

Research Article

Valorization of Kitchen Waste from University Restaurants for Biogas Production - Case of Joseph KI-ZERBO University

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Abstract

The management of food waste in university restaurants represents a significant environmental challenge, particularly in developing countries where waste treatment infrastructure is limited. This study investigates the energy valorization of kitchen waste generated by the central restaurant and its annexes (RU SIAO, RU Chinoise) at Joseph KI-ZERBO University in Ouagadougou, Burkina Faso, through anaerobic digestion. The objective is to propose a sustainable solution for managing food waste, reducing its environmental impact, and producing renewable energy. A quantitative and qualitative characterization of the waste was conducted over several weeks, assessing its volume, composition, and methanogenic potential. The results reveal an annual production of approximately 188.78 tons of waste, of which 72.2% consists of fermentable organic matter (rice, pasta, sauces, vegetables, peels), ideal for methanization. Laboratory tests, conducted with inoculum from the ONEA biogas plant in Kossodo, demonstrated a biogas yield of 320 to 350 L/kg of dry matter, with a methane content of 57 to 62%, suitable for local applications such as cooking, heating, or electricity production. The nutrient-rich digestate can be used as organic fertilizer for campus green spaces, reinforcing circular economy principles. Physicochemical analyses indicate a dry matter content of 22.4%, a volatile organic matter content of 86.5%, and an optimal C/N ratio of 25.3, promoting efficient anaerobic digestion under mesophilic conditions (35 ± 2 °C). Challenges include seasonal variability in waste composition, the need for rigorous sorting to eliminate contaminants (plastics, packaging), and investment in infrastructure such as industrial digesters. To ensure success, the study recommends a strengthened selective sorting system, medium-scale pilot projects to validate technical and economic feasibility, and awareness-raising among students and staff. By adopting this strategy, Joseph KI-ZERBO University could reduce greenhouse gas emissions, minimize waste management costs, and become a model of sustainability for African academic institutions, contributing to sustainable development goals.

Keywords

Kitchen Waste, Anaerobic Digestion, Biogas, Energy Valorization, Sustainable Management

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1. Introduction

The management of food waste in university restaurants represents a major environmental and logistical challenge, particularly in developing countries where waste treatment infrastructure is often limited [1]. At Joseph KI-ZERBO University in Ouagadougou, Burkina Faso, the central restaurant and its annexes (RU SIAO, RU Chinoise, others) serve between 4,000 and 7,000 meals daily, generating approximately 188.78 tons of waste annually, of which 72.2% consists of fermentable organic matter such as rice, pasta, sauces, vegetables, and peels [2]. These wastes, often poorly managed, contribute to campus unsanitary conditions, soil and groundwater pollution, and greenhouse gas emissions, notably methane (CH_4) and carbon dioxide (CO_2), exacerbating climate change impacts [3]. Methanization, an anaerobic digestion process, provides a sustainable solution to convert these wastes into biogas, a renewable energy source containing 50 to 65% methane, suitable for cooking, heating, or electricity production, while reducing the volume of waste sent to landfills [4]. The digestate from this process can also be used as organic fertilizer, aligning with circular economy principles [5]. Conducted in collaboration with the Institute of Research in Applied Sciences and Technologies (IRSAT) and the ONEA biogas plant in Kossodo, this study aims to characterize the kitchen waste from university restaurants in terms of quantity, composition, and physicochemical properties, evaluate their methanogenic potential through laboratory experiments, and propose an energy valorization pathway tailored to the local context. Results show a biogas yield of 320 to 350 L/kg of dry matter, with a methane content of 57 to 62%, confirming the technical viability of this approach [4]. By adopting such a strategy, Joseph KI-ZERBO University could reduce the environmental impact of its waste, promote green energy, and become a model for sustainable waste management in African academic institutions. This article is structured into sections detailing the context, methods, results, discussion, and recommendations for practical implementation, contributing to sustainable development goals.

2. Materials and Methods

2.1. Hypotheses on Waste Composition

Kitchen waste is assumed to consist mainly of biodegradable organic matter, such as food scraps (rice, vegetables, sauces) and peels, with a high content of volatile organic matter (VOM). Non-organic contaminants (plastics, metals) are considered minor and removed through prior sorting.

2.2. Assumptions on Methanization

The methanization process is assumed to occur under mesophilic conditions ($35 \pm 2^\circ\text{C}$), with a stable inoculum from an operational digester. The biogas produced is primar-

ily composed of CH_4 (50-65%) and CO_2 , with traces of hydrogen sulfide (H_2S) and other gases.

2.3. Assumptions on Operational Conditions

Operational parameters, such as pH (6.8-7.4), carbon/nitrogen ratio (C/N, 20-30), and retention time (30 days), are assumed to be optimized to maximize biogas yield.

2.4. Study Site

The study was conducted at the central restaurant of Joseph KI-ZERBO University and its annexes (RU SIAO, RU Chinoise, others) in Ouagadougou. These facilities serve 4,000 to 7,000 meals daily, generating significant amounts of food waste.

2.5. Equipment Used

- 1) *Collection*: Plastic bags, sorting bins, electronic scales (100 g precision), wheelbarrows for transport.
- 2) *Characterization*: Laboratory oven (105 $^\circ\text{C}$ for moisture content), muffle furnace (550 $^\circ\text{C}$ for volatile organic matter), sieves for manual sorting, pH meter for aqueous analyses.

The oven used to determine the moisture content is shown in Figure 1.



Figure 1. Oven for determining moisture content.

- 3) *Methanization*: Laboratory digesters (500 ml), biogas volume measurement system by water displacement, GA 5000 portable analyzer for biogas composition (CH_4 , CO_2 , H_2S).

Figure 2 illustrates the experimental setup for methanization.



Figure 2. Experimental Methanization Setup.

Biogas Measurement: The volume of biogas produced was measured daily by water displacement. The biogas composition (CH_4 , CO_2) was analyzed using the GA 5000 portable analyzer, presented in Figure 3.



Figure 3. GA 5000q Portable Analyzer.

2.6. Waste Characterization

The waste was collected after each service for three consecutive weeks, manually sorted into categories (food scraps, peelings, inerts), and weighed. The physicochemical parameters were determined as follows:

- 1) **Moisture Content:** Moisture was determined by drying in an oven at 105°C until a constant weight was achieved. The process typically takes 24 hours, and the waste sample to be dried ranges from a few grams to several kilograms [6]. It is expressed as a percentage relative to the wet weight of the waste.
- 2) **Dry Matter (DM):** The volatile organic matter content was determined following the AFNOR/X 34 B No. 113 protocol, calculated using the equation:

$$MS = \frac{M_f - M_v}{M_i - M_v} \quad (1)$$

where M_f is the mass after drying, M_i is the initial mass, and M_v is the mass of the crucible.

- 3) **Volatile Organic Matter (VOM):** The dry matter content was determined following the AFNOR/X 34 B No. 110 protocol from samples prepared for incubation. The process was repeated twice to calculate the average value. The dry matter content for each test is given by equation:

$$MS = \frac{M'_f - M_v}{M_f - M_v} \quad (2)$$

where M'_f is the mass after calcination at 550°C .

- 4) **pH:** Measured on an aqueous extract.
- 5) **C/N Ratio:** Determined by chemical analysis.

2.7. Anaerobic Digestion Tests

Organic waste was homogenized, ground, and mixed with an inoculum from the ONEA biogas plant in Kossodo. The digesters were maintained under mesophilic conditions ($35 \pm 2^\circ\text{C}$) for 30 days. Biogas volume was measured daily using water displacement, and its composition (CH_4 , CO_2 , H_2S) was analyzed weekly with the GA 5000 analyzer.

2.8. Fundamental Equations

The methanogenic yield (Y_{CH_4}) is calculated as follows:

$$Y_{\text{CH}_4} = \frac{V_{\text{CH}_4}}{\text{MMS}} \quad (3)$$

where V_{CH_4} is the volume of methane produced (L) and MMS is the dry matter mass (kg).

The volatile organic matter (VOM) content is determined by:

$$\text{VOM}(\%) = \frac{M_{550^\circ\text{C}}}{\text{MMS}} \times 100 \quad (4)$$

where $M_{550^\circ\text{C}}$ is the mass lost during calcination at 550°C and MMS is the dry mass.

Seasonality affects the quantity and composition of waste, with higher production in the dry season due to increased attendance.

The kg/meal ratio varies from 0.012 to 0.07, reflecting differences in menus and consumption practices.

3. Results and Discussion

3.1. Quantity and Current Waste Management

The university restaurants produce an average of 240 kg/day of waste at the central restaurant and 60 to 80 kg/day per annex, resulting in an estimated annual production of 57.6

tons for the central restaurant and 14.4 to 19.2 tons per annex. Current management involves basic sorting, followed by disposal in landfills or partial valorization by local farmers for animal feed.

The waste is primarily composed of easily biodegradable organic matter. Food scraps (rice, pasta, sauces, vegetables) make up the majority of the waste, followed by peelings and a small proportion of inert waste (plastics, packaging). The different types of waste are presented in Figure 4, Figure 5 and Figure 6.

The carbon/nitrogen (C/N) ratio, derived from the chemical composition of the waste, ranges optimally from 20 to 30 to maximize biogas production. The distribution of waste by affiliated restaurant is presented in Table 1.



Figure 4. Sweet potato and zucchini peelings.



Figure 5. Waste collected at the meal distribution service.



Figure 6. Onion peelings, pepper scraps, and eggshells.

Table 1. Distribution of waste by affiliated restaurant.

Designation	Dry season			Rainy season		
	Number of dishes	Quantity of waste produced (kg)	Waste ratio per dish (kg/dish)	Number of dishes	Quantity of waste produced (kg)	Waste ratio per dish (kg/dish)
Kitchen	7740	223.4	0.029	7243	85	0.012
Central RU	5000	335.5	0.07	4179	217	0.052
Annex RU	1821	122.18	0.07	1402	42.00	0.030
Chinese RU	919	61.66	0.07	595	17.82	0.030
SIAO RU	-	-	-	967	28.97	0.030
Daily total	7740	742.75	0.125	7243	390.80	0.066

Seasonal variations significantly influence waste volumes, with higher production during the dry season due to increased attendance at university restaurants, driven by intensified academic activities. This period, characterized by arid climatic conditions, leads to more standardized food consumption, resulting in larger quantities of collected organic waste.

Determination of physicochemical parameters:

- 1) *Moisture content*: Measured by drying samples at 105 °C until constant mass, quantifying the water fraction in the waste.
- 2) *Volatile Organic Matter (VOM)*: Determined by calcination at 550 °C, reflecting the biodegradable organic

fraction.

- 3) *pH*: Assessed from an aqueous extract of the waste, critical for ensuring compatibility with methanization conditions.

3.2. Physicochemical Characteristics of the Waste

The waste consists of 85% organic matter (rice, pasta, sauces, vegetables, peelings), with a small proportion of inert contaminants (plastics, packaging).

The waste was sorted according to the MODECOM protocol, revealing a composition of 72.2% fermentable waste, 15.0% plastics, 7.3% cardboard, 5.1% unclassified non-combustibles, and 0.4% metals. The waste sorting session by category is

presented in Figure 7.



Figure 7. Sorting operation by category.

The physicochemical characteristics of the substrates are presented in Table 2.

Table 2. Physicochemical Characteristics of Substrates.

Substrat	pH	Temperature	DM (%)	VOM (%)
Sewage sludge (SS)	7.88	37 °C	5%	43%
Food waste (FW)	7.72	37 °C	5%	92%
Kitchen waste (KW)	7.45	37 °C	5%	96%
Mixture (SS+FW+KW)	7.34	37 °C	5%	88%

- 1) *Dry matter (DM) content*: 22.4%
- 2) *Volatile organic matter (VOM) content*: 86.5% of DM
- 3) *pH*: 6.2 to 6.8
- 4) *C/N ratio*: 25.3 (within the optimal range for methanization)

These characteristics indicate high biodegradability, ideal for biogas production. The high VOM content suggests significant methanogenic potential, while the slightly acidic pH can be adjusted during methanization to maintain optimal conditions.

3.3. Biogas Production Potential

Methanization tests showed that the mixture (sewage sludge, food waste, kitchen waste) produced biogas richer in methane (37% v/v on day 5) and in greater quantities than individual substrates. Food waste alone also reached 37% methane on day 5, while sewage sludge peaked at 24.1% on day 6. After 8 days, methane production from food waste declined, likely due to acidification ($\text{pH} < 6.4$), highlighting the need for pH adjustment.

Laboratory tests yielded a cumulative biogas volume of 320 to 350 L/kg of DM over 30 days, with an average composition of:

- 1) *Methane (CH_4)*: 57 to 62%
- 2) *Carbon dioxide (CO_2)*: 37 to 41%

- 3) *Hydrogen sulfide (H_2S)*: $< 0.5\%$

The methanogenic yield (Y_{CH_4}) reached approximately 200 L of CH_4 /kg of DM, comparable to results reported for similar food waste in the literature [7]. The methane content allows direct use for cooking or, after purification, for electricity production.

The methane content, as shown in Figure 8, progressively increases to 62% by day 30, making the biogas suitable for cooking or, after purification, for electricity generation in local contexts.

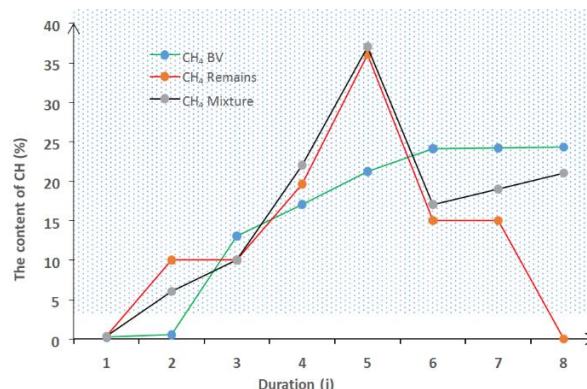


Figure 8. Evolution of Methane Content in Different Substrates.

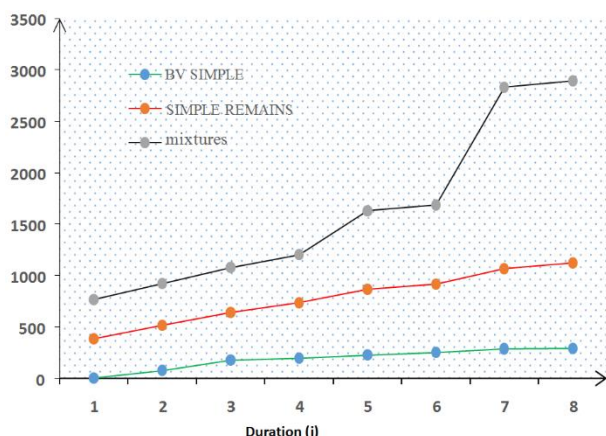


Figure 9. Evolution of the Cumulative Biogas Volume Produced from Different Substrates.

Figure 9 illustrates the cumulative biogas volume (L/kg DM) as a function of time, reaching 350 L/kg DM at 30 days.

3.4. Analysis of Results

The results confirm the high methanogenic potential of kitchen waste from Joseph KI-ZERBO University, attributable to its high organic matter content and favorable physicochemical properties. The biogas yield (320-350 L/kg DM) and methane content (57-62%) are competitive, reflecting the quality of the substrate composed of rice leftovers, vegetables, and sauces [7]. The C/N ratio of 25.3 falls within the optimal range (20-30), supporting efficient microbial activity [8, 9].

Co-digestion with sewage sludge or used oils could improve yields by balancing nutrients and increasing energy content, as demonstrated in other studies (Valorisation énergétique, 2003). However, several challenges remain:

- 1) *Seasonal variability*: The composition of waste fluctuates depending on menus and attendance, requiring homogenization of inputs.
- 2) *Selective sorting*: Inert contaminants (plastics, packaging) demand rigorous sorting to prevent digester clogging.
- 3) *Infrastructure*: Scaling up requires industrial digesters, collection systems, and regular maintenance.
- 4) *Stakeholder engagement*: Success depends on awareness-raising and training for students and staff.

3.5. Environmental Impacts

Methanization reduces methane emissions from landfills, mitigating the impact on climate change [10]. The nutrient-rich digestate can be used as fertilizer for campus green spaces, strengthening the circular economy [11].

3.6. Socio-Economic Impacts

Economically, waste valorization could lower disposal costs and generate revenue through the sale of biogas or digestate. A detailed techno-economic analysis is needed to assess financial viability. Socially, raising awareness among students and staff is critical to ensure the project's acceptability and sustainability [12].

3.7. Comparison with Other Projects

Comparable projects, such as the Lille Organic Valorization Center or African community biodigesters, demonstrate the adaptability of methanization to various contexts [13-15]. A medium-scale pilot digester could validate the technical and economic feasibility at Joseph KI-ZERBO University.

4. Conclusion

This study demonstrates the significant potential of kitchen waste generated by the university restaurants of Joseph KI-ZERBO University in Ouagadougou, Burkina Faso, for biogas production through methanization, offering a sustainable solution to the environmental and logistical challenges posed by food waste management. With an estimated annual production of over 90 tonnes of organic waste, primarily composed of food leftovers and peelings, energy valorization through anaerobic digestion reduces environmental impact, notably by limiting greenhouse gas emissions such as methane and carbon dioxide from landfills, while producing renewable energy suitable for local applications such as cooking, heating, or electricity generation. Laboratory tests revealed a competitive methanogenic yield, with a biogas volume of 320 to 350 L/kg of dry matter and a methane content of 57 to 62%, confirming the technical viability of this approach. Additionally, the nutrient-rich digestate can be used as organic fertilizer for campus green spaces, strengthening the circular economy. To ensure the success of a valorization system, it is recommended, first, to establish a rigorous selective sorting system to minimize contaminants; second, to invest in anaerobic digesters suited to the campus's production capacity; furthermore, to launch medium-scale pilot projects to validate technical and economic feasibility; and finally, to raise awareness and train students and staff in sustainable waste management. By adopting this approach, Joseph KI-ZERBO University could become a model of innovation for energy transition and circular economy in African university institutions, contributing to sustainable development goals while improving the environmental and social quality of the campus.

Abbreviations

RGPH	General Population and Housing Census
BRAKINA	Burkina Faso Brewery

SONABEL	National Electricity Company of Burkina Faso
UEMOA	West African Economic and Monetary Union
DUT	University Technology Diploma
IFTSA	Institute for Training in Applied Solar Technology
IRSAT	Institute for Research in Applied Sciences and Technologies
ÉPM	École Polytechnique de Montréal
DESS	Specialized Graduate Diploma
kW	Kilowatt
kWh	Kilowatt-hour
kg	Kilogram
ml	Milliliter
UJKZ	Joseph Ki-Zerbo University
RU	University Restaurant
ONEA	National Water and Sanitation Office
RU-UJZK	Joseph Ki-Zerbo University Restaurant
BMP	Biomethane Potential
pH	Hydrogen Potential
MS	Dry Matter
MO	Organic Matter
C/N	Carbon-to-Nitrogen Ratio
AGV	Volatile Fatty Acids
CHP	Combined Heat and Power
MODECOM	Household Waste Characterization Model
DSMA	Household and Similar Solid Waste
CNC	Unclassified Combustible
INC	Unclassified Incombustible

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Author Contributions

Nebyinga Béatrice Komi: Conceptualization, Data curation, Funding acquisition, Methodology, Resources, Visualization

Salifou Cisse: Funding acquisition, Resources, Visualization, Writing - review & editing

Abdoul Aziz Ouiminga: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing

Oumar Sanogo: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Methodology, Project administration, Supervision, Validation, Visualization, Writing - original draft

SiéKam: Supervision, Validation

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Data Availability Statement

All data generated or analyzed during this study can be made available upon request. If necessary, you can contact the corresponding author to obtain an electronic copy of the data.

Conflicts of Interest

The authors declare no conflicts of interest.

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