CHEMICAL ENGINEERING TRANSACTIONS
VOL. 53, 2016

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Valerio Cozzani, Eddy De Rademaeker, Davide Manca

ISBN 978-88-95608-44-0; **ISSN** 2283-9216

DOI: 10.3303/CET1653050

Improved Anaerobic Digestion by a Thermal Pretreatment

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The experimental study was conducted in order to evaluate the effects of thermal pre-treatment of secondary sludge on anaerobic digestion using as substrate a dairy discharge consisting primarily of whey (Numidia Constantine) made up mainly of lactoserum. The inoculums was subjected to heat treatment 120 °C, 160 °C, 180 ° C for 2 hours, while considering the mud without treatment with a corresponding temperature equal to 20°C.
The trials were conducted in a series of reactors of 250 ml in thermophilic phase at 55°C. The effect of heat treatment on the physicochemical parameters of the sludge before incubation shows that: In all cases, heat treatment brings about an important solubilisation of matter: The concentration in soluble matter greatly increases the required minimum time of treatment to achieve the highest rate of solubilisation which is equal to 60 min.The solubilisation of the CDO (Chemical Demand of Oxygen) increases proportionally with the treatment temperature. An increase in the treatment temperature of 120 ° C results in a CDO with a solubilisation ratio of 7% and for a temperature of 180 ° C it is 25%, with a solubilisation rate reaching 34% for a temperature of 18 °C.
The best treatments (160 °C and 180 °C) result in a production of biogas from 2.7 to 3.5 times that of the untreated sludge for duration equal to 25 days.

1. Introduction

Anaerobic digestion is one of the main biological treatment for reducing the content of dairy releases into organic materials, toxic substances, and to generate, at the same time, energy in the form of biogas, used for the production of electricity and heat as well as a digestate that can be used as fertilizer in agriculture.
This experimental study was conducted to evaluate the effects of heat treatment on the inoculums (secondary sludge) and the methane production in the thermophilic phase (55 ° C) with a dairy wastewater constituted mainly of whey. According to bibliographic results, the heat treatment allows the solubilisation of material, the improvement of the degradation of organic material and the increase of biogas production,(Kheiredine and al.2014).
The physicochemical treatments can be implemented in order to compensate for the limits of anaerobie digestion particularly if the effluent to be treated contains bio-resistant or toxic molecules or in the case of a substrate which is slowly biodegradable such as purification sludge. Indeed the active stage of methanation is hydrolysis (Carrere, and al.2006).
The effect of heat treatment on sludge is the liberation of extra and intracellular compounds for example (Li, Y. Y. and Noike, T.1992) have quantified the solubilisation of the main compounds of an activated mud and show that the rate of solubilisation increases with the treatment temperature. (Haug and al., 1978).
The rate of solubilisation increases as the temperature of treatment does so. (Valo and al. 2004),(Bougrier et al. 2004) proposed a treatment at 170°C. According to most of literature results the optimum temperature was 170°C for (Li and Noike, 1992), 175°C for (Haug and al., 1978), and a 130°C treatment with an addition of potassium hydroxide for (Kepp and al., 2000).
Thus the main objective of this study is to quantify, understand the changes related to the heat treatment and to measure the effects on anaerobic biodegradability of sludge to determine the optimum processing temperature.

Please cite this article as: Bani K., Debal K., Bencheikh-Lehocine M., 2016, Improved anaerobic digestion by a thermal pretreatment, Chemical Engineering Transactions, 53, 295-300, Chemical Engineering Transactions, 53, 295-300 DOI: 10.3303/CET1653050

2. Materials and methods

2.1 Methodology

The selected heat treatment range is 120 °C, 160 °C, 180 °C during 2 hours, taking into consideration the temperature at 20 ° C for the untreated sludge. For the same temperature test 10 bottles were carried out. The average of 3 bottles is used for the negative control to estimate the biogas production related to the residual degradation of the inoculums. The average of two bottles will be useful for monitoring biogas and a biodegradability estimation effected by comparing the volumes of biogas produced by the sludge with that produced by a substrate (slag discharge). The last five bottles will allow the follow up in time of the residual physicochemical parameters such as CDO, TS, TVS, MES, MVS, pH, TA and TAC.
The values of biogas production are brought back to standard conditions of temperature and pressure.

2.2 Analytical methods

Liquid phase characterization was undertaken before and after anaerobic digestion period through the determination of pH, total solids (TS), total volatile solids (TVS), Alkalinity (TA) and total alkalinity (TAC), volatile Futty acids (AFG), chemical oxygen demand (COD), according to Standard Methods (APHA, et al , 1998) pH was determined using a pH-meter (Jenway 3510 PH meter).

3. Effect of heat treatment on the physicochemical parameters of sludge before incubation

3.1. Effect of heat treatment on the pH

Figure 1 shows that the pH increases with the augmentation of temperature and of the treatment time, varying between 7 and 8.56. It is a pH exceeding slightly neutrality.
This increase can be linked to proteins desorption or to the volatilization of acid compounds or of CO2. (Carrere, et al.2004).
In all cases, heat treatment causes an important solubilisation of matter. The concentration of soluble matter increases significantly. Figure.2 shows the development of the ratio MES/MS depending on the treatment. The ratio MES/MS decreases significantly with temperature: thus for a period equal to 30 minutes, the ratio MES/MS is equal to 2.18, 1.33 ,1.60 , 1.81 respectively for temperatures equal to 120°C, 160°C 180°C.
As for the untreated sludge, and using the same periods of time, the ratio MES/MS changes a little with the duration of the treatment, for durations greater than 30 min: about 5-10% intervals between the ratios MES/MS at 30 and 60 minutes.

Table.1 the physicochemical parameters of sludge before incubation

	Sludge (T=20°C)	Sludge (T=120°C)			Sludge (T=160°C)			Sludge (T=180 °C)		
Times	t=0	t=0	t=30'	t=1h	t=0	t=30'	t=1h	t=0	t=30'	t=1h
pH	7.0	7.0	7.1	7.2	7.0	7.3	7.3	7.0	7.2	7.5
TS	16,2	16,2	25,8	26,3	16,2	20,1	36,7	16,2	24,7	50,6
TVS	7,5	7,5	11,9	12,1	7,5	10,4	17,8	7,5	11,3	21,3
DCO_s	1.4	1.4	2.5	2.2	1.4	16	1.1	1.4	3.3	6.9
DCO_t	43.7	43.7	41.5	30.4	43.7	34.3	33.2	43.7	22.1	27.5
Solubilité	0	0	50	6,2	0	15,6	-2,3	0	19,7	34,3
Ratio CDO_S/CDO_T	3,2	3,2	5,9	7,3	3,2	4,7	3,4	3,1	15,0	25,0
TA (PH=6)	220	220	180	200	220	160	120	220	280	120
TAC (PH=4)	360	360	260	360	360	300	280	360	560	460
MES	35,4	35,4	34,2	33,5	35,4	32,2	40,6	35,4	44,8	49,1
MVS	29,7	29,730	29,7	28,4	29,7	27,8	30,3	29,7	33,0	34,8
MES/ST	2.1	2.1	1.3	1.2	2.1	1.6	1.1	2.1	1.8	0.9

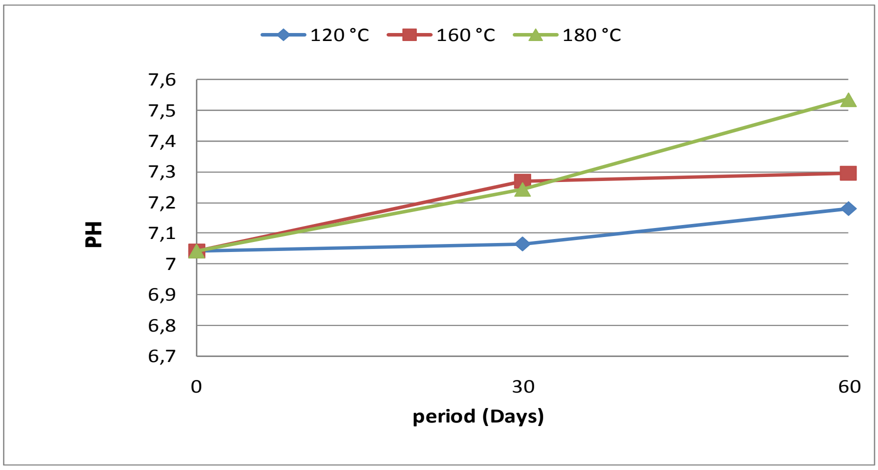

Figure1: Effect of heat treatment on the pH.

3.2 Effect of heat treatment on the solubilisation of the material

On the other hand, it is necessary to ensure a minimal duration of treatment of 30 minutes in order to obtain the highest rate of solubilisation, and therefore the weakest possible MES/MS ratio.

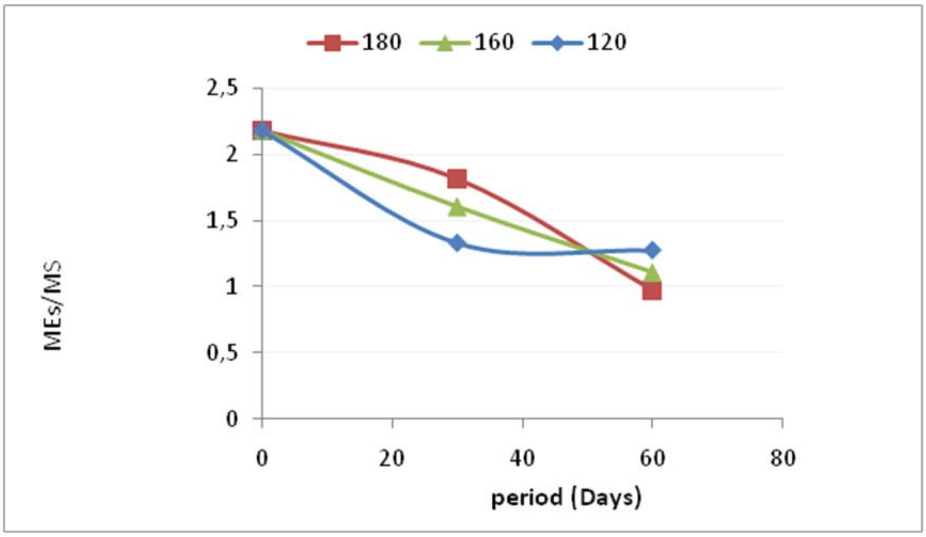

Figure.2: MES / MS report of Evolution a function of the processing time for each temperature.

3.3 Effect of treatment on the soluble and total CDO

In order to compare the results, it is also possible to use the solubilisation rate or the ratio CDOS/ CDOT which reflects the transfer of particulate phase to the soluble one.
The rate of solubilisation. (Clair Bougrrier.2005)
.

$$SCDO = \frac{(CDOs(T°C) - CDOS(20°C)}{CDOpo(20°C)} * 100$$

With :
CDOs soluble CDO of the treated sample (g O2/L)
DCO_{S0} : soluble CDO of the untreated sample (g O2/L)
DCO_{total} : particulate CDO of the untreated sample (g O2/L)
(CDO_{P0} = $CDOt_o$ –CDO so)

Heat treatment leads to a solubilisation of the CDO

Figure.3 shows that the soluble CDO increases according to the time of treatment for each tested temperature. This increase is very significant at a temperature of 180° C. Thus, the soluble fraction of the CDO increases with the temperature and the duration of treatment.However, it appears that, for each temperature, the soluble CDO curve reaches a plateau after 30 minutes of treatment at temperatures of 120 ° C and 160 ° C.

Therefore, the treatment duration has less effect on the solubilisation than the temperature.

However at a temperature equal to 180 ° C the solubility limit is not achieved even after one hour of treatment.

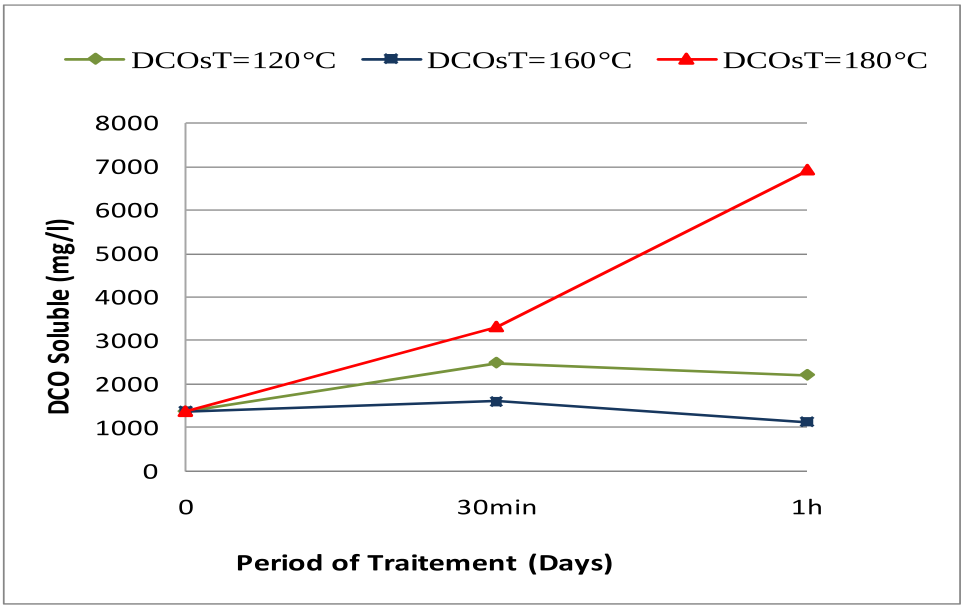

Figure .3: Evolution of the soluble CDO depending on processing time for different treatment temperatures

3.4 Effect on Ratio COD / COD and the solubility rate

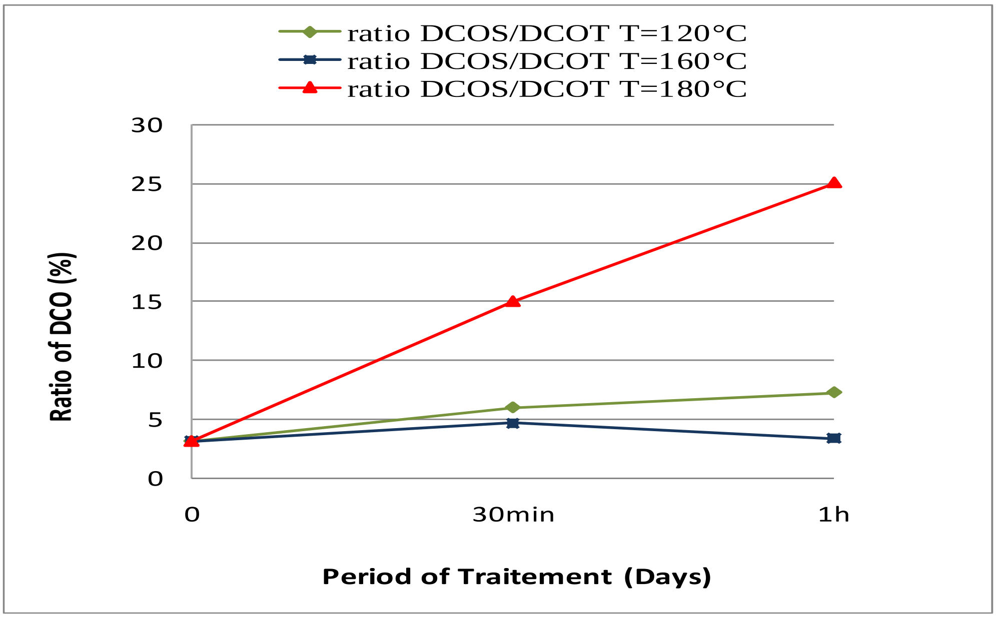

Figure.4: Evolution of Ratio COD / COD depending on the processing time for each temperature.

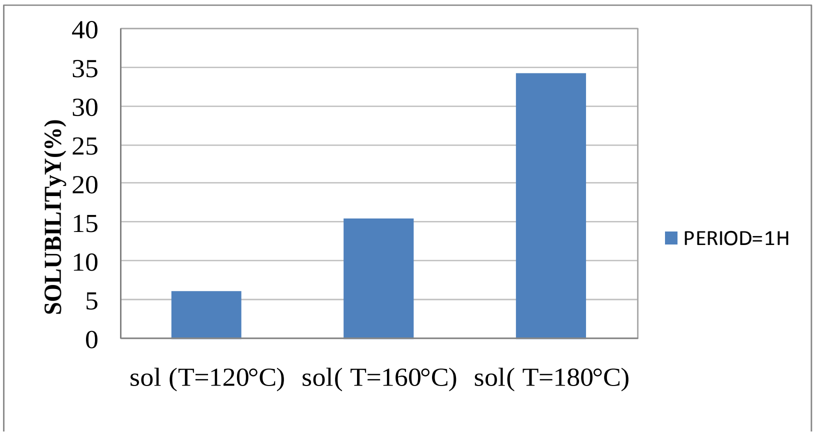

Figure.5: Evolution of solubility depending on the processing time for each temperature

Figure.4 presents the evolution of the ratio CDOs/CDOt depending on the temperature. Thus for a treatment duration of 1 hour, solubilisation of the CDO increases proportionately with the treatment temperature.
An increase in the treatment temperature of 120° C leads to a solubilisation CDO ratio of 7%, whilst at a temperature of 180°C it is 25%, and a level of solubilisation reaching 34% at a temperature of 180°C (Figure 5).
Consequently, according to certain authors for instance, a thermal treatment of 60 min at 180°C allows about 50% of the matter to be solubilised.

4. Variation of the total cumulative volume in biogas product

A latency phase which is identical to all three temperature tests thus making the heat treatment without any particularity for this phase. As for the exceptional phase which begins for the three temperature tests starting from the 4th day, with a kinetic that increases with the augmentation of temperature, thus permitting to account for the most important biogas quantities 400 ml, 300 ml, 150 ml and 90 ml respectively for the test temperatures 180°C, 160°C ,120°C, 20°C.
The plateau phase is from the 28th day, at which stage the production is slow probably under the effect of the exhaustion of the digestion substrate constituting the nutritive and energetic source of the microbiological flora and particularly the methanogenic flora which is directly responsible for biogas production.

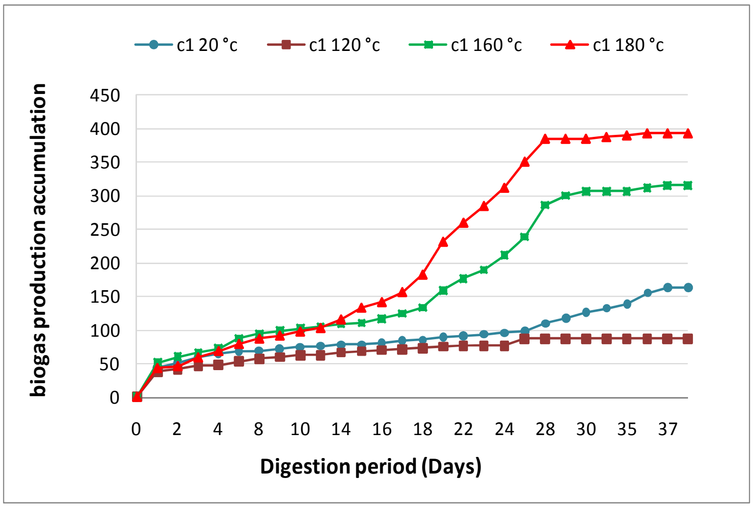

Figure.6: Total cumulative volume as biogas product in thermophilic phase

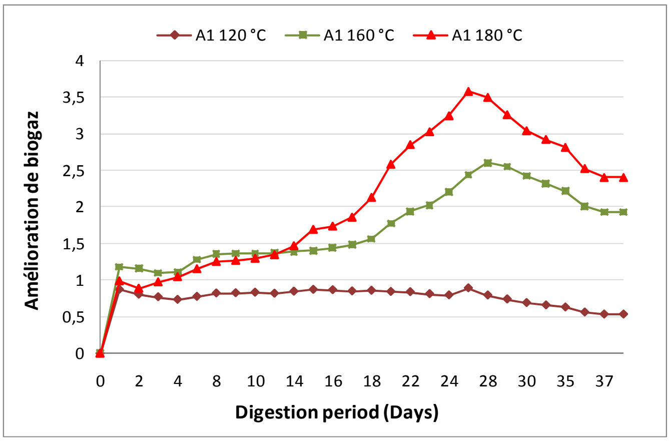

Figure.7: Improvement in biogas compared to mixture of sludge and slag without treatment.

In terms of improvement of the relation between the volumes of biogas produced by the treated and untreated sludge.

$$\text{Improvement} = \frac{\text{volume of biogas produced by treated sludges}}{\text{volume of biogas produced by untreated sludges}}$$

It was noticed that the best treatments (160°C and 180°C) lead to a production of biogas 2,7 – 3,5 times greater than that of untreated sludge for a period of time equal to 25 days. See figure 7.
Consequently from the point of view of biodegradability, heat treatment is efficient for a temperature equal to 180°C and permits to accelerate sludge degradation.

5. Conclusion

In all cases, heat treatment leads to an important solubilisation of matter.The concentration in soluble matter greatly increases the required minimum time of treatment to achieve the highest rate of solubilisation which is equal to 60 min. The solubilisation of the CDO (Chemical Demand of Oxygen) increases proportionally with the treatment temperature. An increase in the treatment temperature of 120 ° C results in a CDO with a solubilisation ratio of 7% and for a temperature of 180 ° C it is 25%, with a solubilisation rate reaching 34% for a temperature of 180°C.The best treatments (160 ° C and 180 ° C) result in a production of biogas from 2.7 to 3.5 times that of the untreated sludge for duration equal to 38 days.

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