Optimization of Sebac Start up Phase of Municipal Solid Waste Anaerobic Digestion

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Laboratory studies on dry anaerobic digestion of mixture of organic fraction of municipal solid waste, mainly putrescible fraction selected source (SS–OFMSW), and others organic compounds (garden waste, rice hulls, animal waste and sludge) demonstrated the optimum efficiency at 35 % total solid and thermophilic conditions (55 °C). Five starts up and stable phase strategies of SEBAC system were compared and a protocol of start up phase elaborated. The mixture of animal waste with SS–OFMSW in the reactor disposed in two layers favored the waste biodegradation and this suppose an important modification in the conventional SEBAC system configuration. However, the treatment strategy using 50 % SS–OFMSW, 15 – 35 % rice hulls or 15 – 35 % garden waste solved the operational problems and favored the star up and stable phase of the process.

Following the conclusions of all experiments, a protocol of start up and stable phase was elaborated. A system operating the optimized protocol showed a rapid start up in the 2 days, initial stable phase in 20 days and initial dead phase in 100 days. At these conditions the performance of this system were a gas production of 6.5 L d^{-1} and the mean methane production of 7.35 per unit mass (1 g) VSS in all experiment; or proximally of 50 % CH_4 in the stable phase.

Key words:
Anaerobic digestion, SEBAC system, thermophilic, source–sorted of organic fraction, biogas

Introduction

Municipal solid waste (MSW) is an environmental and social concern due to large-scale pollution and environmental effects resulting from improper management of municipal deposits. Even the disposal of a fresh solid waste in landfills still remains at unacceptable levels.

The most relevant factor in Europe is the daily production of about 400 000 tons of organics of municipal solid waste.[1] There is an increasing interest for MSW management and disposal due to stringent environmental regulations in the European Union.[2] Nowadays, to reduce the amount of waste that is eventually landfilled or incinerated, new technologies have been introduced, such us pretreatment processes, sorting and recycling.

Anaerobic digestion process has been considered the main commercially option for treatment and recycling of biomass wastes.[3] This integrated system transforms the problem into resources without polluting the environment, reducing biosolid volume with the advantage of producing biogas (methane).

In fact, there are currently more than 50 full scale plants of anaerobic digestion with a treatment capacity of more than 1 million ton per year of solid organic waste, and this capacity are steadily increasing all across Europe.[4] The increase implementation of recycling and source separation programs increased the potential for successful application of anaerobic treatment to organic fraction of municipal solid waste (OFMSW).

Other advantages of the high biogas volume production by anaerobic digestion of municipal solid waste are full resource recovery and preservation of non-renewable energy resources, reduction in greenhouse gas emissions and odors when compared to combustion/incineration, aerobic composting and pyrolysis.[5,6] Furthermore, the applications of anaerobic digestion process reduce carbon dioxide emissions and allow a coupled post–composting process.[7]

Composition of organic fraction of municipal solid waste is affected by various factors, including regional differences, climate, collection frequency, season, cultural practices, as well as changes in the composition which could occur during a year.[8] In this way, many papers had been applied on aspects of anaerobic digestion biodegradation of the putrescent fraction of MSW.

For instance, in laboratory scale, there are serial reports of anaerobic digestion of MSW in SEBAC process,[6,9] in leach bed process,[10,11,12] market waste,[13] domestic waste,[14] fruit and vegetable waste,[15,16] and mechanically sorted and source-sorted OFMSW.[17] In this finish work, *Mata-Alvarez* et al. concluded that feeding exclusively source-sorted OFMSW, or fruit and vegetable waste, or in general, highly biodegradable waste, it is advisable to use a two phase anaerobic digestion process, which permits higher loads in the digesters.

However, several new approaches have been tried to improve the efficiency of semidry anaerobic digestionxiii and dry digestion process (30 – 35 % TS), where no or little water, or sludge,[18] could be added to the organic urban wastes.iv In addition, some systems have been designed to operate in the thermophilic temperature range (approximately 55 °C) for accelerating anaerobic digestion. Thermophilic operations are a reliable and acceptable option for digestion of organic urban wastes.[19]

There is considerable interest in applying this technology to the MSW problem, leading to a number of systems, which demonstrate the feasibility of the process. Among the various processes and technologies available for accelerating anaerobic digestion of the biodegradable fraction of MSW and which could feasibly be scaled up, is the SEBAC process.

The SEBAC process requires two reactors: one containing unsorted fresh waste and the other anaerobically stabilized waste.[9] The process consists to wet a fresh waste with stabilized waste until obtaining a leachate (free moisture) trickle out of the bed. The stabilized waste contains an active and anaerobic balance population of acid-forms and methanogens. The procedure is repeated until a balanced active bacterial population is stabilized in the bed of fresh waste. This bed can be used to initiate inoculation of new bed.[6] The reactors operating in acidogenic and methanogenic conditions produce methane gas. The process guarantees stability with a built-in mechanism for prevention of imbalance, does not require solids handling during the digestion process, it is simple in design and is easy to operate.

A leachate management strategy (or leachate recirculation) was developed for enhance the degradation of solid waste[20,21] while facilitate provision of nutrients and microbes.[22] However, active researches on microorganism activity have been reluctant of accelerating the biological degradation of MSW, mainly the wastes with high contents solid.[23] Then *Ahring*[24] compared two starts up strategies for the thermophilic manure digesters and illustrates that even, if thermophilic inoculum from similar system is available, the start up method is critical for success. Ours results suggest that the effects of several operational parameters on performance of start up strategy for each type of OFMSW should be explored.[25] Mainly, the fraction of total solids (% TS) and the number of stages have great impact on the cost, performance, and reliability of the digestion process.[26]

The objective of this work was related to optimization of traditional performance parameters, in order to evaluate the start up phase of SEBAC reactors for treatment of OFMSW, which content main putrescible fraction. The emphasis was on the rapid conversion of the OFMSW to biogas and final stabilized residue for accomplishing rapid onset of a balanced microbial population in SEBAC process. In addition, to elucidate the efficiency process using organic fraction of municipal waste, rice hulls, garden waste and swine digested waste and, finally, to elaborate a protocol method for start up phase.

Material and methods

Samples and process description

Laboratory studies were done on dry anaerobic digestion of mixture of organic fraction of municipal solid waste, mainly putrescible fraction selected source (SS-OFMSW), from the university restaurant of Faculty of Sea Science & Environmental Sciences of University of Cádiz. The SS-OFMSW was selected, dried (until 20 – 10 % moisture content), and finely shredded in a cross-beater mill to an average particle size of about 2 mm in order to obtain a homogenous sample.

The SS-OFMSW sample was mixed with two types of structural agent: garden waste (GW) obtained from university garden, and rice hulls (RH). Before closing the reactor SS-OFMSW, distillated waster was added until obtaining a TS content at around 35 %.

The swine digested waste (SDW) was obtained from old experiments with SEBAC process. The Guadalete Wastewater Treatment Plant, placed in Jerez de la Frontera (Cadiz-Spain), supplied digested sludge (SLUDGE) by mesophilic conditions.

Table 1 gives initial SS-OFMSW composition in terms of parameters that generally indicated the biodegradability of complex substrates.

The experimental was carried out in a batch discontinuous reactor of PVC with an internal diameter of 0.30 m, a total height of 0.50 m, and the volume capacity of 25 L (laboratory scale), and the application of dry single–phase thermophilic

Table 1 – *Initial mean characteristics of the substrates used in the experiment*

	quantity	Initial values
SS-OFMSW	w_{TS}, g kg^{-1}	83.0
	γ_{VSS}, g L^{-1}	3.4
	Moisture, %	17.0
	COD (w_{COD}), 10^{-6}	4536.0
	pH	6.5
	Alkalinity (g $L^{-1}_{CaCO_3}$)	3.0
	Density ρ, kg m^{-3}	500
	$\gamma_{TN,}$ g kg^{-1}	12600.0
SDW	w_{TS}, g kg^{-1}	57.8
	γ_{VSS}, g L^{-1}	3.5
	Moisture, %	42.2
	COD w_{COD}, 10^{-6}	3440.0
	pH	7.4
	Alkalinity, g L^{-1} $CaCO_3$	61.5
	Density ρ, kg m^{-3}	1200
	w_{TN}, g kg^{-1}	5712.0
SLUDGE	w_{TS}, g kg^{-1}	4.2
	γ_{VSS}, g L^{-1}	3.7
	pH	8.26
	Moisture, %	95.8
	COD (w_{COD}), 10^{-6}	1136.0
	Alkalinity, g L^{-1} $CaCO_3$	844.5
	Density ρ, kg m^{-3}	900
	w_{TN}, g kg^{-1}	2520.0

(55 °C) anaerobic digester. In the reactor there is complete absence of any mechanical part inside. This allows the systems to operate in high–solid conditions without any hindrance to the matter circulation and without maintenance of mechanical devices.

The SEBAC process consisted of two reactors connected, one containing unsorted organic fraction fresh waste and the other stabilized organic waste. In this experiment DS, a potential digested waste, replaced the stabilized organic waste. Table 2 gives details of the composition of reactors in different SEBAC systems prepared.

Table 2 – *Composition of two reactors A and B in the SEBAC systems*

SEBAC Systems	mass fraction	
	REACTOR A	REACTOR B
SEBAC 1	SS–OFMSW	SLUDGE
SEBAC 2	two layers of SS–OFMSW and two layers of SDW	SLUDGE
SEBAC 3	one layer (50 % SS–OFMSW + 35 % GW + 15 % RH)	SLUDGE
SEBAC 4	one layer (50 % SS–OFMSW + 15 % GW + 35 % RH)	SLUDGE
SEBAC 5	one layer (85 % SS–OFMSW + 15 % RH) and one layer (85 % SDW + 15% RH)	SLUDGE

On daily leachate recirculation, analyses were performed and the biogas production and composition were analyzed. Both, the reactors A and B were independently connected to a 40 liters tedlar bag.

The reactors during the experiments were kept inside a special room constructed with galvanized steel foil (0.5 mm) and an intermediate portion of an isolating extinguishable foam (density of 40 kg m^{-3}) (FAYMO-M, Spain). Temperature was controlled by 3 electric heaters (model PC–1000W, S&P, Spain) and monitored by digital sensors (Thermo digital-TFFI, Spain) installed inside the room. An electric fan circulated the air inside the room.

Analytical procedures

The quantities analyzed for the characterization of wastes (SS-OFMSW, SDW and SLUDGE) were: Density, Total Solids (TS), Total Volatile Solids (TVS), Total Suspended Solids (TSS), Volatile Suspended Solid (VSS), Fixed Suspended Solid (FSS), pH, Alkalinity, Total Nitrogen (TN) and Ammonia Nitrogen (NH_3–N), and Total Organic Carbon (TOC). Determining the following quantities monitored the digestion process: TSS, VSS, FSS, pH, alkalinity, TN, NH_3–N, composition and production of biogas. All analytical determinations were performed according to "Standard Methods",[27] after previous drying, grinding and dilution of the samples; this procedure is more representative because of the semi–solid characteristic of the substrate (except TN, TS, and VS that is not necessary dilution of the samples[28]).

The TOC analysis was carried out in a *SHIMADZU 5050* TOC *Analyzer*, for combustion-infrared (5310B) of "Standard Methods". TS and VS analysis were determined by glass filter method; and the TSS samples were dried in an oven at 105 – 11 °C, and for VSS to the dried ash waste in a furnace at 550 ± 5 °C.[27]

The alkalinity of samples was determined in *COMPACT TITRATOR S+-Crison Instruments* S.A. Gaseous analyses were determined by removing a representative sample from the reactor. The volume of gas produced in the reactor was directly measured using a high precision flow gas meter– WET DRUM TG 0.1 (mbar) – *Trallero and Schlee S.A.* – through a meter displacement bag CALI 5 BOND™ – *Trallero and Schlee S.A*. Moreover, the gas composition was carried out by infrared detection in a *GAS ANALYSER 94 A (Geotechnical Instruments, UK*).

Results and discussion

Physical and chemical characteristics of substrates

The experiments were conducted in SEBAC systems with reactors on a laboratory scale, on dry anaerobic digestion at total solid (TS) of 35 % TS and thermophilic conditions (55 °C). In these studies, SLUDGE was employed as feed, and used to obtain an adequate inoculum that would be used as substrate in the anaerobic digestion process. The initial characteristics of SS-OFMSW, SDW and SLUDGE used in the experiments are presented in table 1.

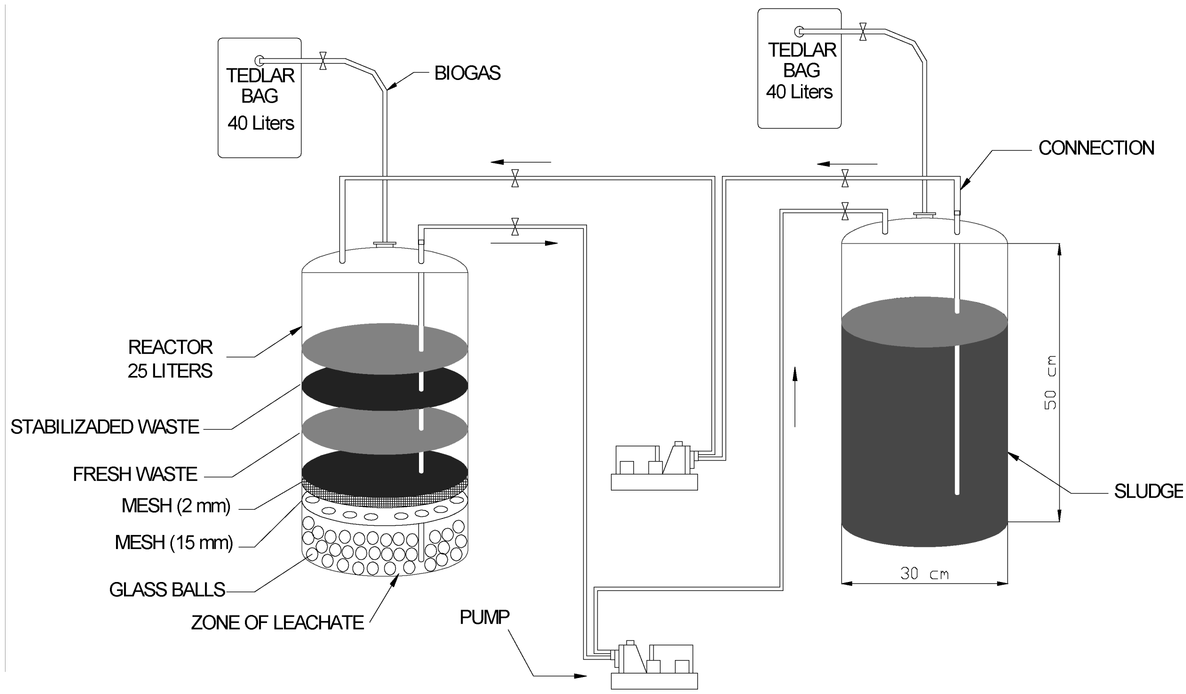
The TS mass fraction had an average of approximately 83.0 g kg^{-1} (83 %) of SS–OFMSW and 57.8 g kg^{-1} (57.8 %) for SDW, which is significantly higher than the 4.0 % TS of SLUDGE, and typically value of sludge digested in a mesophilic anaerobic digester.[18] The SS-OFMSW and SDW constituted a high-solid substrate, with an organic content of 99 % (measured by VS).

The pH and alkalinity of SLUDGE were 8.26 and 844.5 g L^{-1} $CaCO_3$ respectively (Table 1). This showed an adequate alkalinity to maintain a stable pH in the digester for optimal biological activity.

Start-up strategy pretreatment

Pretreatment was designed for the study of start up phase in the SEBAC system using different layers of layouts in the reactor with SS-OFMSW and the SDW, and using SLUDGE as source of inoculum. The new configuration of the SEBAC system with high-solids reactors in the start-up phase had the objective to maximize the biodegradation efficiency of fresh waste.

The SEBAC system used in the experiments followed the classical configuration of two reactors, one reactor A with fresh waste, and another reactor B with stabilized waste. The SEBAC 1 system was composed of two reactors: one reactor A with SS-OFMSW (2 mm mesh net, 15 mm mesh net and a glass balls layer) and another one (reactor B) with SLUDGE. However, the SEBAC 2 was composed of one reactor A with two substrates (SS-OFMSW and SDW) in layers: two SS-OFMSW layers and two SDW layers, both alternating, 2 mm aperture mesh nets; 15 mm mesh net and a glass balls layer. Another one (reactor B) contends SLUDGE (Figure 1).



F i g . 1 – *Schematic diagram of the experimental reactors SEBAC*

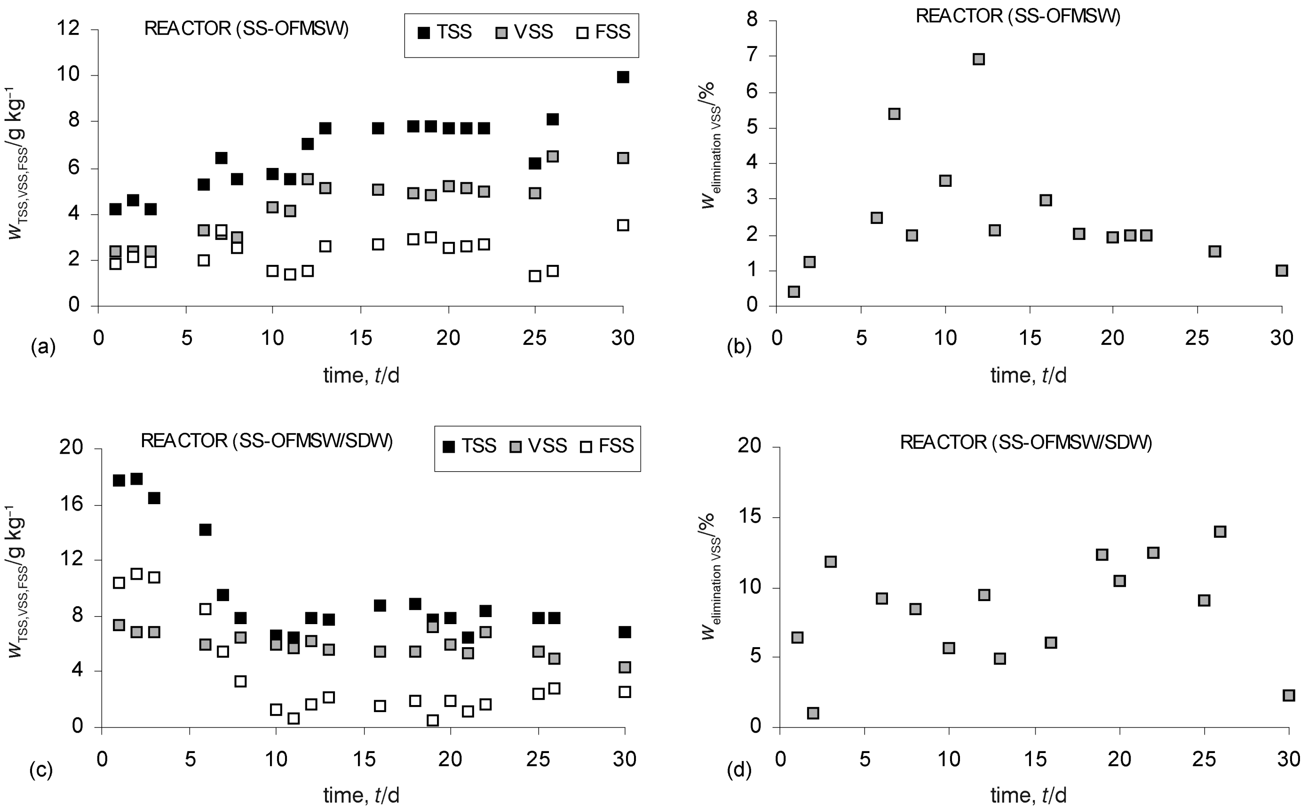


Fig. 2 – *Reactor performance data in the reactor A: (a) TSS, VSS, FSS and (b) elimination VSS levels of SEBAC 1; (c) TSS, VSS, FSS and (d) elimination of VSS levels of SEBAC 2*

The SEBAC 1 system exhibited poor performance during start up. The solids (TSS, VSS and FSS) (Figure 2a, 2b) and the gas production (about 0.9 L) showed litter degradation of organic material at 10 days after the initial of experiment (Figure 3c). The biodegradability of SS-OFMSW was approximately 14.0 % (calculated from COT values). After 30 days, the SEBAC 1 system showed several operational problems, most of them related to leachate production and probably due the reactor A composition (SS-OFMSW). Consequently, after 35 d of operation, the reactor B (SLUDGE) presented low high–solids digestion. This is due to the reduced feed from the reactor A not allowing the recovery of the theoretical leachate amount that would be needed to feed the inoculum reactor (B).

In contrast, the rapid start-up phase was obtained in SEBAC 2, which was initiated in 3 days (Figure 2c). The mixture of SS-OFMSW+SDW in the reactor A (SEBAC 2) disposed in layers favored the start up phase of dry anaerobic digestion in thermophilic conditions, compared with the reactor composed of SS-OFMSW (SEBAC 1). The reactor with SS-OFMSW/SDW, in the solids analyzes (TSS, VSS and FSS) showed a quickly degradation in the first ten days, and a mass fraction of VSS elimination medium of 6.7 during all experiment (Figure 2a, 2b). *Largus* et al.[29] reported on anaerobic treatment of animal waste with an attractive strategy to accelerate the start up phase. The SEBAC 2 presented the highest gas production (about 10.7 L) what took place in 10 d during the start-up phase (Figure 3a). In the same period, the system provided increased CH_4 concentration in the biogas obtained. The mean values of accumulation CH_4 was approximately 65 L at 30 d of experiment (Figure 3b, 3c). The biodegradability of SS-OFMSW+SDW was approximately 24.0 % (calculated from COT) in the first 10 d, higher than those obtained with the SEBAC 1 system.

Based on the results, obtained from the experimentation with SEBAC 1 and 2, can be drawn out that the slow degradation of SS-OFMSW in the SEBAC 1 is related with organic fraction composition. The SS-OFMSW was composed mainly of food waste and thus contained high levels of proteins, carbohydrates, fats, oils, and fatties, with low fiber content. The organic fraction composition could be a critical element responsible for the compaction of the material inside the observed reactor A. Consequently, efforts were done to select an adequate composition of the SS-OFMSW and pre-treatment procedure in order to allow an adequate leachate percolation in the reactors.

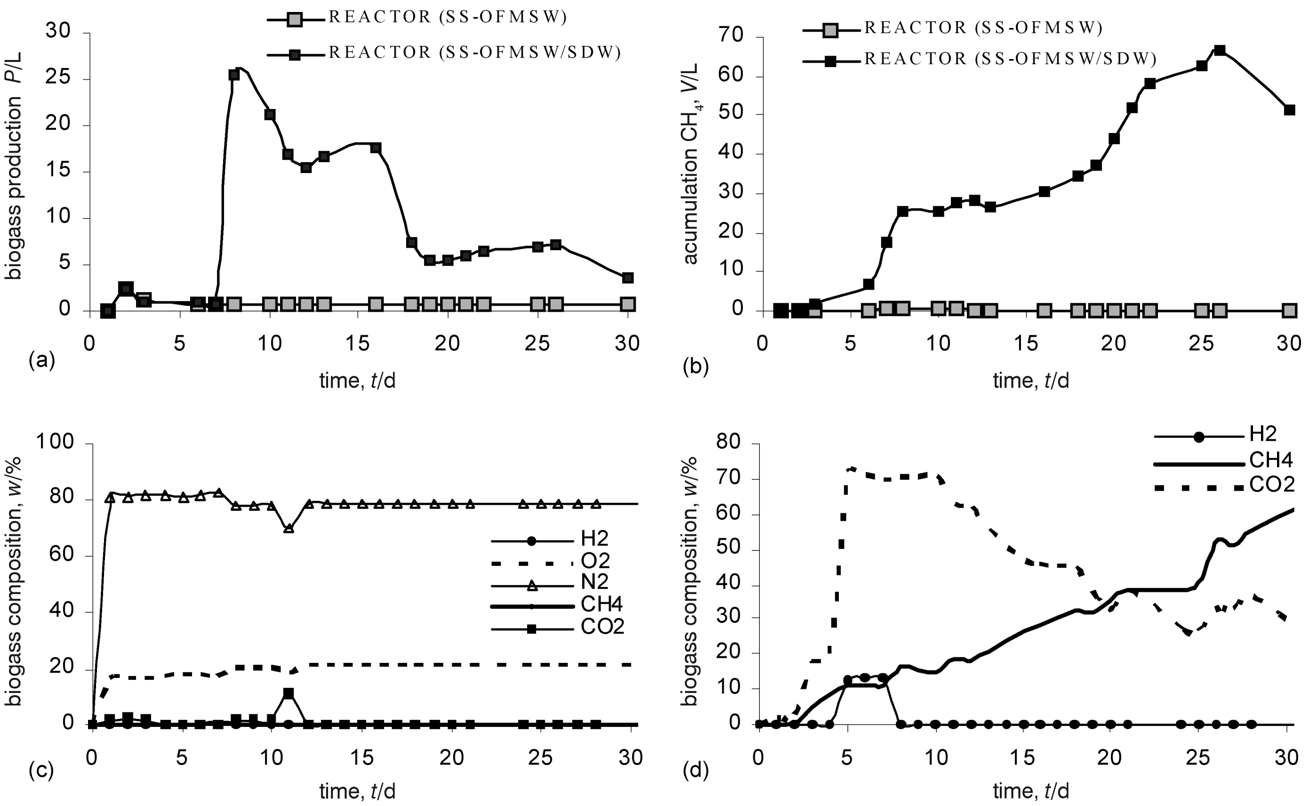


Fig. 3 – *Profiles of different biogas parameters in the reactor A: biogas production (a) and methane accumulation levels (b) of SEBAC 1 and 2; biogas composition in the reactor B of SEBAC 1 (c) and SEBAC 2 (d)*

Performance of start up strategy in the SEBAC 3 and 4 systems

Since the performance of the SEBAC 1 system was not satisfactory a new start up strategy was adopted modifying the characteristic of the reactor A (SS-OFMSW) and two new SEBAC systems (SEBAC 3 and 4) were built. The characteristics of the A reactor (SS-OFMSW) was modified by the addition of a structuring agent and by increasing the drying period in the SS-OFMSW pretreatment (24 hours at 55 °C and 24 h at ambient temperature). The increase of the drying period led to important modifications of the starting material physical characteristics, although it did not altered the moisture of the sample (10 – 20 %).

The SEBAC 3 system was composed of one reactor A with a layer of waste (50 % SS-OFMSW, 15 % of GW and 35 % RH), a 2 mm mesh net, a 15 mm mesh net and a glass balls layer. The SEBAC 4 system was composed of one reactor A with a layer of waste (50 % SS-OFMSW, 35 % of GW and 15 % RH), a 2 mm mesh net, a 15 mm mesh net and a glass balls layer. The reactor A (SEBAC 3 and 4) was moistened and inoculated by leachate from the same reactor B (SLUDGE).

The operation quantities of anaerobic biological degradation of SS–OFMSW reactors A (SEBAC 3 and 4), SS-OFMSW were determined by monitoring traditional performance quantities: TSS, VSS, FSS, pH, alkalinity, COD, NH_3–*N*, composition and biogas production. The initial degradation can be seen by the trends of the pH, alkalinity, NH_3–*H* and TSS quantities in the first week (Figure 4).

The pH, alkalinity and NH_3–*N* of the reactors A (SEBAC 3 and 4) showed a significant increase at 25 day and later on a significant increase until 50 days of experimentation (Figure 4a, 4b, and 4c). After this period, these quantities remained constant. These results show an adequate alkalinity and ammonia levels to maintain a stable pH in the digester for optimal biological activity, and could be the indication of a stable phase, starting from 25th day. The solids analyzes (TSS, VSS and FSS) showed an increase in the first ten days consequence of sludge feed with high solid content; later on begin the degradation process (Figure 4d). The biodegradability of SS–OFMSW in this experiment for SEBAC 3 and 4 were 26.63 % and 20.21 %, respectively, calculated from COD values.

The daily gas production and gas composition was monitored in the SEBAC 3 and 4 systems. The biogas production and composition between the reactors A of both SEBAC showed similar performance. In this case, the Figure 5 showed the biogas

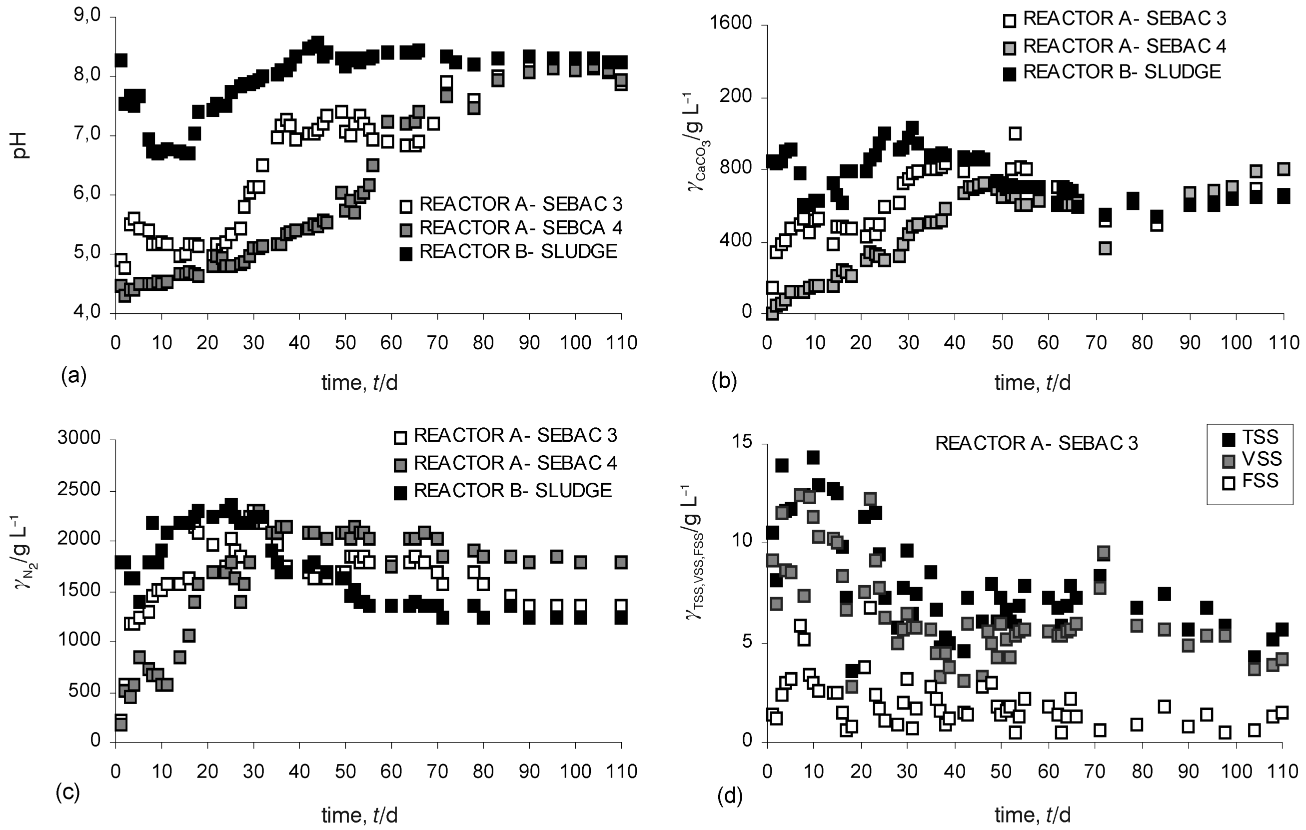


Fig. 4 – *Reactor operating and performance data: (a) pH, (b) alkalinity and (c) amoniacal nitrogen levels of SEBAC 3 and 4; (d) TSS, VSS, FSS levels in the reactor A of SEBAC 3*

evolution in the reactor A of SEBAC 3. The mean gas production in the first 75 days of control was 2.48 L $^{-1}$ and the mean methane production was 4.47 L g^{-1} VSS, suggesting a good methanogenic activity (Figure 5a, 5b). The methane gas concentration increased since initial start up of anaerobic digester until the end of steady state, like the carbon dioxide (Figure 5c). The hydrogen showed a significant increased in 3 and 7 days consequent of start up phase, later on showed a litter production in the stabilization phase, probably due the structure waste degradation, rice hulls and garden waste.

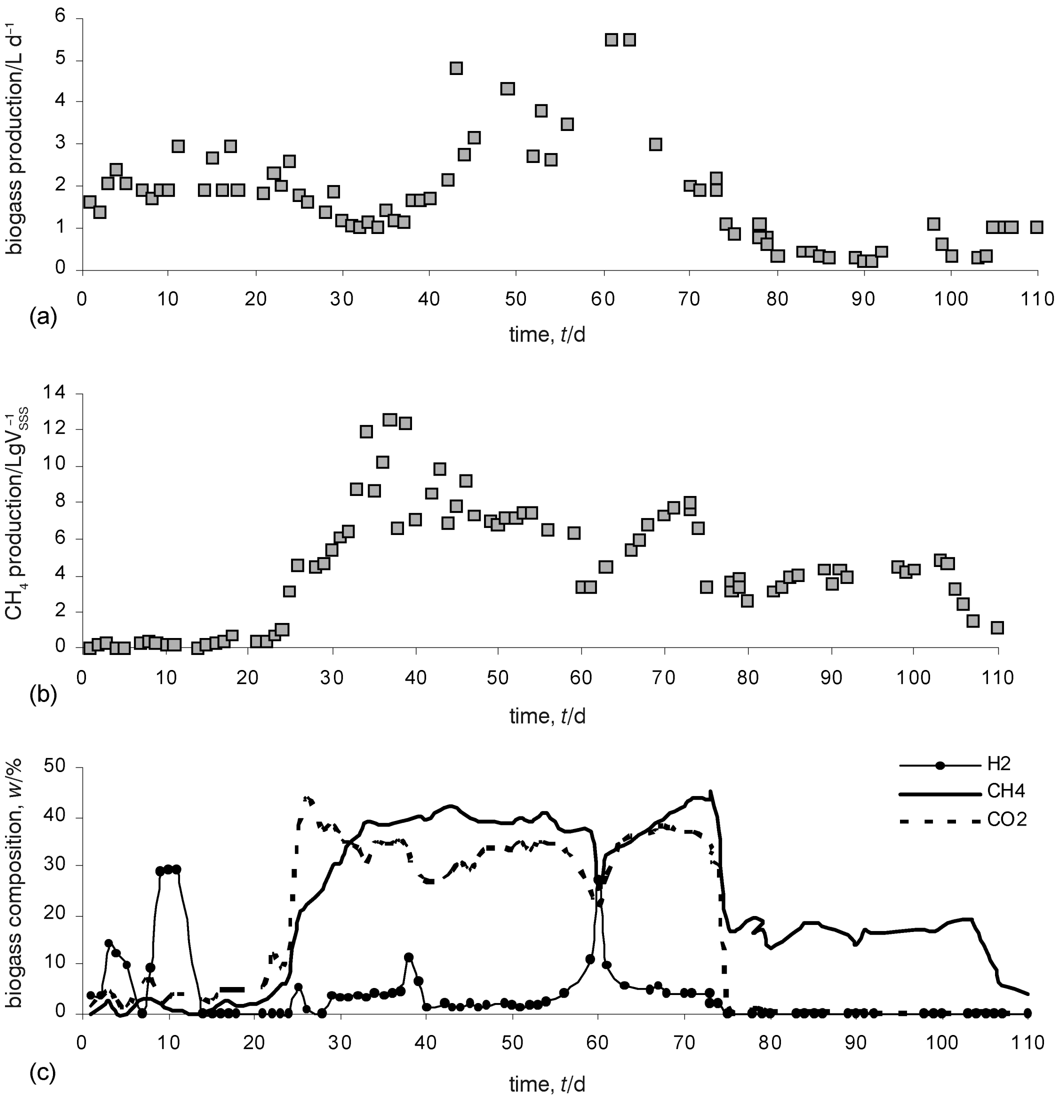
The SLUDGE reactor showed a reduction of pH between 5 to 15 d (Figure 4a). This period also belongs to the steady state of both SS-OFMSW reactors (SEBAC 3 and 4), regarding a period of adaptation of SLUDGE with SS-OFMSW feed. After this period of adaptation, the reactor B of SLUDGE showed favored performance parameters: the pH (8.23 ± 0.18) and alkalinity (760.4 mg L^{-1} ± 130) satisfactory levels and constant until the end (Figure 4a, 4b). According *Nagase* and *Matsuo*[30] the limiting factor of overall methane fermentation for the sludge is hydrolysis, in contrast for soluble sugars the methanogenesis activity is the limiting factor. In fact, anaerobic biological degradation of SS-OFMSW reactor of SEBAC 3 and 4 exhibited favored performance of start up phase feed SLUDGE with inoculum source. These results suggest that anaerobic SLUDGE, from a stable sewage sludge digester provided, could be adjusted to fresh waste and favored a balance microbial population. Results also illustrated, by *Griffin* et al. in the anaerobic co digestion, that a mixture of two mesophilic inoculum was successful for the rapid start up performance (anaerobic sludge and cattle manure), in the treatment of MSW with a high content of nutrient.

Optimization and protocol of the start up phase SEBAC system

According to conclusions of all anterior experiments, the start up phase of SEBAC system of SS-OFMSW in thermophilic anaerobic digestion was optimized and a protocol of start up and stable phase was elaborate. The protocol of start up and steady state phase of reactor SEBAC for SS-OFMSW treatment consisted as follows:

– the pretreatment of SS-OFMSW consists of drying period of 24 h at 55 °C and 24 h at ambient temperature;

– the SS-OFMSW and SDW should be both mixed with 15 % of the rice hulls or garden waste,



F i g . 5 – *Profiles of different biogas parameters in the reactor A of SEBAC 3: biogas production (a), methane production (b) and biogas composition*

after what the water should mixed until the moisture is 65 %;

– composition of reactor A for the reactor with 25 liters of capacity should be: two SS-OFMSW layers (1.0 kg of fresh waste each layer) and two SDW layers (1.5 kg of stabilized waste each layer);

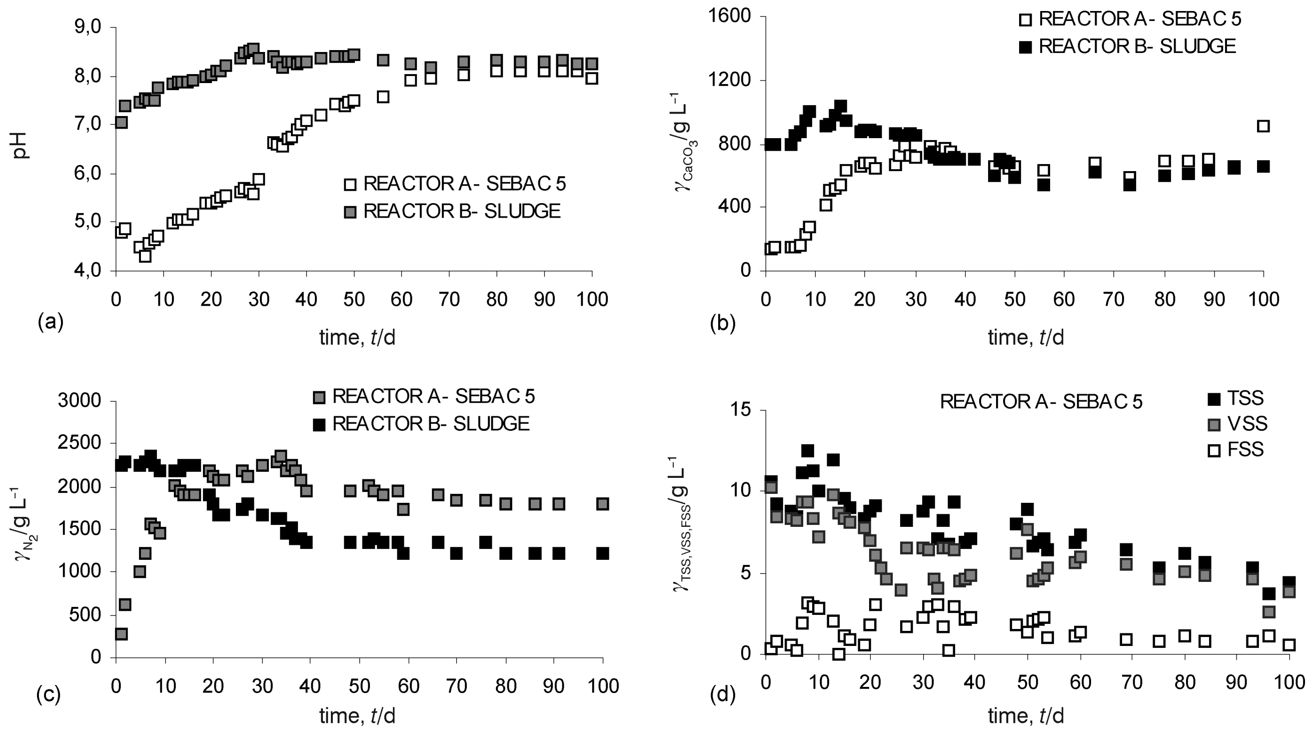
– the waste layers should be divided with mesh net of the 2 mm;

– the reactor A should contain a 2 mm mesh net at the bottom of the layers, a 15 mm mesh net and a glass balls layer (sufficient for 15 % of the leachate production);

– the composition of reactor B should be: mesophilic digested sludge.

In this experimental a new SEBAC 5 system was being built, with all the best characteristics of previous SEBAC system, and using the optimized protocol. The SEBAC 5 system is composed of one reactor A with SS-OFMSW and SDW in layers (both mixed with RH) and one SLUDGE reactor B (Table 2). The reactor A consisted of two SS-OFMSW layers (1.0 kg of organic waste each layer) and two SDW layers (1.5 kg of digested waste each layer). The layers were dividing with a 2 mm mesh net, a 2 mm mesh net at the bottom of the layers, a mesh of 15 mm net and a glass balls layer.

Figure 6 shows the performance of main quantities for the SEBAC 5 digesters. The reactor A (SS-OFMSW/SDW) showed a constant increase of the pH, alkalinity and NH_3–N, until it approached satisfactory levels at day 25 (Figure 6a, 6b and 6c). The pH and alkalinity increased are favored by the increase of free ammonium concentration, which could be explained by hydrolysis product of domestic proteins and consumption of acetic acid during denitrification in the start up. After 25 d, the chemicals quantities (alkalinity and NH_3–N), of both reactors A and B remained constant until the end of



F i g . 6 – *Reactor operating and performance data in the reactor A and B of SEBAC 5: (a) pH, (b) alkalinity, (c) amoniacal nitrogen and (d) TSS, VSS, FSS levels in the reactor A*

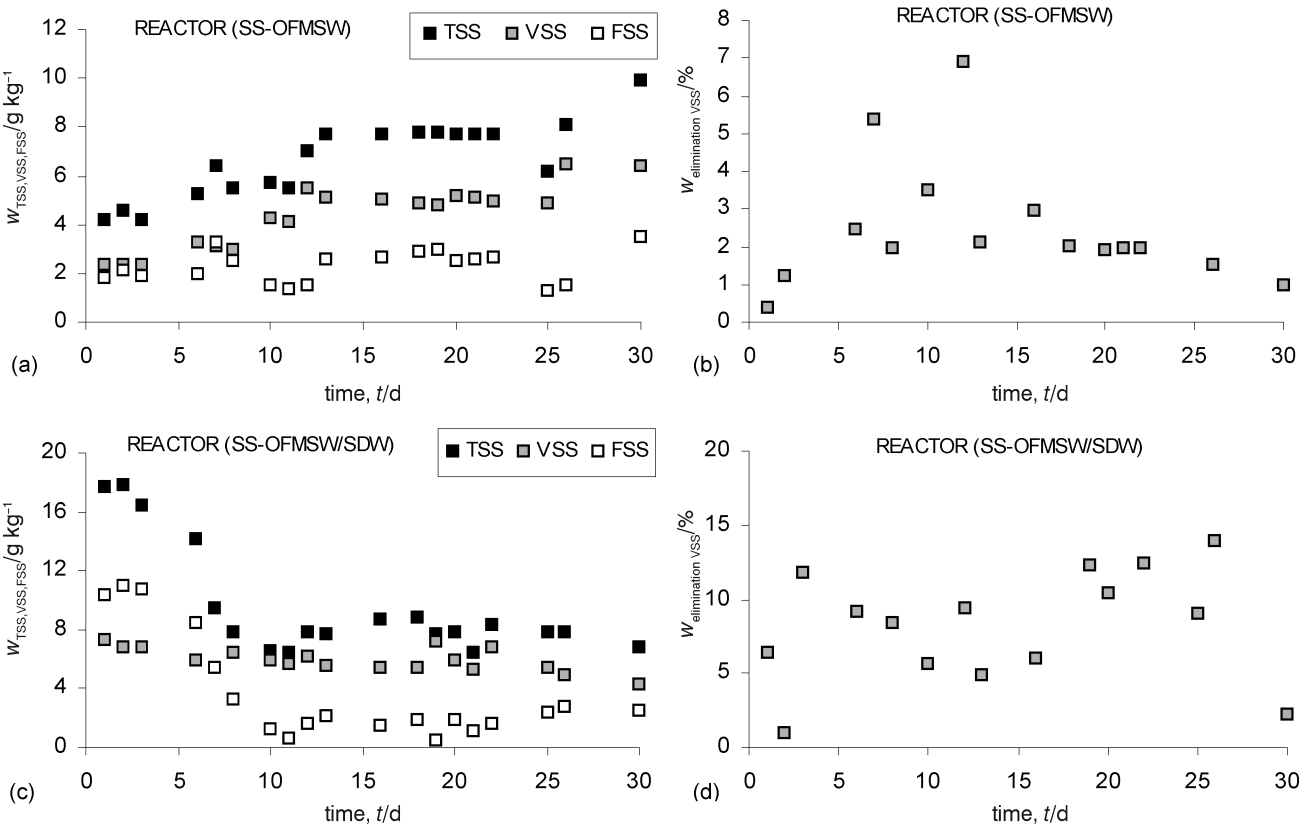
the experiment, suggesting the initial sequence of stabilization phase. The Figure 6d showed a constant solids reduction until the end of the experiment only starting from day 10. The results suggest that the period of adaptation phase of organic fraction fed of sludge. The reactor A with SS-OFMSW/SDW presented a biodegradability of 88.31 %, calculated from COD values, which was much higher than those observed in the others SEBACs, and the reactor B with SLUDGE presented a biodegradability of 28.24 %.

The gas composition and production of, both, reactors A and B can be seen in Figure 7. In the reactor A (SS-OFMSW/SDW) the mean gas production was 6.5 Liter/day and the mean methane production of 7.35 L g^{-1} VSS in all experiments (Figure 7a, 7b). The biogas composition rate can be seen in Figure 7c. The initial methane production occurs in the second day suggesting an initial of start up consequent of accelerate degradation of waste and methanogenic activity. The process demonstrated exhaust of methane production after 80 d of stable phase. The methane gas concentration during the stable process was proximally of 50 % CH_4. A similar result was observed by *Castrillón* et al.[31] in anaerobic treatment of MSW landfill leachate. The absence of oxygen of the biogas occurred at 12th d after the initial experiment, while the carbon dioxide methane content increased gradually and remained constant until final phase. The nitrogen production by biological denitrification of the feed nitrate increased rapidly after the reactor start up, thereafter the nitrogen content remained constant until the end. Figure 7 showed the little levels of hydrogen production in the stabilization phase due to the rice hulls and garden waste slow degradation (Figure 7d).

Conclusions

The start up and the initial phase of stabilization of system are generally the most critical steps in the operation of anaerobic digesters. In this study, five starts up strategies for thermophilic SEBAC system of MSW digesters were compared.

In conclusion, a mixture of SDW with SS-OFMSW in the reactor disposed in layers favored the rapid start up phase of dry anaerobic digestion in thermophilic conditions, compared with the reactor with SS-OFMSW only. These results suppose an important modification in the configuration of conventional SEBAC process. However, the nutrients composition of SS-OFMSW could be critical element, possibly related to the low fiber content, causing compaction of the material inside the reactor A and low leachate production, that reduced feed from the reactor B. The results obtained in the start-up strategy using 50 % SS-OFMSW, 15 – 35 % rice hulls or 15 – 35 % garden waste resolved the operating problems and favored the start up and stable phase. This SS-OFMSW composition resolved



F i g . 7 – *Profiles of different biogas parameters in the reactor A of SEBAC 5: biogas production (a), methane production (b) and biogas composition*

the operating problems of low production of leachate in the reactor A.

According to conclusions of all anterior experiments, the start up phase of SEBAC system of SS-OFMSW in thermophilic anaerobic digestion was optimized and a protocol of start up and stable phase was elaborate. The system operate accorded of this protocol was SEBAC 5 system. The principal results were a rapid start up in the second day, initial stable phase in the day 25 and initial dead phase in the day 100. At these conditions the performance of this system was a gas production of 6.5 L d^{-1} and the mean methane production of 7.35 L g^{-1} VSS in all experiment, or proximally of 50% CH_4 in the stable phase.

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