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Dairy Effluent Characterization And Efficient Treatment Coupling Physical And Biological Methods

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ABSTRACT

Present study reports treatment of the sweet whey by coupling of a physic-chemical and a biological treatment. The physic-chemical treatment performed using aluminium sulphate shows a reduction of 98.63 for turbidity, 61.95% for SS (Suspended Solids), 27.52% for orthophosphate and 16.17% for COD (Chemical Oxygen Demand). The biological treatment by Pseudomonas fluorescens and Bacillus pumilus showed a 50% reduction of COD for 40 days. Coupling physico-chemical and biological treatments is efficient not only in terms of chemical oxygen demand but also in terms of hardness, total nitrogen and orthophosphate. When a physic-chemical treatment is followed by a biological one by Pseudomonas fluorescens, COD reduction was 57.35% for 20 days and 75.49% during 40 days. In addition, 84.1% of the total nitrogen was reduced, 62.7 for hardness and 53.8% for orthophosphate. The biological treatment by Bacillus pumilus resulted in a decrease of 80.1% for COD, 87.3% of kjeldahl nitrogen, 50.5% for hardness and 19.3% for orthophosphate.

Keywords: Sweet whey, Physico-chemical treatment, Biological treatment, *Pseudomonas fluorescens*, *Bacillus pumilus*.

INTRODUCTION

Sweet whey came from the manufacture of pressed cheese cooked or uncooked, present 85% of the milk processed into cheese, that's why the amount of the sweet whey available worldwide is considerable [1, 2]. The dairy effluents especially with cheese production is characterized by a relatively high organic load, monitored by BOD (biological oxygen demand) and COD (chemical oxygen demand) in the range of 0.1-100 kgm^{-3} with an index of biodegradability (BOD5/COD) typically in the range 0.4-0.8 [3]. These wastewaters with high levels of inorganic and organic pollutants pose serious environmental hazards [4] without an appropriate treatment. In the treatment biological and physicochemical processes are usually suggested to deal with dairy effluents [5].

In recent years, biological treatments receive great attention due to their numerous advantages such as low energy consumption, low chemical consumption, low sludge production, vast potential of resource recovery and less equipment required [6]. Therefore, high rate of biological treatment have been increasingly employed for dairy effluent with high chemical oxygen demand (COD). A study shows that among the five selected bacterial strains (*Sporolactobacillus sp., Citrobacter sp., Pseudomonas sp., Alcaligenes sp., Bacillus sp., Staphylococcus sp*., and *Proteus sp*.), biological treatment of dairy effluent by the bacterial strain *Alcaligenes sp*. MMRR7 provides a maximum reduction of the COD (62%) for 5 days of incubation. Chemical coagulation using aluminium sulphate at a concentration of 0.5 g/100 ml was effective in the primary treatment [7]. The biological treatment of the coagulated effluent using the bacterial strains *Alcaligenes sp* MMRR7, leads to a maximum reduction of COD of 91% during 120 h. But this bacteria is pathogenic and can contaminate the industry that treat with it [8].

In the present study *Bacillus pumilus* and *Pseudomonas fluorescens* were used to achieve biological treatment and Aluminium sulphate and lime were used as a coagulant in the chemical treatment [9]. These bacteria produced heat stable lipases and proteases and are characterized by: optimal temperature for growth between 25 and 30^{o}C, not pathogenic, ubiquitous encountered in soils, on plants and especially in fresh and marine waters and multiply even in poor environments [10, 11].

MATERIALS AND METHODS

Sampling: Sweet whey was freshly collected using plastic bottle from the dairy industry AL MARJ located in north Lebanon during March 2012. Wastewater samples were stored in the refrigerator at 4^{o}C for one week and were then subjected to coagulant and biological treatment.

Characterization of sweet whey: Analysis of initial sweet whey allows characterizing discharges by physico-chemical methods described by AFNOR. The following parameters were measured: temperature, pH, conductivity (conductimètre InoLab cond level 2), hardness (AFNOR T 90-003, 1984), turbidity (HANNA HI 93703), and Total Suspended Solids (TSS) (AFNOR T 90-105). Chemical oxygen demand (COD) content, nitrates, total phosphorous (P-PT) and orthophosphate (P-PO43-) were determined by standard AFNOR method (NF T 90-101) (NF T 90-012) (NF T 90-023) respectively, kjeldahl nitrogen (N-NTK) was measured by using the standard Kjeldahl method [5].

Physicochemical and biological treatments: Two treatments were performed: the first one was a physic-chemical treatment by aluminium sulphate followed by the biological treatment using *Pseudomonas fluorescens* and *Bacillus pumilus*, the second treatment was realized starting with the biological then the physic-chemical treatment.

Optimization of the coagulant dosages: Coagulation flocculation tests were performed by the JAR test at 24°C; the first using aluminum sulphate as a coagulant, the second by the lime and the last one was realized using these two coagulants together. Coagulation experiments were carried out by different concentrations of coagulant. The mixture was then agitated at 200 rpm for 3 min and then the speed was reduced to 40 rpm and the system was kept at this condition for 20 min. Thereafter, the solution was kept for settling for 2 h and the supernatant was used to analyze all parameters (residual COD, nitrates, hardness, total suspended solid (TSS) and orthophosphate).

Table 1: Reagents used for the treatment of dairy whey by coagulation

Experiment	1	2	3
Coagulant	$Al_2(SO_4)_3.18H_2O$	$Ca(OH)_2$	$Al_2(SO_4)_3.18H_2O$ + $Ca(OH)_2$
Concentration (gl^{-1})	2.0-4.0	0.4–2.4	3.2+1.6

Biological experiment: After a good settling, the supernatant is carefully removed and used to be inoculated with two types of bacteria: *Pseudomonas fluorescens* and *Bacillus pumilus*. All set was kept on agitation in a rotating agitator platform at room temperature for 40 days.

RESULTS AND DISCUSSION

Sweet whey characterization: The quality of dairy whey collected was evaluated. The water samples before treatment were analyzed for suspended solid, Total Suspended Solid content (TSS), hardness, and phosphorus content (Table 2).

Table 2: Characteristics of dairy effluent

Parameters	Value	Parameters	Value
pH	6.4	DCO (mgl^{-1})	65 280 ± 300
Temperature (°C)	25 ±2	DBO5 (mgl^{-1})	38 900 ± 180
Conductivity ($mscm^{-1}$)	13.31	Orthophosphate (mgl^{-1})	502.26 ± 26
Turbidity (FTU)	744 ± 4	Nitrate (mgl^{-1})	25.72 ± 3
Hardness (°F)	196.46 ± 7	N-NTK (mgl^{-1})	4069.2 ± 81
TSS (mgl^{-1})	1146 ± 52	Global nitrogen (mgl^{-1})	4095 ± 75

The high BOD and COD values in the whey sample indicated that it is heavily contaminated with organic matter.

Physicochemical treatment: Coagulation–flocculation is one of the most important physicochemical treatment steps in industrial wastewater treatment to reduce the suspended materials responsible for turbidity of the wastewater and also for the reduction of organic matters which contributes to the BOD and COD content of the wastewater [12]. This type of treatment is a primary treatment of dairy effluent and it should be necessarily complemented by a biological treatment to reduce all the residual pollutant. Percentage removal of COD and other parameters were calculated and listed in Table 3.

Table 3: Percent reduction of parameters after the treatment by coagulation

Parameters	Exp 1	Exp 3
$Al_2(SO_4)_3$ (gl^{-1})	3.2	3.2
$Ca(OH)_2$ (gl^{-1})	-	0.4
pH	6.2	6.4
Conductivity **($mscm^{-1}$)**	13.75	13.78
	Percentage of reduction	
Turbidity (FTU)	**98.63%**	96.06%
Hardness (°F)	9%	9%
TSS (mgl^{-1})	**61.95%**	48.95%
Nitrate (mgl^{-1})	**39.15%**	24.3%
Orthophosphate(mgl^{-1})	27.52%	**38.24%**
DCO (mgl^{-1})	16.17%	16.17%

The results showed that the optimal dose of coagulation is 3.2 g L^{-1} $Al_2(SO_4)_3$ with a reduction rate of 98.63% turbidity and 39.15% nitrate. Using lime alone, no effect was observed on turbidity. Compared to the two coagulants, coagulation flocculation with lime and aluminium sulphate together reduced 96% of turbidity and 38.24% of Orthophosphate (Table 3). On the other side, Aluminum sulphate was found to be effective coagulant in reducing solids, organics and nutrients in this dairy industry effluent. Hamdani et al. [7] observed only 40% organic matter content removal from dairy wastewater by coagulation with aluminum sulphate.

Coupled treatment

Physicochemical treatment followed by a biological treatment: The experiments were also conducted to study the time effect on COD removal efficiency using two bacteria.

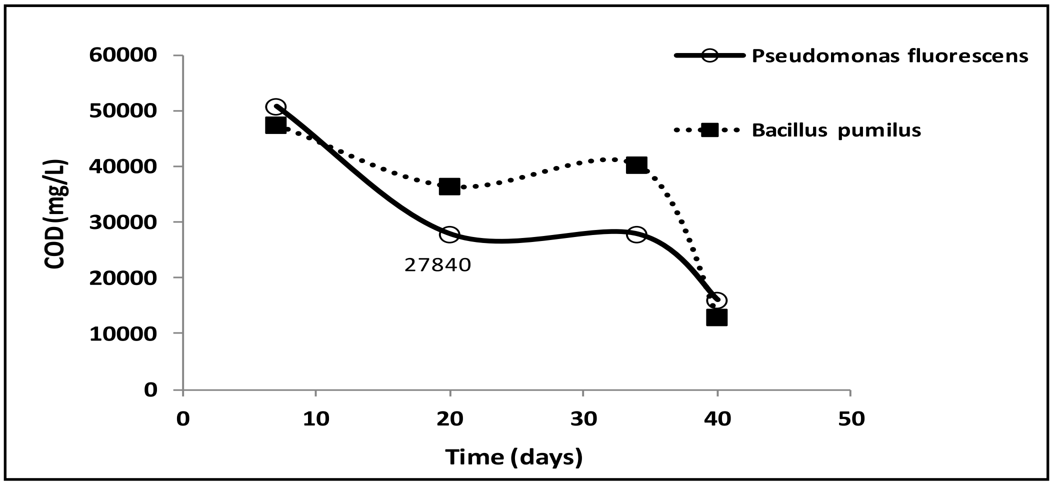

Fig 1: Variation of COD concentration using a physicochemical treatment followed by a biological treatment

The fig 1 showed COD values of the wastewater came down to 27840 mgL^{-1} after 20 days of incubation with *Pseudomonas* and the lowest residual COD concentration for this experiment was obtained after 40 days at 10000 mgL^{-1}. After 40 days of incubation, the biological treatment reduced the COD with 80.14% using *Bacillus pumilus* and 75.49% using *Pseudomonas fluorescens*. These results showed an effective treatment compared with the control (lactic acid bacteria).

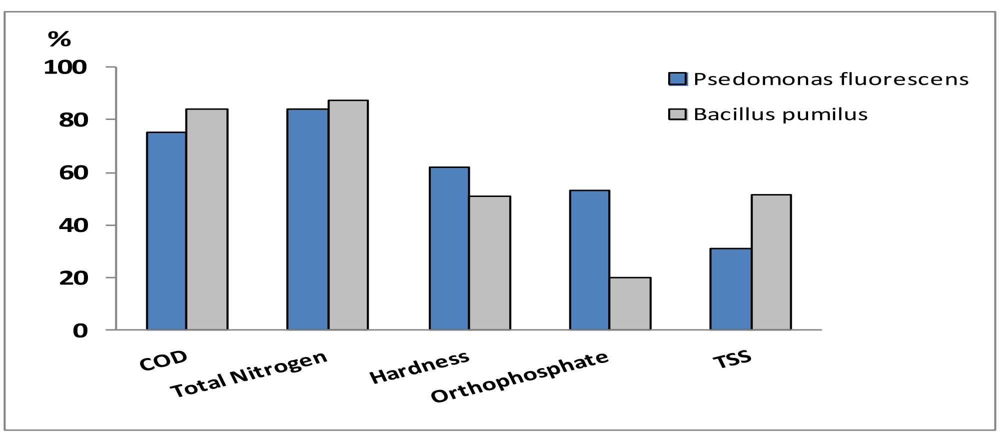

Fig. 2: Percent reduction of different parameters after coupled treatment

Using *Pseudomonas fluorescens* in phase 2 of treatment caused an 84.1% reduction of total nitrogen, 60 % of hardness and 51% of orthophosphate. By comparison, *Bacillus pumilus* also showed the same trend to reduce total nitrogen (87%), hardness (50%). Concerning orthophosphate *pseudomonas* was more effective (50% of reduction) than Bacillus pumilus (19% of reduction) to reduce this parameter. The total COD removal reached 82%, and turbidity decreases with 78.89% for the control (lactic acid bacteria), 76.74% for *Bacillus pumilus* and 65.18% for *Pseudomonas fluorescens* (Fig 2). The physicochemical treatment with aluminum sulphate decreased the turbidity with 98.63%, almost all turbidity is eliminated before the biological treatment.

Biological treatment followed by a physic-chemical treatment: After 40 days of incubation with *Bacillus pumilus* COD in dairy effluent have been reduced with 77.94% and 70.58% after incubation with *Pseudomonas fluorescens*. These values were closed to COD values obtained with the previous treatment (Fig. 3).

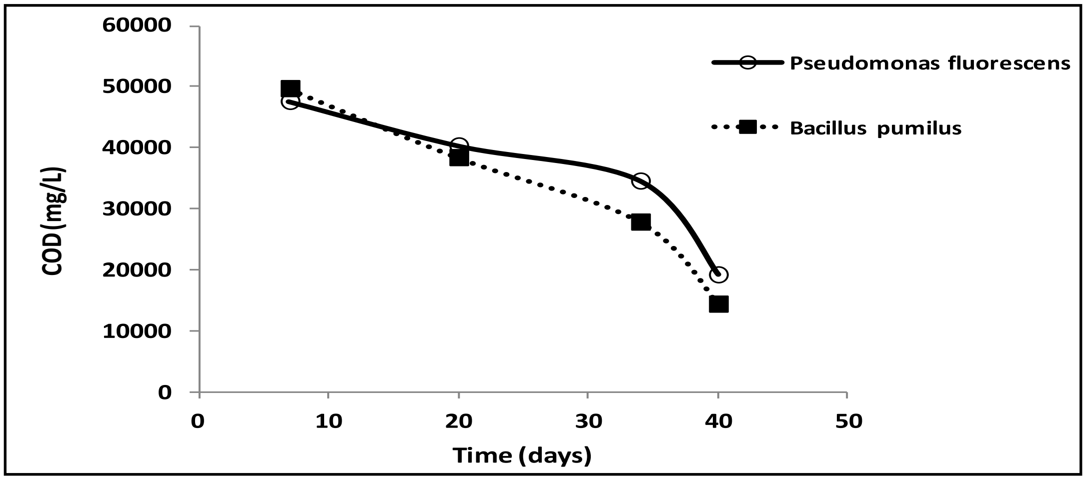

Fig. 3: Variation of COD concentration using a biological treatment followed by a physicochemical treatment.

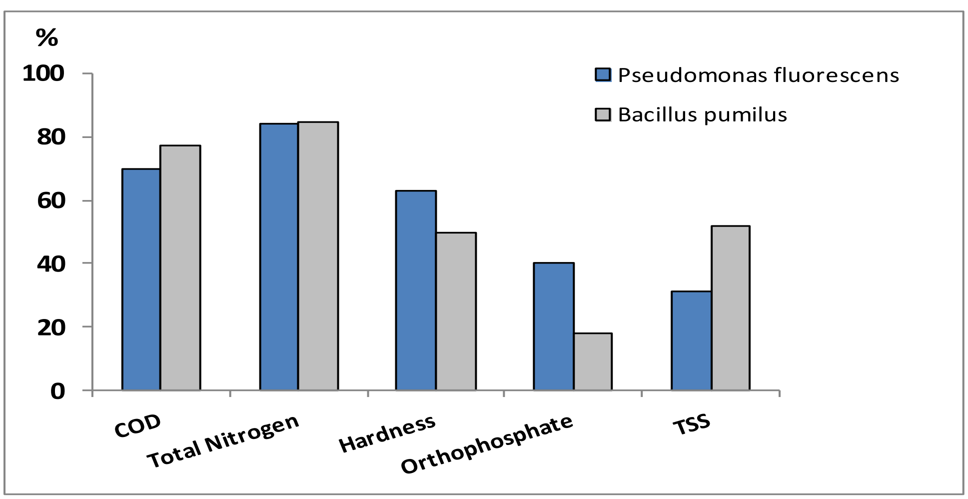

Fig 4: Percent reduction of different parameters after coupled treatment

Figures 3 and 4 showed that the biological treatment reduce 50% of COD after 40 days, also the physicochemical treatment decrease COD and other parameters. 77 % of the COD reduction was observed in this experiment. These results were not statistically different than what was obtained during at the last experiment. The first experiment (Physicochemical than Biological treatment) presented many advantages over the reduction of COD.

However, the physicochemical treatment followed by a biological treatment for 20 days, is the best choice sine bacteria adapts quickly to its environment in a condition of absence of suspended particles. The final characterization of sweet whey values determines the best and faster treatment. The physicochemical treatment must precede the biological treatment to achieve the higher removal of suspended particles. The physicochemical treatment has not proved to be efficient on the hardness (9%). But after biological treatment, the hardness decreased 62.7% using *Pseudomonas fluorescens*. With *Bacillus pamilus*, hardness decreased by 50.5%.

Concerning the nitrate variation after 2 phases of treatment, figure 5 showed a high residual nitrate. The measured concentration was at 300 mg L^{-1} after the biological-physicochemical treatment when we used *Pseudomonas fluorescens* and 150 mg L^{-1} when we used *Bacillus pumilus.* During this experiment, the nitrate increase due to nitrification. These bacteria convert organic nitrogen to ammoniacal nitrogen then nitrate (nitrogen cycle).

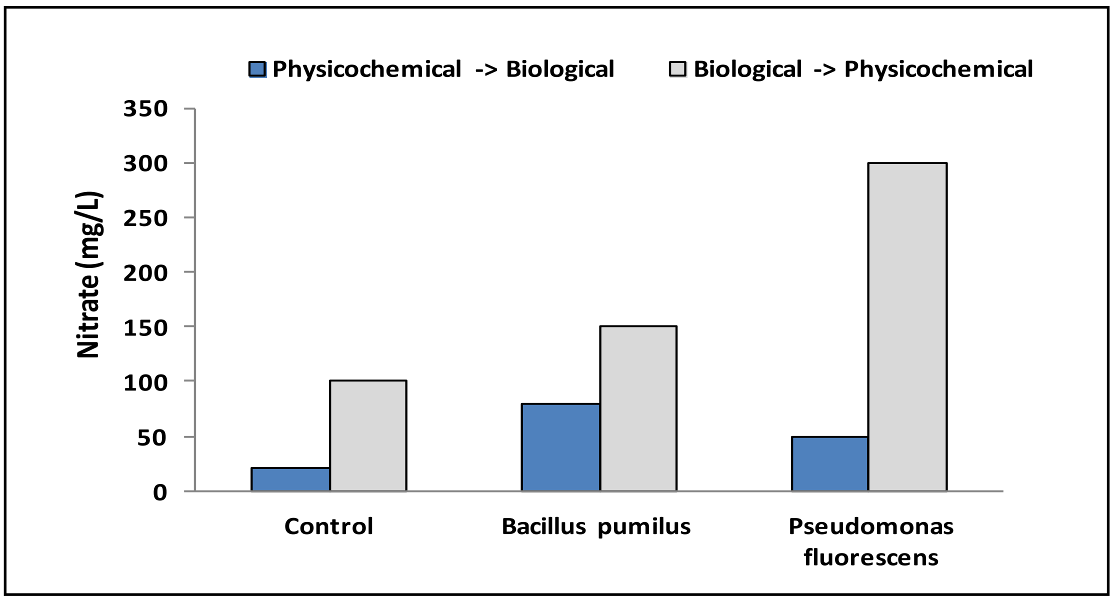

Fig.5: Nitrate concentrations during coupled experiment

The physicochemical treatment reduces nitrate with 39.15% and the biological treatment increase the nitrate especially with *Pseudomonas fluorescens*. The physicochemical treatment after a biological one could not reduce the large amount of nitrate generated by biological treatment. We accentuate the importance of preceding the biological treatment by a physicochemical one.

Different parameters: Total nitrogen decreases from 41.5% by lactic acid bacteria (control sample), while significant reduction were shown with 87.3% and 84.1% for treatment by *Bacillus pumilus* and *Pseudomonas fluorescens* respectively. Coagulation flocculation decrease 57% of TSS for the control, 51.65% for *Bacillus pumilus* treatment and 31.58% for *Pseudomonas fluorescens*. Turbidity decreases with 78.89% for the control, 76.74% for *Bacillus pumilus* and 65.18% for *Pseudomonas fluorescens*. The physicochemical treatment alone with aluminum sulphate decreased the turbidity with 98.63%, almost all turbidity is eliminated before the biological treatment.

APPLICATIONS

This method can be applied to treat dairy effluents on industrial scale. Methods realized in this project could also be used to treat wastewaters generated from different industries (Dairy industry, textile industry, food industries, water treatment industry...)

CONCLUSIONS

As a conclusion, such treatment can be considered effective and feasible on an industrial scale, but further studies should be carried out for optimizing the parameters conditioning treatment.
In the biological treatment, pH, temperature and stirring speed can be studied and optimized to minimize as much as possible the duration of treatment [13] proposed an optimization study of physicochemical parameters such as pH and temperature in the biological treatment of whey by *Streptococcus thermophilus*. In addition, several investigators have attempted to enrich the whey by adding various factors stimulating the growth of bacteria such as yeast extract, sodium bicarbonate, tween 80 [14].

In addition, other microorganisms may be used in biological treatment of whey such as yeasts and fungi in order to obtain best results. For example various studies showed that mixed cultures of fungi enable a greater production of enzymes responsible for the degradation organic matter [15, 16].

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