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► To cite this version:

Romain Cresson, Sébastien Pommier, Fabrice Béline, Théodore Bouchez, Claire Bougrier, et al.. Results from a french inter-laboratory campaign on the biological methane potential of solid substrates. 14. World Congress on Anaerobic Digestion (AD14), International Water Association (IWA). INT., Nov 2015, Viña del Mar, Chile. hal-02743219

HAL Id: hal-02743219

<https://hal.inrae.fr/hal-02743219v1>

Submitted on 3 Jun 2020

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Results from a French Inter-laboratory Campaign on the Biological Methane Potential of Solid Substrates

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Abstract

A French inter-laboratory campaign on BMP assessment was realised in two phases: free protocol at first, then harmonized protocol. Results show good intra-laboratory repeatability and reproducibility, but in spite of an attempt in the harmonization of practices, the inter-laboratory reproducibility could not be improved and ranges in the magnitude of 20% RSD.

Keywords

BMP; methanogenic potential; inter-laboratory study

INTRODUCTION

The determination of the methanogenic potential of substrates, also known as BMP (Biological Methane Potential) is a central and essential parameter for any anaerobic processes. Actually it is used for the technical and economic analysis of a project, for the design of treatment and recovery facilities and for the evaluation of the process performance. It is also a key indicator of the stability of solid wastes stored in landfills. While some publications mention methodologies for the determination of the methanogenic potential, the methods are often very different, especially for solid and heterogeneous substrates. This variability in analytical methods directly results from the lack of standardized protocol or adapted normative reference. It raises many questions about the quality of the results and limits their interpretation.

Some attempts for the standardization of the BMP protocols have been proposed. In particular, the

expert working group on anaerobic digestion (Anaerobic Digestion Specialist Group) of the International Water Association (IWA) has initiated a task group entitled "Task Group for the Harmonization of Anaerobic Biodegradation, Activity and Inhibition Assays". It resulted in the publication of a protocol for solid waste BMP determination (Angelidaki et al., 2009). This protocol relies on previous publications that had already attempted to make recommendations based on the analysis of the involved processes (Owens and Chynoweth, 1993, Angelidaki and Sanders, 2004, Hansen et al., 2004, Rozzi and Remigi, 2004), or on the application to very specific problems such as the substrate/inoculum ratio (Fernandez et al., 2001). However no further action has so far been proposed after this work and the task group recommendations are still only partially followed by the laboratories. As a consequence, the reliability of BMP measurements is in question. This was illustrated by recent inter-laboratory studies. The first one was reported by Raposo et al. (2011) and evaluated the results from 19 laboratories worldwide on simple model substrates (starch, cellulose, gelatine and mung beans). The second one was an Italian campaign reported by Proqueddu et al. (2013) and involved 19 laboratories which evaluated the BMP of freeze-dried samples of cheese whey, silage maize and biowaste. The findings of these studies support a wide dispersion of results with both a high number of outliers and poor reproducibility relative standard deviation.

The aim of the proposed French inter-laboratory campaign was to evaluate the current protocols used in the country for BMP evaluation and to establish their harmonization.

EXPERIMENTAL

Organization of the inter-laboratory study

Eleven French laboratories participated in this campaign. The study involved two experimental phases. For each of them, three samples were sent to each participating laboratory, which achieved 6 methanogenic potential measurements for each sample. During the first experimental phase each partner completed the methanogenic potential measurements according to its own protocol. During the second phase each partner made new measurements according to the common protocol defined after analysing the results of the first phase. For each of the experimental phases, the laboratories performed 2 sets of measurements in triplicates, the second set started at least 4 weeks after the first one. The purpose of these repetitions was to evaluate both the inter-laboratory reproducibility and the intra-laboratory reproducibility of the BMP measurement.

Substrates

A sample of the substrates presented in Table 1 was sent to each laboratory. For the first phase, substrates SA, SA' (same substrate but dried and shredded) and SB were studied. For the second phase, substrates SA', SB and SC were studied.

Table 1. Composition of the substrates used in the inter-laboratory campaign.

Substrate	Composition (% w.b)	TS (%)	VS (%TS)	% VS in mixture	
SA	Potato	40%	20%	99%	27%
	Grain maize	20%	27%	99%	18%
	Beef	30%	27%	95%	26%
	Wheat straw	10%	90%	93%	29%
	<i>total</i>	<i>100%</i>	<i>30%</i>	<i>95%</i>	<i>100%</i>
SA'	Idem SA	100%	97%	95%	100%
SB	Wheat Straw	100%	92%	93%	100%
SC	Mayonnaise	100%	75%	99%	100%

BMP Protocols

For the first phase, participants applied their own typical BMP measuring protocol with the sole obligation to run the tests in two series of triplicates and to include blank samples. The identified factors differing from one laboratory to another were: the main method (manual or automated via AMPTS apparatus), the gas volume measurement technique, the mixing regime, the substrate/inoculum ratio (S/X), the pH buffer addition, the mineral medium complementation and the level of endogenous methane production.

For the second phase, which came after the analysis of results of the first phase, participants were asked to satisfy the following rules: use of a common mineral medium, use of 3 g/L NaHCO₃ as pH buffer and set the volatile solid substrate/inoculum ratio to 0.5.

Statistical Analysis

Calculations of the Relative Standard Deviation (RSD) for repeatability and reproducibility were performed according to the metrological NF ISO 5725-1. The influence of the protocol factors was assessed by ANOVA.

RESULTS

First phase: free protocol

The first phase of the campaign was carried out in 2013. The dispersion of the obtained BMP values is synthesized in Table 2. For each laboratory, both repeatability among triplicates and reproducibility between two sets of tests were satisfactory. Nevertheless, the inter-laboratory reproducibility was quite poor, with a RSD around 20% whatever the substrate. ANOVA analysis did not show clear influence of the identified protocol factors, except for the mineral medium implementation which was found to raise the BMP value. For other factors like the assessment method (manual/automated), the S/X ratio and the buffer addition, the influence on the BMP value was found to be substrate-dependant. The solid substrate preparation before BMP assessment (fresh or freeze-dried) had no significant effect on the results.

Table 2. Synthesis for the first phase of the French inter-laboratory campaign.

BMP (NmLCH ₄ /gVS)	SA	SA'	SB	SC
Mean	425	403	267	-
Median	422	407	267	-
Min	289	250	175	-
Max	629	481	370	-
Intra-laboratory repeatability RSD	7%	4%	6%	-
Intra-laboratory reproducibility RSD	9%	6%	8%	-
Inter-laboratory reproducibility RSD	20%	17%	20%	-

Second phase: harmonized protocol

After the first phase, discussions between the participants led to the proposal of a harmonized protocol with unified practices for the following factors: S/X ratio, pH buffer and mineral complementation (as described in the EXPERIMENTAL section). The subsequent second phase of the campaign was carried out in 2014 on substrates SA' and SB (same as for the first phase), as well as on a new lipid substrate (SC). As shown in Table 3, despite the proposed harmonization, the

inter-laboratory reproducibility was not improved.

Efforts will now be made for the definition of a posteriori validation criterions related to the inoculum activity.

Table 3. Synthesis for the second phase of the French inter-laboratory campaign.

BMP (NmLCH4/gVS)	SA	SA'	SB	SC
Mean	-	405	277	848
Median	-	408	282	828
Min	-	260	195	660
Max	-	525	370	1026
Intra-laboratory repeatability RSD	-	4%	4%	4%
Intra-laboratory reproducibility RSD	-	5%	7%	5%
Inter-laboratory reproducibility RSD	-	19%	21%	13%

ACKNOWLEDGEMENTS

This French inter-laboratory campaign was supported by ADEME.

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