Nitrogen transformation during co-fermentation in agricultural biogas plants

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BACKGROUND AND RELEVANCE

In recent years, there has been an increase in interest in renewable energy sources (RES) due to decreasing fossil fuel resources, the resources of which can still be used for the next several decades. Nevertheless, it is worth investing in advance in the development of renewable energy sources by systematically increasing the share of these energy sources. In 2018, 308 biogas plants were in operation in Poland, accounting for approximately 3.2% of RES. The highest growth in newly built facilities was recorded in the case of agricultural biogas plants (they represent about 32% of all biogas plants in Poland). It seems that the development of biogas plants in Poland in the future will be significant compared to other types of RES such as wind and photovoltaic energy due to the fact that they are permanent sources and do not depend on the weather. In addition, there is developed agriculture and food industry in Poland, which can be a source of raw material for agricultural biogas plants. As a raw material, it can be use corn and grass silage with the addition of waste from the food and agricultural industries. In the case of Poland, circa 400 million m^3 of agricultural biogas was generated in 2018 alone. According to a report by Bioenergy Europe, up to 71% of all biogas plants in Europe are powered by agricultural substrates (silage, slurry agricultural waste, etc.), 16% operate at sewage treatment plants and 8% are biogas plants at landfills [EBA 2019].

The growing number of biogas plants also means an increase in the load of waste products in the form of digestate. In some European countries (such as Germany, France and Italy) attention has been paid to environmental problems associated with its overproduction. agricultural biogas plants face the problem of overproduction of digestate resulting from the concentration of substrates used, often imported from considerable distances. This is connected with the problem of its improper management, which is most often limited to fertilizing agricultural crops in fields located near the biogas plant. The solution of this problem may be found in dewatering of digestates, followed by separate management of the solid and liquid fraction. Due to low hydration, the solid fraction can be dried and burned (as a biofuel) or used directly as an organic fertilizer or after composting. But liquid fraction of digestates (reject water) contains high concentrations of nitrogen and phosphorus, and improper management (e.g. excessive infiltration leading to soil over-fertilization) can lead to leaching of nutrients from soil or their infiltration into groundwater, contaminating this way nearby rivers and negatively affecting the development of aquatic flora and fauna. A literature review shows that the range of total nitrogen (TN) concentration range very widely from 0.06 to 8.7 mgN/L, mainly as ammonium nitrogen. However, the literature lacks information on organic nitrogen fractions and their share in liquid fraction of digestate.

The aim of the study was to determine the transformations of nitrogen compounds contained in the biogas plant feed during the co-cementation of selected products from the agri-food industry. With respect to organic nitrogen, the occurrence of its fraction in the liquid fraction from digestate dewatering from agricultural biogas plants and their transformation during anaerobic digestion were analysed.

MATERIAL AND METHODS

In the research carried out in the laboratory fermentation chambers with a capacity of 44 L. The feedstocks used in the study are presented in Table 1. Fermentation was carried out for 28 days at 37°C. Two tests (1A and 2A) were conducted, differing in the feedstock and inoculum proportion of 20%. Then, two more tests (1B and 2B) were conducted with the same feedstock but with an inoculum proportion of 80%. Table 1 shows the individual tests with the feedstock. The digestate samples before and after fermentation were subjected to mechanical separation into solid and liquid fraction. Separation of the fraction was carried out using a Jouan C3i laboratory centrifuge, with 4000 rpm (characteristic for the operation of industrial centrifuges) and time 30 min.

Table 1.The feedstocks for individual test

Test:	Feedstock:
Test 1A	10 kg=341.7 g corn silage + 3738.7 g slurry + 5918,6 g water; (20% inoculum)
Test 2A	10 kg=5247 g distillery residue+ 433 g corn silage + 4319 g water; (20% inoculum)
Test 1B	10 kg=341.7 g corn silage + 3738.7 g slurry + 5918.6 g water (80% inoculum)

Test 2B	10 kg=381.6 g corn silage + 5131 g distillery residue+ 4470.9 g water (80% inoculum)

RESULTS

Total nitrogen (TN) contained in the leachate included ammonium nitrogen (NH_4-N) and organic nitrogen (ON). Millipore nitrocellulose filters were used to separate individual organic nitrogen fractions. On this basis, the particulete (PON) (> 1.2 μm), colloidal (CON) (from 0.1 to 1.2 μm) and dissolved (DON) (<0.1 μm) fractions were determined, as defined by Czerwionka et al. (2014). Ammonium nitrogen formed during the hydrolysis of proteins and urea (components of feedstock substrates) was the dominant form of nitrogen in post-fermentation leachates, and its concentration was related to the original nitrogen content in the raw material.

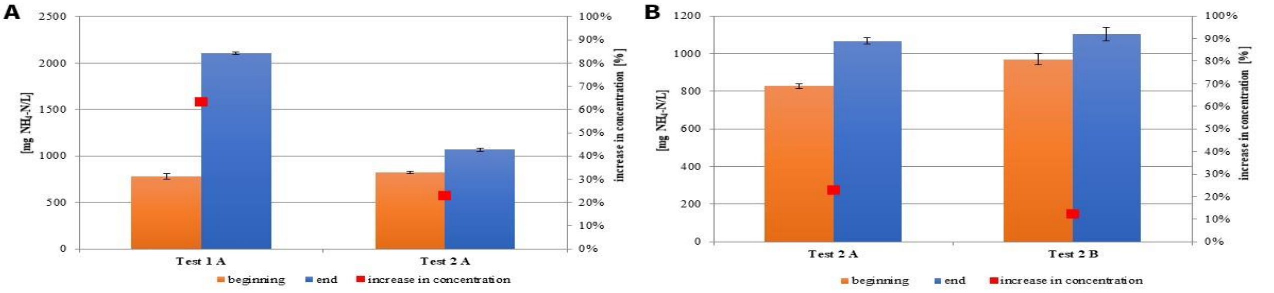

Figure 1. Ammonium nitrogen concentration for test 1A and 1B (A) and for test 2A and 2B (B).

Figure 1 A and B shows the changes in ammonia nitrogen concentrations for selected parameters in the liquid fraction as a result of the fermentation process. An increase in ammonium nitrogen concentration was observed as a result of fermentation, with the level of increase depending on the initial concentration in the feedstock. The highest increase was found for distillery residue and maize silage (over 60%). Figures 2 A and B show the proportion of organic nitrogen fractions in leachate before and after fermentation. One graph shows samples with the same feedstock but with different inoculums. At the beginning of the fermentation, the samples showed a predominance of different fractions of ON: PON, DON to a greater or lesser extent. However, after the fermentation process, the proportion of ON fractions evened out and one of the fractions was dominant. In the case of fermentations with distillery stillage and maize silage, the colloidal fraction was dominant, while in the case of samples with slurry and maize silage, the dissolved fraction was dominant. A lower proportion of inoculum (test 1 A and 1B) resulted in a higher concentration of the dominant fraction than in samples with 80% inoculum (test 2A and 2B).

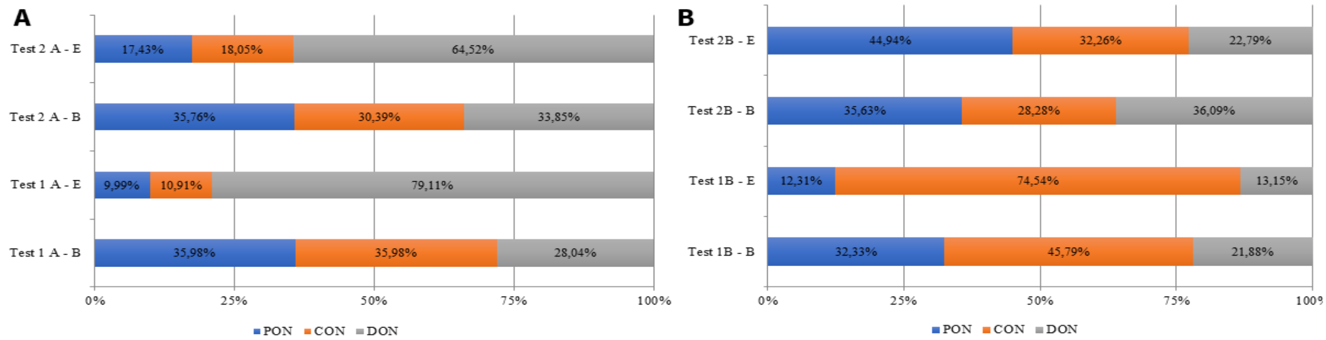

Figure 2: Percentage distribution of organic nitrogen fractions for test 1A and 2A (A) and 1B and 2B (B). B - represents the beginning and E - the end of the fermentation time

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