Pretreated biomass improves digestion

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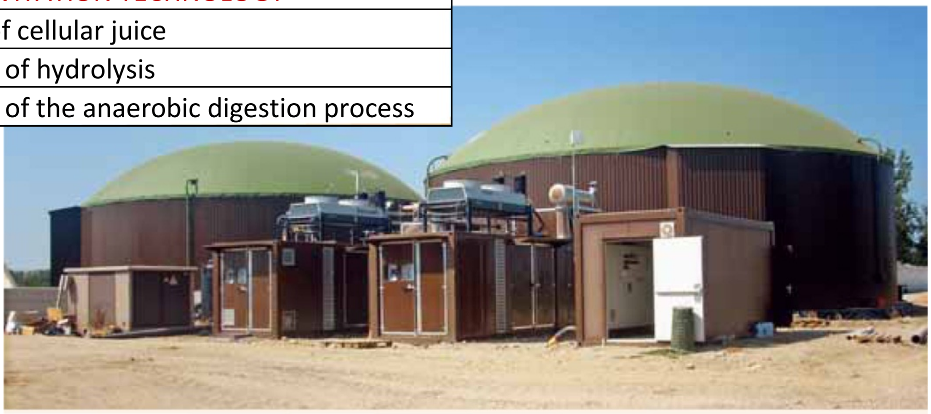
The anaerobic digestion process consists, as is known, in the first place in the degradation of the organic substance into simple compounds and subsequently in converting these into biogas. Each stage of the process is influenced by many chemical and physical parameters, as well as complex microbiological balance. Depending on organic matrices, loaded into the digesters, the process can be more or less fast, and this depends essentially on the complexity of the molecules constituting the organic matrix used: simple compounds such as organic acids and simple sugars degrade very rapidly, more compounds complex such as amino acids, lipids and fibrous fractions, require longer times. Degradation rate is one of the most important parameters in the dimensioning of the volume of the digester and / or in the choice of plant technologies. In general terms, the approach normally used to exploit the energy potential of biomass is to dimension the digesters in such a way as to ensure an hydraulic retention time sufficient for the bacteria to degrade the organic molecules: in case of pig manure, for example, digesters are sized with retention times of 20-25 days; in case of cattle manure, 35-40 days; in case of dedicated biomass, at least 50-70 days.

When you need to change biomass

However, it often happens that the type of organic matrix, initially in the supply plan for the plant, should also be changed in a radical way. Causes are many: poor seasonal course, which results in a poor quality of dedicated biomass produced (as happened for example in the last crop year), major changes in supply costs, new possibilities of using agro-industrial by-products, etc.. All of these conditions cause inevitably a change in the quantity and quality of matrices to be loaded and a consequent change in the physico - chemical characteristics of the diet. Not always technologies of loading, mixing of the digester, discharging of the digestate and, last but not least, retention times available are such as to ensure the maintenance of good conversion performance.

To increase the plant flexibility, and thus ensure the enlargement of supply possibilities, **many techniques for matrix pretreatments** have been proposed: **physical** (extrusion, grinding, disintegration with pulper, etc..), **thermal, chemical, enzymatic**, all with the aim of accelerating the degradation process of organic matter, or speed up the hydrolysis step, or making it more available certain organic compounds.

ADVANTAGES OF CAVITATION TECHNOLOGY
• Availability of cellular juice
• Acceleration of hydrolysis
• Acceleration of the anaerobic digestion process



Some studies have shown that through the cavitation the rate of —bacterial degradation can accelerate up to 4 times compared to conventional treatment

Ultrasounds to accelerate the digestion

Among known techniques in this industry sector, there is also the one that applies ultrasounds, namely waves in a frequency range between 20 and 10,000 kHz. The very wide range of frequencies available allows you to use this technique in many sectors, i.e. biomedical, purification treatment, etc.. However **the most widely used frequency range, whenever it intends to treat a product in order to obtain a chemical or physics matter modification, is the one between 20 and 100 kHz.**

SPR pilot reactor in the set up used to perform controlled cavitation tests.

Cavitation

The generation of ultrasounds can be obtained in several ways, including the cavitation. During cavitation, the energy used for the treatment is converted into an alternated formation and implosion of microbubbles that generates, in turn, a sequence of shock waves (ultrasounds). This alternation is responsible for intense mechanical and thermal energy, transferred on organic matter present in aqueous solution which determines a partial physical destructuration, lysis of cell walls and the consequent release of intracellular content. This action results in increased availability of cellular juice, in an acceleration of hydrolysis processes and, consequently, in an acceleration of the anaerobic digestion process as a whole: various studies already conducted, have shown that the bacterial degradation rate can accelerate up to 4 times compared to conventional treatment.

Controlled cavitation

The innovative technology of controlled hydrodynamic cavitation Has recently appeared on the biogas market (SPR reactor, an acronym of the english ShockWave Power Reactor), already present in other industries, which consists of a steel rotor with blind cavities and rotating within a housing. Its rotation determines a pressure difference inside holes, present on the rotor, which in turn causes the formation and subsequent implosion of microbubbles.

Locally and instantaneously you can reach pressures of several thousand bars and temperatures of the order of several hundred degrees. The rotor extension and diameter, cavity number and diameter, as well as rotor speed and space between rotor and outer housing, are all factors that determine the functioning and efficiency of the machine.

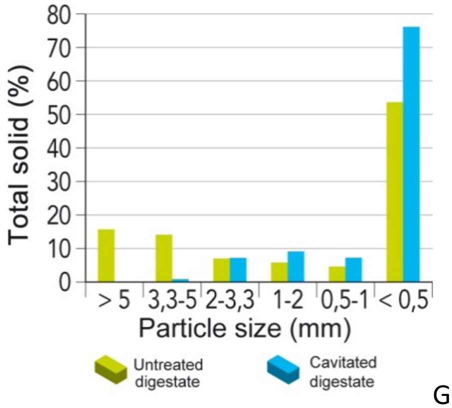
There are some mechanical and functional benefits:

- there are no moving parts with mechanical friction: the rotor is the only moving element. This allows to have low maintenance costs and low risks of damages;
- compactness, simplicity of use and installation, and high flexibility of use (varying rotation frequency more or less energy can be released to the biomass to be treated, and therefore higher or lower efficiency of the treatment) are the most important points that characterize it.

The main expected benefits are related to the reduction of organic material size, to the reduction of the digested viscosity, and the resulting easiness of internal digester mixing, as well as increase of the digestate homogeneity and better pumpability.

The technology could be applied in anaerobic digestion with different plants configurations:

- recirculating over the digester: a pump sucks the digestate from a given point of the digester, drives it through the SPR reactor for treatment, and re-injected into the digester at a second point. With this configuration it is possible to treat and improve the operation of an existing digester, usually the primary one, reducing quite quickly even build-up of non degradated fibrous fractions. In this configuration, treatment efficiency is not maximized, as part of the digestate is treated several times;
- discharging from the primary digester: configuration similar to the previous one, with the difference that the product is treated only once and downloaded in the post digester. This configuration maximizes the efficiency of the post digester;
- treatment of loading biomass, the biomass to be loaded can be mixed with a hydraulic carrier (liquid manure, digestate or water) and driven to the SPR reactor for destructuration before loading. Depending on the plant type, sort of biomass used, and treatment intensity to be obtained, the technology can be applied over the entire biomass loaded or only on a part of it (typically the biomass characterized by fibrous matrices, particularly complex to be degraded).



GRAPH 1 – Particle size of a digestate treated and untreated with SPR reactor.

The treatment has an evident impact: the size larger than 3 mm is in fact missing in the treated digestate, while the fraction <0.5 mm is higher than 42% in treated digestate, compared to the reference.

Digestate	Particle size (mm)					
	> 5	3,3-5	2-3,3	1-2	0,5-1	< 0,5
Untreated	15,55	13,93	6,81	5,64	4,44	53,62
Cavitated	0,14	0,65	7,02	8,94	7,05	76,19

TABLE 1 - Distribution (%) of particles size of the dry matter

Cavitation technology can be applied to all biomass or only to a part of it, usually the one more fibrous and complex to be degraded.

Testing the application

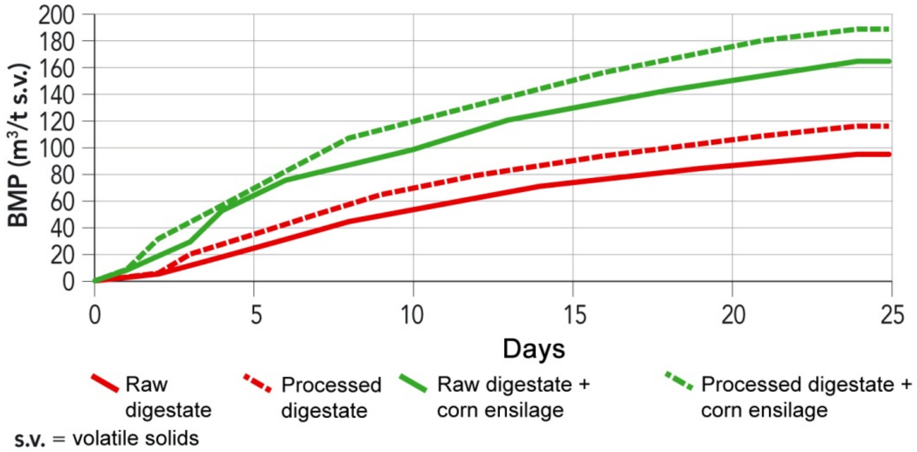
The CRPA performed some tests to verify the application of this technology with a pilot SPR unit. The pilot used for the treatment consisted of a small size machine capable of handling a maximum of 1 m3/hour of mixture, and not equipped to evaluate energy consumption with sufficient precision.

In Table 1 and Graph 1 are reported the size distribution of a digestate dry matter, taken from a plant fed with slurry and dedicated crops, and treated with the SPR reactor (controlled hydrodynamic cavitation), compared to the same untreated digestate. It is evident the great impact the treatment has on size distribution of the present dry matter: fraction larger than 3.3 mm size is basically not present any more in the treated digestate (30% about of the dry substance, present in the reference), while the fraction with a diameter <0.5 mm (soluted and dissolved compounds) is higher than 42% in the treated digestate, compared with reference digestate.

Potential of methane production

To facilitate understanding of the effect that the treatment has had on tested organic matter, two tests were also conducted to measure the potential methane production: in the first case a digestate sample was taken from a primary digester of a biogas plant, fed with slurry and dedicated crops, and was treated with SPR reactor; in the second case at the same digestate was added a quantity of corn silage equivalent to that of the daily load of the same digester (6 kg sv/m3/day) that has been treated with SPR reactor.

The aim of the two comparisons was to check the effect of the treatment on the biomass, already partially attached in anaerobic digestion (configuration of recirculation on the primary digester) **and on the mixture at the load** (configuration of complete loaded biomass treatment, with digestate as hydraulic carrier). Of course, the same tests were conducted on material non-treated with SPR reactor.



GRAPH 2

Comparison of potential methane production between treated and non- treated digested and digested + silage

Thesis	Biogas (Nm^3/t s.v.)	Methane (Nm^3/t s.v.)	Methane (%)	Degradability s.v. (%)
Digestate				
Untreated	178,22	94,85	53,2	23,3
Processed with SPR	214,13	116,07	54,2	27,7
Difference (%)	120	122	102	119
Digestate + corn ensilage				
Untreated	302,34	164,68	54,5	39,1
Processed with SPR	344,06	188,80	54,9	44,3
Difference (%)	114	115	101	113
s.v. = volatile solid				

TABLE 2 - Comparison of potential methane production between treated and non- treated digested and digested + silage

The potential of methane production of treated digestate was higher by 22%, the one of the treated mixture of corn silage + digestate, by 15%. The biogas composition was not significantly different.

Table 2 and graph 2 shows the results of this preliminary test. Analysis of results leads to the following observations:

- untreated digestate showed a residual potential of methane production of about 95 Nm3 CH4 / t s.v., which was increased to 116 Nm3 CH4 / t s.v. after treatment with SPR reactor. The treatment effect was seen since the 3rd day of the test, when degradation rate increased and was maintained higher up to the end of the test (25 days): **the overall potential of methane production of treated digestate was more than 22%**. The mass balance of the test confirmed a higher degradation of volatile solids (+19%);
- untreated digestate, with addition of a quantity of corn silage, equivalent to the volumetric daily organic load, showed a potential of methane production of about 164,7 Nm3 CH4 / t s.v., which was increased to 188,8 Nm3 CH4 / t s.v. after treatment with SPR reactor. The treatment effect was seen since the 2nd day of the test, when degradation rate increased and was maintained higher up to the end of the test (25 days): **the overall potential of methane production of treated mixture was more than 15%.** The mass balance of the test confirmed a higher degradation of volatile solids (+13%);
- The biogas composition in both tests (treated and untreated with SPR reactor) was not significantly different.

The efficiency reduction of the test about the second comparison, clearly highlights the fact that part of the organic substance easily degradable, particularly the one present in corn silage, is not affected by the treatment, and therefore the technique is most advantageous applied in all those situations in which the load is made of more hardly degradable matrices (corn stalks, triticale, manure with straw) or of larger speckling.

In addition to the advantageous effects on digestion efficiency, it remains to examine and verify the flexibility and functional reliability, energy consumption and effects on digestate mixing, in different system configurations.

For this purpose, the CRPA is launching a monitoring campaign of a real scale plant .

The potential of methane production of digestate treated with controlled cavitation was higher than 22%

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