. The benefits of EM-4 include controlling unpleasant odors, accelerating the decomposition process, maximizing the decomposition process, increasing nutrient content, reducing the growth of pathogenic microorganisms, and improving the physical, chemical, and biological structure of soil and bioremediation [30].

6. LIQUID ORGANIC FERTILIZER FROM TOFU LIQUID WASTE

Liquid waste from tofu industries can be processed using many technologies as presented in the previous section. However, they do not offer good economic impacts. Processing of tofu liquid waste as liquid organic fertilizer gives an additional value. Fabrication of liquid organic fertilizer from tofu liquid waste usually needs additional ingredients that are mostly derived from plants [25]. Tofu liquid waste is appropriate to be the raw material of liquid organic fertilizer due to its contents i.e., proteins, fats, carbohydrates, phosphorus, and potassium as discussed previously. Table 4 presents the various types of plants as alternative sources for enriching nutrients

of liquid organic fertilizer. Many types of plants contain nutrients that are essential for enriching the contents of liquid organic fertilizer.

Table 4. Alternative sources for enriching liquid organic fertilizer nutrients

Source of nutrients	N	P	K	Ca	Mg	Reference
Peanut plant residue	4.59	0.25	2.03	1.24	0.37	[15]
Soybean plant residue	5.55	0.34	2.41	0.88	0.37	[15]
Potato pant residue	3.25	0.2	7.5	0.43	0.2	[15]
Sweet potato plant residue	3.76	0.38	4.01	0.78	0.68	[15]
Arachis pintoi	1.7	0.3	2.8	2.2	0.4	[15]
Calopogonium caeruleum	2.9	0.2	2.7	1.9	0.3	[15]
Flemingia	2.9-3.0	0.2-0.4	0.5-1.3	1.6	0.41	[15]
Gliricidia	2.4-3.7	0.2	0.9-2.2	1.9-3.2	0.5-08	[15]
Lamtoro gung (Leucaena leucocephala subsp. Glabrata)	2.6-4.1	0.1-0.2	0.5-0.6	0.91.8	0.4-0.5	[15]
Calliandra	2.6-4.1	0.1-0.2	0.5-0.6	0.9-1.8	0.4-0.5	[15]
Tithonia	2.5-3.5	0.25-0.38	2.5-4.1	0.25	0	[31]
Kirinyuh (Chromolaena odorata)	1.8-2.9	0.13-0.50	1.01-2.60	0	0	[32]
Badotan	(24.5)	0.38	0.139	0.22	0.11	[33]
Asystasia gangetica	(15.5-25)	1.1-1.7	0	1.8-2.0	0.68-0.85	[34]
Sugarcane leaves	1.12	0.08	2.45	0	0	[35]
Cocoa pod shell	0.91	0.2	3.18	0.67	0.29	[36]
Coffee skin pulp	1.91	0.28	3.61	0	0	[36]
Coffee husk as	0	1.03	5.29	0.76	0.38	[36]
Rice Straw Ash	0.6	0.09	1.08	0	0	[37]
Rice husk ash	0	0.32-0.46	1.15-1.50	0.35-0.71	0.12-0.30	[37]
Coir ash	0	0.27	19.85	27.93	0	[38]
Wood ash	0	0.3-1.4	3-4%	7-33%	1-2%	[39]
Palm empty bunch ash	0	4%	30%	5%	6%	[40]

Many additional material combinations in producing liquid organic fertilizer from tofu liquid waste have been widely explored.[41]. Some combination of materials has been applied in the studies of liquid organic fertilizer from tofu liquid waste. The liquid organic fertilizer production with a combination of tofu liquid waste, brown sugar, EM-4 activator, and water was conducted and resulted in a good liquid organic fertilizer[42]. Napoleon et al. combined tofu liquid waste, banana hump, brown sugar, and rice washing water in producing liquid organic fertilizer[43]. Muafidah et al. utilized tofu liquid waste, coconut water, lemon grass, molasses, shrimp paste, and rice bran to produce liquid organic fertilizer [44], while Putra et al. use combination of tofu liquid waste, coconut water, EM-4, and solution of sugar to produce the liquid organic fertilizer [45]. Liquid organic fertilizer from tofu liquid waste has the composition that meet with the standard liquid organic fertilizer composition based on Decree of Agriculture Minister, Indonesia Number 261/KPTS/SR.310/M/4/2019. Liquid organic fertilizer from tofu liquid waste has also been applied to the agriculture sector for various plants i.e. mustard green [46], long bean [47], rice [48][49], Chinese cabbage[50], chili[51], and cucumber [52].

7. CONCLUSION

Liquid organic fertilizer is made from tofu liquid waste, EM-4, and other additional ingredients. Tofu liquid waste is converted into fertilizer through a fermentation process with the help of the EM-4 bio-activator. During the fermentation process, the microorganisms in EM-4 break down the substrate into smaller compounds. Efforts to increase levels of nitrogen (N), phosphorus (P), and potassium (K) in tofu liquid waste should be supplemented with other organic materials. To increase organic C levels in tofu liquid waste, it is necessary to add goat urine. To improve the quality of liquid organic fertilizer, it is necessary to select materials that contain high levels of nutrients, especially macronutrients. It is also necessary to add starters and materials that encourage the growth of decomposers. The use of liquid organic fertilizer has often been tested on various commodities and has shown positive results in increasing plant growth and improving soil properties. Some alternative sources of additional

ingredients to improve or enrich the liquid organic fertilizer have been also widely explored. The liquid organic fertilizer from tofu liquid organic has been also widely produced and the products have a good quality.

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