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ON THE SPENT COFFEE GROUNDS BIOGAS PRODUCTION

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Abstract

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Due to the strict legislation currently in use for landfilling, anaerobic digestion has a strong potential as an alternative treatment for biodegradable waste. Coffee is one of the most consumed beverages in the world and spent coffee grounds (SCG) are generated in a considerable amount as a processing waste during making the coffee beverage. Chemical composition of SCG, presence of polysaccharides, proteins, and minerals makes from the SCG substrates with high biotechnological value, which might be used as valuable input material in fermentation process. The methane production ranged from 0.271–0.325 m^3/kg dry organic matter.

Keywords: Spent coffee grounds, biogas production, fermentation

INTRODUCTION

An increase in coffee import, in calendar year 2013 green coffee imports in Western Europe were 3.244 million tons and consumption, in the Europe average coffee consumption is 4.8 kg per capita, with maximum in Luxemburg 24.4 kg per capita and minimum in Hungary 1.52 kg per capita in 2012 has the direct impact on increased spent coffee grounds production. Current legislation and Zero waste strategy application (Laštůvka *et al.*, 2016) brings new challenges in finding appropriate technologies for the treatment of this specific type of waste. Scientific papers describe the different possibilities for spent coffee grounds (SCG) utilization. Due to its high nitrogen content SCG can be directly used as fertilizer or as soil improver (or compost) (Kondamudi *et al.*, 2008). Due to its high organic matter content, another possible valorisation route is the production of sugars to be fermented for bioethanol (Caetano, 2011) or for pyrolysis (Li *et al.*, 2014). SCG can be used as fuel in industrial boilersdue to its high calorific value (Silva *et al.*, 1998). Some papers describes possibility of SCG use as animal feed (Givens and Barber 1986), high lignin content is a limiting factor for this application (Cruz 1983). A biological treatment of SCG with fungal strains from the genus *Penicillium*, *Neurospora*, and *Mucor* could be an interesting alternative, since these fungi are ableto release phenolic compounds from the SCG structure, decreasing their toxicity (Machado, 2009). Another option is a spent coffee ground anaerobic fermentation. The coffee waste anaerobic fermentation has been reported at mesophilic temperatures (Lane, 1983; Raetz, 1990) and also at thermophilic temperatures (Kida *et al.*, 1992; Kostenberg and Marchain, 1993). The review of the literature suggests that the anaerobic digestion of coffee grounds is possible but long term stability is a problem. The aim of this work was to assess the anaerobic digestion of coffee waste containing coffee grounds using mesophilic reactors in batch digestion studies.

MATERIALS AND METHODS

A mixture of two SCG samples collected from a coffee shop was used. The SCG samples were frozen until required. Dry matter (DM) content was measuredby oven drying at 105 °C ± 5 °C followed by cooling in a desiccator and weighing until a constant weight. Dry organic matter (ODM) content was determined by incineration of the samples in a muffle furnace at 550 °C ± 5 °C according to Czech Standard Method CSN EN 15169, using a furnace (LMH 11/12). Total organic carbon (TOC) was determined by Analytik Jena AG, TOC/TNb analyzer. The total nitrogen (TN) was determined using a conventional Kjeldahl procedure. Samples dried at 60 °C for 48 h and grinded to a particle size < 1 mm were used for determination of crude protein (CP), crude fat (CL), crude starch (CS), neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL). All analysis have been made in triplicates.

Spent coffee grounds biogas production and quality was measured in laboratory batch anaerobic fermenters at the temperature 38 °C ± 1 °C according to VDI 4630. Totally eight 5 dm^3 vessels were used. Vessels were filled with 3 dm^3 of inoculum. For inoculation, fermenter content from commercial biogas plant has been used. The inoculum for the batch anaerobic fermentation tests was specified by analysing the parameters dry matter, dry organic matter and pH. Two from eight vessels were used as blank without any spent coffee grounds addition. Six remaining vessels filled with 4 dm^3 of inoculum were filled with 40 g of SCG sample. The biogas produced was measured daily by applying the liquid displacement method (VDI, 2006) using acidified saturated NaCl solution as barrier solution. Besides other gas components methane (CH_4) and carbon dioxide (CO_2) content were measured during the batch fermentation tests using gas analyser Dräger X-am® 7000 (Dräger Safety AG&Co. KGaA, Germany). Biogas production was converted to standard conditions (T_0 = 273 K, p_0 = 101 325 Pa). The volume of biogas and methane produced by a sample was converted to biogas yield (BY) and methane yield (MY), by expressing them as m^3 per kg of dry organic matter (ODM) of the added substrate.

RESULTS AND DISCUSSION

Chemical analyzes for the dry matter, dry organic matter, ashes, total fibres, acid detergent fibre, neutral detergent fibre, acid detergent lignin, crude protein, crude fat, crude starch, total organic carbon, nitrogen and C/N ratio were determined in spent coffee grounds mixture. The results are reported in Table 1.

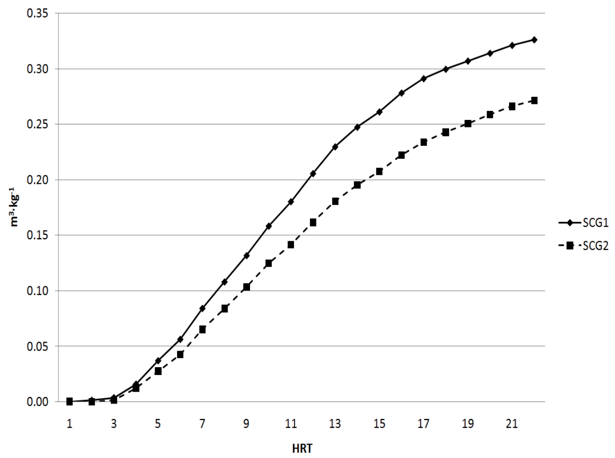
Specific methane yield and methane content in biogas generated after 22 day hydraulic retention time are shown in figure 1 and 2, respectively.

When studying spent coffee grounds biogas production, biogas yields ranged from 0.500–0.598 m^3/kg dry organic matter with methane concentration in biogas 55–61 %. Biogas production 0.54 m^3/kg has been reported (Lane, 1983). Methane yield ranged from 0.271–0.325 m^3/kg dry organic matter. (Neves *et al.*, 2006) reported methane yield ranged from 0.25–0.28 m^3/kg. Biogas production declined steadily over the test period. Even that spent coffee grounds contain materials caffeine, tannins, and polyphenols which can be toxic for fermenter environment no inhibition was observed during tests.

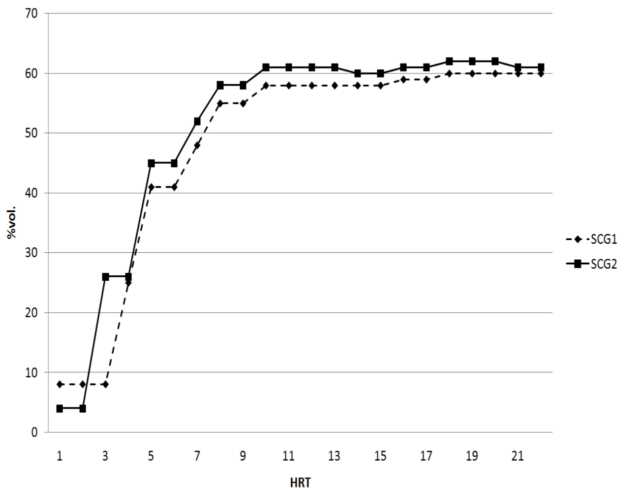
I: *Chemical composition of spent coffee grounds samples*

Components	unit	SCG1[a]	SCG2[a]
Dry Matter	**[%]**	**30.48**	**32.23**
Dry Organic Matter	[%]	98.79	98.57
Ashes	[%]	1.21	1.43
Total fibres	[%]	19.32	20.11
Acid Detergent Fibre (ADF)	[%]	42.14	43.03
Neutral Detergent Fibre (NDF)	[%]	58.44	57.68
Acid Detergent Lignin (ADL)	[%]	15.33	14.97
Crude Protein	[%]	12.27	13.44
Crude Fat	[%]	14.00	13.54
Crude Starch	[%]	2.62	2.39
TOC	[%]	32.61	33.17
Nitrogen	[%]	1.92	2.01
C/N ratio	[-]	17:1	17:1

[a]Values in percent dry-weight basis



1: *Cumulative methane yield during the spent coffee ground digestion*



2: *Methane concentration in biogas*

CONCLUSION

The coffee industry is responsible for the generation of large amounts of wastes. SCG is one of the major wastes generated. Finding the alternative way for processing these wastes is great importance because it would contribute with a reduction of its impact to the environment by the toxicity decrease. Anaerobic co digestion is one option for processing such a waste. It will be necessary to find suitable systems for the collection and transport of waste, which are not commonly used at the moment. Considering high content of valuable compounds other utilization must be taken into account, for example supercritical fluid extraction processes to obtain the lipid fraction or ethanol production. Also economical methods for SCG drying would be very interesting due to its high moisture content, which increases the cost of transport. Dry SCG incineration is also one possibility.

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