Organic kitchen food waste valorization applying the biorefinery concept in the Colombian context

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FOR WOMEN IN SCIENCE
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PROGRAMA COLOMBIA CIENTÍFICA
RECONSTRUCCIÓN DEL TEJIDO SOCIAL EN ZONAS DE POSCONFLICTO EN COLOMBIA

Content

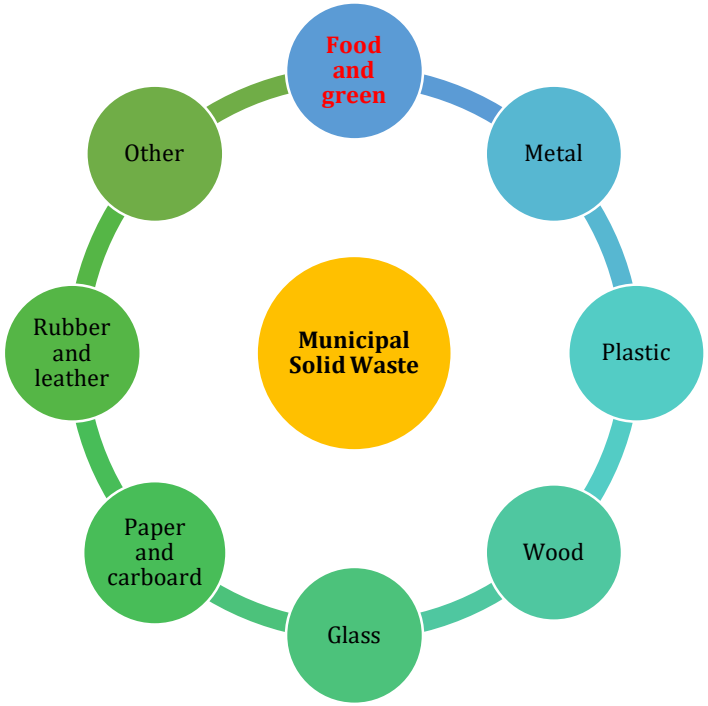
1. Introduction

Municipal Solid Waste (MSW)

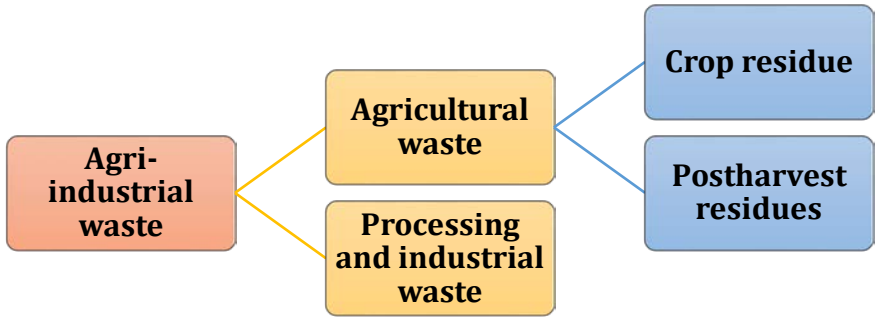
The quantity and composition of MSW depend on the **socio-economic** and **cultural** context analyzed.

Overall average generation of waste per person is very high [1].
The MSW generation is increasing worldwide [2].

Some predictions calculate an increase to **3.4 billion tons by 2050** [3].

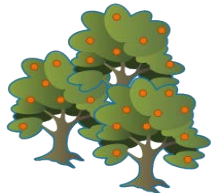


Industrial and Agri-industrial Solid Waste (AgR)



The generation of AgR can cover an average of **30-50% by weight of the raw material** used.

Citrus supply chain



Orange crop

FOOD LOSSES
- ✓ Sheets
- ✓ stems
- ✓ Flowers

60% national production

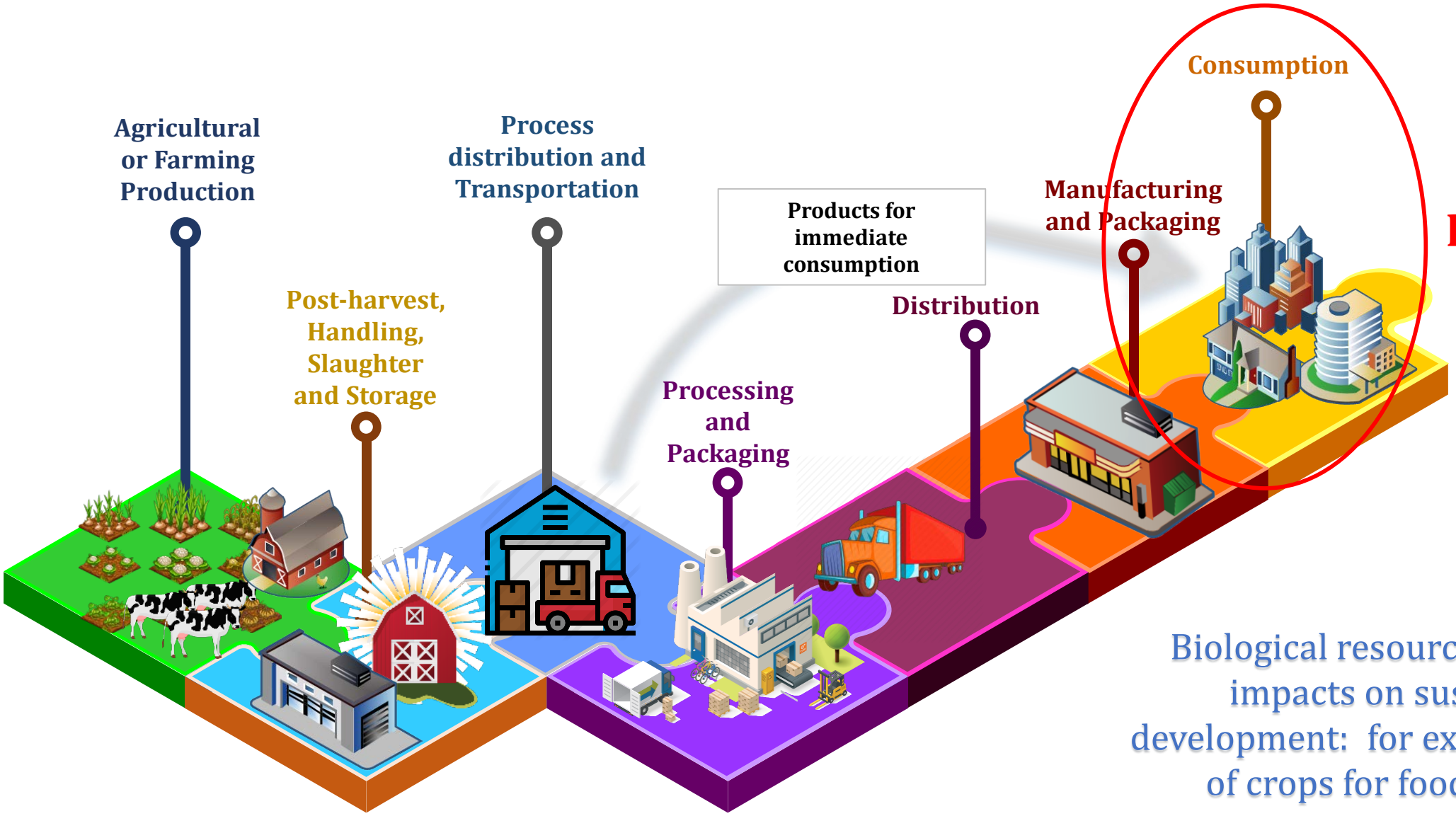
Sale for immediate consumption

40% national production

Agro-industrial processing

FOOD LOSS
Orange peel
40-50% of the fruit

1. Introduction



FOOD WASTE: organic kitchen food waste

Biological resources. Negative impacts on sustainable development: for example the use of crops for food products

Figure 1. General steps of Supply Chain

1. Introduction

Global impacts of residues generation

Economic impact

The economic impact is defined as the combined costs incurred to produce, deliver, and dispose of residues.

Social impact

The social impact is directly and indirectly, related to social welfare, human health, and employment.

Environmental impact

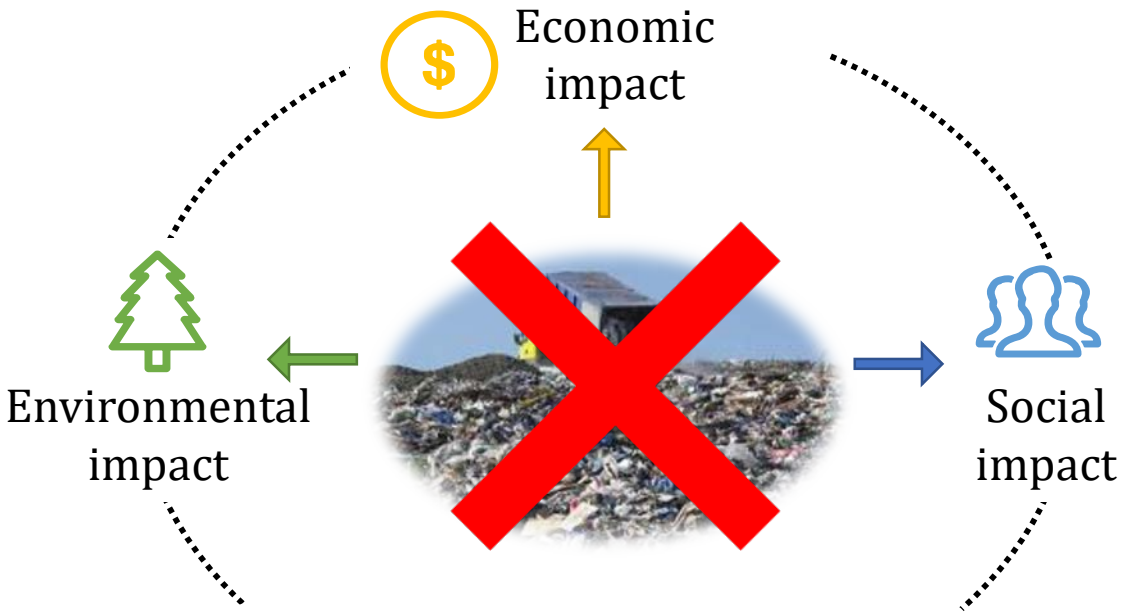
The FAO estimates that the generation of residues represents 8% of global GHG emissions [4]. This is primarily due to the residues elimination pathways. Various environmental impacts on soil and water are also presented.

Impact estimates vary significantly by method, waste type, region, scale, and stage

The FAO estimated a total economic cost of USD 1055 billion, an environmental cost of USD 696 billion and a social cost of USD 882 billion [4].

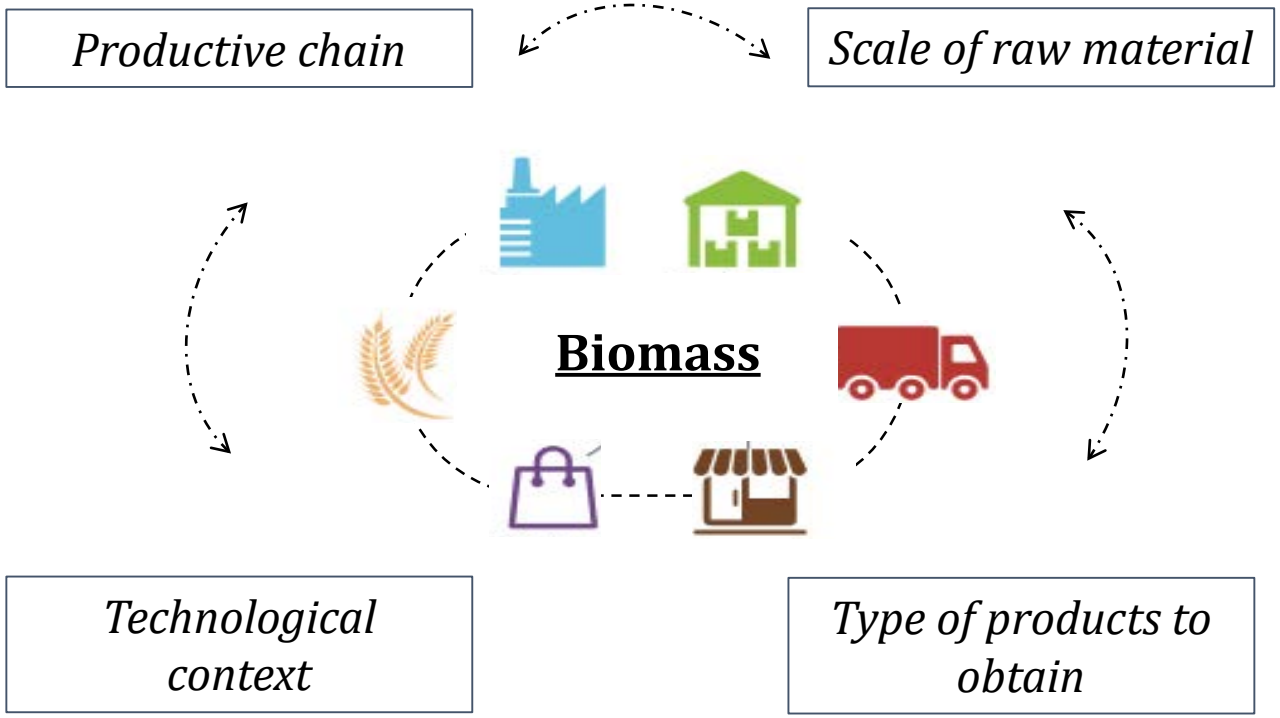
2. Research objective

This work was focused on determining the prefeasibility in technical and economic terms of the most promising alternatives for using food waste generated in Colombia



Sustainability of the food supply chain

Factors to consider:



3. Methodology

Organic Kitchen Food Waste in Colombia

National studies of food waste generated in Colombia were based on the seven food groups proposed by the FAO

Table 1. The share lost in food supply chain established of food groups proposed by FAO [5]

Input	The share lost in food supply chain		Flow generated in Colombia (ton/year)
	World [5]	Colombia [6]	
Fish	3	0.5	475
Meat	5	3	58883
Cereals	19	8	246127
Roots and tubers	20	25	812287
Fruits and vegetables	44	62	282325
Dairy	1	0.5	8407
Oilseeds and legumes	8	2	117749

The most representative food of each group was selected according to national consumption statistics.

Scenario 1

Biogas and Fertilizer production by Anaerobic Digestion

Scenario 2

Ethanol production by Fermentation (*saccharomyces cerevisiae*)

Scenario 3

Ethanol production and Biogas and Fertilizer production by Fermentation and Anaerobic Digestion

3. Methodology

Organic Kitchen Food Waste brutto composition Model for Colombia

Table 2. Composition model of Organic Kitchen Food Waste

Input	The most representative product			
Fish and eggs	(20%) Fishbone	(80%) Eggs peel		
Meat	(40%) Beef bone	(45%) Chicken bone	(5%) Meat waste	
Cereals	(100%) Rice			
Roots and tubers	(60%) Patato peel	(30%) Cassava peel	(10%) Carrot peel	
Fruits and vegetables	(20%) Tomato peel (4%) Lettuce residues	(16%) Onion peel (3%) Cabbage residues	(10%) Bean residues (1%) Beetroot peel	(1%) Pumpkin peel (1%) Celery residues
	(10%) Orange, lemon and mandarin peel	(5%) Banana peel	(5%) Mango peel and seed	(5%) Guava Pulp
	(5%) Tree tomato	(4%) Blackberry Pulp	(3%) Passion fruit peel and Pulp	(1%) Strawberry Pulp
	(3%) Avocado peel and seed	(2%) Papaya peel and seed	(2%) Apple residues	(2%) Lulo peel and Pulp
Dairy	No applied			
Oilseeds and legumes	(100%) Used vegetable oil			

3. Methodology

Experimental work

- **Chemical characterization**

Table 3. The methods used for chemical characterization of raw material

Compound	Method	Ref
Extractives	NREL/TP-510-42619	[7]
Holocellulose	Han, J.S., Rowell, J.S.: Chemical Composition of Fibers	[8]
Cellulose	TAPPI T203	[9]
Hemicellulose	Subtraction between the holocellulose and cellulose	
Acid insoluble lignin	TAPPI T222	[10]
Total pectin	Yu et al. (1996)	[11]
Fat	Rivas et al. (2008)	[12]
Ash	ASTM E871-82	[13]
Moisture		

- **Fermentable sugar production**

Enzymatic hydrolysis with cellulases, glucoamylases and pectinases enzymes

Reducing sugar concentration was analyzed with DNS (3,5-Dinitrosalicylic acid) method

3. Methodology

Simulated and evaluated processes

Organic Kitchen Food Waste Valorization

Conceptual Design

Technical and Energy

- Yield
- Power requirement
- Thermal energy consumption

Economic

- CapEx
- OpEx
- Production cost/Selling Price ratio

Tools

ASPEN PLUS

ASPEN ECONOMIC ANALYZER

aspentech

Aspen plus and Aspen Energy Analyzer

Aspen Process Economic Analyzer

4. Results

Chemical characterization of Organic Kitchen Food Waste

Table 4. The methods used for chemical characterization of raw material

Item	Rice, vegetables and meats [14]	Dinner shop food waste [15]	Kitchen waste [16]	Organic municipal solid waste [17]	Kitchen garbage [18]	This work
Moisture	81.9	75.9	80.3	N.R.	75.2	78.4
Total sugar	48.3	42.3	59.8	56.2	50.2	36.5
Starch	42.3	7.06	N.R.	N.R.	46.1	16.1
Cellulose	N.R.	N.R.		46.3	N.R.	23.8
Hemicellulose	N.R.	10.26		36.5	N.R.	12.6
Lignin	N.R.		0.8	N.R.	N.R.	2.4
Fats	N.R.	3.10	15.7	15.6	18.1	3.9
Protein	17.8	3.9	21.8	N.R.	15.6	2.4
Pectin	N.R.	N.R.	N.R.	4.3	N.R.	1.1
Ash	N.R.	1.25	1.9	1.9	2.3	1.2

The production of fermentable sugars from the enzymatic hydrolysis of OKW was between **80 - 115** g/L. These results are similar to those reported in previous studies

4. Results

Technical and energy analysis

Table 5. Mass and energy indicators

Input	Scenario 1	Scenario 2	Scenario 3
Product yield	Biogas: 1.105 m^3/kg of raw material Methane: 0.638 m^3/kg of raw material	Ethanol: 0.024 kg/kg of raw material Concentration fermentable sugars: 100 g/L	Ethanol: 0.024 kg/kg of raw material Concentration fermentable sugars: 100 g/L Biogas: 0.643 m^3/kg of raw material Methane: 0.373 m^3/kg of raw material
Power requirement	1.372 kWh/ton of raw material	3.561 kWh/ton of raw material	4.713 kWh/ton of raw material
Thermal energy consumption	Medium Pressure Steam: 0.645 MJ/kg of raw material	Medium Pressure Steam:1.852 MJ/kg of raw material High Pressure Steam:38.013 MJ/kg of raw material Cooling water: 13.014 MJ/kg of raw material	Medium Pressure Steam:2.842 MJ/kg of raw material High Pressure Steam:38.013 MJ/kg of raw material Cooling water: 13.014 MJ/kg of raw material

4. Results

Economic analysis

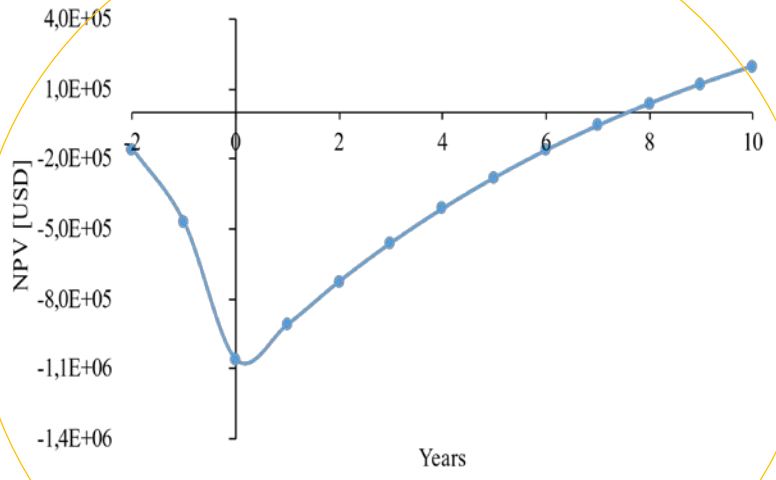


Figure 2. OKFW valorization in Scenario 1 (Biogas)

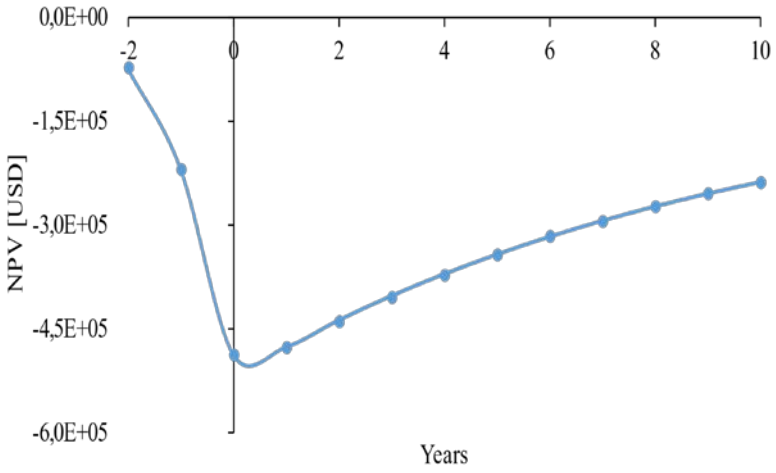


Figure 3. OKFW valorization in Scenario 2 (Bioethanol).

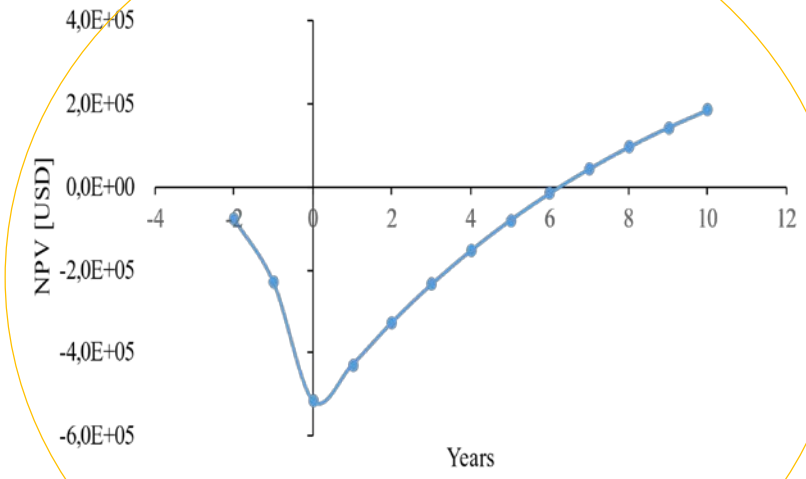


Figure 4. OKFW valorization in Scenario 3 (Bioethanol + Biogas).

Processing scale: 36.5 t/d

5. Conclusions

- The Organic Kitchen Food Waste is a potential raw material to be upgraded applying the biorefinery concept since this raw material has the potential to provide a series of different platforms (e.g., sugars).

- The integration of ethanol production with biogas and fertilizer makes possible the valorization of Organic Kitchen Food Waste in economic terms.

- In addition, the compositional model can be applied in any other context considering the socioeconomic conditions

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