# DIGESTATE APPLICATION RATES WITH REGARD TO EMISSION OF GREENHOUSE GASES

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***Abstract***
*The article focuses on the method and on the rate of digestate application with respect to the environment at impact, especially to the air pollution. Two methods of applying digestate were selected that were performed after harvesting rye as the pre-crop, and before sowing maize. Digestate is a waste product of biogas plants and contains a large amount of nutrients, therefore it is very often used as fertilizer in agriculture. It is not only when it is applied that greenhouse gases are released into the atmosphere, so it is necessary to find an ideal application method that minimizes the release of gases while providing sufficient nutrition for the crop. In this paper, the emissions from two methods of digestate application were compared. For each application technology, emissions at different application rates were assessed. The emissions of ammonia and carbon dioxide increased with higher rates of digestate. This finding was not confirmed for methane emissions though.*

***Key words:*** *disc slurry injector; strip-till slurry injector; ammonia; methane; carbon dioxide.*

## INTRODUCTION
Climate change and global warming are increasing the pressure on all fossil fuel industries (*Jacob et al., 2018*). This issue has been addressed by the European Commission when it set a mandatory share of energy from renewable sources. Biogas produced in agriculture can help to meet these targets (*Mamica et al., 2022*). Because intensive farming is now the predominant way of managing agricultural land, mankind grows enough food and feed on a smaller area than before. Higher yields would not be possible without major advances in plant breeding (*Frei, 2000*). Appropriate fertilization management also contributes substantially. Chemical plant protection is another important aspect, without which intensive farming would not succeed *(Birkhofer et al., 2008)*. On the remaining area of agricultural land, crops including energy crops suitable as the main feedstock for biogas plants (*Voltr et al., 2021*) can be grown. Furthermore, biological waste from crop and livestock production in agriculture is most commonly used as feedstock (*Priekulis et al., 2016*). Anaerobic digestion is the controlled microbial conversion of organic matter without access to air to produce biogas and digestate (*Pain & Hepherd, 1985*). After removal from the digester, the biogas is free of undesirable elements and compounds, and its final quality is specified by a standard. The biogas is then burned in a cogeneration unit which produces electricity by means of a generator. Part of the waste heat is used to heat the fermenter. A large amount of digestate is produced during the production of the gas and is considered a waste product. It is most often used in agriculture as a liquid organic fertilizer, because it contains a large amount of nutrients (*Szymańska et al., 2022*). But there is a reduction of carbonaceous matter. Consequently, digestate contains mainly less decomposable organic matter, so it can sometimes be referred to more as a mineral fertilizer (*Möller & Müller, 2012*). Digestate is continuously discharged from the digester into storage tanks, from which it is then taken to the field according to agronomic deadlines. The digestate contains large amounts of nitrogen, mainly in the form of ammonia. Not only ammonium nitrogen but other elements contained in the fertilizer are lost to the air. The gases monitored in this experiment are among the gases that increase the greenhouse effect of the atmosphere (*Lamolinara et al., 2022*). The most important greenhouse gas monitored is carbon dioxide, whose concentration is steadily increasing in the atmosphere. The burning of fossil fuels contributes in a major way to this increase *(Lamb et al., 2021)*. Methods for measuring greenhouse gas emissions in livestock production are well established, but methods for measurement in

field after application are not uniform. In livestock production, concentrations are higher and easier to measure because of the steady production of emission gases, and a stable environment that is not affected by weathering. The concentration of the monitored gases above the surface of the land where the application took place decreases with time (*Dietrich et al., 2020*). For these reasons, it is advisable to carry out measurements as soon as possible after fertilizer application. In the search for the optimal method and rate at which the least release of greenhouse gases into the atmosphere occurs, the sufficient supply of the necessary nutrients to the plants must not be forgotten. The aim of the experiment was to compare the amount of emissions released after application of different doses by two application methods.

## MATERIALS AND METHODS

The measurement field was located near the village of Čechtice in the Central Bohemia Region, Czech Republic (49.6049206 N, 15.0815178 E), with an average altitude of 550 m above sea level. According to the USDA, the soil texture of the field was sandy loam. Digestate application was carried out using two different implements, i.e. disk injector and strip-till injector. The application of digestate took place on 25 May 2021, approximately one week after the harvest of rye for silage. Maize was then seeded four days after application. In the first part of the experimental plot, the digestate was applied using a self-propelled tanker equipped with a disc injector with a soil cover of approximately 12 cm. In the second part of the plot, the same self-propelled machinery was used but equipped with an injector that applied digestate and processed the soil in a strip-till only manner. The depth of tillage was approximately 16 cm in the latter case. The application at both parts of the plot differing by the injector used was carried out on four variants with different digestate rates. The rates chosen were 10, 20, 30 and 40 $m^3.ha^{-1}$. On the fifth variant considered as the control, only tillage was carried out without any digestate application. Each variant for the disk-applied technology was 24 m wide and 100 m long; for the strip-applied technology, the width was 12 m, and the length 200 m. Measurements of emissions and physical properties of the soil were carried out after application. The monitored emission gases were $CO_2$, $CH_4$, $NH_3$. INNOVA 1412 (LumaSense Technologies A/S, Denmark) was used for the measurement of gas concentrations, linked to the replicator INNOVA 1309 (LumaSense Technologies A/S, Denmark) that enabled to measure all the variants simultaneously. A wind tunnel (CZU Prague, Czech Rep.) was placed on each variant, from which special air tubes led to the measuring equipment. The wind tunnel was a plastic hollow block that did not have a wall at the bottom, the dimensions of which were 50 x 35 cm. There were ventilation openings on the two sides facing each other. One opening was fitted with a fan to provide the required airflow velocity for the wind tunnel, which was around 0.8 $m.s^{-1}$. The second opening carried air into the wind tunnel and was fitted with an anemometer. A thermometer was placed inside to record the temperature during the measurement. The wind tunnels were moved to a different location within a variant after one hour, for a total of three repetitions. All data were recorded with simultaneous transfer to a PC. Furthermore, the concentration of each gas in the ambient air was subtracted from the measured concentrations for each variant. These adjusted concentrations were converted from the area covered by the wind tunnel to an area of one square meter. Finally, the recalculated concentrations were converted to theoretical emissions released during one day. Statistical analysis of the data was performed using Statistica 12 software. ANOVA test was used to evaluate the gas emission differences

## RESULTS AND DISCUSSION

The highest rate of 40 $m^3.ha^{-1}$ was chosen because it contained the maximum recommended nitrogen dose for a single application. The measured methane values for both injectors used were very similar. Concerning digestate rates, statistical difference can be seen (Fig. 1) between the variant without fertilizer dose (control) and all the variants with any digestate dose applied, i.e. with the doses of 10, 20, 30 and 40 $m^3.ha^{-1}$. Otherwise, the measured emissions did not differ significantly among the variants. When compared at the same time interval after the application, the measured emissions of the variants with applied fertilizer were higher than those found by *Czubaszek & Wysocka-Czubaszek (2018)*. Furthermore, it is noticeable that there are no significant differences between the application methods. Similar values were obtained by *Koga et al. (2022)* after application of liquid fertilizer to the experimental post-emergence crop. Methane emissions were higher than measured by *Šařec et al. (2021)*, which may be partially attributed to a different composition of the digestate.

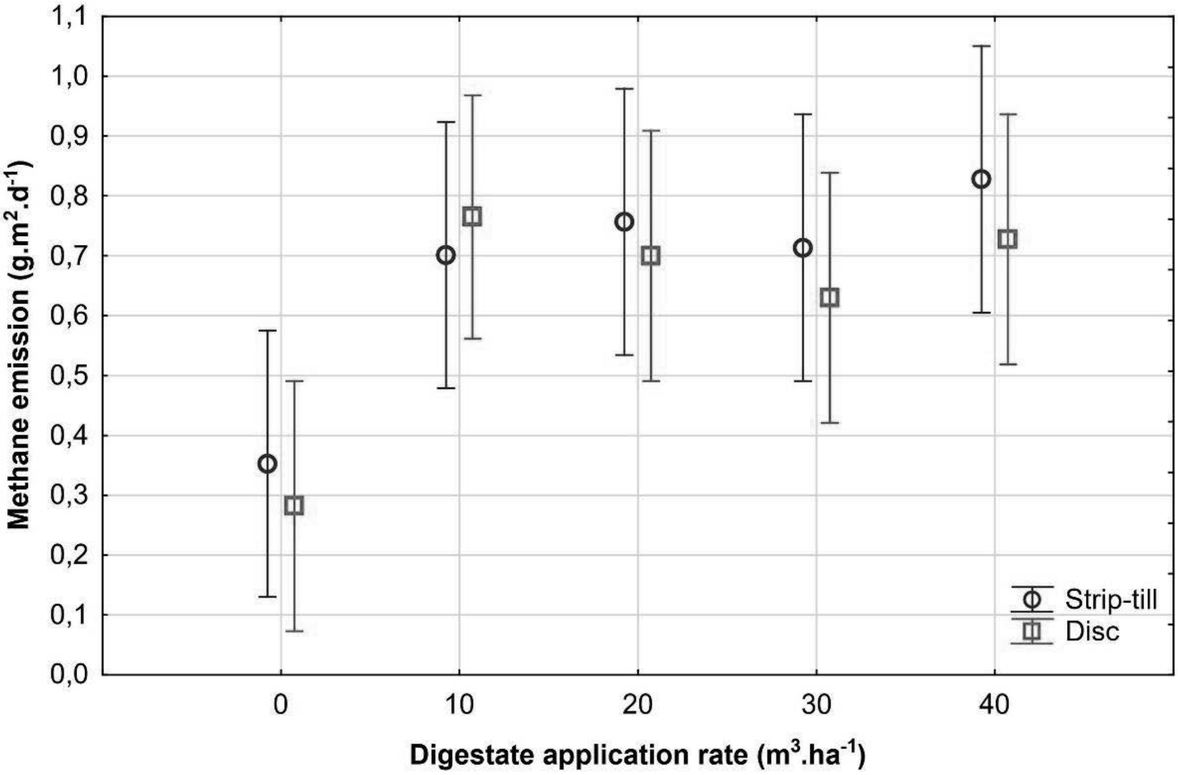


**Fig. 1** Methane emission for different digestate doses and injectors used

According to Fig. 2, the measured carbon dioxide emissions increased also with increasing fertilizer rate. No significant differences were found concerning injectors used. Statistically significant differences were obtained when having compared the control variant and the lowest dose of 10 $m^3.ha^{-1}$ to the doses of 30 and of 40 $m^3.ha^{-1}$. The measured values for all the variants were higher than those of *Rosace et al. (2020)*. This difference may be affected by a different measurement method, although the time development of the emission release is similar.

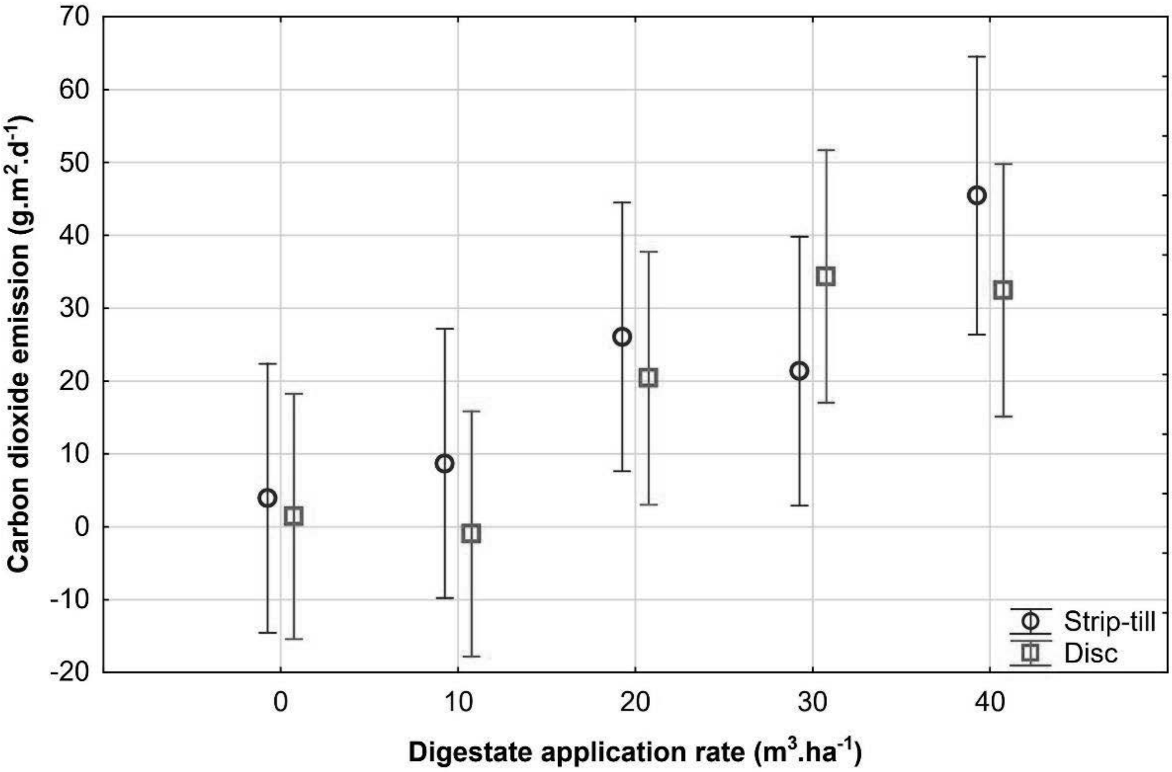


**Fig. 2** Carbon dioxide emission for different digestate doses and injectors used

The Fig. 3 shows some differences between the injectors used, but these were not statistically significant. Concerning digestate rates, statistical difference can be seen (Fig. 3) only between the variant without fertilizer dose (control) and the variant with the maximum dose of 40 m$^{3}$.ha$^{-1}$. Otherwise, the measured emissions did not differ significantly among the variants. The measured $NH_3$ concentration is significantly lower than that by *Wolf et al. (2014)*, where digestate was incorporated in a slightly different way.

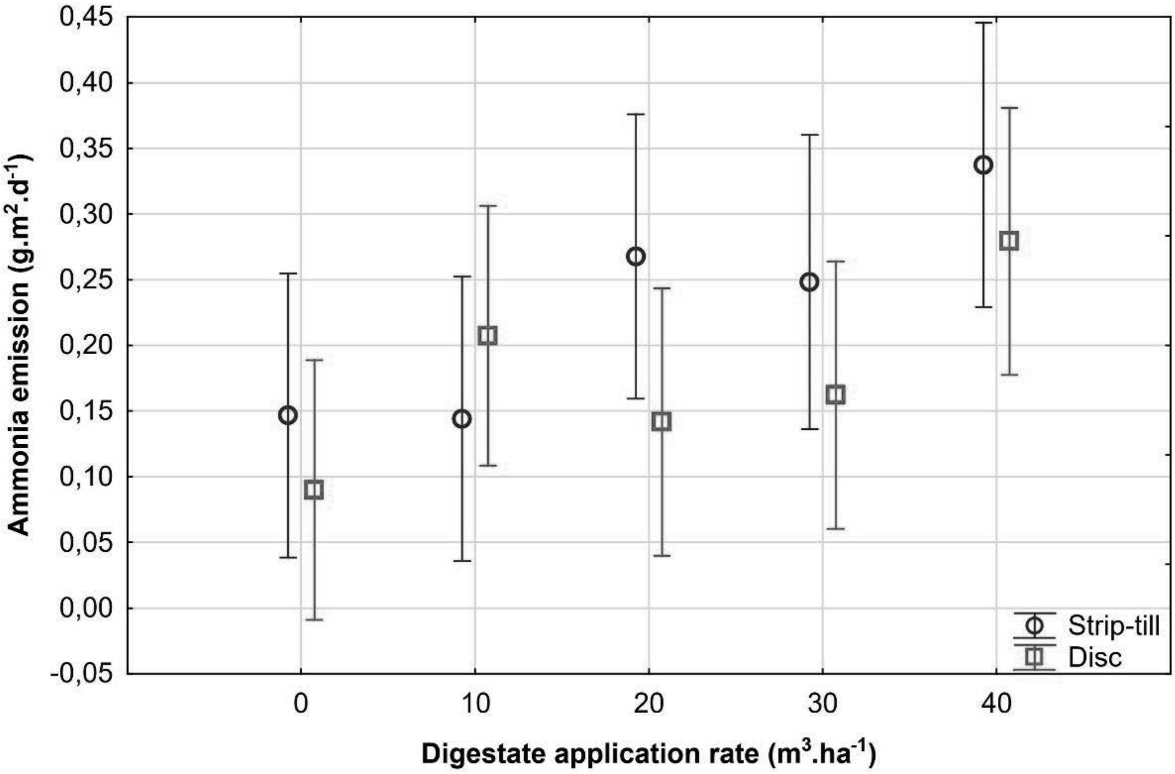


**Fig. 3** Ammonia emission for different digestate doses and injectors used

## CONCLUSIONS

Measurements showed that the digestate dose applied had an effect on the amount of gases released into the air. This was confirmed particularly for carbon dioxide and ammonia emissions. In the case of methane, the measurements suggested that the application of digestate led to the methane released into the air, but the amount of it did not depend on the amount of digestate. Concerning disk and strip-till injectors, no statistically significant differences in emissions were recognized for either of the three measured gasses. Probably the key aspect was that both methods incorporated the digestate into soil.

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