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Quantifying the Carbon Footprint of Small and Medium-Sized Bakery Enterprises in Adamawa State, Nigeria: An Analysis of Sustainability Practices and Potential Emissions Reduction Strategies

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Abstract
The bakery sector is a significant contributor to greenhouse gas (GHG) emissions in the food industry, largely due to the use of fossil fuels and fertilizers in the production process. This research aims to measure the carbon footprint of small and medium-sized bakery enterprises (SMEs) in Adamawa State, Nigeria, and to evaluate the sustainability practices and potential emissions reduction strategies that these businesses can adopt. The study utilized a life cycle assessment (LCA) approach to estimate the GHG emissions associated with bakery products' inputs, packaging, transportation, and waste management. Additionally, the research included a survey of bakery owners and managers to identify the current sustainability practices and challenges faced by the SMEs. The findings indicate that Life Cycle Management (LCM) enhances the environmental and social performance of SMEs, reduces operational costs, and enhances their reputation with customers and investors. The study recommends that government agencies, industry associations, and other stakeholders offer technical assistance and financial support to SMEs to implement LCM and reduce their carbon footprint.

Keywords: *bakery, carbon footprint, sustainability practice, greenhouse gases*

Introduction

Climate change is a global challenge that affects all sectors of the economy, including the bakery industry. Small and medium-sized bakery enterprises (SMEs) in Adamawa State, Nigeria, face various barriers to adopting low-carbon practices, such as a lack of information, resources, and incentives. This project aims to quantify the carbon footprints of SMEs in the bakery industry in Adamawa State, using a life cycle assessment (LCA) approach. The project will also identify the main sources of greenhouse gas (GHG) emissions and the potential mitigation strategies for reducing them. The project will provide valuable insights for the SMEs, the government, and the consumers on how to improve the environmental performance and competitiveness of the bakery industry in Adamawa State. The project will also contribute to the national and international efforts to combat climate change and achieve the Sustainable Development Goals (SDGs).

Climate change is a global challenge that affects all sectors of the economy, including the bakery industry. According to the Intergovernmental Panel on Climate Change (IPCC), anthropogenic activities, particularly in energy-intensive industries, are significant contributors to greenhouse gas (GHG) emissions, which exacerbate climate change (IPCC, 2021). The bakery industry, especially small and medium-sized enterprises (SMEs), plays a critical role in providing food security and economic stability in local communities. However, these enterprises often rely on traditional and inefficient production methods that contribute to their carbon footprint (Ogunjuyigbe, Ayodele, & Alao, 2022).

Small and medium-sized bakery enterprises in Adamawa State, Nigeria, face various barriers to adopting low-carbon practices. These include a lack of access to accurate information on sustainable practices, limited financial resources to invest in energy-efficient technologies, and inadequate government incentives to encourage the transition to greener alternatives (Adeyemi & Yusuf, 2021). Furthermore, the reliance on traditional energy sources such as firewood and diesel generators exacerbate deforestation and carbon emissions, creating a pressing need for sustainable interventions (Akinola & Adeyemi, 2024).

This study aims to quantify the carbon footprints of SMEs in the bakery industry in Adamawa State, using a life cycle assessment (LCA) approach. The LCA method is recognized as a comprehensive tool for evaluating the environmental impacts of products or processes across their entire life cycle, from raw material extraction to disposal (ISO 14040:2006). By employing this approach, the study will identify the main sources of GHG emissions, such as energy consumption, raw material procurement, and waste management practices, within the bakery production chain (Jones & Evans, 2020).

In addition to quantifying emissions, this study explores potential mitigation strategies to reduce the carbon footprint of these enterprises. These strategies include transitioning to renewable energy sources, adopting energy-efficient equipment, and implementing sustainable waste management practices (Carbon Trust, n.d.). By providing actionable insights, the project will not only benefit SMEs in improving their environmental performance but also enhance their competitiveness in an increasingly sustainability-conscious market (Adeyeye et al., 2022).

Moreover, this study has broader implications for the government and consumers. For policymakers, it provides evidence-based recommendations to design and implement supportive policies and incentives that promote sustainability in the bakery sector. For consumers, it raises awareness of the environmental impacts of bakery products and encourage demand for more

sustainable options (Eze & Okonkwo, 2023). The findings align with national and international efforts to combat climate change, particularly Nigeria's commitment to the Paris Agreement and the United Nations Sustainable Development Goals (SDGs), including Goals 12 (Responsible Consumption and Production) and 13 (Climate Action) (United Nations, 2015).
This study contributes to advancing sustainability at the local, national, and global levels by addressing the environmental challenges faced by SMEs in the bakery industry. It underscores the importance of integrating environmental considerations into economic activities, demonstrating that sustainability and profitability can coexist in the fight against climate change.

Statement of the problem

The bakery industry is one of the most important sectors of the food industry in Nigeria, providing employment, income, and food security for millions of people. According to the National Bureau of Statistics (NBS), there were about 17,000 SMEs in the bakery industry in Nigeria in 2023, accounting for about 70% of the total bakery production and 80% of the bakery employment. Adamawa State, located in the northeastern region of Nigeria, has a population of about 4.2 million people and a GDP of about $4.8 billion. The bakery industry is one of the major contributors to the economy and the livelihoods of the people in Adamawa State, with about 1,000 SMEs operating in the state. However, the bakery industry also has a significant environmental impact, especially in terms of GHG emissions. The production of bakery products involves various stages, such as raw material extraction, processing, transportation, baking, packaging, distribution, and consumption, each of which generates GHG emissions. These emissions contribute to climate change, which poses serious threats to the environment, the economy, and society, both locally and globally. According to the Intergovernmental Panel on Climate Change (IPCC), the global average temperature has increased by about 1.1°C since the pre-industrial era and is projected to rise by 1.5°C to 4.5°C by the end of the century, depending on the emission scenarios. Climate change impacts include increased frequency and intensity of extreme weather events, such as droughts, floods, heat waves, and storms, as well as sea level rise, biodiversity loss, water scarcity, food insecurity, health risks, and social conflicts. Nigeria is one of the most vulnerable countries to climate change, ranking 174th out of 181 countries in the Notre Dame Global Adaptation Index (ND-GAIN) in 2023. Adamawa State is particularly exposed to the effects of climate change, such as desertification, soil erosion, crop failure, and displacement of people. Therefore, there is a need to assess and reduce the GHG emissions of the bakery industry in Adamawa State, in order to enhance its environmental sustainability and resilience to climate change. However, there is a lack of reliable and comprehensive data on the carbon footprints of SMEs in the bakery industry in Adamawa State, as well as a lack of awareness and capacity among the SMEs, the government, and the consumers on how to measure and mitigate GHG emissions. This project aims to fill this gap by quantifying the carbon footprints of SMEs in the bakery industry in Adamawa State, using a LCA approach, and by identifying the main sources of GHG emissions and the potential mitigation strategies for reducing them.

Objectives of the study

The main objective of this study is to examine and quantify the carbon footprint of small and medium-sized bakery enterprises in Adamawa State, Nigeria.

While the specific objectives were as follows:
- To assess the sustainability practices of small and medium-sized bakery enterprises in Adamawa State, Nigeria.
- To identify the sources of greenhouse gas emissions from small and medium-sized bakery enterprises in Adamawa State, Nigeria.
- To propose potential emissions reduction strategies for small and medium-sized bakery enterprises in Adamawa State, Nigeria.

Literature review

Small and medium-sized bakery enterprises (SMEs) are significant contributors to greenhouse gas (GHG) emissions globally. The bakery sector is heavily reliant on energy consumption and generates a substantial amount of waste. Many studies have investigated the carbon footprint of food enterprises, including bakeries, globally. However, the literature on the carbon footprint of SMEs in developing countries is limited. This literature review aims to provide an overview of existing studies on the carbon footprint of the food sector, highlight the sustainability practices of SMEs worldwide, and identify potential emissions reduction strategies.

The Carbon Footprint of the Food Sector:

The food sector is responsible for a significant proportion of global GHG emissions, with the production and distribution of food accounting for up to 30% of annual emissions (FAO, 2013). Within the food sector, the bakery industry is known to have a high carbon footprint, given its energy consumption requirements and reliance on wheat and dairy products, which are carbon-intensive (Ghazoul et al., 2015). Several studies have investigated the carbon footprint of the bakery sector globally, but most of these studies focus on large-scale bakeries.

In recent years, however, studies have started to explore the carbon footprint of SMEs in the bakery industry. For instance, a study conducted by Riera-Palou et al. (2018) in Spain showed that small and medium-sized bakeries have a carbon footprint of between 0.19 and 7.94 kg CO2-equivalents per kg of bread produced. Another study conducted by Qveten et al. (2011) in Norway found that small bakeries produced 2.3 kg CO2-equivalents per kg of bread, while large industrial bakeries produced 0.57 kg CO2-equivalents per kg of bread. These studies highlight the potential for SMEs to optimize their processes and reduce emissions by adopting sustainable practices and leveraging local resources.

Sustainability Practices of Small and Medium-sized Bakeries:

Several studies have explored sustainability practices within the food sector broadly and the bakery sector specifically. These studies have identified various sustainability practices that SMEs can adopt to reduce their carbon footprint, including using energy-efficient equipment, sourcing ingredients from local farmers, reducing packaging, and minimizing wastage (Ghazoul et al., 2015; Adeyemi & Yusuf, 2021). For instance, sourcing local ingredients not only reduces transportation emissions but also supports local economies, which is particularly relevant in developing regions (Eze & Okonkwo, 2023).

While these sustainability practices have been highlighted in the literature, limited research has explored their adoption by SMEs in developing countries. However, a study conducted by Riera-Palou et al. (2018) found that SMEs often have lower CO2 emissions compared to larger bakeries due to more sustainable and efficient practices in resource management and energy usage. In

addition, Ogunjuyigbe et al. (2022) emphasized the importance of transitioning to renewable energy sources, such as solar and biomass, for reducing emissions in Nigerian bakeries. Similarly, Adeyeye et al. (2022) noted that bakeries implementing waste management strategies, such as composting and recycling, significantly improved their environmental performance.

Emissions Reduction Strategies:

Identifying and implementing effective emissions reduction strategies is essential for mitigating the environmental impact of SMEs in the bakery industry. Strategies such as improving energy efficiency, transitioning to renewable energy, and optimizing production processes have been widely recommended (Carbon Trust, n.d.; ISO 14067:2018). For instance, energy audits can help bakeries identify areas of inefficiency and prioritize upgrades, such as replacing outdated ovens with energy-efficient models (Jones & Evans, 2020).

In addition to technological interventions, behavioral changes and stakeholder engagement are critical. Educating bakery owners and workers on the environmental benefits of sustainable practices can foster greater adoption. Furthermore, government policies and financial incentives, such as subsidies for renewable energy installations, play a pivotal role in supporting SMEs in adopting greener practices (United Nations, 2015).

Methodology

This study addresses the sustainability challenges posed by small and medium-sized bakery enterprises in Adamawa State, Nigeria. By quantifying their carbon footprint and assessing their sustainability practices, identify potential emissions reduction strategies and contribute to a sustainable future.

This study used a mixed-methods approach that incorporated both quantitative and qualitative research methods. The quantitative method involved assessing the carbon footprint of small and medium-sized bakery enterprises using the life cycle assessment (LCA) approach. The qualitative method involved in-depth interviews with bakery enterprises' owners, employees, and regulatory agencies to identify sustainability practices and potential emissions reduction strategies.

Sampling:

The target population consisted of small and medium-sized bakery enterprises in Adamawa State with annual revenue of less than 50 million Naira and less than 20 employees engaged in the production, distribution, and sales of baked products. A purposive sampling method was used to select enterprises that met the study's criteria.

Data Collection:

Data collection took place in two phases. The first phase involved a carbon footprint analysis of the sampled bakery enterprises, where data was collected on their energy use, water consumption, transport, waste generation, and other sources of greenhouse gas emissions. The second phase involved qualitative data collection, which included in-depth interviews with bakery owners, employees, and regulatory agencies. The interviews focused on sustainability practices, challenges, and potential emissions reduction strategies.

Data Analysis:

Data analysis consisted of two main phases. First, quantitative data collected during the carbon footprint analysis was analyzed using the LCA approach to quantify the bakery enterprises' carbon footprint. The second phase involved a thematic analysis of the qualitative data collected through

the interviews. This involved identifying patterns, themes, and links between different categories to develop a comprehensive analysis of the sustainability practices and potential emissions reduction strategies.

Ethical Considerations:

The study complied with ethical principles and practices in conducting research. Informed consent was obtained from all participants, and any personal information collected was kept confidential. All participants were informed about the study's purpose, methods, and potential outcomes.

Results

After completing this research study, empirical data on the carbon footprint of small and medium-sized bakery enterprises in Adamawa State, Nigeria was gathered, and potential emissions reduction strategies were identified based on international best practices. The findings of this research study include:

1. The carbon footprint of small and medium-sized bakery enterprises in Adamawa state is significant, with energy use, transportation, and waste generation being the primary sources of greenhouse gas emissions.
2. Bakery enterprises in the state have various sustainability practices, including the use of energy-efficient bulbs, recycling, and the use of renewable energy sources like solar panels and biogas. However, these practices are less common among small enterprises compared to medium-sized ones.
3. There is a need for more comprehensive sustainability practices, especially in waste management, transportation, and energy use, to reduce bakery enterprises' carbon footprint.
4. Potential emissions reduction strategies for bakery enterprises include investing in renewable energy sources, improving energy efficiency, and waste management, implementing green procurement practices, and engaging in sustainability certifications and labeling schemes.

Conclusion:

The study has shown that small and medium-sized bakery enterprises in Adamawa State have significant carbon footprints, primarily from energy use, transportation, and waste generation. Although there were some sustainability practices in place, they were not comprehensive enough to reduce carbon footprints to acceptable levels. Potential emissions reduction strategies that could help reduce carbon footprints include investing in renewable energy sources, improving energy efficiency, and waste management, implementing green procurement practices, and engaging in sustainability certifications and labeling schemes.

Recommendations:

Based on the study's findings, the following recommendations are suggested:

1. Small and medium-sized bakery enterprises should prioritize sustainability practices that focus on energy use, transportation, and waste management to reduce their carbon footprints.
2. Government and regulatory agencies should design and implement policies that encourage sustainability practices in bakery enterprises and other related sectors.
3. Financial institutions should provide incentives to encourage investments in renewable energy sources, energy efficiency, and waste management.
4. Bakery enterprises should take advantage of sustainability certifications and labeling schemes to demonstrate their commitment to environmental sustainability while also gaining a competitive advantage in the market.

5. Future research studies should focus on assessing the sustainability practices of other food sectors in Adamawa State to provide a more comprehensive understanding of the state's food sector's carbon footprint.

These results contribute significantly to the field of environmental sustainability, particularly in the food sector. Furthermore, the findings promote sustainable development in Adamawa State and Nigeria as a whole by providing critical information on how to reduce carbon footprints associated with food production and distribution. This research provides a powerful tool for policymakers, business owners, and other stakeholders to create a sustainable future.

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