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Anaerobic co-digestion of olive mill wastewater with olive mill solid waste in a tubular digester at mesophilic temperature

Fezzani Boubaker *, Ben Cheikh Ridha

Biogas Laboratory, Energy Department – Engineers National School of Tunis: Postal Box 37, 1002 El-Belvedere Tunis, Tunisia

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Abstract

Anaerobic co-digestion is a well established process for treating many types of organic wastes, both solid and liquid. In this study we have investigated, on a laboratory scale, the anaerobic co-digestion of olive mill wastewater (OMW) with olive mill solid waste (OMSW) using semi-continuous, feeding, tubular digesters operated at mesophilic temperatures. Each digester was fed with an influent, composed of OMW and OMSW, at an organic loading rate (OLR) varying between 0.67 and 6.67 g COD/l/d. The hydraulic retention times (HRT) were 12, 24 and 36 days. The TCOD concentrations of OMW used as the main substrate were 24, 56 and 80 g COD/l; the amount of the dry OMSW used as a co-substrate was fixed to approximately 56 g/l of OMW. The results indicated that the best methane production was about 0.95 l/l/day obtained at an OLR = 4.67 g COD/l/d, corresponding to influent TCOD = 56 g COD/l at an HRT = 12 d. In contrast, the maximum TCOD removal efficiency (89%) was achieved at an OLR = 0.67 g COD/l/d, corresponding to influent TCOD = 24 g COD/l at an HRT = 36 d. Moreover, the inhibition of biogas production was observed at the highest OLR studied.

Keywords: Olive mills wastewater; Olive mills solid waste; Tubular digester; Anaerobic co-digestion; Biogas; Mesophilic temperature

1. Introduction

In the Mediterranean olive growing countries, olive mills using a three phase centrifugation process produce significant quantities of liquid waste called olive mill wastewater (OMW) and solid waste called olive mill solid waste (OMSW). The annual production of these wastes are estimated at thirty million cubic meters of OMW and twenty million tons of OMSW (Fiestas et al., 1996). To resolve the environmental problems caused by OMW several processes have been developed (Boari et al., 1984; Borja et al., 1993; Demirer et al., 2000), including anaerobic digestion process, but this process is not entirely successful in reaching the treatment efficiencies required by the national regulations of all the Mediterranean area countries. Essentially, these difficulties are due to the presence of organic and phenolic compounds in OMW at high concentrations (TCOD = 120 g/l and total poly-phenol = 9 g/l). Moreover, OMW is an acid effluent (pH = 5 and alkalinity = 0.6 g $CaCO_3$/l) containing low amounts of nitrogen (TK-N = 0.6 g N/l and NH_4^+–N = 66 mg N/l). To overcome these problems, OMW has to be submitted to pretreatment, before anaerobic digestion, such as an aerobic biological treatment (Borja et al., 1992–1995; Hamdi, 1996) or dilution with water (1:10) and the addition of urea as nitrogen source (Boari et al., 1984). However, the major disadvantage of these pre-treatments is their reduction of subsequent biogas productivity due to a decrease in COD of OMW after pre-treatment. Another approach recently adopted by researchers to minimise the disadvantages of OMW anaerobic digestion is the co-digestion of OMW with other substrates to compensate for its lack in alkalinity and ammonia. In fact, the use of the co-digestion process to treat OMW was first investigated by Angelidaki Irini who studied the co-digestion of OMW with manure as

* Corresponding author. Tel.: +216 97 37 69 69.
E-mail address: B.Fezzani@Laposte.net (F. Boubaker).

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Nomenclature

OMW	olive mill wastewater
OMSW	olive mill solid waste
TS	total solid (g/l)
VS	volatile solids (g/l)
MS	mineral solids (g/l)
TSS	total suspended solids (g/l)
VSS	volatile suspended solids (g/l)
MSS	mineral suspended solids (g/l)
COD	chemical oxygen demand
TCOD	total chemical oxygen demand (g COD/l)
SCOD	soluble chemical oxygen demand (g COD/l)
TK-N	total kjeldahl nitrogen (g/l) or (g/kg TS)
NH_4^+–N	ammonia nitrogen (g/l) or (g/kg TS)
HRT	hydraulic retention time (days)
OLR	organic loading rate (g COD/l/day)

a source rich in ammonia nitrogen (NH_4^+–N = 2.5 g N/l) and alkalinity (alkalinity = 14.5 g $CaCO_3$/l). In this process, the alkalinity and ammonium in manure compensate for the low values of alkalinity and ammonium in OMW (Angelidaki et al., 1997).

Furthermore, Demirer has proven that OMW could be treated in an anaerobic batch digester with high efficiency (85.4–93.4%) when a basal medium containing $NaHCO_3$, NH_4Cl and NH_4HPO_4 was added as a nutritive element for anaerobic bacteria growth (Demirer et al., 2000).

In this work, we have studied the anaerobic co-digestion of OMW with OMSW which is a substrate rich in nitrogen (TKN = 15 g N/kg). The experiments were carried out using tubular digesters operated at mesophilic temperatures ($\Theta \approx 35$ °C) with the emphasis placed on the evaluation of optimal values of biogas production, methane percentage and TCOD removal efficiency under different combinations of influent TCOD concentration and hydraulic retention time (HRT).

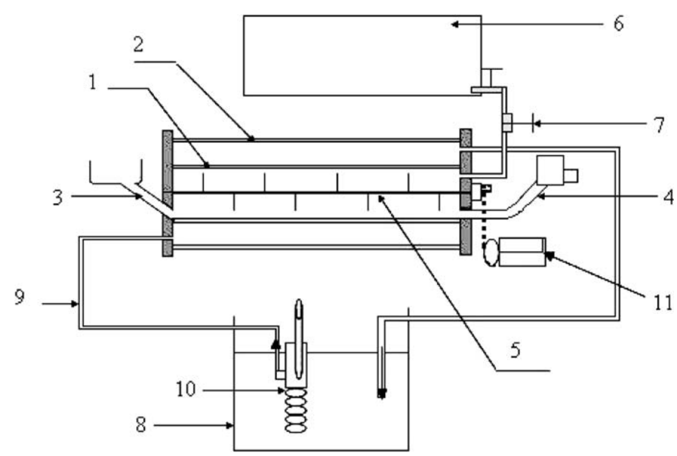

Fig. 1. Semi-continuous feeding tubular digester. (1) Inside cylinder of 20 cm diameter. (2) Outside cylinder of 30 cm diameter. (3) Input port. (4) Output port. (5) Agitator. (6) Plastic bag. (7) Plastic tap. (8) Metal container filled with water. (9) Plastic pipe. (10) Water Heater with thermostat and pump. (11) Agitator Motor.

2. Methods

2.1. Equipments

Seven tubular, semi-continuously feeding digesters were employed. Each tubular digester consisted of two coaxial cylinders. The Plexiglas outside cylinder had a 30 cm internal diameter, 0.5 cm thickness and 70 cm length. The glass internal cylinder had a 20 cm internal diameter, 1 cm thickness, 70 cm length and a volume of 22 l. The latter was equipped with three ports, two of them for feeding and effluent discharge and the other port for collecting gas into the bag. These digesters were warmed with a water heating system equipped with thermostat and pump. Agitation was provided by a motor agitator (see Fig. 1).

Table 1
Average composition of OMW used as main substrate

Parameter	Units	Average value	Standard deviation
pH	–	5	0.15
Density	kg/l	1.02	0.03
TS	g/l	77	1.5
VS	g/l	57	0.7
MS	g/l	20	0.5
TSS	g/l	35	1
VSS	g/l	30	0.9
MSS	g/l	5	0.9
TCOD	g/l	80	2
SCOD	g/l	60	1
NH_4^+–N	mg N/l	170	10
TK-N	g N/l	1.25	0.5
Poly-phenols	g/l	7	0.1

2.2. Substrates composition

2.2.1. Olive mill wastes

The OMW and OMSW used in this study were collected from a three-phase olive mill located at Kssar Said in Tunis (northern Tunisia). The average composition of OMW and OMSW are summarised in Tables 1 and 2.

2.2.2. Aerobic sludge

The sludge that we used to start the anaerobic digestion process was collected from an aerobic wastewater treatment plant located in Beja (northern Tunisia). Its composition, in average values, is given in Table 3.