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Perceptions of hotel and restaurant operators on the use of biogas produced from organic waste as a source of energy in the district of Abomey-Calavi in Benin

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Abstract

The proliferation of hotel and catering infrastructures in the Abomey-Calavi Borough is leading to an increasing production of waste, which represents an environmental challenge. The aim of this study is to assess the perceptions of hotel and catering stakeholders on the use of biogas produced from their organic waste as an energy source in the Abomey-Calavi district of Benin. To this end, a descriptive cross-sectional and analytical study was carried out among 147 stakeholders in 05 hotels and 29 restaurants. These agents were composed of 56.5% men and 43.5% women. With an average age of 29.05 (±5.434) and a predominance of single people (66.0%), the majority had a secondary education (71.4%). The study revealed that the solid waste reported by 100.0% of respondents was produced more by hotel services than the liquid waste reported by 96.6%. The most common types of waste produced in these facilities are meal leftovers (95.2%), followed by edible oils and fats (74.8%). Waste management is handled by NGOs, which are responsible for collecting waste from the various facilities. According to respondents, 53.1% of waste is thrown away unsorted, compared with 49.0% after sorting. Waste is incinerated in 18.4% of cases and landfilled in 0.7%. Hotel and restaurant promoters perceive the exclusive use of gas produced from the waste from their operations as cost-effective compared with other types of fuel. For hotel and restaurant customers, the exclusive use of gas produced from the waste from your operations compared with other types of fuel is economical and reduces pollution. For cleaners, cooks and housekeepers, installing a waste-to-energy system to produce biogas in the workplace is a risk. Overall, the various results of this study show that it is possible to think about a waste recovery policy through biogas production in hotels and restaurants in the city of Abomey-Calavi.

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Introduction

Today's world faces many challenges, including environmental and sustainable development challenges in the context of the energy needs of an ever-growing population (FAO, 2009). Today, 2 billion people around the world depend on wood from forests as a source of domestic energy and these forests are under increasing pressure (Odjoubéré, 2014). Indeed, the fuelwood crisis has continued to worsen (Keita, 2004) and the degradation of the natural environment as well as the fragility of ecosystems are evolving at an alarming rate in recent years (Bouraima, 2005).

In Africa, wood represents 89% of energy sources. This massive use of wood is a major cause of deforestation, leading to drought, desertification and an increase in greenhouse gas emissions contributing to global warming (Mfouapon, 2007). Thus, ecosystems and wood resources have experienced a sharp decline, especially over the last twenty years (Assouni, 2009). This degradation has several causes including the construction of roads and access routes to agricultural resources, the downgrading of classified forests for the benefit of populations and above all the energy needs of the population (FAO, 2009).

In West Africa, this degradation is more accelerated and more than 12 million hectares disappeared between 1990 and 2000 (FAO, 2000). In Benin, the problem of domestic energy is acute and wood constitutes the main source of energy (bioenergy) for urban and rural households (Koba, 2010). Indeed, the diagnosis of the forestry sector carried out within the framework of the national forestry policy estimated in 1994 the overall demand for fuelwood at 5,200,000 tonnes/year and that of charcoal at 19,000 tonnes/years. Populations remain dependent on traditional energies, because consumption is high for the country. Thus, according to Moisse (2020), increasing the quality of life of rural populations in Benin will involve improving access to energy for these populations and preserving their environment.

Today, the primary source of energy consumption for a rural Beninese family is the kitchen. The fuel used is most often wood which puts a lot of pressure on forest ecosystems (Adam, 2012). This situation reveals the urgent need to use other sustainable energy sources. It is therefore to respond to this energy challenge that organic waste, by providing biogas through methanization, is emerging as a renewable energy source. The establishment of biomethanization units in African communities can be a lever for development and energy emancipation (Gbesso *et al.*, 2013). Indeed, in Benin, the hotel and catering industry are activities at the center of this industry which consumes large quantities of wood energy and other fossil fuels but also generates significant quantities of organic substrates (Gankam and Tchawa, 2018).

Thus, to meet the dual challenge of protecting the environment and meeting energy needs, particularly in hotel complexes and restaurants, large consumers of wood energy, it is imperative to promote the management and recovery of organic waste, particularly kitchens and human waste.

This study therefore aims to assess the perceptions of hotel and restaurant stakeholders on the use of biogas produced from their organic waste as an energy source in the Abomey-Calavi District in Benin.

Materials and methods

Study site

The study took place in the central district of the Commune of Abomey-Calavi, located between 6°24'46" and 6°30'49" north latitude and between 2°18'28" and 2° 22'42" East longitude. It was carried out in hotel establishments and restaurants in the city (Fig. 1.).

Type and period of study

This is a descriptive cross-sectional study carried out in December 2022 among hotel and restaurant stakeholders.

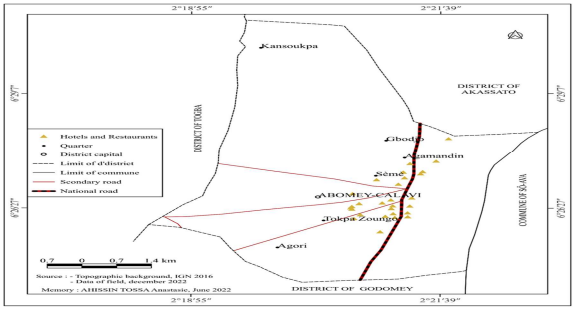

Fig. 1. Map of study area with hotels and restaurants investigated

Sampling

The sample size (N) was obtained using the normal approximation of the binomial distribution proposed by Dagnelie (1986).

$$N = \left[\left(U_{1-\frac{\alpha}{2}}\right)^2 \times p(1-p)\right]/d^2 \quad \text{Avec :}$$

$U_{1-\alpha/2}$ the value of the normal random variable for the probability value of 1-α/2, α being the risk of error. For α = 5%, the probability 1-α/2 = 0.975 and we have U1-α/2= 1.96. P is the proportion of people using or not using restaurants and having knowledge in the use and management of waste; sources of gas production and d (1%≤d≤15%), the margin of error of estimation, retained at 5% in this study.

Using the p-values derived from the results of the exploratory phase of the study, a total of 147 people were selected. They were divided according to their role in the restaurants and hotels. In each structure (hotels and restaurants), respondents were identified using simple random sampling (Bello *et al.*, 2017; Avaligbé *et al.*, 2021).

Variables

The variables of interest are the socio-economic characteristics of the study participants, their perceptions on the valorization of waste from hotel complexes into biogas, the types of waste produced, the waste management methods, the frequency of waste collection.

Data collection

Several techniques were used to collect data from the actors mentioned above. First, surveys were carried out with developers, cooks, customers, maintenance workers, garbage collectors, local residents, etc. based on an electronic questionnaire. Then, the resource people (staff from the district office, town hall, non-governmental organizations etc.) were interviewed using an interview guide. The data collected during the exchanges relate to the types and methods of waste management, the quantity of waste produced, the frequency of waste collection, and the production of biogas. Direct observations based on an observation grid were made to complete these surveys. They provided information's on waste management methods in hotels and restaurants. Furthermore, all the tools used as part of the study have been digitalized. Thus, the quiz, the interview guide, the observation grid, the census and georeferencing sheet were hosted in the KoboCollect application.

Statistical analysis of data

The data collected during the survey were coded, entered and processed with SPSS (Statistical Package for Social Sciences) version 20.0 software (Norusis, 2002) for the determination of descriptive statistics in terms of percentage and mean. The quantitative data collected were then subjected to an analysis of variance (ANOVA) using the PROC GLM procedure of SAS (Statistical Analysis System) software version 9.2 according to Bello *et al.* (2017). Multiple mean comparisons were made using the Student Newman-Keuls test (Dagnelie, 1986).

Next, the different uses made of waste were subjected to a simple Correspondence Factor Analysis (CFA) while perceptions on gas production devices were subjected to a Principal Component Analysis (PCA) using Minitab 14 software according to Bello *et al.* (2017). The results of the different analyses are presented in tables and figures according to Kisauzi *et al.* (2012).

Results

Socio-professional characteristics of the study participants

The perceptions reported in this manuscript were obtained from 147 people in 05 hotels and 29

restaurants. 56.5% male and 43.5% female, the participants were made up of 31 maintenance workers, 6 customers, 1 garbage collector, 50 cooks, 13 promoters and 46 servants. With an average age of 29.05 years (±5.434) and a predominance of singles (66.0%), the majority of them had a secondary level of education (71.4%) as shown in Table 1.

Table 1. Socio-professional characteristics of study participants

Characteristics	Statistical parameters	
Age	Average	Standard deviation
	29,05	5,434
Sex	Frequency	Percentage
Female	64	43,5
Male	83	56,5
Total	147	100,0
Marital status	Frequency	Percentage
Single	97	66,0
Married	50	34,0
Total	147	100,0
Education level	Frequency	Percentage
Primary	23	15,6
Secondary	105	71,4
Superior	19	12,9
Total	147	100,0

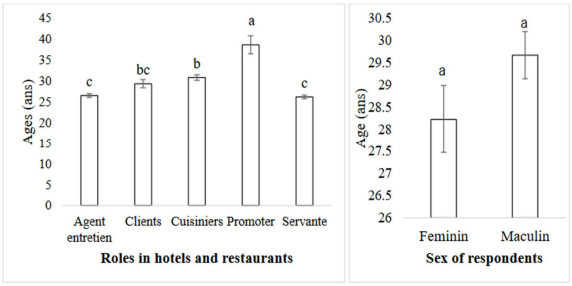

Fig. 2. Age of respondents (mean ± standard error) by role and sex

Bars indicate standard errors. Bars followed by the same alphabetical letters are not significantly different (P > 0.05) according to the Student Newman-Keuls test.

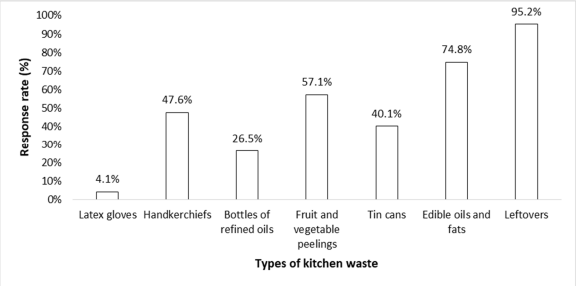

Fig. 3. Types of waste found in hotel and catering kitchens

Analysis of variance and the Student Newman-Keuls test revealed that hotel and restaurant promoters were the oldest ($p<0.05$) compared with maids and cleaners, who were the youngest. However, there was no significant difference ($p>0.05$) in age between men and women (Fig. 2).

Characteristics and typology of kitchen waste

The data collected made it possible to know the nature of waste produced by hotel and catering services in the Abomey-Calavi District. Indeed, solid waste reported by 100.0% of respondents is produced more by hotel services than liquid waste reported by 96.6%. Better yet, seven (7) different types of waste are produced by hotel and catering services. From observation in kitchens and trash cans, the most waste produced in these hotels and catering infrastructures is leftovers from meals (95.2%) then edible oils and fats (74.8%) as evidenced by the Fig. 3.

The Correspondence Factorial Analysis (CFA) carried out to describe the relationships between these restaurant and hotel stakeholders and the uses made of waste shows that the first two axes explain 83.13% of the total information.

The results of the Correspondence Factorial Analysis (CFA) carried out (Fig. 4) showed that for promoters, kitchen waste is cans and bottles of refined oil. For customers and cooks, service waste is collected by the gas manufacturing companies. Similarly, gloves and latex are kitchen waste. As far as cleaners and servants are concerned, solid and liquid waste, as well as tea towels and handkerchiefs, are characteristic of hotel and restaurant waste. Similarly, edible oils and fats are kitchen waste. As far as waste management is concerned, NGOs are in charge of waste collection in the various facilities.

Waste management method

Several approaches are adopted for waste management in the hotel and catering infrastructures of the Abomey-Calavi District. Indeed, in these hotels and restaurants, 53.1% of waste is thrown in the trash without sorting compared to 49.0% after sorting

according to the respondents' statements. Waste is incinerated in 18.4% of cases and buried in only 0.7% of cases (Fig. 5). The majority of hotels and restaurants investigated as part of this study have bins with a capacity varying between 60 liters (42.9%) and 80 liters (56.5%). These bins are most often filled either in 1 day (38.8%) or 2 days (59.9%) according to Fig. 6.

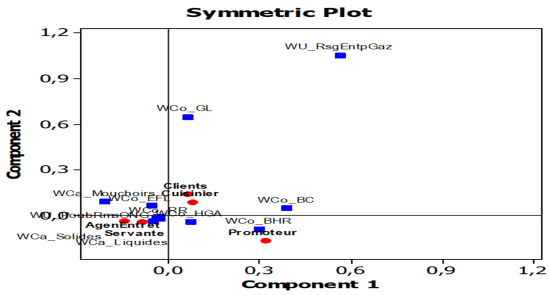

Fig. 4. Results of Correspondence Factorial Analysis (CFA) performed on hotel and restaurant actors and waste characteristics

Legend: WCo: Waste cooking; WU: Waste use; WCa: Waste Characteristics; HGA: Food Oil and Fat; BHR: Refined Oil Bottle; GL: Gloves and latex; BC: Can; EFL: Fruit and vegetable stalks; RR: Meal remainder.

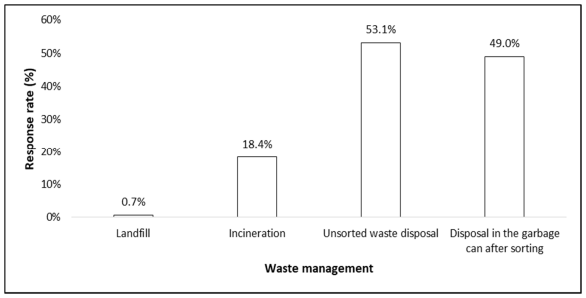

Fig. 5. Waste management in hotels and restaurants

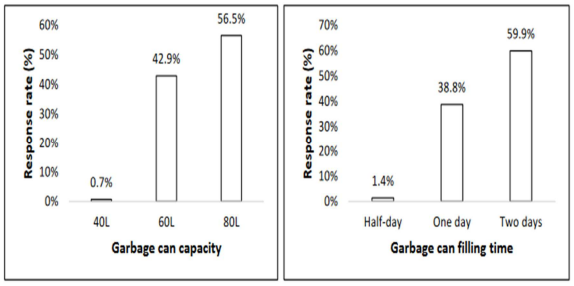

Fig. 6. Bin capacity and filling time

The frequency of waste collection in these structures is twice a week for 97, 3% of people surveyed. This collection is ensured by the solid waste management company (SGDS), a state company which ensures sanitation in five cities of Benin, namely: Cotonou, Abomey-Calavi, Porto-Novo, Sèmè-Podji and Ouidah.

Types of fuels used in cooking

In the kitchens of the hotels and restaurants investigated, three (3) types of fuel are used, the most common of which are gas (96.6%) and coal (95.2%). Wood is sometimes used, in 25.9% of cases (Fig. 7).

Indeed, according to the people surveyed, gas and coal are more available on the market. The quantities of gas and coal used vary per day (Fig. 8).

Most hotels and restaurants (53.1%) use at least one large gas bottle (12 kg) per day and this consumption can go up to 3 bottles when they receive event orders. Furthermore, 36.1% of hotels and restaurants use a large bag of charcoal per day (Fig. 8). Most hotels and restaurants usually have coal available to manage unexpected gas shortages.

The Correspondence Factorial Analysis (CFA) carried out to describe the relationships between restaurant and hotel stakeholders and the types of fuel and uses made of service waste revealed that the first two axes explained 97.42% of the total information.

The results of the Correspondence Factorial Analysis (CFA) carried out (Fig. 9) showed that for promoters, waste is collected every day. For hotel and restaurant guests, wood is the most commonly used fuel, and service waste is disposed of in unsorted garbage cans. On the other hand, housekeepers and cooks incinerate the waste they put in the garbage cans after sorting. This waste is collected twice a week, and the fuels they use are gas and coal. As for the maids, they bury the collected waste.

Perceptions of hotel and restaurant stakeholders on the exclusive use of gas produced by waste

Those involved in hotel and catering services have diverse perceptions on the exclusive use of gas produced by waste. According to them, this exclusive use of gas produced by waste is economical in 95.9%

of cases, profitable in 64.6% of cases and can reduce pollution in 49.7%. But this practice can be costly for 1.4% of people interviewed (Fig. 10).

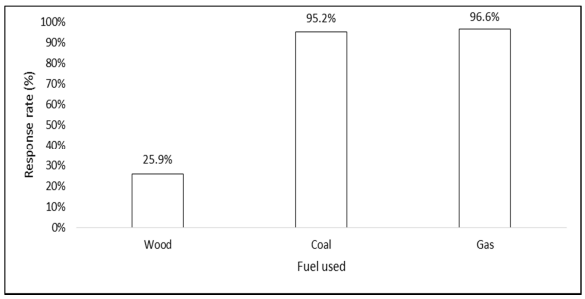

Fig. 7. Fuels used in hotel and restaurant infrastructures

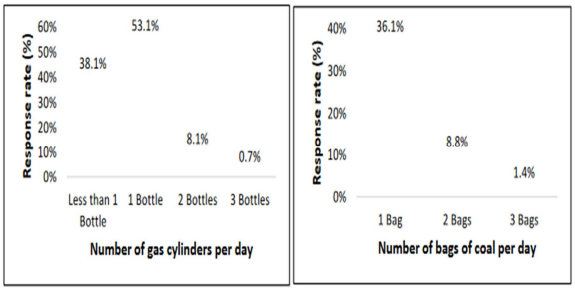

Fig. 8. Quantities of gas and coal used per day in hotels and restaurants

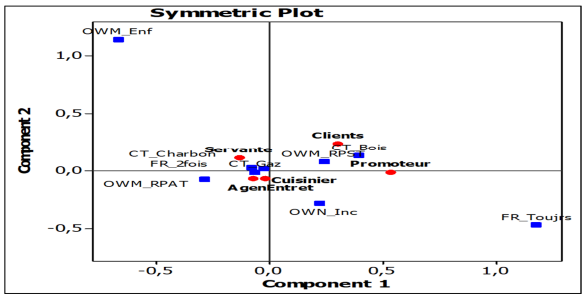

Fig. 9. Results of Correspondence Factorial Analysis (CFA) performed on hotel and restaurant stakeholders and fuel types as well as waste collection frequency

Legend: OWM: Service waste management; RPAT: Discharge into waste garbage can after; RPST: Discharge into sorting garbage can; Enf: Landfill; Inc: Incineration; FR: Frequency; CT: Combustible Type

Indeed, according to 61.9% of stakeholders, the installation of a biodigester contributes to environmental sanitation through waste collection. Likewise, 49.7% of these stakeholders think that this installation would contribute to reducing pollution. However, this installation can constitute a danger and a source of pollution respectively for 54.4% and 2% of these people surveyed (Fig. 11).

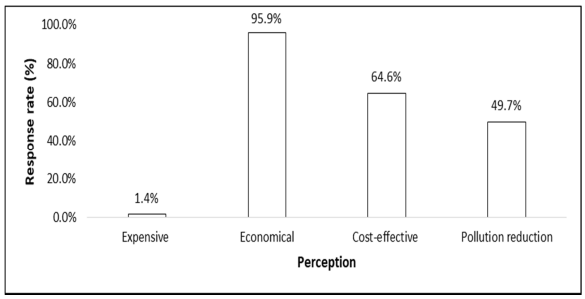

Fig. 10. Perception of exclusive gas use

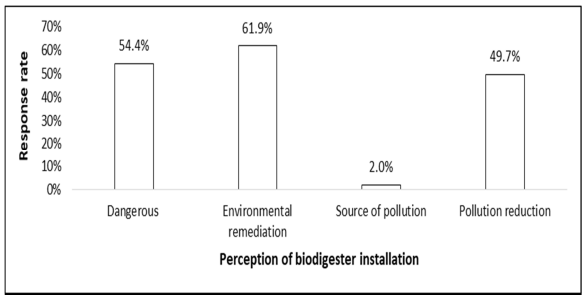

Fig. 11. Perception of biodigester installation

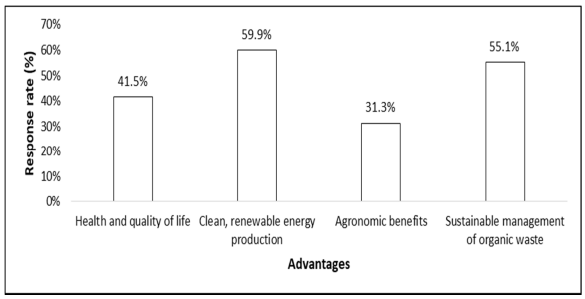

Fig. 12. Advantages of installing a gas-from-waste system

However, according to the statements of the same actors, the installation of a gas storage device allows the production of clean and renewable energy (59.9%), the sustainable management of organic waste (55.1%). It also ensures health and quality of life (41.5%) and provides agronomic advantages (31.3%) according to Fig. 12.

Overall, 98.7% of hotel and restaurant stakeholders express their willingness to use gas from their waste compared to 1.3% who believe that this is not hygienic. Almost all hotels and restaurants (96.6%)

have sunny space for a long period (05 years) which can accommodate the installation and maintenance of the biodigester (Fig. 13).

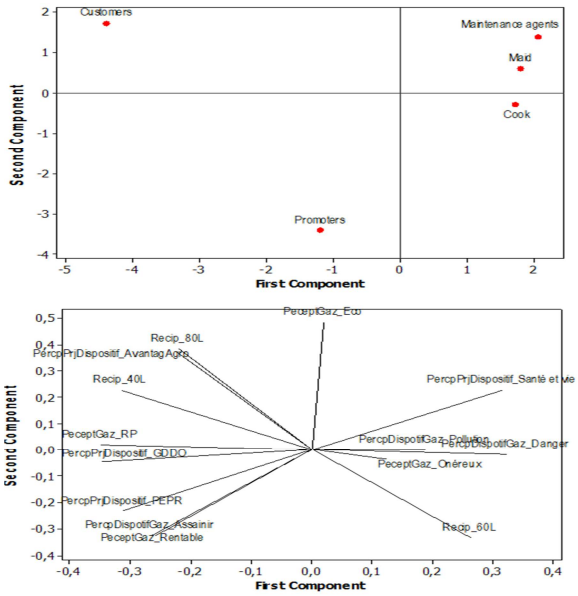

Fig. 13. Advantages of installing a gas-from-waste system

Legend: Eco = Economical, Rent = Profitable, RP = Pollution reduction, Oné = Expensive, AE = Maintenance agents, Cli = Customers, Co = Garbage collectors, Cui = Cook, Pro = Promoter, Serv = Maid, RP: Reduction pollution, PeceptGaz: Perception on the exclusive use of gas produced by waste from your activities compared with other types of fuel, PercpDispotifGaz: Perception on the installation of a waste recovery system to produce biogas at your workplace PercpPrjDispositif: Benefits derived from the project, PEPR: Clean, renewable energy production, GDDO: Sustainable management of organic waste

Relationship between hotel and restaurant users and perceptions of waste use in domestic gas production

Relationships between hotel and restaurant users and perceptions of gas use were established using Principal Component Analysis (PCA). The analysis reveals that the first two axes explain 85.70% of the total information. The results of the Principal Component Analysis (PCA) were presented in the form of a figure (Fig. 13).

The analysis reveals that hotel and restaurant promoters perceive the exclusive use of gas produced by the waste from their activities as cost-effective compared with other types of fuel.

According to their perception, installing a waste-to-energy biogas plant in your workplace will contribute to a cleaner environment. The benefits of gas production include the production of clean, renewable energy and the sustainable management of organic waste. The containers used by the promoters have a capacity of 60 L.

As far as hotel and restaurant customers are concerned, the exclusive use of gas produced by the waste from your activities as opposed to other types of fuel is economical and will help reduce pollution. The advantages derived from the gas manufacturing system are agronomic, and the containers used by promoters have a capacity of 40 L or 80 L.

As for maintenance workers, cooks and maids, installing a waste-to-energy device to produce biogas in your workplace is a hazard. However, the benefits of gas production include good health and a better quality of life (Fig. 13).

Discussion

This study focused on the perceptions of hotel and restaurant users on the recovery of organic waste through the production of biogas as an independent energy source in these establishments in the district of Abomey-Calavi in Benin. The data obtained as part of this study on the socio-demographic profile of the people interviewed, reveal that restaurants and hotels in the Abomey-Calavi district are more frequented by single men, on average aged 29 with an average educational level. (secondary). These results reflect the situation at the national level, showing a predominance of the active population (juvenile layer) in Benin according to the 4th global population and housing census of the National Institute of Statistics and Economic Analysis (INSAE, 2016).

In our study, the results show that the waste produced in hotel and food catering establishments in the Abomey-Calavi district is solid and liquid waste.

These types of waste are the same ones mainly produced in households in the city of Abomey-Calavi and other cities in Benin and elsewhere. Thus, the two types of waste were identified in households in the city of Goma (Noreddine and Ahmed, 2014; Lwanzo *et al.*, 2023).

The waste produced in the hotels and restaurants investigated consists of latex gloves, handkerchiefs, bottles of refined oils, fruit and vegetable peelings, cans, edible oils and fats and leftover meals. This means that hotel and restaurant complexes produce a plurality of garbage like households in African cities. Indeed, in tourism establishments in Cameroon, the waste produced has characteristics identical to those of our study (Gankam and Tchawa, 2018). On the other hand, in the Katindo district in the city of Goma in the DRC, the frequentation of hotels by external and internal populations of the country is constantly associated with an increased production of waste whose composition and quantities produced daily are not known (Lwanzo *et al.*, 2023).

In the Abomey-Calavi district, waste produced by hotels and restaurants is either buried, incinerated or thrown in the trash after sorting or without sorting. Indeed, waste thrown in the trash is collected by the Solid Waste Management Company (SGDS), a state company. These results partially resemble those obtained by Maamar and Kechout (2016) during a study carried out in Algeria, who found in the commune of Tizi-Ouzou that 67.7% of households do not practice the selective sorting activity of waste. In the Democratic Republic of Congo, people use waste for composting, recycling and biogas production (Noreddine and Ahmed, 2014). Furthermore, the main sources of greenhouse gases (GHG) are uncontrolled solid waste landfill sites; and at this rate, the production of food waste will increase and will increase from 08% to 10% of emissions of these gases by 2025 (Beck, 2015). The pollution caused by these types of residues is a very worrying problem because the waste left pell-mell constitutes a real threat to the environment (Noreddine and Ahmed, 2014). At the same time, in the health field, the practices used for waste management in the commune of Djakotomey are open burning, landfilling, incineration and uncontrolled dumping (Nouade, 2012).

Our study reveals that the bins available in hotels and restaurants have a capacity of between 40 L and 80 L and can be filled in half a day, in one day or maximum in two days. This therefore reflects that hotels and restaurants produce a large quantity of waste in a period of time thanks to the frequentation of customers. A similar observation was made during a study carried out by Nkituhanga (2010), which showed that 63% of the population of Kinshasa use small trash bins of various kinds to store their garbage (buckets, bags, bags).

Furthermore, the hotels and restaurants visited in the Abomey-Calavi district generally use coal and gas for cooking food. Some hotels and restaurants use up to three (3) bags of charcoal per day when orders are intense. The same goes for gas, the use of which goes up to four (4) large bottles (12 kg) per day when hotels and restaurants receive orders for events. This state of affairs proves how the use of gas for cooking is a proven habit in these establishments. But, this use of gas is not exclusive.

When we did the analysis of perception, it revealed that the exclusive use of biogas produced by waste is economical according to the maintenance agents and servants and therefore reduces expenses unlike the promoters who assert that it is profitable, requiring enough expenses and bringing a lot of profit in return. The minority of stakeholders recognizes that the installation of a biodigester in hotels and restaurants contributes to environmental sanitation through the elimination of waste, unlike the majority who think that such an installation is dangerous and a source of pollution. These perceptions are different from those obtained by Malika and Mohamed (2019) in a study carried out in Algeria, the results of which announced that waste recycling contributes to the fight against poverty and environmental sanitation. This implies little knowledge of the advantages of installing a biodigester by stakeholders and requires awareness

and information work for better adoption of this option among stakeholders.

However, all stakeholders agree that the installation of a gas storage device allows the production of clean and renewable energy, the sustainable management of organic waste, ensures health and quality of life and provides agronomic advantages. This represents hope for the implementation of a policy to promote biogas production in hotels and restaurants in the city of Abomey-Calavi.

Conclusion

This study made it possible to collect and assess the perceptions of hotel stakeholders on the use of biogas produced from organic waste as a source of energy in the district of Abomey-Calavi in Benin. Overall, the waste produced in hotels and restaurants is mainly biodegradable and can be transformed into biogas. Perceptions on this transformation of organic waste into biogas for autonomy of hotels and restaurants are varied but mostly positive for the installation of a biodigester with its advantages for environmental protection.

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