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International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Conversion of Weeds and Crop Residues into Organic Fertilizer and Electricity for Agricultural Production using Rumen Hybrid Methane Fermentation System – A Potential Project to assist Cambodian Farmers

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ABSTRACT :

This article is to review the existing concept note on "Conversion of Weeds and Crop Residues into Organic Fertilizer and Electricity for Agricultural Production using Rumen Hybrid Methane Fermentation System – A Potential Project to assist Cambodian Farmers", which will be expectedly implemented in Cambodia and the near future. The overall goal of the project is to consolidate the rural poverty reduction process and prevention of deforestation by lowering farming production cost and increasing productivity through the use of produced organic fertilizer and electricity to grow their crops, thereby ensuring sustainable agricultural development and making agriculture more productive, conducive to the development of other sectors of the economy, which are beneficial to the Cambodian people at large and to the strengthening of development and peace in the region.

Keywords: Weeds & Crop Residues, Organic Fertilizer, Rumen Hybrid Methane, Fermentation System

1. Introduction :

A Japanese team visited Cambodia and found mine clearance areas to be the project location. suddenly, the team initiated an idea proposing the conversion of weeds and crop residues into organic fertilizer and electricity for agriculture production by introducing of Rumen Hybrid Methane Fermentation System. This consolidates the rural poverty reduction process and prevention of deforestation by lowering farming production cost and increasing productivity. Through this system, the project expected that farmers will be able to use the produced fertilizer and electricity to grow their crops, thereby ensuring sustainable agricultural development and making agriculture more productive, conclusive to the development of other sectors of the economy, which are beneficial to the Cambodian people at large and to the strengthening of development and peace in the region.

In order for Cambodian farmers to use the produced organic fertilizer and electricity from Methane gas for their crop production effectively, Cambodian and Japanese teams anticipated that by introducing the Rumen Hybrid Methane Fermentation system; which produces organic fertilizer and electricity from crop residues in Cambodia. The teams expected that at least 95% of the farmers in the project site will adopt the System in the next five years. This will lead to adaptation nationally and regionally in the next 15 to 20 years. Therefore, the Japanese team's initiative will be accomplished through integrated components for concrete adaptation outputs, namely (1) development of technology for implementation of Rumen Hybrid Methane Fermentation System in mine clearance sites; (2) establishment of an Innovation Community Center to effective use of Rumen Hybrid Methane Fermentation Systems at the project sites.

2. Overview of Current Condition of Cambodia's Agriculture Sector:

In Cambodia, the agriculture sector continues to generate the largest percentage of the country's Gross Domestic Product (GDP). For almost 80% of Cambodians, it is the primary source of income and means of subsistence in rural areas **[10]**. It has been considered as one of the country's leading sectors since it has contributed to Cambodia's economic development and poverty reduction. As for the share of GDP, agriculture sector has decreased from 35.7 percent in 2000 to 22.15 percent in 2019. However, from 2010 to 2019, the agricultural value-added increased from 15,938 billion Riels to 22,786 billion Riels (Khmer currency), with average growth of 4 percent annually. However, for the past few years, Cambodia has been a net importer of agricultural products, which has led to an agricultural trade deficit of 1.26 billion US dollars in 2018 **[11]**. Agriculture and agro-industry have been identified as export potentials in Cambodia in order to create a more varied export structure and a better distribution of domestic income **[5]**. This has been seen that agricultural growth is critical to continued poverty reduction, the Royal Government of Cambodia (RGC) has developed successive

National Strategic Development Plans and Rectangular Strategies, particularly, the NSDP 2019-2023 and the Rectangular Strategy Phase-IV, aimed at enhancing productivity and competitiveness in agriculture so as to ensure food security and boost exports of agricultural products. Although efforts have been made and results achieved, agriculture production grew only marginally. According to a World Bank's report [18], since 2013, "agriculture has experienced very little growth", and the Asian Development Bank has further added that in 2020 the "agriculture production" grew only by 0.5 percent. The RGC has acknowledged this fact. In the National Agricultural Development Policy 2022-2030 adopted by the Council of Ministers in September 2022, it said that "the average growth in the agriculture sector was about 1.7 percent in 2017, and 1.1 percent in 2018". Promoting a two-pronged strategy, policymakers hope to make Cambodia the third-largest rice exporter in the world by 2015 by increasing yield and productivity—especially on small family farms—and switching output to higher-value commercial goods[17]. However, Cambodian soils are not very fertile, and traditional rice farming obliterates any structure that may exist. Farmers are urged to use animal dung instead of inorganic fertilizers, and their usage is quite low **[4]**.

2.1. Uses of Chemical Fertilizer

Rice pests and damage have been linked to agronomic techniques including fertilizer application and seed rates, although the data is sometimes hazy in studies on pest management choices and invisible in studies on pesticide lock-in **[6]**. China's Ministry of Agriculture unveiled two Actions in 2015 with the goal of having no increase in chemical pesticide and fertilizer use by 2020. If these goals are accomplished, agricultural non-point source pollution will be reduced, cost effectiveness, energy conservation, and emission reductions will increase, the nation's grain supply and agricultural products will be safe and of high quality, the ecological environment will be protected, and agriculture will be able to develop sustainably **[12]**. The overuse of chemical nitrogenous fertilizers has detrimental effects on soil, water, and air quality, among other environmental components. Because nitrogen pollution is causing soil and water biodiversity to decline, the sustainability of the environment is in jeopardy. The health of people and animals was also impacted by the heavy use of these fertilizers. Numerous tactics have been used to lessen the harmful effects of nitrogenous fertilizers **[16]**. Applying fertilizer is still a crucial agricultural input needed to meet the demanding output targets of the twenty-first century. On the other hand, fertilizer application is known to degrade our surrounding ecosystem [2]. Many other developing countries including Cambodia face the issue of low technological efficiency and excessive use of chemical fertilizer in grain production, which results in significant contamination of the environment and expensive costs associated with environmental control (Sun & Li 2021). In Cambodia, it was discovered that a variety of issues and worries faced by farmers included soil erosion, weeds, illnesses, insect infestations, high production costs, flooding, droughts, shifting patterns of rainfall, and inconsistent rainfall distribution **[15]**. In addition, Tann et al., (2012)**[14]** found that fertilizer use is generally ignored in Cambodia and performs badly when compared to other nations in the region.

2.2. High Cost of Rice Production

In some areas in Cambodia, unlevelled land is the main problem causing rice farming costs high. Unlevelled topography results in uneven fertilizer and water distribution across the rice fields and soil erosion. Unlevelled land also complicates mechanized farming operations such as ploughing, transplanting, and harvesting. According to a joint-study, the yield of rice production on unlevelled land is low, around 2-3 tons per hectare. It is estimated that approximately 40 percent of rice fields throughout the country are still unlevelled. Since 2020, Non-Profit Organization Japanese Mine Action Service (NPO JMAS) has succeeded in increasing rice yield to 4-6 tons per hectare, doubling the previous level by levelling rice fields with high precision using Komatsu Construction machines equipped with ICT. Farmers, especially, underprivileged ones, have spent money on almost everything, ranging from buying seeds, ploughing land through harvesting. In some areas because of lack of proper irrigation network, farmers have to spend money buying fuel to pump water. Money has also been spent on chemical fertilizers, pesticides, and herbicides. If the yields and incomes are not high, depending on rainfall and market, farmers will incur losses. A study conducted by Kea et al. (2016) **[8]** on "Technical efficiency and its determinants of rice production in Cambodia found that the amount or output of rice produced in Cambodia varies depending on the province-level technical fertilizer application, total harvested area, and capital investment in agricultural machinery.

2.3. Potential Project for conversion of weeds and crop residues into organic fertilizer and electricity using Rumen Hybrid Methane Fermentation System

Among the most widely used and easily obtainable forms of renewable energy at the moment are bioenergy and biofuel produced from biomass. Utilizing different kinds of weeds as a biomass source for the conversion of such weeds into bioenergy and biofuels can lessen reliance on limited resources, which can also contribute to environmental preservation. Unwanted plants known as weeds coexist with farmed crops in wetlands and agricultural fields. By decreasing the productivity of farms and forests and invading crops, they pose a serious threat to the ecosystem by endangering native plants and animals as well as rivers and forests **[7]**. Weeds, crop and animal residues are available in Cambodia. An expert team from Japan has studied an area where weeds, crop and animal residues can be converted into organic fertilizer and electricity. After the study, there will be a potential project which is crucial for Cambodian farmers to reduce their rice production costs. The project will focus on the conversion of weeds and crop residues into organic fertilizer and electricity using Rumen Hybrid Methane Fermentation System. The System is a technology used for the anaerobic digestion of organic waste to produce biogas, primarily composed of methane. The potential project will be the contribution to the consolidation of rural poverty reduction process and prevention of deforestation by lowering farming production costs and increasing productivity through the use of produced organic fertilizers and electricity to grow their crops, thereby ensuring sustainable agricultural development. The Rumen Hybrid Methane Fermentation System, which produces organic fertilizer and electricity will be introduced in Cambodia in the near future.

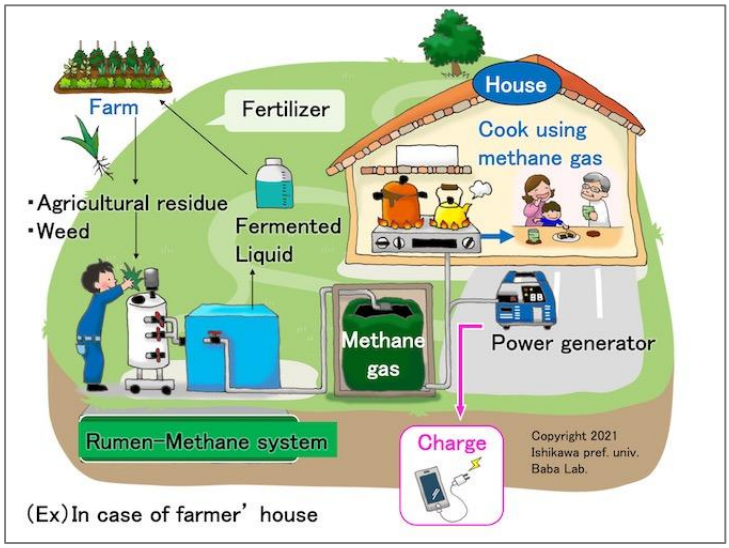
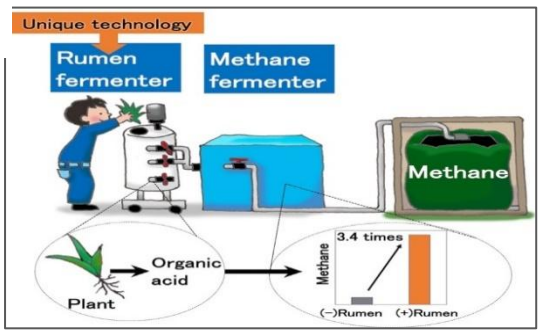


Figure 1: Conversion of Weeds and agricultural residues into organic fertilizer and electricity

Methane fermentation is a technology for converting waste into methane, electricity, and fertilizer. However, plant biomass, which is the most abundant biomass on earth, has a persistent lignocellulosic structure, which significantly lowers the efficiency of methane fermentation. A research team at Ishikawa Prefectural University (Prof. Baba) has developed a Rumen Hybrid Methane Fermentation System (Figure 1) that uses bovine rumen microorganisms to improve the efficiency if methane fermentation of plant biomass, which is difficult to ferment **[3]**. The system has been demonstrated under a Japanese Grant-in-Aid for Scientific Research (Figure 2).

a



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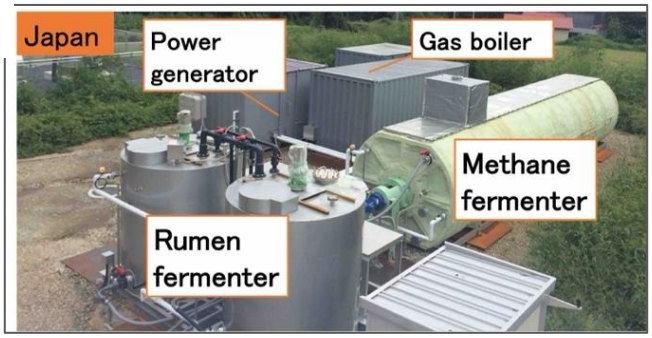

Figure 2: (a) Rumen Hybrid Methane Fermentation Systems; (b) Large-scale pilot plant

At the time of development, it was necessary to transport the rumen microbes periodically, but now it is only necessary to transport the rumen microbes once because the plant biomass degrading capacity of the rumen microbes has been successfully maintained in the fermenter for more than one year. This has made it possible to install a Rumen Hybrid Methane Fermentation System anywhere, regardless of the location of the slaughterhouse. With the success of this technological development, a demonstration test using crop residues discarded from the food market is currently being conducted (NEDO Projects in Japan), and the technology is now at a practical level. Currently, Komatsu and JMAS of Japan are creating farmland on mine clearance land in Cambodia and promoting reconstruction, but farmers are unable to purchase fertilizer due to the high price of fertilizers. In addition, farmers need to pump water from the river to cultivate crops, and the cost of fuel for this is putting pressure on the family budgets of farmers.

3. Technology development for implementation of Rumen Hybrid Methane Fermentation System in mine clearance sites

3.1. Development of technology to increase the density of microbial symbiotic mechanisms used in the Rumen Hybrid Methane Fermentation System

In order to implement this methane fermentation system, it is necessary to cultivate the rumen microbial symbiosis mechanism discovered by **[3]** However, there are no facilities for cultivating microorganisms in mine clearance sites

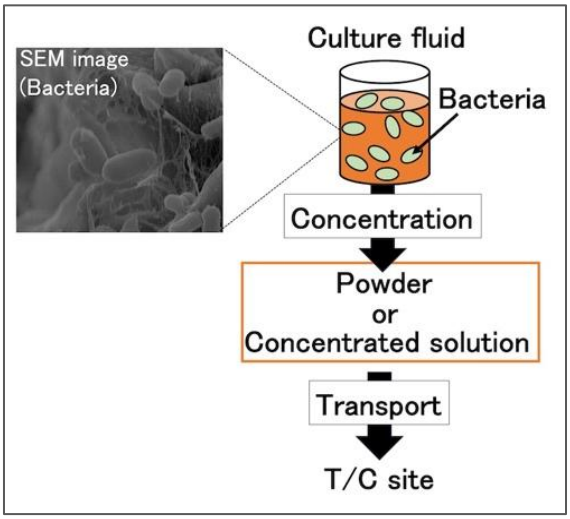

Figure 3: high-density enrichment of rumen bacteria

Therefore, it is necessary to transport the microbial symbiosis system from Japan to the project site while maintaining the plant biomass decomposition ability of the symbiosis system. In order to reduce the cost of transportation, it is desirable to reduce the volume of the culture solution while maintaining the plant biomass degrading ability, and to make it into a concentrated solution or powder (Fig. 3). If the concentrated solution or powder can be stored at room temperature, it will also be possible to store the microorganisms at the project site. This would also allow the microorganisms to be added to the fermentation system as needed when the ability of the fermentation system declines. This project aims to achieve a high density of rumen microbial symbiosis while maintaining the ability to degrade plant biomass, and to introduce a Rumen Hybrid Methane Fermentation System to the project site.

3.2. Development of heating equipment with no power and no fossil fuels

The optimum temperature for methane fermentation is 35°C. However, electricity and fossil fuels are required to maintain the temperature at 35°C at all times. Large-scale methane fermenters can burn surplus methane gas to heat up to 35°C, the optimum fermentation temperature, but it is difficult to secure surplus methane gas for small-scale methane fermenters that target vegetable scraps from one to several farm households. Small-scale methane fermenters, which are currently being tried for widespread use in Cambodia, are not heated for the same reason as above, and their methane production is lower than the theoretical value (Fig. 4).

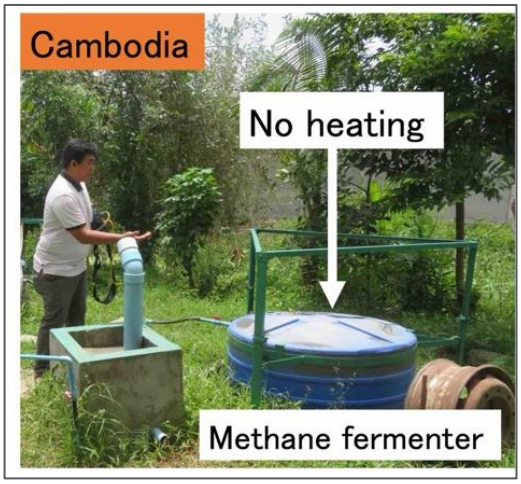

Figure 4: Methane fermenter in Cambodia

Therefore, with funding possibility, we will develop a heating system using heat-generating microorganisms in addition to the Rumen Hybrid Methane Fermentation System. This device will be used to heat the Rumen Hybrid Methane Fermentation System to achieve a methane yield close to the theoretical value.

3.3. Importance of Rumen Hybrid Methane Fermentation System for Cambodian Farmers

The hybrid Rumen Methane Fermentation System is a technology used for the anaerobic digestion of organic waste to produce biogas, primarily composed of methane. Some purposes and benefits of using a Rumen hybrid methane fermentation system are:

a) ***Biogas production***: the primary purpose of the Rumen hybrid methane fermentation system is to produce biogas, which is a renewable energy source. Biogas can be used as a substitute for natural gas for heating, cooking, and electricity generation. It helps reduce reliance on fossil fuels and decrease greenhouse gas emissions;
b) ***Waste management and treatment***: The system enables the effective management and treatment of organic waste, such as agricultural residues, food waste, and wastewater sludge. By digesting the waste in an anaerobic environment, the system helps break down complex organic compounds, reducing the volume of waste and minimizing its environmental impact;
c) ***Energy generation***: biogas produced from the Rumen hybrid methane fermentation system can be used for electricity generation through combined heat and power (CHP) units or for direct combustion in boilers. This allows for on-site energy production, reducing reliance on grid electricity and providing a decentralized energy solution;
d) ***Nutrient recovery***: The fermentation process in the system also facilitates the recovery of valuable nutrients, such as nitrogen and phosphorus, from organic waste. These nutrients can be used as fertilizers for agricultural purposes, promoting sustainable farming practices and reducing the need for chemical fertilizers, hence organic fertilizers are produced;
e) ***Carbon Footprint Reduction***: The use of methane gas from the Rumen hybrid methane fermentation system helps reduce the carbon footprint of various sectors, including agriculture, waste management, and energy production. By utilizing organic Waste as a feedstock for biogas production, greenhouse gas emissions are minimized, contributing to climate change mitigation efforts;
f) ***Environmental Benefits***: The system helps divert organic waste from landfills, reducing methane emissions from decomposition. Methane is a potent greenhouse gas, and its capture and utilization through anaerobic digestion contribute to mitigating climate change. Additionally, the system promotes sustainable waste management and practices and supports the transition to a circular economy;
g) ***Economic Opportunities***: The Rumen hybrid methane fermentation system can offer economic benefits by creating opportunities for local employment, fostering the growth of renewable energy industries, and providing a revenue stream through the sale of biogas or electricity generated from it.

Overall, the Rumen hybrid methane fermentation system serves multiple purposes, including biogas production, waste management, energy generation, nutrient recovery, Odor reduction, and carbon footprint reduction. It offers a sustainable and environmentally friendly approach to resource utilization and contributes to the transition to a low-carbon economy. In the future, the greenhouse gas emission reductions from this project have the potential to be developed into a "Joint Crediting Mechanism" (JCM) (bilateral trading of carbon credits between Cambodia and Japan).

4. Conclusion

The conceptual design of the conversion of weeds and crop residues into organic fertilizer and electricity using the Rumen Hybrid Methane Fermentation System has been developed by Yasunori Baba, Ishikawa Prefectural University, Japan; designed to ensure that farmers living in the selected mine clearance lands and other lands can produce organic fertilizer, light, cooking gas, and electricity, thereby their crop production intensified and diversified. A rise in farm productivity will have positive effect on farm incomes, especially if farmers use modern technologies accompanied by higher efficiency through the use of high quality of inputs. Farmers, especially underprivileged farmers, have spent money on almost everything, ranging from buying seeds, ploughing land through harvesting. In some areas because of lack of proper irrigation network, farmers have to spend money buying fuel to pump water. Money have also been spent on chemical fertilizers, pesticides, and herbicides. If the yields and incomes are not high, depending on rainfall and market, farmers will incur losses. In order to reduce farmers' expenses, thereby increasing their incomes, some sorts of energy should be found to replace fuel for water pump. Chemical fertilizers should also be replaced by other forms of fertilizers that could be produced locally using new technology. Lowering production costs through better use of existing resources is the key to maintaining farm competitiveness. It is, therefore, necessary to introduce the Rumen Hybrid Methane Fermentation System to tackle the farmer's problem of having high production costs and uses of chemical fertilizer.

Acknowledgements

We would like to express our sincere gratitude to all those who have contributed to the realization of this research article.
First and foremost, we extend our heartfelt appreciation to Professor Yasunori Baba from Ishikawa Prefectural University, Japan, for his pioneering work in developing the concept of the Rumen Hybrid Methane Fermentation System. Without his innovative research and technological advancements, this project would not have been possible.
We are indebted to the Japanese team who visited Cambodia and identified the potential for implementing the Rumen Hybrid Methane Fermentation System in mine clearance areas. Their vision and dedication to assisting Cambodian farmers in reducing production costs and increasing productivity are commendable.
Special thanks to Dr. Tep Khunnal, Board Chairman, UME, and, Dr. Tun Pheakdey, President, of UME, Cambodia, for their support and collaboration in this endeavor.

Furthermore, we appreciate the invaluable insights and feedback received from anonymous reviewers during the preparation of this manuscript. Their constructive comments have greatly enhanced the quality of our work.
Last but not least, we express our gratitude to the Cambodian farmers who will benefit from the adoption of the Rumen Hybrid Methane Fermentation System. Their resilience and dedication to sustainable agricultural practices inspire us to continue our efforts in supporting rural development and environmental conservation.
This research article is a culmination of collaborative efforts and would not have been possible without the contributions of all those mentioned above. Thank you.

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