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Original Research Article

Experimental Study on the Biotreatability of Wastewaters from Food Processing Industries in Aerobic Sequencing Batch Reactors

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ABSTRACT

The study was carried out to assess the effectiveness and limitations of aerobic biological treatment for the removal of organic matter from the food industry wastewaters. Four wastewaters from the UK food and drink industry were treated using an aerobic biological process carried out in lab-scale sequencing batch reactors (SBRs). Each reactor was inoculated with soil and monitored for chemical oxygen demand (COD) and total suspended solids (TSS) removal. The results showed high COD removal efficiencies for all the wastewaters, in the range of 64 – 95 %. The removal of TSS was different for the four wastewaters, and was not satisfactory. The food to microorganism (F/M) ratio calculated in all the reactors was quite low (0.13 - 0.29 kg COD/kg biomass.day) which contributed to the incomplete COD removal and poor TSS removal. In spite of the same cycle pattern, hydraulic retention time and length of the phases, the results indicate that solids removal is mainly determined by the nature and size of the particulate matter, rather than the process conditions. The residual soluble COD in the effluent was not further biodegradable, as indicated by extended aeration tests. The performance of the reactors was virtually unaffected by the solids retention time (SRT) (in the range investigated, 7–18 days), indicating that very good COD removal can be achieved at relatively lower SRT, with potential savings in capital and operating costs.

1. INTRODUCTION

The food and drink sector include a wide range of industries and processes such as fish processing, meat processing, baking, milling, sugar processing and refining, brewing, distilling etc. (Malagie et al., 1998).

These processes may produce wastewaters of complex compositions and constitute major concerns to the environment (Polprasert et al., 1992). For example, meat, dairy, slaughterhouses wastewaters contain high levels of fats, suspended solids, chemical oxygen demand (COD), biological oxygen demand (BOD) and nutrients (Masse et al., 2000; Sroka et al., 2004; Kushwaha et al., 2013; Myra et al., 2015). These components are key environmental parameters which need to be controlled (Alvarez-Mateos et al., 2000). Walter et al. (1974) reported that wastewaters from slaughterhouses and meat processing industries have been classified by the Environmental Protection Agency (EPA) as the most harmful to the environment. If these wastewaters are discharged without treatment, the organic compounds within the wastewater decompose rapidly and deplete the dissolved oxygen level of the receiving streams resulting in anaerobic conditions and release of strong odors that could endanger the environment (Seif and Moursy, 2001; Shete and Shinkar, 2013).

Biological processes based upon a sequencing batch reactor (SBR) have gained wide acceptance for the removal of BOD, COD and nutrients in wastewaters (Kim et al., 2004; Mohseni-Bandpi and Bazari, 2004; Kim et al., 2008; Islam et al., 2011; Ganigue et al., 2012). The SBR has become increasingly popular as an effective biological treatment system due to its flexibility of operation and simplicity (Dionisi et al., 2001). The SBR is basically a single tank that serves both as a reactor and settler. In SBR systems, biological reactions and settling occurs in the same tank in a temporal sequence, whereas they occur simultaneously but in different tanks in continuous-flow systems (Artan and Orhon, 2005). This means that the SBR does not require a settling tank and a sludge recycle stream, as in conventional continuous-flow activated sludge processes. Other advantages include low cost, easy operation and ability to handle hydraulic fluctuations (Keudel and Dichtl, 2000). Because it involves a cyclic operation, SBR cycles for COD removal typically consist of the following phases: fill, react, sludge withdrawal, settle, effluent withdrawal and idle (Dionisi et al., 2001; Mohseni-Bandpi and Bazari, 2004; Artan and Orhon, 2005). Important parameters associated with SBR operation include number of cycles, hydraulic retention time (HRT), duration of phases in a cycle, sludge retention time (SRT) and number of tanks.

The SBR has been widely explored and tested for the treatment of food processing wastewaters like dairy, winery, brewery, slaughter houses, piggery, etc. with satisfactory and reliable performance (Torrijos and Moletta, 1997; Ling and Lo, 1999; Raper and Green, 2001; Neczaj et al., 2008; Suresh et al., 2011). In spite of this, the use of SBR in the treatment of food and drink wastewaters at industrial scale is still limited. For example, considering the four UK-based food and drink companies involved in the present study, none of them currently use the SBR or any form of on-site biological treatment process for their effluents. The treatment methods on-site are mainly physical and chemical technologies. Although one of the companies use a biological treatment which involves injecting microorganism mixtures (Bioamp) in drains or using bioremediation pillows. However, these technologies give results that are only partially satisfactory in terms of COD and BOD removal. The effluents are not always compliant to the regulatory limits and this may cause costs to the industry, e.g. due to the requirement of the installation of expensive chemical-physical technologies to comply with the limits. Therefore, this study investigates the aerobic biological treatment in SBR of the liquid effluents from four food and drink companies.

2. MATERIALS AND METHODS

2.1. Wastewater and Inoculum

Wastewaters were collected from four different food and drink industries across Scotland, UK. A, B, C and D were assigned to the wastewaters for discretion. The wastewaters were stored in large airtight barrels prior to sampling. The wastewater samples were characterized based on their physical-chemical parameters: pH, total COD, soluble COD and total suspended solids (TSS). Soil from Craibstone, Aberdeen, Scotland, UK, homogenized and stored in plastic containers at room conditions, was used as inoculum (see Bartram et al.

(2014) for a detailed microbial characterization of this soil). The soil was used without any acclimation to the wastewaters.

2.2. SBR Set-up and Operating Conditions

Two parallel glass reactors were operated at room temperature (22 °C) to allow the treatment of two wastewaters simultaneously. Table 1 shows the reactor operation conditions, which were the same for all wastewaters.

Table 1: SBR operating parameters

Parameter	Value
Liquid volume	1000 ml
HRT	4 days
Target SRT*	28.6 and 14.3 days
Cycles/day	4
Cycle pattern	
Feed (aerated)	2 min
Aeration	5 h
Sludge withdrawal	Manual (daily) at the end of aeration phase
Settling	58 min
Effluent withdrawal	2 min

*The target SRTs are the maximum SRT values in the absence of solids losses in the effluent

The reactors were aerated with a constant flow of air during the fill and react phases. Mixing was carried out using a magnetic stirrer. The reactor feed was sampled once or twice a week while the effluents were sampled and analyzed three times every week. The reactor was supplied with oxygen by fine bubble air diffuser from an Interpet Airvolution AV Air Pump (UK). A programmable 220-250 V Energenie four socket power management system, UK was used to control the length of phases for each cycle in the SBR. The mineral solution shown in Table 2 was prepared and added to the wastewaters in order to buffer the pH to a value of 7.0 and to prevent any possible nutrient limitation. Prior to treatment, 50 ml of mineral solution was added per litre of the reactor feed for all the wastewaters, except for wastewater D where 100 ml was added per litre of the wastewater.

Table 2: Composition of mineral solution

Compound (salt)	Concentration
NH_4Cl	16 g/l
K_2HPO_4	348 g/l
NaH_2PO_4	240 g/l
Thiourea	0.4 g/l

The reactors were started with 5 g/l of soil inoculum, which was mixed with 1l of wastewater. The cycle was started with the settling phase, followed by effluent withdrawal. Then the first feed was added and reactor operation continued according to the programmed cycle pattern. For each wastewater the reactor was operated at two different values of the SRT. Initially the reactor was operated at the longest SRT, and then after steady state was achieved, the SRT was decreased. Control of the SRT was done by manual withdrawal of sludge from the mixed reactor at the end of the reaction phase. The volume of sludge withdrawn was 35 and 70 ml/day in the first (high SRT) and second (low SRT) phases respectively.

The HRT and SRT were calculated using the following expressions:

$$HRT = \frac{V}{Q} \tag{1}$$

$$SRT = \frac{V \cdot X}{Q_w \cdot X + Q_{eff} \cdot X_{eff}} \tag{2}$$

Where V is the volume capacity of reactor (ml) and Q is the daily feed flowrate (ml /day), X is the solids concentration in the reactor (measured as TSS), Q_W and Q_{eff} are the daily sludge and effluent withdrawal volumes respectively and X_{eff} is the solids concentration in the effluent. The target SRT values (28.6 and 14.3 days) are the maximum SRT values in the absence of any solids losses with the effluent. SRT was calculated based on the measured values of X and X_{eff} and the average value for the treatment were reported in the results section.

2.3. Extended Aeration Tests

Extended aeration tests were conducted on each wastewater at the end of each run. The sludge wasted from the reactor was used to inoculate the batch reactor. The effluent collected at the end of the cycle was immediately charged into the batch reactor then mixed and aerated for duration of 6 hours and samples were taken every hour to measure soluble COD.

2.4. Analytical Methods

The measured parameters include pH, total suspended solids (TSS), total and soluble COD. The pH was measured using a Thermo Scientific Orion Versastar pH meter (USA). Total suspended solids was measured using a glass micro fiber filter with 0.45 µm pore size (Cat. No.1822-047, Whatman). The residue retained on the filter paper was then dried at 104 °C for 4 hr. A Millet syringe filter with 0.45 µm pore size (Darmstadt, Germany) was used for filtering samples (for soluble COD) prior to analysis. A Spectroquant TR 620 thermo-reactor (Darmstadt, Germany) and NOVA 60 (Darmstadt, Germany) photometer was used in the COD analysis. COD was measured with the Spectroquant COD cell test 1.14690.0001 (range 50-500 mg/l) after appropriate dilution.

3. RESULTS AND DISCUSSION

3.1. Wastewater Characterisation

The characterisation of the four wastewaters is reported in Table 3. COD values were in general high, ranging between 1000 and 8000 mg/l. A significant fraction of the COD is present as insoluble form.

Suspended solids were also high. It is interesting to see that the total COD and TSS of the raw wastewaters collected from the four industries are much higher than those of typical domestic wastewaters, which have total COD values up to 1000 mg/l and TSS up to 350 mg/l (Metcalf, 1991). These wastewaters have very high COD because of the high levels of fats, oils and grease present in the raw materials. If left untreated, it will substantially increase the burden on the final municipal treatment plant and can cause discharge of pollutants to the receiving water bodies with undesirable environmental effects. The UK effluent standard for treated domestic wastewaters (EHS, 2007) in terms of COD is 125 mg/l. Therefore, these wastewaters need treatment to reduce the COD and TSS.

Table 3: Characteristics of the wastewaters

Wastewater	Nature	Current onsite treatment	pH	Total COD (mg/l)	Soluble COD (mg/l)	TSS (mg/l)
A	Cake manufacturing	Biological treatment	3.4	3146	1869	1314
B	Traditional meal making	Physical treatment	8.6	1163	543	865
C	Meat processing	Chemical treatment	6.2	2642	416	2159
D	Fish processing	Physical treatment	6.3	8052	5308	6407

3.2. SBR Performance

The performance results of the four reactors are shown in Figures 1 – 4, where the time profiles of COD (total and soluble) and of TSS (in the mixed reactor and in the effluent) are presented. The average values of the measured parameters are reported in Table 4. As far as COD removal is concerned, in general, good performance was observed. For wastewaters A, B and C, total COD removal was in the range 75-86%. A lower COD removal was observed with wastewater D, with only 60% removal of total COD. This is however mainly due to the poor removal of TSS, as discussed later. The reactors performance was also good with respect to soluble COD removal, where in general the removal was higher than 70%, with the exception of wastewater C (60-66% removal of soluble COD). For wastewater C, however, the soluble COD is only a minor fraction, about 15%, of the total COD (Table 3).

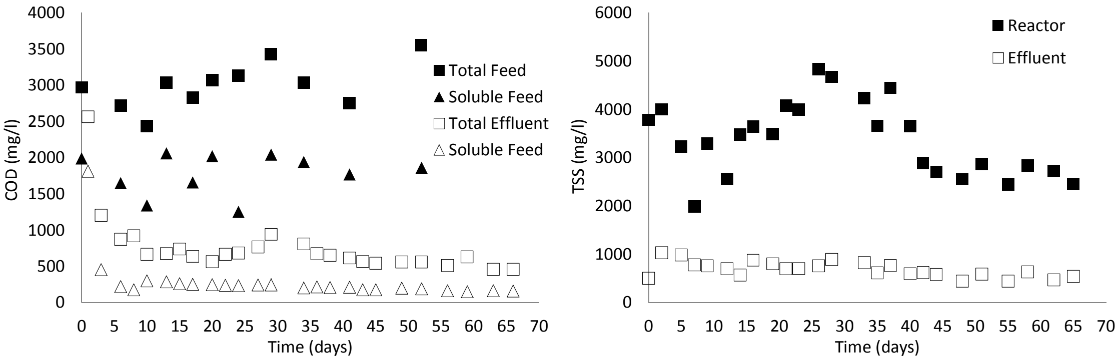
Table 4: Summary of results

Wastewater	Parameter	Effluent	% Removal	Effluent	% Removal
A	Average SRT (days)	13.8		9.5	
	Total COD (mg/l)	707 (114)	78	535 (58)	83
	Soluble COD (mg/l)	225 (18)	88	171 (16)	91
	TSS (mg/l)	739 (96)	44	538 (78)	59
B	Average SRT (days)	13.4		9.2	
	Total COD (mg/l)	228 (11)	80	252 (19)	78
	Soluble COD (mg/l)	102 (4)	81	105 (3)	81
	TSS (mg/l)	415 (17)	52	437.7 (48)	49
C	Average SRT (days)	17.9		10.6	
	Total COD (mg/l)	380 (57)	86	310 (68)	88
	Soluble COD (mg/l)	132 (8)	68	126 (15)	70
	TSS (mg/l)	508 (139)	76	510 (134)	76
D	Average SRT (days)	8.1		6.5	
	Total COD (mg/l)	2950 (717)	63	2924 (190)	64
	Soluble COD (mg/l)	414 (81)	92	256 (157)	95
	TSS (mg/l)	6484 (1177)	0	6047 (304)	6

Average values and, in brackets, standard deviation
The % removal was calculated on the basis of the composition of the feed to the reactors, i.e. after addition of the mineral solution

For wastewater D, which showed a relatively poorer total COD removal, the removal of soluble COD was very high, higher than 90%, and this confirms that the lower efficiency in the removal of total COD is due to the presence of suspended solids in the effluent.

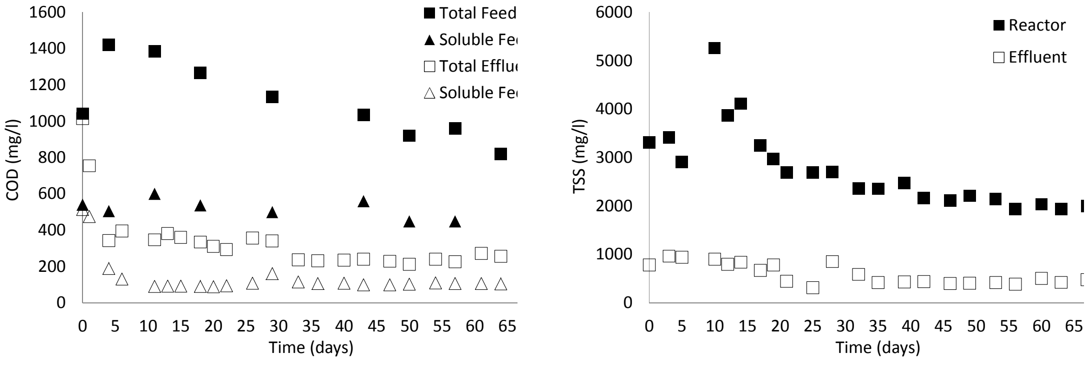
The removal of suspended solids, as measured comparing the effluent and the feed TSS, was in general not satisfactory. The best performance was observed with wastewater C (65-67% removal), while in the worst case, for wastewater D, virtually no removal of the TSS was observed. From visual observation of the reactors, it seemed evident that a fraction of the solids in the reactor was made of very fine particles with very low settling velocity. This is also evident from Figures 1 – 4 which show that the solids in the effluent were always much lower than the solids in the mixed reactor, so indicating that at least a fraction of the solids in the reactor showed good settling properties. For wastewater D, where virtually no removal of TSS was observed comparing the effluent and the feed, the solids in the effluent were approximately 50% of the solids in the mixed reactor (Figure 4), so indicating that settling was occurring in the reactor. For this wastewater, settling was made more difficult because of the high concentration of the wastewater, which caused a very high concentration of solids in the reactor (higher than 10 g/l). It is well known that the settling velocity decreases with increasing solids concentration and this has probably contributed to the high concentration of TSS in the effluent (Daigger and Roper Jr, 1985; Janczukowicz et al., 2001; Guo et al., 2009). The high concentration of solids in the effluent of this reactor is also the reason why the removal of total COD for wastewater D was lower than for the other wastewaters.



(a) (b)

Figure 1: Wastewater A. (a): Total and soluble COD of the reactor feed and effluent. (b) TSS in the mixed reactor and effluent (SRT changed on day 41)

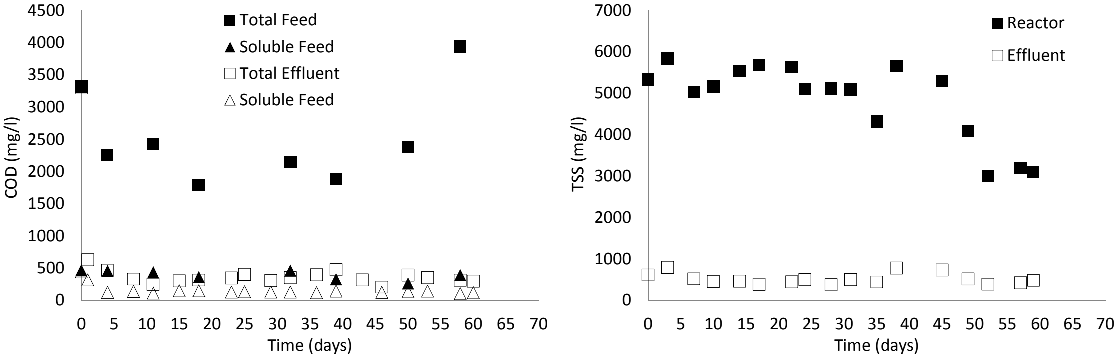
Regarding solids removal, an important observation is that the removal efficiency was significantly different between the four wastewaters, even though the cycle pattern, length of the phases and hydraulic retention time were exactly the same. It is reported that particles with low size distribution are less effectively removed than those with large size distributions (Celenza, 2000). Therefore, this indicates that the solids removal efficiency is mainly determined by the properties of the wastewaters, e.g. the nature and size of the particulate matter, rather than by the process conditions. It is also important to observe that the length of the settling phase used in this study was quite long (58 mins), longer than in most SBR studies reported in the literature (e.g. Keasling (2004) reported a settling duration of 30 minutes in their study). This indicates that, at least for the wastewaters considered in this study, if an improvement of solids removal is needed some treatment additional to the biological process is needed, e.g. addition of flocculants or use of membranes.



(a) (b)

Figure 2: Wastewater B. (a): Total and soluble COD of the reactor feed and effluent. (b) TSS in the mixed reactor and effluent (SRT changed on day 50)

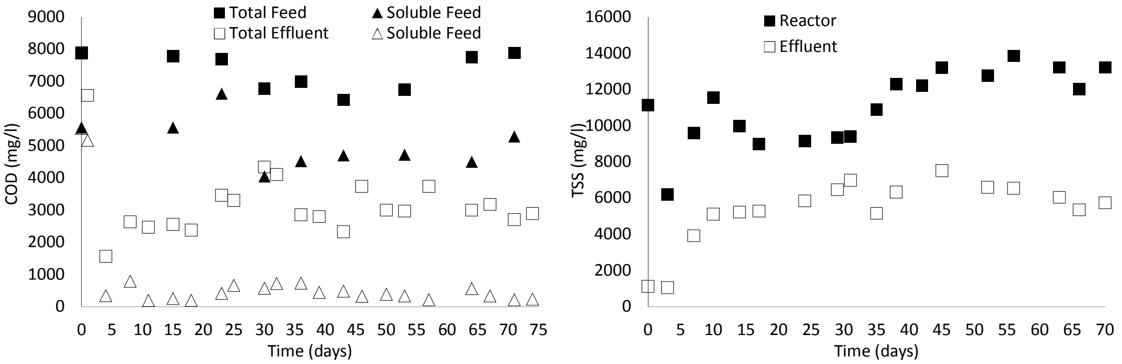
An important observation that can be made from Figures 1 – 4 is that acclimation of the microorganisms to the wastewaters was very fast. In all cases very good COD removal was recorded just after 2 or 3 days from the start of reactor operation. To this regard, it is important to observe that the microorganisms had not been acclimated to the wastewaters before the start of reactor operation. From the practical point of view, these results indicate that the start-up phase of biological reactors treating food and drink wastewaters can be very short. Also, from the time profiles shown in Figures 1 – 4 it is evident that the performance of the reactors in terms of COD and TSS removal was usually very stable, despite some fluctuations in the feed composition. Fluctuations in the feed composition were due to the fact that the feed was sampled from the storage barrels, where some heterogeneity was present in spite of the thorough mixing that was done before sampling for the feed preparation. The stability of the performance of the reactors indicates that, at least for COD removal, the reactors were probably able to remove a higher organic load than the one applied in this study.



(a) (b)

Figure 3: Wastewater C. (a): Total and soluble COD of the reactor feed and effluent. (b) TSS in the mixed reactor and effluent (SRT changed on day 39)

Another important observation that can be made from the figures and from Table 4 is that the change in SRT caused virtually no change to the performance of the reactors with respect to both COD and TSS removal. In theory, a lower COD removal is expected at shorter SRT, however the effluent COD was very little or not at all affected by the decrease in SRT. The SRT in the reactors depended (Equation 2) both on the amount of sludge withdrawn daily from the mixed reactor and from the solids lost in the effluent. While the amount of sludge withdrawal was the same for all the reactors and was lower in the first phase of the runs (high SRT) and higher in the second phase (low SRT), the solids lost in the effluent were different in the various reactors and this explains the different SRT in the reactors. Also, this explains why the difference between high and low SRT was larger for some wastewaters and lower for others. For wastewater D, where high solids losses in the effluent were observed, the SRT was the lowest and also the effect of the reduction in the sludge withdrawal rate was minimum (the SRT reduced from 9 to 7 days) because the SRT was essentially controlled by the solids in the effluent. On the contrary for wastewater C, which observed the best removal of TSS, the SRT was the highest and the difference between the two phases was the largest (20 vs 12 days).



(a) (b)

Figure 4: Wastewater D. (a): Total and soluble COD of the reactor feed and effluent. (b) TSS in the mixed reactor and effluent (SRT changed on day 50)

These results on the effect of the SRT seem to indicate that it is possible to carry out biological treatment of food and drink wastewaters with low values of the solids residence time. It is important to observe that the range of SRT explored in this study is limited due to solids losses in the effluent. Therefore, there is the need to further explore wider ranges of SRT to fully appreciate its effect on reactor performance. Working at low SRT has the advantage of lower capital costs, because a smaller reactor size may be required, and lower operating costs due to the lower aeration requirements (Henze, 2008; Grady Jr et al., 2012; Agathos and Reineke, 2013). On the other hand, a shorter SRT gives a higher production of waste sludge with an increase in the sludge treatment costs. However, a recent study (Ge et al., 2013) has shown that the effluent of aerobic processes working at low SRT can be successfully used as substrate of anaerobic digestion, with consequent value recovery via methane production.

3.3. Extended Aeration Tests

Figure 5 shows the results of the extended aeration tests, where the wasted microorganisms were added to the effluent of each respective reactor and the mixture was further aerated for several hours. The aim of the tests was to determine if a possible extension of the aeration phase would give a higher COD removal.

However, the tests indicate that the effluent COD was no further biodegradable, as evident from the constant profile of soluble COD in Figure 5. This indicates that all the biodegradable component of the organic matter was virtually totally removed and that the BOD associated with the soluble COD can be considered to be virtually zero.

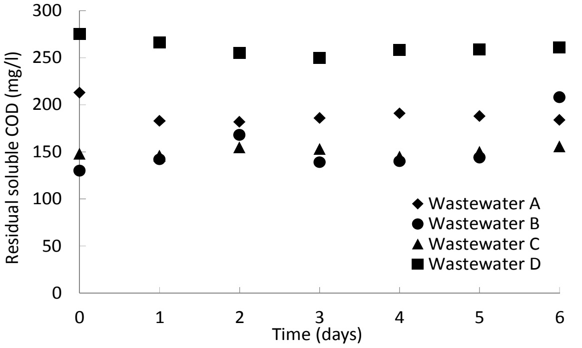


Figure 5: Soluble residual reactor effluent COD of A, B, C and D during the extended aeration tests

3.4. Comparison with Previous Work

Table 5 summarises the results of previous studies on aerobic biotreatment of food and drink wastewaters. Most wastewaters in the literature were different from the wastewaters considered in this study. Indeed, most previous studies have been done with dairy or winery wastewaters, while this study has investigated meat-processing, cake manufacturing traditional meals and fish processing. However, the results obtained in this study are generally in line with the reported literature studies. The total COD removal obtained in this study is in general slightly lower than in most other studies in Table 5. However, this lower COD removal in this study is due to the lower removal of suspended solids rather than to a lower performance of the biological reactor, as discussed in previous sections. Little information is reported in the literature about removal of soluble COD and TSS. This is probably due to the nature of the wastewaters considered in this study. It is also important to observe that this is the only study, among those reported in Table 5, where microorganisms from soil, instead of from activated sludge processes, were used as inoculum. The good performance observed in terms of COD removal indicates the ability of soil microorganisms to quickly acclimate to the organic matter contained in food and drink wastewaters.

3.5. Analysis of F/M Ratio

Wastewater treatment plants can be operated by SRT or food to microorganism (F/M) control because both methods regulate the growth and metabolism of the microorganisms and both methods are interrelated and changing one parameter affects the other directly. The F/M ratio is defined as the ratio between the mass of food entering the biological reactor and the mass of microorganisms in the biological reactor. It is usually evaluated for systems that are controlled based on SRT, such as this study, in order to provide a point of reference to previous activated sludge design and operating performance (Metcalf and Eddy, 2003). The F/M ratio is an important control parameter, as the quantity of biomass present in the biological reactor will influence the treatment performance of the process. Typical values of F/M ratio for optimum performance in SBR process are in the range of 0.2 - 0.5 kg COD/kg biomass.day (Spellman, 2013). Typical biomass concentration in SBRs that ensures good settling is in the range of 2000 – 5000 mg /l (Metcalf and Eddy, 2003). The F/M ratios during the treatment of these four wastewaters were calculated and the values are reported in Table 6. It is interesting to observe from the table that SRT varies inversely with the F/M ratio as expected. The results showed the biomass concentration in the reactors were generally high for most of the operations especially when less sludge is withdrawn. It is also important to observe from the table that the resulting F/M ratios in all the treatments were generally quite low (0.13 – 0.29 kg COD/kg biomass.day) as compared to the optimum design values.

Table 5: Literature studies on aerobic biotreatment of food and drink wastewaters

Wastewater type	Process and reactor conditions	Influent total COD (mg/l)	Influent soluble COD (mg/l)	Influent TSS (mg/l)	Total COD removal %	Reference
Brewery	SBR: Attached and suspended growth; HRT = 1.56 days	1038-4709	-	450-1044	89-97	(Ling and Lo, 1999)
Meat processing	RBR	1180-2160	686-803	613-2020	81	(Wahaab and El-Awady, 1999)
Wine and distilleries	RBR: HRT = 50 hours	4500-70000	-	-	46-68	(De Bazua et al., 1991)
Dairy	SBR	410-480	-	-	90-92	(Mohseni-Bandpi and Bazari, 2004)
Dairy	SBR: HRT = 15-30 hours.	3900	-	-	95	(Kushwaha et al., 2013)
Piggery	SBR	10580	-	-	93	(Bortone et al., 1992)
Piggery	SBR: HRT = 3 days	3769	-	-	95	(Su et al., 1997)
Winery	FBBR	7130	5805	692	67–97	(Andreottola et al., 2005)
Winery	Conventional activated sludge: SRT = 36-48 days	-	-	-	93–96	(Brucculeri et al., 2005)
Dairy	SBR	2800	1500	300	90	(Schwarzenbeck et al., 2004)
Milk industry	SBR: HRT = 3 - 8 days	5000-10000	-	-	87-98	(Sirianuntapiboon et al., 2005)
Winery	SBR: HRT = 1.9 days	400-2000	<470	320-1440	90	(Brito et al., 2007)
Swine	SBR: HRT = 5 days; SRT = 41 days	1972	-	670	80	(Islam et al., 2011)

RBR=rotating biological reactor; FBBR= fluidised bed biological reactor

This is why there is a poor sludge quality in terms of biomass in the effluent and deterioration in the quality of the final effluent. A low F/M ratio means there are many microorganisms (evident from the table) but there is a limited amount of food. Therefore, only when the food supply is limited do the biomass begins to agglomerate and form a dense floc that settles well. Thus, in this case, the biomass does not settle properly which ultimately deteriorates substrate removal. Significant foaming was also observed in the reactors during the treatments, which has been associated with low F/M ratios (USEPA, 1999).

The removal efficiency was significantly different between the four wastewaters, even though the cycle pattern, length of the phases and HRT and most importantly the sludge withdrawal rates were the same. This analysis of F/M ratio therefore indicates that better performance of the reactors would probably be obtainable with different values of the operating parameters for each wastewater, e.g. reduce reaction length and increase settling time.

There are two ways to increase the F/M ratio in the SBR treatment of these wastewaters: decrease the HRT, which increases the Q/V; and/or increase the QW, which decreases the SRT and the biomass concentration as a consequence. For wastewater A where the reactor biomass was initially 4117 mg/l, which is still within the acceptable values in SBR operations, increasing the QW from 35 to 75 ml/day increased the F/M ratio from 0.19 to 0.29 kg COD/kg biomass.day. As a result, the COD removal increased from 78 % to 83 %. However for wastewater B where the biomass concentration is on the lower end of the typical SBR operation values (2262 mg/l), increasing the QW reduced the biomass concentration even lower (2006 mg/l) and the F/M ratio did not change much (0.13 – 0.14 kg COD/kg biomass.day) which led to a slight decrease in COD removal (80 to 78 %). Therefore, a viable option to significantly raise the F/M while still having optimum values of the biomass in the reactor would be to decrease the HRT, which increases the Q/V. In the runs where biomass concentration is very high such as in the case of wastewater D (11582 mg biomass/l), the best option would be to significantly increase both Qw and decrease the HRT.

Table 6: Sludge withdrawal rate (Q_w), SRT, F/M ratio, COD removal and biomass concentration (X). (The COD removal is based on the total COD)

Wastewater	Q_W (ml/day)	SRT (days)	F/M ratio (kg COD/kg biomass.day)	% COD removal	X (mg /l)
A	35	13.8	0.19	78	4117
A	75	9.5	0.29	83	2681
B	35	13.4	0.13	80	2262
B	75	9.2	0.14	78	2006
C	35	17.9	0.13	86	5149
C	75	10.6	0.18	88	3735
D	35	8.1	0.18	63	11582
D	75	6.5	0.16	64	12796

In the end, a general recommendation to be made here is that, at least for the wastewaters considered in this study, if an improvement of solids removal is needed, some treatment additional to the biological process is needed, e.g. addition of flocculants or use of membranes. Also, as mentioned earlier, the aerobic SBR is most suitable for low strength wastewaters (<2000 mg/l). Therefore, with these wastewaters, it could that aerobic-anaerobic treatment will be more effective due to the high COD in the wastewaters.

4. CONCLUSION

Four wastewaters from food and drink companies were treated in aerobic sequencing batch reactors. Each reactor was inoculated with soil and operated at two SRT values. The removal efficiencies of total COD were in the range of 63 – 86 %, and the removal of soluble COD was in the range of 68 – 95 %. The effluent soluble COD was not further biodegradable as indicated by extended aeration tests, indicating that the removal of the soluble BOD was virtually complete. Removal of suspended solids was in general not satisfactory. The fact that the solids removal was different for the four wastewaters, even though the cycle pattern, hydraulic residence time and length of the phases were exactly the same, indicates that the incomplete removal of the solids was due to the nature of the solids particles in the wastewaters, rather than to the process conditions. The SRT had little effect on the performance of the reactors indicating that satisfactory COD removal can be obtained also at relatively low SRT. The F/M ratios calculated in all the reactors were low (0.13 - 0.29 kg COD/kg biomass.day) which contributed to the poor solids removal and incomplete COD utilisation. The results suggest that, at least for the wastewaters under consideration, an improvement in the solids removal may require some additional treatment, e.g. addition of flocculants or membrane processes.

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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