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Exploring the potential of fur farming wastes and byproducts as substrates to anaerobic digestion process

I. Zarkadas [a, *], G. Dontis [a], G. Pilidis [b], D.A. Sarigiannis [a]

[a] Aristotle University of Thessaloniki, Department of Chemical Engineering, Environmental Engineering Laboratory, 54124, Thessaloniki, Greece
[b] University of Ioannina, Department of Biological Application and Technology, University Campus, 45110, Ioannina, Greece

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ABSTRACT

Mink farming is a well-established economic activity with a significant environmental footprint. In this work mink farming derived organic waste was assessed, for the first time, as substrate to anaerobic digestion plants. The substrates assessed were; (a)fresh mink manures, (b)weathered mink manures, (c) waste feed and (d)mink derived meat and bone meal. Substrates with in inoculum to substrate ratio of 2 offered specific methane productions ranging between 368 and 591 mLCH_4/gVS$_{added}$ corresponding to 67.4 and 91.1% of their theoretical methane potential. In the second phase of the experiments three organic loading rates and three inoculum to substrate ratios were assessed. Substrate/inoculum ratios, in batch mode, lower than 1 seem to affect negatively the process, due to slow hydrolysis and acetogenesis of the macromolecules. In addition, initial organic loading rates of up to 50 gVS/L can be applied in batch systems when manure is utilized as substrate. In contrast to this, when mink derived byproducts are used the same loading rate will result into an irreversible process inhibition due to the accumulation of intermediate products.

1. Introduction

European fur production is a dynamic and well established industry with long tradition in the production of quality products and significant exporting experience and capabilities. The European Union is the main exporter of pelts worldwide accounting for the 64% of the total production with the States of Denmark, Netherlands, Finland and Greece being the main producers [1]. Other significant fur producers are the United States of America and China, with China being the main exporter of fur derived commodities and clothing. The specie farmed for its fur is the American Mink (*Neovison vison/Mustela vison*) which is a carnivore, semi-aquatic mammal [2], with the full grown males reaching the 45 cm in length, 20 cm in height and the 2 kg in weight. The diet of the farmed animals is composed of low cost protein and fat rich byproducts, including slaughterhouse and aquaculture wastes [3]. The wastes generated from mink breading facilities includes manure and waste feed. Both are collected under the animal cages in small piles of up to 50 cm in height. The waste management options for this waste stream are constrained by the high solids, organics and nitrogen content that are significantly hampering the abilities of aerobic biological processes to treat or valorize them. Even so, composting is widely employed, due to low cost [4]. Mink farmers in order to stimulate the application of the generated compost offer it free of charge. However, acceptance by local farmers and application rates to the fields are disappointing; bad odors one of the main reasons for this rejection. Manure stockpiling and composting on the other hand can promote nitrogen and phosphorus leachate and runoff formations leading to algae blooms and eutrophication of surface waters while, contamination of underground waters with fecal microorganisms is not uncommon.

After pelting dead mink bodies are either sent for incineration or rendering where they are converted into bone and meat meal (BMM). The EC Animal By-product Regulation enforces the pretreatment of the dead minks through crushing, milling and cooking at 133 °C and at least 3 bars of pressure for 20 min. The high protein meal after the process is used as soil amendment (fertilizer) or as alternative fuel. Unfortunately, this market is undeveloped and the ready product is stockpiled. Bone and meat meal on the other hand can become a hazardous commodity during both storage as well as transportation due to its tendency to self-heating and igniting without the requirement for an external source of heat or fire [5].

* Corresponding author.
E-mail addresses: giannis@eng.auth.gr (I. Zarkadas), gndontis@cheng.auth.gr (G. Dontis), gpilidis@uoi.gr (G. Pilidis), denis@eng.auth.gr (D.A. Sarigiannis).

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Abbreviations

TOC	Total Organic Carbon
TS	Total Solids
AD	Anaerobic Digestion Process
HRT	Hydraulic Retention Time
FMM	Fresh Mink Manure
WMM	Weathered Mink Manure
WF	Waste Mink Feed
BMM	Mink Derived Bone and Meat Meal

A waste management option which can be employed for the valorization of fur farming wastes is anaerobic digestion (AD). AD is a biomass bio-conversion process disengaged from weather conditions which offers the advantages of self-sustainability, income generation and waste valorization with limited material requirements. Anaerobic digestion of manures and plant waste material offers the opportunity for recovery of both biogas (a methane rich gas) and hygienized and nearly odorless stabilized digestate which can be applied onto agricultural land as an organic fertilizer.

Anaerobic digestion has been assessed and applied to a plethora of different substrates/wastes/low value or negative value by products including animal manures [6], industrial wastes and wastewaters, municipal solid wastes, energy crops [7] and mixtures of different substrates in co-digestion schemes [8,9].

The substrates evaluated in this work were fresh and weathered mink manures (FMM, WMM respectively), waste mink feed (WF) and bone and meat meal (BMM) that is being generated by the mink carcasses after pelting.

The scientific community has shown very limited interest for the management of the mink farming waste and byproducts. This can be due either to the absence of these operations in most of the developed world or due to the negative publicity that these operations have as an effect of the number of animals sacrificed so that their furs become high value human clothing and accessories. This is the first time that the mink farming waste is assessed as candidate substrate to anaerobic digestion process.

2. Material and methods

2.1. Substrates and inoculum

The substrates selected included all important waste streams generated during the life cycle of minks. Unfortunately seasonality is a significant problem as most of the wastes are generated between May and November. During winter and early spring only low volumes of manure and waste feed are produced by the males and the breading females.

The substrates were assessed in batch vials under mesophilic conditions mainly due to the known problems related to the inhibition of the process by elevated concentrations of unionized ammonia. This inhibitory process is driven by the bio-conversion, of protein into ammonia and it is assisted by the high temperature and pH experienced in thermophilic systems. Inoculum was collected from two 6 L laboratory scale CST reactors treating mixtures of cattle manure and food waste and operating under an OLR of 3.1 $kgVSm^3R$-d and a HRT of 28 days. Prior to the preparation of the batches the inoculum was degassed for 1 week.

Mink manure was collected from a medium size farm housing approximately 20.000 minks and located in the area of Kastoria. Fresh mink manure was considered the manure located at the upper part of the pile that kept its as excreted shape; weathered manure was considered the one located inside the piles, which had lost its shape and its physical appearance had been altered into a thick paste. The smell of both substrates were strong and unpleasant. Waste feed was collected from the same farm and composed by the uneaten feed provided on top of each mink cage. BMM was collected from a rendering operation which is responsible for the disposal, during the pelting season, of the mink bodies and operating according to the EC Animal Byproduct Regulation. In this facility waste fat is recovered and sent for biodiesel production, while BMM is sold as fertilizer or as renewable fuel.

2.2. Batch preparation

During the preparation of the batches, the vials were filled with the inoculum, the substrates and distilled water was used as filler to the active volume of 120 mL. Finally the oxygen removed through nitrogen bubbling and the batches were placed within a temperature controlled cabinet at $36 \pm 1\ ^{\circ}C$ for 30 days. The same steps were used for the preparation of the batches utilized for the assessment of the different I/S ratios except that instead of water, 0.02 M potassium phosphate buffer (pH 7.2) was used for inoculum dilution. The volumetric gas production assessed daily, pH and VFA concentrations analyzed every 3–5 days and all experiments took place in triplicate. In this work three inoculum to substrate ratios 2,1, 0.5 (initial OLR of 12.5 $kgVSm^3$) as well as three organic loading rates have been assessed. The data related to the batch preparation are presented in Table 1. To date there is a lack of standard methodologies for the application of bio methane potential test [10]. The assessment of the effect of the inoculum to substrate ratio in the digestion of different substrates is done through stepwise increase of the organic loading [11,12]. Although this is technically correct, in many cases, especially when high solid substrates are assessed, it offers data related to the tolerance of the process in extreme loading rates not applicable in real life digestion systems. In this work the idea of keeping constant the OLR and diluting, with a pH buffer, the inoculum added into the systems has also been assessed. Such an approach has been used in the past by Hashimoto [13], and Brulé et al. [14] when examining the biodegradability of straw, silage and green clippings. The dilution of the inoculum is affecting a number of operational parameters, including the number of the available cells and the concentration of trace elements [14]. At the same time the presence of an inhibitor might be revealed through this stepwise process. Successful digestion demonstrates the acceptability of the substrate by the process.

2.3. Analytical methods

2.3.1. Volatile fatty acids, TOC, TKN, pH, soluble COD & biogas quality, ammonia

For VFA analysis samples were centrifuged to 9000 RPM for 10 min and the supernatant were analyzed with a Shimadzu

Table 1
Composition of the experimental series.

Experimental series	OLR 12.5 $kgVS/m^3$	OLR 25 $kgVS/m^3$	OLR 50 $kgVS/m^3$
FMM(g FM)	4.08	8.17	16.34
WMM(g FM)	5.16	10.33	20.66
WF (g FM)	4.10	8.21	16.42
BMM(g FM)	1.84	3.69	7.39
	I/S 2	I/S 1	I/S 0.5
Inoculum (gVS)	3.01	1.50	0.75
FMM(g FM)	4.08	4.08	4.08
WMM(g FM)	5.16	5.16	5.16
WF(g FM)	4.10	4.10	4.10
BMM(g FM)	1.84	1.84	1.84