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CO-DIGESTION OF COW MANURE AND RYE SILAGE

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ABSTRACT
The Symbiosis Project is a European project funded by the Interreg Poctep Program, which is developed in the Spain-Portugal Cooperation Area of the Castilla y León Region and the Central Region of Portugal. The project aims to demonstrate that on-farm scale biogas plants are suitable for wastes treatment in rural areas, promoting energy self-supply, job creation and strengthening these areas. For that, a farm-scale prototype of anaerobic digestion is planned to be installed in a farm during the project. Different studies were carried out in order to determine which co-substrates were available to use in the biogas plant. For that, milk cow manure and rye silage were used as potential co-substrates. Hence, the aim of this work was to determine the methane potential of co-digestion of cow slurry with rye silage, two substrates that are available in the area in which the on-farm scale biogas plant is planned to be installed. Results showed that the highest methane yields (569 L CH_4 kg VS^{-1}_{added}) were achieved for the treatment consisting of 55% of manure and 45% of rye silage. Regarding methane percentage in the biogas, increasing amounts of rye silage decreased the percentage of methane in the biogas, from 71% to 46%.

Keywords: Biogas; rural areas; animal wastes; digestate.

INTRODUCTION
The Spain-Portugal Cooperation area of the Castilla y León Region and the Central Region of Portugal is characterized by an economy mainly based on the agriculture and livestock sectors, with small productions for subsistence, which makes difficult to fix the population in the area. The Symbiosis project is closely linked to the promotion of a local economy with low carbon emissions and resistance to climate change, all through the management of waste and the generation of renewable energy. The main waste treatment and valorization technology to be used will be the anaerobic digestion of animal and agro-food wastes in an on-farm level plant, obtaining biogas and a digestate to be applied to land as organic fertilizer.

In some areas of the Spain-Portugal Cooperation area of the Castilla y León Region and the Central Region of Portugal cultivation of rye is quite common, as it is a crop with few water needs. In the particular case of the studied milk cow farm, rye is sowing in poor nutrient soils, with a small grain yield. Therefore, harvested rye (grain and straw) was ensiling for its further use. In this work, rye silage was studied as a potential co-substrate in a biogas plant. Considering that ensiling is a storage method that could be feasible in terms of energy storage and guaranteeing the feedstock availability for the whole year in a biogas plant, it could be a good alternative for economically feasible supply of these type of crops and straw for biogas production [1]. Therefore, the objective of the present study is to determine the methane potential of co-digestion of cow slurry with rye silage, two substrates that are available in the area in which the on-farm scale biogas plant is planned to be installed.

MATERIALS AND METHODS

Origin of manure, rye silage and inoculum

Cow manure and rye silage were collected from a milk cow farm located nearby Salamanca (Spain). Anaerobic sludge (AS) used as inoculum was collected from an anaerobic digester in the municipal wastewater treatment plant of Valladolid (Spain) and presented a VS concentration of 17.3 g/L. Characteristics of the cow manure and the rye silage used in the study are shown in Table 1.

Anaerobic biodegradability assays

Anaerobic biodegradability assays were carried out at 37 ± 0.4 °C for 37 days in 0.57 L bottles with a total liquid volume of 300 mL. A substrate/inoculum ratio of 1 (based on VS) was used. Eleven different mixtures in terms of the percentage of VS of cow manure used in relation with the percentage of VS of rye silage used were studied, as shown in Table 2. In addition, for the determination of endogenous methane production, blanks containing only anaerobic sludge were tested. The bottles were closed and the headspace was flushed with N_2 to remove the O_2. The biogas production was measured by the overpressure in the headspace. Constant agitation was provided by a shaker. All experiments were carried out in duplicate and the results were expressed as means.

Analytical procedures.

Total solids (TS), volatile solids (VS), total chemical oxygen demand (TCOD), pH, total Kjeldalh nitrogen (TKN) and total ammonia nitrogen (TAN) were determined following APHA Standard Methods [2]. Biogas composition was analyzed using a gas chromatograph (Agilent 7890A) with a thermal conductivity detector, separated by a HP-Plot column (30m 0.53mm 40μm) followed by a HPMolesieve column (30m 0.53mm 50μm). Helium (7mL min^{-1}) was used as the carrier gas. The injection port temperature was set at 250ºC and the detector temperature was 200ºC. The temperature of the oven was set at 40ºC for 4min and after that increased to 115ºC for 1min and 45s.

RESULTS AND DISCUSSION

Characteristics of both substrates are showed in Table 1. According to Table 2, methane in the biogas varied from 46 to 71%, and methane productivity varied from 275 to 569 L CH_4 kg VS^{-1} $_{added}$.

Table 1. Characteristics of cow manure and rye silage used in the study.

	pH	**EC**	**TS**	**VS**	**TCOD**	**TKN**	**TAN**
Co-substrates		[mS cm^{-1}]	[g L^{-1}]	[g L^{-1}]	[g L^{-1}]	[g L^{-1}]	[g L^{-1}]
Cow manure	6.9	13.13	37.87	25.4	74.2	2.25	1.23
Rye silage	n.d.	n.d.	64.25	56.95	n.d.	n.d.	n.d.

n.d. Not determined

Table 2. Treatments of AD, specific methane production and percentage of methane in the biogas.

Assays	**Percentage of manure (VS of the total VS_{added}) [%]**	**Percentage of rye silage (in VS of the total VS_{added}) [%]**	**Specific methane production [L CH_4 kg $VS^{-1}{}_{added}$]**	**Percentage of methane in the biogas[%]**
T1	100	0	275.2	70.9
T2	95	5	289.0	67.2
T3	90	10	355.7	63.1
T4	85	15	383.4	60.9
T5	80	20	388.4	57.8
T6	75	25	440.4	59.7
T7	70	30	452.7	55.8
T8	65	35	492.1	54.3
T9	60	40	508.6	52.7
T10	55	45	568.9	52.0
T11	50	50	543.5	46.2

Figure 1 shows the accumulated methane production during the experimental set up of the different mixtures. According to obtained data (Table 2, Fig. 1), increasing rye silage percentage in the mixture increased specific methane production. This is probably due to the high content in volatile fatty acids of rye silage, which are easily degradable to anaerobic bacteria. The highest methane yields were achieved by treatment T10, consisting of 55% of manure and 45% of rye silage (569 L CH_4 kg VS ^{1} $_{added}$). The obtained values are remarkably higher than those obtained by Molinuevo-Salces et al., (2015) [2], who reported methane yields in the range of 154-173 m^3 t^{-1} of VS for ensiled catch crops together with straw. These differences in methane yield could be probably due to the high straw content of ensiled samples, which resulted in low methane yields. The same authors, using not ensiled catch crops obtained a maximum of 400 m^3 of methane t^{-1} of VS [3]. The values obtained in the present study are probably higher due to the ensiling process, since it could have worked as a pretreatment for rye, resulting in an enhanced methane production. Regarding methane percentage in the biogas, increasing amounts of rye silage decreased the percentage of methane in the biogas, from 71% in T1 (100% of cow manure) to 46% in T11 (50% cow manure and 50% rye silage).

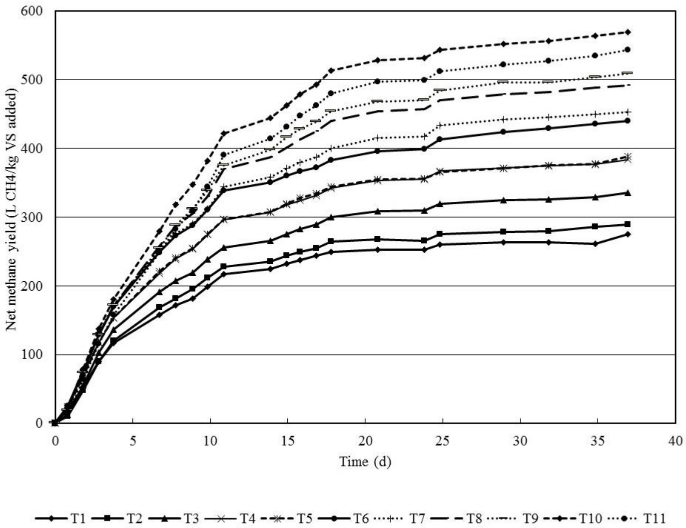

Figure 1. Methane yield produced during the experimental set up.

Bearing in mind these results as previous studies for the real AD, the following considerations should be done: 1) approximately 90% of the total methane production occurred in the first 20-25 days, therefore for a real biogas plant these results are interesting to use a residence time of about 25 days in order to maximize daily production of methane; 2) an equilibrium between methane production and its concentration in the biogas will be needed in the real biogas plant, being the choice of the mixture important to prioritize methane production or methane richness.

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