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EVALUATION OF METHANOGENIC ACTIVITY AND POTENTIAL METHANE GENERATION FROM ORGANIC WASTE SUBJECTED TO ANAEROBIC CO-DIGESTION

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ABSTRACT:
He present job has by aim study he performance of production of biogas in L/ kgSV in mixtures of the organic fraction of urban waste, with bovine excreta (EB) that was used as inoculum. They were carried out essays of Methanogenic Biochemical Potential (MBP) with 3 different mixture percentages by volume ("Test 1": 50% RO-50% EB; "Rehearsal 2": 25% FORSU-75% EB; "Rehearsal 3": 12.5% FORSU-
87.5% EB), the which HE were done in duplicate. For assess Yeah exists performance improvement of biogas HE added biochar of peel of hazelnut for assess Two groups were used: Group A (mixtures without biochar) and Group B (mixtures with biochar), with their respective duplicates, considering the previous mixtures. The research showed that the mixtures with biochar and a higher cow manure content (25%) FORSU and 75% EB with biochar ; and also 12.5% FORSU and 87.5% EB with biochar) they had older productions of biogas with 423.47 and 253.57 L biogas/kg of SV respectively, By it so much, he use of biochar generated a 67% increase in biogas production in Trial 2 Group B and 27% increase in biogas production in Trial 3 Group B in the co-digestion of FORSU and EB.

KEYWORDS: co-digestion , biogas, biochar , Excreta Bovines, Fraction Organic of Urban Waste, food casino.

INTRODUCTION

Nationally, 4.6 million tons of OFMSW are generated annually as municipal solid waste (MMA, 2021). Within the University of Santiago, Chile (USACH), there is a high generation of organic waste (OFMSW). The USACH Central Cafeteria alone generates 55 kg of OFMSW per week (USACH Central Cafeteria, 2024), which is currently only collected a couple of times a week to feed worms, but this is insufficient to address the full magnitude of the problem.
This waste has polluting characteristics as it is an emitter of greenhouse gases. as it are he methane and he dioxide of carbon, where he first has a warming potential global 28 times further powerful than the dioxide of carbon. Methane HE emits as part of the 1.5 m 3 of biogas that generates a kg of SV of the FORSU; while CO2 is emitted at 4.2 kg per kg of FORSU wasted (Bioenergías Santa Fé , 2026; Gerardi, 2003; Metcalf C Eddy et al., 2014; Appels C Dewil, 2014; Stronach and to the., 1986; Horan and to the., 2018). By it former mentioned, the The Sustainability Unit of USACH has decided to implement an Integrated Organic Waste Management Plan (PGIR), which initially includes the valorization of the whole of the waste organic produced in he Casino USACH Central , as suggested by the principles of the USACH Sustainability Policy of the 2019 (Unit of Sustainability, 2019).
Biogas yield is improved by 44% when OFMSW is mixed with cow manure (Li et al., 2009; Balagurusamy C. Chandel, 2020; Wu, 2024). This precedent is considered in the present work, where anaerobic co-digestion with cow manure will be carried out to improve the efficiency of the process. Zhou et al. and Nikolausz C Kretzschmar (2020, 2021) state that the incorporation of biochar improves anaerobic digestion by increasing biogas production by 26.2%. In the present work experimental, seeks assess the improvement of the production of biogas, That is, anaerobic digestion using biochar , with the innovation of testing different percentages of mixtures in the co-substrates used in the research. Details are provided on how the FORSU (Organic Fractional Waste of Municipal Solid Waste) from the Central Casino was processed, the routine measurements taken in the laboratory, and the interpretation of the laboratory results for practical application, taking into account groups of waste treaties with biochar , and others without biochar . Parameters such as biogas production (PBM and yield in L biogas/kg SV), Solids will be measured Totals (ST), Solids Volatiles (SV), N ammoniacal, pH and alkalinity relationship C:
N. (Meghvansi) C Goel, 2022; Sudalyandi C Jeyakumar, 2022)

METHODOLOGY:

1.Materials :

For the realization of the study HE should have do a harvest of samples of FORSU for a week coming from the Central Casino, which is heavy prior to quartering according to the NMX (1985) (Manual of Biodigesters Rural, Bioenergies Holy Faith , 2026), for then be cracked and packaged in a bag transparent for his labeling and subsequent treatment. After collecting the samples on the 5 operating days of the central casino (Monday to Friday), the characterization tests were set up. physical chemistry of the FORSU Besides, he biochar was made to start pyrolysis to 700°C of peel of hazelnut (Zhou and to the., 2020; Balagurusamy C Chandel, 2020) that has he laboratory Ko -Yaku of Works Civilians USACH.

2.Model experimental :
The experimental trials corresponded to those described in Table 1. They are as follows:

Table 1. Model experimental for measurements of potential methanogenic

	Sample	Inoculum (%)	FORSU (%)	Manure (mL)	FORSU (mL)	Total biomasa (mL)	Total agua (mL)
Sin	A1	50	50	25	25	50	50
biochar	A2	75	25	37,5	12,5	50	50
	A3	87,5	12,5	43,75	6,25	50	50
Con	B1	50	50	25	25	50	50
biochar	B2	75	25	37.5	12.5	50	50
	B3	87.5	12.5	43.75	6.25	50	50

Fountain: Original work

mL amber glass bottles , where he volume to wear will be of 100 mL , leaving 100 mL free for the generation of biogas. Rubber plugs were placed, perforated with a drill bit for press-fitting. a hose of the that are used in medicine for place roads Venous pipes with 3-way valves. This valve will serve to shut off the flow of biogas; finally, it was added a hose extra to the system provided that facilitate the later measurement from biogas. Then of mount each one of these 6 essays, to know, 1A, 2A, 3A (until (Here are the mixtures without biochar), 1B, 2B, 3B (these are the mixtures with biochar , which is biochar to to start of peel of hazelnut pyrolyzed to 700°C; HE add a 1g of biochar by L of mix, by it that HE add 0.1 g to each bottle by are contain 100 mL of sample divided into 50 mL of solid phase and 50 mL of water); their respective are assembled duplicates.

3.Analysis Analytics :
The biogas obtained will be measured using a saline solution, as Manobanda points out. (2018), with a solution barrier for retain he carbon dioxide carbon, such as 0.01N NaOH. Inverted test tubes will be used, which were modified to allow the measurement of the biogas as HE sample to continuation:

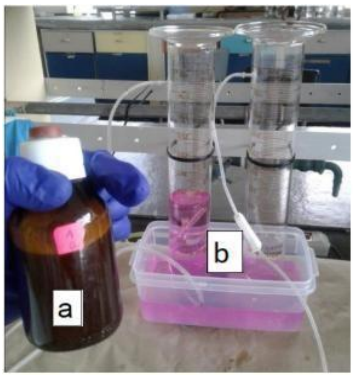


Figure 1. Biogas measurement system Source: Barrera; Manobanda (2018)

To perform these analyses, Total Solids (TS) and Solids were measured Volatiles (SV) (this indicator gives us an estimate of the amount of carbon in the sample) (US Environmental Protection Agency, 2001; Metcalf C Eddy et al., 2014), ammoniacal N (parameter that together with the SVs allows us to have the C:N ratio) (Liang et al., 2016; Horan et al., 2018), Alkalinity (Mintrop) and to the., 2000; Appels C Dewil, 2014), pH and relationship C:N of Samples from Casino Central. US Environmental The Environmental Protection Agency (2001) indicates that Total and Volatile Solids should be measured gravimetrically; that is, the weight of the sample is taken before and after subjecting the mixture to high temperatures, and then knowing the volume The content of the mixture that was introduced is determined. of Solids in mg/L. For he case of the ST HE leaves the sample in he oven to 105°C by a day and then proceeds to measure again elapsed that time he weight of the crucible in he that The sample is being taken to the oven. In the case of volatile solids, it is taken to the muffle furnace. to 550 °C by two hours the sample and then HE proceeds to carry out the measurement of the mass again to estimate SV in mg/L; it should be noted that SV are generally measured then of measure ST for avoid errors by the humidity. Liang and to the. (2016) indicate that ammoniacal N must be measured after performing a filtration of the sample to be measured. ammoniacal so that it can be taken by Using a micropipette and following the standard procedure of the laboratory kit, the reagents are mixed. chemicals for do A colorimetric reaction is evaluated at a wavelength of 655 nm in a spectrophotometer to determine the absorbance, and thus, using a calibration curve, the concentration of ammoniacal nitrogen is obtained. Alkalinity is extent to through of a degree potentiometric (Mintrop) and to the., 2000) which changes from intermediate alkalinity to 5.75 pH and the total to 4.3 of pH. He pH was measured directly with a pH meter Horiba . Then of carry out the Analysis of samples from the Central Casino for their physicochemical characterization established study groups for the biochemical potential of methane (BPM). Three

mixtures of FORSU (Municipal Solid Waste) from the Central Casino were prepared with Bovine Excreta (BE) taken from a plot in the Melipilla commune, Pabellón locality. with bales alfalfa and pumpkins.

RESULTS:

a)Solids Totals

Table 1 describes the amount of Total Solids (TS) in the analyzed samples. The main results was that all the samples were by Regarding the 100,000 mg/L mark, it was particularly observed that in trials with higher manure content, the total solids content rose considerably, exceeding 400 g/L. The total solids values, when compared to the literature (around 100 g/L), were as follows :

Board 2 . Solids totals of the essays

Sample	ST (mg/L)	Mix	ST average	Theorist*
1st	55682	1	112768	100,000
2nd	455504	2	405594	105,000
3rd	458666	3	507113	115,000
1B	169854			
2B	355684			
3B	555560			

1A-Cluster of mixtures to the 50% in FORSU-EB volume; without biochar
2A-Group of mixtures at 75% by volume of EB, 25% of FORSU; without biochar 3A-Cluster of mixtures to the 87.5% in volume of EB, 12.5% of FORSU; without biochar 1B-50% by volume FORSU-EB mixture group; with biochar
2B-Group of mixtures at 75% by volume of EB, 25% of FORSU; with 3B biochar-Cluster of mixtures to the 87.5% in volume of EB, 12.5% of FORSU; with biochar

Fountain: Original work; Bioenergies Holy Faith , (2026); Metcalf & Eddy and to the., 2014; Stronach et al., (1986)

b)Solids Volatiles

Table 2 describes the amount of Volatile Solids (VS) that the analyzed samples had. The main ones The results were that all the samples were above the 19,000 mg/L, in particular HE had that the essays with further manure HE raised

considerably the amount of solids totals by about the 25g/L of SV. The values of SV to the be compared with the literature (around of 40 g/L) were the following:

Board 3 . Solids Volatiles of the essays

Sample	SV	Sample	SV	Theorist*
	(mg/L) average			
1st	19666	1	19933	
2nd	25660	2	28927	400,000
3rd	44874	3	43775	400,000
1B	20200			
2B	32194			
3B	42676			

1A Cluster of mixtures to the 50% in FORSU-EB volume; without biochar
2A Group of mixtures at 75% by volume of EB, 25% of FORSU; without biochar 3A Cluster of mixtures to the 87.5% in volume of EB, 12.5% of FORSU; without biochar 1B 50% by volume FORSU-EB mixture group; with biochar
2B Group of mixtures at 75% by volume of EB, 25% of FORSU; with 3B biochar Cluster of mixtures to the 87.5% in volume of EB, 12.5% of FORSU; with biochar

Fountain: Elaboration own, Bioenergies Holy Faith (2026); Gerardi, 2003; Appels C Dewil, (2014)
In the Board 3 of details the relationship SV/ST, of the following shape:

Board 4. Relationship SV/ST (in %)

Average sample (THE y B)	SV/ST
1	17.6
2	7.1
3	8.6

1 =17.6
2 =7.1
3 =8.6
1 =Group 50% EB 50% FORSU
2 =Group 75% EB 25% FORSU
3 =Group 87.5% EB 12.5% FORSU
Fountain: Original work

c)Nitrogen ammoniacal
The Board 4 describe the amount of N ammoniacal that they had the samples analyzed. The main results was that all the samples were by about 600 mg/L, in particular HE had that the essays with further manure (1) HE decreased in a

The amount of ammoniacal N was 42.7% lower than in test 2 and 60.4% lower than in test 3. The ammoniacal N values, when compared with the literature (around of 200-1500 mg/L) were the following:

Board 5. Nitrogen ammoniacal of each sample

Sample	N Theoretical (mg/L)	ammoniacal (mg/ L)*
1	1117.35	
2	640.32	200- 1500
3	674.45	

Sample N Theoretical ammoniacal
(mg/L) (mg/ L)*
1 1117.35
2 640.32 200- 1500
3 674.45
1 Group 50% EB 50% OFMSW
2 Group 75% EB 25% OFMSW
3 Cluster 87.5% EB 12.5% FORSU
Fountain: Elaboration own, Manual of Biogas (2026); Horan and to the., 2018; Wu, (2024)

d)pH and alkalinity
Table 6 describes the pH of the analyzed samples. The main results was that all the samples were in he range appropriate of pH, according to the literature HE have the following results:

Board 6. Evolution of the pH by sample

Sample	pH	Theorist*
1 A	7.03	
2 A	7.26	
3 A	7.38	
1 B	7.02	6.8-7.5
2 B	6.98	
3 B	7.01	

1A Cluster of mixtures to the 50% in FORSU-EB volume; without biochar
2A Group of mixtures at 75% by volume of EB, 25% of FORSU; without biochar 3A Cluster of mixtures to the 87.5% in volume of EB, 12.5% of FORSU; without biochar 1B 50% by volume FORSU-EB mixture group; with biochar

2B Group of mixtures at 75% by volume of EB, 25% of FORSU; with 3B biochar Cluster of mixtures to the 87.5% in volume of EB, 12.5% of FORSU; with biochar

Source: Own elaboration; Bioenergías Santa Fé (2026); (Gerardi, 2003; Metcalf C Eddy et al., 2014)
And the alkalinity results show that the value increased as we increased the amount of cow manure; furthermore, alkalinity increased by 126.5%. of the sample 3 with the addition of biochar ; while that in the sample 2 increased in a 10.1 % to the add biochar . The results are the following:

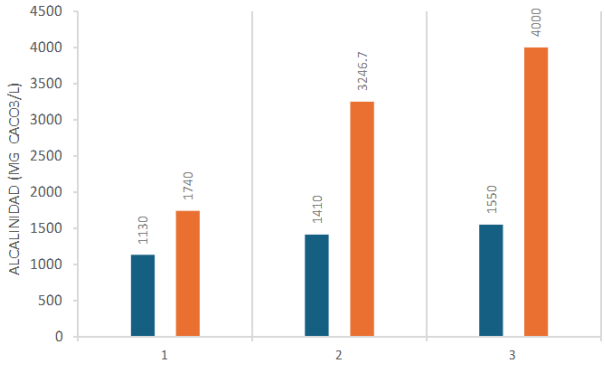


Figure 2. Evolution of alkalinity for samples 1A, 2A, 3A of the co- digestion test anaerobic exercise performed with values intermediate alkalinity (blue) and total (orange)
Fountain: Original work

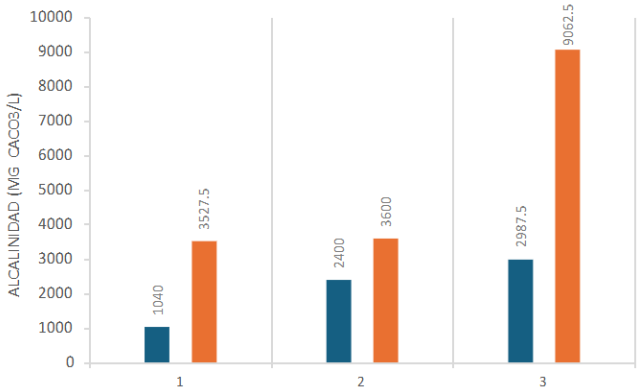


Figure 3. Evolution of alkalinity for samples 1B, 2B and 3B of the anaerobic co- digestion assay performed with intermediate (blue) and total (orange) alkalinity values

1 Cluster of 50% EB 50% FORSU
2 Group de 75% EB 25% FORSU
3 Group de 87.5% EB 12.5% FORSU
Source: Own elaboration

e)Relationship C:N
Based on the results of SV and The ammoniacal nitrogen is calculated based on a direct ratio of it that is the relationship of carbon and nitrogen (C:N), giving the following results:

Board 7: Relationship of C:N

Sample	C/N	Theorist*
1	17.84	
2	45.18	20-30
3	66.53	

1 Cluster of 50% EB 50% FORSU
2 Group of 75% EB 25% FORSU
3 Group of 87.5% EB 12.5% FORSU
Source of Preparation own; Bioenergies Saint Faith (2026)

f)Potential Biochemical Methanogenic :

Finally, the daily volume recording was carried out of biogas generated daily for one month in the anaerobic reactors. The cumulative graph of biogas produced, as well as the net yield in L of biogas/kg of VS, is presented below :

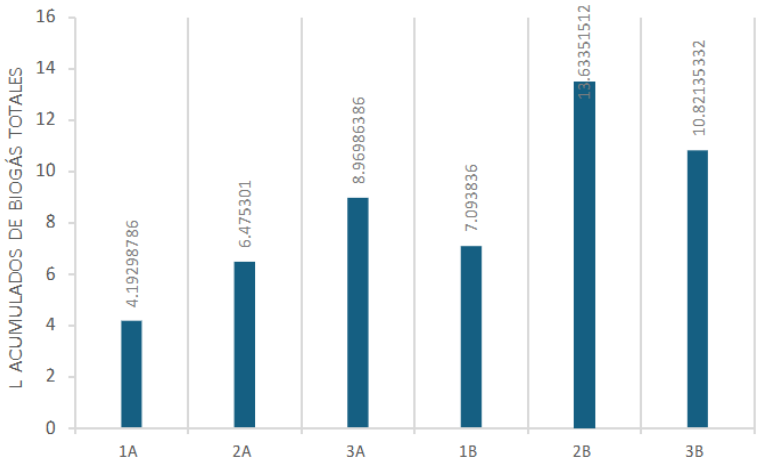


Figure 3. Potential Biochemical Methanogenic

COMPARISON OF PRODUCTION OF BIOGAS

Fountain: Original work

HE appreciates that the elderly production of biogas HE you attributes to the mix of the rehearsal 2B. The net biogas production yield per kg of volatile solids (L biogas/kg VS) is then provided.

Board 8. Performance net of biogas

Sample	L biogas/kg SV	Theoretical*
1 A	213.21	
2 A	252.35	
3 A	199.89	200
1 B	351.18	
2 B	423.48	
3 B	253.57	

Fountain: Elaboration own; Manual of Biogas MMA Chili (2026)

DISCUSSION OF THE RESULTS:

It can be seen that the characterization of the FORSU delivers a rather neutral with values very nearby to 7 (Gerardi, 2003; Appels C Dewil, 2014), besides HE has to the values of ST and SV increased from the samples 1 toward the samples 3, which ha of owe to the increase of material rich in C as is he manure of cow. Regarding C :N (Li et al., 2009; Balagurusamy C Chandel, 2020) the samples were increasing the relationship to extent that HE he added manure of cow to the essay; being the optimum mixture 1 or 2.

By other side, HE has the alkalinity, where HE achieves a elderly ability tampon in the sample 3 in both essays TO and B, No However, HE appreciates a marked improvement of the alkalinity in the sample 3B, This has to be successful thanks to the addition of biochar (Zhou et to the., 2020; Nikolausz C Kretzschmar, 2021; Wu, 2024), it that it does further stable and with a lower risk of acidification

Finally, in how much to PBM HE respects, HE achieves a elderly production in the groups 2 and 3 (Balagurusamy C Chandel, 2020; Sudalyandi C Jeyakumar, 2022), achieving maximum performance in mixture 2B, with 67% more biogas production in Group 2 with biochar , and 27% more biogas production in Group 3 with biochar .

HE go that he N increases considerably in the mixtures rich in FORSU and decreases in the rich in manure, it that suggests that the FORSU is rich in N (intuitive because of the green color), and manure has a higher C content, contributing a higher C:N ratio to the mixture.

CONCLUSIONS:

co-digestion of RO with EB can be proposed for the management of organic waste from the Central Casino of USACH , where findings of improvement in alkalinity were observed. and biogas production with the addition of biochar (Zhou et al., 2020; Appels C Dewil, 2014) generated by pyrolysis in a muffle furnace at 700 °C. Alkalinity increased significantly in group 3B due to the addition of biochar ; however, the best biogas production was obtained in group 2B, where a value of 423.48 L biogas/kg was achieved. SV.

This production value must be due to the incorporation of biochar (Gerardi, 2003; Wu, 2024) as well as the carbon-nitrogen ratio which is the most moderate within the three mixed samples that were studied (C:N = 45.18)

Therefore, it is recommended that the USACH Sustainability Unit treat it in co- digestion anaerobic waste organic of the Casino Central USACH with mixtures between a 75% of manure of cow and allocate so only a 25% of volume solid to the FORSU. By For example, if 20L are produced of RO per day, it They will need 60 L of cow manure plus 80 g of biochar plus a liquid volume of 80 L of water, so as not to do the optimal management of FORSU in order to minimize the environmental impact, but it will also be done in order to optimize the anaerobic digestion process (Metcalf C Eddy et al., 2014; Balagurusamy C Chandel, 2020; Nikolausz C Kretzschmar, 2021).

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