Desalination and Water Treatment
www.deswater.com

doi: 10.1080/19443994.2013.813692

52 (2014) 2893–2902
March

Improvement of biological process using biocoagulation–flocculation pretreatment aid in olive mill wastewater detoxification

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Received 25 January 2012; Accepted 19 May 2013

ABSTRACT

Olive mill wastewaters (OMWW) are a significant source of potential or existing environmental pollution in the Mediterranean countries. Treatment and reuse of OMWW present significant challenges, both due to the nature of olive oil production (seasonal and concentration in a small scale) and due to the characteristics of the wastewater (high chemical oxygen demand (COD) and high phenolic content). In the present work, experiments of different pretreatment methods were undertaken and compared in order to select the most adequate process to be applied before biological treatment of OMWW. In fact, three different pretreatments were tested and compared: two different coagulants (alginate and Kim2120) and electrocoagulation (EC) process. At the second stage, biological treatment (using white-rot fungus) was investigated. Tests were conducted with raw OMWW and with OMWW diluted in 50% tap water and adjusted to a neutral pH with lime. The raw effluent presents high COD (178 g $O_2 l^{-1}$), about 6.4 g l^{-1} of total suspended solids (TSS), a high conductivity (29 mS cm^{-1}), acidic pH 4.8, and turbidity of 90 NTU. Results show that after 90 min of EC process, using 15 V/m^2 voltage, a maximum of 49% of organic matter removals was achieved. The optimum removals of COD and turbidity obtained were 39 and 75%, respectively when 20 mg l^{-1} dose of alginate is used, especially at pH 7. Coagulation using Kim2120 at 10 mg l^{-1} applied on diluted OMWW showed reduction reaching 52.3% of COD and 85% of turbidity. The maximum removal of total polyphenols, tyrosol and hydroxytyrosol obtained were 60.1, 23.1, and 59.1% with lime/alginate and 64.2, 67.8, and 76.3% with lime/kim2120, respectively. Only 57% of polyphenols was removed by EC. The pretreated effluents by different physicochemical processes tested showed that the best yields were obtained with lime/kim2120. The pretreated olive mill wastewater was then treated

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Presented at Water and Environment International Conference (WATEIC 2011), Marrakech, Morocco, 26–29 October 2011

aerobically with white-rot fungus. The results showed that the white-rot fungus was capable of reducing 68% and 75% of COD, respectively for the diluted OMWW and pretreated by lime or lime/Kim2120, after only 5 days of growth. The best biological treatment was obtained with neutral pH.

Keywords: Olive mill wastewater; Electrocoagulation; Coagulation; Kim2120; Alginate; Biological processes; Fungi

1. Introduction

A major environmental concern in the Mediterranean countries is the disposal and treatment of large quantities of olive mill wastewater (OMWW) produced during the olive-growing season. Generally, olive oil extraction processes generate three phases: olive oil, solid residues, and black aqueous liquor (OMWW) which averagely represents 20, 30, and 50%, respectively, of the total weight of the processed olives. In the Mediterranean area, where more than 95% of the world's olives are harvested, up to 30 million tons of residues arise per year [1,2]. The high polluting power of OMWW is generally associated with the high chemical oxygen demand (COD) and biochemical oxygen demand (BOD). Their concentrations were generally in the range 80–200 g $O_2 l^{-1}$ for COD [3] and 12–63 g $O_2 l^{-1}$ [4] for BOD. Moreover, it has been reported that polyphenolic components of OMWW are responsible for its antibacterial [5,6] and phytotoxicity activities [7]. The treatment of OMWW has been the object of several studies. Many processes have been developed to treat this effluent: physicochemical methods (flocculation, coagulation, filtration …), chemical oxidation using photocatalytic oxidation [8], wet oxidation [9] or advanced oxidation processes (AOP) [10,11], a combination of ozone with hydrogen peroxide or UV radiation, electrochemical treatments, and ultrafiltration/reverse osmosis [12]. Biological methods used for OMWW treatment are aerobic which activated the sludge or anaerobic digestion [13]. The interest in the electrochemical methods for wastewater treatment, such as Electrocoagulation (EC) and electrochemical separation, is permanently increasing [14]. It is based on the fact that the stability of colloids, suspensions, and emulsions is influenced by electric charges. Therefore, if additional electric charges are supplied to the charged particles via appropriate electrodes, the surface charge of the particles is neutralized and several particles combine into larger and separable agglomerates [15]. Coupling different coagulants with biological processes has received a lot of attention in recent years as a promising treatment alternative for effluents that are too toxic to be treated biologically [16].

In the present work, three different pretreatments were tested and compared: two different coagulants, alginate and Kim2021, and EC process, in order to select the appropriate pretreatment before the biological treatment. The aim of the physicochemical treatment was to remove a part of turbidity, COD, and phenolic compounds in order to improve the efficiency of the subsequent biological treatment. Accordingly, the removal efficiency of the treatment was investigated by monitoring the decrease in turbidity, total suspended solids (TSS), COD, total polyphenols, tyrosol, hydroxytyrosol, and pH evolution.

2. Materials and methods

2.1. OMWW, reagents, and standards

The original wastewaters used in the present study were obtained from an olive oil production plant located in the city of Beni Mellal between the Middle Atlas and the plain of Tadla, in the coordinates (32°20′22″N, 6°21′39″W) in central Morocco, which uses a semiautomatic process for olive oil extraction. Table 1 shows the physicochemical characteristics of the raw and diluted OMWWs. The dilution is done with tap water. A high performance liquid chromatography HPLC-grade acetonitrile (99.9% purity; CAS N°.75-05-8) purchased from Sigma-Aldrich is used. Tyrosol and hydroxytyrosol, utilized as standards, were obtained from Fluka (⩾97%). Kim2120 and alginates were kindly provided by B. Lekhlif (Ecole Hassania des Travaux Publics, Morocco).

2.2. Physical-chemical analysis of OMWW

A digital calibrated pH-meter (JENCO 6,230) and a conductivity-meter (ORION 125) were used to measure the pH and conductivity of olive mill wastewater samples. COD was determined by dichromate method [17]. The appropriate amount of OMWW samples was diluted up to 250 times and introduced into a lab-prepared digestion solution containing an excess of potassium dichromate, sulphuric acid, and mercuric sulphate. The mixture was then incubated for 120 min

Table 1
Physical-chemical characteristics of raw and diluted olive mill wastewaters with tap water

Parameters	Average value	Dilution *D*4 (20%)	Dilution *D*3 (30%)	Dilution *D*2 (40%)	Dilution *D*1 (50%)
Total suspended solid ($g\,l^{-1}$)	6.4	5.15	4.48	3.84	3.22
Chemical oxygen demand ($g\ O_2\,l^{-1}$)	178	176	153	144	112
Conductivity ($mS\,cm^{-1}$)	29	28.6	21.6	19.8	18.5
Polyphenols (g of tyrosol l^{-1})	3.8	3.04	2.66	2.28	1.9

at 150°C in a COD reactor. COD concentration was measured colorimetrically using UV/VIS spectrophotometer (PALINTEST 7,000). The standard solution was prepared using potassium biphthalate. The absorbance was determined at 620 nm. The turbidity was measured with a turbidimeter (Orbeco-Hellige). TSS were determined after filtering a sample through a GF/C filter and drying the retained residue at 105°C for 4 h [18]. The liquid–liquid extraction of the phenolic fraction has been carried out according to the method described by Macheix et al. (1990) [19]. The determination of total phenols was done using the reagent Folin–Ciocalteu [20], the absorbance was read at 760 nm and converted according to the standard curve into equivalent tyrosol acid ($g\,l^{-1}$). The phenolic extract was analyzed by HPLC at 280 nm on a JASCO HPLC system, equipped with a JASCO UV intelligent detector (UV-975) operating at 280 nm and using software GALAXY for data acquisition. A reversed phase Lichrosphere C-18 (4 x 250 mm i.d 5 μm) column was used using an isocratic mobile phase [H_2O (containing 1% acetic acid)/Acetonitrile]. The flow rate was $0.7\,mL\,min^{-1}$ and the injection volume was 20 μL. The identification of a compound is based on its retention time, which corresponds to the time of release of this product from the column. The content of the sample in different compounds was quantified by comparing the areas of the product with the corresponding standard solution.

2.3. Experimental procedures

2.3.1. Description of EC using aluminum electrode

EC is a process consisting of creating a floc of metallic hydroxides within the effluent to be treated by electrodissolution of a soluble anode. The generation of coagulant in this technique occurs *in situ* by dissolution of a sacrificial anode and it involves three main processes [21,22]: electrolytic reaction at electrode surface, formation of coagulants by electrolytic oxidation in aqueous phase, and adsorption of colloidal particles on coagulant and removal by sedimentation, or flotation. It is well known that in EC process, the main reactions occurring at the aluminum electrodes during electrolysis are:

At the anode:

$$Al_{(s)} \rightarrow Al^{3+}_{(aq)} + 3e^- \tag{1}$$

$$2H_2O \rightarrow O_2 + 4H^+ + 4e^- \tag{2}$$

At the cathode:

$$3H_2O(1) + 3e^- \rightarrow \frac{3}{2}H_2 + 3OH^- \tag{3}$$

In the solution:

$$Al^{3+}_{(aq)} + 3H_2O \rightarrow Al(OH)_{3(s)} + 3H^+_{(aq)} \tag{4}$$

Species can interact in solution in several ways: (Eq. (1)) Migration to an oppositely charged electrode (electrophoresis) and aggregation due to charge neutralization. When the anode potential is sufficiently high, secondary reactions may occur, especially oxygen evolution (Eq. (2)). Hydroxyl ions and hydrogen gas occur at the cathode (Eq. (3)). The metal ions generated are hydrolyzed in the electrochemical cell to produce metal hydroxide ions according to reaction (Eq. (4)). The Al^{3+} and OH^- ions produced at the electrodes can react to form various mononuclear ($Al(OH)_2^+$, $Al(OH)_2^+$, $Al_2(OH)_2^{4+}$) and polynuclear ($Al_6(OH)_{15}^{3+}$, $Al_7(OH)_{17}^{4+}$, $Al_8(OH)_{20}^{4+}$, $Al_13(OH)_{34}^{5+}$, and $Al_13O_4(OH)_{24}^{7+}$) species, which are finally transformed into aluminium hydroxide: $Al(OH)_3$. The large specific area of $Al(OH)_3$ then facilitates compound adsorption and traps the colloids [23,24]. Finally, these colloid-adsorbed flocs can be removed by sedimentation or by floatation with H_2 bubbles produced at the cathode.

2.3.2. EC procedure

EC experiments were carried out using two parallel aluminum electrodes (effective area of electrode [STE] 4.5 cm^2 × 2 face), because they are cheap, readily available, and proven effective. The anode/cathode gap was kept constant at 2 cm. For each run, 100 cm^3 of OMWW was placed into the electrolytic cell. A gentle magnetic stirring rate of about 200 rpm was applied to the electrolyte in all tests to allow the chemical precipitate to grow large enough for removal (with a stir bar of ø 6 mm × 15 mm long). 15 V/m^2 of voltage has been applied from 0 to 180 min and was kept constant for each run. Thereafter, the samples were decanted for 24 h before being subjected to vacuum filtration through filters with a pore size of 0.45 μm. The total time duration of electrolysis was 180 min for the most test runs. The EC step was performed on raw OMWW diluted in 50% tap water, without adjustment of pH. The effect of the electrolysis treatment on OMWW quality was characterized by using mainly pH, COD, and total phenols as indicators for water quality change.

2.3.3. Coagulation–flocculation process

Experiments were carried out in a jar-test apparatus (JLT6 leaching test/jar test) equipped with six beakers of 1 L volume. At the beginning of each experiment, the OMWW samples were analyzed with respect to their initial turbidity, TSS, pH, and COD. The initial pH of the solutions was adjusted by adding lime coagulant; six different appropriate dosages of both coagulants (alginate and Kim2120) were applied. Following 20 s of rapid mixing and 30 min of slow mixing periods to facilitate flocs agglomeration, the sample was then left to settle and as soon as separation was achieved, the supernatant was analyzed. Three different OMWW were tested: OMWW diluted at 30, 40, and 50% with pH neutralization for each case.

2.3.4. Fungal remediation

Fungi remediation of OMWW has been studied using 500 ml Erlenmeyer as flask reactors filled with 100 ml of OMWW. Three different treatment of OMWW were tested: diluted OMWW at 50% (OMWW), diluted at 50% OMWW treated by Lime, and diluted OMWW at 50% treated by lime/Kim2120 (W D50% + Lime + Kim2120).

The inoculation of each Erlenmeyer flasks has been done with white-rot fungus, previously isolated from old stored OMWW samples and cultivated in adequate media by added increasing concentration of OMWW daily before using it in the treatment flasks. The inoculated flasks were incubated at 28°C for five days. Aquarium aeration pumps (commercially easy to find) were used to provide aeration and agitation. The pH and soluble COD were analyzed every day in the culture media.

Table 2
Evolution of the effluent pH (current density 15 mAcm^{-2}) according to operating time of electrocoagulation

Time (min)	pH
0	4.4
30	4.49
60	4.86
90	5.01
120	5.32
150	5.7
180	6.04

3. Results and discussion

3.1. Pretreatment of olive mill wastewater using different physicochemical processes

3.1.1. EC of OMWW

The effects of operating time on pH results are illustrated in Table 2. The initial pH of the diluted OMWW at 50% was 4.4. OMWW are also highly saline (electric conductivity 18.5 mS/cm), due to the salting practiced to preserve olives during triturating, there is no need to add any supporting electrolyte.

The EC treatment using aluminum electrodes induced an increase of the pH value when the initial pH value of the olive wastewater was 4.4. This could be explained by hydrogen evolution at cathodes [25,26] and OH$^-$ ion accumulation in aqueous solution during the process. However, Chen et al. [27] explained this increase by the release of CO_2 from wastewater owing to H_2 bubble disturbance. Indeed, phenols have higher acidities and their removal from the solution reduces its acidity [23]. Hanafi et al. [25] and Chen et al. [27] reported that the highest removal efficiencies have been obtained in acidic medium, at pH values in the range 4–6. It can be seen from Fig. 1 that the removal efficiency of COD depends immediately on the process duration. The graphs of COD removal vs. retention time demonstrate an increasing trend up to 90 min. So, for the 90-min retention time, aluminum provided 49% of COD removal.

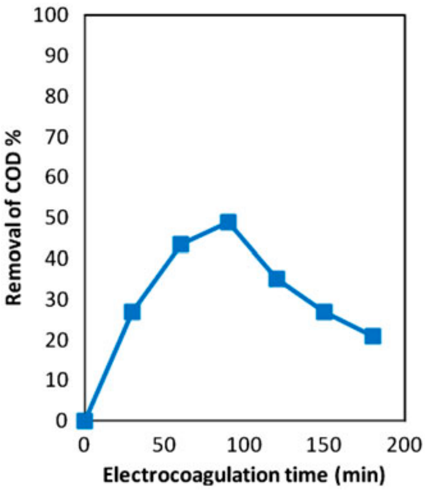

Fig. 1. Effect of electrocoagulation time on the removal efficiencies of COD (current density 15 mA cm^{-2}).

The curves show that the retention time 90 min is optimal for COD removal at acidic medium (pH 5). Within the EC cell the amount of coagulant generated at fixed time is related to the current flow, using Faraday's law [27,28]:

$$M = ItM/zF$$

where I is the current intensity, t is the time, M is the molecular weight of aluminium (g/mol), z is the number of electrons transferred in the reaction (=3), and F is the Faraday's constant (96.486 C/mol). The efficiency of COD removal depends on the quantity of hydroxide flocs. When significant amounts of oxidized aluminium are generated, a greater amount of precipitate is formed, increasing the removal of colloidal particulates and destabilization of emulsion [29].

3.1.2. *Coagulation–flocculation process of OMWW by coupling lime with various natural organic coagulants*

3.1.2.1. Effect of flocculants dosage. The neutralization of pH by adding lime, allows OMWW coagulation and their dilution at the same time.

The effect of coupling lime with various concentrations of alginate on OMWW treatment results are summarized in Fig. 2. The result shows that lime has a very important capacity of removing organic pollutant by coagulation. In this regard, Khoufi et al. [23] and Esra Aktas et al. [24] have attributed the lime effect on OMWW pretreatment to the polymerization and precipitation of long chain fatty acids and of the large molecular mass of polyphenols. It was also observed from the Fig. 2 that as dosage of alginate increases COD and turbidity removal also increases. Optimum COD and turbidity removals, respectively (39, 75%) were obtained after treatment by the addition of 20 mg l^{-1} of alginate to the diluted (50%) and neutralized wastewater. Turbidity is an index of the presence of suspended particles in the effluent. The removal of turbidity is certainly due to the formation, destabilization, and sedimentation of these big aggregates.

Fig. 3 shows the effect of flocculants dosage on removal efficiency expressed in terms of turbidity in both the samples (diluted at 50% and diluted at 20%). It can be seen that the optimum dosage for Kim2120

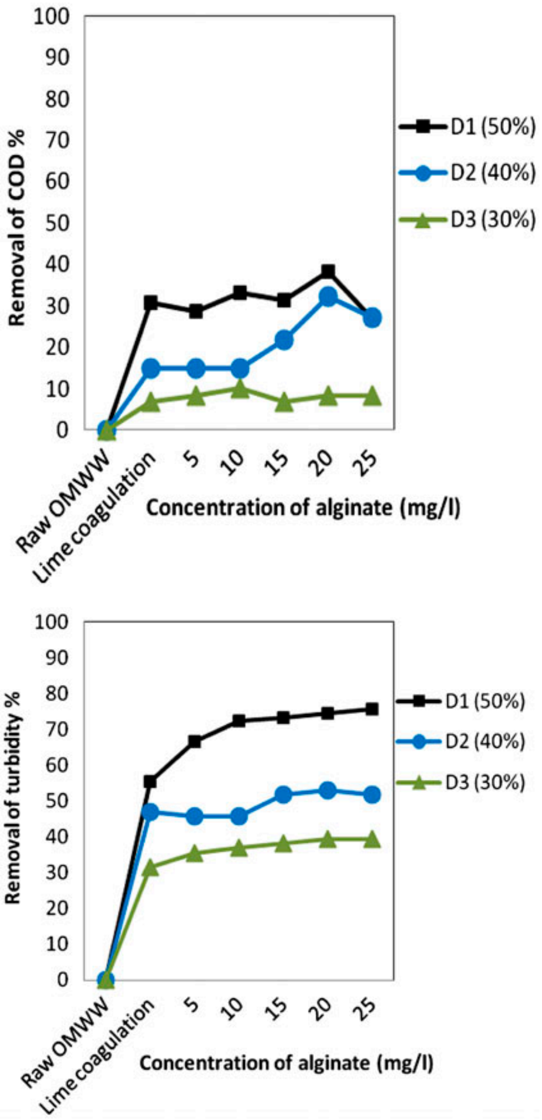

Fig. 2. Removal percentages of COD and turbidity according to the lime and alginate concentrations.

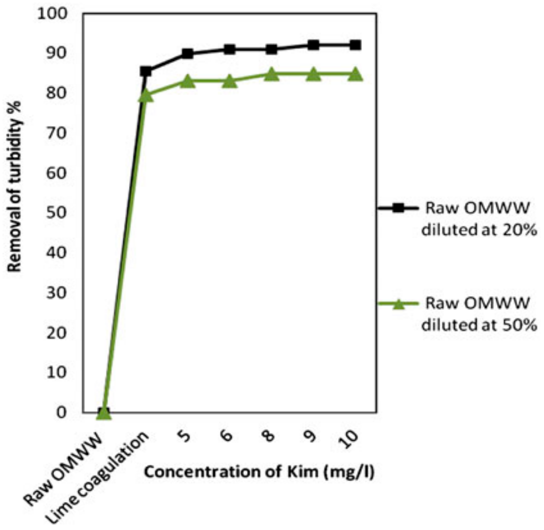

Fig. 3. Effect of coagulant kim2120 dosage on turbidity removal efficiency in the two diluted Raw OMWW at 20 and 50%.

was found to be 10 mg/L. Lime and kim2012 performed much better than lime and alginate for turbidity removal (Figs. 2 and 3). Because good turbidity removal occurs when flocs possess a negative charge, this suggests that both lime and kim2120 perform coagulation–flocculation by charge neutralization and by the bridge-formation mechanism [30]. During the experiment, it was also found that the flocs formed by lime and kim2012 were larger than those obtained by lime and alginate.

3.1.2.2. Reduction of phenolics content and COD in OMWW. The qualitative and quantitative characterization of monocyclic aromatic compounds of ethyl acetate OMWW extracts was attempted through HPLC analysis. The fraction presented several UV-detectable peaks at 280 nm, tentatively ascribed to monomeric and polymeric aromatic compounds. Only two peaks were clearly identified by co-elution with pure monocyclic aromatic compounds, tyrosol and hydroxytyrosol (Fig. 4(A)).

Based on a comparison of the chromatograms of treated and untreated OMWW (Fig. 4), it was determined that some of the phenolic substances could be removed totally or partially.

Chromatographic analyses showed that the removal efficiency of a large number of phenolic compounds was higher than 50% (Fig. 4(B) and (C)). Esra Aktas et al. [24] observed that the substances with two phenolic groups in molecule like catechin were totally removed; the substances which contain both phenolic and carboxyl groups, such as vanillic acid, syringic acid were adsorbed partially and the substances which have only one phenolic or carboxyl group, such as tyrosol was not affected by lime. They concluded that only 28% was removed by lime treatment. This observation suggests that the higher removal of tyrosol and hydroxytyrosol observed in our experience was principally due to the presence of alginate and/or kim2120. For the coagulation by lime/ and kim2120, the contents of hydroxytyrosol and tyrosol are reduced around 76.3 and 67.8%, respectively. They are, respectively reduced on the order of 59.1 and 23.1% for the lime /alginate coagulation. The biopolymer like alginate and chitosan has an extremely high affinity for many classes of contaminants: it has demonstrated outstanding removal properties of organic matter [31], phenolic and aromatic derivatives [32].

Some authors clearly demonstrated that chitosan has an intrinsic capacity to be used as a coagulant to reduce TSS, turbidity, and COD. These works also reported that positively charged cationic macromolecules can destabilize the negative colloidal suspension by charge neutralization as well as by bridge formation Johnson and Gallanger [33], Moore et al. [34], No et al. [35], and Sievers et al. [36]. OMWW treatment with lime/alginate and lime/kim2120 resulted in 60.1 and 64.2% reduction in total phenols, respectively (Fig. 5).

We conclude that the pretreated effluents by the different physicochemical processes showed that the best yields were obtained with kim2120. When dosage of kim2120 was 10 mg/L, COD removal efficiency reached 52.27%, about 3–12% more than that using alginate at 20 mg/l or EC (Fig. 5). Lime and kim2120 were selected as coagulants prior to biological further treatment, since they offered better COD, turbidity, and polyphenol reduction as compared to other tested coagulants.

3.2. Integrated coagulants and biological treatment of OMWW

3.2.1. Kinetic of fungal remediation of OMWW

Fig. 6 shows the COD and pH changes in OMWW with white-rot fungi essays. The pH of the fermented OMWW was always much higher than their initial values. The observed pH increase was due to the consumption of organic acids, such as lactic and acetic acids present in the OMWW [37,38] or also through release of NH_4^+ after degradation of proteins [39].

The results showed that the best biological treatment can be obtained with neutral pH. Under the tested conditions, the most efficient treatment, as

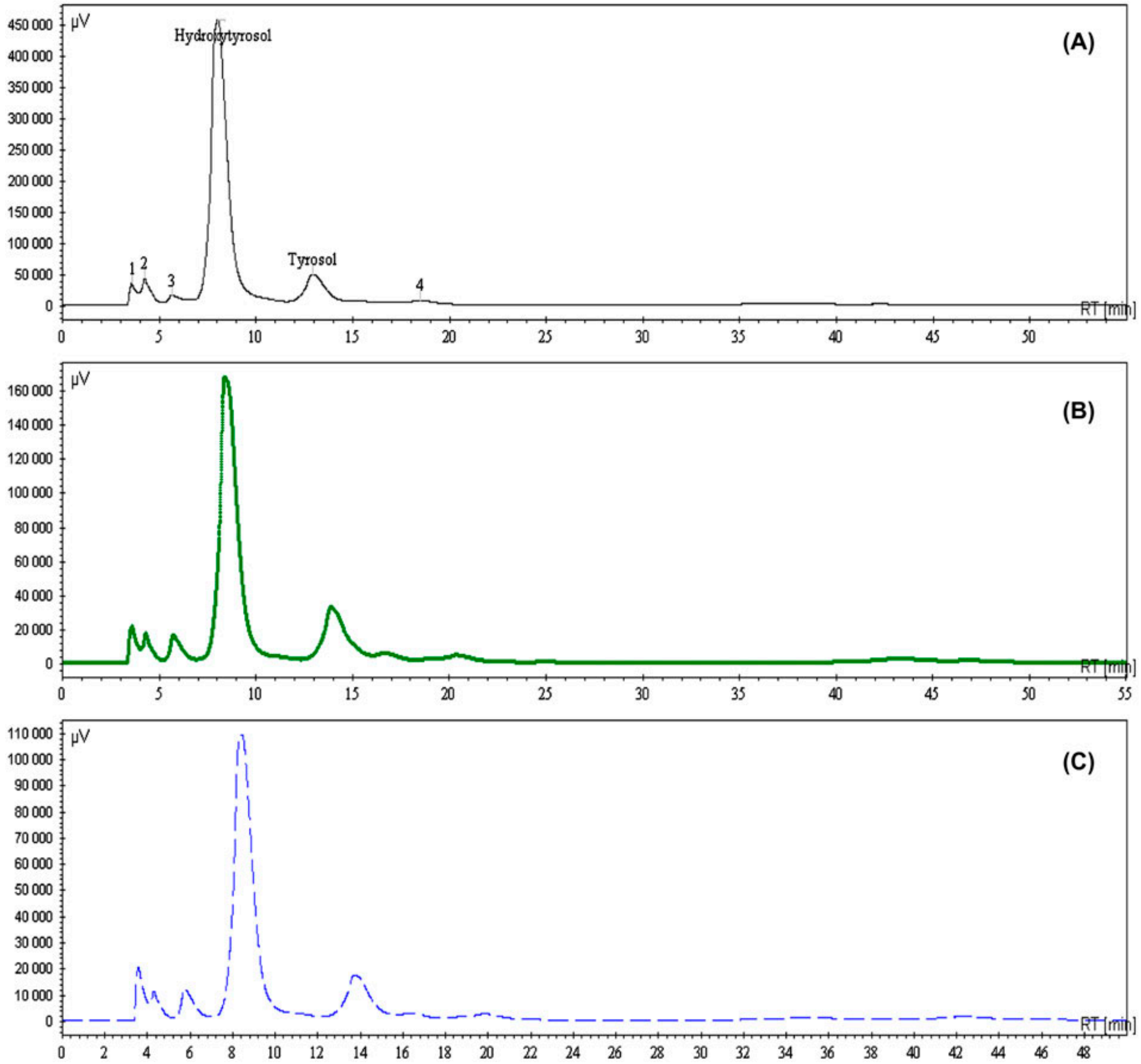

Fig. 4. HPLC chromatograms of ethyl acetate extracts of the polyphenols in (A) OMWW, (B) OMWW treated by lime and alginate (C) OMWW treated by lime and kim2120. Peak identification: 1, 2, 3, and 4 not identified, Hydroxytyrosol and Tyrosol. RT: Retention time.

regards of COD and total phenols reduction, was obtained for OMWW diluted at 50% and pretreated with lime/Kim2120 followed by biological treatment, reaching 75 and 85.22% reduction of the initial COD and phenolic contents, respectively. However, OMWW diluted at 50% and treated with lime achieved 68 and 17.5% removal of COD and phenolic contents, respectively after 5 days of fungi action (Fig. 6, Table 3). Pretreatment with lime and lime/kim2120 seemed reducing the toxicity of OMWW and improved its biodegradability, since the removal of COD and total phenolics were more important than those obtained with unmodified OMWW. The results of this work are relatively similar to those found by previous workers. Borja et al. [40], found COD and phenols reductions of 63.3 and 65.6%, respectively by using *Geotrichum candidum*. Hamdi et al. [41] obtained a 52.5% removed COD using *Aspergillus niger* fungi in aerobic condition. Other fungal strains used, such as *Aspergillus tereus* and *Geotrichum* [42], pretreatment with *A. niger*, *A. tereus*, or *G. candidum* resulted in a decrease of the concentrations of tannins and aromatics which decreased the inhibitory effect of these phenolics on anaerobic digestion. The COD in unmodified OMWW was increased to 130 g $O_2 l^{-1}$ during the incubation,

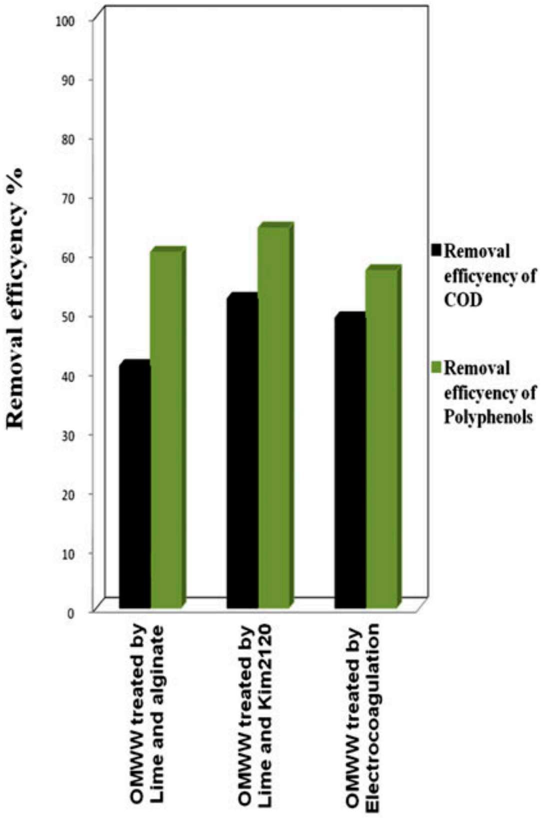

Fig. 5. Comparison of OMWW treatments by different physicochemical processes.

possibly resulting from a toxic effect of the OMWW phenolic and/or other compounds. A critical concentration could cause a biomass destruction and release of internal organic compound outside the cells. The determination of toxic/biomass ratio and substrat/biomass ratio could have helped to better understanding the processes that occur during this test.

3.2.2. *Phenolic removal from OMWW using fungi*

By comparing the results of the HPLC analyses at the beginning and at the end of the incubation (Table 3), aromatic compounds decrease after five days in the effluent treated by lime/Kim2120 and then by fungi. The evolution of the major OMWW phenolic monomers (tyrosol and hydroxytyrosol) showed a significant reduction in OMWW pretreated by lime/kim2120 (Table 3).

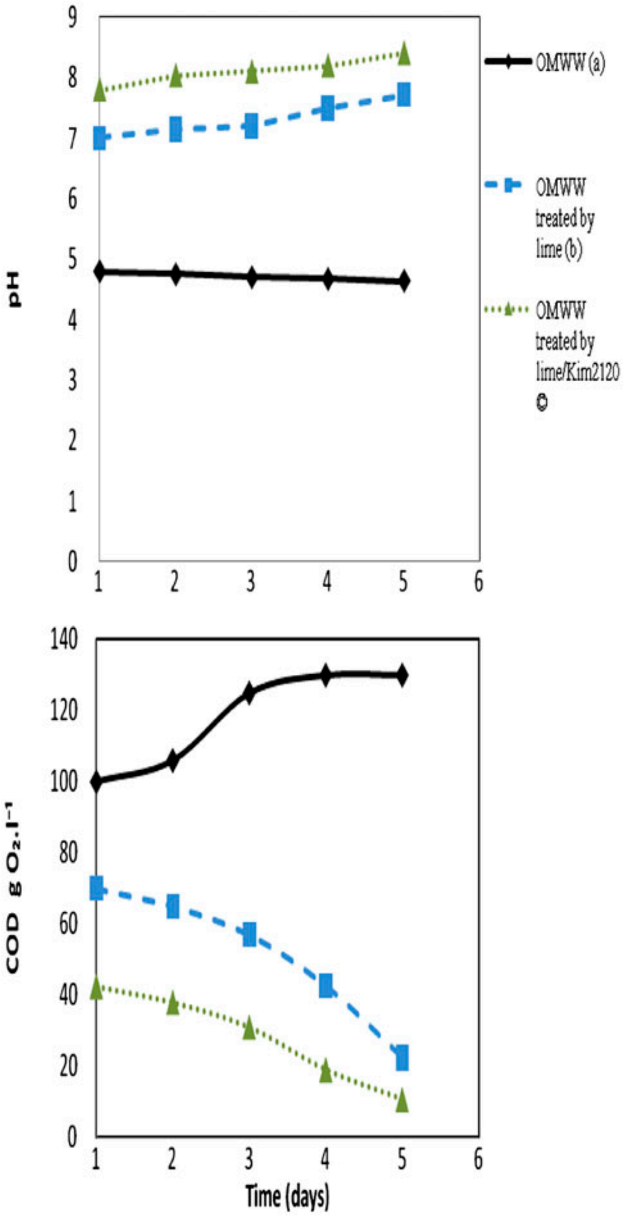

Fig. 6. Time course of COD and pH evolution in fungi essays: (a) (W D50%), (b) (W D50% + Lime) and (c) (W D50% + Lime + Kim2120).

This reduction was less important in OMWW pretreated with lime; nearly 12.85 and 37.3% of hydroxytyrosol and tyrosol were removed, respectively. In OMWW, the levels of the aromatic constituents of the tested samples did not decrease. We would suggest that OMWW in high concentration had an inhibitory activity against micro-organisms. It was due probably to the presence of toxic compounds in the effluent, such as simple phenolic compounds. Sayadi et al. [43] reported that OMWW represents a complex medium containing mainly polyphenols of different molecular mass. High molecular-mass polyphenols are the most recalcitrant compounds and inhibit bacteria as well as fungi. They should be removed completely or partially from OMWW prior to treatment by aerobic process or anaerobic digestion.

Table 3
Phenols removal and monocyclic phenols removal as a function of various coagulants added to 50% OMWW treated with white-rot fungi

	Attribution	Retention time [Min]	Quantity [g/l]	Removal efficiency
OMWW	n.d 1	3.58	0.072	0
	n.d 2	4.25	0.129	0
	n.d 3	5.65	0.071	0
	Hydroxytyrosol	8.03	2.455	0
	Tyrosol	12.91	0.311	0
	n.d 4	18.48	0.0199	0
	Total phenolics		3.79	0
OMWW treated by lime/kim2120 and fungus	n.d 1	3.58	0.049	31.94
	n.d 2	4.25	0.0066	94.9
	n.d 3	5.65	0.038	46.55
	Hydroxytyrosol	8.03	0.35	85.74
	Tyrosol	12.91	0.098	68.59
	n.d 4	18.48	0.012	44.51
	Total phenolics		0.56	85.22
OMWW treated by lime and fungus	n.d 1	3.58	0.059	18.15
	n.d 2	4.25	0.091	29.56
	n.d 3	5.65	0.0422	40.61
	Hydroxytyrosol	8.03	2.14	12.85
	Tyrosol	12.91	0.195	37.3
	n.d 4	18.48	0.0176	11.71
	Total phenolics		3.13	17.4

4. Conclusion

Based on the experiments conducted in this study, the following conclusions are drawn:

1. The aim of the physicochemical treatment is to remove particles and organic load from wastewaters. In our case study, the EC treatment makes good COD and phenols removal efficiency, 49 and 57% respectively, after only 90 min EC time (CD = 15 mA cm^{-2}) and pH increased to 5. However, pretreatment by coagulation–flocculation showed that the best efficiency was obtained with the effluent pretreated by lime/kim2120. The results showed that the optimal pretreatment conditions were obtained with Kim2120 concentration of 10 mg l^{-1}, substantial removal of COD (52.3%), total phenols (64.2%), and turbidity (85%) were achieved.
2. Since toxicity of OMWW is caused especially by simple phenolic compounds, chemical pretreatment is potentially a good detoxification approach.
3. OMWW could be treated under fungal remediation under aerobic conditions with high COD removal after diluting 50% and lime/Kim2120 pretreatment. We found that, under these conditions, fungi could remove 85.22 and 75% of the total phenolic compounds and COD, respectively, only after 5 days cultivation. The treated wastewater became clarified by this treatment.

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