Evalua… of the environment… chnical a… economic … rmance c… anaerobic co-digestion processes in Colombian scenarios

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Introduction

Residual biomass from agro-industrial activities in Colombia

Implementation of biological processes for energy generation

Researches over the technical, environmental and economical approach

Several varieties of residues derivate from agro-industrial activities in Colombia are susceptible to be valorized, some of them are ***pig manure (PM)***, ***sewage sludge (SS)***, ***organic fraction of municipal solid waste (OFMSW)***, ***residues from the bottled fruit drinks industry (RBFDI)*** and ***cocoa industry residue (CIR)***.

Materials and Methods

The treatment capacity was defined by using the available information. After this, all the mass and energy balances were constructed for each substrate mixture.

The environmental performance was evaluated through the quantification of the potential environmental impacts employing the **Life Cycle Assessment (LCA)** technique using the *SimaPro* software, where the behaviour of the different mixtures was evidenced.

An ***economic evaluation*** was carried out, taking into account the operating and administrative costs, incomes, profits and depreciation of the equipment.

The best mixture was chosen by the methodology of the analytic hierarchy process.

Technical framework

Mosquera et al. [4] evaluated the anaerobic co-digestion of PM, SS, OFMSW, RBFDI and CIR, for the maximization of the biogas production of different mixtures.

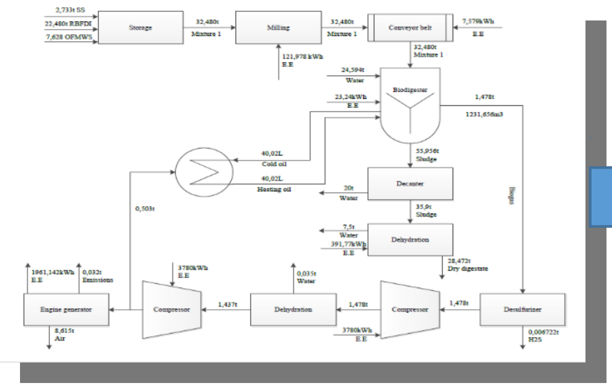
Table 1. Maximized mixtures.

	PM (%)	CIR (%)	SS (%)	RBFDI (%)	OFMSW (%)
Mixture 1			8.321	68.452	23.227
Mixture 2	28.297	35.336		36.367	
Mixture 3		14.550	29.612		55.838

The residue availability reported by Piñeros et al [2], show that the residues are highly accessible in different municipalities of Cundinamarca, the cocoa industry is placed in Yacopí, piggery farms in San Antonio de Tequendama, sewage sludge from Madrid wastewater treatment plant, fruit juice industries are in Bogotá as well as the OFMSW recovery.

Life cycle assessment

Mass and energy balances



Potential impact categories	*Equivalent units*
Terrestrial acidification	Kg SO_2 eq
Freshwater eutrophication	Kg PO_4 eq
Climate change	Kg CO_2 eq
Photochemical oxidation	Kg C_2H_4 eq
Ozone depletion	Kg CFC-11 eq
Abiotic depletion	Kg Sb eq

Table 2. Potential environmental impacts categories according to the ***EPD methodology***

Economic assessment

Step 1

- Evaluation and quotation of basic equipment, auxiliary equipment, and services necessary for each plant.

Step 2

- Definition of direct and indirect labour required, and calculation of payroll including the benefits of the Colombian law.

Step 3

- Calculation of initial investment, working capital, production and administration costs.
- The net profits comprised a depreciation of 10%, taxes on profits and equity, and inflation as relevant variables for the calculation.

Step 4

- Calculation of financial indicators: Net Present Value (NPV), through the sum of the year-to-year profits carried at present value with an attractive minimum rate of 10%, minus the total investment; and the Internal Rate of Return (IRR), verifying the annual projection when the NPV begins to give a positive result to the investment.

Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process has been widely used to evaluate alternatives based on different analysis criteria, where a hierarchical model is constructed to organize information and make decisions regarding an analysis of complementary criteria [15].

In this case, it permits the selection of the best scenario within the three different mixtures evaluated in previous stages.

Results and discussion

Technical framework

Table 3. Productive aspects evaluated for each mixture.

	Mixture 1	Mixture 2	Mixture 3
Installed Capacity (Ton)	32.840	61.807	71.752
Reactor volume (m3)	6.148	9.225	9.846
Biogas production (m3)	1231.656	2943.175	3525.078
Potential (KWh)	1961.412	4687.006	5613.687

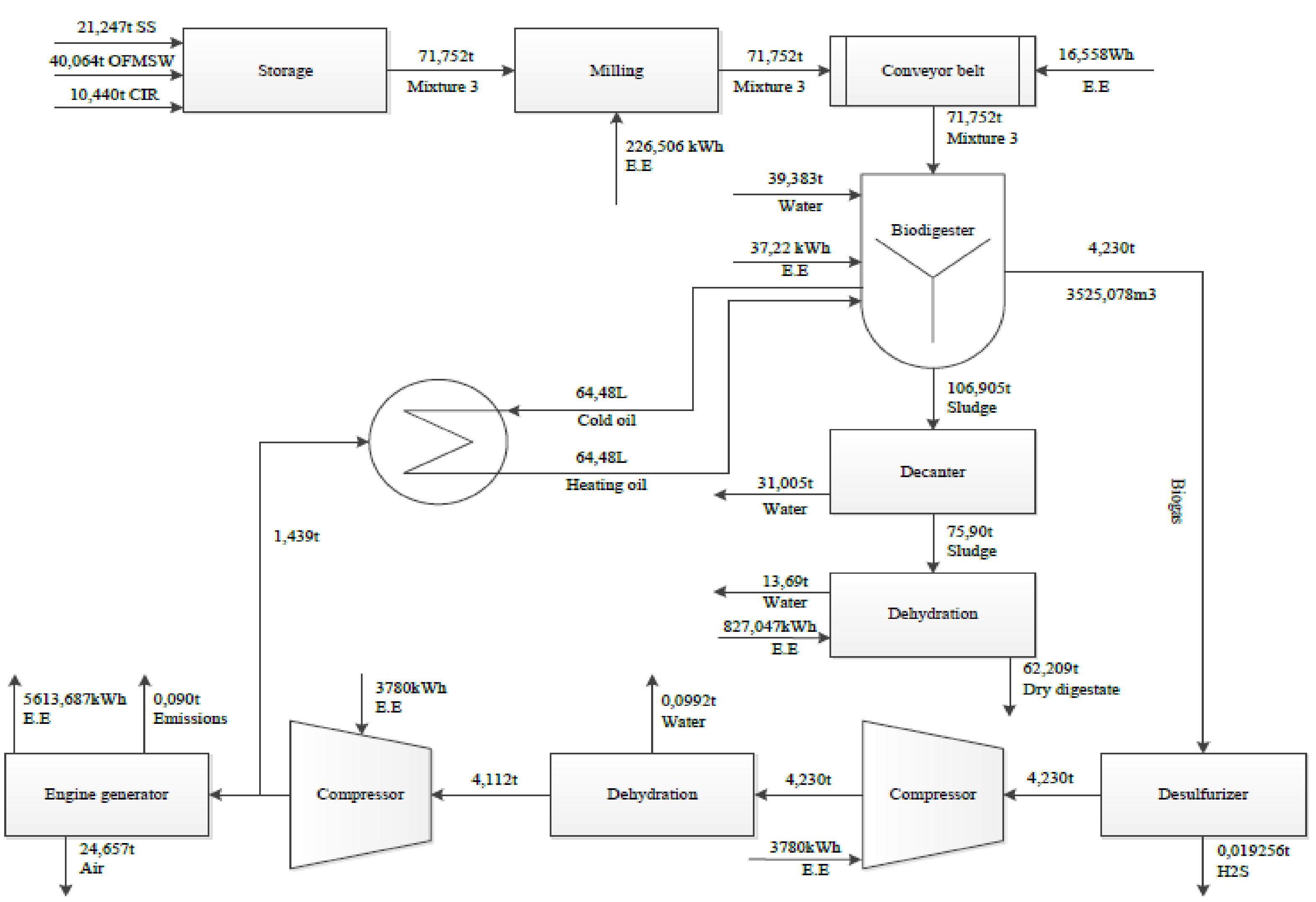


Fig. 1 Process flow diagram for Mixture 3.

Life cycle assessment

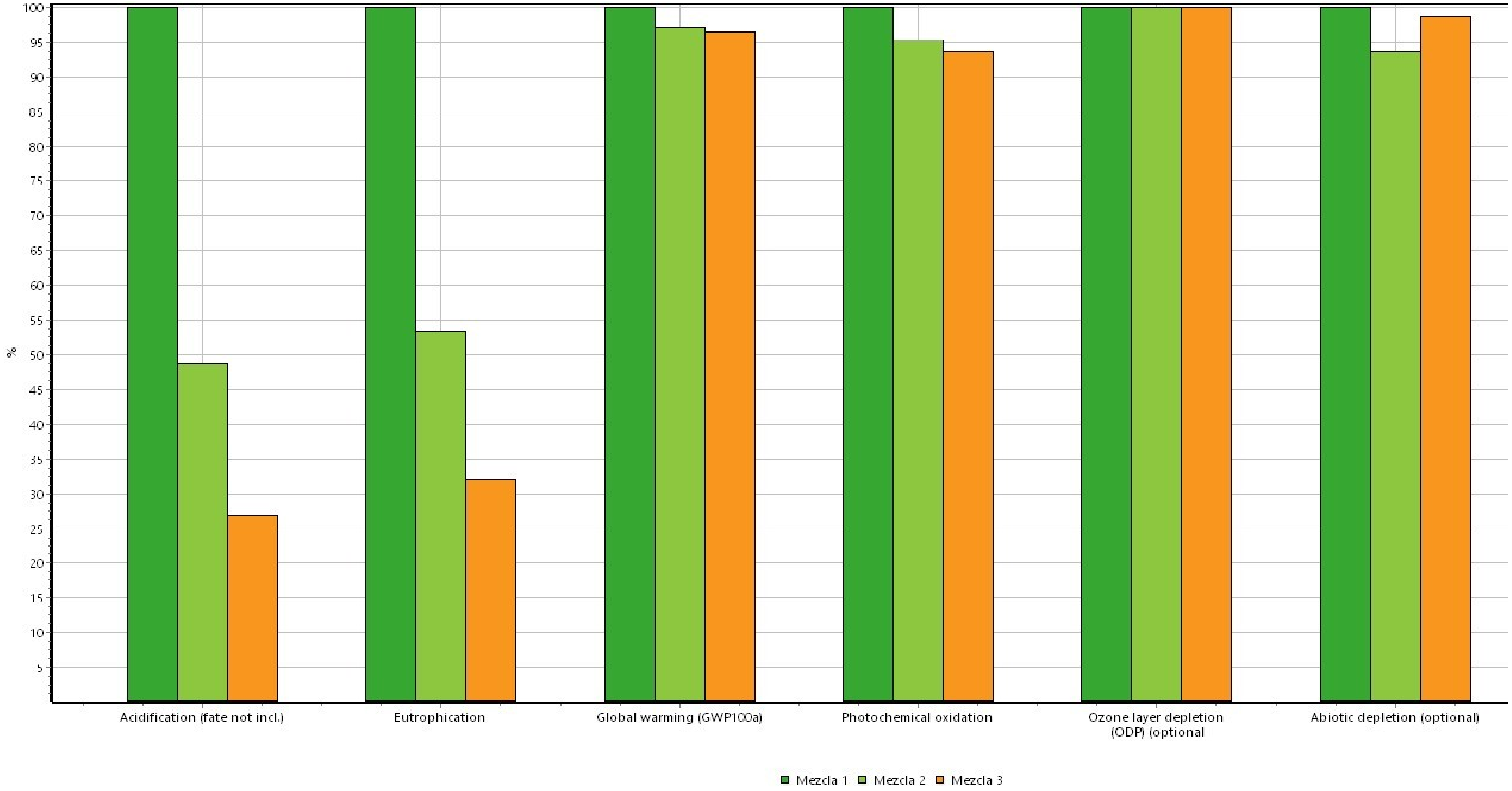


Fig. 2 Comparative environmental profile of the three mixtures.

Economic assessment and AHP results

Table 5. Results for the economic evaluation and analytic hierarchy process.

	Mixture 1	Mixture 2	Mixture 3
Total initial investment	$ 2,580,118,254	$ 2,605,082,104	$ 2,607,350,904
NPV	$ 134,720,193	$ 4,184,207,848	$5,498,301,525
IRR	0.11	0.32	0.39
Analytic hierarchy result	0.476	7.989	9.683

Conclusions

- The best mixture to generate electric energy is mixture three since it generates the most significant amount of biogas at 56401,248 m3 per year.
- Mixture 3 obtained the best results in the economic study with an NPV for the last year of COP 5,507,646,009 and an IRR of 38.99%.
- Regarding the environmental analysis, it was also found that the mixture that generates less potential environmental impacts is mixture 3, closely followed by mixture 2.
- After conducting the LCA using the EPD methodology and the *SimaPro* databases, it was observed that the environmental impact is also associated with the size of the plant. These results are mainly because many operations generate the same impact with low production as with high production, when increasing capacity, there was a greater volume of a product without incurring in a significant increase in the environmental impact generated.

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Thank you