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Biogas production from fruit juice wastewater

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***Abstract*— Orange and apricot fruits have been grown commercially in Algeria, both for local consumption and for export. In addition to juice, orange and apricot production generate a broad range of other commodities including orange blossom and apricot honey, apricot orange syrup and marmalade. Often the processing of fruits generates two types of waste - a solid waste of peel/skin, seeds, etc and a liquid waste of juice and washwaters.**

The aim of this study is to quantify the biogas production from the apricot and orange juice cocktail that comes with pulp from Algerian fruit juice industry. The experiments were conducted in a laboratory-scale using a stainless steel digester of a capacity of 5 liters under a mesophilic and a thermophilic temperature. During experiments various parameters have been recorded as: Chemical oxygen demand (COD), biological oxygen demand (BOD), cells growth, pH, total sugar content in juice, etc. Note that the biogas analysis is carried out using headspace sampling coupled with gas chromatography (HS-GC). It is found that the maximum growth rate achieved was about 0.0103 h^{-1} under mesophilic temperature, while it is higher in the case of thermophilic temperature, 0.0143 h^{-}. The biodegradability of the effluent is about 200 mg/l under thermophilic temperature and it is higher that in the case of a mesophilic temperature. The quantity of biogas produced is about 435 ml under thermophilic temperature while it is about 144 ml under mesophilic temperature.

***Keywords*—** Biogas, Fruit juice wastewater, Digester, Mesophilic/Thermophilic temperature, Energy.

I. INTRODUCTION

Recently high energy demand can be observed which is linked to the increase of both the prices of fossil fuels and the environmental concerns. Biogas production through anaerobic digestion, of different organic materials, provides an alternative solution.

Anaerobic digestion is a process in which organic substrates are degraded in the absence of oxygen, via enzymatic and bacterial activities. This fermentation leads to produce biogas that can be used as a fuel for electricity and heat generation. The residual digestate after anaerobic digestion may be used as an organic fertilizer and/or soil amendment. Anaerobic treatment is now being increasingly used to eliminate or reduce contamination from agricultural and industrial wastes containing medium to high levels of biodegradable organic matter [1]. This fermentation process can be applied to vegetable and fruit wastes [2-3-4-5], to organic solid wastes with or without wastewater treatment plant sludge [6-7-8], to animal wastes [9].

The research in this field is focused on the study of the effects of different parameters such as : temperature, solid concentration, inoculum to substrate ratio, etc.
Anaerobic digestion in Algeria is studied by [10-11], they tested several materials as : organic solid wastes and animal dungs.

The main aim of the present study is to quantify the biogas production from apricot and orange cocktail that comes with pulp from Algerian fruit juice industry. It focuses on the effect of the temperature on fermentation process.

II. EXPERIMENTAL SET-UP

The digester used in this study is given in fig.1. It consists of a cylindrical stainless steel vessel of about 0,355 m in height and about 0,15 m in diameter with double water jacket in its exterior side of about 0,165 m in height. This allows to keep a constant temperature during fermentation process. The bottom of reactor is hemispherical and is joined to the top by straight sides ; the effective volume of the reactor is 5 liters.
The valve for the bottom purge/or a sample pipe is set, while the top is equipped with a stainless steel flange. The mixing inside the digester is ensured manually by using an impeller. The digester is filled with apricot and orange cocktail with pulp, sealed, the fermentation process is proceed using dispersed growth-bacteria until gas production decreases. The gas produced is trapped on the top of digester and analysed by headspace sampling coupled with gas chromatography (HS-GC). The volume of gas produced during digestion is measured by water displacement method. The reactor cover is provided with several pipes in order to monitor different parameters as : temperature, cells growth, volume of biogas, redox potential, etc. Note that the digester is operated under mesophilic (38°C) and thermophilic temperature (58°C).

Fig. 1 Experimental set-up

III. SUBSTRATE

The substrate used contains apricot and orange cocktail that comes with pulp from Algerian fruit juice industry. This substrate does not sell in the market. The characteristics of this substrate are shown in Table 1. It shows high concentrations of organic matter.

TABLE I
SUBSTRATE CHARACTERISTICS

Parameters	**Values**
pH	7.39
conductivity (mS/cm)	2.06
potential of oxydoreduction (mV)	-20.8
COD (g/l)	500
BOD_5 (g/l)	179
COD/BOD_5	2,79
total sugar (g/l)	0.78

IV. RESULTS AND DISCUSSION

1. CHEMICAL DEMAND OXYGEN (COD)

The chemical demand oxygen is an important parameter to determine wastewater biodegradability. Figure 2 shows the comparison between the chemical oxygen demand, COD, in the case of mesophilic and thermophilic temperature. It can be seen that the chemical oxygen demand decreases as the time and the temperature increase too. In the case of thermophilic mode a significant decrease of the organic compounds is seen until reaching a value of 200 mg/l after 9 days. In the case of mesophilic temperature and under the same conditions the chemical oxygen demand is slightly higher and less than 250 mg/l. The anaerobic decomposition of biomass improves with increase of temperature. In this case the fermentation process takes place much faster. The time of fermentation is shorter in thermophilic mode than the one obtained in mesophilic mode. Note that 54-60% chemical oxygen demand removel is reached. These results are in agreement with previous study of Álvarez *et al.* (2006) [12] who found 54-58% total chemical oxygen demand in the case of raw domestic wastewater.

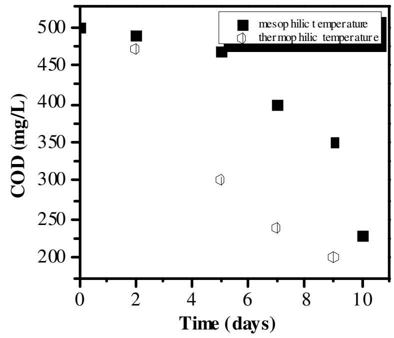

Fig. 2 : COD versus time

2. BIOMASS GROWTH

Figure 3 shows the biomass growth during the fermentation process. Five phases have been distinguished: lag phase, acceleration phase, exponential phase, deceleration and plateau phases. In lag phase, an initial biomass adaptation to the chemical growth environment is observed during the first day. This phase contains aerobic microorganism, the latter die an absence of oxygen, only acidogenic microorganisms, whose concentration is low grow in the acid medium [13]. In acceleration phase, cells division is occured during two days. The biomass growth increases until four days, in this phase a cell number begins to increase exponentially which is characterized by a maximum specific growth. It is found that the maximum growth rate achieved is about 0.0103 h^{-1} under mesophilic temperature, while it is higher in the case of thermophilic temperature, it is about 0.0143 h^{-1}. In such case, a significant decrease of organic compounds is also seen. The variation in the biomass concentration becomes limited by the concentration of nutrient during 6 days. In the phase five, the variation in the biomass concentration is less, indicating that the stationary rate is reached with a biomass concentration of 6.96 $*10^5$ cells per ml under thermophilic mode while it is lower and about 5.28 $*10^5$ cells per ml under mesophilic mode. This means growth of biomass improves with increase of temperature.

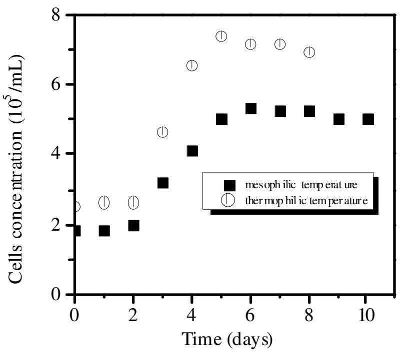

Fig. 3 : Evolution of biomass concentration during the fermentation process

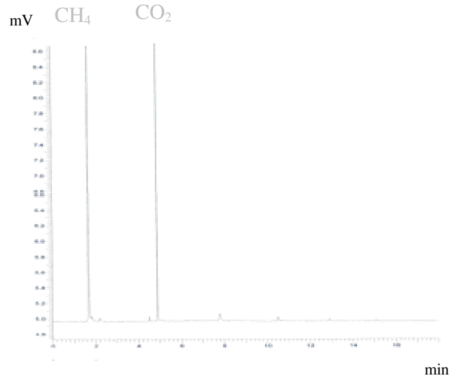

Fig. 5 : Biogas chromatogram

3. Biogas volume

In Fig. 4, the experimental data in the case of mesophilic temperature are compared to those obtained in the case of thermophilic temperature. The results shows that the increase of temperature leads to increase the biogas production, the optimal biogas volume production can be obtained in the case of thermophilic process (55-70°C), it is about 435 ml, while it is about 144 ml under mesophilic process (20-45°C). The same observations have been reported by Sambo *et al.* (1995) [14], they reported that in excess of temperature leads to slow down gas production.

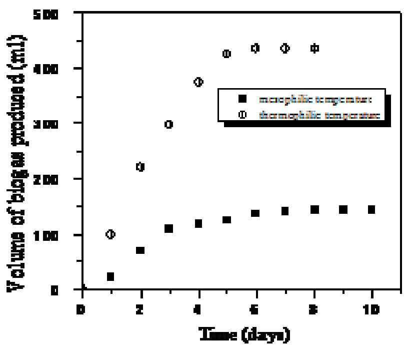

Fig. 4 : Effect of temperature on volume of gas produced

Analysis of gas composition have been carried out using Perkin Elmer Clarus 500 headspace sampling coupled with gas chromatography (HS-GC). The nitrogen carrier gas flow is 0.95 bar. It is found that the biogas produced comprising mainly CH_4 and CO_2 (Fig.5).

4. Total sugar

Fig 5 shows the total sugar content of the cells. It can be seen that the amount of sugar in the culture medium decrease about 53% during the first 3 days after assimilation of sugar by cells which is important in methane production. The sugar is used as an energy source by cells. Then total sugar increased in less important proportion before reaching stability but reflected also the reactivation of methanisation process. This accompanied by a progressive consumption of nutrients.

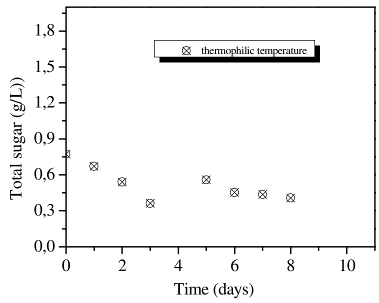

Fig. 5 : Kinetic variation of total sugar

V. Conclusion

The biogas production from the apricot and orange juice cocktail has been experimentally studied. Among the two temperatures studied, experimental results clearly show that the biogas production was highest from the digester operated at thermophilic mode, in this case the quantity of biogas produced is about 435 ml. The anaerobic decomposition of biomass improves with increase of temperature. In such case the fermentation process takes place much faster. Analysis of gas composition have been carried out using headspace sampling coupled with gas chromatography (HS-GC). It is found that the biogas produced comprising mainly CH_4 and CO_2.

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