Production of biogas from poultry waste using the biomass of plants from Amaranthaceae family

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Abstract. The experimental results of kinetics of biogas formation for the organic waste utilization are presented for the case where combinations of technological and microbiological methods are used to enhance the process (ultrasonic pre-treatment and coenzyme with a new plant supplement). The plants from Amaranthaceae family are used as plant supplements. The influence of *Amaranthus hypochondriacus* and *Amaranthus retroflexus* L. on the process of methanogenesis for poultry wastes is analyzed. Based on the experimental results it is obtained that the maximum daily yield of biogas from substrate including the *Amaranthus retroflexus* L. and *Amaranthus hypochondriacus* are 310 ml and 252 ml respectively. For example the maximum daily yield of biogas from substrate without any plant supplements was 211 ml (“pure substrate”). Thus the biogas output rate from poultry waste using the biomass of plants from Amaranthaceae family is 47% higher than standard case. The total biogas yield using the plants supplement from Amaranthaceae family is higher than standard case.

Introduction

One of the modern ways to increase the biogas yield during fermentation is co-fermentation, i.e. joint processing of organic wastes of different origin [1]. At present time, many plant additives are known, however, the use of plants from Amaranthaceae family remains poorly studied.

Mindubaev A.Z. et al. [2] were the first who investigated the effect of *Amaranthus cruentus* on the process of methanogenesis.

It is established that the phytomass of *Amaranthus cruentus* is a stimulant for methanogenesis of hard-fermented substrates, such as beer beet and beet pulp.

The influence of amaranth on the efficiency of the process of obtaining biogas from organic waste was represented in PhD thesis by Belostotsky D.E. [3]

Yagafarova G.G. et al. [4] have developed a method for increasing the biogas yield in the fermentation of waste by applying ultrasound treatment for 4 to 8 minutes at a frequency of 22 kHz. They used shredded phytomass of crimson amaranth and aerobically stabilized sludge in the ratio 1:1 as complex stimulator. Unfortunately, the influence of each factor (phytomass and sludge) on the biogas production has not been analyzed separately.

The intensification of anaerobic fermentation of the wine burg and alcohol distillation is described in [5] by using natural biologically active substances (betulinol and amaranth extract) to increase the biogas yield and the content of methane in there.

Sitkey V. et al. [6] developed a technology of "dry" fermentation using silage of amaranth.
The possibility of biogas production by joint fermentation of manure and silage of amaranth *A. Caudatus* was experimentally tested in horizontal fermenter operating in the mesophilic regime.

In 2015 Adamovics A. and Dubrovskis V. represented some results on co-fermentation [7]. The silage of *Cannabis sativa L.*, *Helianthus cultus L.* and *Amaranthus L.* were used as plant supplements. Additionally, the *Metaferm* was used as the catalyst. Despite the greatest biogas yield when using *Amaranthus L.*, Adamovics A. and Dubrovskis V. proposed to use *Cannabis sativa L.*, because the latter can be used entirely, the plant contains a significant leaf mass. A significant part of the phytomass of amaranth consists of stems that are not useable for the process.

The aim of present work is the utilization of organic waste using a combination of technological and microbiological methods (ultrasonic pre-treatment and co-fermentation using a new plant supplement - *Amaranthus retroflexus L.* The feature of this study is the investigation of the methane fermentation by using *Amaranthus retroflexus L.* as plant supplement, which is recognized as a weedy plant unlike *Amaranthus Caudatus* и *Amaranthus cruentus*.

**Methods**

**Substrate composition**

As a substrate, chicken dung from a private farm was used with 29.9% of dry matter content. The dried *Amaranthus hypochondriacus* and *Amaranthus retroflexus L.* (humidity less than 5.7%) was used as the stimulator of biogas production (fig. 1).

In three series of experiments, the chicken dung was used from one dung sample with identical characteristics.

The shredded Amaranth phytomass was added to substrates as an additional food for microflora. *Amaranthus hypochondriacus* and *Amaranthus retroflexus L.* were grown on an experimental field located in the Verkhneuslons district of the Republic of Tatarstan (harvest 2017). They were collected in the dissemination phase.

The investigated substrates are follows:

1. Control substrate composes 131 g of chicken dung which is dissolving in distilled water to reach 400 ml volume.
2. Substrate №2 composes 65.5 g of chicken dung with 9.9 g of *Amaranthus hypochondriacus*
which is dissolving in distilled water to reach 400 ml volume.

3. Substrate №3 composes 65.5 g of chicken dung with 9.9 g of *Amaranthus retroflexus L.* which is dissolving in distilled water to reach 400 ml volume.

**Biomass ultrasonic pre-treatment**

Before the experimental study of biogas production, all considered substrates were treated by ultrasonic wave. As an ultrasonic source, the UZTA-0.2/22-OM was used with following characteristics: power – 200 W, frequency – 20 kHz. Ultrasonic pre-treatment was conducted under the intensity of 10 W/cm² during 6 minutes.

The ultrasound treatment led to homogeneous of the substrate, the stratification was not observed during the day and during the experimental study of producing biogas.

**Batch experiments**

The biogas production was experimentally studied in laboratory anaerobic digesters (500 ml) during 85 days. The process of methane fermentation was carried out in the mesophilic regime under a fixed temperature of 37° C (Fig. 2, 3).

![Fig. 2. Scheme of biogas production: 1 – water bath, 2 – anaerobic digester, 3 – plastic container, 4 – tank](image)

The volume of produced biogas was registered daily by the volumetric method (measuring a volume of the displaced saline solution).

![Fig. 3. The laboratory anaerobic digesters](image)

The chemical composition of produced biogas was analyzed every 10 days by gas-liquid
Results and discussion

Fig. 4 shows the kinetics of biogas production from control substrate and substrates including plant supplements: *Amaranthus hypochondriacus* and *Amaranthus retroflexus L.*

It can be seen that the maximum daily yield of biogas corresponds to substrate including *Amaranthus retroflexus L.* (310 ml on 37 days). Meanwhile for the substrate including *Amaranthus hypochondriacus* the maximum daily yield of biogas is registered on 41st day and reached 211 ml. After simple calculation, it is obtained that the biogas output rate from poultry waste using the biomass of plants from Amaranthaceae family is 47%, which is higher compared with results for control substrate.

Fig 5 illustrates the cumulative biogas production for investigated substrates.

After 85 days of holding the total biogas production from substrate №2 and substrate №3 are higher...
on 19% and 9% respectively compared with the same results for control substrate. Thus it is shown that the biomass of the *Amaranthus retroflexus* L. stimulates methanogenesis like the biomass of *Amaranthus hypochondriacus*.

**Conclusions**

In earlier studies [2, 4, 7], it has already been shown that plant phytomass from Amaranthaceae family can be considered as the stimulator of methane fermentation. It is very important and useful result which can be applied in creating a new technology for obtaining renewable fuel. Since a cultivated type of amaranth (for example, *Amaranthus hypochondriacus*) is an expensive raw material, it is unprofitable to use it to increase the biogas yield. Therefore it is important to find affordable and cost-effective plant stimulants for methanogenesis. The aim of the present work was the study of the efficiency of using *Amaranthus retroflexus* L. (weed plant) as plant stimulants to enhance the production of biogas from poultry waste. The conducted experiment demonstrated the same enhancing effect on methanogenic microflora for both plants: *Amaranthus retroflexus* L. and *Amaranthus hypochondriacus*. It should be emphasized that the *Amaranthus retroflexus* L. is recognized as weed plant, so its phytomass generally has no cost value, and its disposal is a topical issue.

According to the experimental results, it can be concluded that biomass of *Amaranthus retroflexus* L. can be used as plant stimulator to enhance the production of biogas like a well-known *Amaranthus hypochondriacus*. These results were obtained for the first time and have no analogs in scientific literature. Accordingly, it makes sense to use the biomass of *Amaranthus retroflexus* L. (a weed plant), in practice to increase the yield of renewable biogas fuels.

**Reference**

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