Two approaches on the utilization of fruit wastes as Co-substrate for pig manure anaerobic Co-digestion – the effect of the COD:N:P balance

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Introduction

Fruit wastes (FW) are produced in large quantities in centralised fruit storage and distribution facilities of producers, during the selection and rejection processes before fruit enter into the market. The waste stream targeted by this study was originated from a group of apple and pear producers.

One of the most promising alternatives for managing these organic wet wastes is anaerobic digestion (AD). A major limitation of anaerobic digestion of FW is a rapid acidification of these wastes decreasing the pH in the reactor, and a larger volatile fatty acids production (VFA), which can stress or inhibit the methanogenic biomass activity (Bouallagui *et al*, 2005). Decentralised management of these flows in farm scale digesters could be a solution to avoid this limitation and improve the economy of digester investments already done in the past, and to contribute to the recycling of nutrients in the local agriculture areas.

A previous research work concluded that a bioconversion process of fruit wastes before feeding a co-digestion process with pig manure (PM) was considered advantageous, once the result of this bioconversion is a stable product (Bioconverted Fruit Wastes - BFW) in anoxic conditions, more convenient to be stored, handled and improves the stability of the AD process (Ferreira *et al*, 2007). The same work studied the co-digestion of a mixture of BFW:PM , 30:70 (v/v) with an organic loading rate (OLR) based on the chemical oxygen demand (COD) of 4 kg COD/$m^3.d^{-1}$, operating at a hydraulic retention time (HRT) of 16 days.

The amount of nitrogen and phosphorous needed to satisfy anaerobic bacterial activity and maintain acceptable digester performance may be achieved through an adequate COD:N:P ratio in the feedstock. Generally 1000:7:1 has been used for high-strength wastes (Gerardi, 2003).

Taking this into account, different approaches can be exploited on the utilization of these two organic waste streams. Co-digestion processes can be performed using BFW as a co-substrate with pig manure or utilizing pig manure as the co-substrate with BFW.

This work is a contribution for the assessment and comparison of these approaches.

Objective

The main objective was to evaluate for a similar organic loading rate, the influence of an improved COD: N: P balance on the mixture of bioconverted fruit wastes (BFW) with pig manure (PM). Two mixtures of BFW and PM, with a volumetric composition of 30% BFW: 70% PM and 66% BFW: 34% PM were studied for the same organic loading rate of 4,1 - 4,4 Kg COD/$m^3.d^{-1}$.

Methods

Origin of materials - The substrates used were, screened pig manure (PM) from a farrows-to-finish pig farm and fruit wastes (FW) characterised by a mixture of refused flows of apples and pears. Samples of pig slurry were collected according to a procedure in order to get weekly composed samples. Fruit waste was pulped with a fruit mill with a 5 mm screen. Fruit pulp (30 litres) was stored in a 50 litre closed vessel with mechanical mixer at environmental temperature, in order to develop a spontaneous fermentation process. After 10 days of fermentation, the pulp was considered ready to be used as a co-substrate (BFW).

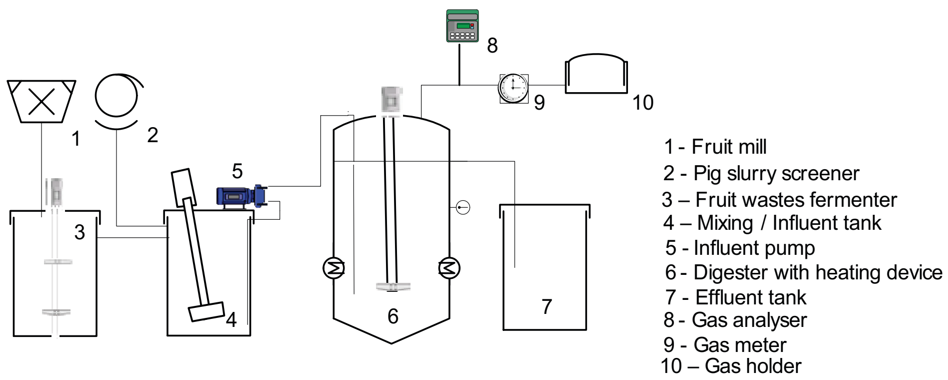
Inoculum was obtained from a mesophilic (35ºC) sewage digester.
Characteristics of BFW and PM are presented in Table 1.

Continuous trials – Continuous lab trials, using a stainless steel digester (CSTR) with V= 11 litre (Figure1) were performed at 37º C $\pm$ 4 ºC.

Considering the goal proposed, two dynamic mesophilic continuous lab trials were setup. In order to significantly improve the COD:N:P ratio (C/N $\geq$ 25) of the previous studied mixture of BFW:PM , 30:70 (v/v), keeping aprox. the same OLR, it was prepared a mixture BFW:PM , 66:34 (v/v). Therefore both trials were operated at OLR 4,1 - 4,4 kg COD/m3.d^{-1}, which was set, feeding the mixtures of BFW:PM , 30:70 and 66:34 with HRT=16 days and HRT=27 days, respectively.

The continuous trial performance using the mixture BFW:PM , 30:70 with a previsional COD:N:P = 170:4:1 was compared with the mixture BFW:PM , 66:34 with a previsional COD:N:P = 500:5:1. The main process operational parameters (methane, carbon dioxide, H_2S and COD fractions of the digest, nitrogen and phosphorous) has also been investigated. Results were obtained considering a steady-state achieved after three reactor volumes.

Figure 1. Schematic diagram of the laboratory-scale experimental setup



Analytical methods – pH, chemical oxigen demand (COD), total solids (TS), volatile solids (VS), Nkj, N-NH_4^+, total phosphorous (TP), total volatile fatty acids (T-VFA), Bicarbonate alkalinity were determined according to standards methods (APHA, 1995). Glucose, fructose, ethanol and organic acids were determined by isocratic high performance liquid chromatography (HPLC) with IR or UV detection.

Results and Discussion

Characterization of waste materials

Table 1. Initial characteristics of waste materials (average figures)

		BFW	PM
pH		3,69	7,53
Conductivity	$mS.cm^{-1}$	3,76	17,04
TS	g/l	56,31 [a]	22,35
VS	g/l	48,79 [b]	15,07
COD	mg/l	168283,40	33768,80
CODsoluble	mg/l	132131,55	15404,40
T-P (If it is P tot)	mg/l	109,23	582,33
TK-N (if it is N tot Kjeldahl)	mg/l	641,08	2304,69
NH_4^+ - N	mg/l	117,03	1747,71
T-VFA	g acetic acid/l	5,99	n.d
Glucose	g/l	0	n.d
Fructose	g/l	0	n.d
Ethanol	g/l	44,00	n.d

a) – Non volatile fraction at 104ºC ;
b) – Volatile fraction at 550ºC of the non volatile fraction at 104ºC ;
n.d - not determined

It is possible to see from Table 1 the low TS content of pig slurry after the screening operation. In comparison, fruit waste pulp had almost ten times more solids and 98 % of them were volatile. Buffiere et al. (2005) reported very similar characteristics for apple wastes.

Table 2. Characteristics of the mixtures BFW:PM and respective digests (average figures)

		30%BFW:70%PM		66%BFW:34%PM	
		Inflow	Outflow	Inflow	Outflow
pH		6,45	7,71	4,83	7,97
COD	mg/l	70593,96	17507,30	113196,09	23896,00
CODsoluble	mg/l	50175,08	8529,76	71801,04	8073,00
T-P	mg/l	427,24	143,08	257,52	180,92
TK-N	mg/l	1775,45	1490,00	1330,00	1165,42
COD:N:P		165:4:1	-	440:5:1	-

Table 2 shows the characteristics of both mixtures utilised. It can be observed the real COD:N:P ratio difference between the mixtures and that a better C/N ratio was achieved in the mixture 66%BFW:34%PM when compared with 30%BFW:70%PM. On the other hand the $COD_{soluble}$ of both outflows, seems to show a similar existence of a recalcitrant soluble COD fraction.

It can be seen on table 3, that biogas resulting from digestion of 66%BFW:34%PM mixture, became slightly poor in methane. On the other hand the biogas productivity of this mixture is 20% higher. This better performance could be directly related with a much better C/N balance on this composition (Gerardi, 2003).

The biogas quality regarding the H_2S content improved significantly. The reduction achieved from the digestion of the mixture 66%BFW:34%PM, results mainly from the low S content of the BFW.

Process stability was not affected although T-VFA/BA ratio results, indicated that an increase of OLR based on BFW:PM mixture, could become problematic to digester balance (results not shown).

Table 3. Operating and process performance for the two mixtures

Mixture BFW:PM (% v/v)	HRT days	OLR kg COD/ $m^3.d^{-1}$	m^3 biogas/ m^3 digester.d^{-1}	Biogas quality % CH_4	Biogas quality ppm H_2S	COD removal %	m^3 biogas/ m^3 biomass
30:70	16	4,1-4,4	1,57	67	605	75	25
66:34	27	4,1-4,4	2	63	152	80	56

Conclusions

1 - Improving the nutrient balance COD : N : P of a BFW:PM mixture, a direct effect on the digestion process was observed :

- It was possible for a similar OLR to increase 20% methane productivity although biogas quality was slightly poor in methane.
- The biogas quality concerning H_2S content dramatically decreased 75%.
- The stability indicators used, suggests the OLR = 4,1 - 4,4 kg COD/$m^3.d^{-1}$, as maximum recommended.

2 - Operational indirect effects can also be envisaged by the consequence of a better nutrient balance COD : N : P, on the mixture of BFW:PM :

- To digest the same volume of BFW, a smaller digester is need (24% reduction).
- Regarding a waste management perspective, in particular the recycling of digestate in agriculture, the digestion of the same volume of BFW, requires a waste management system with aprox.45% of the arable land.

References

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