Liquid fraction digestate

Technology description

The solid/liquid separation of digestate generates two outputs, the liquid and the solid fraction of digestate. The liquid fraction of digestate is a pumpable liquid fraction, richer in nitrogen than digestate. The solid fraction consists of stackable fibrous material, rich in organic matter. There are several separation methods, such as belt press, sieve drum, screw press, sieve or decanter centrifuge (Figure 1 below). Furthermore, chemical aids (i.e. flocculants and coagulants) can be used to improve separation efficiency. All these methods combined with aids result in differences in separation efficiency of dry matter, N, P, or K portioning into liquid and solid fractions.

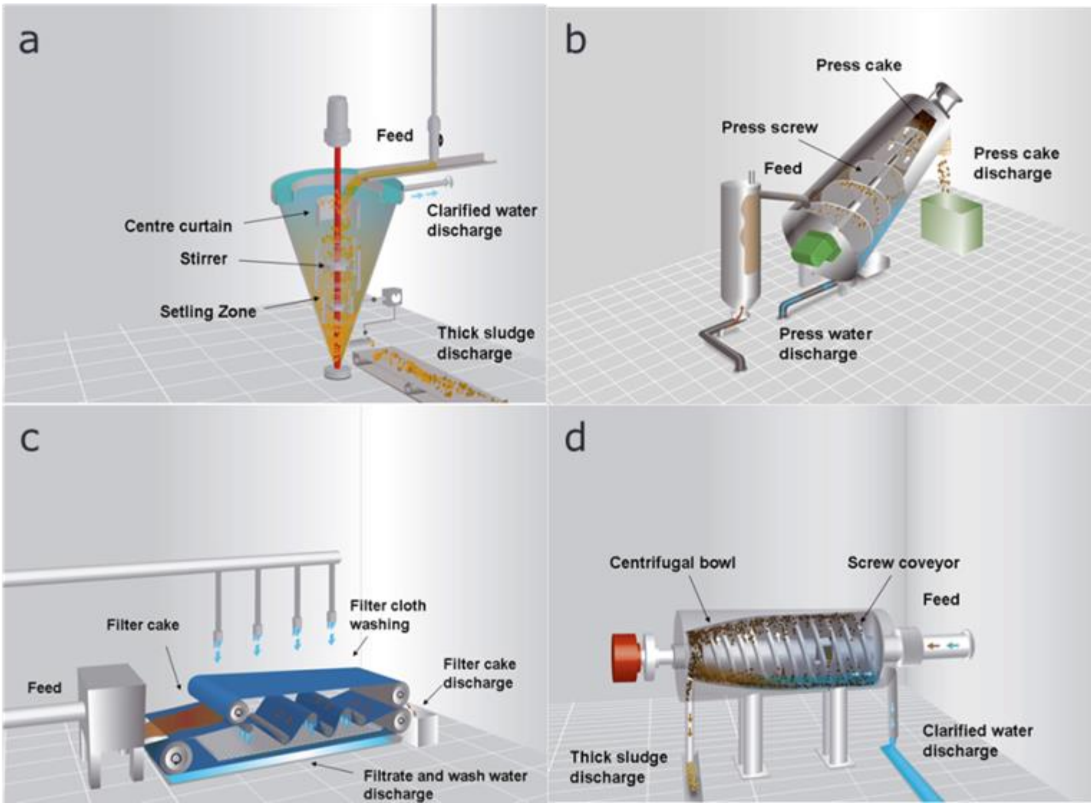

Figure 1: Examples of mechanical solid/liquid separators: a. thickener for sedimentation; b. typical screw press; c. typical belt separator with pressure rolls; d. typical decanter centrifuge (Hjorth et al., 2009).

Product characteristics

The liquid fraction of digestates has a high range of variation of chemical, physical and biological characteristics due to the type of solid-liquid separation, the chemical aids along with the type of substrates used to feed the digester. Centrifugation and screw press with coagulant are the most efficient separation techniques, which result in low total solids concentration in liquid fraction of digestate. Screw press or vibrating screen are the least efficient separation techniques, which lead to similar total solids concentration in liquid fraction of digestate as in ingoing raw digestate. The origin of substrates, especially manure, determines the characteristics of liquid fraction of digestate.

Table 1 reports the chemical characteristics obtained from 13 Italian full-scale anaerobic digestion plants (Tambone et al., 2017; 2019), 11 French full-scale co-digestion plants (Akhiar et al., 2017) and data of the EBA database with different feedstocks.

Parameter	Unit	Median	Mean	Minimum	Maximum	Reference
Dry matter (DM)	g kg^{-1} FM	51.0	53.9	0.23	257	EBA
pH	[-]	7.90	7.91	7.20	8.70	EBA
Conductivity	mS cm^{-1}	38	14	29	27	Akhiar et al, 2017
TOC	g kg $^{-1}$ DM	395	383	0.02	525	EBA
COD	g L^{-1}	40.2	40.9	10.3	83.1	Akhiar et al, 2017
BOD_5	g L^{-1}	4.5	4.8	1.2	9.3	Akhiar et al, 2017
TKN	g kg^{-1} DM	96.7	131	17.9	959	EBA
TAN	g kg^{-1} DM	53.6	80.4	2.74	397	EBA
TAN/TKN	[-]	55.4	61.4	15.3	41.4	EBA
P_2O_5 total	g kg^{-1} DM	4.21	4.42	0.06	13.8	EBA
C/N	[-]	3.35	3.70	2.70	4.93	Tambone et al, 2017
Biological stability OD_{20}	mg O_2 DM^{-1} 20 h.	37.2	40.1	13.1	70.2	Tambone et al, 2017
Alkalinity	g L^{-1}	14.1	16.5	7.4	24.7	Akhiar et al, 2017

Table 1. Chemical characteristics of liquid fraction of digestate samples based on three sources, their maximum (max) minimum (min), median (med) and average (av).

Agronomic aspects

The use of the liquid fraction of digestate as fertiliser is recent and few data are freely available to support its effectiveness in substitution of commercial synthetic fertiliser. Results of two trials were reported. Riva et al. (2016) indicated that sub-surface injection of digestate and derived products at pre-sowing and topdressing, gave crop yields similar to those obtainable with the use of urea. Sigurnjak et al. (2019) found in a three-year field trial that the liquid fraction of digestate used as a NK-fertiliser next to treatments with animal manure or digestate, showed similar effects on biomass yields and soil properties as the traditional fertilisation regime with animal manure and synthetic NK- fertilisers.

In both studies, yields obtained by fertilising with liquid fraction of digestate showed no significant differences with those obtained with conventional practices (using only synthetic N or synthetic N in addition to animal manure). Future perspectives indicate that nutrient variability in bio-based fertilisers will be one of the greatest challenges to address in the utilisation of these products.

Nitrogen use efficiency

The use of the liquid fraction of digestate as a fertiliser in agriculture is a recent practice and thus data on nitrogen use efficiency are scarce. Currently, two papers report data on Nitrogen Use Efficiency (NUE) of liquid fraction of digestate (Table 2). Both are based on pot experiments.

Crop	N application rate, mg N/kg soil	NUE, %	Reference
Barley	300	61	Maurer et al, 2019
Barley	500	47	Maurer et al, 2019
Lettuce	210	62	Sigurnjak et al, 2016

Table 2. Nitrogen use efficiency (NUE) of liquid fraction of digestate used as a fertiliser

The NUE values show variability depending on crop (barley and lettuce) and the application rate of nitrogen. NUE values reported for the liquid fraction of digestate are lower than those reported for conventional synthetic fertilisers. Sigurnjak and colleagues report a NUE value for liquid fraction of digestate of 62% which was lower than the NUE for Calcium Ammonium Nitrate (CAN) which amounted to of 71% (Sigurnjak et al. 2016).

Environmental aspects

Because of the origins of the matrices from which digestate and the relative fractions (liquid and solid) are obtained, i.e. animal slurry plus by-products and energy crops, heavy metals content and presence of pathogenic microorganisms must be considered.

Heavy metals

Table 3 reports the results of Tambone et al. (2017) on 13 samples of liquid fraction on principal heavy metals which are in line with the concentrations of poultry manure, sewage sludge and compost.

Metal	Tambone et al, 2017	EBA
Cd	0.3 ± 0.2	0.4 ± 0.2
Cr	11.6 ± 6.3	12 ± 11
Cu	55 ± 27	90 ± 89
Ni	9.8 ± 4.8	10.4 ± 5.6
Pb	1.7 ± 0.8	1.7 ± 0.8
Zn	245 ± 117	361 ± 320

Table 3. Heavy metals content in liquid fraction of digestate in mg/kg dry matter

Pathogens

The main factors affecting pathogen decay during anaerobic digestion are the hydraulic retention time (HRT), temperature, volatile fatty acids (VFA) present, batch or continuous digestion, bacterial species and available nutrients (Sahlström et al., 2008). In general, anaerobic digestion reduces pathogen counts, above all when thermophile conditions are adopted (Franke-Whittle and Insam, 2013) because of high temperature.

A study conducted on ten full-scale biogas plants characterised by different plant designs (e.g. single digesters, parallel or serial digesters), plant powers (ranging from 180 to 999 kWe), hydraulic retention time (HRT) (ranging between 20 to 70 days) and feed mixes monitored pathogens both ingestates and digestates (Orzi et al., 2015). Pathogens studied (Enterobacteriaceae, fecal Coliform, *Escherichia coli* and *Clostridium perfringens*) were significantly reduced during the process, both because of ammonia production and because of competition for substrate between pathogens and indigenous microflora. Plants showed different abilities to reduce pathogen indicators, depending on the pH value and toxic ammonia content. Similar results, on fecal coliforms, *E. coli*, *Salmonella*, *Campylobacter* spp. and *Y. enterocolitica*, were previously obtained in a psychrophilic anaerobic digestion plant (Massé et al., 2011).

Emission

In the EU, new legislation on environmental protection will require methods to reduce both ammonia and odour emission due to the spreading on the land of animal slurries. Among different methods proposed to reduce emissions, slurry treatment through anaerobic digestion and the direct injection of digestate into the soil have been proposed as successful practices (Orzi et al., 2018).

Ammonia volatilisation

As example of ammonia volatilisation during the utilisation of digestate and liquid fraction of digestate is reported in Riva et al. (2016) in a short-term experiment, in which digestate products were used as substitutes for mineral (N) fertiliser in a corn cultivation. In brief, digestate and the liquid fraction of digestate were applied to soil at pre-sowing and as topdressing fertilisers in comparison with urea, both by surface application and sub-surface injection. After each fertiliser application, ammonia emissions were measured. Ammonia emission data indicated, as expected, that the correct use of digestate and derived products, injected into the soil, avoided ammonia volatilisation. Sub-surface injection allowed the reduction of ammonia emissions to levels that were similar to those obtained by using urea.

Odour emission

Odour emissions are related to the anaerobic digestion process and are caused by the emission of volatile organic compounds (VOCs), (sulphur compounds, VFA, indoles and phenols) derived from fermentation and/or anaerobic respiration of degradable organic matter during the AD process (Orzi et al., 2010).

Mesophilic anaerobic digestion reduced the potential odour impact at ten full-scale biogas plants with different designs (Orzi et al., 2015). A reduction was found compared with odour from ingestates from 99106 ± 149173 OU m^{-2} h^{-1} (n = 15) to OU digestate = 1106 ± 771 OU m^{-2} h^{-1} (n=15). Apart from the effect of the anaerobic process by itself, some open field experiments (Orzi et al., 2015 and Orzi et al., 2018) compared the use of digestate and liquid fraction of digestate with untreated cow and pig slurries, testing different spreading methods: surface *vs* injection.

When the digestate and liquid fraction of digestate were dosed on soil, odours emitted were much lower than those from soils on which untreated slurries were used. Furthermore, slurries/digestate injection reduced much more odour emitted, until reaching a value similar to the untreated soil (Orzi et al., 2015 and Orzi et al., 2018).

Nitrate leaching

Sigurnjak (Sigurnjak et al. 2017) measured the nitrate content in the soil at a depth of 90 cm after the harvest period of maize crops, in field trials carried out in Belgium. The nitrate concentration of the parcels fertilised with digestate liquid fraction was always slightly higher than the concentration measured in the control plots fertilised with chemical fertilisers. However, the values do not exceed the legal limits imposed in Dutch (75 kg NO_3-N ha^{-1}) (VLM, 2015).

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A similar experiment in Belgium was carried out by Tsachidou (Tsachidou et al. 2019) on a grassland soil used for grazing. In this case, the concentration of nitrate at 90 cm depth for the parcels fertilised with digestate liquid fraction was always lower than that found at the same depth for the parcels fertilised with ammonium nitrate. Furthermore, it was reported that by increasing the amount of nitrogen dosed from 230 kg ha^{-1} to 350 kg ha^{-1}, the concentration of nitrate detected at 90 cm depth in the parcels fertilised with ammonium nitrate has quadrupled, while no differences were found in the parcels fertilised with digestate liquid fraction.

These results strongly suggest, in the short-term, that digestate liquid fraction applied as the sole nitrogen source and at the maximum rate of 350 kg N ha^{-1} yr^{-1} does not increase the potential nitrate leaching risk in comparison to chemical fertilisers.

Current legal view on liquid fraction of digestate

EU member states have national requirements for use of digestate as a fertilising product. These national regulations differ amongst the member states. If the requirements of these national regulations are not met, the digestate has to be treated as waste. The new EU Regulation for fertilising products 2019/1009 set standards for Fresh Crop Digestate (CMC 4) and Digestate Other Than Fresh Crop Digestate (CMC 5). From CMC 4 and CMC 5 fertilising products (organic fertiliser, organo-mineral fertiliser, organic soil improver, growing media) can be produced which can be labelled with a CE marking.

The national regulations will implement the new EU Regulation 2019/1009 and this will have an effect on the designation of feedstock substrates and their criterions. This process will be finalised in July 2022. Then it will be clear which feedstock substrates meet the requirements of the new EU Regulation and which will not and thus need additional national regulations. EU Regulation 2019/1009 is a facultative one and thus a manufacturer of a digestate can choose if the digestate is labelled with a CE marking or not.

Digestates which use manure are designated as manure and thus they have to fulfil the requirements on use of the Nitrates Directive (91/676/EC).

Some relevant references

Akhiar, A., et al., 2017, ‘Comprehensive characterization of the liquid fraction of digestates from full-scale anaerobic co-digestion’, Waste Management, 59, pp. 118–128: https://bit.ly/36IJfkH

Sigurnjak, I., et al., 2017, ‘Fertilizer performance of liquid fraction of digestate as synthetic nitrogen substitute in silage maize cultivation for three consecutive years’ Sci. Total Environ., 599–600, 1885–1894: https://bit.ly/2CfwLTq

Tambone, F., et al., 2017, ‘Solid and liquid fractionation of digestate: Mass balance, chemical characterization, and agronomic and environmental value’ Biores. Technol., 243, pp. 1251–1256: https://bit.ly/2WNB2H0

Tambone, F., et al., 2019, ‘Measuring the organic amendment properties of the liquid fraction of digestate’ Waste Management, 88, pp. 21–27: https://bit.ly/2JSUEnS

All references are given in: Ehlert, Phillip, Ivona Sigjurnak, Erik Meers, Marieke Verbeke, Fabrizio Adani, Massimo Zilio, Fulvia Tambone and Oscar Schoumans, 2019. Nitrogen fertilising products based on manure and other organic residues. Supporting literature of the SYSTEMIC factsheets. Wageningen, Wageningen Environmental Research, Report