BIO-ELECTRIC

Revitalization BIOGAS Digester by Enhancing with Adding Microbial Fuel Cell Component as Solution for Waste Integrated System in Ruminant Slaughterhouse

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***Abstract*— Along with the increasing demand for meat as the consumption needs in Indonesia made slaughterhouse improve their production capacity. Like on Slaughterhouse Malang, every day ±50 cattle were slaughtered. However, each cattle possible to produces rumen wasted around 24,5 Kg [2]. Whereas, just a small number who reused rumen waste as the biogas and normally go through into canal. That would affect raising pollution for environment and surely make uneasiness for society. Analyzing characteristic of rumen waste, most type microbia are consist of bacteria in the anaerobic condition. In the mitochondria, enzyme dehydrogenase capable to change NADH become NAD and enzyme ATPase would change ATP 4 become ADP, this process is released electron (e-) and proton (H+). The differential potential from both load is resulting electricity source usually called by Microbial Fuel Cell Technology [3]. Biogas digester mostly produce gas using as the fuel not for electricity. Because, to utilize biogas become electricity need to convert first and budget required for machine (generator). From this complicated mechanism and inefficiency of digester performance are potentially to be developed by adding microbial fuel cell component as an attempt to revitalize and enhancing digester performance supposed to improve productivity slaughterhouse by producing self-electricity source.**

***Keywords*— CO2, disaster, evacuation, volcano, wireless**

I. INTRODUCTION

Indonesia is a country that developing in livestock sector, especially in cattle. Nowadays according to the data that obtained, population of beef cattle in Indonesia can be estimated 10,8 million beef and dairy cattle 350.000-400.000 tails [4]. Beside that process the development of cattle breeding, Indonesia also have environment problem caused by large number of cattle waste that has not been treated properly. One of wastes that not been conducted is the rumen of cattle. Slaughter process in daily worth 800 cattle in every day. Wastes that produced by slaughtering process, liquid wastes approximately 400 m3 [5]. Meanwhile, it is known that livestock waste causing for the highest carbon emissions in environmental pollution and the impact on the earth's ozone hole. Livestock wastes in high capacity will be negative impact there are an increase in pollution of microbial pathogens that can be contamination [6].

Besides environmental problem, Indonesia also estimated will undergoing crisis of energy. Availability of energy becomes one of the essential requirements for human life. The increase in energy demand caused by population growth, decreasing oil resources and the problem of emissions from fossil fuels. Indonesia's electricity in prediction will grow an average 8.46% per year [7]. The consumption of electrical energy is not balanced by the availability of electrical energy source and caused the energy crisis. Besides the availability of access to electricity is still the world's problems, it is estimated there are about 1.3 billion people, equivalent to 20% of the total population in the world who do not have access to electricity [8].

Local government company slaughter house (PD. RPH) Sukun Malang city, have problem in livestock wastes processing. Some wastes such as feces and urine have been utilized in an integration system and not cause environmental problem. Meanwhile, other wastes from slaughtering cattle in everyday there are rumen of cattle are still dumped become waterways without any treatment or processing and do not have an integrated system to handle it “fig. 1”. Besides that, cattle wastes such as rumen contains many microbes, if allowed to growth freely can damage the environment. Moreover, the location of the slaughterhouse in the middle of the township residents which can cause air pollution that disrupts around the society. Less maximal utilization of waste because it does not create a system for handling and cattle's rumen waste processing.

Fig. 1. Rumen Waste Unutilized

One alternative to solve these problems is the use of available resources has not been managed for the maximum in the livestock system. The availability of livestock waste in Indonesia is a potential resource for the production of renewable energy alternatives. Cattle rumen fluid contains a variety of bacteria that can be used as a source of electrical energy. In the research results showed the number of rumen microorganisms average of 2.7 x 107 CFU / gram [9]. Bacteria will perform metabolism to break down glucose become hydrogen (H2) and oxygen (O2). Hydrogen is a raw material used for the reduction reaction with oxygen; This potential is then called by technology Microbial Fuel Cell (MFC). This technology triggered some reaction cohesive referred to as bio-electrochemical namely biochemical reactions, physical, physio-chemical, electrochemical, oxidation-reduction.

Seeing these conditions, this system has the potential to be applied. Bio-Electric is a wastes processing system to handle cattle rumen with microbial fuel cell technology expected to produce energy sources that provide benefits to the efficiency operational productivity of PD. RPH of PD.RPH Malang. This system aims to provide economic value of a waste as a solution to decreasing environmental pollution and energy shortage.

II. Material and Method

The method of this research is based on literature study related with the main topic of this idea. We collecting all research and combine then arrange become the accurate data. This writing method is done with qualitative descriptive method by taking case study and source data from local and international journal, then we describe by systematically, factual and accurate.

A. Material

All material needed in this research such us rumen waste, substrate (waste water), KmnO4 solution, buffer pH 7, graphite sheet, platinum wire, membrane sheet (glass bead and glass wool), inverter, tank compartment, voltmeter, and inverter. Other equipment's regard to arrange and matching all compartment be the one system BIO-ELECTRIC. Normally, by product from slaughtered beef just throwing out to the channel waste which is no have system to handle or process it. Sometimes, treatment like washing and drying of rumen waste was done to produce fertilizer. But it's not have effectively.

B. Method

This system is conducting in two chamber of microbial fuel cell reactor. There are two chamber/tank/digesters. Design of BIO-ELECTRIC seems in the "fig. 3". which is following the step and work mechanism as follows:

1. After the rumen washing out from the organ tact then throwing into digester 1 to conducting fermentation and biochemically mechanism by the aid of buffer solution and substrate.

2. Along with time in fermentation, the anode in compartment digester 1 will react with the electron (e-) as the outer result of metabolism.

3. After the electron, have attacked by anode, the proton (H+) as the missing one of the result metabolism would throwing past to the channel into digester 2.

4. In the digester 2, with the aid of KmnO4 and buffer as the catalysator to giving aeration in the improving proton production.

5. From digester 1 and digester 2, the load attacking by anode and cathode will distributed through the platinum wire which met in the inverter.

6. Inverter as the medium to accommodate the both load (+ / -) which is resulting DC type electricity would be convert become AC type. And the electricity can be utilized.

7. This system also possible to produce biogas, on the digester 1 and digester 2 fitted with channel for throwing the gas.

8. After rumen waste are following through both digester, then the slurry will go through rough container to prepare become sludge.

9. Slurry through past into final container (sludge). In this way, the byproduct of this system can be utilized as the fertilizer.

In the step 6, the calculation can be done to show how is the electricity which produced by voltmeter. The measurement needed to evaluate work system of BIO-ELECTRIC.

III. Result and Discussion

A. General Overview of Rumen Waste

Indonesia has a growing livestock sector to increase over time, especially cattle population commodity on beef cattle. This occurs in proportion to the market demand for meat consumption needs to increase as well. Today the Indonesian people began to realize the importance of nutrition comes from animal food, especially the beef meat which contains proteins, fats, carbohydrates,

vitamins and minerals. Animal protein will become popular then vegetable protein. Public awareness and cause meat consumption in Indonesia is increasing every year. It can be seen from the percentage of the population of cattle in 2014 increased by 15.66% [12].

With the increasing population, some regional companies' slaughterhouses also improve cattle slaughtering capacity per day to supply the market demand. PD.RPH Malang everyday slaughtering 50 cattle, while the Surabaya area slaughter capacity reaches 500 cattle's every day. The number of cattle slaughtered for their meat produce wastes quite a lot, especially cattle's rumen waste because of rumen have large volume in the body of the cow. Whereas per cattle's can produce fresh rumen contents 24.5 kg or 3.8 kg Dry Weight, because it contains 15.5% Dry Weight [13]. This if calculated with daily capacity of slaughtering, the waste so much not have processing. If it is will not processing, all that happened was a buildup of waste resulting environmental pollution. Addition with the condition of most slaughtering house not so far from society houses. Surely this would be disturbing the public when the waste problem, especially this waste will disrupt the ecological balance of the environment.

B. The Potential of Rumen Waste in Implementation BIO-ELECTRIC

Rument is a part of digestion organs in ruminants that the function feed fermentation by microorganisms they are in. So, that when the cattle rumen slaughtering will generate waste in the form of substrate feed that has been degraded by fermentation of microorganisms. Profile of microorganisms in the rumen as follows: have a number of protozoa as much as 64.12 µL of rumen fluid, the amount of 2.7 x 107 bacterial and fungal amount of 9.3 x 104 [14]. Conditions in the rumen is an anaerobic, which means living microorganisms in the absence of oxygen and is only able to survive in an environment that has very little oxygen levels. Temperatures in the rumen is A temperature in the rumen is 32-42oC with a pH of 6.8 for the profile of microorganisms in the rumen average normal life on the pH scale. Bacteria in the rumen include *Bacteroides sussinogenes, Ruminococcus albus, Bacteroides sussinogenes, Ruminococcus albus, Methanobacterium formicium, Methanobrevibacter ruminantium, Clostridium lochheaddii, Streptococcus bovis, Bacteroides amylophilus, Eurobacterium ruminantium, Lactobacillus ruminus, Anaerovibrio livolytica, Veillonella alcalescens, Selonomonas and Veillonella alcalescens, Ruminococcus sp, Butyrivibrio fibriosolvens* [15]. Rumen waste characteristics have been explained match with the concept of Microbial Fuel Cell technology work. MFC system works very suitable to be applied on the condition of anaerobic microorganisms that is the same as the characteristics of the rumen condition. The metabolic processes of anaerobic bacteria through the Krebs Cycle is not supposed to happen, but from the cytoplasm to the mitochondria directly. In mitochondria, the enzyme NADH dehydrogenase change NADH become NAD and ATP 4 ATPase change to ADP, the change process releases electrons (e-) and proton (H +) [16]. So, that the microorganisms in the rumen has the potential to be applied to a processing system based microbial fuel cell that is able to work in bio-conversion generating electrical energy

C. BIO-ELECTRIC

Basically, this Cattle Rumen Waste Processing system combines the design of the system waste processing biogas by microbial fuel cell technology substitution. Start from the basic characteristic of rumen waste, the concept of microbial fuel cell is potentially found. The main condition of it is strengthen by the result of research [17] shows that the life time of the bacteria in cattle waste is said that the "System E. coli juice of rumen conditions remain at 51.59 hours. While E. coli cattle feces system conditions remain at 17.58 hours. This main characteristic make rumen waste are compatible to conducted with microbial fuel cell and also show in the "fig. 2". The long resistance of rumen waste would support the performance of BIO-ELECTRIC.

Bio-Electric System consists of several compartments, namely digester 1, canal membranes, digester 2, rough container, the container of sludge and additional supporting components such as the substrate tank, aeration and inverter.

1) Bio-Electric Design

This system is designed to simplify the process waste rumen to produce renewable electrical energy sources and friendly, with using microbial fuel cell reactor compartment digester system type tubular flow, Membranes-Less Microbial Fuel Cell based "Fig. 3". MFC prototype most potentially to be developed on an industrial scale is the model of tubular type reactor [18].

2) Mechanism of Bio-Electric

Basically, this digester is a space or a media of microbial fuel cell. In this space the conversion of chemical energy become electrical energy by using microorganisms as catalysts. In the metabolism of microorganism's anaerobic conditions will change macromolecule substrate become CO2, protons and electrons. The electrons then flow through a circuit with a charge on the platinum wire anode.

Anode:

$$C6H12O6 + 6H2O \xrightarrow{microbe} 6CO2+24H+ +24e-$$

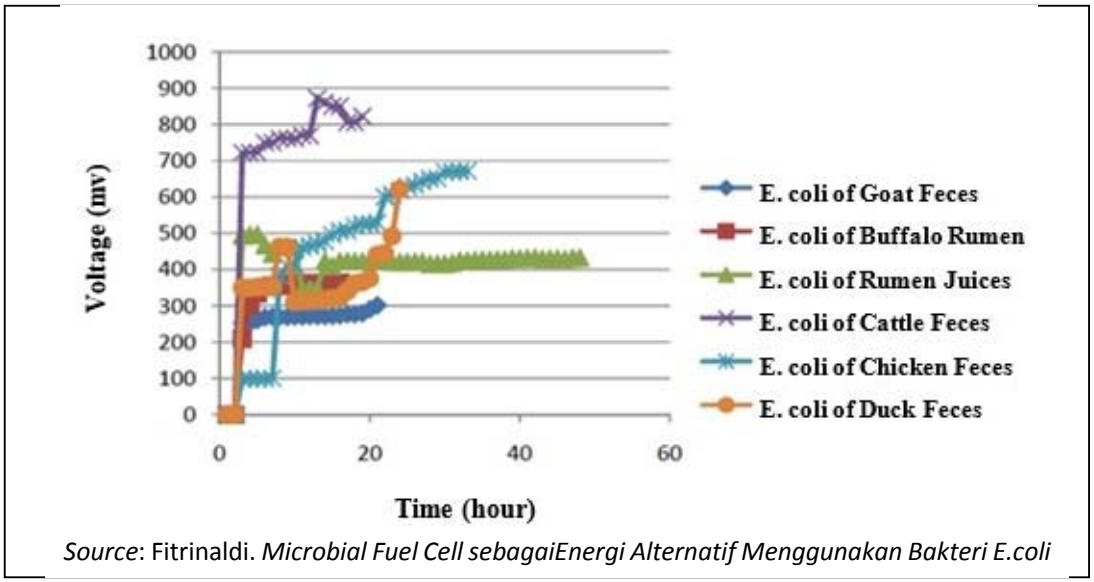
In aerobic conditions, bacteria use oxygen or nitrate as final electron acceptor to form water.

Cathode:

$$O2 + 4H+ + 4e- \xrightarrow{microbe} 2H2O$$

Protons then flow through the electric circuit to the charge at the cathode. The potential difference between the anode and the cathode along with the flow of electrons can produce power [19].

3) Membrane-less Continue Tubular Flow



Source: Fitrinaldi. *Microbial Fuel Cell sebagaiEnergi Alternatif Menggunakan Bakteri E.coli*

Fig. 1. Comparison of time and voltage producing of MFC based on activity of E. coli isolated from fecal samples of goat, cow, duck, chicken, buffalo and rumen juice.

This reactor collaborating the principle of dual chamber, adding the components glass bead and glass wool that is installed on the channel between the anode and cathode digester. Cattle's rumen waste on digester 1 is completed by substrate drain hole which has gone through a fermentation process to the maximum and flows continually. The substrate that used may be household waste such as wastewater. It is expected to continually on the substrate flow speed of 0.28 mL/min to 1.83 mL/min [20] could provide the maximum of efficiency in the electrons reduction process in microorganisms.

4) Anode

The mechanism electron transfer involves cell membrane proteins cytochrome of microorganisms Components anode arranged in digester 1 is a disc graphite shape as the electron acceptor which is reduced by microorganisms and provide a wider space for the interaction of electron transfer.

5) Membranes: Glass Bead and Glass Wool

Glass bead and glass wool plugged between channel of digester 1 and 2 as an insulator, flow medium, and as a space divider anode and cathode. These mediators as exchange membrane replace the function of the membrane to transfer proton metabolism product of microorganisms.

6) Cathode

Cathode in graphite material to place with a distance of 10 cm from the underlying components to provide the fullest re-oxidation cathode space "Fig. 3". At the cathode space given for aeration channels with the addition of a KMnO4 catalyst continually. Permanganate has a high redox potential, the potential difference in the anode and cathode will be even high so that the electrical energy produced will increase [21]. At the anode and cathode space are also given the flow channel phosphate buffer the function to balance pH 7.0 in the second compartment. Phosphate buffer have function to add the ionic strengthen and solution conductivity to increase the value of power density [22] and also provides a proton [23].

The electrodes in the anode and cathode space are connected using a platinum wire conducted to generate electric current. Platinum wire through a potential difference in electron and proton generate electric current type DC or unidirectional. While society in general use of electricity in AC or alternating. Thus, the electricity produced by the MFC must first be converted to AC by an inverter components "fig. 3". The basic principle with alternating current models of the simplest phase where a light as strain. After the electric inverter, could applied to the lamp or other tools that want to be electrified using a cable. After the rumen waste through a digester 1 and 2 so as to generate electricity, then the next rumen waste would lead to a rough container and final container that produces a byproduct sludge. These byproducts are safe and can be used as fertilizer because it has been through the fermentation process.

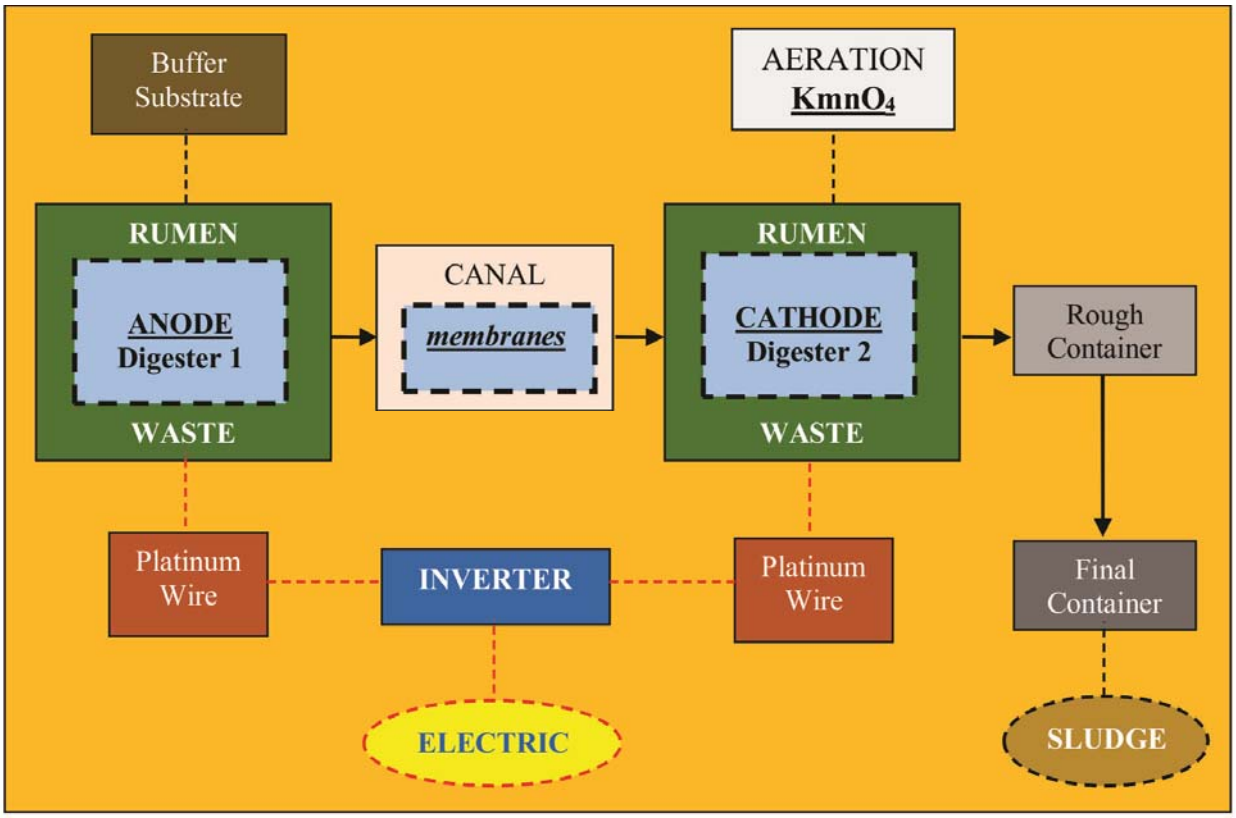


Fig. 3. Flow Chart of Mechanism Waste Integrated System of BIO-ELECTRIC

7) Rough container

Rough container is a temporary container of processing digester tank. Tank is a process of preparation and already processed of sludge before out on sludge container. In this tank the fermentation process of feces residue product and the substrate that has been through absorption cargo on compartment digester. These tanks keep the continuity of the process of waste processing in the digester. Digester channel towards this tank with a slope of 45o is expected when there is an empty space in the waste digester tank will be returned to the digester for processing and absorption of the capacity and the residual gas.

8) Final Container (Sludge):

Sludge container is a final container of the Bio-Electric system as sludge container that ready for use. Sludge in the container is just residue that is safe to use as fertilizer or used for any other. Because the maximum fermentation process and the absorption of toxic gas has been carried out.

D. Advantage of BIO-ELECTRIC

The Principle of waste cattle's rumen microbial metabolism is bio-electrochemical. The change process by the enzyme produce NAD and ADP will release electrons and protons H+. Both of these electric capacities can be forwarded to produce electricity. When viewed from the calorie content of glucose microbes can produce 3 kWh per kg of organic matter (dry weight) assuming the efficiency of fermentation 100% [24]. Besides that, rumen is the one potential waste which still have large raw material suppose the bacteria degrade it. Several component substances that still exist on here is cellulose which come from degradation fiber of forage residue that do by bacteria. As we know that mostly bacteria culture in rumen waste was placed by cellulose bacteria such us pseudomonas sp., cellulomonas sp. and cell vibrio sp. [25]. Research has study about it, approve that bacteria inside rumen waste capable to degrade 78% cellulose from rough material rumen in the condition normal pH [26]. Complicate by another research that 1 g/L of cellulose generate 143 mW/m2 anode area and 59,2 mW/m2 cathode area [27]. This result show in "fig.4". The advantage of this system is the direct disposal of waste can be supplied to the digester 1 which will react with the substrate. Electrodes were released by microbes could be directly pass through the electrode so that the electric energy generated more high. This system provides the efficiency of the process changes the chemical energy become electrical energy, making it easier to get electricity without having to change the gas energy become electrical energy which is known must use generators. The system also uses a continuity system on all channels and pipe, so as to provide convenience to the process operation.

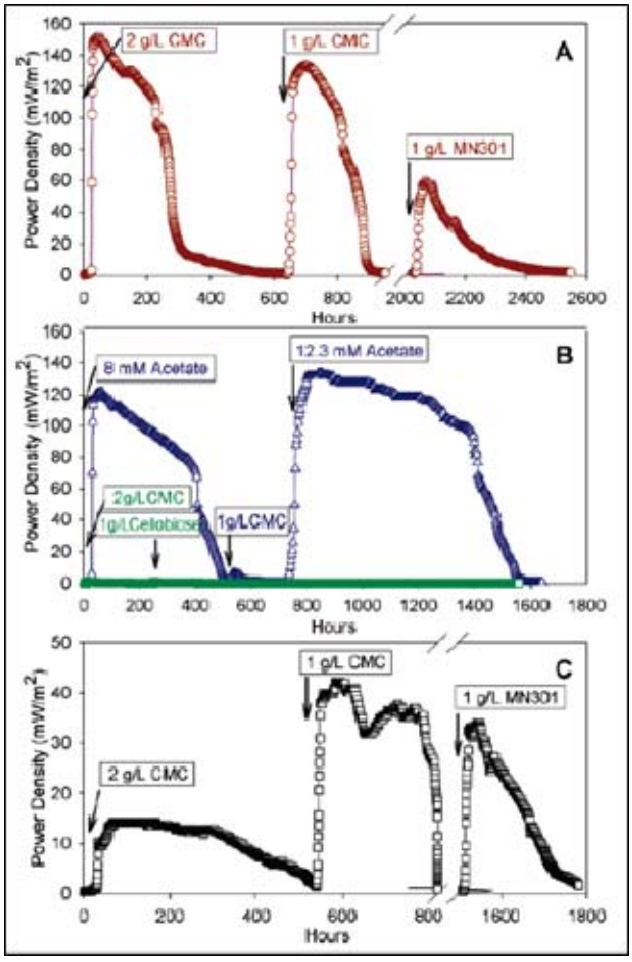


Fig. 2. Electricity generation by (A) binary culture, (B) C. Cellulolyticum or sulfurreducess and mixed culture.

Source: Zhiyong, et. al. 2007. [26]

E. Application

Bio-Electric System is designed for rumen wastes processing systems of ruminants are plentiful, especially in slaughterhouses. Rumen waste utilization is usually just thrown away and directly made fertilizers, while there is no processing system. Application of Bio-Electric wasted integrated system will be able to handling the issue of waste problem and give benefits to the waste itself. Bio-Electric is able to generate an output source of electrical energy and sludge. Sludge produced even safer because it has been through the process of fermentation was completely during the process of Bio-Electric.

IV. CONCLUSION

The Conclusion of this idea is

1. The concept of Bio-Electric combining biogas digester systems with the substitution of microbial fuel cell technology as the main compartment. Mechanism of Bio-Electric using microorganisms in the rumen waste is by the process of anaerobic metabolism is not through Krebs cycle but from the cytoplasm to the mitochondria directly. In mitochondria, the NADH dehydrogenase enzyme change NADH become NAD and ATPase change ATP 4 become ADP, the change process releases electrons (e-) and proton (H+) which is then supplied by electrode circuit and the potential difference between the two charges will produce electricity.

2. The advantages of Bio-Electric is able to handle the rumen waste are abundant with produce output source of electrical energy efficiently and sludge can be used as fertilizer.

3. Application of Bio-Electric can be applied to the company's slaughterhouses, especially ruminant's slaughterhouse that do not have rumen waste processing systems.

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