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ISBN: xxx-xxxx-xx-xxxxx, pp.xx-yy

Proceedings of the WasteSafe 2017 – 5th International Conference on
Solid Waste Management in the Developing Countries
25-27 February 2017, Khulna, Bangladesh

Potential of ANAEROBIC Digestion to Increase Food Chain Value of Aquaculture Systems

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Key words: *aquaculture, anaerobic digestion, food chain*

8.1 billion people in 2025, 9.6 billion people in 2050 and almost 11 billion people in 2100 – according to the latest estimates of the United Nations [UN, 2013] the earth will not only be more densely populated in future, the leaders of the world will also face huge challenges on how to allow an environment- and climate-friendly existence while securing the rising demand for food. Even today, over 800 million people are considered chronically undernourished by the Food and Agriculture Organization of the United Nations (FAO) [FAO, IFAD and WFP, 2014]. Although this number has decreased significantly over the past years, the situation is likely to become aggravating again, regarding the general global developments of:

• an increasing scarcity combined with a rising competition for the natural resources land and water,

• an ongoing degradation of soils, mainly due to agricultural over-exploitation and climate change [FAO, 2011],

• growing environmental problems like eutrophication caused by an intensification of terrestrial food production [FAO, 2011] and

• an over-exploitation of wild fish stocks [FAO, 2014].

Apart from a growing world population, the mean living standard is also increasing and general demographic patterns are changing. It is expected that global food production needs to increase by at least 50% until 2050 in order to secure the world's food demand [FAO, 2009]. It is further assumed that the delivery of animal proteins is getting more important and meat production needs to be almost doubled in this time [FAO, 2009]. Terrestrial food production, however, is almost reaching its limits as valuable cropland is becoming scarcer and currently managed areas are increasingly under pressure due to climate change and degrading soils. This quotation of the latest report of the FAO on the global fishery and aquaculture industry underlines today's importance of fish production for the global food supply. However, the production of fish is not equally distributed across the continents. The strongest increase in total fish production and aquacultural fish generation in particular has been observed in Asian countries. In 2012, around 59 Mio. tonnes and thus, almost 90% of the total aquacultural grown fish, have been produced in Asian aquaculture systems with around 41 Mio. tonnes alone in China. Compared to the 2.9 Mio. tonnes produced in European aquaculture farms, the dominating role of this country becomes obvious. [FAO, 2014] Bangladesh has a unique position in the sub-tropical region, within the delta of three great rivers, the Ganges, the Brahmaputra (and Jamuna) and the Meghna covering an area of 14,4 million ha. In view of this important river system, inland fisheries and aquaculture are prime contributors to food security and employment. About 1,2 million people find jobs in inland water fishing, while another 0,3 million people find jobs in marine fishing. Fish provides 55 percent of animal protein intake in Bangladesh.

Modern technologies, like recirculating aquaculture systems (RAS), have been developed to allow a more sustainable fish production. However, the widespread commercial implementation is still insufficient, mainly due to their high investment and operational costs. Surprisingly, a proper waste management concept for the generated organic-rich sludges has still not been worked out. Nevertheless, efficient waste treatment will be essential to reduce the operational costs and to allow a broad-based market launch of RAS even for the production of low-cost food. In this context, anaerobic digestion (AD) was suggested as the probably best (i. e. most efficient) solution to stabilize aquaculture sludges, where – at the same time – valuable biogas for a further utilization is produced. The main aim of this work is to condense and extend the recent knowledge of the general digestibility of aquaculture sludges and to validate the ability of AD technologies to enhance the energy efficiency of RAS. Biochemical methane potential assays (BMPs) with sludge from a pilot-scale tilapia freshwater RAS have been conducted at Chulalongkorn University in Bangkok, Thailand.

ISBN: xxx-xxxx-xx-xxxxx, pp.xx-yy

Furthermore, a co-digestion with cassava was tested as a potential practical approach to stabilize the process and to increase gas yield.

In comparison to other research results, the tilapia sludge like analyzed in this study had a low gas yield, which could be either due to its worse quality compared to conventional RAS sludges or due to the already mentioned process inhibition.

Summary of the main test results

	100/0 n.n.	100/0 w.n.	80/20	60/40	40/60	20/80	0/100
Ymax	118.1	146.9	223.6	282.4	358.2	432.4	593.1
[NmL g−1 VSadded]	(2.90)	(1.60)	(9.10)	(3.00)	(2.50)	(4.70)	(1.80)
t0.5	9.4	14.9	3.5	3.1	3.1	3.2	3.1
[days]	(1.10)	(2.30)	(0.30)	(0.08)	(0.05)	(0.08)	(0.02)
VS reduction	58.3	79.6	55.8	77.9	89.9	73.2	94.8
[%]	(14.70)	(2.80)	(7.20)	(24.90)	(17.50)	(26.60)	(7.60)
biogas production	bipha-	bipha-	sig-	sig-	sig-	sig-	sig-
progress	sic; no lag	sic; no lag	moidal	moidal	moidal	moidal	moidal
co-digestion effect	–	–	neutral	antago-nistic	antago-nistic	antago-nistic	–

In case of the co-digestion assays, significant higher gas yields were measured, the higher the added cassava amount was. Except for sample 20/80 there was also a trend for higher VS removal efficiencies at lower sludge/cassava ratios. However, due to substrate inhomogeneities, deviations among the samples were high and thus, no significant differences could be found. Even in co-digestion samples with low cassava ratios, sigmoidal instead of biphasic gas curves were observed and half of the total gas amount was already measured after 3 till 3.5 days. Thus, a faster degradation was possible compared to the sludge mono-digestion. This indicated a more stable process. However, for no co-digestion ratio synergistic effects could be observed, probably due to the low S:I ratio and sub-optimal physicochemical characteristics of the chosen inoculum. Thus, it was assumed that potential synergistic effects, caused by a more optimal feedstock C:N through cassava addition, were superimposed by the properties of the inoculum. In summary, according to the targets of this investigation, following statements can be derived from the experimental results:

- gain more detailed knowledge about the composition of biofloc sludge with regard to its suitability for AD,
- determine the maximum gas and methane yields of different biofloc sludge types under optimal experimental conditions,
- further investigate a potential nutrient limitation of the sludge digestion (e. g. by testing different nutrient concentrations),
- analyze potential process inhibitions (e. g. by monitoring the ammonia concentration during the whole process) and
- test different co-substrates on their ability to improve sludge digestion.