CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

Assessment of pineapple waste management among smallholder farmers in Nigeria: Case of Edo state

MASTER'S THESIS

Prague 2024

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Declaration

I hereby declare that I have done this thesis entitled **Assessment of pineapple waste management system amongst smallholder pineapple farmers and processors in Iguobazuwa, Ovia south-west, Edo state, Nigeria** independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 2024

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AKINLADE SHERIFF S.

Acknowledgements

I wish to acknowledge the endless effort, understanding and support of my supervisor Associate Professor Ing. Hynek Roubík, Ph.D. for his inputs in sharpening my research work to a success. My profound appreciation goes to my Dean of the faculty Professor Van Damme Patrick Ph.D for his fatherly love and support throughout my stay in the institution. I commend the effort of all my lecturers and others for steadily sharing with me their wealth of knowledge since my very first day in the department they've indeed been helpful in all ramifications and their support saw me through the years of study. I am indeed very grateful to them all.

Words is not enough to express my gratitude expression to my beloved caring parents, Mr and Mrs Akinlade and my great uncles and aunties for their understanding, love and support both financially, morally, physically, educationally and spiritually. You are indeed more to me.

And finally, to Almighty ALLAH.

Abstract

Agricultural or food waste has become a menace in recent time. The improvement in agriculture with seed modification and large-scale production has enhanced food production and has also caused more wastage. This study aimed to assess the level of awareness, waste management practices, and restrictions facing small-scale pineapple farmers in the study area. Surveying 108 smallholder pineapple farmers and processors within Iguobazuwa, village, a region well-known for its pineapple production in Nigeria, was done. The study utilised descriptive statistics, and exploratory factor analysis to explain the tested objectives. The results revealed that in the study area, the male gender is dominant within the pineapple farming sector, with age ranging from 55-65years. The main means of pineapple disposal as established by the study is burning and forage feed production, however the majority of these farmers generate less than 1000kg of pineapple waste annually. The findings also reveal a low level of awareness among farmers about the various uses of pineapple waste, despite the high level of education. Lack of access to extension officers and training on waste management was identified as a major factor contributing to this low level of awareness. The study also identified labour shortage, lack of time, pest and disease attraction, and high costs as the major constraints faced by smallholder farmers in managing pineapple waste. The fruit and crown were identified as the major sources of waste, with less than 1000kg of waste generated annually at every stage of harvest. These findings highlight the need for increased awareness and training on waste management practices and the development of sustainable waste management strategies for smallholder pineapple farmers in the study area.

Key words: Pineapple waste, Agricultural Waste, Smallholder farmers,

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List of the abbreviations used in the thesis.

% - Percentage

^{o}C – Degree Celsius

BCR – Benefit Cost Ratio

CH_4 - Methane

CO_2 - Carbon dioxide

EE – Economic Efficiency

eq/kg – equivalent/kilogram

EU – European Union

FAO- Food and Agriculture Organization

FCT – Federal Capital Territory

g – gram

GDP = Gross Domestic Product

km - Kilometre

mg – milligram

n. d. – No Date

N_2O - Nitrogen oxide

NFI – Net Farm Income

NH_3 – Ammonia

PPWAC - Activated carbon from pineapple peel waste

PW – Pineapple Wastes

TE – Technical Efficiency

USA = United State of America

1. Introduction

Considering food is one of the basics of growth and human existence, and agriculture is its root, food waste and agricultural waste are inseparable as most agricultural processes are aimed at producing food for human consumption. The thin line difference translates to the aspect along the value chain. Agricultural waste will refer to the wastes from production to processing, while food waste would refer to the wastes from distribution and market to final consumers. These wastes include animal excreta, bones, blood, leaves and stems, crop residues, weeds, leaf litter, sawdust, forest waste, carcasses, etc.

With the advancement of technology and the increasing human population, food and agricultural production have increased, as have agricultural waste and food waste. Globally, 30 –50 % of food produced for human consumption is either lost or wasted each year along the food supply chain (Food and Agriculture Organization, 2012) from planting to harvesting, transportation and the final consumers. These losses are the result of poor handling, inadequate storage facilities, market factors, and poor transportation facilities. To efficiently cut these losses, ensure environmental protection, renewable energy generation, sustainability, and agricultural development, recycling and utilizing agricultural wastes are the sustainable order of the century. Some of these agricultural wastes are quite useful in concrete production in structural engineering (Fapohunda et al., 2021). Biogas and biofuel for energy production (Bušić et al., 2018), Drugs and Important phytochemicals production in the health sector (Rao and Rathod, 2019), Nanotechnology (Akhayere and Kavaz, 2022), Fibre for commercial products such as strings and ropes (Mathis et al., 2022), Activated carbon for water purification (Mohan and Singh, 2002) Fertilizers and livestock feed production and many other fields. The generation and management of agricultural waste as a result of its abundance, economic value and energy need becomes a priority.

According to the World Bank report on food security, each year, Nigeria loses and wastes 40% of its total food production, ranking the country 96 out of 113 on the Global Food Security Index (World Bank, 2020). Like many other developing nations, Nigeria’s food insecurity is not only specific in food production, but also a function of imbalance and inadequacy along the supply chain. Minimising waste and fighting the problem of food security in a developing nation such as Nigeria is based on incorporating the concept of conservative, integrated and sustainable agriculture that can address the nutritional needs of one-eighth of

the undernourished population within the country and provide solutions to the poverty-ridden economy.

One-third of the world's food is produced by small farm holders, producing roughly 35% of the world's food in value terms (Lowder et al., 2021). These small farm owners in most developing countries manage agricultural waste by discarding it due to either ignorance or the appropriate channels to transfer and use it (Dhamodharan, 2022). In Nigeria, more than 80% of the farms producing their food are small farm owners with less than 10 hectares (Mgbenka and Mbah, 2016). With the vast expanse of arable land and favourable weather, most of the Pineapple farmers are concentrated in nine (9) states in the southern states, namely, Abia, Akwa Ibom, Benue, Cross River, Edo, Ebonyi, Enugu, Imo and Ondo (Ola-David and Osabuohien, 2015)

Pineapple (*Ananas Comosus*) from the family *Bromeliaceae* is one of the globally demanded fruits and is among the most popular and nutritious tropical fruits grown in most tropical and sub-tropical countries (Cabrera et al. 2000). Nigeria produced about 6% of the total pineapple production in 2020 occupying the eighth position in the world and Africa's largest producer of pineapple fruit (FAO, 2020). Production is largely done by small-scale farm holders in a mixed cropping system and recently few large-scale farm holders in a mono-cropping system as a result of the enhanced value of fresh fruits, resuscitation of pineapple cultivation and local processing (Akhilomen et al. 2015).

Pineapple waste (PW) is a by-product of pineapple production and processing, which is mostly dumped and discarded into the environment and ultimately pollutes the environment (Makinde et al., 2011). The waste consists of residual skin, peels, pulps, stems, and leaves (Mathus et al., 2022). Wastes are abundant and are generated mainly by poor management of the fresh fruit, storage, and transportation system (Praveena and Estherlydia, 2014)

1.1. Problem Statement

Agricultural waste diversity and sustainability issues have become a serious concern lately that have led to huge financial and environmental implications in developing countries and sub-Saharan Africa in perspective (Onu and Mbowa, 2021). The demand for pineapple has continued to increase over the years due to the diversification of the product and the discoveries associated with its waste. Although Nigeria occupies a prominent position in

pineapple production in Africa and the world at large, her inability to fully exploit the economic potential of the crop could reflect the inefficiency in pineapple production, which otherwise would have served as an important tool to achieve some of the objectives of the transformation agenda in Nigeria (Nwobodo 2017). Therefore, most of the pineapple produce harvested in the country is wasted, and this may be due to production inefficiencies, post-harvest losses, a low level of technology to facilitate the processing of quality pineapple products, and an inefficient marketing system (Ivan et al. 2011).

Unfortunately, farmers are still fighting the issues of post-harvest losses and the disposal or utilisation of pineapple waste that can be traced back to activities such as harvesting, handling, storage, processing, and transportation. As a result of inadequacy in transportation, the movement of pineapple to the main market in Lagos takes up to 13 hours to 3 days (Ege et al., 2011), these delays during transit have a huge impact on fruit and its waste generation. Ultimately, pineapple fruits that eventually reach the processing industry have only about 52% of the fruit that are used for pineapple production, while about 48% of waste materials consisting of pineapple peel, crown, and leaves (Rabiu et al., 2018). These wastes have high moisture content and constitute a nuisance in the environment with the current practice.

Most farmers find it difficult to foresee and manage such situations and offer alternative solutions to the conversion of post-harvest pineapple waste into valuable products for sustainable waste management. This study aims to identify the main causes of post-harvest losses among smallholder pineapple farmers in the Edo state, Nigeria, the main sources of waste generated, constraints to proper and sustainable disposal of the wastes, identify the waste management system adopted by most farmers in the study area, the level of awareness, and investigate the demographic characteristics of small farmers that influence the different methods of waste management.

2. Literature Review

Pineapple is a fruit of unique appearance and flavour, consumed naturally or processed to obtain different products (Vieira et al., 2022). With over ninety (90) varieties cultivated globally (Hasan et al., 2010), pineapple is a global fruit that is produced in the tropics and is only preceded by banana and citrus in the chain of importance (Hossain et al., 2015). However, a recent study by FAO (2021) mentioned that avocado, mango, and pineapple are the most traded tropical fruits in terms of export quantities. Pineapple has also been successfully cultivated in the subtropics as evident in Hasan et al (2010), hence the wastes associated with pineapple production are substantial and are attracting different literature in modern days.

Before 1998, agricultural wastes were not considered with utmost importance, the phenomenon, despite being researched for about 60 years now, only became relevant afterwards and has attracted more than 60% of the scientific production and publication in the last 13 years (Monica et al., 2020). This chapter reviews opinions and conclusions from various sources and authors, starting with an overview of pineapple production in Edo state, the economic importance of pineapple production, current practices for pineapple waste management among smallholder farmers, the environmental impact of pineapple waste, and the economic importance of pineapple waste, case studies of successful and sustainable pineapple waste management. The last section reviews challenges and barriers to implementing sustainable waste management in smallholder farmers in Nigeria.

2.1. Overview of pineapple production in Edo State

One of the prominent crops cultivated in Edo state is pineapple with the state being one the highest pineapple-producing state in Nigeria (Edekhe et al., 2020; Ola-David and Osabuohien, 2015). There are more than 1,700 pineapple farmers in Edo state, Nigeria (Akhilomen et al., 2015). The crop production represents an extraordinary commitment to the financial change of the state region as the most preferred economically produced crop (Esobhawan et al., 2014). The production and marketing of fruit is a widespread economic activity among rural people in the State (Edekhe et al., 2020) Cultivated largely grown by smallholder farmers and widely adopted by both genders (Esobhawan et al., 2014). Most of these farmers are youth between the ages of 28 and approximately 45 years (Abiola et al., 2019; Fawole, 2008), although Akhilomen et al. (2015) identified an older number of pineapple

farmers between the ages of 41 and 72 within the state, a figure near Meludu and Gbojubola (2006) who reported that the majority of pineapple farmers in Edo state are between the age of 41 and 50 years. This age bracket indicates the investment of the adult group in the pineapple business as a result of the labour-intensive nature of pineapple farming with its time-consuming factor.

The majority of pineapple farmers in Edo state are married (Onyemekonwu et al., 2019) as most small farmers in Nigeria use the family as workers in agricultural fields. A higher proportion of pineapple farmers in Edo state have formal education which goes a long way in decision making (Onyemekonwu et al., 2019) and is crucial in farmer training and different agricultural extension services.

The production of the pineapple is mostly for profit making as found by Fawole (2008) that 75% of pineapple farmers in Edo State attributed their main purpose of pineapple production to profit-making. However, Esobhawan et al. (2014) concluded that the female farmers derive a higher net income per ha than their male counterpart, but the cost of production for the females are higher as a result of expenses from farming operations such as hiring labour.

A mix of traditional and modern techniques characterises pineapple production in the Edo State, some of these techniques researched by Fawole (2008) showed that the majority of farmers utilise modern techniques such as the mini-set techniques of cutting suckers and crowns into pieces. A large percentage of farmers also use the stem defoliation sectioning technique and the trenching technique to harvest plantlets as they emerge. Traditional techniques of planting suckers while splitting them into four equal parts are also a common practice among farmers (Fawole, 2008).

Previous research has been conducted on pineapple production in the state. For example, Akhilomen et al., 2015 researched the economic efficiency analysis of pineapple production in the state, using a stochastic frontier production approach. Ege et al (2011) evaluated the impact of climate variability on pineapple production in the state. Other researchers include Abiola et al., 2019; Esobhawan et al., 2014; Amao et al., 2011 among others, yet none of these researchers has been able to quantify the exact amount of hectares or the yield of pineapple production in the state. However, Akhilomen et al. (2015) concluded that the average technical efficiency of pineapple production in the state is about 70%, while the estimated economic efficiencies (EE) differ substantially among the farmers, but with an average of 68%. There are no established standard weights and measures for pineapple fruits,

and the pricing system is rudimentary. Therefore, the prices of pineapple in Edo state vary depending on the season, falling sharply during the maximum supply period before rising dramatically during its off-season period.

Conducting research on marketing channels for pineapple production in Edo state, Edekhe et al. (2020) found that pineapple products are sold to agents, who assemble during harvest, wholesalers, retailers, and even consumers. The majority of the pineapple produced in the state is transported to Abuja (Edekhe et al., 2019) and Lagos (Ege et al., 2011). These two regions serve as the market for most of the crops produced in the country because of the large commercial and economic activities in these regions.

Despite the vast area of land cultivated by small farm holders in Edo state, Meludu and Gbonjubola (2006) reported that the constraints affecting pineapple producers are extensive as a result of inadequate capital to invest in large-scale farming, lack of high-yielding planting materials, cost of farming materials and chemicals, cost of labour required on the farmland, lack of hired labour were also identified to sufficiently to the problems faced by pineapple farmers in producing at a large scale.

Investigating the challenges of pineapple production in Edo state, Researchers like Onyemekonwu et al., (2019) conducted research on factors influencing the adoption of improved pineapple production practices in Edo state, the result also highlighted inadequate credit/finance as the most important constraint. Other highlighted constraints were the inaccessibility of improved seeds, pest and disease problems, labour shortage, high cost of farm chemicals, land procurement problems, inadequate transportation facilities, seed procurement problems, insufficient storage / preservative facilities, poor market, inadequate technical know-how, insufficient irrigation facilities and inadequate extension services. It was concluded that pineapple production is restricted by several factors that are capable of reducing farmers' productivity and possibly forcing them out of production. The study recommends that relevant extension agencies link farmers with sources of farm input and possible funds.

Edekhe et al. (2019) also blame high transport costs, high fruit perishability, inadequate storage facilities, limited working capital and the absence of reliable credit facilities and sources for the poor marketing of pineapple in Edo state.

2.2. Economic importance of pineapple production

In most cases, pineapple is mainly cultivated for food production, either as juice and flavour from its fruits that are consumed fresh (Sodjinou et al. 2022) or as add-ons in snacks. Pineapple is a very profitable business in Nigeria, as it constitutes the financial stability of various individuals in Nigeria and the world. Ajayi and Wahab (2022) in the study on the economics of pineapple harvest in the Ejigbo local government area of Osun state, Nigeria, concluded from the budgetary analysis that pineapple production was highly profitable in the study area with a benefit cost ratio (BCR) of 2.31. Using the net farm income (NFI) analysis, Edekhe et al. (2019) researched the costs and return analysis of pineapple marketing in Edo and FCT Abuja, Nigeria. The result of the study showed that pineapple marketing for both wholesale and retail marketing operations in Edo and FCT is profitable. The researcher further concluded that the highest profit is in the off-peak season of the product compared to the peak season. Ajayi and Wahab (2020) also gave the average return on investment in pineapple production as 1.74. This indicates that for every naira spent, the farmer makes a gain of one (1) Naira 74 kobo returns. However, for pineapple marketing, Enibe et al. (2018) reported that the average return on investment for wholesalers as 0.23 and 0.32 for retailers. This translates to a gain of 23 kobo and 32 kobo for wholesalers and retailers respectively for every naira spent. This also further emphasizes the profitability of the fruit at every stage of its production to the final consumers. Although, some studies suggest that the profit margins for smallholder pineapple farmers in Nigeria may be relatively low due to a lack of access to inputs and technology, high production costs, and low prices for the fruit (Akhilomen et al., 2015; Olukosi et al., 2016).

Pineapple farming is an important economic activity in Nigeria; this is also evidenced as Nigeria is ranked 1st in fruit production in Africa. This underscores the current job opportunities within the fruit production and supply chain. Amao et al., (2011) mentioned that harvested pineapple coming from the farm through the farmers passes through agents, wholesalers, retailers, marketers, production companies and many more along its supply chain before getting to the final consumers.

Pineapple is a widely traded fruit in the global market, and countries that produce and export pineapple can earn significant foreign exchange. The gap between pineapple production and consumption opens the opportunity for the export of the fruit market (Untoro et al., 2021)

market. According to FAO (2022), pineapples remained by far the predominant commodity in quantity with global exports of 3.3 million tonnes. The appeal of the fruit in international trade is largely due to its extremely low average export unit price. Untoro et al. (2021) mentioned that the market opportunity for finished pineapple products offered by the EU leads to competition between various fruit exporters. Costa Rica and the Philippines are the largest exporters of fruit in the world, while Nigeria, Cote d'Ivoire, and Ghana are the leading fruit producer in Africa. The production of fruit in the mentioned countries has contributed to the foreign exchange of these countries, as the USA, the Netherlands, China, Spain, the United Kingdom, and Germany are the biggest importers of pineapples in the world, with the USA purchasing nearly 40% and the European union accounting for about 30% of the global export consumption (FAO 2022). Pineapple production can contribute significantly to a country's gross domestic product (GDP), especially in countries where it is a major agricultural commodity.

Pineapple contains considerable calcium, potassium, fibre and vitamin C (Hossain et al., 2015) which are essential nutrient supplements for human development. Depending on the variety, an average pineapple has 47.8 mg of vitamin C and 13 mg of calcium per 100 g of pineapples (Aili-Hamzah et al., 2021). According to Akhilomen et al. (2015), Pineapple is a popular dessert choice among many health-conscious people. Its health benefits include everything from warding off the common cold to removing cancer-causing free radicals. This inexpensive food supplement is a great way to have a healthy physique and a clear digestive system. The fibre in pineapple helps us digest food normally, makes it easier to eliminate waste, and provides our bodies with the nutrients they need.

Bromelain is a protein digesting enzyme classified as protease (Abreu and Figueiredo, 2019) that is extracted from pineapple. Pineapple bromelain is commercially used as a meat tenderising enzyme, in brewing and baking in the food industry (Ketnawa et al., 2012). As an active component in dentifrices and skin products that whitening teeth can cure acne, wrinkles, and dry skin, as well as to reduce post-injection bruising and swelling, bromelain has a wide range of uses (Arshad et al., 2014). Bromelain has also shown activity with interference with malignant cell growth, inhibition of platelet aggregation, fibrinolytic action, anti-inflammatory processes, and skin debridement (Akhilomen et al., 2015).

Various food items such as jam, jelly, and pickles are produced from pineapple (Hossain et al., 2015). Juice, canned pineapple, cocktail, jams, wines, powder, frozen pineapple, and fruit

punch are examples of processed pineapple goods [Hossain 2016]. The processed pineapple items that are used the most frequently are canned pineapple products, which have a long shelf life and are commonly used in salads, main courses, appetisers, beverages, and desserts (Siow and Lee, 2016). Pineapple powder is also a useful pineapple-based product from the dehydration of the fruit, with a long shelf life and can be used as a food additive and flavouring (Aili-Hamzah et al., 2021).

2.3. Current practices for Pineapple waste management in smallholder farming

Waste management refers to actions taken to manage unwanted or discarded materials from inception to the final stage of disposal (Rabiu et al., 2018) Owing to the highly perishable nature of fruits, postharvest losses are higher in fruits and vegetables than cereals, tuber and root crops (Ajayi and Wahab, 2022), the losses are significant sources of waste for smallholder farmers. These wastes can include wastes of organic nature, crop waste, processing waste, chemical waste from the use of inputs such as fertilisers and pesticides, and much more. Certain crop wastes have historically been utilized as fuel, animal feed, roof thatch, compost, soil mulch, matchsticks, and papermaking materials. (Koul et al., 2022)

Specifically, as with most fruits and vegetables, pineapples are fundamentally perishable, and as such their production to finishing is associated with a lot of waste. The abundance of these wastes has been emphasised by many different authors, one of which is Baidhe et al. (2021) who mentioned that pineapple wastes are largely from the crown, peel, core, and base, which are mostly from the processing of the fruit. The management of this waste has also been extensive, from reuse as planting materials to landfill disposal or burning.

The findings of Matius et al. (2022) revealed that Samarahan pineapple smallholders employ several practices to manage pineapple waste, including reuse, where farmers use the pineapple crown as new planting material, animal feed, and compost material. The study has also identified several challenges in the management of pineapple waste, such as lack of time, high cost, difficulty finding the buyer of the waste product, shortage of labour, and the waste product attracts pests and diseases, and produces a foul smell which discourages them from managing the pineapple waste.

Gerald and Charles (2021) carried out a study on Waste Management Systems among Smallholder Farmers in Masaka and Lyantonde Districts, in Central Uganda. The study showed that common practices for waste management among small farmers were mainly surface deposition, with more than 40% of the respondents practising the act. Burning, composting, and burying were also common practices among the farmers surveyed. The removal and recycling were the least used methods among the sampled respondents, with less than a tenth of the respondents utilising the method. Gerald and Charles (2021) also found that the choice of waste management practices by farmers was affected by their age, the purpose of the waste product, season and amount of waste, awareness of waste management policies, farmer commitment, and the economic status of the farmer.

In Uganda, the findings of Kumar et al. (2016) noted that the disposal of pineapple waste from fruit processing companies is dumped in gardens or processing yards. Ugwu and Enweremadu (2020) also noted that most of the agricultural-based and biodegradable waste in South Africa is disposed of in landfills or is incinerated. Ruslan et al. (2017) are also of the opinion that pineapple waste is mainly eliminated by burning or decomposing in Malaysia. Dumping and landfill deposition was also the opinion of Ayeni et al. (2019) on the most adopted pineapple waste management practices.

Aruya et al. (2016) in the study on the assessment of crop residue characteristics and factors militating against efficient management in the Ikara local government area of Kaduna state, Nigeria, obtained a different result from the previously mentioned researchers. Most of the farmers sampled in the study utilise the agricultural waste reuse method as their disposal method, with uses such as sale, animal feed preparation, cover crops, domestic use, and construction in local settings. Although, most farming households still engage in inefficient management practices such as open dumping and burning of their agricultural waste.

Conclusively, from the reviewed research, the different strategies adopted by many smallholder farmers have not been sustainable, Zziwa et al. (2017) also mentioned that strategies used by farmers employing the use of on-farm waste have not yielded significant contributions, as most farmers are into landfill and open burning means of waste management.

2.4. Environmental Impacts of Pineapple Wastes

When discharged into the environment, agricultural wastes can be both beneficial and detrimental to both the human and social environment. The increasing amount of waste when exposed to the natural environment can cause severe environmental problems, site contamination and risk of infectious diseases (Roda and Lambri, 2019). The waste from pineapple production has increased over the years and contributed too many environmental issues (Ruslan et al., 2017). The management of such waste is an important issue for smallholder farmers in Nigeria and in the world at large as it can have significant environmental and health impacts if not properly managed.

According to Yusri et al. (2015), pineapple leaves are a major part of pineapple plants are usually left to decay or burn. This happens in the field during harvesting time due to the limited technology and the ignorance of farmers and local communities about the existence of commercial uses of pineapple leaves. Furthermore, the stems, crown, and core are other sources of pineapple waste generated during pineapple processing because they are removed and cut before the peeling activities (Saravanan et al., 2013). These numerous wastes are usually directly disposed of via landfills and open burning. These acts have been linked with numerous environmental impacts. Matius et al (202) argued that waste dumping attracts pests and diseases, and it produces a foul smell, which results in air pollution within the environment. Rabiu et al. (2018) are also of the opinion that pineapple waste when subjected to open burning contributes to air pollution.

Ong et al. (2014) argued that the disposal of pineapple waste could be problematic because the waste material is high in moisture and sugar content, which is prone to microbial spoilage. Microbial spoilage when exposed directly to the environment can shape immune surveillance early in human life and can disrupt the balance between the host microbiome and the immune (Sharma and Gilbert, 2018). This emphasises the dangers of exposure to an open landfill or the dumping of biodegradable agricultural waste such as pineapple waste.

Landfill deposition of organic waste produces methane and CO_2, which are the two main greenhouse gases responsible for climate change. Sanchez et al. (2015) reported that agricultural activities and their wastes are responsible for approximately half of the methane and 13% of the CO_2 in the atmosphere. En and Sabiti (2011) mentioned that exposure of agricultural waste in an open field or open burning is associated with the emission of carbon

dioxide (CO_2), nitrogen oxide (N_2O), methane (CH_4) and ammonia (NH_3). Evaluating the opportunities to reduce the carbon footprint of fresh and canned pineapple processing in central Thailand, Usubharatana and Phungrassami, (2017) revealed that the average carbon footprint of pineapple cultivation is about 172 g CO_2 eq/kg of fresh pineapple. The study also revealed that fertiliser use contributes the most to the value, accounting for about 58-79%. By extension, the carbon footprint of fresh pineapple is seen in the waste, since the waste represents more than 40% of the pineapple fruit. Rani and Nand (2004) reported that improper disposal of pineapple peel waste could lead to significant environmental pollution as a result of the richness of the waste in cellulose, hemicellulose, and other carbohydrates that produce potential substrates methane during anaerobic digestion.

Conducting an environmental impact assessment of pineapple farming using life cycle assessment (LCA), Phrommarat and Oonkasem (2021) revealed that, on a per-hectare basis, conventional pineapple farming is less environmentally friendly. The practise had a greater environmental impact in all categories mainly related to the use of chemical fertilisers, particularly Nitrogen (N) fertilisers. The resulting environmental impact of pineapple waste, when combined with the environmental impact of its production, deserves the utmost attention. Although Phrommarat and Oonkasem (2021) mentioned that integrated pineapple farming that utilises the waste from pineapple farms shows more environmentally friendly traits than conventional practise.

The disposal and burying of pineapple waste is not all negative to the environment. As a result of the organic nature of pineapple waste, when buried, composting, which usually takes about 35 weeks (Hoang et al., 2019) can be a source of soil nutrients, providing the soil with various nutrients. The crown of pineapple has also been reported to have been used for soil amendment, with pineapple waste noted for the development of fertilisers as it has a high Carbon/Nitrogen ratio (Baidhe et al., 2021). The nutrient from the waste can help enhance different nutrient cycles in the locality thereby ensuring the nutrient balance in the ecosystem and supporting microorganisms and soil faunas.

2.5. Economic Importance of Pineapple Waste

Poor management of fresh fruit, storage, and transportation system (Praveena and Estherlydia, 2014) mostly generates an abundance of waste in the pineapple industry. The

waste, which is approximately half of the total weight of pineapples (Dorta and Sogi, 2017) is a never-ending product of the fruit processing companies and associated smallholder farmers. The transformation of pineapple waste into wealth through value-added products, for example, the extraction of fibre from pineapple leaves to produce commercial products such as string and rope, is important to emphasise as an income source for small farmers and economic growth for the country (Ruslan et al., 2017). Despite the environmental setback of the waste, there are several economic importance attached to the waste. Different authors, finding uses for this waste and, thus, cutting the losses of small farm holders and providing another source of income along the fruit supply chain, have researched the importance of these wastes.

The pineapple stem, a significant part of the waste produced by processing factories and different players along the fruit supply chain, has been linked to the production of starch. In Thailand, pineapple stems have become a significant agricultural waste as a starch source, which has unique and distinct properties compared to commercial starch (Nakthong et al., 2017). Roda and Lambri (2019), who gave a detailed review of the extraction of starch such as polysaccharides and their associations within the overall substrate from pineapple waste, also affirmed this.

According to Wijayati et al. (2016), the pineapple peel, which is usually thrown away and considered waste, contains vitamin C, carotenoids, and flavonoids. Ayeni et al. (2019) utilized *Aspergillus niger* to produce citric acid from pineapple waste and also emphasised the benefit of the management of pineapple waste in the production of citric acid as a result of the surge in demand for citric acid. Furthermore, the crown and leaves of pineapple are a good source of vitamin B1, vitamin B6, manganese, and vitamin C, an important antioxidant (Akhilomen et al., 2015). Praveena and Estherlydia (2014) also mentioned that pineapple peels could be used in the production of vinegar through simultaneous fermentation processes. The vinegar produced was found to have a higher antioxidant capacity compared to vinegar products from other fruit wastes.

The potential for the use of Nigerian pineapple leaves as alternative fibre in the pulp and paper-making industry was confirmed by Aremu et al. (2015) in the study on pulp paper production from Nigerian pineapple leaves. Using the Surface morphology analysis, the study found that there is a condensed and packed arrangement of fibres within the pineapple leaves. This finding can help reduce the stress of pulp production from trees, reduce deforestation, and enhance sustainable waste management practise. Akhilomen et al. (2015) also mentioned that

the 'Barong Tagalog' in the Philippines created from pine textiles is a good waste management culture to convert pineapple waste. In addition, the fibres of the crown and leaves that are removed and weaved are important raw materials to produce wallpaper and furniture.

Production of bioenergy from pineapple waste seems to be the most sustainable way to minimise dependency on fossil fuel use in the recent economy (Aili-Hamzah et al., 2021). Pineapple waste using pyrolysis can be converted into end-user energy products such as charcoal, char and bio-oil (Rabiu et al., 2018) which can in a long way supply energy to energy-deficient areas in developing countries. The use of waste as biomass for energy sources such as biogas, biofuels, bioethanol, and briquettes is also an important economic and environmental consideration. The use of pineapple waste for the production of briquettes is already established on an industrial scale in Kenya (Cohen and Marega, 2013). Antonio et al. (2015) gave an account of the use of pineapple waste in biofuel production using fermenting yeast with a focus on fermentation. Using the waste as substrates, Jehan et al. (2017) noted that the pineapple waste, the core, can be used in the production of biogas, while Hossain (2016) mentioned that the peels of the pineapple waste can also be used in the production of gas. As a result of the rich intercellular sugars and plant cell walls of pineapple waste (Casbar et al., 2019) the wastes can be used in the production of bioethanol (Casbar et al., 2020).

Conducting research on simple and quick methods for recycling pineapple waste into animal feed, using wheat offal was used as an absorbent for the moisture content of the pineapple waste, Makinde et al., 2011 mixed pineapple waste and wheat offal in different proportions to obtain the optimal proportion for quality feed production and high nutrient yield. The study finds that mixing pineapple waste with wheat offal in a 2:1 ratio retains the quality of the feed and has a high content of nutrients. Although the study by Ososanya et al. (2014) advised the limit of use of pineapple waste with other mixtures to be 60% as a result of the suspected effect on semen characteristics.

Single-cell protein has been widely used by farmers in providing nutrition for animals; the uses have been established in piggery, dairy and livestock production (Baidhe et al., 2021). Mensah and Twumasi (2017) in Ghana also established the production of Single - cell protein from pineapple waste. Single cell protein is not just important in animal feed; its use has been reported in human food. Nasseri et al. (2011) mentioned that single cell protein has a high nutritional value due to the high amount of protein, vitamin and essential amino acid and lipid content.

Yahayu et al. (2017) also deeply establishes in the study on the efficacy of pyroligneous acid from pineapple waste biomass as a wood preservation agent that pyroligneous acid can act as an antifungal and anti-termite agent in the preservation of weeds.

Different researchers have also highlighted the use of pineapple waste for the treatment of wastewater, specifically the removal of heavy metals from the waste. Mahmad et al. (2015) in their study on the preparation and characterisation of activated carbon from pineapple waste biomass for the removal of dyes mentioned that pineapple biomass (crown, leaves, and stem) is an effective adsorbent in the removal of dyes in wastewater. Yamuna and Kamaraj (2016) also concluded that activated carbon from pineapple peel waste (PPWAC) has also been shown to be an effective sorbent to remove methylene blue (cationic dyes) from wastewater by increasing its chelating power using sulfuric acid. Chromium, aluminium, lead, and cadmium are some of the heavy metals that have been adsorbed by a pineapple-based adsorbent (Aili Hamzah et al., 2021)

2.6. Case Studies of Successful Pineapple Waste Management Initiatives

Pineapple waste management is an important issue for small farmers, as it can have significant environmental and health impacts if not properly managed. To address these challenges, it is helpful to examine case studies of successful pineapple waste management initiatives that have been proven by previous researchers.

One such case study is the vermicomposting of pineapple waste with earthworms in Ghana (Mainoo et al., 2009). This initiative concluded that *E. eugeniae*, a vermicomposter, produced homogeneous humus-like materials that is rich in total nitrogen, phosphorus, and potassium of 0.4%, 0.4% and 0.9% respectively. The vermicompost produced was concluded to be a good soil conditioner that can be utilized by smallholder farmers. Milito et al. (2021) also concluded in the study on the assessment of the suitability of pineapple waste as feedstock for vermicomposting that the degradation of the pineapple waste by earthworms demonstrated the practicability of vermicomposting as a low-cost and straightforward technology of converting pineapple waste into a nutrient-rich soil amendment.

Another successful initiative is the use of anaerobic digestion of pineapple wastes for biogas production (Unnikrishnan and Vijayarghavan, 2021). This initiative tested the potential

of pineapple waste to produce biogas through the installation of a biogas plant in the home. The study concluded that pineapple peels are a promising feed for biogas generation as they were rich in carbohydrates and proteins as the waste can produce up to 64% methane and approximately 51% CO_2. This notion was also supported by Oranusi et al. (2015) who reported the generation of biogas (71% CH_4, 18% CO_2, 7.0% N_2, 1.5% H_2, 1.5% H_2S, 1% O_2) using co-digestion of pineapple peels with food waste in equal ratio.

Composting agricultural waste or converting it into compost is considered one of the most favourable, inexpensive, and simple methods used to treat and stabilise different types of waste, as well as to generate organic fertiliser (Kamoga and Ssekyewa, 2021). This initiative is also applicable to pineapple waste (Hoang et al., 2019).

In conclusion, the aforementioned initiatives have been carried out in different parts of the world and on different scales and have ultimately led to a reduction in waste volumes, improved energy security for participating farmers, and reduced greenhouse gas emissions.

2.7. Challenges and Barriers to Implementing Effective Pineapple Waste Management in Smallholder Farming

Farm waste management is owed to several factors from outdated technology to time constraints and varies across different levels of development of countries. Smallholder farmers are in the habit of maximising land usage and production yield and are more focused on producing commercially viable goods, rather than focussing on the waste generated or finding a use for the waste. With the severity and abundance of the waste, smallholder farmers are facing several challenges in waste management.

Mathius et al., 2022 in a study on current practises and challenges of smallholder pineapple growers in managing pineapple waste in Malaysia, observed that lack of time and high cost of implementation of waste management are the main obstacles facing smallholder farmers in the country. Ruslan et al. (2017) also found that time constraints, high costs, and outdated technology have affected the utilisation and management of pineapple waste. The finding indicates that the smallholders know about waste management. They also have a positive perspective towards the practice. However, several barriers limit them to manage the waste such as time constraints, high cost and availability of outdated technology.

Aruya et al. (2016) observed that lack of awareness and ignorance of the benefits and management strategies of agricultural waste is the leading factor in the poor utilisation of crop residue among smallholder farmers in Kaduna, Nigeria.

2.8. Summary of Research/Research Gap

Although the literature on agricultural waste has been gaining momentum in the last century as a result of the attribution of the waste and greenhouse gas emissions. This cannot be said of agricultural waste in Nigeria or other developing countries across Africa. Specifically, Nigeria is faced with the problem of effective solid waste management with all the focus on commercial and domestic waste, and as such, attention to agricultural waste may not be seen in recent years. The review of the literature established the magnitude of pineapple production in the Edo state and the socio-demographic characteristics of farmers and the waste associated with the production and processing of pineapple, the benefit of pineapple fruit production, the established uses of the pineapple waste, the possible environmental impact of the waste and the successful and sustainable management of the waste. However, there has been little or no literature on pineapple waste management in prominent areas of pineapple production, and this study attempts to quantify the amount of waste generated by pineapple farmers, the challenges of disposal and management, and their level of awareness of the usefulness of the waste, this will bridge this gap identified in this review.

3. Aims of the Thesis

This study aims to identify the main causes and sources of waste generated among smallholder pineapple farmers in Edo state, Nigeria, and seek to encourage the adoption of sustainable waste management practices among the smallholder pineapple farmers.

3.1. Research Objectives

Based on the issues raised on the background and the statement of the problem, this study seeks to achieve the following purpose:

- To analyse the demographic characteristics of small farmers that influence the different methods of waste management.
- Find out the sources and causes of pineapple loss and waste and quantify the amount of waste.
- Find out the challenges of the disposal and management of pineapple waste.
- To determine the level of farmers' awareness on products that can be gotten from pineapple waste utilisation.
- To determine if farmers receive any training on pineapple waste management.

3.2. Research Questions

The following research questions were raised to guide the study:

- What are the demographic characteristics of smallholder farmers engaged in pineapple production in Edo State?
- What are the sources and causes of pineapple waste and losses?
- What method of waste management do small-holder farmers adopt to dispose of pineapple waste and losses?
- What constraints do the farmers face in pineapple waste disposal?
- What training have the farmers received on pineapple waste received in recent times.

4. Methods

4.1. Study Area Description

Edo State is one of the thirty-six States of Nigeria with a population of 3,233,366 (NPC, 2011) and a total land area is 19,794 km^2. The state lies approximately between latitudes 5°44'N and 7’37’’N and longitudes 5°44 and 6'43" (Figure 1).

Iguobazuwa is a community in Edo State, Nigeria on latitude: 6° 33’ 57” N and Longitude: 5° 21’ 16” E. The community is located in the Ovia-Southwest Local Government Area in Edo State with 26,300 people based on the 2006 census (World Gazetteer, 2010). Iguobazuwa is famous for its incredible pineapple production. The target groups will be pineapple farmers and other players along the supply chain within the community.

Water Resources: The water resources of the area of study can be grouped into surface water and groundwater. The Iguevinyoba River, which flows through the western portion of the study area and encompasses its northwestern portion, is the primary source of surface water there. The Usen River, Okada River, Igbogo River, Iguevinyoba River, Oha River, and Siloko River are only a few of the many tributaries that feed into the river (Weather Spark, n.d.).

Climate: The study region has a tropical environment with frequent rainfall. In the Köppen climatic classification, a tropical climate is one in which the average monthly temperature is over 18°C. There is no winter season and there is more annual rainfall than annual evaporation. The difference in temperature in Iguobazuwa is low throughout the year. (Weather Spark, n.d.).

The average percentage of the sky that is cloudy in Iguobazuwa varies significantly seasonally throughout the year. At Iguobazuwa, the clearer season starts around November 13 and lasts for 3.0 months, finishing around February 12. December is the clearest month during this period. (Weather Spark, n.d.).

Topography: The elevation of Iguobazuwa varies by around 325 feet, with a 423-foot average height above sea level. Within 50 kilometres, there are significant height differences (3,015 feet). Land use within Iguobazuwa comprises, cropland (46%) and trees (21%), grassland (21%), trees (18%), and shrubs (15%) are present (Weather Spark, n.d.).

Economic Activities: As indicated by land use, more than 40% of the land in the study area is designated for crop farming. These include cash crops such as pineapple, rice, cassava, maize etc. The presence of a pineapple processing company in the community also further emphasises the extent of its pineapple production. With farming being the leading economic activity, other activities within the study area include civil service as the community houses the local government administrative offices, trading, businesses, etc.

People and Settlement: The study area houses about 40 settlements such as Okoro, Okokpon, Iguogun etc., and its residents are mostly indigenous people of Edo**.** Being a nodal settlement, there are several non-indigenous people who are on business trips or farm agents who have come to purchase some of the produce from the farms.

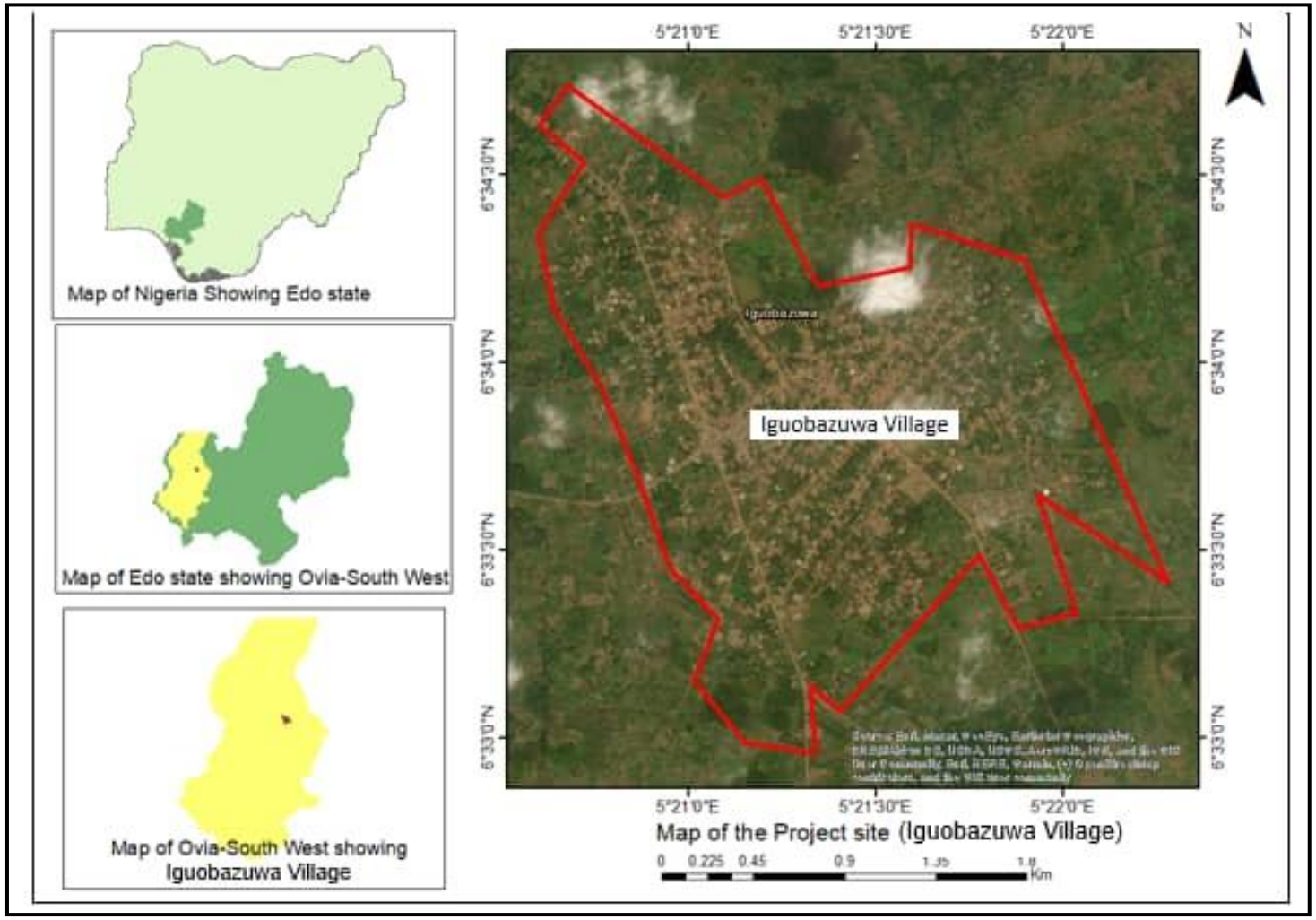

Figure 1: Map showing the project site

4.2. Data Collection

Before starting data collection, a semi-structured questionnaire was designed to obtain information from pineapple farmers and pineapple juice producers throughout the community.

To ensure the instrument's reliability, an internal pilot study was conducted with few of the farmers to detect possible design flaws, ambiguity, and other potential issues with the instrument. Feedback from the enumerators and respondents was used to adjust the questionnaire before it was used to collect the final data.

The questionnaire (Appendix 1) was designed in a Google format and 3 enumerators were mobilised from the community to farmers and producers to ensure the questions were well understood regardless of the level of farmer education and to ensure minimal time spent by busy farmers. The explanation and interpretation of the questionnaires was made in local languages by the enumerators to the respondents who cannot communicate in English. In some situations, incentives were given to encourage participants. A total of 108 responses were received within 2 months.

The questionnaire guides were designed in a way that included close-ended questions to capture data on the socioeconomic data of the farmers, approaches used in pineapple waste management, amount of waste acquired during harvest, and the entire life cycle of pineapple production.

The data collection instrument was made up of four sections; A, B, C and D. Section A contained questions about the socio-demographic profile of the pineapple farmers and processors. Section B covers the waste production information including the level of awareness, waste amount and sources of the waste. Section C focused on the challenges in managing the generated pineapple waste, while section D elicited their responses regarding access to information on Pineapple and Pineapple waste By-Products and the uses for the waste.

4.3. Sampling Techniques

The main study respondents in this thesis were pineapple farmers and other players along the supply chain within the community. These farmers were sampled using simple random, purpose-orientated and convenience sampling techniques to obtain effective data from the target population.

Criteria were established for the selection of the respondents, and these included:

i. Voluntary participation.
ii. Ownership of pineapple farmland or marketer of the fruit within the community.

4.4. Data Analysis

Primary data collected from the selected participants were cleaned up for errors and blank spaces. The responses obtained from the Google form were exported to Excel and further imported into SPSS (Statistical Package for Social Sciences) version 21. Each of the responses was assigned values (e.g. male = 1, female = 2, prefer not to say = 3) and analysed using a variety of approaches that include descriptive statistic; cross-tabulation, frequency and percentage tables and inferential statistics; correlation and binary logistic regression.

The research question one that seeks demographic characteristics of the respondent consists of questions that are qualitative and nominal categorical data that are assigned values. These values do not exhibit quantitative characteristics and as such, arithmetic operations cannot be performed on them. Therefore, the mean (and standard deviation) is inappropriate (Jamieson, 2004). Descriptive statistics such as the mode, frequency, and percentage were then used to summarise the data. Chart such as bar chart and pie charts were also used to present the data.

The research question two aims to quantify the sources and possible causes of pineapple waste between farmers and across the supply chain consists of close-end questions that allow the respondent to choose from available options on the amount of waste in tonnes, the part of the fruit that constitutes the most waste and their awareness of the source of the different stages of production producing the waste. As a result of the quantitative nature of the data, arithmetic operations such as mean and standard deviation provided meaningful information from the responses. Mode, frequency, and percentage were then used to summarize the data. Chart such as bar chart and pie charts were also used to present the data. To further explain which of the sources contribute the most to waste in the region, the responses were subjected to an Exploratory Factor Analysis (EFA) using a principal component analysis and varimax rotation.

The research question three offers to answer to the challenges faced by smallholder farmers on pineapple waste disposal were analysed using the component factor analysis. Variables with a loading value of 0.4 and above are considered a significant challenge compared to those less.

The research question on the training of farmers and the accessibility to the extension agent was also analysed using basic descriptive statistics as a result of the qualitative nature of the question. Frequency and percentage were used to analyse the data, while bar charts were used in the presentation of the results.

4.5. Limitation of the Study

As a result of the remoteness of the study site and the insecurity currently plaguing Nigeria, the number of enumerators engaged was only three and could only cover a relatively small sample size. This was also because some of the farmers choose not to entertain strangers for safety reasons.

5. Results and Discussion

This chapter presents the study findings based on the research objectives highlighted in Chapter 3, starting with the socio-economic information of the respondents, the source and use of pineapple waste. Based on the information contained in the results, discussions were also made in this chapter. 108 pineapple farmers and processor respondents were surveyed and analysed. The results for each objective are presented in this chapter.

5.1. Socio-Demographic Information of the Respondents

Analysing the socio-demographic information of survey respondents is a usual practise in research studies as this provide context and background into the other responses obtained from the respondents.

Table 1 below reports the descriptive characteristics of the 108 respondents of pineapple farmers and processors. The results showed that most of the respondents (68.5%) are males while 31.5 of the respondents are female. This emphasises the role of male gender in the pineapple sector within the study area and is also in agreement with the findings of Onyemekonwu et al. (2019), who also found a similar male-to-female ratio. Farming activities often require significant labour inputs, especially the traditional farming system that is being practised in the study area. In many cases, men are indeed more commonly associated with primary agricultural production tasks, such as land preparation, planting, and harvesting. This trend is often influenced by cultural norms and historical divisions of labour in the agricultural societies, while the female counterparts work downstream pf the sector in the processing and marketing zone.

The modal age group of the respondents was 55-65 years representing 23.0% of the total respondents. Age 18-25 and 35-45 also represent about 21% each of the respondents. The frequency range of these age groups is less (Table 1), which indicates the interest of the different age groups in fruit farming. Although earlier studies by Onyemekonwu et al., 2019 and Abiola et al., 2019 indicated that youths are the dominant groups within the state, Akhilomen et al. (2015) mentioned the adults as dominant group among the farmers within Edo. The findings however do not support the global trend suggested by Liu et al (2023), with ageing farmers and intensifying lack of successors.

Esobhawan et al., 2014 suggest that profitability is a key factor influencing young people's decisions to venture into pineapple farming within the region. The interest of both aged and youth farmers in pineapple production is suggestive of not just the trend of economic option and viability of the region, but the profitability of pineapple farming activity within the region.

The pineapple farmer and processors within the study area are quite educated, with the majority (28.7) of the respondents having at least a secondary school education. The cumulative percentage (52.9%) of the respondents having tertiary education training is indicative of the extensive training of the respondents. This is also stated by Onyemekonwu et al., (2019) within the region. The findings could translate to the openness of these farmers to training and development sessions and influence the adoption of innovation and decision-making should need be. Research by Baruwa (2013) also suggests that higher education levels among farmers can correlate with a greater willingness to adopt new technologies and best practices. Farmers with higher education levels often have better access to information through formal education channels, research institutions, and extension services and are more likely to stay updated on advancements in agricultural technology and management practice. This could also translate to their willingness to cut waste and increase profit.

A higher proportion (63%) of the respondents were married who probably engage in pineapple production to cater for the families and using their family member along the production and supply chain of the fruit. For example, Wilcox et al. (2015) found that 100% of pineapple marketers were female. Analysis of the years of pineapple farming experience revealed that majority of the respondents have a 6 to 10 years of experience in the sector. The farmers indicating 1 to 5 years' experience in the sector can indicate the adoption of the fruit production in the state as Esobhawan et al (2014) suggests that pineapple production is highly profitable in the region. This statement is also supported by the respondents' modal response (100%) of profit making as the reason for pineapple cultivation within the study area.

Table 1: Distribution of Respondents by Socio-economic Characteristics (n = 108)

Socio-Demography		Frequency	Percentage (%)
Gender	Male	74	68.5
	Female	34	31.5
Age	18-25 Year	22	20.4
	25-35 Years	10	9.3
	35-45 Years	22	20.4
	45-55 Years	10	9.3
	55-65 Years	25	23.1
	Above 65 Years	19	17.6
Marital Status	Single	33	30.6
	Married	68	63.0
	Divorced	5	4.6
	Widowed	2	1.9
Specialization	Pineapple Farmer	99	91.7
	Pineapple processor	9	8.3
Education Level	Non formal	8	7.4
	Primary	13	12.0
	Secondary/high school	31	28.7
	NCE/Diploma	29	26.9
	Graduate	25	23.1
	Postgraduate	2	1.9
Farming Experience	1-5 Year	34	31.5
	6-10 Years	42	38.9
	11-20 Years	25	23.1
	21 and Above	7	6.5
Purpose of Pineapple farming	Profit	108	100
	non-profit	0	0.0

Source: Author's fieldwork, 2023

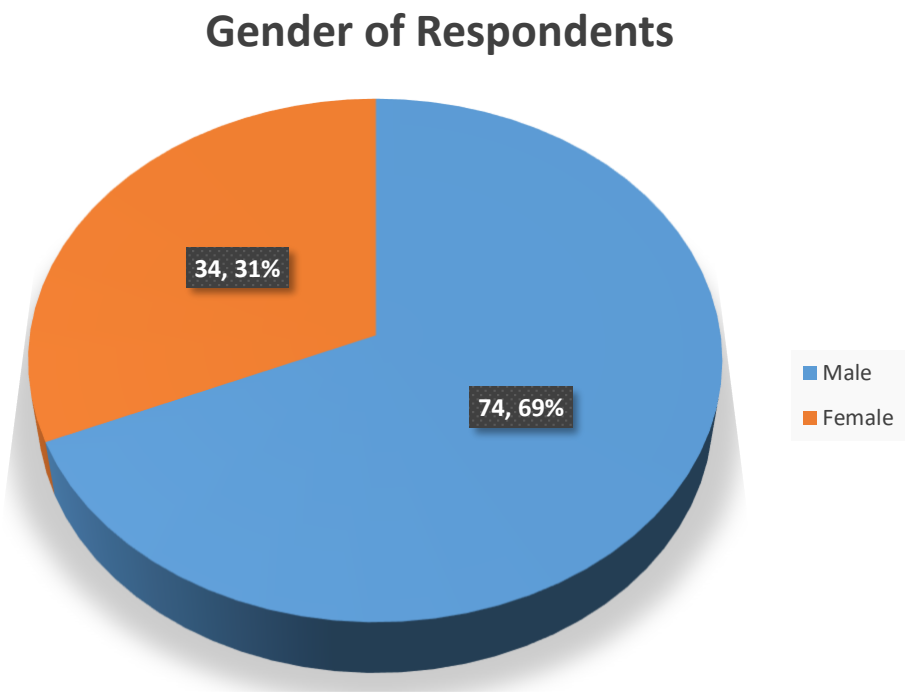

Figure 2: Gender distribution of the respondents.

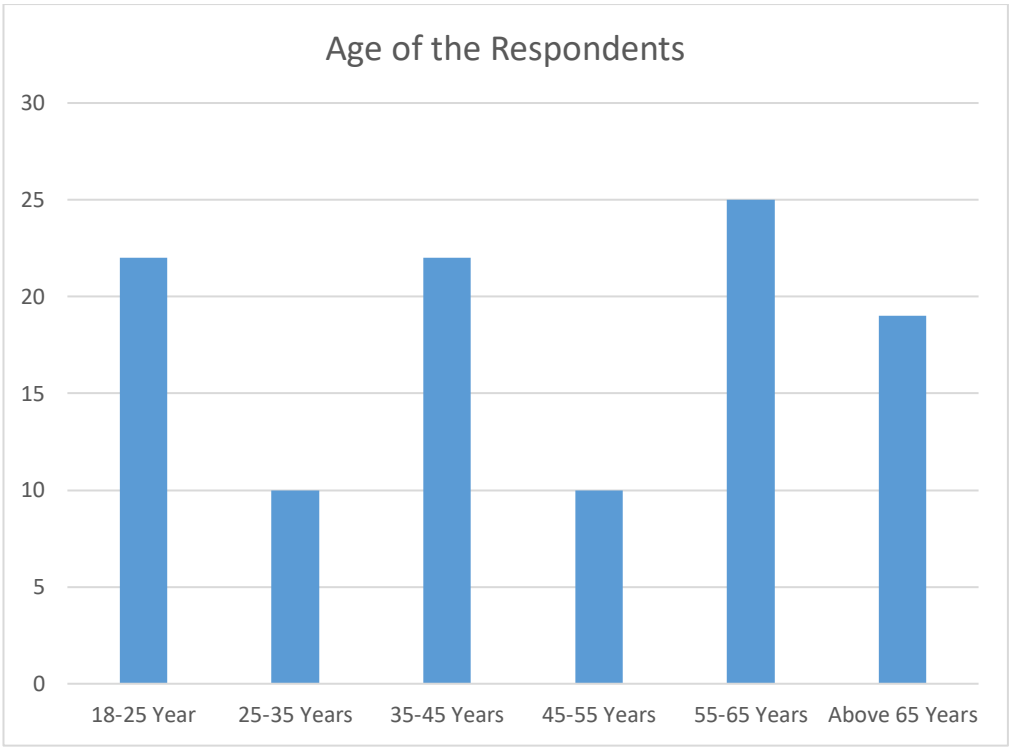

Figure 3: Age distribution of the respondents.

Based on the table and figures above, it can be summarised that most smallholder pineapple growers in Iguobazuwa, Edo state, are young farmers, quinquagenarian and sexagenarian, who are highly educated. Majority of these farmers have about a decade experience, while the young farmers having less than 5 years are also dominant in the region. These is further explained by the high profitability of the fruit in the Iguobazuwa region.

5.2. Source of Pineapple Wastes

The result of the sources and amount of waste incurred from pineapple production and along its supply chain is presented below.

Table 2 revealed that majority of the respondents indicated that harvesting has little to no waste no waste, while a substantial amount of the respondents (41%) also believed that the waste from harvest is little. This translates to the farmers' efficiency in the production of the fruit. This is also the view of Akhilomen et al (2015) who found the production efficiency of the fruit in the region to be about 70%. This suggests that harvesting practices are relatively efficient, with a minimal amount of waste generated and the farmers in this region therefore have control of the amount of waste generated under harvest.

The transportation process was also stated to generate the least waste by a large proportion of these farmers. These could be as a result of the farmers only having to transport the fruit to the agents as mentioned by Edekhe et al. (2020) that agents assemble during harvest to buy these fruits. This means that the risk of waste from transportation has been transferred to these agents who therefore must travel to the final points of sale with these fruits. Ege et al. 2011 documents the vast amount of waste as a result of transportation of the fruit to the major consumption source. The notion of the farmers recording least waste from transportation can be traced to the short distance of transportation from interior part of the farm to the assembly points of the agent which usually a short distance.

Most of the respondents opined that the most waste of their process comes from storage. A cumulative opinion of the fact that there is a lot of waste and most of the waste from fruit storage revealed that about 74% of the respondents believe the waste from

storage is substantially high. This was also supported by the findings of Praveena and Estherlydia, (2014) who also found that storage is one of the leading source of waste for smallholder pineapple farmers. Edekhe et al. (2019) also corroborated the findings listing inadequate storage facilities as one of the sources of pineapple waste within the state. Onwude et al (2023) also recorded poor storage facility as one of the bottlenecks of freshfood supply among Nigerian farmers.

The indifference in the responses to the amount of waste generated from pineapple processing by the respondent could be a result of the high proportion (92%) of them being farmers and not processors of the fruit. Edekhe et al. (2019) opined that the larger percentage of pineapple waste is from its processing and storage, with this waste often being managed by sales agents rather than individual farmers. As such, farmers may primarily focus on waste generated at the farm level, which could be reused as organic manure to support further production.

The cumulative number of respondents that identify a lot of waste and most of the marketing waste (65%) is also suggestive of the use of a household member at the end of the market of the fruit supply chain. As mentioned by Wilcox et al. (2015) that most of the marketers of the fruit are females, some of whose husbands are into farming of the fruit. The information transfer between these households and possible agents could be the source of the opinion on high waste from the fruit market. As a result of the substantial amount of pineapple production recorded in the region, the marketing of pineapple with inadequate storage facilities is suggestive of imminent substantial waste source. Inefficient storage facilities may result in spoilage or damage to the fruit during storage, leading to higher levels of waste in the market.

The majority of the respondents (73%) are also of the opinion that waste from animal and pest attacks are substantial. This is in tandem with the high opinion of the storage waste as a substantial source of fruit waste. The high perishability of the fruit and the inadequate storage facility could be the main reasons for this decision of the respondents. This finding also corroborates Edekhe et al. (2019), who also blames high fruit perishability and inadequate storage facilities, among others, for the poor marketing of pineapple in the state. The perishable nature of pineapples makes them particularly susceptible to spoilage, especially when storage conditions are suboptimal, which furthers makes the fruit susceptible to pest and disease attack.

Table 2: Distribution of waste source from pineapple production and supply chain

Waste Source		Frequency	Percent
Harvesting	No Waste	53	49.1
	Least Waste	44	40.7
	Much Waste	11	10.2
	Most Waste	0	0
	Total	108	100.0
Transportation	No Waste	15	13.9
	Least Waste	72	66.7
	Much Waste	20	18.5
	Most Waste	1	.9
	Total	108	100.0
Storage	No Waste	5	4.6
	Least Waste	23	21.3
	Much Waste	27	25.0
	Most Waste	53	49.1
	Total	108	100.0
Processing	No Waste	31	28.7
	Least Waste	33	30.6
	Much Waste	32	29.6
	Most Waste	12	11.1
	Total	108	100.0
Market	No Waste	7	6.5
	Least Waste	31	28.7
	Much Waste	51	47.2
	Most Waste	19	17.6
	Total	108	100.0
Animal, Pest & Diseases	No Waste	7	6.5
	Least Waste	22	20.4
	Much Waste	42	38.9
	Most Waste	37	34.3
	Total	108	100.0

Source: Author's field work, 2023

Analysis with an Exploratory Factor Analysis (EFA) was performed using a principal component analysis and varimax rotation, with the minimum factor loading criteria set to 0.50. The result also revealed that Storage, Market and Animal Pests and Disease are the large contributor to the waste source within the study area.

This indicates that these three factors play significant roles in generating waste in the pineapple production and supply chain within the farmer in the study area. Storage practices, including inadequate facilities and improper handling, contribute to waste during the post-harvest stage. Market-related factors, such as inefficiencies in distribution and marketing channels, also contribute to waste accumulation. Additionally, challenges related to animal pests and diseases impact fruit quality and quantity, leading to increased waste during cultivation and storage.

Table 3: The Exploratory Factor analysis of the sources of the wastes

Rotated Factor Matrix[a]	
Waste Source	Factor
Harvesting	-.210
Transportation	.280
Storage	.523
Processing	.153
Market	.611
Animal, Pest & Diseases	.844
Extraction Method: Principal Axis Factoring.	
Rotation Method: Varimax with Kaiser Normalization.	
a. Rotation converged in 2 iterations.	

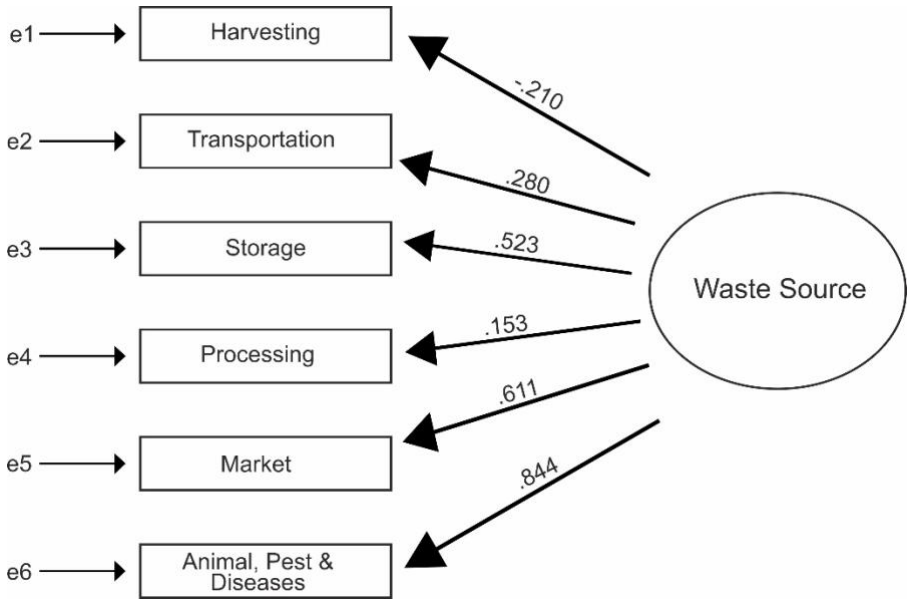

Figure 4: EFA distribution of waste sources

The investigation into the plant part with the most waste revealed that the fruit and the crown are the dominant source of waste in the study area (Table 3). This can be backed by the responses of animal, pest and disease and storage were the principal source of the waste. A destruction by animal, pest, and disease, could leave the whole fruit as a waste for this small farm holders. The high proportion of respondents who identify the crown as the main waste source suggests the consumption of fruit by households and the less use of the crown for the replanting of the fruit.

Furthermore, the study also revealed that smallholder farmers in the study area generate less than 1000kg of pineapple waste annually at every stage of harvest. This could be attributed to the profit-making justification of the farmers, which encourages technical efficiency in production as noted by Akhilomen et al (2015).

Table 4: Amount of Waste incurred by the respondents.

Waste Amount		Frequency	Percent
Pineapple waste in Year	Less than 1000 Kg	91	84.3
	1001 to 10000Kg	16	14.8
	10001Kg and above	1	9
	Total	108	100.0
Pineapple waste in harvest	Less than 1000 Kg	80	74.1

	1001 to 10000Kg	26	24.1
	10001Kg and above	2	1.9
	Total	108	100.0
Pineapple waste after harvest	Less than 1000 Kg	90	83.3
	1001 to 10000Kg	17	15.7
	10001Kg and above	1	.9
	Total	108	100.0

Source: Author's field work

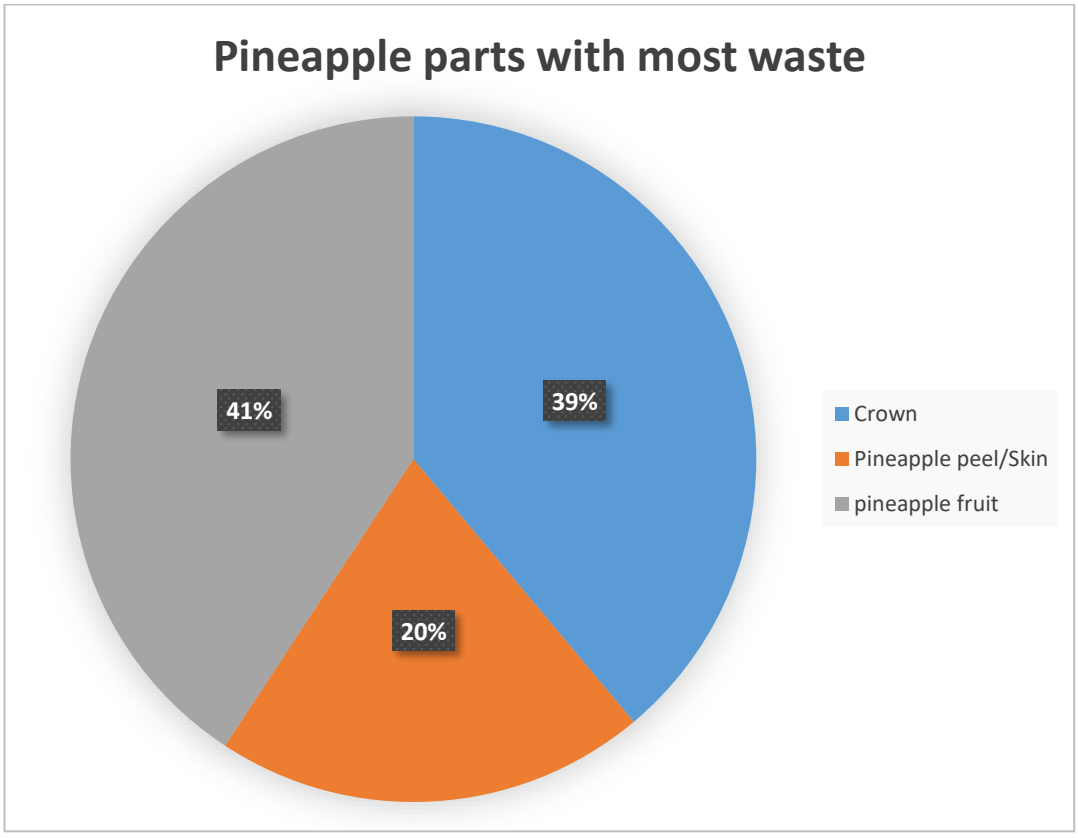

Figure 5: Wastes from Pineapple parts within the study area

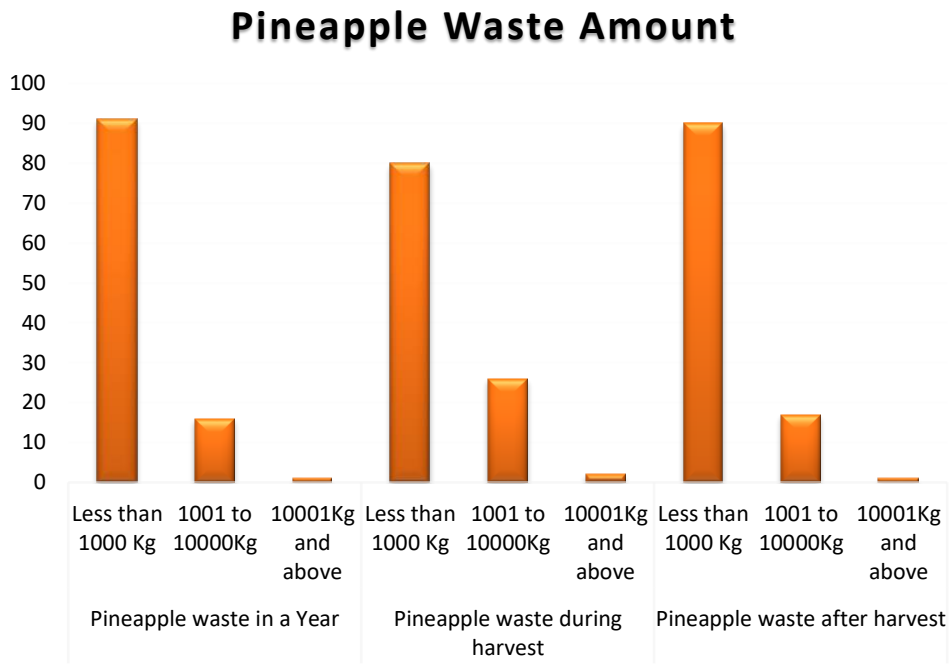

Figure 6: Amount of Pineapple waste generated in the study area

The summary of the sources of waste from pineapple fruit production and supply chain revealed that the most waste in the study area is from Animal, pest & disease; Market; and Storage in that order. The waste from harvest is rated minimal and less than 1000kg annually by most of the respondents. However, the principal part of these wastes are the pineapple fruits itself and the crown. This waste is often generated as a result of the action of pests and animals during storage, due to the lack of appropriate post-harvest storage technologies for farmers.

5.3. Constraints of Pineapple Waste Disposal and Current Practices of Pineapple Waste Management in the Study Area

The study also aimed to identify the challenges and constraints faced by pineapple smallholders in managing their pineapple waste. As presented in Table 5, the majority of the smallholder farmers (52.8%) identified labour shortage as the most significant constraint to waste management in the study area. Additionally, around 41% of the respondents reported that they do not have enough time to manage the pineapple waste. This finding is consistent with the study by Matius *et al.* (2022), who also identified lack

of time as the most perceived challenge to waste management among smallholder farmers. This is because the farmers' work hours are focused mainly on planting and harvesting, leaving little time for waste management activities. Ioannis and Persefoni (2008) emphasize the limited time for farmers due to competing demands on a farmer's workday restricts their ability to effectively manage waste. Amol et al (2023) also suggested that core activities like planting and harvesting take priority for farmers, leaving waste management as a secondary concern due to time constraints.

Furthermore, a significant proportion of respondents (around 40%) highlighted the attraction of pests and diseases and the high costs of managing the waste as challenges in waste management on their farms. Other challenges cited by pineapple farmers and processors included the bad smell associated with the waste (25%) and difficulty finding a buyer for the waste (33%). Hikal et al (2021) also opined that improperly managed pineapple waste attracts pests and diseases, posing a threat to the management of the waste. Generally, financial constraints are a common setback in waste management, which also might extend to smallholder farmers with limited resources to make proper waste management.

These limitations have led to unsustainable methods of managing pineapple waste, as evidenced by the prevalence of burning as a waste disposal method in the study area (Figure 7). The use of burning as a waste management strategy not only poses environmental hazards, but also contributes to air pollution and negatively impacts the health of nearby communities. This finding is in tandem with Baidhe et al. (2021) and Rabiu et al. (2018) which also underscored the prevalence of burning as a waste management strategy and its associated environmental and health impacts. However, the adoption of burning as the principal means of waste disposal by the smallholder farmers in the region can be attributed to the unavailability of effective waste management by the state and the remoteness of the area. In many rural areas, particularly those with limited access to waste management services and facilities, smallholder farmers may resort to burning as a convenient and inexpensive method for disposing of agricultural waste, including pineapple waste. Additionally, the remoteness of the region may also be responsible for the adoption of burning, as transportation costs and logistical constraints may hinder the adoption of alternative waste disposal methods.

Therefore, it is essential to address the constraints and challenges faced by smallholder farmers in managing their pineapple waste through education and training programs, collaboration with local authorities and waste management groups, and the adoption of sustainable waste management practices. This will promote more environmentally friendly and economically viable waste management practices, reduce the negative impact on human health, and contribute to sustainable agricultural practices.

Table 5: Waste Management Constraints Frequencies Distribution

Constraints		Responses		Percent of Cases
		N	Percent	
Challenges of Waste Management	Challenge: Lack of Time	44	17.6%	40.7%
	Challenge: High Cost	43	17.2%	39.8%
	Challenge: Pest & disease	43	17.2%	39.8%
	Challenge: Labour Shortage	57	22.8%	52.8%
	Challenge: Bad Smell	27	10.8%	25.0%
	Challenge: Finding Buyer	36	14.4%	33.3%
Total		250	100.0%	231.5%

a. Dichotomy group tabulated at value 1.

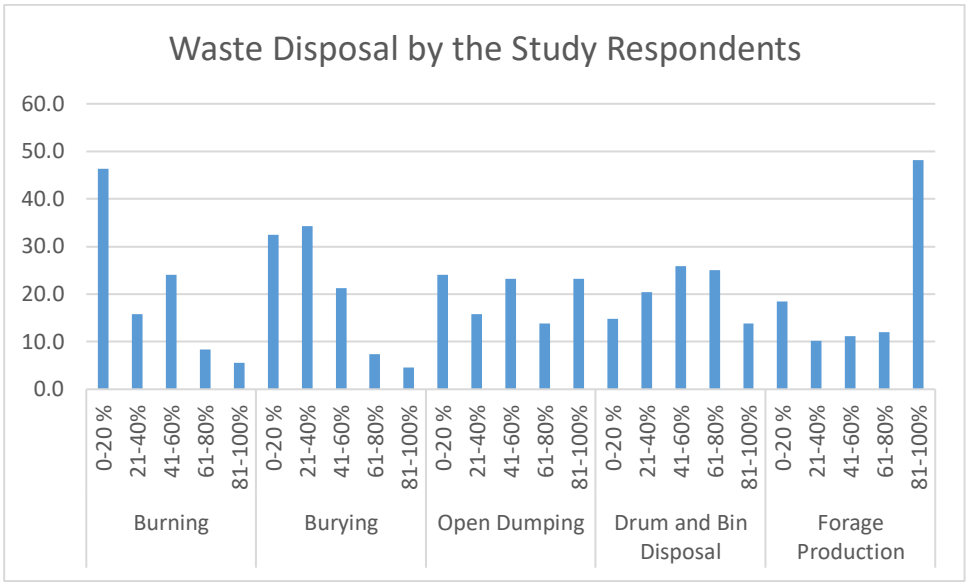

Figure 7: The waste disposal practise among study respondents

Based on the findings presented in Figure 7, it can be inferred that burning is a common practice among smallholder farmers for the disposal of pineapple waste. Specifically, 46% of the respondents reported burning less than 20% of their waste, while more than 48% converted the waste into forages for animal feed.

This finding is consistent with the results reported by Gerald and Charles (2021), who found similar percentages of respondents using burning as a means of waste disposal. The prevalence of this practice among smallholder farmers in rural areas may be due to the limited options available for waste management, particularly in areas where waste management services provided by local authorities are limited or non-existent. Waste management practices such as dumping and landfill, and burying, may be the only feasible options in these areas.

Furthermore, the study revealed that the majority of the respondents did not belong or patronise any waste management group or authority. This suggests that smallholder farmers make their own decisions about waste management without consulting or seeking the advice of any authority or group. The lack of involvement with waste management groups or authorities may be attributed to various factors, including the remoteness of the area, logistical challenges in accessing support, or a perceived lack of relevance or effectiveness of existing waste management initiatives. Additionally, the self-reliant nature of smallholder farmers, coupled with limited outreach and

communication efforts from waste management authorities, may further contribute to the disconnect between farmers and formal waste management structures.

Figure 8: Frequency distribution of Patronage of waste management group or local authorities

5.4. Awareness on the Uses of Pineapple Waste

Table 6 presents the results of a survey conducted to assess the level of awareness of smallholder farmers on various uses of pineapple waste, including biofuel production, biogas feed production, fertilizer production, paper production, and animal feed production. The findings revealed that a significant proportion of the respondents had a low level of awareness of these potential uses of pineapple waste. The findings underscore the need for increased education and information dissemination among smallholder farmers regarding alternative uses of pineapple waste. By enhancing awareness and understanding of the diverse opportunities for utilizing pineapple waste, stakeholders can unlock the potential for sustainable waste management practices and create additional avenues for income generation and resource utilization in pineapple farming communities.

Despite the relatively high level of education of the respondents, the survey results showed that most farmers (93%) were not aware of the potential use of pineapple waste for biofuel production. Similarly, a large proportion of the respondents (94%) were also unaware of the potential use of pineapple waste as a biogas digester feed. These findings suggest that smallholder farmers have limited exposure to information and technologies related to these waste utilization options. The advanced level of education of the farmers could not be directly linked to agriculture knowledge or prior knowledge on biofuel and biogas utilization as the respondents could have been trained from different backgrounds of science. These smallholder farmers often lack access to extension services, research updates, and information on innovative technologies. This can limit their knowledge of alternative waste management practices.

Interestingly, the survey also found that awareness of the potential use of pineapple waste for animal feed production was relatively higher (34%) compared to other uses. However, in general, the level of awareness among farmers surveyed about the potential uses of pineapple waste was low. This corroborates the mention by the respondents of the pineapple waste through forage food for animals in the previous subsection. The relatively higher awareness of pineapple waste utilization for animal feed production suggests that most of these farmers practise integrated farming where wastes from the crop are not perceived as such and are fed to livestock. However, the low overall awareness indicates a significant opportunity to further educate farmers about alternative uses of pineapple waste, such as biofuel production, fertilizer production, paper production, and biogas feed production.

The survey results highlight the need for greater awareness and education on the various potential uses of pineapple waste among smallholder farmers. This could help to promote the adoption of sustainable waste management practices and support the development of a circular economy in the pineapple industry.

Table 6: Awareness on the uses of pineapple waste

Pineapple Waste Use		Frequency	Percent
Biofuels	Aware	7	6.5
	Unaware	100	92.6

	Undecided	1	.9
	Total	108	100.0
Biogas	Aware	4	3.7
	Unaware	101	93.5
	Undecided	3	2.8
	Total	108	100.0
Fertilizers	Aware	11	10.2
	Unaware	96	88.9
	Undecided	1	.9
	Total	108	100.0
Paper Production	Aware	19	17.6
	Unaware	85	78.7
	Undecided	4	3.7
	Total	108	100.0
Animal feed	Aware	26	24.1
	Unaware	66	61.1
	Undecided	16	14.8
	Total	108	100.0

Source: Author's Field work, 2023

In order to identify the source of awareness among the respondents, the study conducted an inquiry into the respondents' relationship with their extension officers and their level of training on pineapple and agricultural waste management. The findings of the study revealed that a large majority of the respondents (87%) did not have any relationship with an extension officer. Furthermore, about 82% of the respondents reported that they had never received any training on pineapple waste management or any waste management.

The study also examined the frequency with which respondents received information on waste management from different sources of media. The results showed that the majority of the respondents had never had the opportunity to receive information on waste management from any of the media sources surveyed. This indicates a significant gap in communication and information dissemination regarding waste management practices among smallholder farmers. Lack of access to relevant information

from media sources may contribute to limited awareness and understanding of waste management strategies and their potential benefits.

This gap presents an opportunity for training and awareness programs to be implemented for smallholder farmers. Such programs could improve their knowledge and understanding of pineapple waste management and the potential uses of pineapple waste.

Overall, the study highlights the need for improved communication and collaboration between extension officers and smallholder farmers. This could facilitate the dissemination of information on pineapple waste management and promote the adoption of sustainable waste management practices in the pineapple industry.

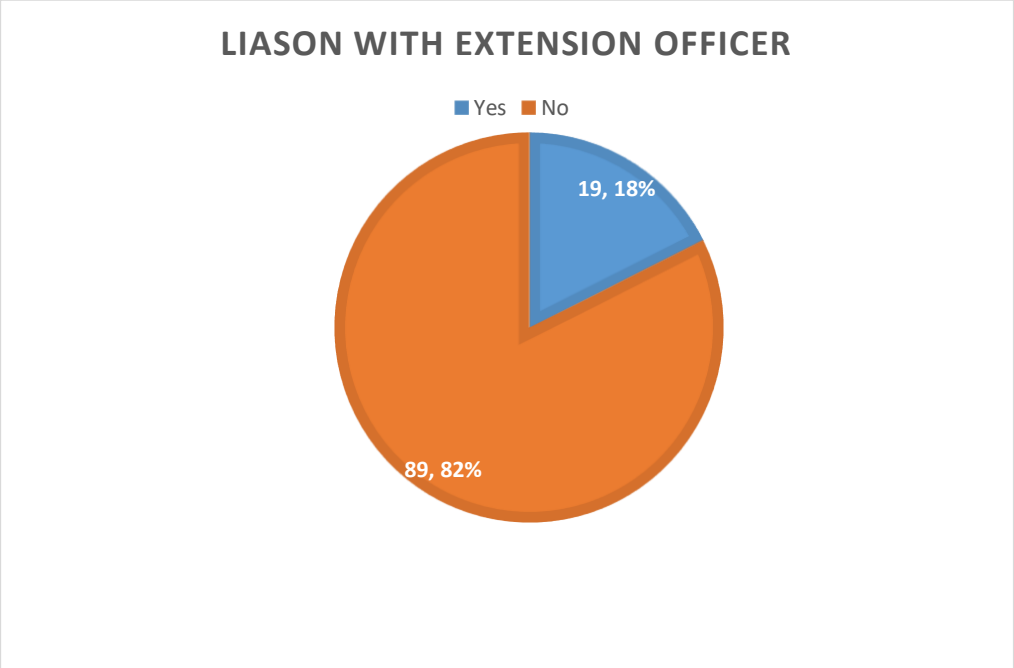

Figure 9: Distribution of respondents on relationship with an extension officer

6. Conclusions

This study was designed to investigate, review, and provide information on pineapple waste management, challenges faced in managing waste generated, source, and level of awareness or training among smallholder farmers in Igbozuwa village in Edo state in Nigeria. The study gathered and analysed data from 108 smallholder farmers within the study area.

The majority of the pineapple farmers and processors in the study area were male, with the modal age group being 55-65 years. The respondents were also found to be quite educated, with many having at least a secondary school education and a significant proportion having tertiary education. A higher proportion of the respondents were married and the majority had 6 to 10 years of experience in the pineapple farming sector. The respondents cited profit-making as the primary reason for their engagement in pineapple cultivation.

The results of the study on the sources and amount of waste generated from pineapple production and along its supply chain revealed that the pineapple farming harvest stage has little or no waste attached to it, indicating the efficiency of farmers in fruit production. Transportation was also perceived to generate the least waste, possibly because the risk of waste from transportation has been transferred to agents who buy the produce from the farmers within a few miles from the farmland. However, most of the respondents identified storage as the main source of waste, supported by previous studies. Indifference in responses for waste from processing could be due to most respondents being farmers and not processors. Waste from marketing was perceived to be substantial, possibly due to household members and agents involved in the supply chain. Finally, respondents identified animal and pest attacks as a substantial source of waste, which is attributed to the high perishability of the fruit and inadequate storage facilities, a stand that is consistent with previous studies.

The study has also revealed that the fruit and crown are the main sources of waste in the study area, supported by the responses of the respondents on animal, pest, disease, and storage as the principal sources. The high proportion of respondents identifying the crown as a waste source suggests that households consume the fruit more than utilizing the crown for replanting. Additionally, the study found that smallholder farmers generate

less than 1000kg of pineapple waste annually at every stage of harvest, which could be attributed to the farmers' profit-making justification and technical efficiency in production

The study also identified the challenges and constraints faced by pineapple smallholders in managing their waste in the study area. The labour shortage and lack of time were identified as the most significant challenges faced by small farmers. The attraction of pests and diseases, the high costs of managing the waste, the bad smell associated with the waste, and the difficulty in finding a buyer for the waste were also highlighted as challenges in waste management on their farms.

The study's findings suggest that burning is a common practice for smallholder farmers in the study area to dispose of pineapple waste. Nearly half of the respondents (48%) also use the waste as animal feed, while 46% reported burning less than 20% of their waste. The prevalence of this practice in rural areas may be due to the limited waste management options available to farmers, especially in areas where local authorities do not provide waste management services. In such areas, dumping, landfilling, and burying may be the only feasible waste management options.

Additionally, the study showed that most smallholder farmers did not belong to or seek advice from any waste management group or authority. This implies that farmers make independent decisions about waste management without consulting any authoritative body. Most of the respondents had a low level of awareness of the waste utilization options, despite their relatively high level of education. Specifically, 93% of the surveyed farmers were not aware of the potential use of pineapple waste for biofuel production, and 94% were not aware of its potential use as a biogas digester feed. These results suggest that smallholder farmers have limited exposure to information and technologies related to these waste utilization options. Although awareness of the potential use of pineapple waste as animal feed production was relatively higher at 34%, the overall level of awareness among farmers surveyed about the potential uses of pineapple waste was low. These findings underscore the need for increased awareness and education on the various potential uses of pineapple waste among smallholder farmers. This can support the adoption of sustainable waste management practices and contribute to the development of a circular economy in the pineapple industry.

6.1. Recommendations

Based on the findings of this study, the following recommendations can be made:

- There is a need for increased education and awareness programs for smallholder farmers on sustainable pineapple waste management practices. This can be achieved through collaboration with local authorities, waste management groups, and extension officers.
- Innovative and cost-effective waste management technologies should be explored, such as biogas digesters, composting, and vermicomposting, to reduce the environmental and health hazards associated with the burning of waste.
- The development of a circular economy in the pineapple industry should be encouraged, where waste products can be repurposed or recycled for different uses, such as animal feed, fertiliser production, paper production, and biofuel production.
- There is a need for improved communication and collaboration between extension officers and smallholder farmers to facilitate the dissemination of information on pineapple waste management.
- Policies and regulations should be implemented to enforce sustainable waste management practices in the pineapple industry. This can be done through the provision of incentives and penalties for smallholder farmers and pineapple processors to promote the adoption of sustainable waste management practices.

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Appendices

List of the Appendices:

Appendix 1: Questionnaire

Assessment of pineapple waste management system amongst smallholder pineapple farmers and processors in Iguobazuwa, Ovia south-west, Edo state, Nigeria.

Dear Sir/Madam,

We would like to ask you to fill in the following questionnaire. We are students at the Czech University of Life Science Prague, Czech Republic, and we are conducting a study to learn more about the "Climate Change Awareness of Youth. All the data are collected anonymously. We would appreciate it very much if you would fill in and help us conduct this research. The filling would only take a few minutes.

QUESTIONNAIRE

Dear Sir/Madam,

We would like to ask you to fill in the following questionnaire. This questionnaire is designed to assess the pineapple waste management system amongst smallholder pineapple farmers and processors in Iguobazuwa, Ovia south-west, Edo state, Nigeria.

All the data are collected anonymously. We would appreciate it very much if you would fill in and help us conduct this research. The filling would only take a few minutes.

SECTION A: Demographic questions

please mark (x) in the box of your answer.

1. Category: pineapple farmer ( ) pineapple Processor ( )
2. Age: 15-20 ( ) 21 - 40 ( ) 41-60 ( ). 61 and above ( )
3. Sex: male ( ) Female ( )
4. Marital Status: Single ( ) Married ( ) Divorce ( ) Widowed ( )
5. Farming Experience: 1-5 yrs.( ) 6- 10yrs ( ) 11-20 yrs. ( ) 21 - above (.)
6. Educational attainment: No formal ( ) Adult Education ( ) Primary Education ( ) Secondary education ( ) Tertiary education ( )
7. Farm Size: less than 1 hectare ( ) 2 - 4 hectares ( ) 5 hectares and above ( )

8. Production purpose: Profit ( ) Nonprofit ( ) Others ( )

SECTION B:

Pineapple waste production information

Purpose: to determine farmers' opinion on what stage of pineapple production large post-harvesting losses occur the most. please mark (x) in the most appropriate box

What stages of post-harvesting do you incur the most waste?

STAGES	No waste	Least waste	Much Waste	Most waste
Harvesting				
Transportation				
Storage				
Processing				
Market				

14. What amount of Pineapple Waste do you incur every season? Less than 1,000 tonnes { } 1,001 to 10,000 tonnes ( ) 10,001 tonnes and above ( )

15. What part of the pineapple does most of the waste come from?

Leaves ( ) Crown ( ) Pineapple peel/Skin ( ) Pineapple fruit ( )

SECTION C: Challenges in managing the pineapple waste and Pineapple Waste Disposal Method

16. What is the main challenge you have in disposing of pineapple waste?

17. Lack of time ( ) High cost ( )Finding buyer ( ) Attract pest and disease ( ) Labor shortage ( ) Bad smell ( )

What method of disposal do you utilize in the discarding of pineapple waste?

Method of Disposal	Never used	Least Used	Moderately used	Frequently used	Approximate percentage.
Incineration					

Burying					
Dumping in landfill					
Drums and Bins					

Access to information on Pineapple and Pineapple waste By-Products

Information Source	Daily	Weekly	monthly
Radio			
Television			
Newspaper			
Cooperatives and Extension Agents			

SECTION D: to ascertain farmers' awareness of products that can be gotten from pineapple waste utilization.

STAGES	AWARE	UNAWARE	UNDECIDED
Biofuel			
Animals feed			
Fertilizers			
Paper production			

SECTION E: to determine if farmers receive training support from agricultural extension officers or professionals in the field. Please check all that applies in this section

31. Do you engage in training on how to minimize pineapple post-harvest losses ? Yes ( ) No ( )

32. How often is the training?

Monthly ( ) Annually ( ) Bi-Annually ( ) None ( )

33. How often does an extension officer visits your farm or processing center?

Weekly ( ) Monthly ( ) Quarterly ( ) Yearly ( ) Others ( ) None ( )

34. What major function(s) does the extension officer(s) provides ?

Access to finance ( ). Input and fertilizer supply ( ) Transportation ( ) Storage ( ) Research ( ) Training ( ) Marketing ( ) Packaging ( )

35. How accessible is the agricultural extension officer?

Very Accessible ( ) Fairly Accessible ( ) Poorly Accessible ( ) Undecided ( )