Use of Ethoxylated Surfactants to Improve Digestate Stability

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Thermal or thermocatalytic treatment of sludge resulting from anaerobic digestion in continuous flow installations involves conditioning it in order to homogenise it and stabilize of these suspensions. In this study the digestate resulting in the processing of the algal biomass was conditioned in the presence of potato processing waste. The conditioning was done in several stages. In the first stage, the water content was reduced by controlled evaporation. The partially dried digestate was then ground, and the particle size distribution was determined bydynamic light scattering (DLS) using Nano ZS (Red badge). The digestate suspension was stabilized by adding ethoxylated surfactants and a lipid fraction. The stability of the digestate suspension was determined using a Turbiscan Lab. The stability of the digestate slurry was improved by the addition of lipid fraction and by addition of ethoxylated castor oil.

Keywords: conditioning of digestate, ethoxylated surfactants, algal biomass

The conditioning of the digestate can be accomplished by various methods. The first stage of conditioning usually consists in reducing its water content. The destruction of substances and of extracellular polymer cells as well as the decrease in particle size should contribute to improving the degree of dewatering of anaerobic digestate by this conditioning method. Several ways have been proposed to increase the water removal capacity of sludge due to the considerable impact of the large sludge volume on the processing costs. A recent study [1] has proposed an innovative approach to improving this process by combining the treatment with zerovalent iron in the presence of hydrogen peroxide at *p*H 3.0. The combination of zero valent iron at a concentration of maximum 4.0 g / g total solids and hydrogen peroxide at a concentration of maximum 0-90 mg / g total solids and at a *p*H of 3.0 significantly improved the dewatering of anaerobic digestate. The highest increase in the concentration of anaerobic digestate was obtained at 18 mg hydrogen peroxide / g total solid and at 2.0 g zero valent iron / g total solids, the capillary aspiration time being reduced by up to 90%. Economic analysis has suggested that the proposed treatment has more economic benefits compared to the classic Fenton process.[1] Another method of digestate treatment [2] consists in the use of a nanofiltration membrane, thus removing nitrogen (in the form of ammonia / ammonium) and phosphorus (in the form of phosphate ions) present in this digest, according to pH (between 3-11). Filtration of nitrogen and phosphorus from complex aqueous solutions has been shown to be dependent on membrane load and ionic species. However, from an economic point of view, the use of chemicals to adjust *p*H is costly and determinant in the process.

Another study [3] explored the possibility of using C, N and P from pig manure resources by dry anaerobic digestion, followed by ammonia removal, volatile fatty acid separation and phosphorus retention in the solid residue. Increasing the amount of biomass from solid waste correlated with increased demand for renewable resources has led to the diversification of the use of anaerobic digestion due to the advantages of reducing the mass and volume of raw material, controlling smoldering emissions through stabilization and recovering renewable energy [4]. Large-scale application of anaerobic digestion resulted in large amounts of residual digestate to be processed. Anaerobic digestate after post-treatment is good as fertilizer [5] and soil conditioner and as a pollutant absorber. Dehydration is a necessary step in digestate treatment. Thus, as a result of dehydration, the liquid fraction and digestate fibers are separated for storage, transport, post-treatment and other purposes. Effective dehydration significantly reduces digestate volume and cost of further processing. For example, separation of solid and liquid phases can reduce transport costs by up to 60%, and can be reduced by another 25% after drying. To optimize the dewatering operation, it is necessary to clarify the factors that influence the absorption capacity. Although the dehydration of sludge, in general, and of digestate sludge has been thoroughly studied, the degradation capacity of anaerobic digestate resulting from other organic wastes is less well known, although there are many technical methods for separating it. The total solid fraction of the fiber digestate resulting from food residues is higher if the separation is performed with a settling centrifuge (22.3%), followed by the separation with a screw press (12.9%) and by a belt press (8.7%). Digestion should take more than 8 days to get more hydrolysates but no more than 30 days because dehydration occurs.

Numerous studies [6-10] have shown that biomass digestion and especially anaerobic digestion have a strong energy potential and its composition and implicitly the characteristics of extracellular polymeric substances play an important role in dewatering sewage sludge. Extracellular polymeric substances are composed of a variety of organic substances including carbohydrates and proteins as the main constituents and humic substances, uronic acids and nucleic acids in smaller amounts [11-13].

The use of surfactants has proved effective in various fields, favoring the homogenization of heterogeneous mixtures [14-16]. In this paper, it was studied the improvement of the digestate slurry stability for further processing by treating with surfactants in the aqueous phase or in the reverse emulsion.

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Experimental part

The surfactants used in these experiments are 20 EO polyethoxylated sorbitan monooleate (Polysorbate80 Aldrich) and 10 EO polyethoxylated castor oil. The digestate selected for tests is resulting in anaerobic fermentation of algal mass and vegetable waste.The caracteristics of the lipid fraction used in the experiment are shown in table 1.

Table 1
CHARACTERISTICS OF THE LIPID FRACTION USED IN THE EXPERIMENT

No. crt.	Characteristics	Values
1.	Acid value, mg KOH/g	157
2.	Saponification value, mg KOH/g	185
3.	Flash point, °C	175
6.	Water, % gr.	4
7.	Specific weight at 20°C, g/cm^3	0.86
8.	Viscosity,mPa.s (cP), 20°C	286

The conditioning of the digestate was carried out in three stages: removal of the excess moisture, grinding of the partially dry digestate, and preparation of a stable homogeneous suspension.The moisture content and the ash content of the digested sample was determined by thermogravimetric analysis in the inert gas atmosphere with a DuPont Instruments *Thermal Analyst 2000/21*00 coupled with a *951 Thermogravimetric Analyzer* module at a heating rate of 10°C / min. The removal of the digestateexcess humidity was carried out by drying in an MEMMERT DRYING OVEN with natural convection, continuous adjustment of pre-heated fresh air admixture, vent connection with restrictor flap, microprocessor PID-temperature controller with integrated autodiagnostic system with fault indicator, at 80 °C.

Digestate grinding was done in a cutting mill GRINDOMIX GM200 with speed adjustment, grinding time Disk speed optimization as well as grinding time was evaluated based on the distribution of dimming particle size. The dimensions of the particles obtained by grinding and the distribution of their dimensions were determined using a Dynamic Light Diffusion (DLS) particle size measurement system with a Malvern-ZetasizerNanoZS (Red Badge) instrument. For this purpose the samples were dispersed in heptane at a concentration of 1.6g / 100mL of solvent. Preparation of digestate suspensions was carried out in a balloon fitted with a variable speed stirring system, at a speed of 2000 rpm. Two variants of digestate suspension stabilization systems have been selected: i) aqueous medium for suspending the digestate particles in the presence of surfactants; and ii) suspending the digestate particles in an inverse emulsion of the lipids fraction resulting from the processing of the raw digestate. Determination of the stability of the conditioned digestate suspension was achieved by the transmission method, respectively the diffusion of light. A TurbiscanLab appliance was used with dedicated software for recording and interpreting data: TlabTurbisoftFormulaction.

Results and discussions

The water content of the crude digestate,determined from the thermogravimetric curve was 80.66 wt.% and the ash content was 5.35wt.%.

The medium dimension of the grinded particles obtained by DLS analysis and the distribution of their dimensions are presented in figures 2 and 3.

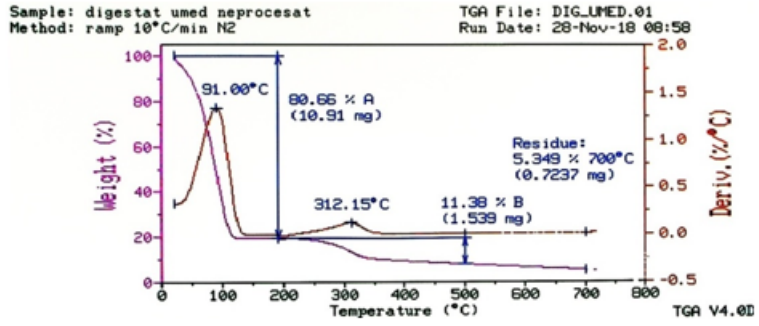

Fig.1. Thermogravimetric curve of crude digestate

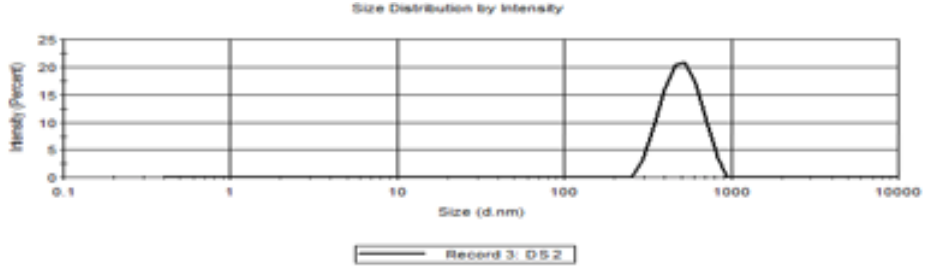

Fig. 2.Particle size distribution for the solid digest sample milled at 8500 rpm

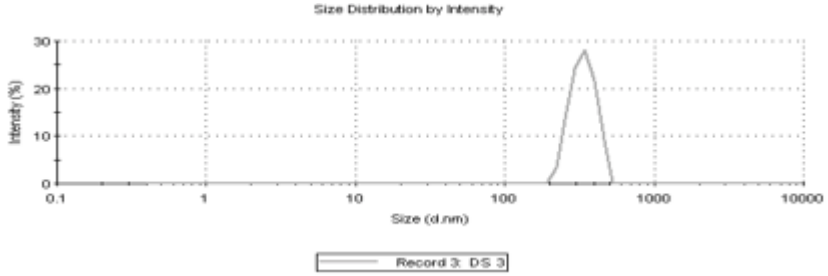

Fig. 3.Particle size distribution for the solid digest sample milled at 9500rpm

From figure 2 and 3 it is observed that making the grinding process at higher rotor speeds favors the reduction of the average particle size and of the minimum and maximum size of these particles. Thus at a speed of 8500 rpm. the average diameter of the digested digestate particles was 631.9 nm, their minimum size was approximately 150 nm and the maximum size was approximately 950 nm, while at the speed of 9500 rpm. the average diameter of the digested digested particles was 600 nm, their minimum size was approximately 100 nm and the maximum size was approximately 400 nm. Also the area of variation of the particle size of the digested digestate is also diminished from approximately 800 nm at 8500 rpm. to approximately 300 nm at 9500 rpm.

The aqueous suspensions of digestate were prepared according to the recipes shown in table 2 and of the oily suspensions in table 3.

Evaluation of the stability of the prepared suspensions was performed after periods of time suggestive of the proposed application for each sample.The transmission and blackscattering profiles of PA1, PA2, PL1 and PL2digestate suspensions are shown in figures 4-7.

Table 2
RECIPES USED TO PREPARE AQUEOUS SUSPENSIONS OF DIGESTATE

Sample	Component, mL		
	Powdery digestate	Distilated water	Polysorbate 80
PA1	40	159.0	1.0
PA2	40	156.0	4.0

Table 3
RECIPES USED TO PREPARE OILY SUSPENSIONS OF DIGESTATE

Sample	Component, mL			
	Powdery digestate	Distilated water	Lipid fraction	10EO Castor oil
PL1	40	15.9	143.1	1.0
PL2	40	15.6	140.4	4.0

The addition of hydrophilic surfactantto the digestate aqueous solution favors the separation of the digestate powder both in the lower zone and in the upper zone.Increasing the concentration of hydrophilic emulsifier from 0.5 to 2% attenuates insignificantly the tendency of solid phase separation.

The use of a hydrophobic surfactant in the presence of lipid fraction at an oil / water ratio of 9/1 improves the stability of the digestate slurry. Increasing the surfactant concentration of this suspension from 0.5 to 2% slightly improves the stability of that suspension. An important contribution to stabilizing the suspension also has the reverse emulsion formation, which due to the higher viscosity value decreases the rate of deposition of the digestate particles. The presence of water in the droplets of the internal phase moistens the digestate particles and prevents separation of the digestate particles in the upper area of the tube.

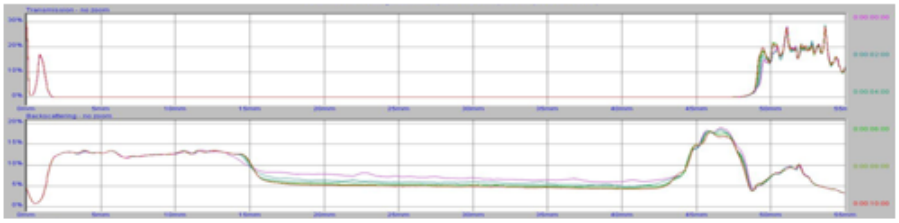

Fig.4.Stability over time of the digestion suspension PA1

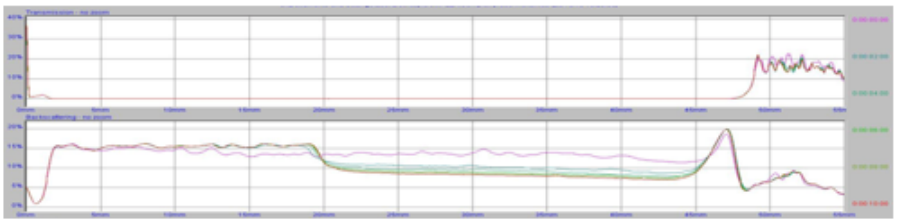

Fig.5.Stability over time of the digestion suspension PA2

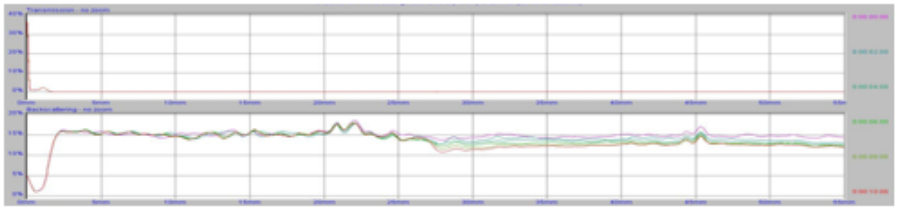

Fig.6.Stability over time of the digestion suspension PL1

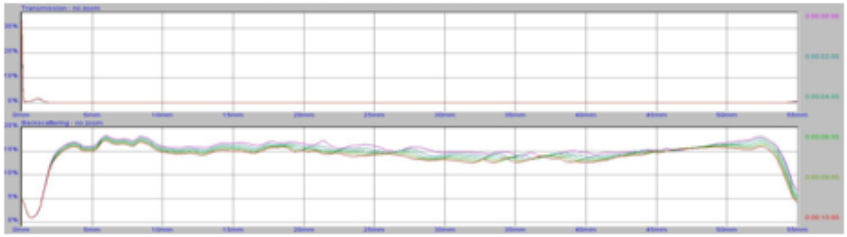

Fig.7.Stability over time of the digestion suspension PL2

Conclusions

Thermal or thermocatalytic treatment of sludge resulting from anaerobic digestion in continuous flow installations involves conditioning it in order to homogenise it and stabilize of these suspensions. In this study the digestate resulting in the processing of obtaining biogas . The conditioning was done in several stages. In the first stage, the water content was reduced by controlled evaporation. The partially dried digestate was then ground, and the particle size distribution was determined by dynamic light scattering (DLS) using Nano ZS (Red badge). The digestate suspension was stabilized by adding ethoxylated surfactants and a lipid fraction. The stability of the digestate suspension was determined using a Turbiscan Lab. The stability of the digestate slurry was improved by the addition of lipid fraction and by addition of ethoxylated castor oil.

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