Quali-quantitative characterization and wastewater treatment of a winery located in the mid-west of Santa Catarina state, South of Brazil

A. R. C. Ortigara, P. H. Sezerino, A. P. Bento and D. Scaratti

ABSTRACT

This paper analyses variations in the quali-quantitative characterization of winery wastewater, and the behavior of the treatment of these effluents. The wastewater produced is sent to two disposition systems: Point A receives the wastewater from the production area whereas Point B receives the wastewater from the area where the washing of bottles takes place. Two Aerated Submerged Biofilter (ASB) reactors (with oyster shells as support material) were built at lab scale to promote the treatment of the winery effluent. Water usage and effluent production values of the 2008 harvest season indicate that grape processing accounted for 30% of the total water usage. The median value found for the effluent at Point A was 8,260 mg COD L\(^{-1}\) and at Point B 358 mg COD L\(^{-1}\). The average C/N/P ratio found at Point A was 100/0.29/0.28 during the harvest and 100/0.27/0.25 during the non harvest. For ASB 1 the COD removal efficiency ranged from 56% to 90%, with the removed organic load ranging from 1.5 kg COD m\(^{-3}\) d\(^{-1}\) to 2.7 kg COD m\(^{-3}\) d\(^{-1}\), respectively. For ASB 2 the COD removal efficiency ranged from 63% to 82%, with the removed organic load ranging from 1.8 kg COD m\(^{-3}\) d\(^{-1}\) to 1.7 kg COD m\(^{-3}\) d\(^{-1}\), respectively.

Key words | aerated submerged biofilter, quali-quantitative characterization, winery wastewater

INTRODUCTION

The state of Santa Catarina, located in the Southern region of Brazil, is the country’s fifth grape growing state with 4,914 hectares of vines. The state’s producers are divided into medium and small land holders, and manual workers, and are based in areas such as Rio do Peixe Valley, Carbonífera (coal basin) and Planalto Serrano (highland plateau). Around 90% of production takes place at Rio do Peixe Valley (Epagri 2000), and most of it is consumed as table wine. Grape harvesting in the state usually takes place from late January to March, but winemaking is a year-round activity. Major improvements have been observed in that sector. However, environment management in some wineries is still precarious.

Winery wastewater comes from the disposal of sub-products (petioles, seeds, grapes leaves, shell, etc), from the wasting of gross products (the waste of must and wine which occurs accidentally or during washing), from products used in wine treatment (diatomaceous earth), and from cleaning and disinfecting products used to wash the floor and equipment (Rodrigues et al. 2006). According to Torrijos & Moletta (2000), washing operations during the wine making process are responsible for the production of wastewater with a high organic level. These operations can be divided into washing and disinfecting of equipment, floor washing with or without cleaning products, washing vessels and washing diatomaceous filters.

Several alternatives have been used for winery wastewater treatment like anaerobic digestion (Moletta 2005), fixed bed biofilm reactor (Andreottola et al. 2005), sequencing batch reactor--SBR (Rodrigues et al. 2006) and
activated sludge process (Bolzonella et al. 2007), among others. In Brazil, the studies about application and performance of winery wastewater treatment are insubstantial. However, the activated sludge process has been used at wineries. Another potentially good alternative is the Aerated Submerged Biofilter (ASB). The ASB has been emphasized in Brazil because it is compact, highly efficient and produces little sludge.

This work analyses the variations in the quali-quantitative composition of the liquid effluents produced in a winery located in mid-west Santa Catarina in the South of Brazil, and the behavior of the treatment of these effluents in Aerated Submerged Biofilter reactors.

MATERIALS AND METHODS

This study was carried out in a winery of the city of Iomerê in the state of Santa Catarina, South of Brazil (874 m altitude above sea level, 27°00'15"latitude south and 51°14'32"longitude west), from January to December 2008. The winery has 27 employees and two product lines: wine produced from a grape variety called Vitis Labrusca, the best-selling line in the market, and wine produced from Vitis Vinifera grapes. In 2008, 5 million litres of wine were produced at the winery from locally grown grapes.

Water usage

The water used by the winery in the process is from an underground shaft. A 2 inch hydrometer (theoretical flow rate of 10 m³ h⁻¹ and minimum flow rate of 0.4 m³ h⁻¹) was installed at the storage tank to quantify the total amount of water used. The volume was written down every hour in the sample day.

Wastewater characterization

The wastewater produced is sent to two disposition systems, as shown in Figure 1. Point A receives the wastewater from the production area, which contains the pressing and filtering machinery and the wine vessels, whereas Point B receives the wastewater from the area where the washing of bottles and bottling of the wine are performed.

To characterize the wastewater during harvest, the flow rate was measured using a Becker and chronometer at Point A, the wastewater temperature was measured, and a composed sample (Composed Sampling Procedure) was collected every 30 minutes, from 8 a.m. to 6 p.m. One sample with a proportional instantaneous volume of flow rate was carefully measured and collected in loco. The samples were put in the same container. This container was homogenized at the end of the day and taken to the laboratory to be analyzed. This procedure was done 7 times during the harvest period and 17 times during the non harvest period. The wastewater at Point B was characterized by 21 punctual samples collection.
Lab scale treatment

Two “Aerated Submerged Biofilters” (ASB) reactors were built at lab scale to promote the treatment of the wastewater samples collected during harvest and non-harvest periods (Figure 2). Each ASB reactor (5 L volume) was filled with oyster shells as support material. Each reactor was fed twice a day with 1.7 litres. The influent of the reactors was characterized and the nutritional balance was adjusted to supply the relation BOD/N/P to 100/5/1 by the addition of NH₄Cl and KH₂PO₄. The treated ASB effluent was collected 3 times a week for analysis.

For the lab tests, an amount of the winery effluent used in ASB 1 was frozen which was enough to feed the reactor for a 14-week period (Sept–Dec 2008), defined with basis on the average duration of a harvest period. The effluent was collected during 2 regular production days in the winery. Every half hour from 9 am to 4 pm, 12 litres of effluent were collected. Overall, 56 bottles with 3 litres of effluent each were collected each day. Each group lasted a week. For ASB 2, the effluent used was that collected as composed samples during the non harvest period.

Upward feeding was carried out after the balancing and settling of the suspended solids found in the affluent. To feed reactors ASB 1 and ASB 2, the first 4 weeks, were used for biomass acclimation to the support material. After acclimation two feeding modes were employed, as can be seen in Table 1. It is important to highlight that the filtering material used was the same throughout the experiment, and that no bottom discharges or washing of the filtering material were applied.

ASB support material

Shells provided by oyster producers from southern Florianópolis were used as filtering material for the reactors. The choice of material was due to good previous results presented by Magri et al. (2007) and also to the possibility of it adding alkalinity to the effluent under study, so that there would be no need for pH correction during the preparation of the effluent for reactor feeding. These shells, measuring between 10 and 15 cm, were washed and broken into pieces varying in size from 2 to 3 cm, as Figure 3 shows.

Physico-chemical characterization of samples

All physico-chemical parameters of the Composed Samples and treated ASB effluent were analysed according to the Standard Methods for the Examination of Water and Wastewater (2005) at the Laboratory of Experimentation and Environmental Microbiology (UNOESC, Campus Videira). The analytical parameters assessed in this study were: pH, Alkalinity, Chemical Oxygen Demand (COD), Sulfate (SO₄²⁻), Total Nitrogen (NT), Ammonia Nitrogen (NH₃-N), Nitrite Nitrogen (NO₂⁻N) Nitrate Nitrogen (NO₃⁻N), Reactive Phosphorus (PO₄³⁻), Total Iron (Fe), Total Copper (Cu) and Total Zinc (Zn).
RESULTS AND DISCUSSION

Water usage

From January 28th to December 20th 2008 the winery consumed 9,057.8 m$^3$ of water. By comparing this amount with the amount of wine put on sale by the winery (5,075,023 litres), an average water usage is arrived at of 1.78 litres per litre of wine produced. In French wineries the average water usage was 2.9, and in Israel 0.5 litre/litre of wine (Van Der Leeden et al. 1990). From these water usage and effluent production figures, it is possible to infer that grape processing accounted for 30% of the total water usage during the harvest season.

The year’s average water usage in the winery was 823.44 m$^3$ per month. Figure 4 shows the monthly usage variation for 2008. The highest (1,427.60 m$^3$) and lowest (513.50 m$^3$) usage levels were registered in the months of May and September, respectively. Figure 4 shows also the total amount of wine, in litres, sold each month, the highest sales levels occurring in May and June (663.2 m$^3$ and 686.2 m$^3$ of wine, respectively).

Wastewater characterization

The average values found for the winery wastewater (Point A: wastewater from production area; Point B: wastewater from bottle-washing and wine bottling) are shown in Table 2. These results concern the period from January 2008 to December 2008, which includes the harvest (January 28th to March 19th) and non harvest (March 20th to December 3rd) periods, and Point B, related to the washing area (April 9th to December 3rd).

pH values at Point A ranged from 3.76 to 6.19, whereas at Point B variation was wider, ranging from 5.63 to 10.78. It should be stressed that Point B receives effluent from bottle-washing, an activity that uses alkalizers for sterilization. Andreottola et al. (2005) reported pH values varying from 3.8 to 8.2 during the grape harvest season and from 4.0 to 11.4 during the non harvest season.

Table 2 | Average values of winery wastewater characterization in Point A and Point B

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Harvest (January 28th to March 19th 2008)</th>
<th>Non harvest (March 20th to December 3rd 2008)</th>
<th>Total Period</th>
<th>Washing area (Point B) (April 9th to December 3rd 2008)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of samples</td>
<td>7</td>
<td>17</td>
<td>24</td>
<td>21</td>
</tr>
<tr>
<td>pH</td>
<td>$4.28 \pm 0.29$</td>
<td>$4.50 \pm 0.62$</td>
<td>$4.50 \pm 0.56$</td>
<td>$8.14 \pm 1.36$</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>$24.20 \pm 2.90$</td>
<td>$20.70 \pm 3.40$</td>
<td>$21.93 \pm 3.63$</td>
<td>$20.30 \pm 3.21$</td>
</tr>
<tr>
<td>Alkalinity (mgCaCO$_3$ L$^{-1}$)</td>
<td>$80.80 \pm 45.10$</td>
<td>$52.00 \pm 4.40$</td>
<td>$60.38 \pm 43.10$</td>
<td>$169.32 \pm 72.16$</td>
</tr>
<tr>
<td>COD (mg L$^{-1}$)</td>
<td>$10,649 \pm 5,664$</td>
<td>$11,540 \pm 8,467$</td>
<td>$11,280 \pm 7,642$</td>
<td>$836.00 \pm 1,037$</td>
</tr>
<tr>
<td>TN (mg L$^{-1}$)</td>
<td>$15.42 \pm 13.06$</td>
<td>$15.42 \pm 15.21$</td>
<td>$15.42 \pm 14.31$</td>
<td>$11.60 \pm 18.02$</td>
</tr>
<tr>
<td>NH$_3$-N (mg L$^{-1}$)</td>
<td>$2.28 \pm 1.68$</td>
<td>$1.96 \pm 0.88$</td>
<td>$1.25 \pm 1.30$</td>
<td>$2.70 \pm 7.56$</td>
</tr>
<tr>
<td>PO$_4$ (mg L$^{-1}$)</td>
<td>$14.85 \pm 10.48$</td>
<td>$14.41 \pm 10.10$</td>
<td>$14.50 \pm 9.90$</td>
<td>$6.10 \pm 8.60$</td>
</tr>
<tr>
<td>SO$_4$ (mg L$^{-1}$)</td>
<td>$12.85 \pm 11.65$</td>
<td>$5.00 \pm 2.10$</td>
<td>$5.90 \pm 7.70$</td>
<td>$2.60 \pm 4.71$</td>
</tr>
<tr>
<td>Total Fe (mg L$^{-1}$)</td>
<td>$5.04 \pm 5.73$</td>
<td>$4.96 \pm 1.97$</td>
<td>$4.98 \pm 3.58$</td>
<td>$2.12 \pm 2.17$</td>
</tr>
<tr>
<td>Total Cu (mg L$^{-1}$)</td>
<td>$0.68 \pm 0.22$</td>
<td>$0.87 \pm 1.80$</td>
<td>$0.80 \pm 1.48$</td>
<td>$0.93 \pm 2.10$</td>
</tr>
<tr>
<td>Total Zn (mg L$^{-1}$)</td>
<td>$0.27 \pm 0.22$</td>
<td>$0.47 \pm 0.25$</td>
<td>$0.40 \pm 0.25$</td>
<td>$0.25 \pm 0.19$</td>
</tr>
</tbody>
</table>
According to the values shown in Table 2, the average alkalinity of the effluent was 60.38 mg CaCO₃ L⁻¹ at Point A. The typical alkalinity of domestic sewage is 200 mg CaCO₃ L⁻¹ (Von Sperling 2005). In aerobic biologic treatment, alkalinity levels are advised to remain high so as not to affect biological reactions. For that reason, support materials must be found that allow the supply of alkalinity to maintain biological activities.

COD values offered in the literature vary widely. Andreottola et al. (2005) described the effluent of a winery located in the province of Trento, with a production of 30% red wine and 70% white wine, and found the average value of 7,130 mg COD L⁻¹. Rodrigues et al. (2006) found the average value of 14,150 mg COD L⁻¹ for the effluent of a winery in the non harvest period. This wide variation may be due to different processing procedures, techniques and technologies, and sampling procedures adopted in each region.

In view of the high standard deviation found for COD (Table 2), median values are usually used in the characterization of winery effluent. The median found for the effluent at Point A, for the whole period, was 8,260 mg COD L⁻¹.

During the non harvest period, two Biochemical Oxygen Demand (BOD₅) analyses of the effluent were conducted at Point A. One analyzed sample contained raw effluent and the other, raw effluent supplemented with nutrients to improve the nutritional balance to 100/5/1. The average BOD₅ values found were used to obtain a BOD₅/COD ratio of 0.15 for the raw effluent and 0.75 for the supplemented effluent. According to Canler et al. (1998), the BOD₅/COD ratio for winery effluent ranges between 0.5 and 0.6. The addition of macronutrients in the biological treatment of winery effluent is common, since winery effluent has a different nutritional balance from that recommended for biological synthesis. In the present study, the average C/N/P ratio found at Point A was 100/0.29/0.28 during the harvest period and 100/0.27/0.25 in the non harvest period, with the BOD₅ value equal to 0.5 COD as proposed by Canler et al. (1998).

On the issue of metal emissions, particularly the presence of copper and zinc in the effluent, Andreottola et al. (2007) highlight that the concentration of these metals in winery effluent is usually incompatible with Italian standards for emissions into the public sewage system (0.4 mg Cu L⁻¹ and 1.0 mg Zn L⁻¹). However, the average

![Table 2](https://iwaponline.com/wst/article-pdf/60/4/1025/449029/1025.pdf)
values obtained for the total Zn and Fe parameters in this study were below the maximum values recommended for the effluents emitted into water bodies by the Brazilian environmental legislation described in Resolução CONAMA N° 357/2005 (1.0 mg L$^{-1}$ for dissolved Copper; 5.0 mg L$^{-1}$ for Total Zinc and 15 mg L$^{-1}$ for dissolved Fe) (Brasil 2005).

The average carbon, phosphorus and nitrogen loads produced by the studied winery (122 kg COD d$^{-1}$, 0.15 kg TN d$^{-1}$ and 0.15 kg PO$_4$-P d$^{-1}$) showed that nutrient addition was necessary to improve the biological treatment.

Aerated submerged biofilters (ASB)

The values shown in Table 3 show an increase in pH and alkalinity values in both reactors due to the alkalinity potential of the support material (oyster shells). Different authors in several studies have neutralized winery effluent by adding basic compounds during equalization. In the present study, by contrast, neutralization was effected by the support material.

As can be observed in Figure 5, for ASB 1 during the 1st operational time the applied organic load ranged from 2.2 to 4.2 kg COD m$^{-3}$ d$^{-1}$ (2.8 kg COD m$^{-3}$ d$^{-1}$ on average) whereas the removed organic load averaged 1.5 kg COD m$^{-3}$ d$^{-1}$, with a removal efficiency of 56%. During the 2nd operational time, the applied organic load averaged 2.9 kg COD m$^{-3}$ d$^{-1}$ (0.7 to 4.4 kg COD m$^{-3}$ d$^{-1}$), the removed organic load averaged 2.7 kg COD m$^{-3}$ d$^{-1}$ (0.6 to 4.3 kg COD m$^{-3}$ d$^{-1}$) and removal efficiency reached 97%, maintaining a 90% average.

For ASB 2 during the 1st operational time, the applied organic load remained in the range between 1.5 and 3.7 kg COD m$^{-3}$ d$^{-1}$ (2.8 kg COD m$^{-3}$ d$^{-1}$ on average), whereas the removed organic load averaged 1.8 kg COD m$^{-3}$ d$^{-1}$, with a removal efficiency of 63% (higher than ASB 1 in the same period). During the 2nd operational time, the applied organic load averaged 2.0 kg COD m$^{-3}$ d$^{-1}$ (0.6 to 3.5 kg COD m$^{-3}$ d$^{-1}$), whereas the removed organic load averaged 1.7 kg COD m$^{-3}$ d$^{-1}$ (0.4 to 3.0 kg COD m$^{-3}$ d$^{-1}$), therefore achieving a removal efficiency, like ASB 1, of 97%, but with a lower average of around 82%.

The high NH$_3$-N values relate to the nitrogen form added to the affluent of ASB 1 and ASB 2 (NH$_4$Cl). However, the concentration values of NO$_2$-N and NO$_3$-N in the treated effluent were low, which indicates that the nitrogen added in NH$_4$ form was not transformed into other forms, rather it was either assimilated by the biomass or retained in the sludge. It should be pointed out that no retro washings or bottom discharges were carried out in the period under study. For that reason, when the cells died, they settled down on the bottom of the reactor, and part of that nitrogen went back into the liquid media, the total nitrogen outflow therefore higher than the inflow. The average phosphorus removals increased over time for both reactors. Average removal efficiency during the 2nd operational time was, 58% for ASB 1, and 53% for ASB 2.

CONCLUSIONS

Though the water/wine ratio found in this study (1.78 L L$^{-1}$) was lower than that cited for other countries, it could be improved by measures of usage rationalization such as: the elimination of waste, changes in the operation...
procedures, operator training and the replacement of devices and equipment.

The analyzed winery effluent shows low pH and alkalinity levels, reinforcing the need for neutralization, or, as was done in this study, the use of reactors that promote the necessary adjustment within the system itself. The use of oyster shells as support material allowed for the addition of CaCO₃ to adjust the pH and alkalinity so as not to hamper biological synthesis. The shells promoted an average alkalinity increase of 180.4 mg L⁻¹ in ASB 1 and 318.6 mg L⁻¹ in ASB 2.

The efficiency achieved in terms of COD was 90% for ASB 1 and 82% for ASB 2, for the period during which the reactor was fed continuously. Nutrient removal was not satisfactory although COD removal and biofilm growth occurred in both reactors. No nitrogen removal occurred in ASB 1, while the average removal in ASB 2 was 31% for the two periods analyzed.

The average values obtained for the total Zn and Fe parameters in this study were below the maximum values recommended for the effluents emitted into water bodies by the Brazilian environmental legislation.

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