



## Organic fertilizer and biogas production from poultry wastes

Y. M. El-Hadidi \* and A. I. Al-Turki

College of Agriculture and Veterinary Medicine, Qassim University, Buraydah, P.O.Box 1482, Saudi Arabia.

\*e-mail: ymelhadidi56@yahoo.com

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### Abstract

Batch type anaerobic digesters were used in these experiments at mesophilic temperature (around 35°C) to investigate the possibility of utilization of poultry waste as an organic fertilizer and alternative energy source. A comparative analysis of biogas yield and chemical composition of the effluent slurry as organic fertilizer of four mixtures were studied: Mixture 1 (100% cattle feces), Mixture 2 (100% poultry droppings), Mixture 3 (100% poultry droppings + 0.1 ml/kg Agrotain) and Mixture 4 (50% cattle feces and 50% poultry droppings). Methane and carbon dioxide contents of daily biogas production were recorded. Chemical analysis of influent slurry was also carried out. Influent and effluent enumeration of total fecal coliforms and *Salmonella* was done. The biogas production from Mixture 4 was 16.9, 47.6 and 42.5% higher than that for Mixtures 1, 2 and 3, respectively. The fermentation process efficiency was 77.4, 72.4, 76.2 and 79.4% for Mixtures 1, 2, 3 and 4 respectively. The results also showed that the digested mixtures under study have the potential of being soil conditioners.

**Key words:** Anaerobic fermentation, methane, pathogens, organic fertilizer, Agrotain.

### Introduction

Recently animal production has attracted public interest not so much for providing high quality food but for being responsible for a number of environmental problems. Solid waste emanating either from animal wastes or crop residues causes hygienic problems. Expansion of livestock and poultry housings during the last few years has created situations where the production of animal waste occurs in large quantities on small areas. This situation causes many problems. These problems as mentioned by Rashed and El-Hadidi<sup>33</sup> may include the following points: 1) large areas are needed for spreading the manure for drying processes; 2) air pollution and offensive odor create a big problem with the environmental and hygienic authorities in the council; 3) the appearance of significant hygienic problems to the flock itself due to stocking of the solid manure behind the farm.

Poultry production is considered an important source of animal proteins. In Saudi Arabia, the production of poultry has rapidly increased. According to Saudi Agricultural Statistical Year Book<sup>36</sup>, the production of birds increased from 404,118,252 birds in 2000 to 474,777,887 in 2004. These birds produced about 10% of their body weights as poultry waste which may cause the above mentioned environmental problems.

Odhuba<sup>29</sup> reported that in feeding poultry waste, it is important to note that depending on the type and standard of management of the birds, the material may be a potential source of harmful agents including pathogenic bacteria, e.g. *Salmonella*<sup>2</sup>. Also there may be problems associated with nutrient loss mainly through volatilization of ammonia<sup>8</sup>. Beside that some forms of poultry waste such as caged-layer waste have a particularly offensive odour and are rather messy to handle. In addition to that the high ash contents, especially in caged-layer waste, tend to reduce the energy value of the waste.

Many diseases can be transmitted through manure pollution of

the environment. Subclinical excretors and latent carrier animals may be the source of pathogenic coliform organisms that are excreted in feces and can survive in fecal particles for weeks or months. Cruchaga *et al.*<sup>12</sup> reported that *Salmonellas* are a large group of bacteria comprising more than 2500 known pathogenic stereotypes that can cause a range of symptoms from mild gastroenteritis to death. *Salmonella* spp. infection is one of the most commonly reported causes of water- and food-borne diseases in the world. *Salmonella* spp. are capable of infecting a variety of cold- and warm-blooded animals. Natvig *et al.*<sup>28</sup> added that one of the main concerns with pathogenic enteric microorganisms is their survival in soil after manure or biosolids deposition. Any soil condition that favors extended growth and survival of enteric pathogens presents a health hazard because it increases the likelihood of disease transmission. It has been documented that roots and leaves of vegetables were found to be contaminated with *Salmonella* when grown in contaminated soil.

On the other hand, utilization of these wastes, as it is, may cause some indirect problems such as the prolific reproduction of flies and mosquitoes which increase the demand for domestic insecticides in the form of aerosols. These aerosols should be injected with the aid of chlorofluoro-hydrocarbons, which are known to be adversely affecting the ozone layer. Indirect problem may also be extended to the harmful effects from these insecticides which are considered as carcinogenic substances. However, the utilization of agricultural wastes for the production of non-traditional energy and organic fertilizers were found to improve health conditions and the general life pattern in rural areas.

Conversion technologies for the production of energy from biomass can be classified as biological or thermal technology<sup>11</sup>. The choice of such technologies depends strongly on the material properties together with the social and economic situation.

Anaerobic digestion is one of the biological technologies to produce renewable and clean energy (biogas) from biomass<sup>38</sup>. Since the end of the last century, anaerobic digestion has been applied in man-made environments for both energy production and as a cost-effective method for waste stabilization and waste water treatment<sup>25</sup>.

El-Mashad<sup>15</sup> revealed that anaerobic digestion (AD) is a microbial degradation process of organic matter in the absence of oxygen. Such process occurs naturally in soils and in the digestive tract of ruminants. AD has been applied for decades as a key method for stabilizing wastes like sewage, industrial and agricultural wastes. Ranzo<sup>34</sup> stated that the anaerobic decomposition of any complex organic substance is basically a two-stage process. The first stage consists of conversion of the complex organic materials into organic acids by acid-forming bacteria with the production of carbon dioxide (CO<sub>2</sub>). Bacteria, known as methane-producers producing methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>) from organic wastes, will act upon these organic acids in the second stage. Many factors, such as the feed composition, fermentation temperature, hydraulic retention time (HRT) and stirring of slurry, affect the AD process performance and its stability<sup>3,14</sup>.

The major advantages of biogas technology, besides cooking, lighting and electricity generation, is the utilization of effluent (residual slurry) obtained after digestion as a beneficial organic fertilizer (biogas manure). It is considered as a potential source for macro- and micronutrients. The biogas manure is devoid of pathogens, parasites and grass seeds as compared with traditional manure prepared from other organic manures<sup>16</sup>. It can be 30 percent more effective than raw manure in crop production, since it has tremendous nitrogen content in the form of ammoniacal nitrogen. Anaerobic digestion makes the effluent slurry sterile and C:N ratio is lowered to 12:1 which is ideal for higher yields<sup>10, 18, 21, 22, 24, 37</sup>. Mathers and Stewart<sup>27</sup> and Juiliana<sup>23</sup> stated that fertilization with slurry increased the organic matter and phosphorus content in the soil. Hydraulic conductivity has been increased, whereas bulk density decreased.

The properties of biogas are similar to those of natural gas and it may replace natural gas. Most equipment used for natural gas can be operated with biogas after suitable modifications<sup>13</sup>. Biogas as a product of anaerobic process has a relatively high calorific value in the range of 20-25 MJ/m<sup>3</sup> depending on its methane content. Such biogas can be burnt directly in a boiler to produce hot water, a proportion being used to heat the digester or used to fuel an internal combustion engine driving a generator or other equipments. Combined heat and power units consist of a suitable engine with a generator to produce electricity and heat exchangers for recovering the waste engine heat as hot water. There is also a potential for using compressed gas as an automotive fuel<sup>30</sup>. In many villages in rural areas, biogas could be directly used for cooking, replacing the environmentally unfriendly burning of biomass or the use of non-renewable energy source<sup>15</sup>.

The main feed for biogas plants is cattle feces which is not available in sufficient quantity within the proximity of the biogas

plants. Parsons<sup>31</sup> found that anaerobic digestion of cattle slurry with the present technology has no economical value when considered only as a source of energy. To cope with this problem, it is becoming essential to evaluate the biogas yield potential of other available organic wastes. Poultry droppings are one of such organic wastes which could be used in the biogas digester to increase the energy production from biogas plants.

Manure contains compounds, i.e., proteins and urea, which upon degradation release ammonia, a potent inhibitor of aceticlastic methanogens<sup>20</sup>. Angeldaki and Ahring<sup>5</sup> reported that urease enzyme catalyzes the decomposition of urea to ammonium and carbamate ions by its active site that contains two nickel (II) atoms. To inhibit the effect of urease enzyme, chemical inhibitor (Agrotain) was used. Philombios<sup>32</sup> reported that Agrotain (nBTPT) is a new generation nitrogen fertilizer additive that stops N volatilization losses up to 14 days by inhibiting the activity of the urease enzyme.

The main objective of the present work was to study the possibility of producing alternative energy and organic fertilizer from poultry droppings and to study the effect of addition of Agrotain in poultry droppings.

### Materials and Methods

This research work was carried out at the biogas laboratory of the College of Agriculture and Veterinary Medicine, Qassim University, Kingdom of Saudi Arabia. As shown in Fig. 1 the fermentation system consists of 4 conical glasses (2.0 litres capacity) used as fermenters and were placed in water bath which keeps the slurry temperature thermostatically at 35°C. The slurry was mixed four times daily by manual shaking. Four experimental mixtures were tested in each digestion system to evaluate the fermentative potential. The composition of the mixtures is shown in Table 1.

The cattle feces used in this study were collected from the dairy cattle farm, College of Agriculture and Veterinary Medicine, Qassim University, while the poultry droppings were collected fresh from a pit under caged laying-hens at Almshageh poultry farms, Alqassim region. The cattle feces and poultry droppings were diluted with distilled water to a concentration of 9 percent. Then the amount of water required to adjust the total solid fraction in the digester was calculated by using the following equation<sup>26</sup>:

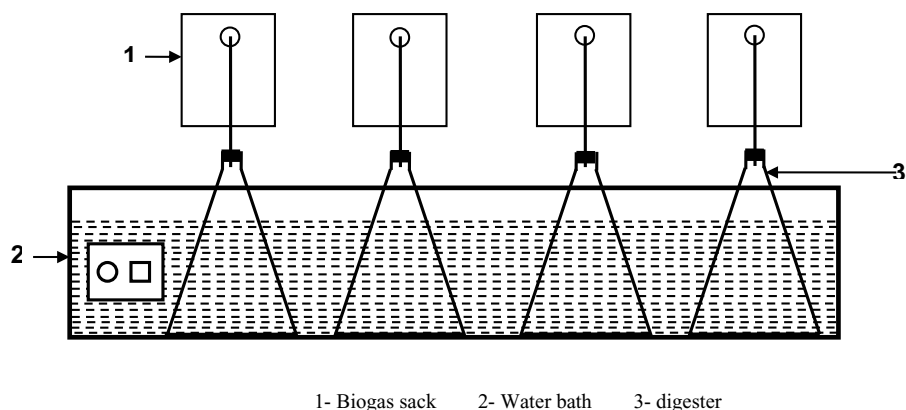


Figure 1. Schematic diagram of the first laboratory digester system.

$$Y = x [(TS_{\text{man}} - TS_{\text{dig}}) / TS_{\text{dig}}] \quad (1)$$

where Y=dilution water required, kg; X=amount of raw material, kg;  $TS_{\text{man}}$ =total solids fraction of raw material, %;  $TS_{\text{dig}}$ =total solids of slurry (Influent), %. Total solid concentrations (TS) analyses of influent and effluent substrates were determined in a drying oven at 105°C for 24 hours according to APHA<sup>7</sup>. Chemical analyses of fresh and treated substrates were carried out according to A.O.A.C.<sup>6</sup>. Tables 2 and 3 show the chemical analysis of cattle and poultry feed respectively. The pH of the digested mixtures was estimated at the start and end of each experiment. Laboratory system of the anaerobic digestion process used is shown in the schematic diagram (Fig. 2). Enumeration of total and fecal coliforms was done according to Feng *et al.*<sup>17</sup>. Salmonella was isolated using the protocol of Adrews and Hammack<sup>4</sup>.

**Table 1.** Composition of the different experimental mixtures.

Mixture	Cattle feces, %	Poultry droppings, %	Agrotain, ml/kg
1	100	0	0
2	0	100	0
3	0	100	0.1
4	50	50	0

**Table 2.** Chemical analysis of cattle feed.

Ingredient	Value
Crude protein, %	18.0
Crude fat, %	3.0
Crude fiber, %	6.0
Ash, %	6.5
Calcium, %	1.0
Salt, %	0.7
Phosphorus, %	0.6
Vitamin A, Iu/g	20.0
Vitamin D, Iu/g	3.0
Vitamin E, Iu/kg	15.0

The daily biogas production was collected in aluminium sacks

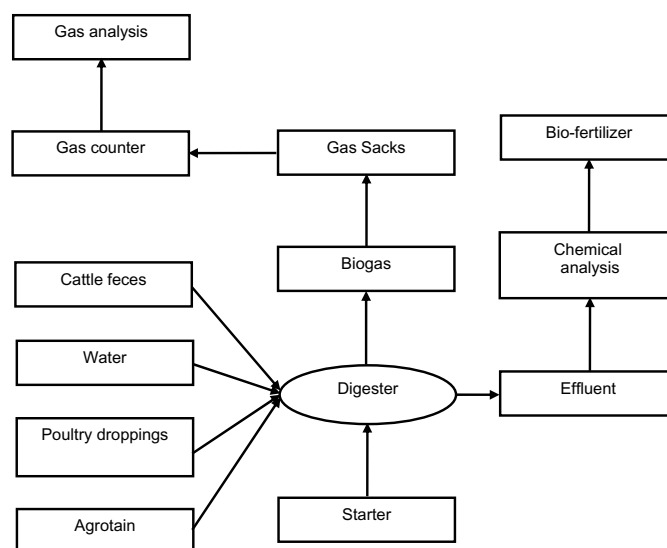
**Table 3.** Chemical analysis of poultry feed.

Ingredient	Value
Crude protein, %	17.0
Crude fat, %	2.5
Crude fiber, %	2.5
Calcium, %	4.0
Phosphorus, %	0.65
Methionine, %	0.6
Methionine+ cystine, %	2.0
Lysine, %	0.8
ME, kcal/kg	2730

and measured at atmospheric pressure and room temperature using a Ritter gas meter according to CET<sup>9</sup>. It was converted into standard conditions (273 °K and 1.013 bar pressure) as stated by Gosch *et al.*<sup>19</sup> using the following equation:

$$V_{\text{tr}} = V_{\text{f}} \{ 273.15 (P_1 - P_2 - P_3) \} / (T \times 1013) \quad (2)$$

where  $V_{\text{tr}}$ =volume of dry gas under standard conditions, litre;  $V_{\text{f}}$ =volume of wet gas at pressure P and temperature T, litre,  $P_1$ =air pressure at temperature T, millibar,  $P_2$ =pressure of wet gas at temperature T, millibar;  $P_3$ =saturation steam pressure of water at



**Figure 2.** Schematic diagram of laboratory biogas system.

temperature T, millibar; T=temperature of wet gas, °K. Gas analysis was performed for composition every 5 days during the biomethanation of different mixtures. The methane content (%) was determined by using GA 45 gas analyzer.

Biochemical oxygen demand (BOD) test of the different mixtures (influent and effluent) was measured. BOD was followed up by manometric respirometer supplied with a BOD incubator maintained at 20°C (BODTRAK, hach tester). The following equation was used to determine the efficiency of fermentation process according to Abdel-Maged<sup>1</sup>:

$$FPE = 100(BOD_{\text{in}} - BOD_{\text{eff}}) / BOD_{\text{in}} \quad (3)$$

where FPE=fermentation process efficiency, %;  $BOD_{\text{in}}$ =BOD influent, mg l<sup>-1</sup>;  $BOD_{\text{eff}}$ =BOD effluent, mg l<sup>-1</sup>.

## Results and Discussion

The results of anaerobic digestion are shown in Figs 3–6 and Table 4. As shown in Fig. 3, the biogas production rate for Mixtures 1, 2, 3 and 4 was 7.418, 5.878, 6.087 and 8.683 litres per litre of effluent, respectively. This means that biogas production from Mixture 4 was 16.9, 47.6 and 42.5% higher than those from Mixtures 1, 2 and 3, respectively. This variation in biogas production may be attributed to the limitation imposed by the substrate concentration. Statistical analysis (ANOVA) indicated that there were significant differences ( $P < 0.05$ ) among the Mixtures 2-4 and 3-4, while, there were no significant differences among the Mixtures 1-2, 1-3 and 2-3.

The results also showed that the hydraulic retention time (HRT) was 42 days for anaerobic fermentation of different mixtures. Accordingly, the mean values of biogas production rates during this study were 0.18, 0.17, 0.14 and 0.20 litres per litre of effluent for Mixtures 1, 2, 3, and 4 respectively.

Fig. 4 revealed that the methane content in the produced biogas varied between minimum values of 32, 5, 17 and 36 percent to maximum values of 70, 63, 66 and 73 percent for Mixtures 1, 2, 3 and 4, respectively. This pattern indicates that only CO<sub>2</sub> rather than CH<sub>4</sub> was produced during the first week of fermentation.

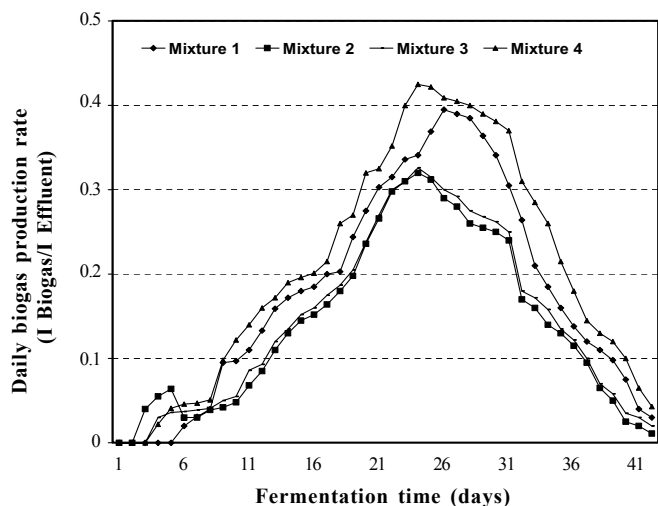


Figure 3. Effect of different mixtures on daily biogas production.

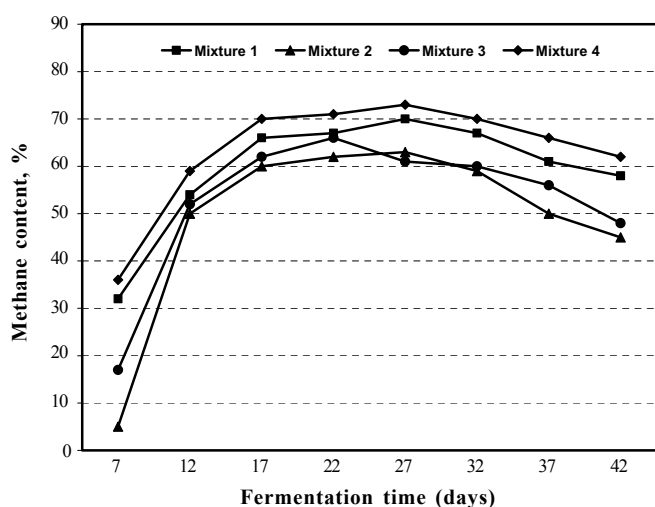


Figure 4. Effect of different mixtures on daily biogas production.

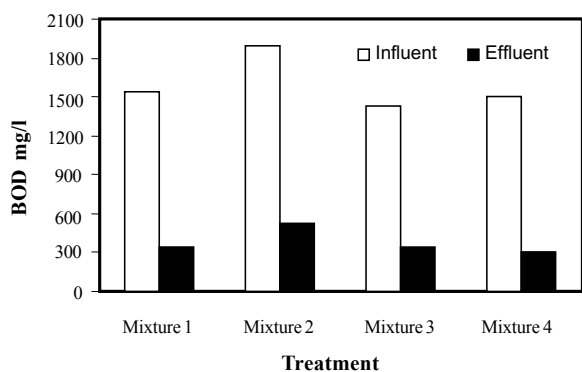


Figure 5. Effect of different mixtures on BOD status.

Table 4. Chemical composition of the mixtures studied.

Constituent	Mixture 1		Mixture 2		Mixture 3		Mixture 4	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
D.M, %	5.17	4.64	4.20	4.05	5.07	7.09	5.48	7.25
N, %	2.53	2.63	2.20	2.59	2.17	2.48	2.20	2.36
C, %	21.10	23.50	27.10	28.10	22.30	16.10	19.70	18.10
C/N ratio	8:1	9:1	12:1	11:1	10:1	6:1	9:1	8:1
K, %	0.68	1.26	0.46	0.88	0.54	0.61	0.58	0.74
P, %	1.11	1.67	1.06	1.25	1.04	1.08	1.07	1.13

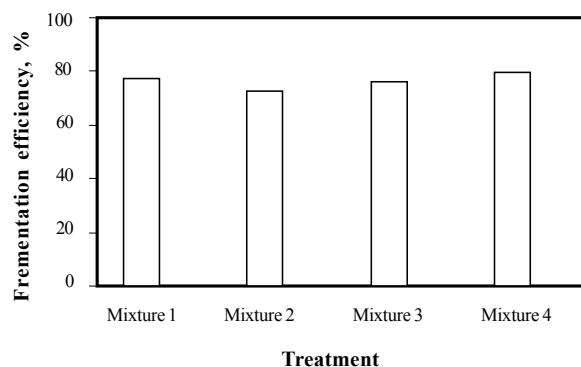


Figure 6. Effect of different mixtures on fermentation process efficiency.

On the second week after the  $O_2$  in the digester was consumed anaerobic conditions prevailed and combustible gas generation started. These results were in agreement with that obtained by Sayed-Ahmed and Huzayyin<sup>35</sup>.

Fig. 5 illustrates the BOD status for the influent and effluent of the different mixtures under study. The results showed that the BOD value of the influent of Mixture 2 was 19.0, 24.9 and 20.9% higher than that for Mixtures 1, 3, and 4, respectively. These results revealed that the BOD values of the effluents varied according to the chemical composition of each mixture. As shown in Fig. 6, the fermentation process efficiency of the different mixtures was 77.4, 72.4, 76.2 and 79.4% for Mixtures 1, 2, 3 and 4, respectively. This indicates that the addition of Agrotain to poultry droppings in Mixture 3 improved the fermentation process efficiency of poultry droppings by inhibiting the activity of urease enzyme which catalyzes the decomposition of urea to ammonia.

The data obtained from chemical analysis (Table 3) showed that the effluent slurry of the different mixtures could be used as a good organic fertilizer. It is evident from Table 3 that the effluent slurry of Mixture 1 has the highest concentration of nitrogen (2.63%), potassium (1.26%) and phosphorus (1.68%). It can also be seen that the effluent of Mixture 2 had the most suitable C/N ratio, which is ideal for the mineralization of organic material. This implies that the effluent of Mixture 2 has the potential of a good organic fertilizer in sandy soils.

These results were in line with those obtained by El-Shimi and Badawi<sup>16</sup> who stated that the effluent slurry obtained from biofermentation process contains high concentration of plant nutrients and organic matter and its application at the rate equivalent to traditional chemical fertilizer increased the yield of maize, wheat, broad bean, carrot and spinach by 35.7, 12.5, 6.6, 14.4 and 20.6%, respectively.

**Table 5.** Levels of total and fecal coliforms and *Salmonella* in different mixtures.

Treatment	Total coliforms*	Fecal coliforms*	Salmonella	
Mixture 1	Influent	4.6 x 10 <sup>5</sup>	9.3 x 10 <sup>3</sup>	Presence
	Effluent	Nil	Nil	Absence
Mixture 2	Influent	1.1 x 10 <sup>6</sup>	1.5 x 10 <sup>4</sup>	Presence
	Effluent	Nil	Nil	Absence
Mixture 3	Influent	1.2 x 10 <sup>5</sup>	4.3 x 10 <sup>3</sup>	Presence
	Effluent	Nil	Nil	Absence
Mixture 4	Influent	2.1 x 10 <sup>5</sup>	1.1 x 10 <sup>5</sup>	Presence
	Effluent	Nil	Nil	Absence

\*Determined by most probable number (MPN).

Table 5 shows the levels of total and fecal coliforms and *Salmonella* in influent and effluent of different mixtures. It indicates the absence of total and fecal coliforms and *Salmonella* of all effluent slurries of the different mixtures. This implies that any pathogenic or non-pathogenic bacteria present in the waste are killed as a result of high temperature and due to gases produced by anaerobic fermentation. It is clear that the effluent of different mixtures has the potential of a good organic fertilizer in soils.

### Conclusions

Based on the results obtained in this study, the following conclusions can be drawn: 1) The poultry droppings may be used as an organic fertilizer and non-traditional energy source by mixing in suitable well formulated ratios with cattle feces in an anaerobic digestion process. 2) The biogas generation during the anaerobic conditions seems to be feasible at 100% poultry droppings. 3) Adding Agrotain to poultry droppings improves the fermentation process efficiency. 4) The different fermented mixtures have the potential of appropriate soil conditioners. Since the present work showed good role for Agrotain in fermentation of poultry droppings, work will be continued to study in details the effect of different levels of Agrotain concentrations on anaerobic fermentation performance and biogas production from poultry droppings.

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