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Effect of Agitation on Anaerobic Co-Digestion of Swine Manure and Food Waste

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HIGHLIGHTS

- This study investigated the effect of agitation on anaerobic co-digestion.
- The co-digestion of food waste and swine manure was evaluated.
- Agitation contributed to higher biogas production.

Abstract: The synergism of food waste associated with swine manure can provide an increase in biogas production, besides promoting greater stability in the anaerobic co-digestion process. To verify this effect, co-digestion tests were performed in two reactors, one with agitation, and the other without agitation. In both systems, gasometers were used to measure biogas production in an experiment lasting two hydraulic retention times (HRT). On each feeding day, the temperatures of the ambient and of the effluent taken from the reactors were measured, and samples of the food waste and effluent were collected to perform analysis of pH, total solids (TS), volatile solids (VS), fixed solids (FS), volatile acidity (AV), and total alkalinity (TA). In addition, the chemical oxygen demand (COD) was determined every five days, and gas composition was determined at the beginning of the second HRT. As important results, in both reactors a decrease in pH was verified due to the weakening of the buffer effect of the medium. This was due to the low alkalinity found in the food waste, causing an increase in acidity in the contents of the reactors. The volume of biogas produced was higher in the reactor with agitation, which meant an increased efficiency of the process. Finally, a low methane content was verified through chromatographic analyses, indicating a reduction in the activity of the microorganisms present in the medium. Thus, it is concluded that agitation linked to anaerobic co-digestion of swine manure with food waste exerted a positive effect on biogas production.

Keywords: agitation in reactors; co-digestion; food waste.

INTRODUCTION

The development of actions that stimulate the use of organic materials for the production of biofuels, such as animal waste and food waste, becomes an alternative to enrich the energy matrix, expanding the possibility of raw materials with potential for energy generation. Food waste consists of residues originated during the preparation of food and after meals [1]. On the other hand, the swine manure is produced in intensive breeding systems, generating a large amount of this material, requiring appropriate disposal and treatment [2].

Food waste and swine manure have different characteristics. The swine manure has a high buffering capacity and a low carbon/nitrogen (C/N) ratio. In addition, the ammonia concentration generally exceeds the recommended requirements for microbial growth and can become inhibitory to the development of methanogenic archaea [3-5]. In contrast, food waste has a high C/N ratio, can be easily hydrolyzed, has low buffering capacity and, depending on its biodegradability, produces a large amount of volatile fatty acids [6-8].

The anaerobic co-digestion of two or more feedstocks can overcome the problems inherent in the digestion of a single substrate [9], contributing, as an example, in stabilizing the pH, improving the buffering capacity of the medium and reducing the concentration of ammonia by dilution [4,5]. In this way, the performance of solid waste digestion is improved, since it allows increasing the biogas production due to the positive synergism established between the substrates and the supply of missing nutrients in the system [10].

To verify this behavior, Zhang and coauthors [11] performed digestion tests in laboratory considering as substrates food waste, swine manure and mixtures of both substrates. In the anaerobic digestion of food waste, it was verified a reduced methane production rate, the accumulation of volatile fatty acids and a reduction of pH. The digestion of swine manure, on the other hand, showed greater stability, but with a lower yield of methane production compared to the co-digestion trials.

Several parameters can influence the performance of anaerobic co-digestion and the conversion of feedstock into biogas. Agitation in biodigesters, for example, keeps the solids in suspension and homogenizes the input substrate with the active microbial community, avoiding dead zones and providing higher biogas production [12]. On the other hand, biodigesters without agitation (or with an inadequate agitation process) can promote non-uniform distribution of substrates, enzymes, and microorganisms, culminating in incomplete waste stabilization, decreased methane production, and pathogen destruction [13,14].

It is also important to highlight that it is a challenge to establish the relationship between the characteristics of the agitation process and the performance of the biogas production process, since a number of factors can have influence. Thus, studies need to be developed for each type of substrate used, reactor model employed, among other aspects. Thus, the present work seeks to evaluate the effect of agitation in anaerobic reactors in the process of co-digestion of food waste with swine manure in order to contribute to this field of research.

MATERIAL AND METHODS

The present study was developed in the Laboratory of Analytical Chemistry and Environmental Analysis at the Federal University of Paraná (UFPR) - Palotina Sector.

Assembly of anaerobic co-digestion systems

Reactor with agitation

An existing stainless-steel bench reactor was adapted with a motor and a speed reducer connected to a shaft to promote agitation. A single-phase 1/4 HP induction motor, model Aberle® B56E154 and an angular speed of 1730 rpm was used. The motor was coupled to a Romak speed reducer, model Q30 1/25 63B14 and reduction factor of 1:25. Thus, the rotation available in the stainless-steel reactor shaft was approximately 70 rpm, enough to promote the homogenization of microorganisms and raw material. This angular speed was close to that used by Rodriguez and coauthors [15], who employed 50 rpm in their experiments.

The reactor agitation was controlled by a digital timer programmed to run the motor for 10 minutes every 4 hours, thus resulting in 6 agitation processes per day.

The reactor had a height of 54 cm, internal diameter of 20 cm, and total volume of 18 L. During the experiments, only 15 L were filled with the microorganisms and raw material, because the effluent outlet was from the top, limiting the complete filling of the reactor, as observed in Figure 1. An oil seal was inserted in the central shaft to inhibit any gas leakage.

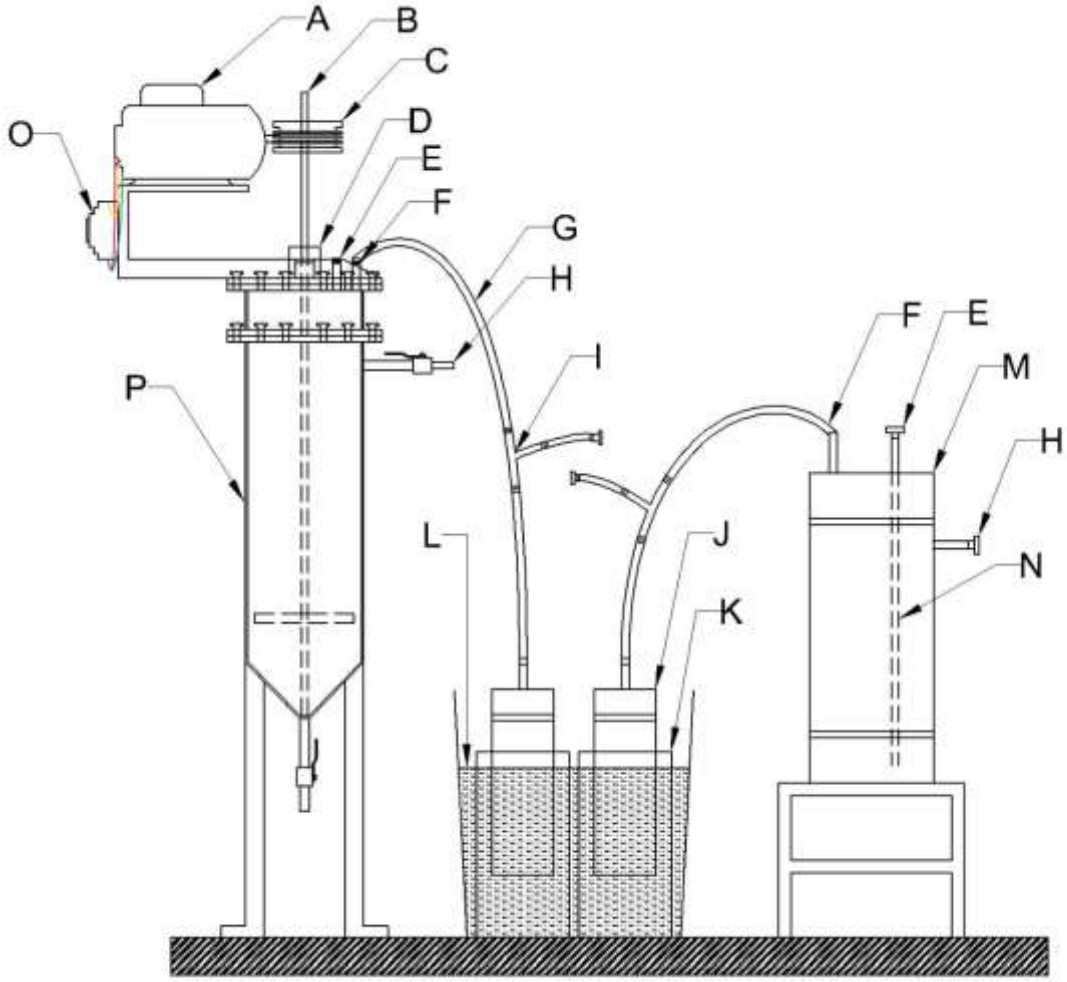

Figure 1. Representation of the reactors with and without agitation: A) Single-phase motor; B) Central shaft; C) Speed reducer; D) Oil seal; E) Feed inlet; F) Biogas outlet; G) Biogas hose; H) Effluent outlet; I) Connection for the collection of biogas samples; J) Gasometer; K) Gasometer guide; L) Salt solution seal; M) Reactor without agitation; N) Feed hose; O) Digital timer; P) Reactor with agitation.

Reactor without agitation

The reactor was built in bench scale using the materials presented in Table 1. The reactor without agitation was assembled with the use of a glass saw drill. The purpose of using the polyurethane was to attach the components and prevent any gas leakage. The reactor (Figure 1) had a height of 47 cm, an internal diameter of 20 cm, and a total volume of 15 L. During the experiments, only 10 L were filled with the microbial community and the raw material, with a 5 L space at the top for effluent removal.

Table 1. Accessories used to assemble the reactor without agitation.

Accessories	Amount
Polyvinyl chloride (PVC) pipe (200 mm diameter)	47 cm
PVC pipe cap (200 mm diameter)	2
PVC hose barb½''	3
PVC Female adapter ½''	3
Polyurethane	---

Measurement of biogas production - Gasometers

Biogas production was quantified using gasometers made with 100 mm diameter PVC pipes immersed in an acidified salt solution. Measurements were made based on the displacement of the pipe caused by biogas production. The measured volume was corrected for Standard Temperature and Pressure (STP) according to Equation (1) [16].

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad (1)$$

Where:
P_1 - Pressure STP (mmHg);
V_1 - Volume STP (L);
T_1 - Temperature STP (K);
P_2 – Local pressure (Palotina-Pr) (mmHg);
V_2 - Volume measured in the gasometer (L);
T_2 - Ambient temperature measured at the time of sample collection (K);

Table 2 shows the components needed to assemble a PVC gasometer. It was necessary to make two units, one for each reactor

Table 2. Components used to assemble a gasometer

Accessories	Amount
PVC pipe (100 mm diameter)	30 cm
PVC pipe cap (100 mm diameter)	1
PVC hose barb ½".	1
PVC Female adapter ½"	1
Polyurethane	---
PVC pipe guide (150 mm diameter)	30 cm

Guides were inserted into the container with saline solution to conduct the gasometers during biogas production (Figure 1). The saline solution consisted of 25% (m/v) sodium chloride and 3% (v/v) sulfuric acid and served as a water seal to prevent the biogas from leaking and dissolving the CO_2 contained in the gas [17].

Start-up and Feeding of reactors

The anaerobic co-digestion process in the reactors was initiated using fresh swine manure inoculum. The inoculum was added to the reactors with a percentage of 20% of the useful volume [18] and the rest was filled with fresh swine manure.

After the initial feeding of the reactors, a period of 15 days was waited for the bacteria to become adapted to the substrate. The anaerobic ecosystem does not settle immediately after the introduction of waste into the reactor, and it is necessary to wait a period for the microbial population to grow and reach an equilibrium point [19]. After this period, the reactors were regularly fed with food waste and the measurement of biogas production was performed by reading the displacement of the gasometers in the salt solution.

The food waste used for the experiment was collected from the university restaurant of the UFPR–Palotina Sector. The establishment operates from Sunday to Saturday, serving approximately 1300 meals a day, including breakfast, lunch and dinner.

The waste was collected in buckets after meals and transported to the laboratory. Next, the waste was prepared and then inserted into the reactors. The preparation consisted of removing the coarse materials, such as: bones, napkins and toothpicks. Next, the biodegradable material, consisting mainly of raw and cooked food waste such as rice, beans, meat, lettuce, bread, fruit peel, vegetables, eggs and coffee powder, were processed in a mixer (900W) together with water to reduce the particle size and adjust the density based on the fresh swine manure effluent and the inoculum initially used to feed the reactors. This feeding routine occurred on 3 days of the week: Mondays, Wednesdays and Fridays, and the hydraulic retention time (HRT) used lasted for 20 days, being performed two HRTs for each reactor, totaling a period of 40 days of experiment.

The composition of the food waste and the physical characteristics throughout the preparation process is shown in Figure 2.

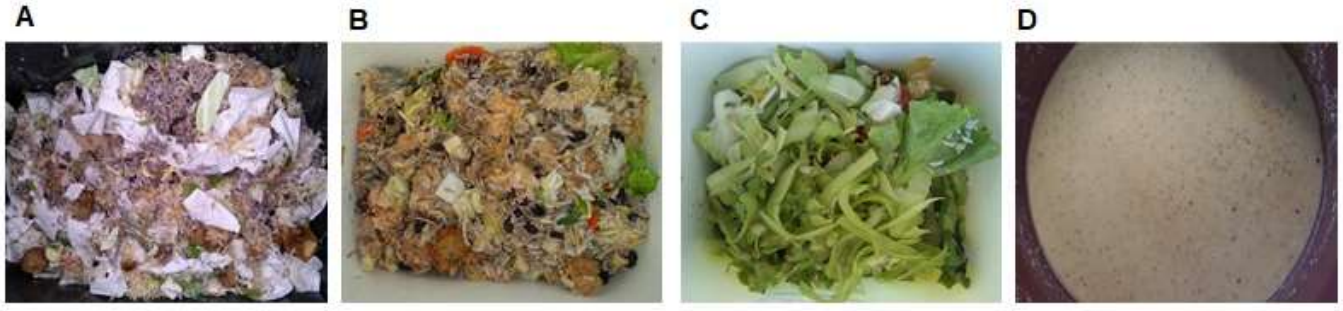

Figure 2. Processing of food waste: (A) food waste at collection; (B) food waste after removal of coarse materials; (C) raw food waste; (D) food waste after shredding.

The reactors were always fed after lunchtime in both HRT, thus maintaining a standardization in the feeding frequency. To determine the amount of food waste that would be fed to each reactor, Equation (2) was used.

$$Q = \frac{V_{net}}{HRT} \quad (2)$$

Where:
Q is the average reactor feed flow rate (L/day);
V_{net} is the reactor net/useful volume (L);
HRT is the hydraulic retention time (days);

The useful volumes for the reactors with and without agitation were 15 and 10L, respectively. The HRT was determined based on the literature [11,19,20], being selected for this study the most recurrent value found in the works, which was 20 days. Thus, the feeding volume of the waste on the respective feeding days for each reactor is presented in Table 3.

Table 3. Feeding volume of the reactors

Reactor/Flow	Mondays(L)	Wednesdays(L)	Fridays(L)
Reactor with agitation	1.5	1.5	2.3
Reactor without agitation	1	1	1.5

In the work, two HRT were adopted for each reactor. Thus, the first HRT was evaluated with the effect of the codigestion of swine manure with food waste (swine manure was added only to start the process), while in the second HRT the interest was to evaluate the digestion of food waste, assuming that the swine manure was no longer present due to the long period in which it was degraded.

Physicochemical, microbiological and gas composition analyses

Every time each reactor was fed with food waste, the same volume of effluent was collected through the reactor outlet connection (Figure 1 - point H), the effluent temperature was measured and the samples were stored for further analysis. Samples of food waste (reactor feed) and effluents from the reactors with agitation and without agitation were stored in a freezer near -20ºC to preserve the characteristics until the analyses were performed. This procedure was followed during the two HRTs of each reactor.

Table 4. Performed analyses and used methodologies

Variable	Unit	Principle	Methodology
pH	-	Potentiometric	--
T	ºC	Thermometer	--
TS	g L^{-1}	Gravimetric	[21]
FS	g L^{-1}	Gravimetric	[21]
VS	g L^{-1}	Gravimetric	[21]
VA	mg CH_3COOOH L^{-1}	Titulometric	[21]
TA	mg $CaCO_3$ L^{-1}	Titulometric	[21]
$COD_{soluble}$	g O_2 L^{-1}	Spectro	[21]

Table 4 presents the analyses performed on the stored samples and the methodology adopted. The analyses of pH, temperature (T), total solids (TS), fixed solids (FS), volatile solids (VS), volatile acidity (VA) and total alkalinity (TA) were performed parallel to the feeding of the reactors and removal of the effluent. The chemical oxygen demand (COD) analysis was performed every 5 days during each HRT of each reactor.

For the determination of the composition of the biogas produced, an aliquot of the gas was collected with the help of gasometer ampoules, through the connection of the gas outlet (Figure 1). The collection was performed on the sixth day of the second HRT for both reactors. The methodology followed to determine the gas composition is described by Penteado and coauthors [22].

RESULTS AND DISCUSSION

Temperature

Figure 3 shows the temperature profiles of the ambient and effluents removed from the reactors with and without agitation in the first and second HRT.

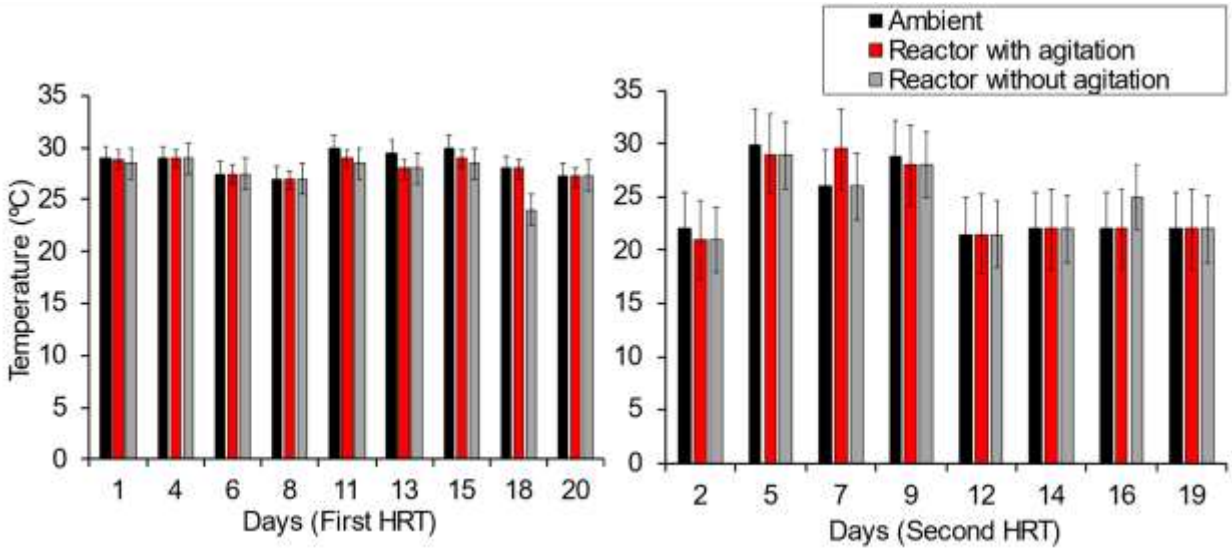

Figure 3. Ambient and effluent temperatures for the first and second HRT.

Considering that the temperature of the effluents removed during the feeding was close to the internal temperature of the anaerobic reactors, it can be seen that the temperature of the reactor content suffered interference from the ambient temperature, due to the absence of temperature controllers and thermal insulation surrounding the reactors, thus contributing to a temperature variation between 21 and 30ºC.

In the first HRT the temperature of the reactors remained stable, keeping close to the temperature of 28ºC. This behavior may have contributed to the proper development of microbial activities, reproduction of microorganisms and a homogeneous production of biogas. On the other hand, the second HRT presented greater variation in the internal temperatures of the reactors, compromising the execution of microbial activities. In general terms, it is observed that the effect of agitation did not influence this parameter, presenting similar behavior in both reactors in the two HRTs.

Microorganisms that act in the degradation of organic materials can be classified into psychrophilic, which perform best in the temperature range of 15 to 20°C, mesophilic (25 to 40°C), and thermophilic (40 to 85°C) [23, 24].

Thus, during the operation of the reactors in both HRT the temperature of the effluents varied between the psychrophilic and mesophilic ranges, which may have favored the imbalance of microbial activities and, consequently, reduced the production of biogas. According to Chernicharo [25] large temperature variations can cause an imbalance between the acidogenic and methanogenic phases, consequently affecting the entire anaerobic process. To minimize these problems and ensure that the microorganisms act in optimal temperature conditions, it is appropriate to use thermal insulation and a temperature control system in the reactors.

Literature works such as Kim and coauthors [26] and Bouallagui and coauthors [27] evaluated the effect of temperature on anaerobic digestion in food waste and found that operation of reactors in the thermophilic

temperature range contributes to higher biogas production compared to psychrophilic and mesophilic temperature ranges, since higher temperatures favor the degradation of the complex organic material present in the food waste.

pH measurements

Figure 4 shows the pH profiles of the food waste used during feeding, and the effluent removed from the reactors with and without agitation.

During the operation of the reactors in the first HRT, it was noted a reduction of pH in the effluents until the 11th day. After this period, the pH remained stable between the values of 4.5 to 5.5. This behavior is explained by the fact that the reactors contained part of the swine manure inserted at the beginning of the anaerobic co-digestion, which contributed until a certain moment to avoid the sudden pH change (buffer effect) in the reactors. However, with the continuous feeding of food waste this action of the swine manure was not maintained, thus resulting in a drop in pH.

The reported behavior is somewhat similar to that found by Gueri [28]. He reports that if too much volatile acid production occurs during the anaerobic process, due to the intense activity of the hydrolysis and acidogenesis phases, pH decay can occur if the alkalinity of the system is insufficient, and can also lead to the partial or total inhibition of methanogenic microorganisms.

The pH values of the food waste used in this work are similar to those presented by Gomez-Romero and coauthors [29], who obtained for fruit and vegetable waste a pH of 5.3, and by Zhang and coauthors [11], who obtained a pH of 6.5 for food waste.

In the second HRT, the pH of the effluents remained stable, since it was close to the pH of the food waste used to feed the reactors, indicating stabilization of this parameter.

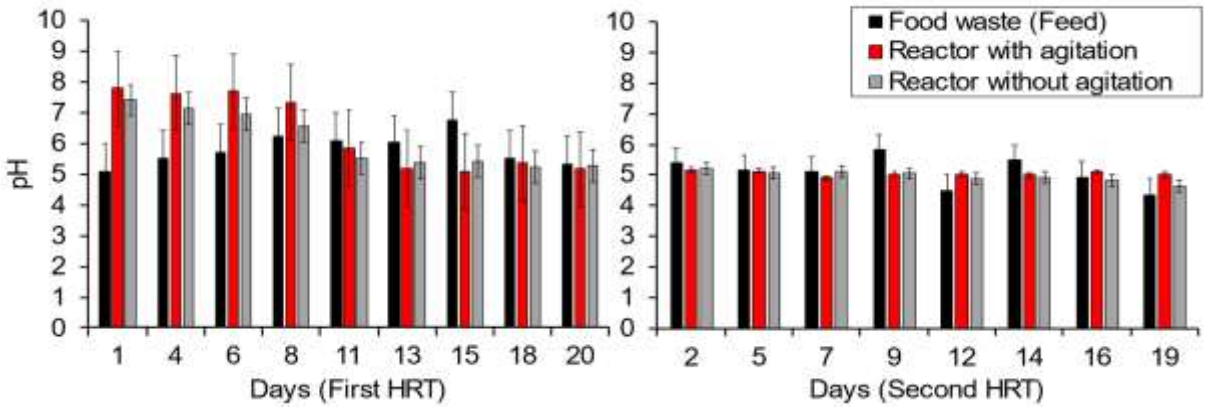

Figure 4. pH of the food waste and the effluent of the reactors with and without agitation.

Total alkalinity and volatile acidity content

Figure 5 shows the alkalinity and acidity profiles of the food waste and the effluent from each of the reactors.

The operation of the reactors until the 8th day of the first HRT showed little variation in alkalinity content, remaining close to 4000 mg $CaCO_3$ L^{-1} for both reactors. After this period, the alkalinity decreased, but remained within the range recommended by Amani and coauthors [30] of 1000 to 5000 mg $CaCO_3$ L^{-1}. The decrease in alkalinity content may have occurred due to the accumulation of acids in the reactors in response to the increased concentration in acidity in the first HRT.

According to Kondusamy and coauthors [31], the volatile acidity (or volatile fatty acids content) parameter is equivalent to the concentration of acetic acid in the solution. According to Amani and coauthors [30] the optimal range for this parameter is between 500 to 2000 mg CH_3COOH L^{-1}. Note that in most of the two HRTs the acidity of the effluents was much higher than the indicated range due to the composition of food waste used in the feeding of the reactors.

Analyzing these parameters for the food waste used to feed the reactors, the average acidity index for the first and second HRT was 944 and 1094 mg CH_3COOH L^{-1}, respectively, within the range established by Amani and coauthors [30]. However, the average alkalinity of the food waste for the first and second HRT was 256 and 218 mg $CaCO_3$ L^{-1}, respectively, values much lower than the range of 1000 to 5000 mg $CaCO_3$ L^{-1} observed by Amani et al [30]. In this regard, the anaerobic co-digestion with continuous feeding of the

food waste may have contributed to the increase of acidity in both reactors, due to the low buffering capacity of the medium. The values of alkalinity content found were close to those of Zhang and coauthors [11], who obtained for food waste a content of 330 mg $CaCO_3$ L^{-1}.

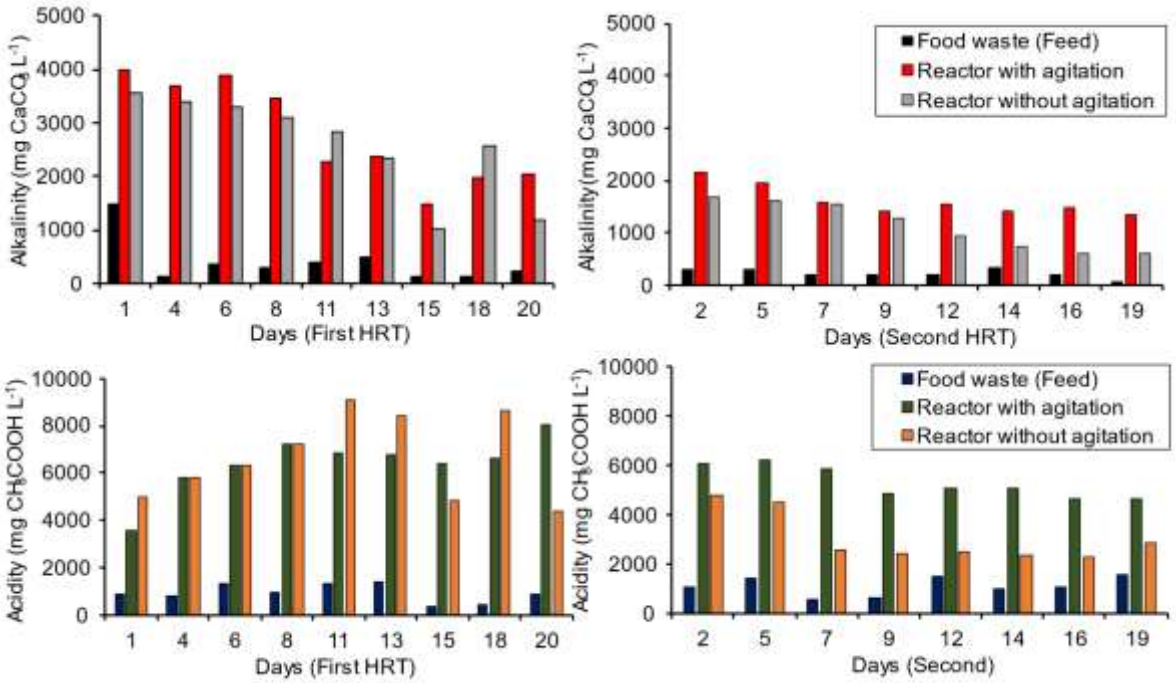

Figure 5. Alkalinity and acidity of food waste and effluents of reactors with and without agitation.

Total, fixed and volatile solids

Table 5 shows the total, volatile, and fixed solid contents of the food waste used to feed both reactors.

Table 5. Total, fixed and volatile solids of food waste

First HRT				Second HRT			
Days	**TS (g/L)**	**VS (g/L)**	**FS (g/L)**	**Days**	**TS (g/L)**	**VS (g/L)**	**FS (g/L)**
1	28.38	23.67	4.70	**2**	63.94	58.64	5.29
4	28.01	25.21	2.80	**5**	126.48	117.85	8.63
6	68.30	63.32	4.98	**7**	44.37	41.02	3.35
8	157.35	126.04	31.31	**9**	79.24	74.37	4.88
11	111.08	104.84	6.24	**12**	94.66	89.49	5.17
13	105.46	101.01	4.45	**14**	108.69	103.85	4.84
15	42.34	40.19	2.15	**16**	154.51	149.80	4.71
18	17.86	15.70	2.16	**19**	130.14	123.93	6.20
20	67.69	63.81	3.88				

It is observed that the concentration of VS in the food waste composition is predominant, what is desirable in providing higher biogas production. The average VS in the first and second HRT was 62.6 and 94.9 gL^{-1}. These results were close to those found by Ratanatamskul and coauthors [32], who obtained the VS concentration of 69.68 gL^{-1}.

The different concentrations of solids in the food waste are due to the diversity of foods that compose the menu of the university restaurant, from the foods offered at breakfast (coffee grounds, cake and bread) to the lunch and dinner meals (rice, beans, meat, vegetable and fruit waste, among others).

The average concentration of TS inserted in both reactors in the first and second HRT, was 7.3 and 10.2%, respectively. These values are in accordance with the recommendation presented by Li and coauthors [33], which reports that the concentration of TS should be less than 15%, because it facilitates the movement and homogenization of the material inside the reactor.

Figure 6 shows the total solids (TS), volatile solids (VS), and fixed solids (FS) content of the effluents from both reactors.

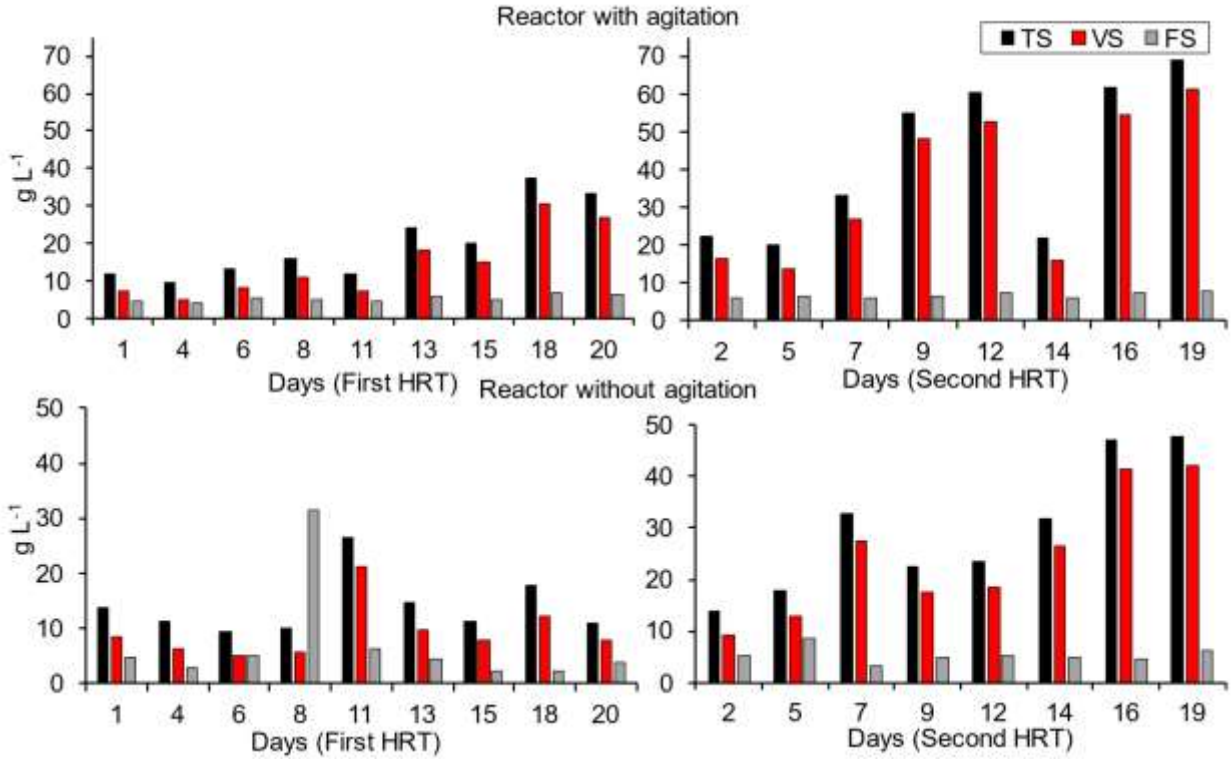

Figure 6. Content of total, volatile and fixed solids of the effluents of both reactors.

The VS concentration at the outlet of the reactors at the beginning of the first HRT ranged between 5 and 35 gL^{-1}, respectively. In the second HRT, in turn, a higher concentration of VS was observed, reaching values of approximately 70 and 50 gL^{-1} for the reactors with and without agitation, respectively. The higher concentration of VS at the outlet of the reactor with agitation is due to the greater homogenization of the internal content and, consequently, greater presence of suspended solids.

Table 6, in turn, shows the average VS and TS removal values for the two HRTs.

Table 6. Removal of TS and VS for the reactors without and with agitation

	First HRT		Second HRT	
Parameter	**No agitation**	**With agitation**	**No agitation**	**With agitation**
TS Removal (%)	68.1	70.6	67.7	53.5
VS Removal (%)	76.3	77.8	71.9	58.7

The removal of VS occurred efficiently in the first HRT, due to the greater stabilization of the process of anaerobic co-digestion in this period. However, in the second HRT there was a reduction in the removal of VS in both reactors, due to the drop in pH, the increase in acidity, low alkalinity content of food waste, and consequently, the reduction of microbial activities. Furthermore, it can be seen that VS removal in the reactor with agitation was lower for the second HRT. This certifies that part of the material was not being biodegraded, compromising the biogas production.

Soluble chemical oxygen demand (COD)

Table 7 shows the results of the soluble COD analyses performed on the food waste and the reactor effluents.

The average soluble COD of the food waste in the first and second HRT was 75.3 and 99.9 g O_2 L^{-1}, respectively. The food waste used by Zhang and coauthors [11] showed a soluble COD of 106.6 g O_2 L^{-1}, while Angeriz-Campoy and coauthors [34] found a value of 281.3 g O_2 L^{-1} in canteen waste.

It can be observed that there was an increase in the concentration of soluble COD in the effluents during the operation of both reactors, due to the characteristics of the anaerobic co-digestion process with the continuous addition of food waste, such as the reduction of pH, the increase of volatile fatty acid

concentration, low alkalinity content of the feed and high concentration of VS in the effluents, being an indication for incomplete degradation of food waste.

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Table 7. Soluble COD of food waste and effluent from the reactors with and without agitation

First HRT						
	Food waste		Effluent (no agitation)		Effluent (with agitation)	
Day	Average (g O_2 L^{-1})	±SD	Average (g O_2 L^{-1})	±SD	Average (g O_2 L^{-1})	± SD
1	86.0	4.3	31.8	2.8	29.5	4.2
6	91.5	1.7	46.4	6.9	22.9	0.4
11	32.4	0.9	57.3	5.2	28.5	0.9
15	53.8	5.2	38.6	1.4	63.6	8.0
20	112.8	25.0	49.2	8.6	48.9	0.7
Second HRT						
	Food waste		Effluent (no agitation)		Effluent (with agitation)	
Day	Average (g O_2 L^{-1})	±SD	Average (g O_2 L^{-1})	±SD	Average (g O_2 L^{-1})	±SD
5	117.1	1.7	77.8	12.0	74.7	14.2
9	58.6	6.9	44.4	7.4	75.7	3.2
14	121.4	2.6	83.0	9.2	74.5	2.4
19	102.5	10.3	128.5	2.5	120.4	14.0

Biogas production

Figure 7 presents the accumulated normal volume of biogas production.

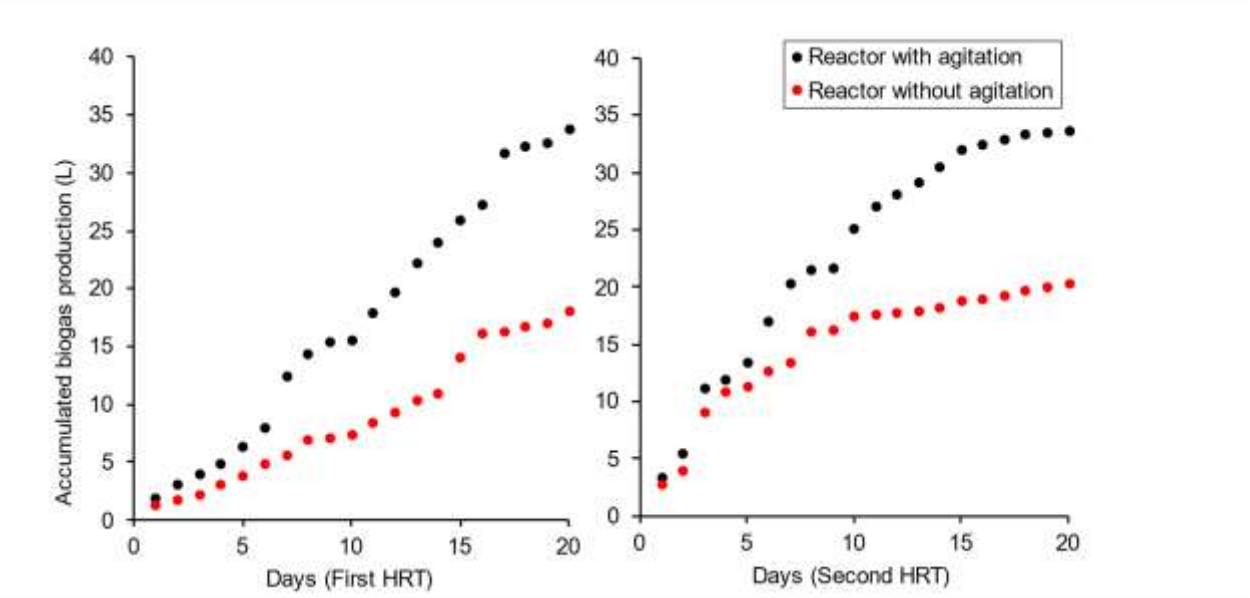

Figure 7. Cumulative normal volume of biogas production for reactors with and without agitation.

In the first HRT the reactors presented good performance in biogas production, indicating that the activities of the microorganisms were adequate. However, in the second HRT the reactor with agitation stood out compared to the reactor without agitation. This showed that the presence of agitation contributed to the development of biogas production, even with the anaerobic medium facing difficult conditions of synchronism with microbial activity due to the condition of the medium. Moreover, the production of biogas in the reactor without agitation was not directly related to the higher VS removal observed earlier, indicating its possible sedimentation at the bottom of the reactor.

The accumulated production of biogas in the first HRT was 33.7 and 18.0 L for the reactors with and without agitation, respectively. In the second HRT, the accumulated production was 33.7 and 20.3 L, respectively. The amount of biogas produced in both HRTs for the reactor with agitation remained stable, demonstrating that agitation positively contributed to the co-digestion process.

Table 8 shows the results related to the yield of biogas production in relation to the soluble COD of the food waste. It is observed that the effect of agitation in the present study was satisfactory, since the reactor with agitation was 25% and 11% more efficient than the reactor without agitation in the first and second HRTs,

respectively. Thus, the effect of agitation contributed positively to the operation of the reactor, especially in the first HRT in which part of the swine manure was present in the reaction medium, keeping the operating conditions stable.

Table 8. Yield of biogas production in reactors without and with agitation

Period	No agitation Yield (Lbiogas $gCOD_{feed}^{-1}$)	With agitation Yield (Lbiogas $gCOD_{feed}^{-1}$)
First HRT	2.4	2.9
Second HRT	2.0	2.2

Composition of the produced biogas

The gas composition was evaluated on the sixth day of the second HRT. The results of the analyses are presented in Figure 8.

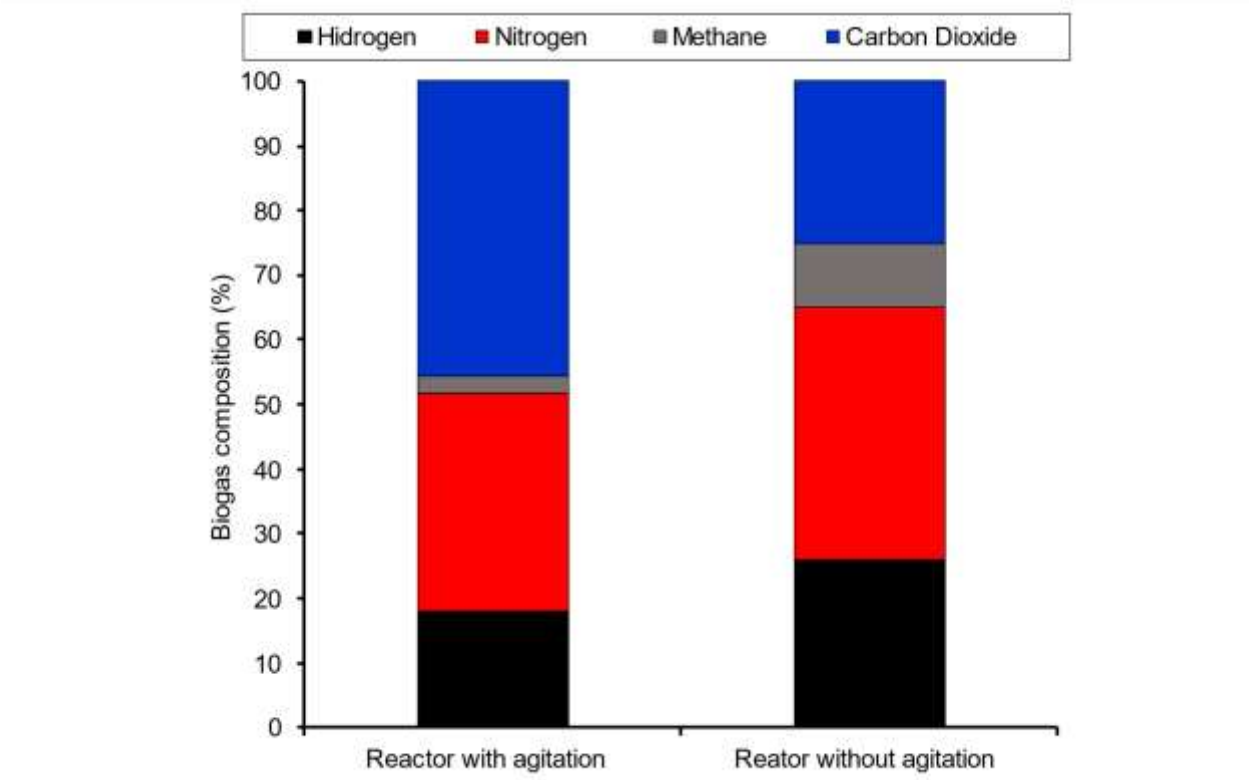

Figure 8. Composition of the biogas produced in the reactors with and without agitation.

The high concentration of H_2 and CO_2 indicates that the methanogenic phase was inhibited in the experiments performed in this work due to the accumulation of volatile fatty acids and reduced pH [35,36]. According to the same authors, this process occurs at pH values between 5.5 and 6. Thus, the low production rate of methane found in both reactors may be related to the inhibition of the methanogenic archaea, which are responsible for methane production [37]. However, for the process of anaerobic biodegradation to occur in a satisfactory manner, a balance between the stages of biogas production is necessary, since the methanogenic archaea are very sensitive to the accumulation of volatile fatty acids [38]. To increase methane production, a possible alternative is the use of two reactors, one containing the hydrolysis and acidogenesis phases and the other the acetogenesis and methanogenesis phases, as was done in the work of Neves [39].

CONCLUSION

This study showed that some factors occurred in the process of anaerobic co-digestion of the swine manure with the food residue independent of the presence of agitation, such as: influence of the ambient temperature in the temperature of the effluents, reduction of the pH, acidification of the reactors, and consequently, increase of the concentration of organic matter in the exit of the reactors.

The VS removal analysis showed that the reactor with agitation obtained a lower index compared to the

reactor without agitation. This occurred due to the suspension of the material when the agitation process was activated, increasing the concentration of solids in the effluent. However, the reactor with agitation provided a higher yield in biogas production. Thus, the VS removal obtained in the reactor without agitation was not directly linked to biogas production, but to its possible sedimentation at the bottom of the reactor.

Thus, the results allowed to identify the positive influence of agitation in the process of co-digestion of the swine manure with the food waste, resulting in a higher yield of the process compared to the reactor without agitation. Furthermore, the combination of swine manure with food waste contributed to the process stability, favoring the growth and development of bacteria, and the synchronism of microbial activities for biogas production.

Conflicts of Interest: The authors declare no conflict of interest.

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