Utilization of agri-livestock by-products and biomass residues as co-substrates for the biogas production through anaerobic co-digestion in batch mode

G. Sismani[1], C. Nikolaidou[1], M. Gaspari[1], P.G. Kougias[1]
[1]Soil and Water Resources Institute, Hellenic Agricultural Organization Dimitra, Thermi, 57001, Greece

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Presenting author email: g.sismani@swri.gr

Massive amounts of organic wastes and by-products that can be used in anaerobic digesters are produced by the agri-livestock industry. These biomass residues are currently disposed of or left in the fields after harvesting since they have no market. Animal manure, waste from oil production mills, crop residues, harvest waste and whey from dairy factories are among them (Escalante et al., 2018). In order to establish a circular bioeconomy, the organic portion of these wastes is processed through the widely used method of anaerobic digestion (AD) for the production of biofuels (biomethane) and fertilizing products (digestate) (Angelidaki et al., 2003). For higher methane production, anaerobic co-digestion (AcoD) -the simultaneous anaerobic digestion of two or more substrates- is a practical option for overcoming the limitations of mono-digestion and enhancing the economic sustainability of AD units (Pan et al., 2021). One of the crucial points of AcoD is to select the optimal co-substrate and mix ratio to promote synergisms, reduce inhibiting substances, maximize methane production, and preserve the quality of the digestate. Despite the growing popularity of AcoD systems, the characterization of complex feedstocks, as well as the investigation of the dynamics of the microbial communities performing the co-digestion is still lacking (Karki et al., 2021). The efficiency of a substrate or a mixture is usually measured through Biochemichal Methane Potential (BMP) assays. BMP assay is common practice to estimate the amount of methane that could be produced during the breakdown of an organic substance (Filer et al., 2019).

In this study, we investigated 12 substrates originating from residual biomass from agricultural and livestock facilities, in terms of their physicochemical properties and maximum methane recovery. The substrates were investigated both as individual components and as mixtures in order to determine the ratios necessary to create an influent mixture that results in the highest possible methane yield. To this end, batch laboratory mesophilic reactors with operational volume of 320mL and 0.2g organic load were used to determine the Biochemical Methane Potential of the substrates and mixturesOnce the mono-digestion tests were conducted, the substrates that presented the highest methane yields and presented the desired physicochemical characteristics were chosen as co-substrates with animal manure to be tested as mixtures in various ratios. In all tested mixtures, 75% of the organic load consisted of animal manure, while the rest 25% (12.5% and 12.5%) consisted of different combinations of triticale, pastry creams, olive mill waste and cheese whey. Throughout the BMP tests methane concentration was measured using Gas Chromatography.

According to BMP tests and statistical analysis, pastry creams had the highest methane yield among single substrates, followed by triticale, olive mill waste, and peas (Figure 1a). As for the mixture of substrates, all treatments displayed generally higher methane yields compared to mono-digestion treatments. The most efficient combination was cattle slurry: pork slurry: cheese whey: triticale (T6 in Figure 1b) in a ratio of 40: 35: 12.5: 12.5. Possibly, this is due to the balance of carbon and nitrogen which occurred when animal manure (low C/N ratio substrates) and lignocellulosic biomass (high C/N ratio substrate) were combined. Furthermore, nitrogen-rich cheese whey (15.3 g/L) acted as a supplement to the animal manure mixture, which had a low organic nitrogen content (1.1 g/L). In contrast, cheese whey in the mono-digestion trial presented significantly lower methane yield, possibly due to an excessive accumulation of nitrogen which is an inhibiting factor of the process.

Overall, the BMP trial findings determined the methane potential of the studied biomass residues. These findings could help expand the range of viable energy sources and reduce the reliance on fossil fuels. Co-digestion, as a more effective processing method, could be used in local biogas facilities to exploit to the fullest biomass residues for biogas production. In addition, animal manure, cheese whey and triticale are biomass wastes with high and continuous/constant national availability, thus can support not only the overall Greek energy production but also the enhancement of circular bioeconomy.

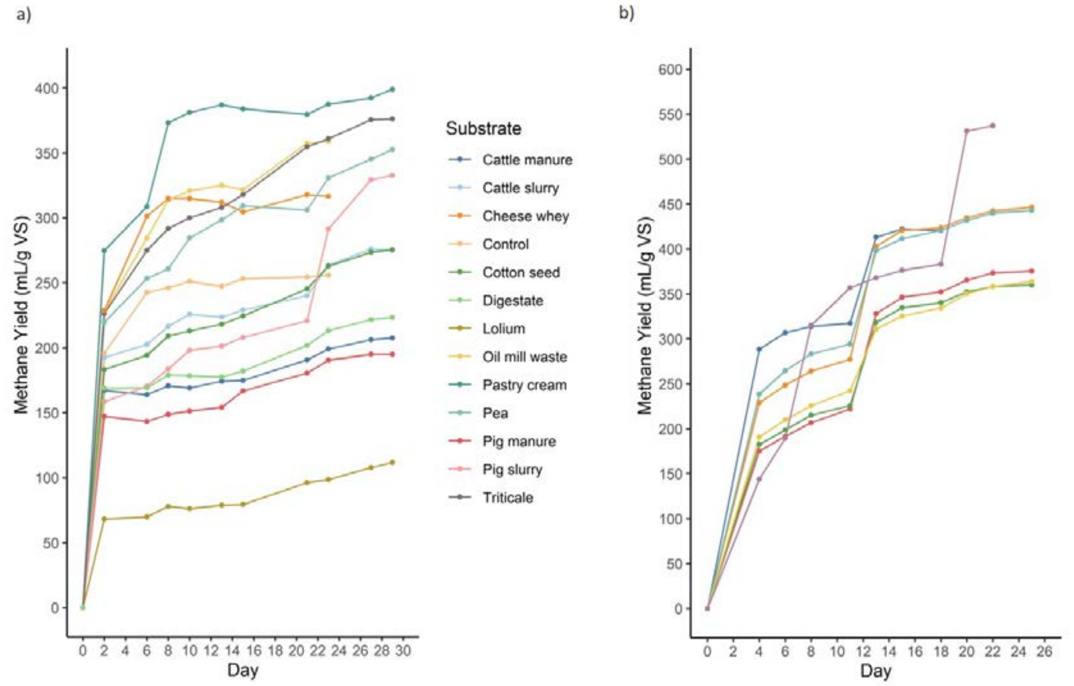

Figure 1. Methane yield curves (mL/g VS) during the BMP test for the twelve individual substrates studied and for the six substrate mixtures studied.(X1: Cattle slurry: Pork slurry: Cheese whey: Oil mill waste, X2: Cattle slurry: Pork slurry: Oil mill waste: Triticale, X3: Cattle slurry: Pork slurry: Cheese whey: Pastry cream, X4: Cattle slurry: Pork slurry: Oil mill waste: Pastry cream, X5: Cattle slurry: Pork slurry: Pastry cream: Triticale, X6: Cattle slurry: Pork slurry: Cheese whey: Triticale)

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