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Use of Slaughter House Waste in Energy Production and Fertilization

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Abstract – **Energy, as a significant driving force of the economy and of all social activities, represents one of the crucial issues in Europe today. Technologies that are currently available are still insufficient and it is necessary to carry out extensive research into various possibilities of the use of waste materials for the energy generation that will not present environmental hazard. Slaughter house waste has become a part of our everyday life. It is generated mostly in slaughterhouses for ungulates and poultry and, because of the increasing consumption of meat; its quantities have been constantly increasing during the last twenty years. Slaughter house waste is processed into meat-bone meal and grease for technical purposes by treatment in rendering plants. After the appearance of the bovine spongiform encephalopathy the use of proteins of animal origin in animal nutrition was banned. Alkaline hydrolysis, as an alternative method of the management of slaughter house waste, imposes itself as one of the solutions for the disposal of high-risk proteins, thus opening new possibilities regarding highly profitable and environmentally acceptable technologies. This paper represents research in the field of alkaline hydrolysis effectiveness as a method for processing slaughter house waste, the use of the method as the pre-treatment in bio gas production and the use of that material in fertilization, comparing production of meat bone meal and hydrolysates.**

Keywords – **Slaughter House Waste, Energy, Alkaline Hydrolysis, Bio Gas, Meat Bone Meal, High-Risk Proteins.**

I. Introduction

One of the priorities all over the world is to find suitable solutions for reducing the environmental pollution and resolve the problem of waste. The problem of waste is one of the essential issues of the modern civilization, emerging from the contemporary way of life. Animal by products or slaughterhouse waste has become a part of our everyday life [1], [2]. It is generated mostly in slaughterhouses for ungulates and poultry and, because of the increasing consumption of meat; its quantities have been constantly increasing during the last twenty years [3]. It is divided into three categories: the first category (K1) is a high-risk category which is suspected of infection with transmissible spongiform encephalopathy (TSE), the second category (K2) is, among other, made of manure and contents of digestive tract, while the third category substance (K3) is meat returned from stores due to expiration reasons, etc.

This waste has high potentials as renewable source of energy and can be transformed into several forms of energy. Meat and bone meals (MBM) were used for producing fodder, but with the occurrence of TSE, a ban was introduced on the use of products of the animal proteins in feeding animals [1], [3]. Animal by product is processed into the meat-bone meal and grease for the technical purposes by the treatment in rendering plants [4]. Proteins of the animal origin have a very high biological value; they are found in bones, skin and blood and originate from the material for whose synthesis they are used [5]. Their composition is most similar to that of yeast, soy and sunflower proteins. However, vegetable proteins used in animal nutrition may achieve a high biological value only if well combined. Furthermore, the use of meat-bone meal has a market value in soil fertilisation, and the increasing quantities of proteins of animal origin open wide possibilities for their use, especially for the energy generation purposes, bio gas production [6].

According to the data of the World Organization for Food and Agriculture (FAO) the production of meat has reached in the year 2011 the amount of 11,841,000 tonnes and has been marking steady growth. The number of slaughtered animals in the Republic of Croatia in the year 2011 was 43 million chickens, 262 thousand cattle, 71 thousand goats, 422 thousand sheep and 1.77 million pigs and piglets [7].

With the development of alkaline hydrolysis technologies [8] the effective possibilities of using animal waste for energy purposes is researched into. Energy-related potential of animal waste is very big and represents a biomass sources for the direct production of electric and heating energy by converting biogases into solid, liquid or gas fuels [9].

Alkaline hydrolysis process is particularly applied for the treatment of contaminated K1 and K2 categories tissues, while hydrolysed substance was treated at depots [9]. Hydrolysed substance is fully decontaminated and proteins and lipids mixture can be used for biogas production. Thereby, alkaline hydrolysis can be used as pre-treatment to anaerobic fermentation process. With the operation of alkaline mediums, temperature and pressure, larger molecules are degraded into smaller ones, which represents an important step in breaking the links in large protein chains, like prions, into smaller chains [10]. Alkaline hydrolysis can be catalysed with enzymes, metal salts, acids and alkali. In conducting experimental tests, authors used aqueous solution of sodium hydroxide, and the effects of alkaline hydrolysis were monitored at different temperatures, including the standard temperature up to ϑ=150°C [11].

The aim of research was to see the effectiveness of alkaline hydrolysis and its contribution to the quality of pre-treatment (sterilisation) of high-risk animal waste (bovine brains) and MBM in producing biogas as fuel for energy-related needs, by using the experimental device and experimental tests.

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II. Materials and Methods

A. Meat bone meal and slaughterhouse waste – biomass for alkaline hydrolysis and anaerobic process

The sample of MBM obtained after rendering process of 2nd and 3rd category of organic slaughterhouse waste was taken from one rendering house in Croatia. Slaughterhouse waste, K1, was taken from slaughtering facility near Zagreb city.

B. Digestion of MBM and hydrolysis process

At the Faculty of Agriculture University of Zagreb there is a lab-scale plant for biogas production, consisting of inox made thermostatic water bath of approx. 80 L, electromagnetic stirrers and batch glass reactors, which fully simulate the conditions of industrial biogas production facilities (Fig 1).

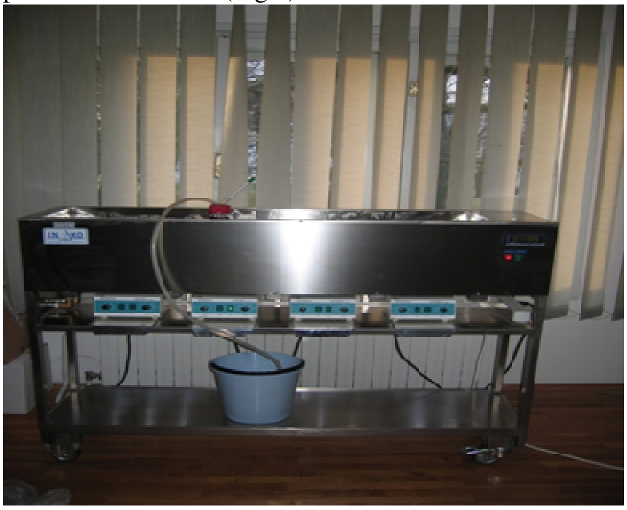

Fig.1. Analytical set up for biogas production

For the purposes of experimental tests, alkaline hydrolysis reactor with elementary physical and technical parameters was designed and used. Laboratory reactor case is made of stainless steel, 175 mm in height and 165 mm in diameter. Ten (10) mm wide space between inner and exterior wall is used for cooling the reactor by circulating plain water of ϑ = 15°C temperature at device's entry point. The needed reaction mixture temperature was maintained through indirect cooling of reactor wall, without measuring water's exit temperature and the quantity of heat driven away. The pressure in digester ranged between 2.5 kPa and 4 kPa. Power input to the chemical reactor was 220 Volts.

There is a manometer built onto reactor's lid with accurate measuring division for continued monitoring of the pressure of reaction mixture, as well as a safety valve for stabilizing possibly excessive working pressure during the course of experiment. Reactor is calibrated for 7 bars. At the bottom of the reactor, there is an opening with the duct used to drive hydrolysed substances away, which significantly facilitates the discharging of the experimental device and reaction mixture. Reactor is mounted on a specifically shaped electric heater with the magnetic stirrer, which is equipped with the thermometer for permanent measuring and monitoring of the reaction mixture temperature. There is a magnet in the reaction mixture, which stirs reaction mixture with the use of magnetic stirrer (Fig 2).

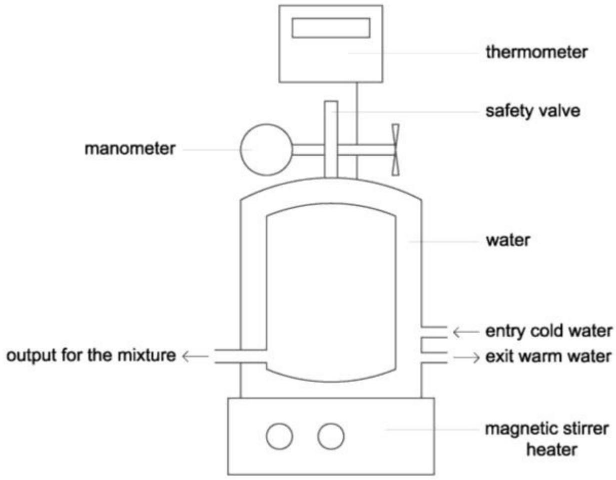

Fig.2. Shematic display of alkaline hydrolysis reactor

High-risk animal waste treatment experiments were conducted using the reactor and through hydrolysis process, at temperature ϑ = 150°C, pre-pressure p = 4 bar and duration t = 2 hours.

Table 1. shows the physical and technical parameters of the alkaline hydrolysis reactor.

Table 1: Physical and technical parameters of the alkaline hydrolysis reactor

Parametres	Values of Experimental Alkaline Hydrolysis Reactor
Capacity, m^3	0,001586
Height · diameter, m	0,175 · 0,165
Wall thickness, m	0,001
Pressure, bar	1 - 7
Temperature, °C	to 180
Hydrolysation time, min	120 - 360
Water speed, m/s	0,5 - 2,0
Water entry temperature,	≈ 15

Samples of K1 and MBM were used, for the purposes of the experiment and research into the efficiency of alkaline hydrolysis method. Hand blender was used for mixing and chopping up the needed quantity of waste until the mixture became homogenous. Homogenous mixture of K1 and MBM were placed in the reactor, and 45% NaOH solution and water were added. The obtained reaction mixture contained 400 grams of experimental K1 and MBM, 30 ml of 45% NaOH and 600 ml of water. Homogeneity of reaction mixture during the running of each experiment was obtained by using a magnetic stirrer and through continuous stirring. Prior to starting to heat up the reaction mixture, the reactor is hermetically closed and there is no contact with environment.

Hydrolysis was conducted under the following testing conditions: hydrolysation duration t1 = 2 hours,

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temperature $\vartheta = 150$ °C and pre-pressure p2 = 4, 78 bars. After experiment under set temperature, pressure and duration values, hydrolysed material was separated, cooled to room temperature and then stored in refrigerator at -20°C until the overall experiment is completed.

All samples of hydrolysed MBM and K1 were prepared for anaerobic fermentation in laboratory biogas reactor.

The chemical analyses included the determination of:

- pH, directly from sample on pH-meter with combined electrode (DIN EN 12506:2003),
- electric conductivity (E.C.), by means of conductivity meter MA5964 with combined electrode design (ISO 7888: 1985),
- total nitrogen, determined by Kjeldahl method (ISO 1871: 1975),
- nitrate-N (NO_3^-), determined by the spectrophotometric method by means of yellow color
- Complex by phenol-disulphonic acid (USDA-SCS-NSCS, 1992),
- ammonium-N (NH_4^+), determined by the spectrophotometric method using Nessler's reagent based on Jackson method (1958),
- phosphorus, determined by the molybdate-blue spectrophotometric method,
- Potassium and sodium determined by f1ame photometry, while all other microelements (Ca, Mg, Mn, Zn, Cu, Fe, Pe, Cd) are determined by the use of atomic absorption spectrometry (AAS).

III. Results

The hydrolysis was conducted under the testing conditions and the first was visual check of material. It shows that all samples of hydrolysed substances (MBM and K1) are of light brown colour with strong odour reminiscent of soap. After mixing with water, there is no heat or gases released and no subsequent chemical reaction or change of color is observed. Cold samples were proceeding in biogas reactor.

The anaerobic digestion of MBM was first started here. The reactor of laboratory biogas plants was filled with MBM mixture, water and inoculums for triggering the digestion (fermentation) reaction, and the biogas production was set out. MBM was water-diluted in percentage of 5% of dry matter. Active slime taken from the waste water treatment facility was the inoculums used as MBM digestion agent. The anaerobic digestion process is conducted in mesophylic conditions, in terms of temperature (35°C) and the time period (30 days).

Biogas production begins with the fifth day of fermentation and achieves its maximum value on day 30, after which it drops, which is usual for such mixtures. Cumulative biogas production started with the fifth day of fermentation, identically as in case of anaerobic fermentation of all other samples of hydrolysed substance. Identical process was done with hydrolysed K1 samples.

All biogas potential of analysed samples MBM and K1 are shown in the Table 2.

Table 2. The mean values of biogas production for fermentation of MBM and slaughterhouse waste after alkaline hydrolysis

The mean values of biogas production for fermentation of MBM and slaughterhouse waste after alkaline hydrolysis			
Sample	Biogas, ml	Sample	Biogas, ml
MBM 1	250.1±0.03	K 1	250.3±0.26
MBM 2	250.2±0.07	K 2	250.0±0.04
MBM 3	250.3±0.17	K 3	250.2±0.16
MBM 4	250.0±0.13	K4	249.8±0.24
MBM 5	250.0±0.13	K 5	250.1±0.06
MBM 6	250.1±0.03	K 6	250.1±0.06
MBM 7	250.2±0.07	K 7	250.0±0.04
MBM 8	250.1±0.03	K 8	249.9±0.14
MBM 9	250.2±0.07	K 9	250.0±0.04

Biogas shown usual composition with values for methane (CH4) 63%, carbon dioxide (CO2) 33%, while the rest is mixture of gases like hydrogen sulphide, water vapour, etc. [1].

After digestion process fermented material are analysed on different chemical parameters which are shown in table 3.

Table 3. Mean values of chemical analyses results of digested MBM and K1

Nr.	Chemical analysis		Digested MBM	Digested K1
1.	pH directly		6.44 ± 0.04	6.98±0.03
2.	E.C. mS/cm		21.79 ± 3.20	27.10±0.07
3.	% (dry matter 105 °C)		4.79 ± 1.84	17.22±0.16
4.	% H_2O		95.21 ± 1.85	82.78±0.17
5.	% burning residue (550 °C)		14.68 ± 1.23	22.33±0.13
6.	% burning loss		85.32 ± 1.33	77.67±0.03
7.	% C organic		45.00 ± 0.62	41.02±0.03
8.	% N	In the natural sample	4,20±0.07	1.62±0.03
9.		Total in dry matter	8,92±0.08	9.32±0.02
10.		Other forms (105 °C)	9,25±0.03	9.28±0.02
11.		NH_3-N	5,12±0.07	0.13±0.01
12.	% P		3.62 ± 0.17	2.61±0.17
13.	% K		3.68 ± 0.11	2.06±0.13

14.	% Ca	2.14 ± 0.12	6.01±0.03
15.	% Mg	0.74 ± 0.02	1.52±0.02
16.	% Na	1.79 ± 0.03	1.22±0.25
17.	mg/kg Mn	49.40 ± 1.77	93.51±0.03
18.	mg/kg Zn	40.31 ± 0.24	66.12±0.14
19.	mg/kg Cu	12.55 ± 0.74	11.32±0.23
20.	mg/kg Fe	272.50 ± 0.84	420.3±0.05
21.	mg/kg Pb	1.31 ± 0.32	0.52±0.04
22.	mg/kg Cd	0.15 ± 0.02	0.19±0.06

The analysis showed low content of dry matter (4.79%) and high content of organic carbon (45.00%) for MBM but for K1 dry matter is higher (17.22%) and the total carbon is almost similar (41.02%). Such a low dry matter level or middle low is normal for digested residues obtained after the biogas production. Measurements of pH values established an almost neutral fertilizer's reaction (pH 6.44 and 6.98), which indicated that digestion performed well, i.e., evaporable fatty acids were not developed, and that there was no acidification of substrate, i.e., methane production was not halted. As for the quantity of basic biogenic nutrients, the examined samples were very rich in nitrogen (8.92% and 9.32% N), phosphorus (3.62% and 2.61% P) and potassium (3.68% and 2.06% K). In order to determine the quality of digested residues, the contents of major biogenic elements was monitored in examined substrate, such as quantity of calcium, magnesium, and sodium. The examined digested residue contained moderate amounts of biogenic elements, which makes them suitable for fertilizer in agricultural production and it can be classified in category of liquefied organic fertilizers. In relation to farmyard manure, this fertilizer has higher amount of nitrogen, phosphorus, potassium, calcium, and magnesium and higher microelements content. Hence, this fertilizer can be used for fertilization but its application should be preceded by soil analysis and determination of needs of individual cultures for macro- and microelements. They are dark-colored, still have offensive odor; when diluted in water there are no chemical back reaction or gas discharges. After being applied on agricultural arable areas, they quickly become subject to further biological decomposition by aerobic bacteria up to the stage of plant nutrient, which in addition to plant nutrition has very favorable influence on microbiological activity in soil [5], [12], [13], [14].

IV. Conclusion

On the basis of conducted experiment, alkaline hydrolysis is very effective method for solving the problem of high risk materials. The advantages of alkaline hydrolysis are in combination of sterilization and digestion into one operation. It is a process in which we reduce total volume of mixture, completely destroy pathogens, which produces limited odour. The standard method of alkaline hydrolysis can be used as a pre-treatment in biogas production. This is particularly important in biogas production when alkaline hydrolyses is used as pre-treatment, i.e. for sterilization and homogenization of the reaction mixture of MBM or K1 and contributes to the more rational use of heat. On the basis of chemical analyses of hydrolysed material, it can be concluded that treated high risk biodegradable waste contained a large amount of water (95.21 and 82.78%), with dry matter of 4.79 and 17.22%. Total nitrogen content was 8.92 and 9.32%. The amounts of micro and macro elements are in values according to the Croatian Regulations. Based on the results obtained and in accordance with the laws of the Republic of Croatia, hydrolyzed material may be classified in the group of organic fertilizers with lower concentration of nutrients, upon mandatory analysis of the soil in areas where hydrolyzed material would be applied. When we see alkaline hydrolysis like pre-treatment, i.e. for sterilization and homogenization of the reaction mixture of high-risk animal waste in biogas production, there is a great contributes to the more rational use of the energy and waste. To summarize in the end, in the waste management process, the alkaline hydrolysis is one very important part. The final product can be used directly for the soil fertilization and it represents the decreasing cost in meat bone meal recovery. Otherwise meat bone meal should be necessary to incinerate what represents the significant cost in total calculation.

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