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Improving waste-to-energy process by co-digestion of exhausted coffee biowaste and WWTP sludge

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Abstract

The purpose of this study is to investigate the effects of using pre-treated exhausted coffee biowaste (ECB) as a co-substrate to optimize sewage sludge (SS) biogas production. The trials were conducted in semi-continuous mode at mesophilic conditions (36 ± 1ºC) with a Hydraulic Retention Time of 17 days and an average organic loading rate (0.94 ± 0.05 g VS $L_{reactor}.day^{-1}$). An anaerobic co-digestion trial (T1) was assessed using a feeding mixture with a ratio of SS (80 %) and LECB (20%), v:v, and compared against a reference scenario (T0). Results showed that the addition of the co-substrate had a significant influence on specific methane production (3 times higher) and biogas quality (12% higher), which is a feasible strategy towards self-sufficient wastewater treatment plant. Furthermore, the stability along assays was ensured monitoring the digestate characteristics (pH, electrical conductivity, total alkalinity and ammonia content) and the specific energy loading rate.

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Keywords: Anaerobic co-digestion, exhausted coffee biowaste, sewage sludge, waste-to-energy

1. Introduction

Wastewater treatment plants (WWTP) generate great amounts of sewage sludge (SS) worldwide and anaerobic digestion (AD) is commonly used to recover bioenergy and simultaneously sustainably treat SS, leading to a number

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of outputs in the solid, liquid and gaseous phase. Then it is crucial to define appropriate waste management scenarios to be applied to WWTP aiming the development of more sustainable integrated solutions for handling residues to enhance biomethanization of SS entails low biodegradability and low methane yields [1-4].

Anaerobic digestion optimization is a common pathway to increase the WWTP energy self-sufficiency. In this regard, considering the plant energy balance, different types of biowaste with high methanogenic potential should be selected to be mixed with SS through anaerobic co-digestion (AcoD) process. The most relevant key factors to promote these synergetic interactions is the optimal feeding blend ratio to improve specific methane production and digestate quality [5]. The optimization of energy recovery through anaerobic co-digestion (AcoD) enhances WWTP environmental performance and lowers its carbon footprint [6]. This approach can contribute to close the loop establishing the linking of agro industrial production and urban consumption systems towards a future circular economy [7, 8].

The production of soluble coffee and coffee drinks includes a water-pressured extraction process of the mixture of coffee and cereals (e.g. malted barley, rye, barley in bulk and chicory). According to Sousa [9], in Portugal this process generates around 15000 tons of exhausted coffee biowaste (ECB) per year, containing the insoluble fraction of organic compounds (i.e. fatty acids, lignin, cellulose, hemicellulose, and other polysaccharides) and therefore is appropriate for bioenergy recovery. Despite these considerations, this biowaste has not received much attention as a co-substrate to enhance biogas production, to our knowledge only Sousa [9] has researched the use of this biowaste as co-substrate in pig slurry anaerobic digestion. The aim of this research was to study the improvement in efficiency of SS biomethanization by the addition of the exhausted coffee biowaste liquid fraction (LECB). The trials were conducted with a feeding mixture of 80% SS:20% LECB (v:v) to assess specific methane production and biogas quality contributing towards an energy self-sufficient WWTP.

Nomenclature

AcoD	Anaerobic co-digestion
AD	Anaerobic digestion
CSTR	Continuous stirring tank reactor
ECB	Exhausted coffee biowaste
GPR	Gas production rate
HRT	Hydraulic retention time
LECB	Exhausted coffee biowaste liquid fraction
OLR	Organic loading rate
SELR	Specific energy loading rate
SMP	Specific methane production
SS	Sewage sludge
WWTP	Wastewater treatment plant

2. Material and methods

2.1. Substrates

The sewage sludge (SS) is a mixture of primary and waste activated sludges (40:60, v:v) and was withdrawn from the thickening tank of a full-scale wastewater treatment plant (WWTP) in Lisbon, Portugal. The WWTP was designed to treat an average flow of 53,000 m^3 per day, which corresponds to a population of approximately 211,000 inhabitant's equivalent (IE). The sewage sludge chemical composition varies depending upon the type of effluent and the raw wastewater characteristics, according with the seasonality and climatic conditions.

Exhausted coffee biowaste (ECB) result from the water-pressured extraction process to produce soluble coffee and coffee drinks and were kindly supplied by Nestlé, Portugal. Samples were stored in a refrigerator at 4 ºC until pretreatment, by filtration using a vacuum pump (BüchiVac V-500:230 VAC; 50 Hz; 240 W), the liquid fraction (LECB) was used as co-substrate for anaerobic co-digestion trial.