Process Biochemistry 50 (2015) 1893–1903

Contents lists available at ScienceDirect

Process Biochemistry

journal homepage: www.elsevier.com/locate/procbio

Review

Recent developments in the anaerobic digestion of olive mill effluents

Ahmet Gunay[a], Dogan Karadag[b,*]

[a] *The Scientific and Technological Research Council of Turkey (TUBITAK), Marmara Research Center, Environment and Cleaner Production Institute, Kocaeli, Turkey*
[b] *Yildiz Technical University, Department of Environmental Engineering, Davutpasa, Istanbul, Turkey*

ARTICLE INFO

Article history:
Received 13 March 2015
Received in revised form 2 July 2015
Accepted 9 July 2015
Available online 13 July 2015

Keywords:
Oil mill effluent
Methane
Bioreactor
Suspended
Granular
Biofilm

ABSTRACT

Liquid and solid olive mill effluents contain considerable quantities of organics, phenols and lipids. Comprehensive papers have been published on the treatment of olive mill effluents. Methane production and organic removal have been studied under varying environmental conditions. This paper reviews the recent reports on anaerobic reactors which have been published during the last 15 years. Olive mill effluents have high amounts of hardly biodegradable substances, with most of them being toxic to microorganisms. It has been proven that pretreatment with aerobic, advanced oxidation and heat methods are an efficient way of removing toxic materials and improving anaerobic treatment efficiency. The effects that organic loading, hydraulic retention time, and temperature have on suspended, biofilm, and granular reactors are discussed. Anaerobic treatment has been performed by feeding only olive mill effluents or co-digestion with other waste streams. Co-digestion enhances methane productivity by balancing nutrient and alkalinity levels. Furthermore, a comprehensive discussion of studies regarding pretreatment is carried out by comparing their performances.

Contents

Abbreviations: OM, olive mill; OMWW, olive mill waste water; OMSR, olive mill solid residue; COD, chemical oxygen demand; BOD_5, 5-day biochemical oxygen demand; LCFA, long chain fatty acids; SS, suspended solid; TKN, total Kjhedahl-nitrogen; OLR, organic loading rate; HRT, hydraulic retention time; VFA, volatile fatty acids; CSTR, continuously stirred tank reactor; ASBR, anaerobic sequencing batch reactor; PABR, the periodic anaerobic baffled reactor; UAF, up-flow anaerobic filter; UASB, upflow anaerobic sludge blanket bioreactor.

* Corresponding author.
E-mail address: dogankaradag@gmail.com (D. Karadag).

http://dx.doi.org/10.1016/j.procbio.2015.07.008
1359-5113/

1. Introduction

Olive oil production is one of the most important agro-industrial activities in the economics of Mediterranean countries. Worldwide olive oil production has been gradually increasing, with around 3 million tonnes produced in 2010 alone [1]. An excess amount of water is consumed during olive oil extraction, with annual wastewater generation being estimated as being around 30 million m^3 [2,3]. Olive oil is produced with either a two- or three-phase extraction method; olive mills (OM), however, are mostly operated under a two-phase method due its low water consumption and less generation of waste streams [4,5]. In addition to olive mill wastewater (OMWW), olive mill effluents contain a highly polluted solid residue as well. Olive mill solid residue (OMSR) – also known as pomace – contains a considerable amount of humidity. Indeed, one tonne of olive oil processing generates around 800 kg of OMSR under a two-phase extraction system [4]. Researchers reported that the amount and characteristics of OM waste streams are affected by a variety of olive fruits, the cultivation conditions of the trees, the degree of their ripeness, climatic conditions, harvesting time and extraction methods [5,6].

OMWW is high strength wastewater with a considerable amount of organic content in terms of COD (25–220 g/l) and BOD_5 (9–100 g/l) [7–9]. Furthermore, OMWW is also rich in phenolic compounds which change the colour of discharging bodies, induce toxicity in living organisms, and decreases the biodegradability in treatment plants [10]. OMSR consists of olive pulp, stones, water, and leftover oil and is rich in lignin, cellulose and hemicelluloses. Moreover, it is also characterised by a remarkable concentration of organic matters, phenols, and volatile fatty acids (VFA) and a low pH [4]. Pomace is generally stored in open ponds which results in the formation of leachate with a dense colour and an organic content of up to 30 g/l along with 3.5 g/l of phenols [11].

The uncontrolled discharge of large quantities of OM waste streams into receiving bodies causes severe environmental problems. Nevertheless, treatment of OM waste streams is complicated due to the inherent characteristics of olive harvesting and OM operation. Olive production varies considerably from year to year and olive mills are operated for only a short amount of time in a given year. In order to remove the pollutants from OM effluents, researchers have proposed various individual treatment methods including advanced chemical [12,13] and membrane [14,15]. The combination of different singular treatment systems, however, is more appropriate since single-step treatments are insufficient for meeting discharge limits. Among other alternatives, biological treatment systems have provided promising successes for the removal of organics and other pollutants from OMWW, and other food production industries as well [16,17]. Aerobic systems have limited application on the treatment of high strength wastewaters since continuous aeration considerably increases operational cost and excess sludge is generated which needs additional treatment. On the other hand, anaerobic technologies provide less sludge generation, overall cost, and nutrient requirements [16,18,19]. Furthermore, methane is a valuable renewable energy source and digestate could be used as fertiliser in for agricultural purposes. The removal of pollutants and methane production from the OM effluents by anaerobic bioreactors has also been extensively documented in the literature. The present study contains considerable evaluation of recent developments in the anaerobic treatment of OM effluents. The literature review provided focuses mainly on papers which were published during the last 15 years. In addition, anaerobic bioreactors have been evaluated based on treatment performance, operational schemes, pretreatment technologies.

2. Characteristics of olive mill effluents

A summary of composition values for OM waste streams is presented in Table 1. In comparison to other food industry wastewaters, OM effluents generally contain more organic pollutants and phenols [20–23]. Both liquid and solid waste streams have acidic characteristics, with pH values ranging from 4.0 and 6.5; in addition, they contain great amount of solids. In OMSR streams, concentrations of total and suspended solids rise up to 206.7 and 143 g/l, respectively. Moreover, El-Gohary et al. [24] have shown that suspended materials in OM effluents are mostly comprised of colloidal solids with low settleability. Although OM waste streams have high COD amount up to 178 g/l, the biodegradability ratio of BOD_5/COD is very low due to the presence of excessive toxic phenolic compounds [25–27]. In contrast, wash water from olive mills has the least amount of pollutants when compared to other wastewater sources.

Additionally to having a great number of organic acids, OM waste streams include more than 30 different phenolic compounds, while the type and concentration of individuals varies significantly with respect to region, type of process, local operational procedures, fruit maturity, storage time and oil extraction method [3,28–30]. OM wastewater is also characterised by a dense colour which varies from brown to black depending on the degradation stage, olive origin, and the amount of solid matter and phenolic compounds [31]. Although some OM waste streams have been reported with sufficient nutrient balances, most studies revealed the deficiency of appropriate nitrogen and phosphorus levels for efficient anaerobic treatment [32]. Solid waste streams generally have a low nitrogen content of less than 0.2% of COD, while ammonium ion ranges from 5.5% to 45% in OM effluents [33–36]. Mineral content comprises 0.5% to 2% of OM effluents, while individual amounts of K^+, Ca^{2+}, Na^+, Mg^{2+} and Fe^{2+} change due to the oil extraction method, the nature of the soils, and the fertiliser and quality of water used in extraction [4,5,37].

3. Pretreatment of olive mill effluents

The anaerobic degradation of OM waste streams has its own difficulties due to the high content of hardly degradable cellulosic materials and toxic substances that they consist of, such as phenols,

Table 1
Reported composition values of olive mill effluents.

Effluent	pH	COD (g/l)	BOD_5 (g/l)	Solids (g/l)	VS (g/l)	Nitrogen (mg/l)	Phenols (g/l)	Lipid (g/l)	Ref.
Two phase OMWW	4.89	21.5	NA	16.7 (TS)	14.0	210 (TKN)	0.06	NA	[84]
Three phase OMWW	5.14	68.78	17.12	49.14 (TS)	NA	220 (TN)	5.06	NA	[26]
Three phase OMWW	5.0	131	41	83.3 (TS)	54.9	0.7	6.8	NA	[37]
Two-phase OMSR	5.3	162	NA	143 (TS)	126	NA	14.9	NA	[77]
Two phase OMSR	4.9	187.9	NA	206.7 (SS)	158.2	NA	NA	NA	[80]
Settled OMWW	5.20	95	19	15 (SS)	NA	NA	11.5	9.8	[88]
OM wash water	6.0	2.735	NA	0.456 (TS)	NA	NA	0.291	NA	[39]
Pomace leachate	6.0–6.5	25–30	NA	1.5–2.0 (SS)	0.3–0.4	NA	3–3.5	NA	[11]

NA: not available; VS: volatile solid, TS: total solid, SS: suspended solid; TN: total nitrogen; TKN: total Kjhedahl nitrogen.