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Anaerobic digestion of fatty effluents by different inoculum bacteria

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ABSTRACT: The anaerobic digestion of the fatty effluents is a biological process, which allows the energy production in the form of biogas. The present study is based on comparing the methanogenic capacity of different inoculum on greasy effluents that result from a restaurant located in Fez city in Morocco. The results showed that the best production of biogas with the inoculum is involved by the one composed of poultry manure and bacterial consortia compared to the other inoculum, during 15 days, the anaerobic digestion of the grease effluent produces 252 cm^3 of biogas per gram of grease and achieve an abatement of 92 % as regards the Chemical demand of oxygen (COD) and an elimination of 98 % concerning greases content in the medium. Therefore, the use of anaerobic digester process of grease effluent is shown to be effective and highly gainful for the production of biogas and at the same time decreasing their harmful impact on the environment, therefore the possibility to adopt this process in industrial scale.

KEYWORDS: anaerobic degradation; Biogas; COD; fatty acids.

1 INTRODUCTION

Anaerobic digestion is an attractive alternative biological process in which organic pollutants are transformed into CH_4, and CO_2. It allows the decontamination of effluent that are rich in organic matter, the production of energy in the form of biogas and compost use. It is based on using closed reactors that occupy much less floor space than conventional treatment plants, therefore the production of a very small amounts of sludge. During the anaerobic treatment, the organic matter contend in wastewaters is converted into biogas, and thereafter it became a renewable energy source [1].

The energy yield of this process depends mainly on the type of organic matter present in wastewater and which is especially when compounds are reduced namely the long chain fatty acids (LCFA) and the main products of lipids hydrolysis[2] Consequently, the production of biogas from wastes or wastewaters with high lipid-content has been consistently reported as a feasible process for renewable energy production[3,4], and it is strongly affected by the composition and characteristics of the waste[5,6]. Moreover, anaerobic digestion of pure fats is inconvenient because they are insoluble, less dense than water and slowly biodegradable. In the present research, we analyze and compare the production of biogas from solid waste greases relying on different inoculum poultry manure of sheep and bacterial consortium.

2 MATERIALS AND METHODS

The substrate in this study acted as a solid grease picked out at the starting from a septic tank, which retains only the effluents of the kitchens of a popular district of the Fez city. After taking away, the greasy substrate is saponified by the KOH until the pH reaches a value of 9 then carried with 80 °C during 30 min.

2.1 INOCULUM

The test of methanogenic capacity has used as inoculums: The poultry manure alone, poultry manure and bacterial consortia, poultry manure and sheep manure and sheep manure lone. As regards the Inoculated poultry manure and manure of sheep were both reclaimed at starting from a farm of the area of Sefrou city in Morocco. After, they are put in solution in distilled water sterile a reason of 1%. The bacterial are isolated from grease of a septic tank and cultivated in anaerobes.

2.2 Methanogenic capacity

The tests were using 21 glasses. Inoculum sludge was degassed for 48 h at 35 °C before the beginning of the methanogenic capacity tests, The series of dilutions of saponified greases varies from 0 % to 100% and inoculated by 100 ml of different inoculums solution with a total of 10^6 bacteria, after splashing with liquid nitrogen, the batch were brought up to a temperature of 37 °C, then, after 5 days of incubation, the biogas produced in each batch was measured[4].

2.3 Continuous digestion Pilot

The pilot of the anaerobic digestion of greases in continuous system consists exhibit the fermenter of a capacity of 2 liters, maintained at a mesophilic temperature of 37°C all along the period of digestion. Inoculated with 100 ml of inoculums composed by manure of sheep and bacterial consortium. Concerning samplings and feed were carried out manually using two openings located at the higher part of the engines, the production of biogas was measured according to the principle displacement of acidified water (Fig.1).

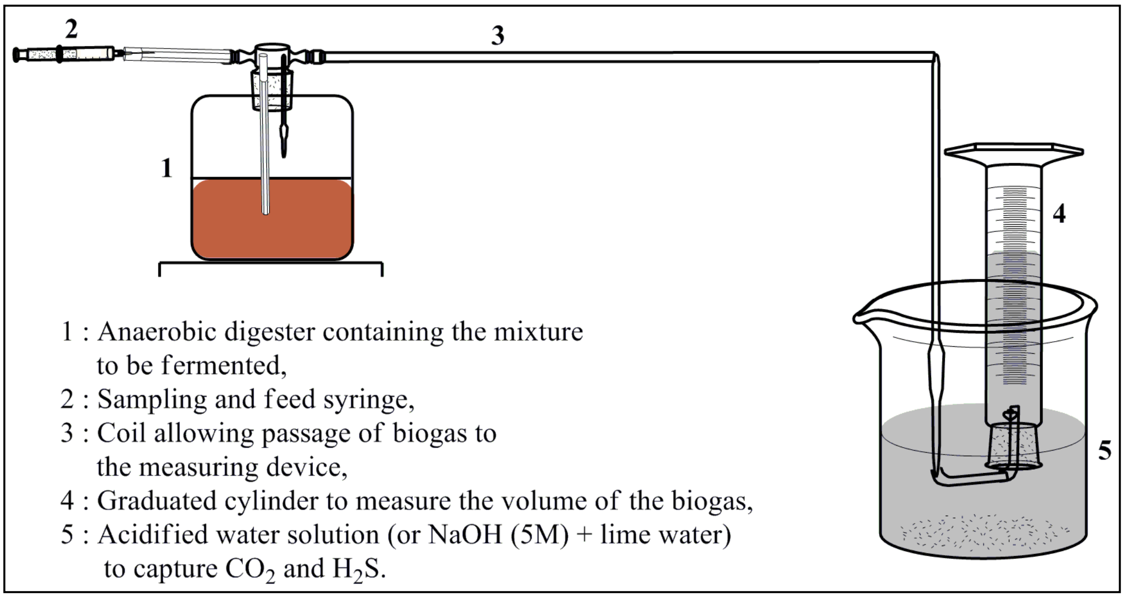

Fig. 1. Schematic representation of anaerobic digester

The experiment continues until the production of biogas tightens towards zero. The results were the average of two experimental measurements during 20 days. The volume of biogas produced during anaerobic fermentation is forwarded to the device of measurement. The produced gases are splashed in a solution of acidified water whose pH is adjusted to 1.2 in order to collect the CO_2, H_2S, NH_3 that are generated during the anaerobic digestion, the remainder (O_2, H_2, CH_4) is recovered in a tight and reversed test-tube.

2.4 Technical analyses

The pH was measured using a standard pH-meter CHECKER® model HI. Chemical Oxygen Demand (COD) was carried out by the method of potassium dichromate [7]. Fat content was determined by extraction with solvent, method chloroform/methanol. The optical density (OD) was measured using a UV/Visible spectrophotometer at 610 nm. The follow-up of OD expresses was maintained to pursuit the evolution of the biomass during the waste processing.

3 RESULTS AND DISCUSSION

3.1 METHANOGENIC CAPACITY ACCORDING TO THE GREASE PERCENTAGE IN THE MEDIUM AND INOCULATED TYPE

The effect of the content of greases on the methanogenic capacity was studied by a series of experiment and was carried out with various percentages of greases in the medium with different inoculated. It is deducted from Figure 2, how the production of biogas increases gradually according to the content of greases.

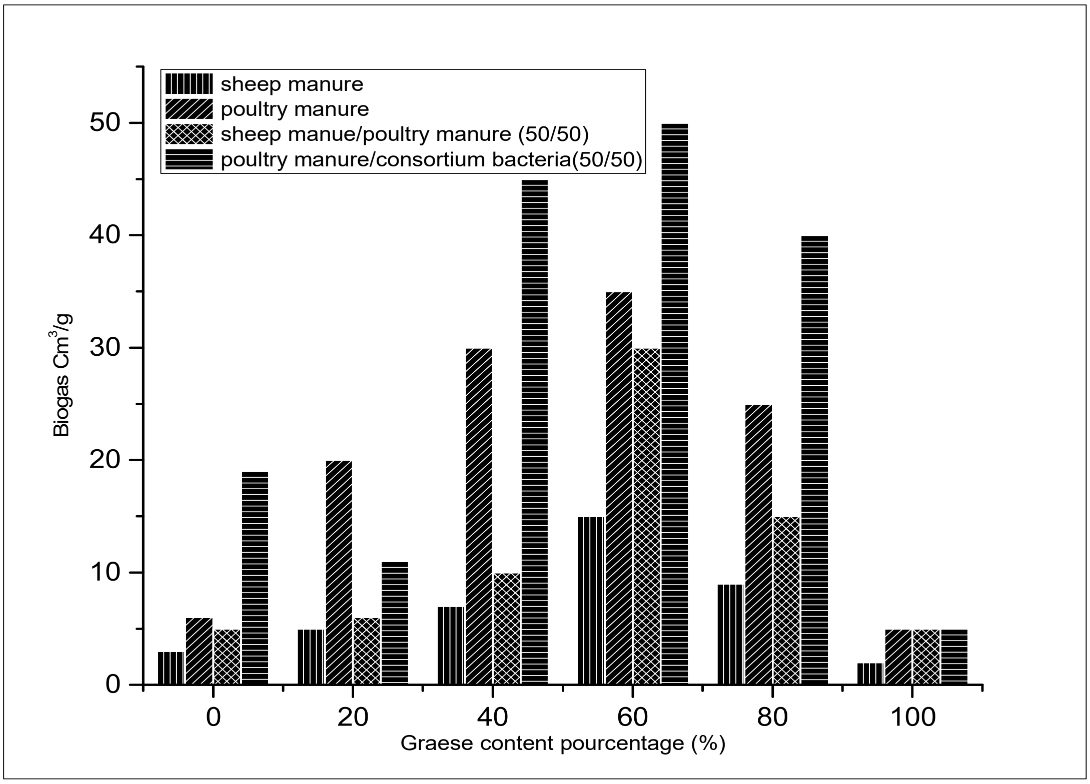

Fig. 2. Methanogenic capacity according to the grease percentage and inoculated type

The production reaches a maximum of 15 cm^3g^{-1} in the presence of 60% of greases as regards inoculum sheep manure, 35 cm^3g^{-1} concerning poultry manure, 30 cm^3g^{-1} for poultry manure / sheep manure (50/50) and 50 cm^3g^{-1} regarding Consortium bacteria (50/50). Behind this rate, we record a reduction in the production of biogas, the cheapest manure generated the weakest production. However, the fraction mixture of poultry manure and consortium are shown to be efficient as inoculum regarding the production of CH_4. The composition of the poultry manure could be at the origin of this strong production of biogas. Indeed, it is rich in phosphorus and nitrogen, which are essential to the bacterial growth which permit the compensation of the deficiency of these elements in greases. Also, the specific methane production rate was significantly influenced by the choice of the inoculum indicate that the substrate mixture is increased by 50 % in the final of CH_4 production [8]. For the more the inhibition of production (80 % and 100 % of greases) could be explained by the very slow time of hydrolysis of greases [10,11] As regards inhibition limiting, it's been procced to co-digest the fat with other wastes namely activated sludge which is highly affective as been described by Wang et al.[10] and Luostarinen et al.[11]. Moreover, the anaerobic digestion of pure greases is shown to be inconvenient because they are insoluble, less dense than water and slowly biodegradable. It is indeed shown that the step that limit the process is the physical transfer of the mass from the solid to the liquid phase which has been legally added. In addition to that, according to some researchers as Rinzema et al. [12], some fatty acids with long chain are supposed to prevent grow same methanogens microorganisms.

Overall, the confirmative test of the capacity methanogenic of inoculated was examined in during 15 days in the presence of 60% of greases (Fig. 3). the best inoculum is the mixture of poultry manure and consortium bacteria.

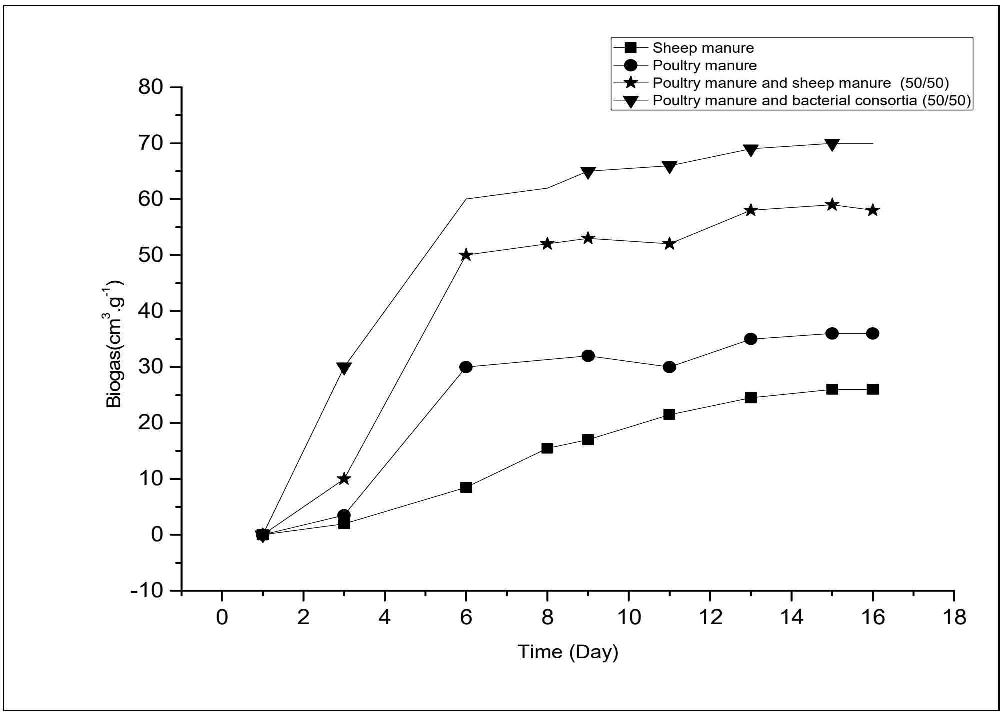

Fig. 3. Methanogenic capacity with 60% of grease content during 15 days of different manure.

3.2 ANAEROBIC DIGESTION OF GREASES

The digestion of grease started by hydrolysis to form free LCFA and glycerin, then these products will be processed by the bacteria into H_2, acetates and carbon dioxide which will be transformed into methane and carbon dioxide by methanogens. In fact, the follow-up of the production of biogas during 20 days shows that the production increase from the first day to fourteenth days where it achieves its stability with a total production of 252 cm^3 of biogas g^{-1} (Fig. 4).

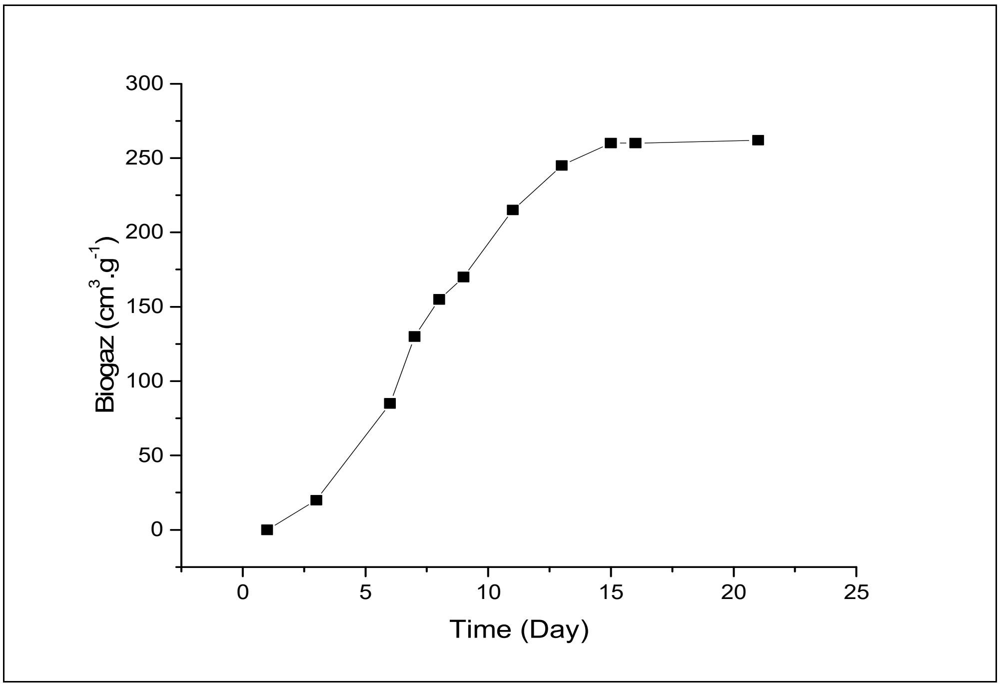

Fig. 4. Evolution of the biogas during anaerobic digestion of greases

These results are similar to those obtained by Salminen et al. [13] as regards the solid degradation of waste of poultry slaughter-house. Referring to[14], the addition of the fatty acids to worn in an anaerobic digester increase the rate production of the methane.it is observed that the initial latency time in the production of methane could be allotted to the fast preparing of VFA and/or LCFA, as propose Salminen et al. [13] In another hand, the pre-hydrolysis step is primordial in order to modify the residue and allow its anaerobic biological breakdown, in the same perspective [13] have made a review where it is noted that that the formation of the free fatty acids with long carbon chains decelerate the process and risk to poison the anaerobic microorganisms and particularly the acetogenesis and methanogenesis steps, in this review, Cirne et al. [9] analyze the effect of the lipids concentration on digester reaction ,it was concluded thereafter that the impact of the fatty acids with long chains on the reaction is not permanent, nevertheless it decelerate the process, consequently, the creation of a longer lead time, which is preferably avoided in industrial scale.

The quantitative analysis of the greases during anaerobic digestion makes it possible to fix the limits of the process. Generally, to ensure a good production of biogas the degradation of all the lipids remains a paramount stage, withal, the more the lipids are faster transformed, the more the process is optimized, The daily output of degradation is related to the chemical composition of the organic matter, in which all the connections are not also ready to undergo a complete degradation, furthermore, the output of degradation is influenced by the speed of degradation of the various components of the substrate, the bacteria will break up much more quickly of greases than of albumin, cellulose or hemicellulose, This could be related to an ineffective consumption of the carbon source and to the reduction in the specific growth rate. The assimilation of AGVs in the metabolism is investigated through association of several metabolic ways, the figure 5 template the evolution of the degradation of the organic matter during the anaerobic digestion of greases with an elimination of 98 % concerning greases content in the medium.

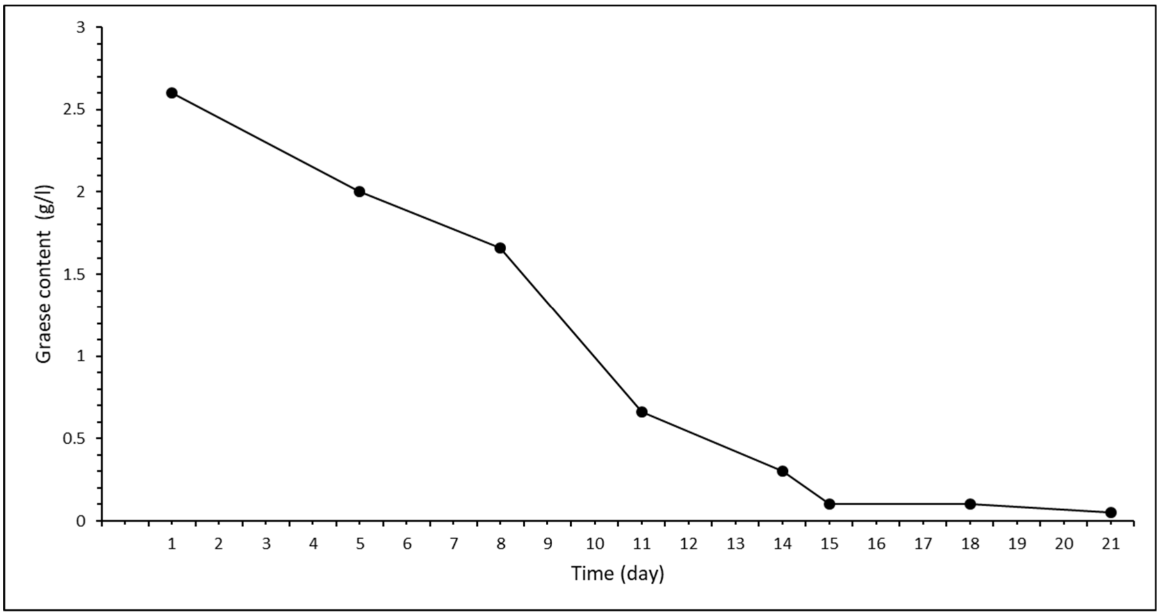

Fig. 5. Evolution of the grease content during anaerobic digestion of greases

It is clearly shown, an efficient reduction from 140 g regarding O_2L^{-1} of COD in first days to 11 g of O_2L^{-1} of the COD in the end of the study, with a degradation rate of 92 % (Fig.6).

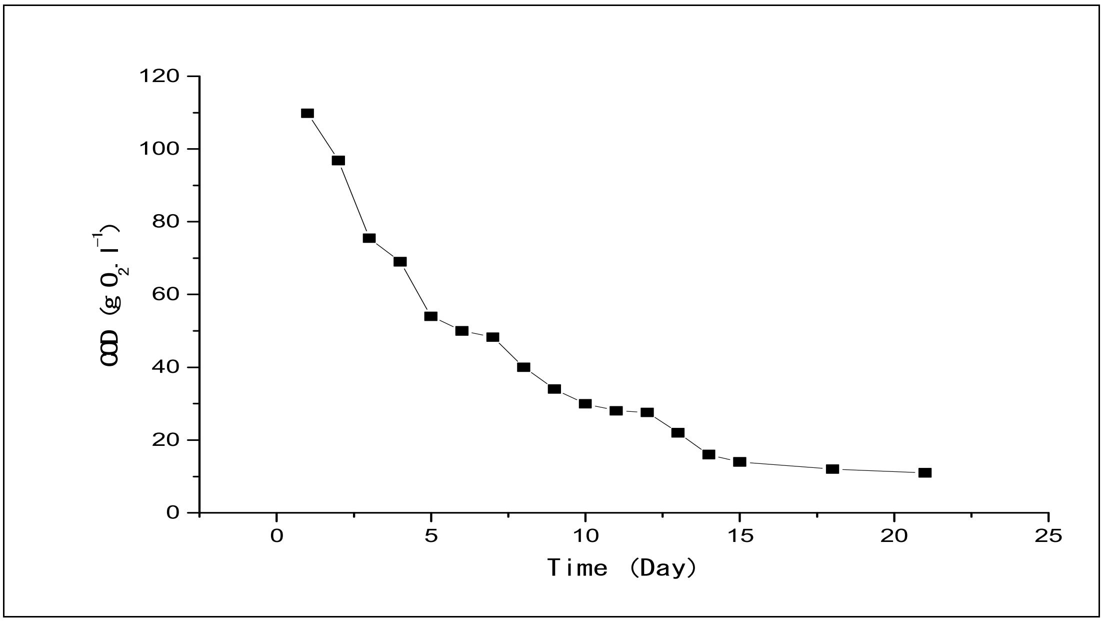

Fig. 6. Evolution of the COD during anaerobic digestion of greases

This performance in the elimination of fat and grease is usually supervised by the percentage of fatty acid released in the reaction and by the reduction of the COD of the effluent. Some authors dispose a positive correlation between the biogas production and COD concentration and the percentage of degrading fats and greases [15–17].

According to the figure 7, it is noticed a reduction in the pH since the first day from 7.3 for is to 6.5 at the end of reaction, this acidification of the medium could be allotted to an incomplete oxidation of the organic matter leading to the production of organic fatty acids in anaerobic conditions with the accumulation of the AGV and liberation of the proton H^+, by consequence, a reduction in the pH of medium [18].

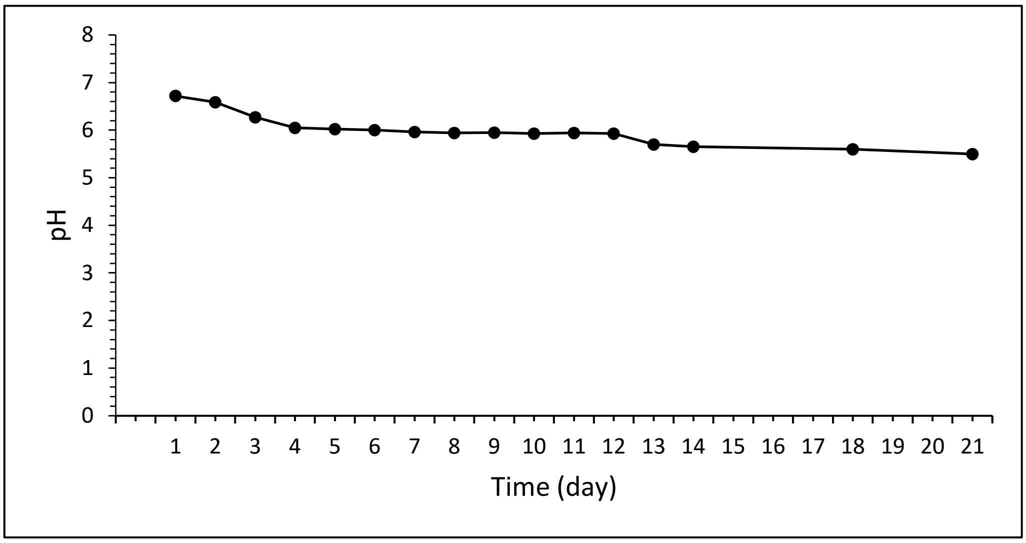

Fig. 7. Evolution of the pH during anaerobic digestion of greases

The effects of the variation of pH on the microbial kinetics are not negligible. Keshtkar et al. [19] and Siegrist et al. [20] prove in the research that the pH inhibits respectively the anaerobic digestion of the manure of cattle and the clarification sludge. However, the pH is only one factor protagonist and was not implied for the optimization of the reports/ratios of pH-methane output. The acid-basic equilibration of the acid couple acetic/acetate is thus a determining condition to limit the acetate toxicity. The results of Fei et al.[21] confirm these results during cultures of *Cryptococcus albidus* while carried out on a range of pH from 4.5 to 8. The presence of some couple's acid/base (H_2CO_3 / HCO_3^-, H_2S/HS^-, H_2PO^{4-} /HPO_4^{2-}, NH_4^+/NH_3) in the medium digestion makes it possible to plug the variations of pH in this zone. The equilibration of digestion depends on intermediate products of degradation which are not accumulated. Thus, the hydrolysis and the acidification of the lipids do not take place with pH lower than 6, because the accumulation of protons H^+ involves the blocking of the methanogenic activity and by feedback of all the syntrophic chain. In the same way, any accumulation of LCFA is toxic for the methanogens bacteria, the result investigated by Bermúdez-Penabad et al. [22] proved the Anaerobic digestion of tuna waste at a pH of 8.0, the VFA production reached 30.611 mg of COD L^{-1}.

4 Conclusions

This present work reveals the efficiency and potency of the anaerobic digestion of greases as a tool in decreasing their harmful impact on the environment. Among the benefits, the biomethanisation allows the degradation of the polluting organic matter (reduction of the rate of the COD) and generated the energy production in the form of biogas. At laboratory scale, the study of the variation of grease content (substrate) involved the comparison between different inoculum on the production of biogas. The better production rate is found by poultry Manure and Consortium bacteria (50/50). Thus, a follow-up of the biological degradation (grease and COD) and the potential hydrogen would be systemically an approach in industrial.

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