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METHANE PRODUCTION FROM SWINE WASTE WITH A MESOPHILIC SOLAR-HEATED REACTOR

The development and operation of a mesophilic solar reactor without supplement heating for methane production from swine waste are discussed. The 1890 dm^3 reactor received the waste from 11 to 45 kg hogs. Results for an operational strategy to optimize methane production and not treatment efficiency show maximum biogas production of 0.88 m^3/kg VS destroyed with a composition of 64 % methane and 28 % CO_2 and an energy rating 2.66 MJ/d for the waste of a 45 kg hog. Solar heating was effective but distillation of a high quality condensate for waste volume reduction was not judged feasible for this reactor.

1. INTRODUCTION

The utilization of animal manure as a fertilizer for crop production is well-known and widely practiced throughout the world. Recently, increased emphasis has been directed to land application as the best recommended animal waste management practice for pollution control and waste utilization. Efforts to produce methane from animal waste have also increased due to utilization or energy conservation interests. Methane has been successfully produced from organic wastes with individual reactors in many areas, and anaerobic sludge digesters at sewage treatment plants reliably produce methane in many countries. The high organic content of animal manures and general composition similarity to other wastes successfully fermented to methane, as well as initial technical successes, justify increasing global interest in methane production from animal wastes. Thus animal waste treatment and energy conservation have become unanticipated synonyms which are gaining accelerated attention from both the general public and trained professionals.

A detailed literature review of animal waste digestion by high rate methane generation has been assembled by SHADDUCK and MOORE [8] where the results for a variety of animal wastes and experimental conditions are presented. An evaluation of methane digesters, as pretreatment utilization schemes prior to land application systems, has also been pre-

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sented [6]. Basic principles concerning methane digesters for fuel gas and fertilizer with complete instructions for two working models have been presented by FRY [3] in a manner which is most helpful for general interest audiences.

PORTEOUS [7] concluded that solar distillation is practical between latitudes 35°N to 35°S. This embraces all global arid zones. There is obviously a wide range of solar radiation intensities for these regions with the highest being in the desert region of Africa and the United States. Most solar stills operate at between 50°C to 65°C which gives a large temperature difference between the water vapour inside the still and the outside or ambient temperature. Performance analysis of solar stills indicates entrapment of about 85% of the incoming solar radiation.

The purpose of this study was to examine the anaerobic digestion of swine wastes with solar heating assistance to improve methane production. Another facet of the digester was solar distillation to yield high quality condensate and thus reduce the effluent waste volume. Examinations of the effect of mixing, a heat balance, and the temperature response of this solar-heated methane generator were also undertaken.

2. EXPERIMENTAL FACILITIES AND PROTOCOL

A 1.2 m by 1.2 m (4 ft) by 1.2 m steel tank having a reactor liquid volume of 1890 dm^3 (500 gal), with an inverted pyramid bottom sloped at 30° with respect to the horizontal was constructed to serve as the study reactor, figures 1 and 2. The top of the reactor was sloped at 20 degrees with respect to the horizontal for better sun penetration and condensate removal. The reactor top faced south to allow better entrapment of solar energy for the site latitutde, 36°N. The transparent top was designed to test two materials side by side, glass and plexiglass.

Two, 5 cm diameter ports were installed into the bottom of the tank and extended up into the liquid. One port opening was 15 cm from the tank bottom and the other 15 cm from the liquid surface, fig. 2. Recyling of reactor liquid through these discharge ports provided unit mixing. Sampling was through a 1.25 cm diameter pipe with an opening 15 cm below the liquid surface. A 15 cm diameter hole was cut in the back side of the tank and a 0.30 mm vinyl sleave was attached for access to measure radient energy transfer through the top materials.

Gas was removed through a 1.25 cm diameter pipe extending into the top portion of the reactor where the gas was allowed to accumulate. Gas was exhausted to the atmosphere when the pressure exceeded the friction resistence of the wet test meter (approximately 0.25 cm of water) used to measure gas volume.

Reactor moisture condensed on the underside of the solar panel materials and drained to the collecting trough. Condensate from each top material was collected separately in bottles underneath the reactor. The condensate drain lines had "U" tubes to maintain a system pressure sufficient for wet test meter operation and also to serve as relief values in case of restrictions due to wet test meter blockage or gas line clogging. A third "U" tube

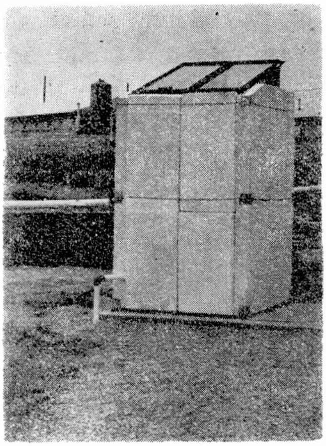

Fig. 1. Photograph of solar-heated methane generator

Rys. 1. Fotografia generatora metanowego ogrzewanego energią słoneczną

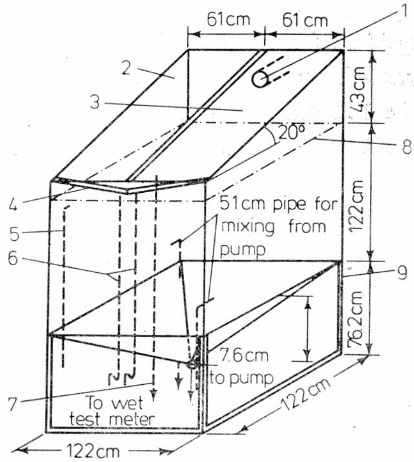

Fig. 2. Schematic of solar-heated methane generator

Note: All pipe shown as single dotted line: *1* — acces port vinyl tube, *2* — plexiglas top, *3* — glass top, *4* — condensate collector, *5* — sampling port, *6* — condensate removal ports 1.3 cm pipe, *7* — gas removal pipe, *8* — liquid level, *9* — 6.4 cm × 6.4 cm × 6.4 cm support angles

Rys. 2. Schemat generatora metanowego ogrzewanego energią słoneczną

Uwaga: wszystkie rurociągi są oznaczone linią przerywaną *1* — winylowy króciec wlotowy, *2* — pokrywa z plexiglasu, *3* — pokrywa ze szkła, *4* — zbieracz kondensatu, *5* — króciec do poboru prób, *6* — króćce do usuwania kondensatu, *7* — króciec do usuwania gazu, *8* — poziom cieczy, *9* — podpory 6.4 × 6.4 × 6.4cm

relief valve was constructed into the back of the tank as a precautionary measure after one incident resulting in a ruptured top.

The tank was insulated by the use of 15 cm rigid polystyrene to maintain reactor temperature during low radient energy inputs. This was only partially successful in maintaining a temperature of about 36°C because of installation and maintenance deficiencies. Subsequently 0.15 mm black polyethyene was placed around the insulation to reduce convective losses from large seams and separations between the 1.2 m by 2.4 m pieces of insulation.

Mixing was accomplished by pumping through the 7.6 cm diameter intake port in the pyramid bottom of the tank and two, 5 cm diameter discharge ports in opposite corners of the tank, one with the discharge 15 cm from the bottom of the tank and the other one 15 cm from the liquid surface. Mixing duration was controlled by a 15-minute cycle timer which could be adjusted to operate for any portion of a 15-minute cycle. A microswitch on the timer operated a NEMA 1 magnetic starter which completed the circuit for pump engagement. A $3.7 \cdot 10^3$ N Gorman Rupp pump capable of handling 7.6 cm solids was used for pumping and mixing the reactor contents.

Liquid samples were taken from the 1.25 cm diameter pipe with an inlet 15 cm below the liquid surface. The mixing pump was allowed to run for two minutes before sampling and was left running during the sampling event to allow as representative sample as possible. The 1.25 cm gate valve was opened and one dm^3 of liquid was taken from the reactor in order to remove the waste that had settled in the pipe from previous sampling. A second dm^3 of liquid was immediately taken and 180 cm^3 transferred into a sample bottle for analyses. All chemical analyses were performed according to standard test methodologies [1] and adaptions proven for animal wastes [5].

Gas samples were taken by connecting a 250 cm^3 gas sampling tube to the gas removal pipe. The 250 cm^3 sampling tube was first filled with distilled water which was then displaced by gas. This gas sampling method minimized air contamination.

The methane (CH_4), carbon dioxide (CO_2), oxygen (O_2), and nitrogen (N_2) content of the reactor gas (biogas) was determined by a Fisher Orsat Gas Apparatus Model No. 10-605 which uses an absorption manometric technique. The CO_2 was determined by taking a 50 cm^3 sample of the gas and absorbing the CO_2 in a solution of potassium hydroxide. The O_2 in the sample was determined by absorption in a solution of alkaline pyrogallate. The CH_4 was determined by combusting the remainder of the 50 cm^3 sample in a pure atmosphere of O_2 with a platinium catalyst. The remainder of the gas volume was assumed to be other gases resulting from anaerobic fermentation.

The reactor fluid and gas temperature was monitored by a Rustrak Model 90 recorder. The bimetalic sensing element was attached to the steel tank bottom and a piece of polystyrene was used to insulate the probe from the surrounding atmosphere. The recorder was connected to the timer measuring the fluid temperature when the mixing cycle occurred. The total amount of incoming radiation from the sun was measured with a radiometer. The probe was placed within the reactor in the same plane as the sloped reactor top and the measurement made directly.

Swine wastes were used as the input microbes and microbial substrates. Swine waste was obtained weekly from a 7,500 dm^3 mixing tank receiving all the waste emptied from one of four underslat pits located in two adjacent swine confinement buildings. Animals were raised from 10 kg to 100 kg in these units and the waste management involved pen scraping and minimal water spillage. A slurry sample from the mixing tank was brought to the laboratory and blended to improve homogeneity and analyzed for chemical oxygen demand (COD). The waste was then diluted to about 40,000 mg COD/dm^3 for reactor input. In this manner field concentration variations (40,000 to 110,000 mg COD/dm^3) were reduced to the lower level of analytical variability and the reactor inputs were then representative of average characterization values per 45 kg hog in 7.5 dm^3 of wastewater volume (expected concentrations when extraneous water inputs are minimized). A total volume of 570 dm^3 per week was loaded to the digester in three equal increments through the week. Thus the waste input was equivalent to the generated from about 11, 45 kg hogs. The raw waste was added while the reactor contents were being mixed simultaneously with the withdrawal of an equal volume of reactor contents. Waste input and reactor concentrations are summarized in table 1.

Table 1

Performance of solar-heated anarobic digester for swine waste

Charakterystyka pracy beztlenowej komory fermentacji ścieków ogrzewanej promieniowaniem słonecznym

Wastewater

	Input waste	Effluent or mixed reactor contents
	mg/dm³	
COD	40,000	23,000
TOC	12,000	7,500
VS	24,000	10,500
TS	31,000	19,000
TKN	3,100	3,100
pH		7.6

Reactor operation

Reactor volume	— 1890 dm^3
Reactor loading	— 570 dm^3/week
Reactor detention time	— 3.3 weeks

Gas produced

4/15/74-5/27/74	34.2 m^3 = 5.7 m^3/wk
6/3/74-6/24/74	27 m^3 = 9 m^3/wk

Gas composition

CH_4	64%
CO_2	28%
Others	8%

3. RESULTS AND DISCUSSION

Gas production was measured during two periods in which different ambient and reactor fluid temperatures were measured. The first period was 4/15/74 to 5/27/74 when the reactor and ambient average temperatures were 26°C (range 24°C to 28°C) and 20°C (range 10.5°C to 25.5°C), respectively. Average temperatures during the second period, 6/3/74 to 6/24/74, were 29°C (range 26°C to 31°C) and 22°C (range 17°C to 27°C) for the reactor liquid and ambient air temperature, respectively. During the average temperature period of 26°C, the gas production was 5.7 m^3 per week; while at the higher temperature period of 28°C, 9 m^3 per week of gas were generated. Since the solar input also heated the gas produced in the space at the top of the reactor, the change in volume per mass of gas produced due to thermal expansion was determined. Using gas space temperatures, this expansion would amount to only approximately a 4% increase in apparent volume; and hence recorded gas increases were judged to be primarily due to increased biological production kinetics.

During the period of 4/15/74 to 6/24/74 the gas produced from the solar-heated reactor had a fairly uniform concentration of 64 % CH_4 and 28 % of CO_2. Water vapour accounted for 4 to 5 % of the gas volume with the remainder being H_2S, NH_3, N_2, and other volatile components. Assuming a heat value of 22.5 MJ/m³ for anaerobically generated biogas [3], the energy content of the reactor gas produced was calculated. At the average production rate of 7.3 m³ per week (4/15/74 to 6/24/74), the digestion gas was equal to 165 MJ per week or an equivalent of about 4.8 dm³ of gasoline.

The methane-base natural gas requirements of an average person with the United States standard of living has been estimated to be 63 MJ per day. Based on the maximum measured gas generation of 1.3 m³ per day estimated BTU content (22.5 MJ/m³), this reactor could supply about 46 % of such per capita daily natural gas requirements. Assuming methods were available to conserve all energy from the investigated reactor and maximum production rates could be maintained, then the manure from about 24 hogs would supply the per capita U.S. daily natural gas energy needs.

As a pretreatment process for animal waste, high rate anaerobic digestion must be evaluated in regard to changes in chemical content of the input wastes. Primary reduction in waste concentration was found for the parameters reflecting organic content; i.e., chemical oxygen demand (COD), total organic carbon (TOC), volatile solids (VS) and total solids (TS), table 1. A 42 % reduction of COD and a 37.5 % reduction of TOC were measured. The VS removal was approximately 56 %, and in terms of changes in reactor concentration magnitudes was similar to measured TS losses thus indicating internal measurement consistency.

A comparison was made of the gas generation per unit amount of volatile solids destroyed, a common performance parameter for methane generators [8]. Because of gas and volatile solids measurement variabilities, the weekly ratio fluctuated considerably. However, over the 63-day evaluation period, the average biomass gas generation was about 0.88 m³/kg VS removed (at standard temperature and pressure), table 1. An additional comparison was made between the carbon content of the gas generated and carbon loss from the swine waste added to the reactor. In relation to the gas content, the loss of TOC in the reactor liquid was about 25 percent less, indicating the variability of the overall experimental data.

The total Kjeldahl nitrogen (TKN) of the reactor contents was approximately equal to that of the raw waste input indicating no substantial loss. A TKN loss, if it occurred, would be by means of ammonia volatilization. Because ammonia is highly soluble in the aqueous phase and gas volumes removed were small, nitrogen losses in the biogas removed were minimal. Thus in terms of the final land receiver, the methane reactor is highly conservative of nitrogen. In comparison to all other available animal waste pretreatment processes, methane generators yield the greatest conservation of nitrogen [6]; and with the selective conversion of organics to biogas, an additional fraction of animal waste is also utilized.

On objective of utilizing direct solar heating of swine wastes was to determine the feasibility of distilling high quality water and concentrating the waste to reduce the residue volume to be applied to land. The average condensate production rate from the glass cover was about 1.5 $dm^3/d/m^2$ cover area. Only about 0.5 $dm^3/d/m^2$ was produced from the plexiglas side. The maximum condensate production from the glass side was 2.0 $dm^3/d/m^2$ which was only about 2.5% of the reactor volume loading rate. Therefore, very little distillation or volume reduction occurred. The average glass side condensate rate was 25 to 60% of the rates described by researchers using saline water [7, 4]. During the 9-month operation period neither the glass nor the plexiglas became deteriorated.

The condensate appearance was quite clear with a COD of less than 30 mg/dm^3. The ammonia content was, however, quite high reaching 1,200 mg NH_3-N/dm^3. Of course the distillate would contain soluble volatile compounds; hence, the high ammonia content. The condensate quality was not sufficient to consider stream discharge of this effluent. Thus in terms of major reductions in waste volume or the production of high quality effluent, the concept of solar distillation of swine waste did not appear feasible.

3.1. EFFECT OF DIGESTER AGITATION

Mixing the contents of the solar-heated anerobic digester can potentially increase methane production. By agitating the reactor contents, the entire volume is used for biological growth since stratification of nutrients and microorganisms is minimized. A second benefit of mixing the solar-heated liquid is to prevent temperature gradients associated with heating the upper digester liquid. Mixing then would also improve heat transfer and temperature uniformity.

An initial mixing procedure of two minutes out of each 15 minutes did not prove satisfactory because of excessive foaming during the mixing cycle. The foam was so extensive that it clogged the entire system, including the blowoff ports, and thus excessive pressure developed within the reactor causing the glass top to rupture. The second mixing procedure of 15 seconds out of each 14.75 minutes satisfactorily solved the foaming problems.

After a number of detailed gas evolution measurements within a 15-minute cycle, it was demonstrated that there was a rapid gas generation during the early part of the cycle. Between 60 and 80% of all the gas generation in a 15-minute cycle was complete in the first five minutes. One possible explanation is that the agitation caused coalescence of small bubbles which were then liberated immediately after the mixing. If this were true, the agitation would not affect the overall steady-state generation of gas since that is controlled by microbial metabolism and not the short-term liberation phenomena. Thus agitation would not be justified. A second explanation is that the agitation provided more intimate contact of microbes and waste nutrients; thus the enhanced gas generation reflects greater microbial activity under these conditions. More frequent short mixing (possibly 15 seconds every 5 minutes) would then result in greater overall steady-state gas production. The justification for such mixing would then be dependent upon an economic balance between increased gas energy generated versus pump energy requirements. In any event, more experimentation is needed to clarify the mechanic and economic impact of mixing on anaerobic methane generation from animal waste.

3.2. SOLAR INPUTS AND HEAT BALANCE

In considering the overall energy balances of a solar-heated anaerobic digester, the thermal losses are associated with heat transfer between the reactor and ambient air, and the heat required to raise the swine waste temperature to that of the reactor liquid. Thermal gains are associated with the solar radiant energy captured by the reactor and the methane gas produced. During the winter months the thermal losses were greatest and the reactor, as constructed, maintained a temperature gradient of about 11°C above ambient conditions with the lowest reactor liquid temperature being 18°C during the coldest ambient temperature of 7°C recorded in mid-February. Higher temperature differences and achievement of the mesophilic optimum of 36.7°C during warmer months were not achieved because of problems in maintaining adequate reactor insulation. The 30-year annual average is 15.3°C with the lowest monthly average being 5.3°C in January and highest being 26.2°C in July.

An approximate energy balance was performed for this physical system as a design tool for future solar-heated reactors. Standard equations for thermal conductance and corresponding convection heat transfer coefficients to ambient air from the ASHRAE Handbook were used. Solar energy inputs were based on winter conditions and equalled 8.9 MJ/m^2/d. Results given in table 2 show that without insulation the heat losses far exceeded energy gains or methane production. However, as insulation was added the gap between energy loss and gain was reduced until with approximately 15 cm of rogod polystyrene, a thermal flux balance was achieved. More insulation would result in a net heat gain and thus the cost of insulation must be weighed against the value of methane gas produced.

Table 2

Approximate energy balance for solar-heated anaerobic digester

Przybliżony bilans energetyczny ogrzewanej energią słoneczną komory fermentacji beztlenowej

	Sides and bottom	Clear solar panels	Solar input through clear* panels	Methane production**	Sensible heat for swine waste	Energy
	MJ/wk					
Totally uninsulated	−329	−0.25	13	29	7.12	−294
Sides and bottom covered with:						
a. 1.3 cm fiberboard	−162	−0.25	13	29	7.12	−120
b. 15 cm rigid polystyrene	−32.7	−0.25	13	29	7.12	+10

* December — 30 yr monthly average is 5.5°C and solar input equalled 8.9 MJ/m^2/d

** Maximum Recorded Rate, 1.3 m^3/d or 29.25 MJ/d

A detailed study of the temperature and radiation inputs over a 24-hour cycle was performed, fig. 3. The gas temperature followed the ambient air temperature (being 5–10° C higher) until the solar radiation began. Then the gas temperature rose substantially. The liquid, having a much higher heat capacity, did not rise in temperature as much as the gas phase; but over the 24-hour period there was a net increase in reactor liquid temperature.

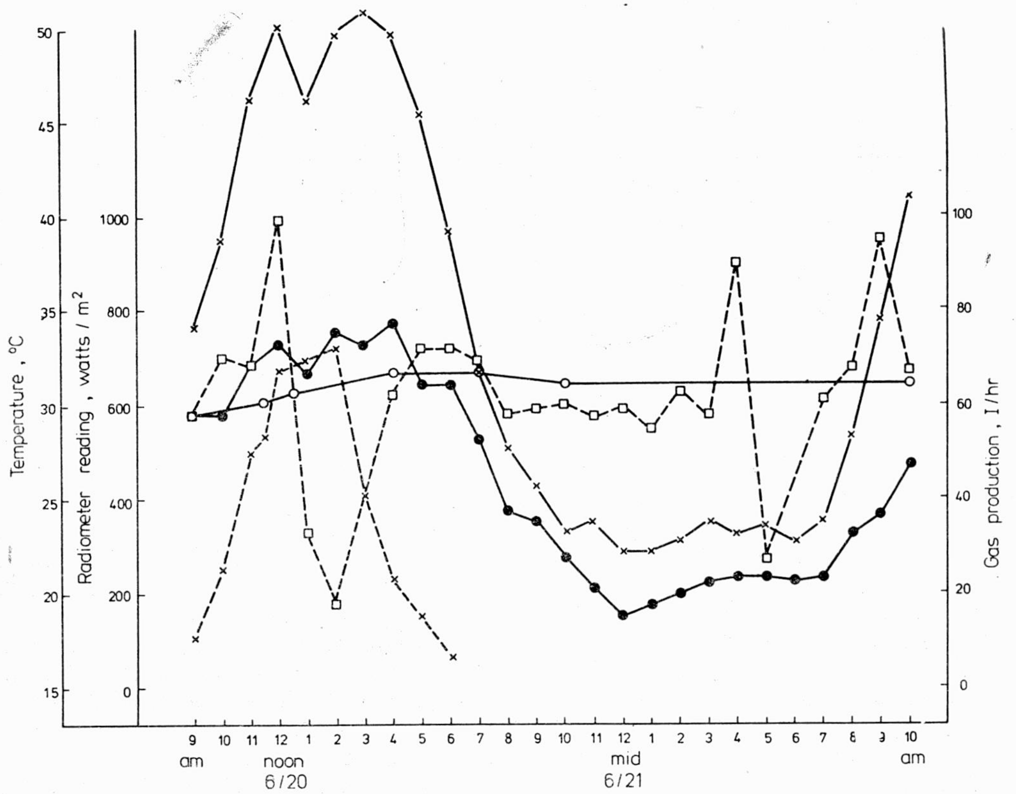

Fig. 3. Temperature and radiation inputs over a 24-hour cycle fo ɹthe solar-heated methane reactor o——o ambient air temperature, °C; ×——× gas temperature within reactor, °C; ●——● reactor liquid temp., °C; × – – – – × rad. reading, walts/m², □– – – – □ gas production, l/hr

Rys. 3. Dopływ promieniowania i zmiany temperatury dla reaktora metanowego ogrzewanego energią słoneczną

o——o temperatura otoczenia, °C; ×——× temperatura gazu w reaktorze, °C; ●——● temperatura cieczy w reaktorze, °C; × – – – × natężenie promieniowania, wat/m²; □——□ produkcja gazu, l/h

No substantial conclusion could be regarding methane gas generation since the methane production was erratic. However, except for several deviations, the gas production was fairly constant with time indicating a primary dependence on bulk liquid temperature and microbial kinetics rather than gas phase or liquid surface temperature effects.

SUMMARY

The pretreatment of swine wastes by high-rate anaerobic digestion was evaluated. The COD and TOC reduction were about 40 %, while VS removal was about 55 % for a loading rate of 1.76 kg COD/d/m³ or 1.6 kg VS/d/m³ of reactor volume. Total nitrogen losses were minimal.

The operational strategy to optimize methane production and not treatment efficiency resulted in a maximum biogas production of 1.3 m³ per day or about 29.25 MJ/d at a rating of 22.5 MJ/m³ of biogas which according to the steady-state input was about 2.66 MJ/d from the waste of a 45-kg hog. Biogas generation for the total 63-day experimental period averaged 0.88 m³/kg VS destroyed with a composition of 4 % CH_4 and 28 % CO_2. Mixing resulted in enhanced short-term gas evolution, but the steady-state effect on total gas generation was not documented. Calculations based upon study results and theoretical consideration indicate that utilization of direct solar heating, through clear plexiglas or glass, and proper insulation of reactor walls could result in a system which will operate near optimum mesophilic temperatures without supplemental heating.

REFERENCES

[1] American Public Health Association (APHA), Standard methods for the examination of water and wastewater, 13th Edition, New York 1971, 354 pp.

[2] ASHRAE Handbook, Fundamental and equipment, George Banta Co., Menasha, Wisconsin 1966.

[3] Fry J. L., *Methane digesters for fuel gas and fertilizer with complete instructions for two working models*, New Alchemy Institute Newsletter No. 3, Spring 1973, Box 432, Woods Hole, Massachusetts, 02543.

[4] Hay H. R., *V-cover solar stills*, Sun at Work, 2nd Quarter, 1966.

[5] Overcash M. R., Hashimoto A. G., Ridell D. L., and Day D. L., *Evaluation of chemical analyses for animal wastes* [In:] *Standardizing Properties and Analytical Methods Related to Animal Waste Research*, St. Joseph, Michigan American Society of Agricultural Engineers, pp. 333–355, 1975.

[6] Overcash M. R. and Humenik F. J., *State-of-the-art: swine waste production and pretreatment processes*, EPA-600/2-76-290, Environmental Protection Agency, Ada, Oklahoma 1976, 167 pp.

[7] Porteous A., *The theory, practice and economics of solar distillation*, Chemical Engineer No. 225, November 1971, pp. 406–411.

[8] Shadduck G. and Moore J. A., *The anaerobic digestion of livestock wastes to produce methane*, Agricultural Engineering, St. Paul, University of Minnesota 1975, 103 pp.

PRODUKCJA METANU Z GNOJOWICY ŚWIŃSKIEJ W MEZOFILOWYM REAKTORZE OGRZEWANYM ENERGIĄ SŁONECZNĄ

Przedstawiono budowę i zasady działania mezofilowej komory fermentacji dla produkcji metanu z gęstej gnojowicy świńskiej: Reaktor o pojemności 1890 dm³ przyjmował ścieki od 11 świń o wadze 45 kg, o stężeniu rozcieńczonym do stałej wartości ok. 40 000 mg/dm³ — ChZT. Działając jako urządzenie podczyszczające reaktor spowodował obniżkę 40 % ChZT i CWO (całkowity węgiel organiczny) oraz 55 % ZL (związków lotnych) przy obciążeniu 1.76 kg ChZT/m³·d, lub 1,6 kg ZL/m³d, przy minimalnych stratach azotu.

Pracując nad maksymalizacją produkcji gazu (PG) uzyskano średnią PG 0,88 m³/kg ZL rozłożonych, przy składzie średnim w ciągu 63 dni pracy komory 64 % CH_4 i 28 % CO_2. Mieszanie nie poprawiało produkcji gazu. Obliczenia dowiodły, że wykorzystanie energii słonecznej w warunkach dachu z przezroczystego szkła organicznego i dobrej izolacji ścian może spowodować wystąpienie optymalnych warunków fermentacji bez dodatkowego ogrzewania.

METHANPRODUKTION AUS SCHWEINEGÜLLE IM MESOPHILEN, MIT SONNENENERGIE BEHEIZTEN REAKTOR

Dargestellt wird das Prinzip und die Wirkungsweise einer mesophilen Faulkammer zur Methanproduktion aus Schweinegülle. Dem Reaktor von 1,89 m^3 Inhalt, flossen Abwässer mit einer konstanten CSB-Konzentration = 40000 g/m^3, von elf 45 kg schweren Schweinen zu. Der Reaktor, als Vorreinigungsstufe gedacht, baute den CSB und den organischen Kohlenstoff um 40 % die flüchtigen Stoffe um 55% ab, bei einer Belastung von 1,76 kg CSB/m^3 d bzw. 1,6 kg org. TS/m^3d und bei minimalen Stickstoffverlust.

Der maximale Gasertrag war 0,880 m^3/kg org. TS wobei während den 63 Tagen der Prozessführung das Gas sich aus 64 % Methan und 28 % Kohlenstoffdioxyd zusammensetzte. Das Mischen des Reaktorinhaltes brachte keine Erhöhung der Gasmenge. Entsprechende Berechnungen ergaben, daß die Nutzung der Sonnenenergie möglich ist. Das kann durch die Abdeckung des Reaktors mit einer durchsichtigen Kunststoffplatte und durch gute Isolierung der Wände erreicht werden, was auch zur Optimierung der Bedingungen der Fermentation führen kann.

ПРОИЗВОДСТВО МЕТАНА ИЗ СВИНОЙ ЖИЖИ В МЕЗОФИЛЛОВОМ РЕАКТОРЕ, ОБОГРЕВАЕМОМ СОЛНЕЧНОЙ ЭНЕРГИЕЙ

Представлены строение и принципы действия мезофилловой бродильной камеры для производства метана из густой свиной жижи. В реактор, объемом в 1890 дм³, поступали стоки от 11 свиней, весом 45 кг каждая; концентрация была разбавлена до постоянного значения — ок. 40 000 мг/дм³ ХСК. Действуя в качестве установки для частичной очистки, реактор получил снижение на 40% ХСК и полного органического угля, а также 55% летучих соединений при нагрузке 1,76 кг ХСК/м³ · д или 1,6 кг/м³д при минимальных потерах азота.

Работая с точки зрения максимизации производства газа, получили в среднем 0,88 м³/кг разложенных летучих соединений при среднем составе в течение 63 дней работы камеры 64% CH_4 и 28% CO_2. Перемешиванием не добивались улучшения производства газа на более длительное время. Расчеты показали, что применение солнечной энергии при наличии крыши из прозрачного органического стекла и хорошей изоляции стен может вызвать возникновение оптимальных условий для брожения без применения добавочного обогревания.