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Biodigesters in Restaurants and Food Courts: A Technical-Economic and Regulatory Study

Biodigestores em Restaurantes e Praças de Alimentação: Um Estudo Técnico-Econômico e Regulatório

Biodigestores en restaurantes y patios de comidas: un estudio técnico-económico y regulatorio

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Abstract:
This article analyzes, from technical, economic, and regulatory perspectives, the treatment of organic waste in medium-sized restaurants and food courts. It examines the Brazilian and international scenarios regarding methods of waste collection, separation, and disposal, as well as the market for biodigesters for commercial applications. Applied technologies, implementation costs, financial viability, biogas and biofertilizer production , energy integration, and regulations are evaluated. The study culminates in market projections and trends for automated and hybrid solutions, pointing to sustainable and economically viable paths for the sector.

Keywords: biodigester, organic waste, biogas, biofertilizer , restaurants, economic viability, regulation.

Resumo:
Este artigo analisa, sob as perspectivas técnica, econômica e regulatória, o tratamento de resíduos orgânicos em restaurantes de médio porte e em praças de alimentação. Examina-se o cenário brasileiro e estrangeiro quanto aos métodos de coleta, separação e disposição de resíduos, bem como o mercado de biodigestores para aplicações comerciais. Avaliam-se tecnologias aplicadas, custos de implantação, viabilidade financeira, produção de biogás e de biofertilizante, integração energética e regulamentação. O estudo culmina em projeções de mercado e tendências para soluções automatizadas e híbridas, apontando caminhos sustentáveis e economicamente viáveis para o setor.

Palavras-chave: biodigestor, resíduos orgânicos, biogás, biofertilizante, restaurantes, viabilidade econômica, regulamentação.

Resumen:
Este artículo analiza, desde perspectivas técnicas, económicas y regulatorias, el tratamiento de residuos orgánicos en restaurantes y patios de comidas de tamaño mediano. Examina los escenarios brasileños e internacionales en cuanto a métodos de recolección, separación y disposición de residuos, así como el mercado de biodigestores para aplicaciones comerciales. Se evalúan las tecnologías aplicadas, los costos de implementación, la viabilidad financiera, la producción de biogás y biofertilizantes, la integración energética y la normativa vigente. El estudio culmina con proyecciones de mercado y tendencias para soluciones automatizadas e híbridas, señalando vías sostenibles y económicamente viables para el sector.

Palabras clave: biodigestor, residuos orgánicos, biogás, biofertilizante, restaurantes, viabilidad económica, regulación.

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1. Introduction

Organic waste generated by food establishments represents a significant fraction of urban solid waste. Its inadequate management—including disposal in landfills or sewage systems—causes environmental impacts such as greenhouse gas emissions, contamination of surface and groundwater, and sanitation problems resulting from disposal in dumps or water sources. This article presents a comprehensive study on current separation and cleaning practices, the performance of the market for biodigesters adapted to restaurants and food courts, and the technical, economic, and legal perspectives applicable to Brazil.

2. Study on the methods of separating and cleaning this organic waste today in Brazil and abroad.

In Brazil, the most common methods for separating and cleaning organic waste in restaurants involve the use of grease traps . Traps), mandatory in food service establishments according to ANVISA legislation[1], as well as grinders (macerators) and solids and fat separators, as primary barriers before discharge into sewage systems. In some European countries and the USA, advanced practices include selective biological collection systems with refrigerated transport and decentralized treatment, through composting or in situ biodigestion , reducing the volume sent to landfills. This approach favors the circular economy and energy recovery.

3. Current percentage of collection and separation of this waste in Brazil and abroad.

The rate of collection and separation of organic waste is still low in Brazil. Estimates indicate that only 3%–5% of urban organic waste is collected separately for composting or biodigestion . In contrast, in European Union countries such as Germany and Austria, this rate can exceed 50%, driven by public policies and specialized infrastructure for organic waste. This discrepancy highlights the latent potential in Brazil to expand the collection and reuse of this waste.

4. Impact of organic waste on nature, sewage, rivers, and the soil layer in landfills.

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Organic waste disposed of in landfills or dumped into inadequate systems generates methane during anaerobic decomposition – a gas with a global warming potential approximately 25 times greater than CO_2. Furthermore, toxic leachates resulting from decomposition can contaminate soils and groundwater, affecting water quality and biodiversity. When dumped into sewers, solid and greasy waste causes blockages and increases the maintenance costs of the sewer system. Deposition in rivers and water bodies promotes eutrophication, impacting aquatic ecosystems and human health.

5. Companies that collect this waste and generate a market for it.

In Brazil, companies like Emaús Ambiental and Ambev (via the "Troca de Trocento " project) and startups like Compost Group and Óleow implement selective collection of organic waste in restaurants and food courts, transforming it into compost or biogas. Digital tools and collective logistics apps have facilitated the connection between waste generation points and composting or digestion units, fostering the creation of a market for previously discarded waste.

6. Current market for biodigesters in a commercial profile, restaurants

The Brazilian market for biodigesters for commercial use is expanding, with suppliers offering everything from prefabricated modular solutions (HomeBiogas , rotomolded tanks) to medium-sized continuous reactors (CSTR, plug- flow), already integrated with treatment, pre-treatment, and monitoring systems. Establishments such as small to medium-sized restaurants and food courts have been the focus of pilot projects and implementation plans.

7. Most commonly used types for restaurants

The most common types of biodigesters for restaurants include:

a) Modular "plug & play" units like HomeBiogas : compact systems for a few cubic meters of biodigestion ;
b) Prefabricated HDPE tanks: as biodigesters combined with septic tanks for small installations;
c) CSTR reactors (*Continuous Stirred Tank Reactor*): continuous mixing tanks, suitable for mixed organic loading and constant feeding;

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d) Plug- flow / continuous-flow reactors: efficient for waste with moderate solids content, but more sensitive to load variation;
e) UASB (*Upflow) Anaerobic Sludge Blanket*): best suited for liquid effluents, used in integrated systems focused on the liquid portion of the waste.

8. Average purchase costs of a biodigester for use in a restaurant.

The cost of acquiring a biodigester for restaurants varies depending on its capacity, the technology used, and the level of automation.

a) Compact modular systems (up to 3 m³): range from R$ 1,500.00 to R$ 5,000.00, generally manufactured in high-density polyethylene (HDPE) and suitable for small kitchens or restaurants with low waste volume.
b) Medium-sized systems (5 to 15 m³, with simple pre-treatment): range from R$ 15,000.00 to R$ 80,000.00, including pump, mixer and basic safety elements.
c) Complete commercial systems (20 to 100 m³, with temperature control, agitation and gas purification): range from R$ 100,000.00 to values exceeding R$ 500,000.00, depending on the complexity of the project and energy integration.

These prices include only the equipment and basic installation, and do not cover costs for civil works, licensing, or operational staff training.

9. Financial viability of a biodigester for a medium-sized restaurant

Viability depends on three main factors:

1. Cost savings with LPG replacement: restaurants that spend more than R$ 4,000.00/month on gas tend to see a faster return on investment.
2. Reduced waste collection costs: depending on the municipality, the disposal of organic waste in landfills is subject to a fee; on-site digestion reduces this cost.
3. Sale or use of biofertilizer : can generate extra income or reduce costs in the acquisition of fertilizers for home gardens.

Studies indicate a payback period of between 2 and 5 years for well-designed medium-sized systems, considering the replacement of 30% to 50% of LPG and savings in transportation and waste disposal.

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10. Technology and design parameters (biodigesters currently used in the restaurant market)

In Brazil, two technological formats predominate for restaurants:

a) CSTR (Continuous Stirred Tank Reactor) in mesophilic regime (35–37 °C), with hydraulic retention time (HRT) of 20 to 30 days and organic loading rate (OLR) of 3 to 6 kg of volatile solids/m³.day.

b) Plug- flow horizontal, suitable for more solid waste, with a HRT (Human Resource Transfer) between 30 and 40 days. Comparing conventional systems with automated models (pH, temperature, pressure, and level sensors), the following is observed:

i. Greater operational stability in automated systems;

ii. Ability to operate with higher OLRs due to real-time control;

iii. Less need for human intervention, reducing the risk of operational failures.

11. Biogas installation for hybrid operation with LPG.

The integration of biogas and LPG is technically feasible and widely used in Asian and European countries. In Brazil, this installation must comply with ABNT technical standards (NBR 15526 and NBR 13523), using:

- Automatic gas mixer (blending) to ensure proper pressure and composition;
- Non-return valves to prevent flame backflow ;
- Biogas reservoirs with desulfurization to remove H_2S, preventing corrosion and odor.

The hybrid system allows for automatic switching between LPG and biogas, maintaining continuous operation during peak hours.

12. Estimated biogas/methane production

Biogas production can be estimated in two ways:

- Via BMP assay (Biochemical Methane Potential (PV): laboratory analysis that measures the amount of methane generated per kg of volatile solids (VS).
- Based on typical values from the literature: for food waste, the range is 0.45–0.60 m³ CH_4/kg VS, corresponding to ~0.8–1.1 m³ of biogas/kg VS. Practical example: A

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restaurant that generates 120 kg/day of organic waste with 20% total solids and 80% VS would produce: VS/day = 120 × 0.2 × 0.8 = 19.2 kg VS/day;

- CH_4/day = 19.2 × 0.5 m³/kg = 9.6 m³ CH_4/day (~96 kWh/day of thermal energy).

Biofertilizer production estimate

During the anaerobic digestion process, organic matter is decomposed, generating biogas and a nutrient-rich liquid effluent, the digestate . In food waste biodigesters, the typical ratio between the treated waste and the biofertilizer produced is 0.8 to 1.0 liter of biofertilizer per kg of wet waste. Practical example for a medium-sized restaurant:

- Daily waste: 120 kg.
- Daily production of biofertilizer : ~100 to 120 liters;
- Annual production: 36,000 to 43,800 liters.

Digestate is a source of nitrogen, phosphorus, potassium, and micronutrients, and can be applied directly to the soil or after stabilization processes .

Biofertilizer market and comparison with 100% natural, pesticide-free fertilizers

biofertilizer market is growing, driven by organic agriculture and pressure for sustainable practices. Key differences:

- biofertilizer : resulting from anaerobic decomposition, with high bioavailability of nutrients and faster action in the soil.
- Traditional organic fertilizer: obtained through aerobic composting, with a slower release of nutrients.

According to the Food and Agriculture Organization of the United Nations (FAO), the use of biofertilizers can increase vegetable productivity by up to 25% compared to traditional organic fertilizers.

15. Cost-benefit analysis of biofertilizer production

The cost of producing biofertilizer is practically zero after the implementation of the biodigester, considering that the raw material is a residue that would already have a disposal

cost. The market value of liquid biofertilizers in Brazil varies from R$ 0.80 to R$ 3.00 per liter. Thus, for a restaurant that produces 36,000 liters/year, the potential revenue (or savings, if used internally) can range from R$ 28,800.00 to R$ 108,000.00/year.

16. Cost of waste shredding logistics

The waste pre-treatment stage is fundamental to increasing the efficiency of the biodigester. Equipment such as industrial shredders and pulpers have an acquisition cost of R$ 2,000.00 to R$ 15,000.00 for commercial applications. The operational cost involves:

- Electrical consumption (~1 to 3 kWh per ton of shredded material);
- Labor for operation;
- Preventive maintenance.

For restaurants that already use similar equipment in their kitchens, the additional impact is minimal.

17. Biogas purification/conditioning

Raw biogas contains impurities such as H_2S, CO_2, and water vapor, which can damage equipment and reduce efficiency. Typical purification steps:

- Desulfurization : use of iron or activated carbon filters to remove H_2S;
- Drying: condensers or silica gel for moisture removal;
- Upgrading biomethane : removing CO_2 to raise the CH_4 content above 96%, making it equivalent to natural gas .

Compact systems for restaurants cost between R$ 5,000.00 and R$ 25,000.00, depending on the level of automation.

18. Energy integration (partial replacement of LPG)

Biogas has a lower calorific value (~5.5 kWh/m³) compared to LPG (~12.8 kWh/kg). Therefore, to replace 30% of the LPG consumption of an average restaurant (which consumes 400 kg/month), approximately 650 m³ of biogas per month would be needed. Advantages:

- Reduction of operational costs;
- Lower CO_2 emissions;

- Partial independence from gas suppliers

19. Economic feasibility analysis (CAPEX/OPEX, LPG savings, payback) CAPEX (initial investment):

- Medium-sized biodigester: R$ 60,000.00;
- Water purification system: R$ 10,000.00;
- Construction and installation: R$ 15,000.00;
- Estimated total: R$ 85,000.00.

OPEX (operating costs):

- Annual maintenance: ~R$ 3,000.00.
- Energy for operation: ~R$ 1,200.00/year.

savings :

- LPG: ~R$ 18,000.00/year;
- Waste collection: ~R$ 6,000.00/year;
- Biofertilizer : up to R$ 50,000.00/year (if commercialized).

Payback

Between 2 and 3 years, depending on the efficiency and market of the biofertilizer .

20. Applicable regulations and standards (Brazil)

In Brazil, the operation of biodigesters in restaurants must comply with environmental, sanitary, and safety regulations.

Key legislation:

- Federal Law No. 12.305/2010 – National Solid Waste Policy (PNRS) – defines principles for the management of organic waste;

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- CONAMA Resolutions No. 275/2001 and 358/2005 – regulate the disposal and treatment of waste;
- Brazilian Health Regulatory Agency (ANVISA) Resolution RDC 216/2004 establishes best practices for food service. Compliance with these standards ensures operational safety, legal viability, and tax incentives in some municipalities.

21. Standards and laws for biogas storage

Biogas storage must comply with ABNT technical standards:

- NBR 15526:2013 – specifies biogas storage and packaging;
- NBR 13523:2015 – defines safety requirements for pressurized reservoirs;
- Use of vented tanks, pressure relief valves, and gas sensors to prevent accidents.

22. Standards and laws governing the sale of biogas

The commercialization of biogas or biomethane follows energy and gas regulations: • ANEEL – Resolution 482/2012 and complementary regulations for microgeneration of energy; • Supply contracts must guarantee the quality of the biogas, the pressure and the purity, according to ABNT NBR 15526.

23. Standards and laws governing the logistics process of organic waste

- Mandatory selective collection of organic waste in commercial establishments;
- Safe transportation, with enclosed and sanitized vehicles;
- Registration and traceability of waste disposal, in accordance with the PNRS (National Solid Waste Policy) and municipal regulations.

24. Standards and laws for installing a biodigester

Environmental licensing with municipal or state agencies;
Engineering project approved by a technical team, including the sizing of tanks, piping, and safety systems;

Environmental impact assessment (where applicable);

Compliance with ABNT standards for construction and operation (tanks, valves, ventilation).

25. Market projections and trends

The biodigester market in Brazil and worldwide is experiencing continuous growth, driven by:

- Sustainability and circular economy policies; • Tax incentives and energy efficiency programs;
- Growing awareness among consumers and businesses;
- Technological advancements, such as automation and remote monitoring, increase efficiency and reduce operating costs; Integration with hybrid energy systems (LPG + biogas) in restaurants and food courts.

Studies indicate that, by 2030, Brazil could multiply the number of systems installed in commercial establishments by 5 to 7 times, especially in large urban centers.

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