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BIP-CO

Launching BioGAS+ iron nanoparticles additive for biogas output optimization in Colombia

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Introducing nanotechnology in the biogas sector in Colombia

Colombia is building a comprehensive regulatory framework to combat climate change, favour renewable sources of energy and implement sustainable waste management policies with a sustainable and circular economy vision.

Within this framework, biogas (a renewable energy sources produced during anaerobic digestion of organic substrates) is repeatedly highlighted as offering a set of multipurpose advantages: converts organic waste in raw materials, capture methane emissions, can be stored and supplied on demand, can be converted in heat, gas and/or electricity and is a decentralised energy source.

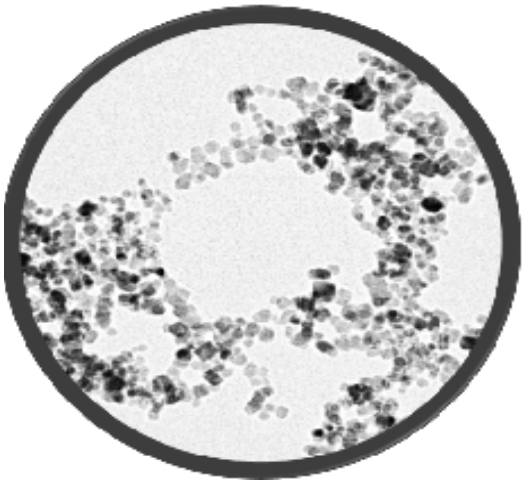
Colombia has identified several of those advantages as strategic:

- Within waste management policies, as a proper way of dealing with organic waste while capturing methane emissions (also helping to reach Climate Change emission targets);
- Favouring substitution of Natural Gas (NG) vehicle fleet to Renewable Natural Gas (RNG) in a country where 25% of vehicle fleet uses NG;
- Increase local farmers' living standards, especially in the ZNI (Zonas No Interconectadas – off grid areas).

But Colombia cannot take full advantage of all this strategic possibilities due to the difficult optimization of the complex processes occurring inside anaerobic digesters and, as a consequence, the low conversión rates of organic waste to energy. Existing technologies and products approaching these problems only obtain modest production increases or/and require costly structural changes in the biogas process.

To radically reverse this situation, BioGAS+ additive offers a disruptive nanotechnology-based innova-

tion that obtains the highest ever-reported improvement of biogas production, together with other fundamental benefits. BioGAS+ makes nanomicrobiology real. Because we believe that BioGAS+ can transform biogas energy in a competitive renewable energy source that bring its full potential in helping to comply with Colombian Sustainable Development Goals objectives, we propose to launch BioGAS+ in the Colombian biogas market through the co-creation of a local value chain.



We propose to develop BioGAS+ value chain by transferring our know-how on the production of BioGAS+ nanoparticles and asking the collaboration and active participation of Colombian nanotechnology and biogas stakeholders for setting up a set of Case Studies.

The introduction of nanotechnology in the biogas sector in Colombia requires a clear strategy in order to give confidence to final costumers and users. Applied Nanoparticles SL and NANOCITEC will design and develop a strategy based on Responsible Research and Innovation (RRI) that implies transparency, communication and dialogue and a product development that follows the safer and sustainable by design paradigm.

The active participation of biogas stakeholders will be canalized by the co-creation and development of three Case Studies. Although any Biogas Plant is a potential end user of BioGAS+ (regardless of size, feedstock or technology used) we are requesting the collaboration of those biogas experts, associations and users that share our vision of the role of biogas as a renewable energy source. We have chosen to focus in biogas plants using waste as feedstock (poultry, pig, bovine, agricultural and organic urban solid waste) and in those areas where biogas helps to the internalization of social, energy and environmental externalities (energy supply in the ZNI Off-grid area and biogas plants producing Renewable Natural Gas as substitution to Natural Gas Vehicle fleet). This positioning is underpinned by our commitment towards RRI and our believe that it is possible to work for the common good while making profitable business (making money doing good).

BioGAS+

Makes the difference

The ambition of BioGAS+ is to help solving the underperformance of Anaerobic Digestion (AD) Plants by introducing the first additive based on iron nanoparticles for outstanding energy production enhancement and/or preventing bacterial disaster in biogas digesters among other advantages. The aspiration of BioGAS+ is to transform waste into appealing raw materials in an economically efficient and sustainable way so that biogas production is converted in a profitable market capable of competing and surpassing fossil fuels based economy effectively.

Nowadays the critical advantages of anaerobic digestion are countered by biogas yields underperformance, unsustainable approaches to biogas production and the dependence on fluctuating subsidies. Applied Nanoparticles SL product, the trace element supplementation BioGAS+, can outstandingly increase the biogas yield.

Concept

BioGAS+ is the first ready to use additive based on safe and sustainable engineered iron nanoparticles directed to the optimization of anaerobic digestion processes and, consequently, the increase of biogas production.

BioGAS+ innovative patent and strategy is based on results showing that engineered iron nanoparticles (FeNPs) can optimize anaerobic processes enhancing the production of biogas, due to their denseness, chemical composition, crystal structure, nanometric size and high reactivity. Applied Nanoparticles offers a nanotechnology-based innovation to anaerobic digestion, that obtains the highest ever-reported improvement of biogas production (triple the biogas yield with cellulose as feedstock in laboratory conditions -DIN-38414)[1], among other significant benefits.

Technical description

It is known that addition of Fe ions to an anaerobic bacterial reactor can increase methane production, however introducing such ions can give rise to toxicity and excess reactivity. Those problems are solved with BioGAS+ iron nanoparticles (NPs). Iron NPs can be designed to provide ions in a controlled manner (corrode and dissolve as ions provider). A unique Fe optimized dosing source. Thus, the process that converts organic waste into raw matter for energy production is optimized by simply adding a small dose of iron NPs to either a large waste treatment reactor, a septic tank or a homemade biodigester.

In conditions of anaerobic breakdown (absence of oxygen) small doses of mixed iron oxide nanoparticles (NPs) serve as a catalyst that stimulates bacteria metabolism and accelerates the production of biogas (a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen, mainly CO_2 and CH_4).

[1]E Casals, R Barrena, A García, E González, L Delgado, M Busquets-Fité et al. Programmed iron oxide nanoparticles disintegration in anaerobic digesters boosts biogas production. *Small* **10**, 2801-2808, 2014

BioGAS+ competitive advantages

Although the unprecedented methane ratio increase is the most appealing advantage of BioGAS+ is only one of the advantages reported. Those differential advantages are:

1. Improving biomass to biomethane conversion efficiency.

2. Increase in both biogas and biomethane production.

3. Better biogas composition (higher methane share).

4. Reduction of the digestate fraction.

5. Higher waste degradation .

6. Increase digestion process stability (more reproducible).

7. Acceleration of the digestion process. Reduction in retention/residential time .

8. Proven to reduce H2S levels (precipitated in the form of pyrite).

9. Reduction on the amount of foam produced.

[2]An improvement of anaerobic digestion of biomass will lead to a less bioactive end-of-waste digestate, being more appealing for composting and re-use.

10. Enrichment of the residual material (digestate) with iron ions to obtain by-products with increased economic value such as high quality fertilizers.

11. Solution to inhibitory substances. Rescue digesters with problems.

12. Additive (it does not require any change in the biogas plant industrial process).

13. It does not require pre-treatment of the substrate/feedstock or maintenance to preserve the microorganisms.

14. Enlargement of biomass feedstock (oil, fat, meat) as it has been proved suitable for "difficult to digest" (recalcitrant) feedstock.

15. Enlargement of biomass feedstock (oil, fat, meat) due to the increased biogas/methane production.

16. Can be used with any kind of anaerobic digester.

17. Reduce AD plant energy consumption.

18. Minimize undesirable side effects in biogas plants such as the odours associated to HS and NH3, thus reducing the cost of associated conditioning measures.

19. Precipitation (recovery) of phosphorus (in the form of ferric and ferrous phosphate).

20. Disinfection of pathogens and multiresistant bacteria.

Patent

The Private Foundation Catalan Institute of Nanoscience and Nanotechnologies (ICN2), the Catalan Institute for Research and Advanced Studies (ICREA), and the Autonomous University of Barcelona (UAB) are the owners of a Patent named "method for increasing the production of biogas in anaerobic digestion processes of biodegradable material by adding iron oxide nanoparticles. This method is protected in Europe by patent nr. EP2683662 and in the USA by patent no. US 9,416,373 B2 BIOGAS PRODUCTION. The Patent owners and Applied Nanoparticles SL have signed an exclusive Licencing Agreement dated 21/07/2015.

The inventors of this method are: Victor F. Puntes, Edgar González, Eudald Casals Mercadal, Ana García Mestre, Lucía Delgado Ramisa, Xavier Font Segura and Antonio Sánchez Ferrer.

Biogas yield increase

The biogas yield increase of methane of approximately the 30% has been

consistently reported with industrial feedstock from diverse industrial sectors. Such increase in methane yield is far above any known technology aimed at increasing biogas production. This is the reason why BioGAS+ have to be considered a disruptive technology. In addition to such direct methane increase, it has to be taken into (economic) consideration the other differential advantages as reported in this briefing.

BioGAS+ and recalcitrant feedstock

Furthermore, from the multiple studies undergone, it has been proved that BioGAS+ product is specifically powerful in enhancing the ability of anaerobic bacteria to degrade difficult or "recalcitrant" organic matter, something that we will test and confirm in further stages. Thus, our steadily shift in focus from urban waste sludge to agricultural/cellulosic residues.

BioGAS+ technology development

We started our studies on the potential benefits of dosing Fe(III) to anaerobic bacteria consortia with remarkably high doses of Fe3O4NPs (back then we didn't have the exact BioGAS+ formulation sorted out) and in a lab controlled atmosphere. For these first phase of preliminary studies, we teamed up with a research group on Anaerobic Digestion at Autonomous University of Barcelona led by Prof. Antoni Sanchez (http://www.gicom.cat/). They suggested us to start testing the potential of biogas production increase of our prototype using micro-cellulose as feedstock following an adapted methodology described by the German Institute for Standardization (Federal Government of Germany, 2001)[3].

These initial studies using an ideal fully-convertible-to-biomethane feedstock gave very promising results with biogas production increases of biogas up to a 185%

[3]Anaerobic assays were performed in 1.5 gas-tight reactors, equipped with a pressure transducer to monitor biogas production. This standard test provides the parameter GB21 for biogas production (GB) expressed as liters of biogas measured under normal conditions produced per kg of initial sample dry matter (l kg−1DM) over 21 days. The cumulative production of methane was calculated by fitting the modified Gompertz model (Eq. 1) to the experimental cumulative methane production curves. The SigmaPlot 12.0 software (Systat Software Inc., California, USA) was used to obtain the equation parameters, namely P, Rmax and λ (Ponsá et al., 2011).

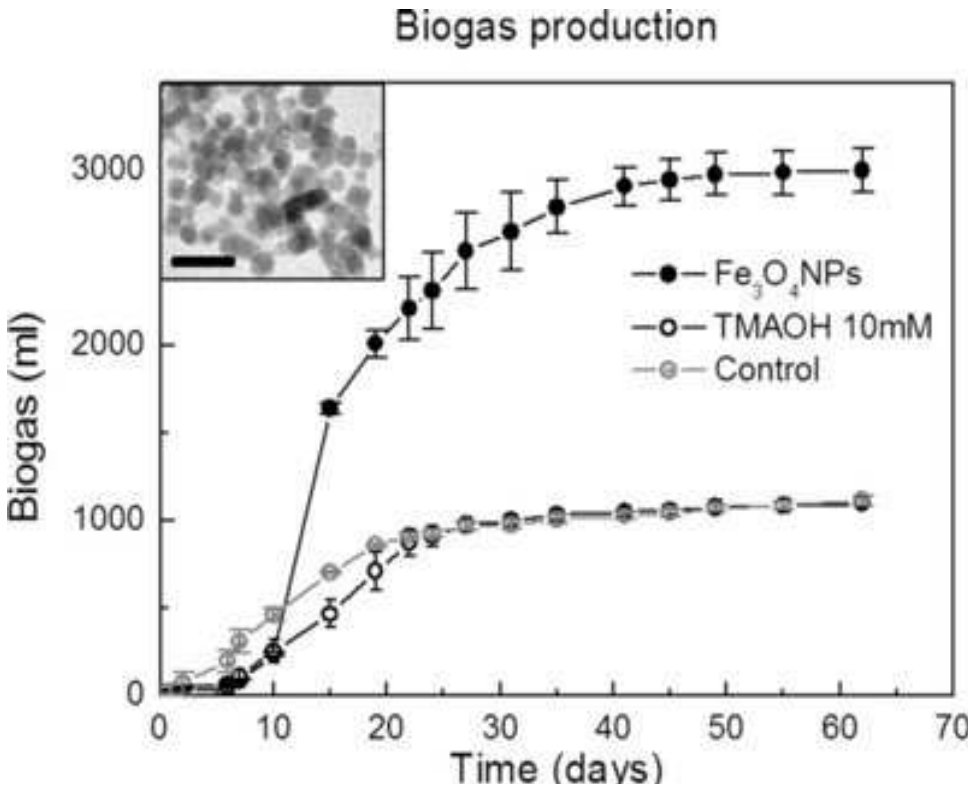


Figure 1. Biogas production boosted by the addtion of Fe3O4NPs

(almost three-fold) and increases of biomethane up to a 230%, as a remarkable increase of methane content was also observed (from a biogas composition of 48% in CH4 without Fe3O4NPs to a 56% in CH4 with Fe3O4NPs).

These first-stage results encouraged us to patent the technology (process in which we had to produce extra experimental evidence to support our claim) and were summarized in a publication on 2014[4].

After patenting the technology and the publication of the biogas boosting effect, we attracted a lot of attention which crystallized with a 3 year incubation award to develop the technology under the umbrella of Repsol Foundation's "Fondo de Emprendedores" (Entrepreneur Fund). Within this incubation period we tested many different model feedstocks (urban sludge, fat, cellulose…), tested lower doses, optimized the formulation, etc.

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[4]E Casals, et.al op. cit.

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As per today, we are collaborating in further developing our technology with different sectoral companies (urban waste, meat, agricultural) as well as biogas solutions providers, while defining the best market entry strategy.

BIOGAS+ additive offers a disruptive nanotechnology-based innovation that obtains the highest ever-reported improvement of biogas production, together with other fundamental benefits.

APPLIED NANOPARTICLES SL.

Applied Nanoparticles SL is a technology-based spin off company derived from the Universitat Autònoma de Barcelona (UAB), the Institut Català de Recerca i Estudis Avançats (ICREA) and the Catalan Institute of Nanoscience and Nanotechnology (ICN2). The company was funded on October 17th, 2013.

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NANOSCALE SCIENCE AND TECHNOLOGY CENTER "nanoCiTec" ESAL.

nanoCiTec is a non-profit association, constituted by professionals and researchers experts in the areas of bio-nanoscience and nanotechnology. It is oriented to promove, coordinate and undertake tasks of research and technological development. The center was funded on October 28th, 2006.

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