Research article

# Studying on Pig Manure Treatment to Minimize Environmental Pollution and Use Bioenergy

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**Abstract** This research was carried out on a pig farm in the HUNG YEN Province of Vietnam from October 2008 to August 2009. The farm had 36 sows, selling about 1.5 tons of weaned piglets and 33 tons of live weight pigs per year. The piglets (from weaning to 15 kg) consumed on average 0.42 kg of feed/head/day and produced on average 0.25 kg of solid waste/day. The ratio of solid waste to feed consumed was 0.59. Pigs (from 15 to 30 kg) consumed on average 0.76 kg of feed/head/day, and the ratio of solid waste to feed consumed was 0.61. Growing pigs consumed 1.64 kg of feed/head/day and the ratio of solid waste to feed consumed was 0.49. This ratio for finishing pigs (>60 kg) was 0.46 and consumed feed was 2.3 kg/head/day. For the sows, this ratio was 0.43 for all periods including gestation and lactation. Over 24 hours in winter the biogas produced was on average 4.16 $m^3$/day in the 24$m^3$ biodigestor. This was much less than in summer (9.06 $m^3$/day). To create one kW electricity, 0.92 $m^3$ of biogas was needed. Pig manure treatment by biodigestor has considerably decreased some pollutants, including $BOD_5$ (Biological Oxygen Demand) concentration down by 77%, the COD (Chemical Oxygen Demand) concentration down by 83%, the dissolved sulphide concentrations down by 88%, the concentration of heavy metals $Cu^{2+}$ down by 52%, $Zn^{2+}$ down by 37%, the $Cl^-$ concentration down by 29% and $NH_4$-N down by 52%.

**Keywords** animal waste, biogas, liquid waste, solid waste

## INTRODUCTION

Livestock husbandry is an important world economic activity, comprising 40% of agricultural Gross Domestic Product (GDP) and creating jobs for 1.3 billion people. In Vietnam, it occupies 27% of agricultural GDP and creates jobs for more than 10 million people (GSO, 2009). However, it produces numerous wastes causing environmental pollution. Polluting compositions contained in livestock waste include organic and inorganic substances, and germs. These wastes can severely pollute the air and exert adverse influences on inhabitants' living environment, on the condition of water and land resources. Therefore it is necessary to undertake treatment of livestock wastes to minimize the above-mentioned adverse effects.

As well, energy requirements for societies are increasing so that biological energy sources are of interest to many countries. Many developing countries have utilized biogas sourced from livestock waste. From 1992 to 2005 about 70,000 biogas bags and 27,000 biogas digesters were installed in Vietnam. Biodigester use mainly focuses on supplying energy for daily activities yet efficiency levels are not high.

This research aims to (1) evaluate pig husbandry waste and waste treatment efficiency for use in biogas systems, and (2) evaluate biogas productivity in winter and summer and its efficiency for electric generators serving farming and everyday living.

## METHODOLOGY

The research was carried out on a pig farm in HUNG YEN province of Vietnam. We utilized models of pig husbandry farms treating waste for biogas systems and using biogas to operate electric generators.

We measured pig feed consumption and daily solid waste (manure) produced by different kinds of pig, including growing pigs (weaning till 15kg/head, growing from 15 to 30 kg/head, and growing from 60kg/head to slaughter age) and sows (from days 1 to 84 of gestation, from days 85 to 114 of gestation, and when suckled by piglets). Measurements included weight and pen data collected 8 times in each month from May to July in summer and from November to January in winter.

The liquid waste (measured as $m^3$/day) consisted of mucking-out water and remaining urine in pens. The research only dealt with daily mucking-out water. We identified the waste quantity (solid and liquid) used in biodigesters and for other purposes.

The coefficient of manure production was calculated by the following Equation (1).

$$\textit{Coefficient of manure production} = \frac{\textit{Produced manure (kg)}}{\textit{Consumed feed (kg)}} \quad (1)$$

Biogas productivity was estimated for the farm in winter and summer and for generated electric energy from biogas. Biogas production was estimated by volumetric measurement of biogas bags. Daily electric energy was measured for an electric generator running with biogas. The generator had an automatic gas adjusting system and electrical energy was measured by a watt-hour meter. The components of liquid waste were analyzed before and after treatment by the biogas system. Waste sampling was carried out according to Le Van Khoa et al. (2000) and analysing some chemical criteria such as $BOD_5$(Biological Oxygen Demand), COD (Chemical Oxygen Demand), dissolved sulphide, $Cu^{2+}$, $Zn^{2+}$, $Cl^-$, $NH_4$-N.

The process of study and analysis of waste samples is conducted directly on the farm and at the laboratory of the Specialized Animal Husbandry Department - Faculty of Animal Sciences and Aquaculture - Hanoi University of Agriculture. Waste samples are analyzed by means of 700, CODPC AQUALITIC Photometer.

## RESULTS AND DISCUSSION

### Pig production at the farm scale

The husbandry scale is a decisive factor of the waste quantity on the farm. The larger it is, the more the waste is produced. The pig husbandry scale of the studied farm is shown in Table 1.

**Table 1 Pig production scale of the studied farm**

| Pigs | Unit | Quantity |
|---|---|---|
| Sows | Head | 36 |
| Boar | Head | 3 |
| Number of piglets after weaning for sale | head/year | 200 |
| Weight of piglets after weaning for sale | ton/year | 1.5 |
| Number of fattened (finished) pigs ready for slaughter | head/year | 300 |
| Weight of fattened (finished) pigs ready for slaughter | ton/year | 33 |

The farm had 36 sows. The annual quantity of weaned piglets sold was 200 with a total weight of 1.5 ton. Weaned piglets are generally supplied to other pig farms within the area as breeding pigs. The remainder is retained by the farm for fattening; 300 pigs are fattened (finished) every year, a total of 33 tons of live weight pork.

### Pig manure production and treatment methods

The pig manure production is directly influenced by the consumed feed quantity and quality as well as the feed digestibility of each pig category. The research results are shown in Table 2.

**Table 2 Feed consumption and coefficient of manure rejection of different pig categories**

| Pigs | Number | Consumed feed (kg/head/day) | Rejected manure (kg/head/day) | Coefficient of manure rejection (manure/feed) |
|---|---|---|---|---|
| | | Mean ± SEm | Mean ± SEm | Mean ± SEm |
| Weaned -15kg | 48 | 0.42 ± 0.01 | 0.25 ± 0.01 | 0.59 ± 0.01 |
| 15 - 30 kg | 48 | 0.76 ± 0.01 | 0.47 ± 0.01 | 0.61 ± 0.02 |
| 30 - 60 kg | 48 | 1.64 ± 0.02 | 0.80 ± 0.02 | 0.49 ± 0.01 |
| 60 kg - finishing | 48 | 2.30 ± 0.02 | 1.07 ± 0.01 | 0.46 ± 0.05 |
| Sow in gestation I and waiting for insemination | 48 | 1.86 ± 0.01 | 0.80 ± 0.01 | 0.43 ± 0.01 |
| Sow in gestation II | 48 | 2.12 ± 0.01 | 0.88 ± 0.01 | 0.41 ± 0.01 |
| Lactating sow | 48 | 3.7 ± 1.54 | 1.62 ± 1.57 | 0.44 ± 1.58 |

These results show that pigs of different age have different coefficients of manure production. The coefficient of manure production varied from 0.46 to 0.61 for pigs from weaning to finishing and from 0.41 to 0.44 for sows in gestation and lactation.

According to Lochr (1984) (*in* Le Thanh Hai, 1997), daily manure production varied from 6 to 8% of pig weight. Hill and Tollner (1982) (*in* Le Thanh Hai, 1997) showed that the daily and nightly manure production of pigs with less than 10 kg of weight was from 0.5 to1 kg, for pigs of 15 to 40 kg was from 1 to 3 kg, and for pigs of 45 to 100 kg was from 3 to 5 kg (Le Thanh Hai, 1997). According to Porphyre and Nguyen (2006), imported sows produce 0.94 to 1.79 kg of manure/day and fattened pigs produce 0.6 to 1.0 kg of manure/day depending on seasons. The results in Table 2 are consistent with these numbers.

The results in Table 2, of typical waste quantities produced by different pig production categories, are essential to establish a pig housing plan and appropriate waste treatment, while minimizing environmental pollution. Estimates of average pig manure production on the farm are presented in Table 3.

**Table 3 Estimating manure production for fattened pigs and sows**

| Pig category | Fattened pig* (estimating for a fattened pig's life) | Sows (estimating for 1 year) |
|---|---|---|
| Consumed feed (kg) | 257.50 | 797.00 |
| Manure produced (kg) | 127.05 | 342.22 |
| Coefficient of manure rejection | 0.54 | 0.43 |

** Fattened pigs are counted after weaning to finishing, ready for slaughter (110kg)*

From Table 3 the estimated feed consumed during a fattened pig's life was about 258 kg (for about 105 days of breeding), the manure quantity produced was 127 kg, and the average coefficient of manure production was 0.54. For sows, annual feed consumption was 797 kg, the manure quantity produced was 342 kg, and the coefficient of manure production was 0.43.

### Biogas quantity produced in winter and summer, and efficiency of transformation to electric energy

Biogas is generated from waste treatment to produce clean energy with the objective of serving people's living activities. Biogas is generated from the anaerobic fermentation of treated manure. The quantity produced is influenced by temperature and the amount of manure supplied to the biodigester. Our research showed that in winter and summer the biogas quantities produced are quite different. In winter the mean temperature is 14.93 $^0$C and the mean relative humidity is 77.5%. In summer the mean temperature is 32.56 $^0$C and the mean humidity is 81.12%. For a biodigester volume of 24 $m^3$ the biogas quantity obtained after 24 hours in winter is 4.16$m^3$, in summer is 9.06 $m^3$ that means the summer quantity is 117% higher than the winter quantity.

**Table 4 Biogas generated by waste treatment in winter and summer**

| Criteria | Unit | N | Winter | Summer |
|---|---|---|---|---|
| | | | Mean ± SEm | Mean ± SEm |
| Temperature | $^0$C | 6 | 14.93 ± 0.14 | 32.56 ± 0.30 |
| Humidity | % | 6 | 77.50 ± 1.52 | 81.12 ± 0.36 |
| Manure led down to the biodigester | kg/day | 6 | 39.03 ± 2.09 | 40.18 ± 2.05 |
| Liquid waste led down to the biodigester | $m^3$/day | 6 | 6.85 ± 0.36 | 7.19 ± 0.42 |
| Biodigester volume | $m^3$ | 6 | 24 | 24 |
| Biogas generated after 24 hours | $m^3$/day | 6 | 4.16 ± 0.22 | 9.06 ± 0.46 |

The production of biogas can partly reduce environmental pollution and permit the users to save energy. According to Bui Van Ga et al. (2008), biogas mainly contains CH4 (50-70%), 1 m3 of burned CH4 can spread out a heat energy equivalent to that of 1.3kg of coal, 1.15 litre of petrol, 1.7 litre of alcohol. The efficiency of biogas transformation to electric energy is shown in Table 5.

**Table 5 Efficiency of biogas transformation to electric energy**

| Criteria | n | Winter | Summer |
|---|---|---|---|
| | | Mean | Mean |
| Biogas produced per day ($m^3$/day) | 6 | 4.16 | 9.06 |
| Number of kW generated (kW) | 6 | 4.50 | 9.80 |
| Biogas quantity generating 1 kW ($m^3$) | 6 | 0.92 | 0.92 |

The produced biogas is stored in a reserving bag system and used for domestic electric generators or cooking stoves. On the farm biogas is used for cooking stoves every day and for electric generators once every two days to save on network electricity. The biogas quantity necessary to generate 1 kW is 0.92 $m^3$. According to Bui Van Ga et al. (2008) a generator consuming 1$m^3$ of biogas can produce power of 1kW and reduce 1kg of $CO_2$ expelled to the atmosphere. The results in Table 5 expressing the efficiency of biogas transformation are higher than those of the above-mentioned authors.

**Chemical compositions of liquid waste before and after treatment**

Properties of liquid waste before pouring to the environment exert great influences on surroundings. No treated manure contains microorganisms, E.coli and worm-egg which are pathogenous to human and animal, COD content which many times surpasses the defined limit to environmental pollution level from husbandry waste. It can be a risk to pollute land, water and air. In order to assess the waste treatment method by biogas systems, we have conducted chemical composition analyses of liquid waste before and after treatment. Obtained results are shown in Table 6.

Our analyses showed that before treatment the $BOD_5$ concentration at 1030.11 mg/l was 3.43 times higher than the tolerable hygienic standard, and then the COD concentration at 2019.78 mg/l was 5.04 times higher than the tolerable hygienic standard. Vu Dinh Ton et al. (2008) showed that $BOD_5$ concentration on pig farms of HUNG YEN province was 4.1 times the tolerable hygienic standard and the COD concentration was 6.32 times the standard. According to LK (2005) the COD concentration in liquid waste of animal husbandry was 3,916 mg/l.

**Table 6 Chemical criteria of liquid waste before and after treatment of biogas**

| Criteria | Unit | N | Before treatment<br>Mean ± SEm | After treatment<br>Mean ± SEm | THS* |
|---|---|---|---|---|---|
| $BOD_5$ | mg/l | 6 | 1030.11 ± 2.86 | 235.50 ± 3.29 | 300 |
| COD | mg/l | 6 | 2019.78 ± 3.81 | 341.81 ± 2.55 | 400 |
| Sulfua | mg/l | 6 | 28.45 ± 0.45 | 3.37 ± 0.15 | 1 |
| $Cu^{2+}$ | mg/l | 6 | 0.67 ± 0.22 | 0.32 ± 0.03 | 5 |
| $Zn^{++}$ | mg/l | 6 | 0.35 ± 0.04 | 0.22 ± 0.01 | 5 |
| $Cl^-$ | mg/l | 6 | 336.57 ± 5.75 | 237.50 ±1.45 | - |
| $NH_4$-N | mg/l | 6 | 6.51 ± 0.13 | 3.13 ± 0.05 | 5 |

** Tolerable hygienicstandard (according to 10TCVN 678 – 2006)*

Our results in Table 6 show that after treatment by biodigestor both of $BOD_5$ and COD criteria were within the tolerable limit of hygienic standards. The $BOD_5$ concentration was decreased by 77% to 235.50 mg/l and the COD concentration decreased by 83% to 341.81 mg/l. According to Vu Dinh Ton et al. (2008), after liquid waste treament by biodigester, $BOD_5$ concentration was reduced by 75 to 80%, COD concentration down by 64.9 to 66.9%. The Institute of Energetic Sciences assessed that $BOD_5$ and COD concentrations were reduced 30 times after treatment by biodigesters.

## CONCLUSION

The coefficients of manure production for different pig categories are considerably different. The results from our farm study show that sows have the lowest coefficient (0.43), followed by fattened pigs from 60 kg to finished (0.46), and pigs from 15 kg to 30 kg have the highest coefficient (0.61). The on-farm produced biogas quantity differed between winter and summer (in summer it was 117% higher than in winter). This was due to lower temperatures in winter which are unfavourable for the development of microorganisms. The coefficient of biogas transformation to electric energy was relatively high (0.92 $m^3$), generating 1 kW. Using biogas digestors can reduce environmental pollution, especially with respect to BOD5 and COD concentrations.

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