Harnessing Eco-innovation Strategies for Sustainable Development in Nigeria's Agri-food Industry

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Abstract

The exposure of Nigeria to climate change, population expansion, and rising food consumption has made the adoption of eco-innovative solutions to be more critical. Therefore, the study aims to examine the impact of eco-innovation strategies on the sustainability of agri-food industry in Nigeria. The study used a mixed-method research approach, beginning with qualitative data collection through literature reviews, followed by a survey (n = 384) targeting agripreneurs in the agri-food industry across Bayelsa, Edo, Delta, and Rivers State. Quantitative data were analysed using descriptive and inferential statistics, while thematic analysis provided qualitative insights. The study revealed that government-sponsored innovation policies emerged as the most impactful driver of sustainability. Integration of renewable energy and promotion of sustainable consumption practices also demonstrated positive effect on sustainability. Sustainable product design had the least positive effect on sustainability. This study holds several theoretical implications, particularly through the lens of Regulatory Focus Theory (RFT) — whether a promotion or prevention focus can influence the adoption of eco-innovation strategies in the agri-food industry. By linking RFT with sustainability initiatives, the study suggests that firms with a promotion-focused mindset, which emphasizes growth and positive outcomes, are more likely to engage in proactive eco-innovation, such as sustainable product design and the integration of renewable energy. In contrast, firms with a prevention focus, which is more concerned with avoiding losses and maintaining safety, are more inclined to adopt reactive sustainability practices, such as compliance with environmental regulations.

Keywords: eco-innovation strategies, government-sponsored innovation policies, sustainable consumption practices, renewable energy integration, sustainable development

1. Introduction

The concerns about environmental destruction, global warming, and resource depletion have increased due to industrial activities, and the need for eco-innovative solutions to boost sustainability in the agri-food industry is becoming more apparent. Sustainable solutions for products and services are part of it. However, when the ecosystems are damaged to the point where they can no longer recover quickly enough, environmental crises arise (Bucheli *et al.*, 2024). Climate change and other environmental issues present companies with new challenges and possibilities for eco-innovation (Keshminder, 2018). Naruetharadhol *et al.* (2024) asserted that eco-innovation is becoming more important due to the increasing severity of environmental issues such as pollution, climate change, and waste management. Averting an ecological calamity requires a transition to a sustainable economy that takes into account the ecosystem (Svitacová & Moravcíková, 2021). Reducing environmental impact and increasing resource efficiency are the goals of eco-innovation, which entails developing and implementing innovative products, processes, and behaviours.

Any innovation that helps companies to become more responsible and efficient while reducing their impact on the environment is considered eco-innovation. Eco-innovation refers to the development of new or significantly improved products, services, and processes that aid in the maintenance of a sustainable ecosystem. Eco-innovation offers solutions to environmental problems like pollution, waste management, and climate change (Buchana, 2023; Sumrin *et al.*, 2021). As an emerging business strategy, eco-innovation boosts performance and competitiveness by promoting sustainability over a product's whole life cycle (Sanni & Verdolini, 2022). It can assist agripreneurs in preserving the environment, expanding their reach in the market, becoming more efficient, drawing in new investors, increasing profits throughout the supply chain, and maintaining a competitive edge.

Government-led innovation policies, sustainable product design, the integration of renewable energy, and sustainable consumption practice are some of the crucial eco-innovation strategies to promote sustainability in the agri-food industry. Sustainable agri-food describes an agricultural system that can supply food for the present consumers without jeopardising the capacity of future generations to do the same. Its primary goals are resource efficiency, ecological preservation, economic sustainability, and social justice.

However, there are government regulations and informal stakeholder regulations that firms must comply with in order to sustain the environment (Wu *et al.*, 2022). The role of governments in supporting eco-innovation is critical, just as it is in the traditional fashion of encouraging innovation. Public policy changes, regulatory requirements, incentives, and environmental concerns have largely given rise to this issues and prospects (Yang *et al.*, 2022). In order to encourage firms to embrace sustainable practices, it is essential for the government to provide financial incentives, grants, and regulatory frameworks (Achmad *et al.*, 2023). Support for R&D, promotion of environmentally friendly technology use, and the establishment of a suitable framework for sustainable activities are the goals of government-funded innovation policy programmes. Stakeholders in the agri-food industry can find the necessary incentives and support mechanisms to embrace environmentally innovative solutions through these initiatives.

Furthermore, sustainable product design aims to create eco-friendly products by considering how they will affect the environment from the moment they are made until they are cast off. Many companies are interested in sustainable product design since it is vital for improving product sustainability (Han *et al.*, 2021). Sustainable product design provide firms especially in the agri-food industry to reduce waste, maximise resource utilisation, and lessen environmental impacts; by doing so, they can make a significant contribution to sustainability.

In addition, using renewable energy like solar, wind, and hydropower can help reduce carbon emissions (Awan *et al.*, 2021; Lehmann, 2013). Wei and Sun (2021) stated that it is feasible to create processes that use less energy. Solar, wind, and biomass power can offer an alternative to the traditional fossil fuels that have long dominated Nigeria's energy landscape. Sustainable development cannot be achieved without incorporating the use of renewable energy into the agri-food industry. This will assist in reducing emissions of greenhouse gases, lowering energy costs, and increasing energy resilience. The usage of conventional fuels is causing increasing environmental harm, which poses a growing threat to the Earth. However, many believe that solar power can effectively address these issues (Singh *et al.*, 2023). Unlike fossil fuels, which release dangerous chemicals into the atmosphere during combustion, solar energy uses the sun's rays to create clean electricity. This means that it has less of an effect on the environment. Switching to renewable energy sources for agricultural energy management might significantly improve energy efficiency, decrease emissions of greenhouse gases, and encourage more sustainable food production (Majeed *et al.*, 2023). But getting there will include tackling obstacles head-on and implementing renewable energy methods and technologies.

The agri-food industry also requires sustainable consumption practices by its stakeholders. It entails making use of products and services that meet basic necessities, improve living conditions, and reduce negative impacts on the environment. Improving the earth's ecological quality and the living environment for future generations is greatly dependent on sustainable consumption habits, especially those of individual and industrial consumers (Minh & Quynh, 2024). The demand for eco-friendly products can be stimulated, and producers can be motivated to adopt sustainable practices if consumers are encouraged to practice sustainable consumption.

When it comes to solving global problems like sustainable development, environmental protection, and food insecurity, the agri-food industry plays a major role. Different nations in Europe and Africa rely on this industry for a substantial portion of their GDP (Adesulu-Dahunsi *et al.*, 2022; Lagaida & Novianti, 2022). Though a lot has come along in terms of putting eco-innovation (EI) into practice, there is a scarce of literature that provides guidance on how to measure EI strategies. Doran and Ryan (2016), Castellacci and Lie (2017), and Rodríguez and Wiengarten (2017) are among the few researchers that attempted to address this issue; however, their focus is on product and process dimensions when investigating EI. Product, process, organisation, and marketing are the four facets of EI that have been the subject of very few studies (Marcon *et al.*, 2017; Astuti *et al.*, 2018).

Furthermore, the Nigerian context is absent from these studies, which instead centred on foreign industries and multinational companies. In addition, the studies that focused on the agri-food industry used a small set of environmental performance indicators (Galdeano-Gómez *et al.*, 2017; El Bilali, 2018). There is an urgent need for more agri-food industry research because the world is demanding more food, and the food value chain needs to be more sustainably produced (Barth *et al.*, 2017). It is also crucial to consider the impact of agriprenuers innovative operations on the environment. The study aims to fill these identified gaps in literature by exploring the impact of eco-innovation strategies on the sustainability of the agri-food industry in Nigeria. This raises four important questions:

i. How do government-sponsored innovation policies influence the sustainability of the agri-food industry?

ii. What is the effect of sustainable product design on the sustainability of the agri-food industry?

iii. How does the integration of renewable energy impact the sustainability of the agri-food industry?

iv. In what ways does the promotion of sustainable consumption practices contribute to the sustainability of the agri-food industry?

The research findings are noteworthy because they highlighted key strategies for the agri-food industry to remain sustainable. The study provided policymakers and industry stakeholders with evidence-based recommendations. The study's results can help shape agri-food industry by prioritising the sustainability of the ecosystem and economic resilience. The study adds to the larger discussion about sustainability by providing concrete strategies for companies in a developing nation like Nigeria to strike a balance between economic development and environmental protection. The remaining part of the paper was structured as follows: Section 2 focused on the literature review, followed by the methodology in Section 3. The results and discussion were presented in Section 4, which is thereafter followed by conclusion and policy recommendations.

2. Literature Review

2.1 Eco-innovation

Eco-innovation includes many approaches, tools, and techniques that aim to reduce the negative impact of companies operations on the environment and promote long-term sustainability (Lopes & Basso, 2023). In order to innovate in a way that promotes and enhances sustainable development, manufacturing companies often adopt eco-innovation strategy (Janahi *et al.*, 2021). In order to make the shift to sustainable production, manufacturing companies must embrace eco-innovation. Specifically, this means making the transition from less polluting industrial processes to more modern ones (Hojnik *et al.*, 2018).

Products, processes, organisations, and marketing are the four main aspects that are classified in the eco-innovation process (Marcon *et al.*, 2017; García-Granero *et al.*, 2018). Eva *et al.* (2020) opined that each dimension of eco-innovation has its own unique set of features that impact how well a company does in the environment. However, efficient use of resources and the separation of economic growth from environmental damage are the goals of eco-innovation. Throughout a product's lifetime, companies aim to maximise efficiency and effectiveness while reducing resource consumption (Szilagyi *et al.*, 2018). Minimising resource consumption in products and services is at the heart of eco-innovation. Another important aspect is creating new business models that are competitive, eco-friendly, and create value at every stage of the value chain.

Eco-innovation is a well-known strategy for companies to attain sustainable development (Bucheli *et al.*, 2024). When we talk about innovation with an emphasis on environmental factors, we are talking about eco-innovation. Innovation is seen from this angle as a multi-faceted process that includes not only new technology but also new organisational structures, commercial models, and operational methods. It advocates for a strategy to attain change driven by sustainability (Peyravi & Jakubavicius, 2022). Reduced environmental impact is an essential part of eco-innovation, which is why stringent regulations governing resource use, emissions, and waste pollutant disposal are so important. Sustainable value creation is the goal of eco-innovation, which places an emphasis on environmental stewardship and employs strategies to reduce pollution and maximise resource efficiency. Tseng *et al.* (2021) posited that it seeks to strike a balance between economic objectives and ecological integrity.

Also, eco-innovation promotes a way of doing business that is both competitive and inclusive. Organisations can enhance their market position, foster consumer loyalty, and capitalise on developing sustainability-focused market opportunities through eco-innovation. Larbi-Siaw *et al.* (2023) added that this can be accomplished by coordinating innovation initiatives with current market trends and stakeholder expectations. At its heart, eco-innovation is about a commitment to sustainability, which places equal value on economic success and social welfare. Environmental stewardship, social responsibility, and long-term viability are the pillars around which eco-innovation can be built, allowing it to transcend beyond short-term profit maximisation (Baumgartner & Rauter, 2017).

Liu *et al.* (2024) posited that eco-innovation is becoming more important as companies become more conscious of the consequences of their actions and are obligated to conduct themselves in a socially and environmentally responsible manner. There is an inherent relationship between eco-innovation and economic success. Eco-innovation is a key factor in economic growth since it lowers production costs, maximises organisational output, and encourages the use of capital-intensive production techniques (Anand *et al.,* 2021; Zayas-Marquez & 'Avila-Lopez, 2022). Cleaner industrial processes, more efficient use of resources, less waste, and the use of renewable energy sources are all essential for reducing environmental repercussions.

2.2 Government-Sponsored Innovation Policies

The government's deliberate attempts to strike a balance between economic growth and environmental protection are known as public policy. The term "public policy on eco-innovation" refers to the various measures taken by the government to oversee, support, and encourage environmentally friendly technology (Pan *et al.,* 2024). The main goal of public policy is to find a way to include environmental concerns while implementing new practices (Li, 2022; Djibo *et al.,* 2022). Its purpose is to offer guidance and a structure for fostering eco-innovation. Governments invest in eco-innovation to offer alternative ways to achieve sustainable development (Chaparro-Banegas *et al.*, 2023; Shang *et al.,* 2023).

McCurdy *et al.* (2024) note that innovation policy programs receive funding from the government with the express purpose of assisting, encouraging, and advancing innovation-related activities. Pollution, resource loss, and climate change are some of the modern environmental issues that the government is attempting to address through its policies. In addition, it helps establish a level playing field for businesses that must follow the same environmental laws (Guo *et al.*, 2018). Grants and loans from governments can help businesses reduce the upfront expenses of creating, launching and using new green technologies or procedures. Governments can incentivise the purchase of environmentally friendly goods, such as renewable energy, by subsidising their production and sale. Agrawal *et al.* (2023) argue that public policy has the potential to encourage sustainable behaviour by creating awareness. A component of this strategy is the implementation of programs like public awareness campaigns and financial incentives for firms to embrace environmentally friendly practices like recycling and taking public transportation.

Research highlights the importance of policymakers considering a wide range of issues when crafting policies to encourage eco-innovation on a global scale. Liobikiene and Miceikiene (2023) posited that offering incentives is a crucial part of eco-innovation projects. Incentives for eco-innovation may come from the government in the form of subsidies, tax breaks, and other financial advantages (Yurdakul & Kazan, 2020). Firms that put sustainability first might benefit from a level playing field if laws were in place requiring them to reveal their environmental impacts and initiatives. By enforcing laws for energy efficiency, emissions, and other environmental aspects, governments can provide a market for eco-friendly products and technologies (Sunarjo *et al.,* 2022). By increasing demand for environmentally friendly products and services, policies that encourage sustainable consumption can help push eco-innovation forward. One aspect of this may be informing potential buyers about the environmental impacts of their choices and advocating for sustainable lifestyles (Liobikiene & Miceikiene, 2023).

To savage environmental problems, efforts must be directed towards research and development (R&D). Funding basic and applied research are both part of this (Pan *et al.,* 2024; Singh *et al.,* 2023). Naruetharadhol *et al.* (2024) research indicated that different countries or international organisations use different policy instruments to encourage eco-innovation. To reduce emissions of greenhouse gases, the Japanese government's Cool Earth Partnership is pushing for renewable energy sources (Pachauri, 2022). Water, land, and air pollution are the focus of China's Eco-Compensation program's restoration and conservation efforts (Jiangyi & Shiquan, 2022). Emissions regulations and air quality requirements were established by the United States Clean Air Act in an effort to decrease air pollution (Geels *et al.,* 2021).

Few of the regulations that the Nigerian government have used in the past to address environmental issues include The Forestry Act (1958), the Management of Solid and Hazardous Waste Regulations (1991), and the Environmental Impact Evaluation Proclamation (1992). In addition, the establishment of the Federal Environmental Protection Agency (FEPA) and State Environmental Departments in 1999 further contributed to this effort (Chukwukadiba & Nnamani, 2023). Enterprises must prioritise environmental sustainability and work together to achieve significant eco-innovation, according to the United Nations Environment Programme [UNEP] (2017).

However, government policies plays a pivotal role in fostering eco-innovation on an all-inclusive scale by offering incentives and support to firms and individuals to embrace more sustainable practices and technologies (McCurdy *et al.*, 2024). The government, companies, and consumers must focus on environmental sustainability initiatives to sustain the future generation. Government-sponsored innovation policies often provide the necessary support and resources for implementing sustainable practices. These policies can accelerate the adoption of environmentally friendly technologies and practices, enhancing the sustainability of the agri-food industry. It was therefore hypothesized that:

H1: Government-sponsored innovation policies significantly advance sustainability in the agri-food industry.

2.3 Sustainable Product Design

The goal of sustainable product design (SPD) is to make products more environmentally friendly from the start to finish of their lifespan (Mengistu *et al.*, 2024). The concept of sustainable development has been implemented in many areas, including manufacturing, in response to diminishing natural resources, increasing environmental degradation, and substantial societal implications (Wang *et al.*, 2018). Adopting sustainability strategies is crucial for manufacturing organisations to tackle these difficulties (Ahmad & Wong, 2019). One of the most important ways to achieve sustainable manufacturing and satisfy stakeholders is to make sure products can last a long time (Hapuwatte & Jawahir, 2021). Appolloni *et al.* (2022) argue that companies should focus on developing innovative products and procedures that benefit their customers and the environment simultaneously.

Bioplastics and sustainable packaging are examples of sustainable materials that may be created by companies through green process innovation (Moshood *et al.*, 2022). This allows them to reduce the environmental impact of their operations (Xie *et al.*, 2019). Throughout a product's lifetime, sustainable design considers all aspects in accordance with the Triple Bottom Line (TBL) method (Feng & Mai, 2016; Yan & Feng, 2014). Supply, production, use, and disposal are all parts of this approach (Shuaib *et al.*, 2014). Hosseinpour *et al.* (2015) posited that SPD has a significant impact on the whole product life cycle. Hassan *et al.* (2017) also note that SPD provides a promising way to make products that can meet different sustainability standards. Because it provides a comprehensive view of the social and environmental impacts associated with each stage of a product's life cycle, the life cycle approach is fundamental to SPD (Maxwell & van der Vorst, 2003).

In addition, it helps with EOL item handling, resource efficiency, and reducing environmental effect (Hapuwatte & Jawahir, 2021). A wide variety of factors influencing the different stages of the product life cycle must be considered for efficient SPD to be achieved. While SPD has been the subject of various research, Saari *et al.* (2021) argued that most of these studies have ignored the social, economic, and environmental aspects of sustainability in favour of studying the environmental one. The eco-bag idea, for instance, was developed by Faradilla *et al.* (2022) using the TBL technique. They evaluated this idea with SPD metrics while employing a sustainable quality function deployment technique. Soomro *et al.* (2021) presented a five-stage design thinking paradigm for a sustainable prototype conceptual framework. A multi-criteria decision-analysis approach to selecting a sustainable product-package design was introduced by Rezaei *et al.* (2019). Sustainable product design emphasizes creating products that reduce environmental impact throughout their lifecycle, from production to disposal. By using eco-friendly materials and efficient processes, firms in the agri-food industry can enhance resource efficiency and align with global sustainability goals. It is hypothesized that:

H2: Sustainable product design enhances the sustainability of the agri-food industry.

2.4 Integration of Renewable Energy

Energy sources that are regenerated organically on a human timescale and sourced from processes in nature are known as renewable energy sources. Renewable energy sources have less of an ecological footprint and last longer than fossil fuels, which have a limited supply and may eventually run out. Environmentally friendly technology is vital to renewable energy sources. Developing solutions that lessen negative consequences on the environment is the goal of green technology. To make the most of renewable energy sources, it is crucial to incorporate green technology. Sustainable Development Goals (SDGs) are becoming the focal points of green technology. Wu *et al.* (2018) added that these goals take over from the Millennium Development Goals that were set in 2000. The SDGs are solar energy's harbinger because they are lofty and have the backing of many countries. Worldwide efforts to combat climate change and achieve sustainable development goals are congruent with the shift in energy thinking towards renewable fuels.

Solar power has many benefits, one of which is a reduction in pollution of both air and water caused by the use of fossil fuels. Consequently, this lessens the impact of climate change on low-income communities and aids in the preservation of ecosystems (Tawalbeh *et al.*, 2021). Further, solar power and other forms of renewable energy promote equality and inclusion in society, notwithstanding differences in economic and social conditions (Tiwari *et al.*, 2021). Agriprenuers can take advantage of economic opportunities when there is access to reliable energy, which reduces socio-economic concerns. Solar power's incorporation into the grid provides a viable answer to the environmental problems of our day and has far-reaching implications for sustainability. Greenhouse gas emissions are reduced as a result of this substitution, which aids the global fight against climate change (Maka & Alabid, 2022). Renewable energy sources can be harnessed by farmers to irrigate crops, which in turn can dry food, extending its shelf life. It could provide some answers to the problems that have developed due to our dependence on fossil fuels, such as decreasing supplies, increasing prices, detrimental effects on the environment, and so on. By utilising renewable energy sources, these challenges can be effectively addressed, ultimately resulting in increased profitability and greater autonomy for the agricultural sector (Majeed *et al.,* 2023). In addition, there will be no loss of natural resources due to the prolonged use of renewable energy sources. The agricultural sector's energy security will be greatly improved by this.

The use of renewable energy sources, such as solar and wind, to power farm vehicles has environmental and economic benefits (Balasuadhakar *et al.,* 2016). Solar-powered irrigation, for example, enables the dispersed and environmentally conscious fulfilment of water pumping energy demands. Many farmers throughout the world could benefit greatly from solar water pumps that are both affordable and energy efficient (Feng *et al.,* 2022). However, the utilisation of photovoltaic-thermal (PVT) systems, which harness the energy of the sun to generate electricity and heat, presents a sustainable power solution for agricultural operations (Singhal *et al.,* 2018; Tariq *et al.,* 2021). Drying systems for value addition are among the most popular uses of solar energy in farming. Ayub *et al.* (2018) stated that the most effective way to dry products while keeping their quality intact is to use a solar tunnel dryer. There is a wide variety of sizes, shapes, and configurations of solar dryers available. Many items, including cereals, potatoes, mushrooms, and carrots, can be dried using the various dryers that are on the market. As a result of using solar drying technology, the product can be dried in an atmosphere free of pollutants, allowing it to meet both domestic and international standards.

Additionally, when it comes to powering farms and ranches, wind energy is dependable and affordable. Hasan *et al.* (2019a, b) study found that using wind turbines to power irrigation water pumps could eliminate the need for expensive and cumbersome electrical equipment including transformers, power cables, and poles. Wind power is less disruptive to nearby residents because it does not contribute to pollutants from fossil fuels. Zhang *et al.* (2018) asserted that this leads to a decrease in the emission of gases that are known to cause harm. Ghafoor *et al.* (2016) stated that modest wind turbines can meet a farm's electricity needs, which range from 400W to 40 kW. So, even on smaller plots of land, farmers and ranchers can harness the wind for power.

Other renewable energy such as biomass can be used to generate energy. Biomass consists of the many plant products and wastes that result from photosynthesis (Armstrong *et al.,* 2014). Several small companies, such as brick and charcoal kilns, use this bioenergy, in addition to households that use it for heating and cooking. An indispensable energy source, bioenergy can meet the needs of the agrifood industry and more, including those for heating, electricity, and transportation fuels (Sanz Rodrigo *et al.,* 2017). Xia *et al.* (2016) study found that biomass byproducts from agri-food can be used to generate energy for various tasks such as processing, storing, and cooking. Bathaei and Štreimikiene (2023) posited that biomass energy can be generated from various sources, including agricultural waste, animal waste, or crops that are specifically engineered to provide heat and power. Agricultural byproducts and waste, including crop leftovers, animal manure, and food processing industry waste, can be transformed into bioenergy through processes including anaerobic digestion and biomass gasification. Anaerobic digestion produces biogas, a sustainable energy source with dual thermal and electrical potential (Obileke *et al.,* 2021). By converting organic materials into a gas, biomass gasification makes them suitable for direct combustion or subsequent processing into biofuels.

Furthermore, the term "geothermal energy" is often used to describe another renewable energy source that originates from the Earth's interior and is typically associated with volcanic and tectonic activity (Tang *et al.,* 2017). The geothermal process typically makes use of heat stored in rocks located deep inside the ground (Xia & Zhou, 2017) or in hyperthermal reservoirs (Rajewski *et al.,* 2014). Geothermal heat can be used for direct heating or to generate energy using power conversion devices (Jankovsky *et al.,* 2021). Renewable energy sources are pivotal in reducing the environmental footprint of agri-food operations. Integrating solar, wind, or biomass energy solutions into production processes can minimize dependence on fossil fuels, lower greenhouse gas emissions, and promote a cleaner, more sustainable industry. We suggest the hypothesis that:

H3: The integration of renewable energy sources has a significant effect on the sustainability of agri-food industry.

2.5 Promotion of Sustainable Consumption Practices

The term "sustainable consumption practices" describes how individuals and companies use raw materials, finished products and services in a manner that does not harm future generations' capacity to fulfil their own needs. Practicing sustainable consumption entails communicating with consumers about sustainability while simultaneously greening the entire supply chain, beginning with the provider of input materials and continuing through production, distribution, and the final market (Tania & Sigrid, 2006). Purchasing habits are just one part of sustainable consumption, which also includes the views and ways of living of governments, companies, and consumers. The goal is to encourage consumers to buy eco-friendly products and adopt a sustainable lifestyle through gradual reduction of consumption and increased preference for high-quality goods (Sun *et al.*, 2021). Improving environmental performance requires cutting down on material consumption. Companies that use eco-innovation strategies reduce their material and resource consumption, which has positive effects on the environment and the bottom line (Obamen *et al.*, 2019). Reducing material consumption is critical for ensuring sustainable environmental performance, according to Barriga *et al.* (2022). The importance of minimising waste and making the most of available resources is emphasised. The importance of controlling emissions and garbage to lessen their detrimental impact on the environment is also stressed by them. Achieving long-term environmental performance requires effective management of emissions and waste.

Past research conducted by De Boer and Aiking (2021), and Schill *et al.* (2019) point to the need of studying consumers' environmental sensitivity as a means to revamp consumption habits in response to massive environmental difficulties. Negative impacts on the environment are substantial results of unsustainable consuming habits. Some of the bad effects of unsustainable consumerism include fast deforestation and increased plastic waste (Daniel *et al.*, 2024). Annual estimates for plastic garbage entering the ocean were at 11 million metric tonnes in 2016, and current projections suggest that number might rise to 29 million metric tonnes in 2040 (Lewis, 2023). In addition, the rate of deforestation is still rather high, with around 18 million acres of forest being cut down every year. This is a major factor in both the loss of biodiversity and the acceleration of climate change (FAO, 2022). Before our world suffers irreversible damage, these sobering numbers highlight the critical need for coordinated effort to reduce wasteful consumption U.N.

Sustainable Development Goals (SDGs) have endorsed such endeavours, urging "urgent action" to "promote prosperity while protecting the planet" (United Nations, 2023a). The aims stress the need of developing policies to safeguard the environment in tandem with those to promote economic growth, a healthy community, and inclusion in order to achieve sustainable development in a comprehensive and methodical way. Sustainable consumption and production (SDG 12) faces this issue head-on. According to the United Nations (2023b), Sustainable Development Goal 12 necessitates finding ways to lessen a nation's material footprint, which includes the input of material resources at every stage from extraction to processing and consumption, without causing harm to communities or the economy. Various elements must be addressed in order to tackle this difficult task, as they can all contribute to the overall objective (Mazzucato, 2018). Furthermore, it is not just consumers who need to adjust their purchasing habits for the better. The ultimate goal of responsible consumption may be to alter the effects of consumer behaviour, but there are many powerful actors in the supply chain, such as manufacturers and retailers, as well as at the state and local levels, who can influence consumer behaviour (Macklin & Kaufman, 2023; Roberts *et al.*, 2023).

In order to promote the ideas of a circular economy, eco-innovation aims to help create closed-loop systems that reuse, recycle, or repurpose resources (Geissdoerfer *et al.*, 2018). To reduce waste and maximise resource utilisation, closed-loop systems that recycle and repurpose materials should be put into place (Xue & Wang, 2020). Because it boosts economic growth while reducing negative environmental impacts, green process innovation is a crucial part of sustainable development (Frare & Beuren, 2022). Furthermore, it gives businesses an advantage over their competitors by lowering costs and increasing brand awareness (Abid *et al.*, 2022). The shift from investing in pollution management to addressing recycling systems and cleaner industrial processes is what eco-innovation is all about, according to Liu *et al.* (2024). For a thorough examination of how to quantify eco-innovation factors, see Garcia-Granero *et al.* (2020). Among these metrics are assessments of energy efficiency, water usage, waste management, and emissions of greenhouse gases; evaluations of patents; and environmental performance indicators.

Beyond buying and using, responsible consumption encompasses both upstream (design and manufacture) and downstream (repair, disposal, and maintenance) behaviours (Marchand & Walker, 2008). Take the sharing economy as an example. It necessitates a shift in behaviour from both suppliers and merchants (in service design and delivery, for instance) and customers (in order to boost uptake and decrease misconduct), among others (Huang *et al.*, 2023). Concerned about the state of the earth, environmentally conscious consumers are eager to find out more about green products (Varela-Candamio *et al.*, 2018). According to Kusmantini *et al.* (2021), environmentally conscious shoppers can feel better about the impact they are having by purchasing green products rather than non-green ones. Sustainable consumption practices involve promoting consumer behaviors that prioritize environmentally friendly and socially responsible products. Encouraging awareness and adoption of such practices can drive demand for sustainable products, influencing producers to adopt sustainable methods and contributing to industry-wide sustainability. We therefore hypothesize that:

H4: Promoting sustainable consumption practices significantly improves the sustainability of the agri-food industry.

2.6 Regulatory Focus Theory

Higgins et al. (1997, 1998) proposed regulatory focus theory (RFT) as a theory of motivation. As an expansion of the basic hedonic principle—that people are motivated to approach pleasure and to avoid pain. Accomplishments and successes drive persons who are focused on promotions. Goals are more like hopes and desires to them, and the pursuit of pleasure drives them to succeed (Watling *et al.*, 2012). Responsibility and safety are the primary concerns of those who prioritise prevention. They see goals as obligatory and necessary, and they are driven to achieve them in order to prevent negative consequences (Watling *et al.*, 2012). A key tenet of regulatory focus theory is that it explains why people have certain tendencies, attitudes, and actions when it comes to pursuing goals (Higgins, 2000).

In general, those who lean towards a promotion-focus orientation are highly motivated to achieve their objectives in the hopes of reaping the benefits, whether those benefits actually materialise or not. On the other hand, those who lean towards preventive are more likely to be aware of the existence (or lack thereof) of bad outcomes, and they take great care to avoid making the kinds of mistakes that could lead to failure and, consequently, to limit their losses. From this, it can be inferred that consumers who are more concerned with promotion are driven to act environmentally friendly because they enjoy the satisfaction that comes from accomplishing their goals, while customers who are more concerned with prevention are driven to act environmentally friendly because they fear the consequences of failing to achieve their goals.

The study extends RFT by showing how the regulatory focus of both policymakers and managers influences the success of eco-innovation strategies. Policymakers with a promotion focus may design incentives that encourage businesses to pursue innovative, forward-thinking sustainability practices, while those with a prevention focus may emphasize regulatory compliance and risk mitigation. This suggests that the regulatory focus of the policymaker can shape the type of eco-innovations businesses pursue, affecting the overall sustainability trajectory of the industry. The study, therefore, offers insights into how RFT can guide the development of policies that are better aligned with industry needs and sustainability goals.

Table 1. Empirical Literature

Authors	Study Focus	Methodology	Key Findings
Rađenović *et al.* (2024)	Average eco-innovation performance among EU member states using the eco-innovation scoreboard and cluster analysis.	Cluster analysis of eco-innovation scoreboard data.	Significant variations in eco-innovation performance among EU nations were observed, with countries transitioning between clusters over time, highlighting changes in goals and tactics regarding eco-innovation.
Chen *et al.* (2024)	Impact of eco-entrepreneurship and green technologies on greenhouse gas emissions in East Asia.	ARDL and NARDL models applied to data from China and Japan.	Linear estimates of eco-entrepreneurship and green technologies significantly reduce greenhouse gas emissions, but nonlinear impacts are more pronounced in Japan.
Durmaz and Fidanoğlu (2024)	Role of sustainable product design and environmental performance in the impact of COVID-19 on corporate sustainability.	Survey of 235 firms in Turkey; data analyzed using SPSS and AMOS tools.	COVID-19 significantly influenced corporate sustainability, with regulatory variables and sustainable supply mediating the effects on environmental performance.
Bucheli *et al.* (2024)	Eco-innovation as a mediator between adaptive environmental strategy, absorptive capacity, and environmental performance.	Structural equation modelling on a sample of 568 Colombian firms.	Adaptive strategies alone do not directly influence environmental performance. Market volatility impacts environmental performance indirectly through eco-innovation and absorptive capacity.
Minh and Quynh (2024)	Influence of pandemics and perceived consumer efficacy on sustainable consumption behaviour in Vietnam.	Mixed-methods approach; data from 645 survey respondents analyzed using SPSS and SmartPLS 3.8.	Pandemics positively affected factors shaping sustainable behaviour. Subjective norms lacked statistical significance. Perceived consumer efficacy positively moderated the intention-behaviour relationship.
Naruetharadhol et	Role of public policies in fostering eco-innovation in	Qualitative methodology examining	Governmental support and renewable energy initiatives were critical for eco-innovation.

al. (2024)	selected countries, focusing on SMEs.	policy instruments for SMEs.	Policies varied widely in effectiveness across countries.
Lee and Hung (2024)	Influence of education on environmentally conscious buying behaviours for sustainable products.	Questionnaire-based survey of 332 participants from Taiwan and Indonesia; data analyzed using CB-SEM with SmartPLS 4.	Sustainable purchases enhance eco-friendly practices and promote cultural transitions towards sustainability.
Supron and Myszczyszyn (2024)	Correlation between renewable/non-renewable energy consumption and agricultural production levels in EU nations.	Panel data (2000-2022) analyzed using VAR model, IRF, and causality tests.	Renewable energy consumption positively affects agricultural productivity in sustainable farming nations, while non-renewable energy use negatively impacts growth.
Cheng *et al.* (2023)	Green process innovation and green production in the sustainability of the cement and plastic industries in Pakistan and India.	Partial least squares structural equation modelling on data from 657 employees.	Green productivity and process innovation significantly enhance sustainability. Environmental consciousness supports sustainable practices.
Ojekemi and Aga (2023)	Renewable energy, eco-innovation, and global integration's influence on BRICS nations' ecological footprints.	PNARDL methodology on BRICS nations (1990-2018).	Renewable energy, eco-innovation, and globalisation reduce ecological footprints, while non-renewable energy and economic growth expand them.
Lopes and Basso (2023)	Eco-innovation adoption in Brazil’s hotel industry.	Quantitative research using questionnaires; data analyzed via PLS-SEM.	Eco-innovation adoption improves operational performance and competitiveness, driven by environmental pressures.
Mondal (2023)	Green entrepreneurship’s influence on global sustainable development.	Panel data analysis using World Bank statistics.	Green entrepreneurship positively impacts financial development, credit policy, and environmental factors.
Chandel (2022)	Green entrepreneurship’s impact on sustainability and environmental issues.	Mixed-methods approach using case studies and theoretical frameworks.	Substantial contribution to eco-friendly product promotion and sustainability. Economic factors often overshadowed by environmental emphasis.
Erika *et al.* (2022)	Open business models for eco-innovation in Slovakia.	Kano model applied to Slovak firms.	High costs, inexperience, and lack of information are major barriers. Strengthened consumer relationships and CSR strategies are crucial.
Saari *et al.* (2021)	Environmental awareness and risk perception's influence on sustainable consumption behaviour in Europe.	Survey of 11,675 respondents across EU and EFTA nations.	Environmental risk perception and knowledge enhance concern, influencing intentions and promoting sustainable purchasing behaviour.
Eva *et al.* (2020)	Emotional intelligence's (EI) role in environmental corporate culture within the agri-food sector in Spain.	Partial least squares analysis of data from 93 companies.	Positive association between EI, environmental corporate culture, and entrepreneurial intention.
Ceptureanu *et al.* (2017)	Sustainable opportunity recognition in green business practices in Romania.	Analysis of green business practices in Romania.	Market orientation and sustainable entrepreneurial orientation enhance opportunity recognition, though environmental awareness and development have less impact.

This study addressed the limitations observed in prior research. Unlike Rađenović *et al.* (2024), whose focus was limited to EU member states, this study explored eco-innovation in a non-EU context, providing valuable insights into developing economies. It surpassed Chen *et al.* (2024) by encompassing multiple eco-innovation dimensions, including government policies, sustainable product design, renewable energy integration, and sustainable consumption, thus offering a holistic view of sustainability strategies. While Durmaz and Fidanoğlu (2024) and others examined sustainability in narrow geographic or industry contexts, this study focused on agripreneurs across four Nigerian states, expanding the scope to underexplored regions. The integration of mixed methods, including surveys and focus group interviews, enriched the findings by combining quantitative relationships with qualitative insights. This balanced methodology addressed gaps in understanding eco-innovation's practical applications, previously noted in studies limited by regional or methodological constraints. By linking eco-innovation strategies to the UN SDGs, the study contextualized its findings within a global framework, thereby enhancing its relevance and applicability.

3. Methodology

3.1 Research Philosophy and Design

This study is grounded in the paradigms of interpretivism and positivism. Interpretivism is generally associated with qualitative research, whereas positivism corresponds with quantitative research. A qualitative approach is selected for its appropriateness in examining the complex dynamics in a study. This method facilitates a comprehensive examination of policy contexts, stakeholder viewpoints, and the intricate dynamics that affect innovative initiatives (Sunarjo *et al.,* 2022). Furthermore, a cross-sectional survey research design was employed. This method was selected for its capacity to yield concurrent observations and insights across a designated timeframe, facilitating effective comparison and analysis (Heiman, 2002).

3.2 The Study Context

The study concentrated on agripreneurs in the agri-food industry. The researchers gathered data from participants in four states in South-South Nigeria: Bayelsa, Edo, Delta, and Rivers. The researchers are uncertain about the precise overall population of agripreneurs in the region. Consequently, Cochran's (1977) formula was employed to determine the sample size of 384 participants, given that the entire population size of the study is unknown. The justification for focusing on agripreneurs was based on the necessity for them to adopt eco-innovation to mitigate climate change effects and shift towards low carbon emission systems, hence minimising ecological footprints.

3.3 Instrumentation

This study used a questionnaire survey to gather primary data. Gathering data using a questionnaire survey is efficient, allowing for the acquisition of substantial data in a short-time (Ironside, 2020). The questionnaire was designed to fulfil the research objectives and was segmented into two parts. The initial half comprised four questions aimed at gathering participants' demographic information, but the other part included 25 questions based on a 5-point Likert scale, from "5 – Strongly agree" to "1 – Strongly disagree". The items for the five variables in Table 2 were adapted from existing literature, with modifications made to the statements to correspond with our research objectives.

Table 2. Variables and the measurement of items

Variables	Items	Measurement items	Cronbach's Alpha	Source
Government-sponsored innovation policies	GPS1	Government policies encourage firms to adopt eco-friendly technologies.	0.76	Naruetharadhol *et al.* (2024)
	GPS2	Financial support from the government helps businesses invest in eco-innovation strategies.		Achmad *et al.* (2023).
	GPS3	The government provides training and resources to promote eco-innovation.		Djibo *et al*. (2022).
	GPS4	Clear regulations from the government make it easier to adopt sustainable practices.		Liu *et al*. (2023).
	GPS5	Incentives from the government encourage firms		Yang *et al.* (2022).

		to prioritize environmental sustainability.		
Sustainable Product Design	SPD1	Using eco-friendly materials in products helps reduce environmental harm.	0.84	Durmaz and Fidanoğlu, (2024).
	SPD2	Reducing packaging materials on products helps cut down on waste.		Faradilla *et al.* (2022).
	SPD3	Using less energy in making products helps protect the environment.		Feng and Mai (2016).
	SPD4	Creating products that last longer helps reduce waste and support sustainability.		Soomro *et al.* (2021).
	SPD5	Making products easier to recycle or reuse reduces waste.		Yan and Feng (2014).
Renewable Energy Integration	RES1	Switching to energy sources like solar and wind reduces pollution in food production.	0.77	Majeed *et al.* (2023).
	RES2	Using alternative energy sources lowers dependence on oil and gas in food production.		Maka and Alabid (2022).
	RES3	Cleaner energy choices help reduce harmful gases released during food production.		Tiwari *et al.* (2021).
	RES4	Solar power provides reliable energy for food businesses.		Balasuadhakar *et al.* (2016)
	RES5	Biomass energy, from agricultural waste, can reduce the environmental impact of food production.		Bathaei, and Štreimikiene (2023), Obileke *et al.* (2021).
Promotion of Sustainable Consumption Practices	PSCP1	Educating consumers about sustainability encourages them to adopt eco-friendly habits.	0.87	Tania and Sigrid (2006).
	PSCP2	Promoting the use of recycled products helps reduce environmental waste.		Minh and Quynh (2024)
	PSCP3	Encouraging consumers to buy eco-friendly products reduces harm to the environment.		Saari *et al.* (2021)
	PSC4	Providing clear environmental impact information on products helps consumers make sustainable choices.		Minh and Quynh (2024)
	PSCP5	Advertising the benefits of sustainable consumption helps to protect the ecosystems.		Minh and Quynh (2024)
Sustainable Development	SD1	Adopting cost-effective waste management practices benefit the environment.	0.82	Paul *et al.* (2016).
	SD2	Reducing pollution from firms' activities helps protect the community health.		Saari *et al.* (2021).
	SD3	Our firm prioritizes long-term environmental sustainability alongside economic growth.		Eva *et al.* (2020).
	SD4	Following environmentally friendly rules helps firms to avoid penalties.		Hensher (2023).
	SD5	Conserving resources helps firms to save costs and protect the planet.		Bhuiyan (2022).

All items were measured on a 5-point Likert scale. The scale ranged from 1 (strongly disagree) to 5 (strongly agree).

The questionnaire had a pre-test with five academic experts to evaluate its content validity and face validity. A pilot research was subsequently undertaken with 25 respondents, all had prior expertise with eco-innovation initiatives, to establish its reliability. The respondents' feedback predominantly focused on improving the clarity and structure of the questionnaire. The suggestions were implemented prior to the distribution of the questionnaire to the primary sample for this study. The internal consistency reliability was estimated. Cronbach's alpha for the pilot data ranged from 0.76 (government-sponsored innovation policies) to 0.87 (promotion of sustainable consumption behaviours). Consequently, the constructs' measurements were considered credible, as each construct's Cronbach's alpha surpassed the 0.7 benchmark.

3.4 Method of Data Collection

Primary data was obtained via structured questionnaires and interviews. To secure an adequate participant pool for the study, 384 questionnaires were distributed to agripreneurs, while qualitative insights were gotten from focus group interviews of 25 agripreneurs. Due to the nature of the research, purposive sampling was used—a non-probability sampling method in which participants are chosen based on specified criteria that align with the study's objectives (Kamboj *et al.,* 2022). This research primarily targeted agripreneurs in alignment with the global sustainability objectives specified in the Sustainable Development Goals (SDGs) (2015–2030), particularly concerning food security, nutrition, sustainable agriculture, and health (United Nations, 2023a). In this context, purposive sampling offers a targeted method to identify the specific subset of the population capable of providing valuable and pertinent insights, rendering it a suitable option for this study.

However, purposive sampling can create bias, as it does not provide every individual with an equal opportunity for being selected. Nevertheless, due to the specialised nature of the research, adopting a random sampling strategy could have led to the inclusion of participants who do not possess the necessary experience, thereby undermining the validity of the findings. Subsequently, to enhance the sample, participants were evaluated using a binary rating scale ("Yes" or "No") for their previous experiences with the use of eco-innovation initiatives. Only individuals who answered positively advanced to the remaining sections of the survey. A cumulative total of 372 responses were obtained, resulting in a response rate of 97%. This is a substantial sample of responses, for comprehensive analysis.

3.5 Data Analysis

This study employed descriptive and inferential statistics to analyse the data collected for the study. They were used to analyse quantitative data, while thematic analysis yielded qualitative insights from focus group interviews. This integration facilitated an extensive analysis of the research variables, providing an in-depth insight into how eco-innovation strategies advance sustainable practices in the agri-food industry. Inferential statistics, such as multiple linear regression, measured the relationships between the variables and was used to test the stated hypotheses. This incorporation of approaches yielded both quantitative assessments of relationships and qualitative insights into the dynamics of fostering eco-innovation strategies.

4. Results and Analysis

4.1 Profile of Participants

Table 3. Demographic data (n = 372)

Characteristics	Category	Frequency (n)	Percentage (%)
Gender	Male	182	48.92
	Female	190	51.08
Age Groups	18–30	151	40.59
	30–45	134	36.02
	45–60	87	23.39
Qualification	Senior Secondary School	106	28.49
	Diploma	111	29.84
	Bachelor Degree	97	26.08
	Master or higher	58	15.59
Length of Business Operations	3 – < 5 Years	132	35.48
	5 – 10 Years	122	32.80
	> 10 Years	118	31.72

Source: Author Calculation (2025)

The demographic sample results of this study are presented in Table 3. The demographic data reveals a balanced gender distribution among the respondents, with females slightly outnumbering males (51.08% vs. 48.92%). Age-wise, the majority of respondents fall within the 18–30 age group (40.59%), followed by 30–45 years (36.02%) and 45–60 years (23.39%). Regarding educational qualifications, most respondents hold a Diploma (29.84%) or Senior Secondary School certificate (28.49%), while fewer possess a Bachelor's degree (26.08%) or Master's degree or higher (15.59%). In terms of business operations, respondents are fairly evenly distributed across the categories, with 35.48% operating for 3–<5 years, 32.80% for 5–10 years, and 31.72% for over 10 years.

4.2 Hypothesis Testing and Regression Analysis

Table 4. Eco-innovation Strategies Effect on Sustainable Development

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	T	Sig.	Tolerance	VIF
1	(Constant)	-5.695	1.419		-4.013	.000		
	Government-sponsored innovation policies	.484	.044	.445	10.902	.000	.653	1.530
	Sustainable product design	.136	.044	.112	3.059	.002	.813	1.231
	Integration of renewable energy sources	.341	.039	.305	8.730	.000	.889	1.125
	Promotion of sustainable consumption practices	.271	.052	.200	5.244	.000	.745	1.342

a. Dependent Variable: Sustainable development

Table 4 shows the statistics of the hypotheses. All four hypotheses are based on direct relationships. Two common measures used for the statistical significance of a hypothesis are a p-value and a t-value. The threshold value for the p-value is 0.05 or less, while the threshold value for the t-value is 1.96 or above. The beta value for each relationship explains the strength of the relationship.

Specifically, the results indicate a significant positive effect of government-sponsored innovation policies on sustainable development ($\beta = 0.445$, $t = 10.902$, $p < 0.05$), supporting the hypothesis (H1). Sustainable product design ($\beta = 0.112$, $t = 3.059$, $p < 0.05$) has the least effect but still contributes meaningfully to sustainable development, supporting the hypothesis (H2). The integration of renewable energy sources has a positive effect on sustainable development ($\beta = 0.305$, $t= 8.730$, $p < 0.05$), supporting the hypothesis (H3). The promotion of sustainable consumption practices ($\beta = 0.200$, $t = 5.244$, $p < 0.05$) has a significant positive effect on sustainable development, supporting the hypothesis (H4).

The results show that all four relationships have a t and p-value within the range of significance. At the same time, the beta value for each relationship shows the strength of the individual relationships. Nguyen and Vu (2020) assert that evaluating the influence of the explanatory variable on the dependent variable requires consideration of two aspects: the significant level of the effects indicated by the P value and the coefficient β. Effects with a coefficient *p* value < 0.05 are considered statistically significant at the 95% confidence level. Hair *et al.* (2019) assert that a VIF of less than 3 indicates the absence of multicollinearity. The results demonstrated that multicollinearity is not present among the variables in the study model.

4.3 Model Fitness

Table 5. Analysis of Variance

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	365.481	4	91.370	138.118	.000[b]
	Residual	242.785	367	.662		
	Total	608.266	371			

a. Dependent Variable: Sustainable development

b. Predictors: (Constant), Promotion of sustainable consumption practices, Integration of renewable energy sources , Sustainable product design , Government-sponsored innovation policies

The results in Table 5 reveal that the F-statistic value of 138.118, coupled with a p-value (Sig.) of 0.000, indicates that the overall model is highly significant, accepting the alternate hypothesis that the predictors collectively affect sustainability.

4.4 Coefficient of Determination

Table 6. Analysis of R-square

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.775[a]	.601	.597	.813

a. Predictors: (Constant), Promotion of sustainable consumption practices, Integration of renewable energy sources, Sustainable product design, Government-sponsored innovation policies

The results in Table 6 indicates an R Square value of 0.601, suggesting that about 60.1% of the variation in sustainability is accounted for by these predictors, hence illustrating the model's efficacy.

4.5 Thematic Analysis

Table 7. Thematic Analysis

Theme	Sub-Theme	Key Insights from Responses
Government-Sponsored Innovation Policies	Encouraging Eco-Friendly Technologies	Policies encourage eco-friendly adoption but face implementation and awareness challenges.
	Financial Support	Financial support is beneficial but inconsistently available.
	Training and Resources	Limited training and resources hinder effective adoption of eco-innovation strategies.
	Incentives for Sustainability	Incentives encourage sustainability, but accessibility is inconsistent.
Sustainable Product Design	Eco-Friendly Materials	Eco-friendly materials reduce harm but are costly and not widely accessible.
	Waste Reduction in Packaging	Reducing packaging helps cut waste, but consumer expectations sometimes conflict with minimalistic

		designs.
	Longevity of Products	Durable designs reduce waste but increase production costs.
	Recycling and Reuse	Many businesses lack the infrastructure for recycling-focused designs.
Integration of Renewable Energy Sources	Reduced Dependence on Oil and Gas	Renewable energy reduces dependency, but limited access to technologies remains a barrier.
	Cleaner Energy Choices	Cleaner energy options improve sustainability, but high setup costs deter many businesses.
	Solar Power Adoption	Solar power ensures reliable energy but requires high upfront investment.
	Biomass Energy Usage	Biomass energy reduces environmental impact but lacks infrastructure and widespread awareness.
Promotion of Sustainable Consumption Practices	Educating Consumers	Education efforts are appreciated but limited by consumer resistance and cost concerns.
	Recycling Promotion	Recycling efforts are underdeveloped due to limited awareness and infrastructure.
	Eco-Friendly Product Advocacy	Consumers respond positively to eco-friendly products but prioritize affordability.
	Advertising Benefits of Sustainability	Advertising is effective in creating awareness but needs broader reach.

In interviews with 25 participants in Table 7, indicate that government-sponsored innovation policies were highlighted as crucial in promoting eco-innovation within the agri-food industry. The majority of participants acknowledged that while government policies encourage the adoption of eco-friendly technologies, they also noted significant challenges related to the implementation and awareness of these policies. Additionally, participants identified inconsistent financial support and the lack of sufficient training and resources as key barriers. They suggested that more streamlined and reliable funding systems, along with better communication and execution, could significantly improve eco-innovation adoption.

Regarding sustainable product design, participants noted that integrating eco-friendly materials into products is a priority for many businesses. However, high costs and limited accessibility of sustainable materials remain persistent challenges. Packaging reduction to cut down waste is another area of focus, though consumer preferences often conflict with sustainability goals, especially when it comes to minimalist packaging designs. Respondents suggested that offering subsidies for sustainable materials and promoting consumer understanding of the long-term benefits of durable and recyclable products could help overcome these challenges.

The integration of renewable energy sources in agri-food operations was also a significant topic. Participants shared that renewable energy, such as solar power and biomass, has proven effective in reducing environmental impact and pollution. However, the high upfront costs and limited access to renewable energy technologies remain major barriers to wider adoption. Many interviewees emphasized that while solar power has been particularly beneficial, the lack of infrastructure and awareness of biomass energy options hinder its broader application. They proposed that providing financial support, technical expertise, and policies to promote renewable energy distribution could increase adoption rates. Additionally, affordable credit options were seen as essential for enabling businesses to transition to cleaner energy sources.

Finally, promoting sustainable consumption practices among consumers emerged as a key focus in the interviews. While participants are working to educate consumers on sustainable practices, they acknowledged that resistance to change and cost concerns remain significant hurdles. Recycling initiatives were deemed underdeveloped, with many businesses lacking the infrastructure or awareness to implement effective recycling programs. Despite these challenges, participants noted that consumers generally respond positively to eco-friendly products, provided they are priced competitively. Many respondents recommended expanding advertising efforts, building awareness campaigns, and introducing mandatory environmental impact labeling to encourage consumers to adopt more sustainable consumption practices and increase the demand for eco-friendly products.

5. Discussion

The study explored the effect of eco-innovation strategies on the sustainability of the agri-food industry in Nigeria. This study found that eco-innovation strategies significantly impacts sustainability as illustrated in Figure 1.

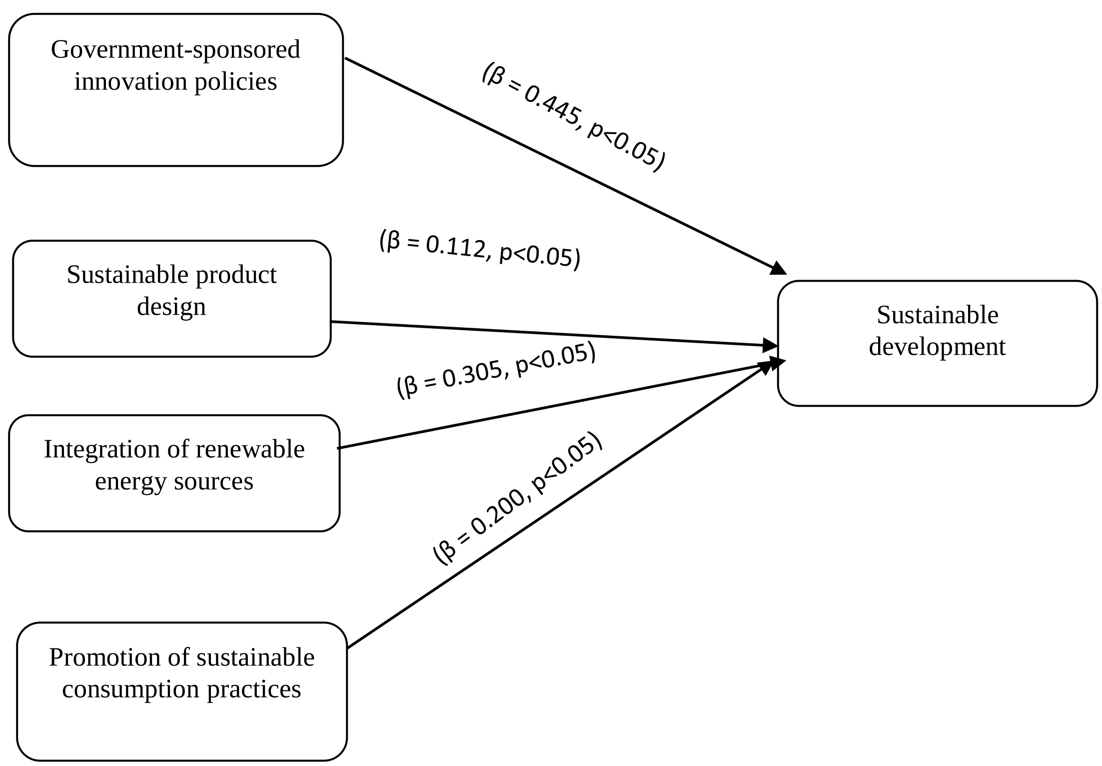

Figure 1. Summary of Findings

Government-sponsored innovation policies are the most important variable to predict sustainability. Previous studies indicated that the enactment of California's Zero Emission Vehicle (ZEV) mandate in 1990 was propelled by governmental efforts to promote the advancement and market integration of alternative fuel vehicles (Liu *et al.*, 2023). Comparable research suggests that government-funded innovation policy programs are explicitly designed to offer support, promote, and enhance innovation-related activities (McCurdy *et al.*, 2024). Public policy can ultimately enhance individual comprehension and encourage sustainable conduct (Agrawal *et al.*, 2023). The findings of Naruetharadhol *et al.* (2024) emphasise that governmental support is essential for achieving a sustainable green future with economic advantages.

According to our findings, sustainable product design positively enhances sustainability. This finding aligns with previous studies indicating that sustainable product design (SPD) is crucial for enhancing a product's sustainability across its full life cycle (Mengistu *et al.*, 2024). This aligns with the findings of Cheng *et al.* (2023) substantiate that green productivity and green process innovation significantly impact sustainability. Comparable results indicate that SPD influences all stages of the product life cycle and presents a viable strategy for creating products that fulfil diverse sustainability standards (Hassan *et al.*, 2017; Hosseinpour *et al.*, 2015).

The study findings show that the integration of renewable energy has a significant effect on sustainability. This result is consistent with Ojekemi and Aga (2023) research which show that the rising use of renewable energy has reduced the ecological footprint, while rising non-renewable energy and economic growth raise the environmental footprint. Solar technology captures solar energy, offering a clean and renewable substitute for fossil fuels. This substitution results in a reduction of greenhouse gas emissions and aids the worldwide initiative to address climate change (Maka

& Alabid, 2022). Prior research has indicated that photovoltaic solar technology presents a feasible alternative for sustainably energising agricultural operations, as it can fulfil both electrical and thermal demands through photovoltaic-thermal (PVT) systems (Singhal *et al.*, 2018; Tariq *et al.*, 2021). While large-scale, centrally situated photovoltaic power plants are more feasible both financially and technically, distributed photovoltaic systems are favoured in agricultural settings such as growth or greenhouse rooms and small-scale rural farms (Devaraj *et al.*, 2020).

According to our findings, promotion of sustainable consumption practices significantly improves sustainability. Consistent with previous studies in various contexts, Saari *et al.* (2021) demonstrate that sustainable consumer behaviour correlates with environmental concern, which is influenced by high levels of environmental knowledge and risk perception. Another research revealed that, environmentally aware consumers typically seek information on environmentally conscious products due to their concern for planetary health (Varela-Candamio *et al.,* 2018). A similar study revealed that green brand communication can inform conscientious consumers about the advantages of selecting a green product over a non-green alternative, thereby enhancing their perceived efficacy in effecting change (Kusmantini *et al.,* 2021).

6. Conclusion

The study examined the effect of eco-innovation strategies on the sustainability of agri-food industry, focusing on government-sponsored innovation policies, sustainable product design, integration of renewable energy, and promotion of sustainable consumption practices. The findings revealed that all four strategies significantly contribute to sustainable development, with government-sponsored innovation policies emerging as the most impactful driver. Renewable energy integration and promotion of sustainable consumption practices also demonstrated strong influences, highlighting their importance in fostering environmental and economic sustainability. Although sustainable product design had the least effect, it still played a meaningful role in advancing sustainability.

This study holds several theoretical implications for eco-innovation research, particularly through the lens of Regulatory Focus Theory (RFT). First, the study contributes to the understanding of how regulatory focus—whether a promotion or prevention focus—can influence the adoption of eco-innovation strategies in the agri-food industry. By linking RFT with sustainability initiatives, the study suggests that firms with a promotion-focused mindset, which emphasizes growth, opportunities, and positive outcomes, are more likely to engage in proactive eco-innovation, such as sustainable product design and the integration of renewable energy. In contrast, firms with a prevention focus, which is more concerned with avoiding losses and maintaining security, may be more inclined to adopt reactive sustainability practices, such as compliance with environmental regulations or reducing waste. This distinction deepens our understanding of the psychological drivers behind eco-innovation adoption.

The study's results offer important insights for various stakeholders seeking to promote eco-innovation and sustainable development in line with sustainable development goals (SDGs). For policymakers, the findings emphasize the importance of designing and implementing policies that foster innovation, particularly in the areas of sustainable product design, renewable energy integration, and promoting sustainable consumption practices. Policymakers should focus on providing incentives for firms to adopt eco-innovative practices, such as subsidies, grants, and tax incentives for green technologies. They can also support research and development in sustainable solutions, ensuring that the agri-food industry aligns with SDGs related to climate action, responsible consumption, and sustainable industry practices.

For agripreneurs, the study suggests that adopting eco-innovation strategies can be a pathway to both sustainability and competitive advantage. Agripreneurs can look to government policies and incentives as opportunities to integrate sustainable practices, such as renewable energy solutions and eco-friendly product designs, without incurring significant costs. These enterprises can also build partnerships with larger corporations, research institutions, and NGOs to access the knowledge and resources needed to implement sustainable innovations. By embracing eco-innovation, agripreneurs can not only contribute to the achievement of SDGs but also differentiate themselves in an increasingly sustainability-conscious market, ensuring their long-term viability and growth.

Despite the significant contributions of our research, it is essential to acknowledge several limitations that can serve as guidelines for future research endeavours. Firstly, given that our study relies on cross-sectional data obtained through questionnaire surveys and interviews, further methods such as field studies or experimental approaches should be employed to corroborate our findings. Secondly, our research primarily focuses on eco-innovation strategies beneficial to the agrifood industry, whereas future studies could enhance understanding by distinguishing various types of environmentally friendly innovations. Thirdly, although our study provides valuable insights into Nigeria as a developing nation, the selection of our research location may constrain the generalizability of our findings. Therefore, replicating this research in other countries is warranted to extend its applicability.

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Authors' contributions

Stanley A. Onobrakpeya: Conceptualization, Investigation, Resources, Writing – original draft, Methodology, Validation, Supervision, Formal analysis**.** Priscillia I. Uwagwu: Data Collection, Data Curation, Validation, Writing – Review & Editing.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the research reported.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of Sciedu Press.

The journal and publisher adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

The datasets generated and analyzed during the current study are available from the corresponding author, upon reasonable request.

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