Policy Brief

Appendix 3b

DFC file no: 11-016 AU
Sustainable production of biogas from waste rice straw and water hyacinth – A demonstration project.

SubProM (Vietnamese acronym for project 11-016AU)

Introduction

The primary objectives of the SubProM project were to:

1. Investigate whether waste rice straw (RS) and water hyacinth (WH) biomass could be used as supplementary/or sole substrate for farm-scale biogas reactors (8 – 10 m^3) in periods when there is a shortage or total lack of pig manure (PM).
2. Develop a simple, low-cost and environmentally friendly pre-treatment process for increasing the biogas potential of RS and WH.
3. Develop a durable, cheap farm-scale biogas reactor for co-digestion of high proportions of biomass such as waste rice straw (RS) and water hyacinth (WH) with pig manure (PM).

Results

Ad 1: We have provided sound experimental evidence that biogas production is increased very significantly (in some cases up to 100%) when RS and WH are used as supplementary substrates in biogas digesters. Both biomass substrates have a higher biogas potential than PM (cf. Fig. 10). Therefore, a standing stock of 4-6 pigs is not a prerequisite for securing a sufficient production of biogas for a farm-household – as long as RS and/or WH biomass is available.

Ad 2: Soaking of RS in water (or digester effluent) for 3 days is the preferred pre-treatment of RS prior to being used as a substrate for biogas production - a cheap, easy and environmental friendly method of pre-treatment. Fresh WH biomass can be used as biogas substrate directly without pre-treatment.Thus there is a great unexploited potential for sustainable biogas production from easy available biomass in the Mekong Delta (MD) of Vietnam and Asia as a whole.



Fig 1 Left: Improved HDPE (IHDPE) digester installed at farm-household
Fig. 2 Centre: Testing the toughness (durability) of the HDPE reactor at a farm site (material thickness of HDPE is 0.75 mm)
Fig. 3 Right : Twin IHDPEs at the Biogas Park at CTU. These reactors are operating with WH as sole substrate (loading: 12 kg fresh WH/day/reactor)

Ad 3: Based on many pilot-scale experiments at different farm households we developed the IHDPE (= Improved High-Density PolyEthylene) digester (total price approx. 400 USD including installation). The IHDPE digester (Figs.1,2,3,7 and 8) has a total volume of approx. 8 m^3 and is made of 0.75 mm HDPE. The IHDPE digester is a simple tube reactor installed with a sloping mid-section to prevent malfunctioning due to biomass flotation – a common problem in many types of biogas digesters. This reactor type has been tested successfully at farm households with very different mixing ratios of pig manure (PM) and RS/WH.

Some digesters installed at households without livestock have produced biogas exclusively from RS or WH for more than two years. Nevertheless - addition of some human excreta, animal manure or household waste to these digesters has proved beneficial - although not necessary for biogas production even during long-term operation.

In 2017, a total of 27 IHDPE reactors were installed around the city of Can Tho by the SubProM project team with the help of about 14-20 volunteer students and farmers. Construction costs for these 27 reactors (7.000 USD in total) were sponsored financially (50%) by the SubProM project - the so-called SDP (Sponsored Digester Program). All farmers of the SDP have so far been very satisfied with the design and function of the improved HDPE biogas digesters. During the SDP, the SubProM team also developed a cheap and more efficient biogas burner for low pressures of biogas.

Background

Various types of household biogas digesters have been in operation for decades in rural areas of Asia, Africa and South America. In China alone about 30 million household digesters have been build (Xinyuan Jiang et al., 2011).

In the Mekong Delta (MD) of Vietnam, family farm sizes range between 0.5-2 ha and currently this region is estimated to have approx. 17.000 farm-scale biogas digesters which typically have a volume of 6 - 10 m^3. The majority of these digesters use pig manure (PM) as sole feedstock. A standing stock of 5 adult pigs is the minimum requirement for producing sufficient biogas for the daily cooking activities of small farm households. However, many farms in the MD have a smaller standing stock of pigs (permanently or momentarily) and those producing biogas only from pig manure may temporarily have a shortage of manure when the size of the stock is reduced after the sale of animals or in connection with disease outbreaks. Shortage of livestock manure apparently has prevented many small farm households from investing in biogas digesters.

It is estimated that around 670 million tons of waste rice straw is produced annually in Asia most of which is burned in the field prior to starting a new crop cycle. Although some burning is advantageous for recycling of minerals, 2 – 3 yearly burnings is a waste of fixed biomass, since rice straw contains more than 50 % (of dry weight) fermentable sugars. Water hyacinth is a dominating and troublesome weed in rivers and channels. In some areas WH is available in almost unlimited quantities (*see Fig. 5*).

Fig 4 Left: Weighing the daily amount of RS to be added to the biogas reactor (The dry RS is soaked in plastic barrels for 3 days prior to anaerobic digestion).
Fig. 5 Right: Water hyacinth blocking a channel – a common sight in the MD of Vietnam.

Implications/ Recommendations

Extensive studies carried out by the SubProM team have unequivocally demonstrated that waste rice straw (RS) and water hyacinth (WH) are better biogas substrates than pig manure (PM) when tested in lab-scale and farm-scale reactors. Thus, significantly higher biogas yields are obtained when pig manure is digested with RS and/or WH as co-substrates (Fig 10). These results have already been communicated to: local authorities and farmers, collaborating research groups at IRRI (Philippines) and in several publications easily accessible in Vietnam (Appendix 3c).

Lately, the BioRist project led by Technische Universität (Berlin) has adopted our concept of using RS for biogas production – although in a very high-tech approach not directly applicable to low-income rural areas (biorist.tu-berlin.de). Our results thus open up for a large expansion of sustainable biogas production - both small-scale and medium-scale in rice producing regions.

The improved 8 m^3 (total volume) HDPE digester developed by SubProM at a total price of 400 USD can provide biogas for the daily cooking needs of a small farm household. However, this investment (with a maximum pay-back time of 4 years when only considering savings in fossil fuels/fire wood and half the time usage for collecting firewood) seems high and risky for a low-income farm household. Financing issues seem to be the major obstacle to a broad dissemination of farm-scale biogas reactors in the MD. This could be alleviated by provision of subsidies from central or local governments or international NGOs (e.g. interest-free loans or direct financial support or a "no cure – no pay" program).

It is our experience that the farmers are not particularly afraid of testing new energy technology (such as biogas) - it is the economic uncertainty issues that raise concerns.

To attain (and keep) momentum for dissemination of farm-scale biogas digesters it will be very important to establish local Biogas Service Offices (BSOs) that can provide technical assistance and training in building and managing household-size digesters.

These services have so far - to a large extend - been provided by the SubProM staff at CTU which will not be possible if many new biogas reactors are to be installed in VN in the future. According to our best conviction without the establishment of such BSOs (operating for an extended period of time), it is not likely that small farm-scale biogas digesters will be able to spread widely in the Mekong Delta of VN. When well-functioning BSOs have been established – the former SubProM team at CTU can reduce their involvement to function as a "back-up group" only solving complicated issues without directly taking part in the construction and monitoring of reactors.

A recently completed SNV project in Vietnam has resulted in the installation of more than 100.000 brick dome reactors in northern Vietnam. This reactor type is significantly more expensive than the IHDPE reactor developed by SubProM. Furthermore, the IHDPE reactor requires less maintenance and is better suited for using high amounts of RS and WH as substrates. The low cost of the IHDPE digester should facilitate its widespread distribution in rural areas with low household income. Although difficult to monetarize other general benefits of using biogas should be communicated to the rural population as additional incentives (Ngo Thi Thanh Truc et al., 2017; Jan Bentzen et al., (2018) submitted).

These benefits include: more hygienic management of animal manure; faster, cleaner and healthier cooking (i.e. as opposed to cooking with firewood) - pulmonary and eye diseases are more frequent in households using firewood for cooking; protection of forests (less deforestation), use of biogas effluent as organic fertilizer for vegetable garden (reduces pollution of channels and rivers). Environmental issues such as CO_2 savings (Ngo Thi Thanh Truc et al, 2017; Jan Bentzen et al., (2018) submitted) are other issues which are less prone to function as incentives for a low-income rural population.

Conclusions

Large resources of vegetable/crop waste and aquatic weed are available in Vietnam and other third-world countries.

During the SubProM project it became evident that biogas production in farm-scale reactors was indeed very resilient towards differences in loading rate and the mixing ratio of the substrates (PM/RS and WH). This is very assuring since the underlying principles (microbiology and biochemistry) of the biogas process is quite complicated and not easily comprehendible for a farmer.

We have been very impressed how biogas farmers were able to operate biogas digesters for several years on a very empirical basis using high amounts of biomass. Despite of this we recommend that new biogas digesters should be installed in "clusters" of 4-5 reactors so that farmers can share experiences and help each other with technical problems (see also "Implementation/Recommendations" regarding Biogas Service Offices).

Fig 6: Students measuring biogas production at the CTU Biogas Park.

Fig. 7: Outlet of IHDPE digester (Biogas Park, CTU).

Fig. 8: Twin IHDP digesters (Biogas Park, CTU).

Fig. 9: Participants at a SubProM workshop inspect IHDPE digesters in the Biogas Park

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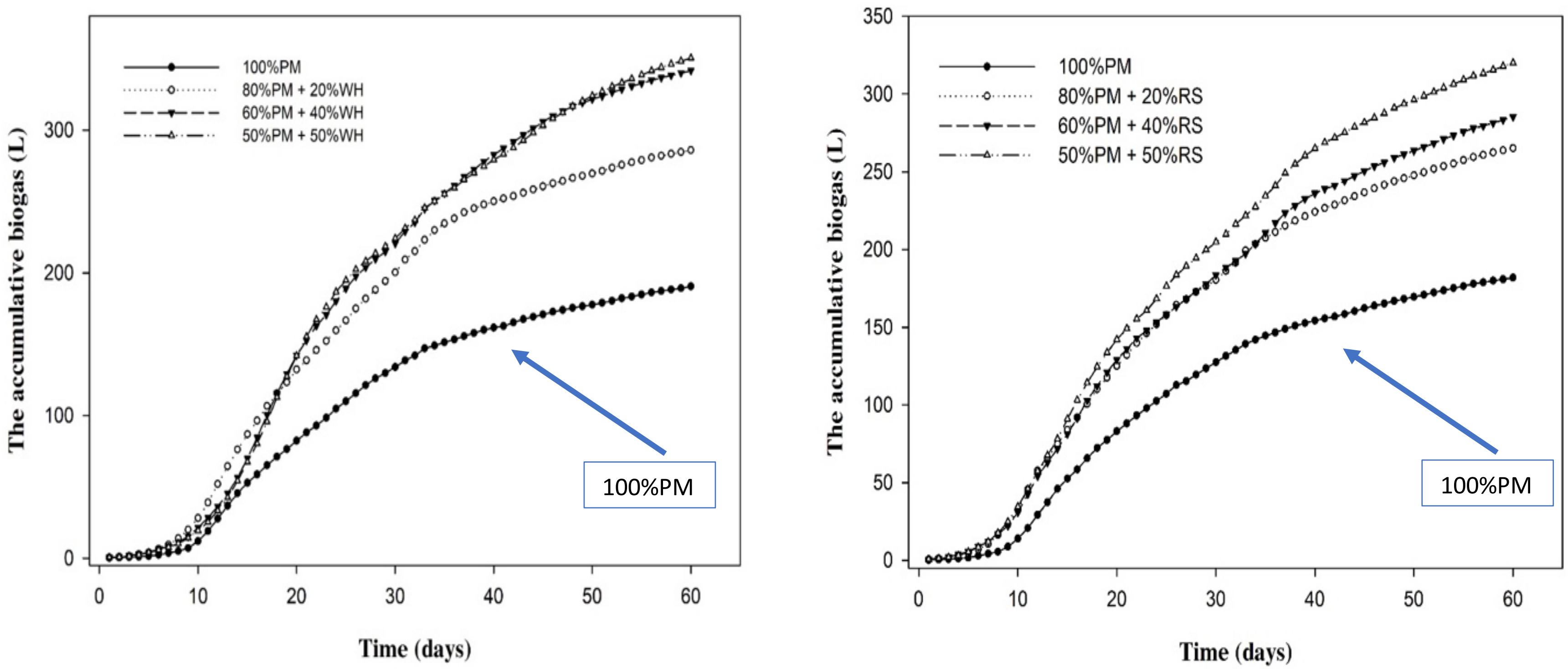

Fig. 10: ***RS and WH biomass boost biogas production in anaerobic digestion.***

Lab-scale batch experiments showing that biogas production is significantly enhanced when pig manure (PM) is co-digested with biomass (WH or RS).
All reactors received the same amount of organic substrate as based on volatile solids (VS).
From: N. V. Chau Ngan et al.,2015

References//Follow up reading

A social cost-benefit analysis of biogas technologies using rice straw and water hyacinth as feedstock. J. Bentzen, Ngo Thi Thanh Truc and Tran Sy Nam. Submitted to (under review): International Energy Journal. Asian Institute of Technology, Thailand.

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