WASTES: Solutions, Treatments and Opportunities
5th International Conference
September 4th – 6th, 2019

BIOGAS PRODUCTION BY ANAEROBIC CODIGESTION USING KIWI WASTE AND WINE SLUDGE

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ABSTRACT
Considering a large generation of wastes, the anaerobic codigestion (AcoD) is an alternative to transform two or more types of organic waste in energy and biofertilizer. To test the biogas production potential using kiwi waste and wine sludge, two AD assays with each substrate isolated and AcoD with four different substrate proportion was realized, using as inoculum sludge from a septic tank. The experimental was realized during 19 days in batch reactor (250 mL). Among digestion results, kiwi waste had de best result, being 27.0 mLN gVS^{-1} of biogas. The most satisfactory value in AcoD was 40.5 mL_N g VS^{-1} of biogas, from treatment with 0.5 g kiwi and 3.3 g wine sludge. The AcoD test produced 16 mLN gVS^{-1} of biogas more than AD.

Keywords: Anaerobic digestion. Fruit waste. Wine sludge. Wastewater

INTRODUCTION
The 28 countries of European Union produced 891 million tons of waste in 2014 and, in the same period, Portugal was responsible to 14,6 million tons [1]. Anaerobic digestion (AD) is an alternative to reuse organic waste, resulting in two materials: a biogas rich in methane (CH_4) and a stabilized mass. Anaerobic codigestion (AcoD) has the same principle of AD, but the difference is that used two or more substrates will be digested together [2, 3].
Actinidia deliciosa known as Kiwi (K), is a fruit with an area of 2.369 hectares to produce in Portugal [4]. It is estimated that, per crop, 25% of production becomes waste [5]. Other significant waste production is derived from wine production. Around 3.5-8.5% of wine production is converted into waste [6]. According to [6], the AD could treat 38.05 10^3 tons/year of waste from wine production, and the wine sludge has a production potential of 1.06 10^6 m^3 of biogas per year. The aim of this study was characterized both substrates and the inoculum utilized, realized anaerobic codigestion between Kiwi fruit and wine sludge in batch reactors in which substrate percentage and the carbon-nitrogen ratio were varied, verifying subsequently the highest production by statistical test.

MATERIAL AND METHODS
The inoculum used in this assay was a sludge (I) collected in a septic tank in January, in the city of Bragança, Portugal. This material was tested and validated in a batch reactor using microcrystalline cellulose, recommended by VDI 4630 [7]. For the substrates, was used wine sludge (W) and Kiwi waste (K). The physic-chemical characterization of inoculum and substrates, like pH, total solids (TS), volatile solids (VL), total Kjeldahl nitrogen (TKN) and chemical oxygen demand (COD), was determined according to standard methods [8].
The experimental apparatus was composed of 21 amber glass reactors, with 250 mL each and cap with rubber septum, operated in batch. The biogas collect was based in [7] where a glass syringe

with 20 mL was used for remove the gas and normalize the pressure inside the reactors. Nine reactors, of treatments T1.0, T1.1 and T1.2 receive just one material, for anaerobic digestion. The others 12 reactors (T2.1, T2.2, T2.3 and T2.4) receive a mix of inoculum and substrate in different portion (Table 1). The reactors with low pH had a correction with sodium hydroxide (NaOH) 40%, keeping the mixture pH above 7.0. To alkalinity, in each reactor was added 0,6 g of calcium carbonate ($CaCO_3$). All glass reactors were placed in a water bath and maintained in controlled temperature of 37ºC. The biogas yield was calculated in normal millilitres per grams of volatile solids (mL_N g VS^{-1}).

Table 2 - Treatment characteristics

Treatment		Description	Kiwi [g]	Wine Sludge [g]	Inoculum [g]	Water [mL]	C:N
AD	T 1.0	I	0.0	0.0	2.5	197.5	-
	T 1.1	I + K	1.0	0.0	2.5	196.5	4.9
	T 1.2	I + W	0.0	1.0	2.5	196.5	104.8
AcoD	T 2.1	I + W + K	0.8	0.2	2.5	196.5	6.2
	T 2.2	I + W + K	0.2	0.8	2.5	196.5	22.3
	T 2.3	I + W + K	0.5	3.3	2.5	193.7	30.0
	T 2.4	I + W + K	0.2	0.7	2.5	196.6	20.0

An analysis of variance (ANOVA) was applied in anaerobic digestion treatments and anaerobic codigestion treatments. Subsequently, a Tukey test, with $p < 0,05$ was used to define which treatment was better.

RESULTS

Physic-Chemical Characterization

Both substrates presented pH below 4.0, and the inoculum pH was 7.2. Even with sludge addiction, the pH reactors needed to be adjusted for 7.0. Regarding to solids, to be considered appropriate by VDI 4630, the VS contents in inoculum must be greater than 80%. The sludge used presented 43.1 g L^{-1} of VS, which correspond to 81% of TS. Kiwi showed 128.7 g L^{-1} of TS, being 80% of VS. [9] found for the same substrate 173 g L^{-1} of TS with 95% of VS. The wine sludge presented 40.8 g L^{-1} of TS with 74% of VS, value similar founded by [10], being 41.4 g kg^{-1} to TS and 37.3 g kg^{-1} to VS. Organic matter concentration was 224.1 gCOD L^{-1} to Kiwi, 257.2 gCOD L^{-1} to wine sludge and inoculum 40.1 gCOD L^{-1}. The total nitrogen quantity was 1.3 g L^{-1} for inoculum, 0.62 g L^{-1} for Kiwi and low to wine sludge, being 0.22 g L^{-1}.

Tests

The two tests (AD and AcoD) had duration of 19 days and was stopped when daily production was less than 1% of total accumulated. Anaerobic digestion test (Fig. 1 – A), had the assay T 1.1 as a best result, with 27.0 mL_N gVS^{-1} of biogas. Wine sludge test had a production of 16.9 mL_N gVS^{-1} of biogas, and the inoculum produced only 3.9 mL_N gVS^{-1}. In a batch reactor with 500 mL capacity and 200 mL of Kiwi and inoculum, [11] founded to 1 g of substrate 1000 L $kgVS^{-1}$ of biogas and to 4 g of Kiwi, 36% of methane. In another assay, the same author used 20 g of Kiwi and 380 mL of substrate and showed a produce to 464 L $kgVS^{-1}$ of biogas with 85% of CH_4.

In anaerobic codigestion test (Fig. 1 – B), the assay T2.3 obtained the highest value (40.5 mL_N gVS^{-1}) while the T2.1 produce 36.1 mL_N gVS^{-1} being the lowest value. The T2.2 produced 36.9 mL_N gVS^{-1} and T2.4 produced 38.3 mL_N gVS^{-1} of biogas. Although the values being different, the analysis of variance for a $p<0,05$, showed that all treatments are statistically equal.

According to [12], codigestion process can enhance from 25% until 400% biogas production. Comparing with AD test, the AcoD produced in media 16 mL_N gVS^{-1} more than AD test and this difference represents 42%.

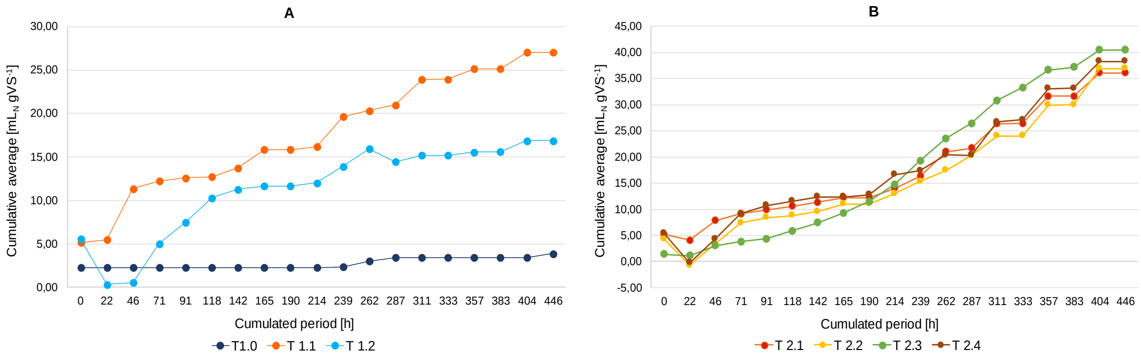

Fig. 1 – Accumulated production of biogas. A – Anaerobic digestion test. B – Anaerobic codigestion test.

CONCLUSION

In relation to anaerobic digestion test, the assay with Kiwi (T1.1) was better than with wine sludge (T1.2) and only with inoculum (T 1.0). Between anaerobic codigestion test, the T2.3 had a higher biogas production, with 40.5 mL_N gVS^{-1}, but statistically, all codigestion treatments was equal. Comparing both tests, is possible to confirm that AcoD was most efficient than AD, producing 16 mL_N gVS^{-1} more of biogas. As a result, an anaerobic codigestion between kiwi waste and wine sludge is viable, must be tested in other proportions, with larger volumes and different reactors configuration.

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