THESIS

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TREATMENT OF CONTAMINATED PACKAGING AND ENERGY RECOVERY FROM CROP WASTE

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List of Abbreviations

CAP- Common Agricultural policy

EC – European commission

ECN -Energy Commission of Nigeria

EEA -European Environmental Agency

EWC- European waste catalogue

EU- European Union

FAO – Food and Agricultural organization

FMP- Federal Ministry of Power

IPM- Integrated Pest Management

MSW – Municipal solid waste

NAFDAC - National Agency for Food and Drug Administration and Control

NBPI- Nigerian Biofuel Policy and Incentives

NREEEP -National Renewable Energy and Energy Efficiency Policy

REMP -Renewable Energy Master Plan

SDG- Sustainable development goal

UN- United nations

UNEP - United Nations Environment Programme

WHO- World Health Organization

1. INTRODUCTION

1.1 Background

The increasing global demand for food has led to the growth of agricultural activities and subsequent generation of waste such as crop wastes, and waste from chemical packaging (containers). Nigeria generates about 18 million tonnes of agricultural crop waste on a yearly basis (Usman et al., 2013). In Europe, Agricultural biomass produced is 956 million tonnes of which crop waste accounts for 46% of the biomass (European commission, 2020). In order to produce agricultural crop products, an estimated 2.7 million metric tons of pesticides is used globally in 2020 (FAO, 2022a), consequently, more contaminated packaging waste will be produced.

Pesticide plastic waste is considered packaging waste and is classified as a hazardous waste under the list of waste codes 15 01 10* named 'Packaging containing residues or contaminated by hazardous substances. (European waste catalogue, EWC 2002). Plastic makes up 15.5 million tonnes of the 79.3 million tonnes of packaging garbage produced in 2020 (Eurostat 2022a). The disposal and management of crop waste coupled with chemical packaging waste e. g pesticide plastic waste has become a significant environmental concern in many nations as they have serious consequences such as soil/water contamination, greenhouse gas emissions.

According to FAO (2018), over 50% of pesticide packaging waste ends up in Landfills or is burned leading to environmental pollution and health risks. The 96/62/EC packaging waste directive of the European Union, aimed to reduce packaging waste in other to preserve the environment and integrate national policies pertaining to the recycling and recovery.

Utilizing biomass can increase the proportion of alternative/renewable energy sources used in energy production and lower the need to use fossil fuels (Fernandes and Costa, 2010). Growing energy demand, declining fossil fuel supplies, sustainable crop waste management, and emission from burning traditional fuels have prompted focus to environmentally friendly biomass energy production (Rathore et al., 2019).

To address the issue of chemical packaging waste and crop waste, approaches such as; recycling, reprocessing or using as raw material for other product (Chen and Patel, 2012) have been developed. Crop waste is a valuable resource that can be used to generate renewable energy. It can be converted into biofuels, biogas or used to generate electricity through thermal or biochemical processes (Zhang et al., 2019). Despite the policies and regulations, as well as new approaches for the management of these wastes, they are often mismanaged especially in developing countries such as Nigeria (Adejumo and Adebiyi, 2020). This study's main contribution to gain insights to the complexities of social phenomenal in terms to the treatment of contaminated packaging and energy recovery from crop waste

To this end, the objectives of this study is

1. To investigate the management practices of pesticide plastic waste and crop waste in Hungary in terms of collection, treatment as well as energy recovery
2. To assess the level of awareness and opinion of people on the management of waste generated from crops and chemical packaging in Nigeria through a questionnaire survey. Identifying people's level of awareness, and perspective about treatment of these wastes can help in determining the extent of people's knowledge, and the possible barriers and challenges to implementing effective treatment/ management of these wastes.

1.2 Hypothesis

1. The level of education and age will have a significant impact of the level of awareness of the environmental impact of pesticide packaging waste.
2. Age will significantly influence the opinion of people of the reusability and recyclability of crop waste

2. LITERATURE REVIEW

2.1 Evolution of waste generation

The United Nations department of economic and social affairs predicted in 2019 that global population will increase to approximately 8.5 billion in 2030 and 9.7 billion in 2050 respectively (UN population, 2019). Everyday activities require the use of a variety of materials/ resources, this implies that as the population increases, waste generation will also tend to increase which in turn can lead to pollution of the environment. Directive 2008/98/EC of the European parliament, define waste as any substance or object that holder discards, intends to dispose or required to be disposed. According to World Bank estimate, 2.01 billion waste is generated globally in 2018 and it was reported that about 33% of this waste are not properly managed, therefore, the waste trend is predicted to increase to 3.40billion in 2050 (Kaza et al., 2018). Ferreira-Leitao et al. (2010) in their research stated that, wastes do not only clog the soil but can also contaminate surface and subsurface water. Furthermore, the waste generated in European Union, was estimated to be 2,153 million tonnes in 2020, with the agricultural sector accounting for 21, 478 tonnes of the total waste generated (Eurostat 2022b). According to estimates, 3330.9 million tons of crop waste was produced in 2003 and 5010 million tons in 2013 worldwide (a 33% rise over ten years), with Europe and Africa contributing 16% and 6% of the total respectively (Cherubin et al., 2018). Plastic makes up 15.5 million tonnes of the 79.3 million tonnes of packaging waste produced in 2020 (Eurostat, 2022a). In addition, there is 18.2% increase in the amount of packaging waste generated between 2009 and 2020(Eurostat, 2022b) this could be as a result of the advancement of technology and the proliferation of packaged goods. The increasing use of plastics and other non-biodegradable materials has also led to the accumulation of waste in the environment, which have negative impacts on ecosystem and human health (Jambeck et al., 2015).

2.2 European (EU) strategies on waste Reduction

The European Union has implemented several strategies and policies for waste reduction. Some of the main ones include:

1. The waste framework directive 2008/98/EC served as the foundation for managing wastes in the European Union and is a key component of the EU's waste reduction plan. This directive developed the steps (waste hierarchy) with the goal of lowering waste generation through prevention, minimization, reuse, recycling, and recovery, as well as lowering waste

disposal to landfills (waste framework Directive, 2008) which is in line with the circular economy model of managing waste.

2. Part of the EU strategy for plastic waste reduction includes; the plan to modify the way products are designed, manufactured, consumed, and recycled. The primary goal of the EU's initiatives is to have all plastic packaging be recyclable and reusable by 2030, minimize the use of single-use plastics, and curb the use of micro plastics (European commission 2018a).
3. In the new circular economy action plan (COM/2020/98) to reduce packaging waste, the commission sets a plan to reinforce the criteria for the type of packaging to be permitted in the European Union with emphasis on lessening excessive and complex packaging of products and take into account limits on the use of some packaging materials for certain uses especially where it is possible to reuse alternative products, which in turn, can ensure that appropriate measures is taken in reusability and recyclability of packaging materials(COM/2020/98).

2.3 Comparison of pesticide use in Europe and Nigeria

According to Eurostat data, sales of pesticides in the EU varied and the total volume sold yearly experienced a fluctuation of 6% around the level of 350 000 tonnes, and it was 346 000 tonnes in the year 2020(Eurostat 2022c). The food and agricultural organization of the united nations(FAO) estimated that the European Union imports over 1.2 million tonnes of pesticides annually, however, owing to the "Common Agricultural Policy" that regulates pesticide usage, it consumption has only increased by 3% over the past few years (FAO, 2022a).

Pesticides are known to contain hazardous chemicals that can harm both human health and the environment. The European Union established a strategy called the Directive 2009/128/EC aimed at achieving a sustainable development that would lessen the impact of pesticide use on human health and the environment, as well as to promote integrated pest management (IPM) and alternative approaches such as non-chemical alternatives to pesticides (European commission, 2009). This approach may consequently result in a reduction in the creation of pesticide packaging waste because less pesticide use will mean less contaminated packaging waste will be generated.

In Nigeria, on the other hand, there is dearth of data on the amount of pesticide use in Nigeria, however, an estimate provided by a study, stated that 120 000 to 130,000 metric tonnes of pesticide is used on a yearly basis (Asogwa and Dongo, 2009). Pesticide sales and use in Nigeria is indiscriminate, as majority of people still uses chemicals that have being banned in the European Union (Oluwole and Robert 2011; Tijani 2017; Olulakin et al., 2015; Adeniyi et al., 2016). Owing to the inadequate use of pesticides and it effect on the environment as well as the people, the federal republic of Nigeria established pesticide registration regulation. This regulation requires that pesticides be registered with the National Agency for Food and Drug Administration and Control (NAFDAC) before manufacturing, formulating, importing, exporting, advertising or selling (Federal republic of Nigeria Official Gazette, 2021) of these chemicals. Hussain et al., (2022) also suggested that IPM strategies can help to minimize the indiscriminate use of pesticides in the nation.

2.4 Agricultural waste and Its Utilization in Europe

Agriculture is said to be one of the most important sources of input for the bio-economy (Bracco et al., 2018). It was estimated that 956million tonnes of agricultural biomass is produced on a yearly basis, which is made up of 514 Million tonnes of primary products such as grains, root, tuber and so on and 442 Million tonnes of secondary products (residues from crops) such as stems, leaves, stalks, husks etc. (European commission, 2020). Agri-food sector contributes to one third of the greenhouse gas emission in the world (FAO, 2022b) a 9% increase in emission since the year 2000. Crop waste can be utilized as animal bedding and mushroom production (Scarlat et al., 2010), for bio-based building material (Duque-Acevedo et al., 2022; Ricciarchi et al.,2021; Diaz et al.,2022), and some crop waste such as straw and hay can be utilized as animal feed. In Europe, straw is a common feedstuff for ruminants and non-ruminant animals (De Lange et al., 2019; Lammers et al., 2017). It is rich in fiber and provides energy for the animals (De Lange et al., 2019). Wheat straw, corn Stover and sugar beet pulp have also been used to produce bio-based chemicals and bioplastics (Toscano et al., 2021). Residues from crops and animals can be used for biogas and biofuel production. According to a report by the European Environmental Agency (EEA), in 2018, about 5.6% of the EU’s total energy consumption was derived from biomass including agricultural waste (EEA, 2021). Utilizing crop wastes in a sustainable way for clean energy can help to lessen reliance on fossil fuels, as well as alleviate the effects of climate change, maximize farmer income, minimize air quality-related health risks, and enhance soil quality and biodiversity (FAO, 2021). Despite the fact that agricultural crop waste used for bioenergy has the advantage of helping to reduce greenhouse gas emissions and could increase energy availability, its removal could result in a decrease in soil organic matter, can lead to degradation of soil structure, and increase the risk of erosion (Cherubin et al., 2018). However, for sustainable removal of crop waste a reasonable amount between 15 to 60% should be collected (Scarlat et al., 2010). The use of Biomass such as crop waste through recycling, for energy generation in the EU corresponds with the renewable energy directive 2018/2001 that involves promoting the use of renewable energy sources including biomass. According to the Directive, renewable energy must account for 32% of total energy consumption by 2030(European commission, 2018b). Recycling, and reusing of wastes from agricultural sector is important for a cleaner and more sustainable future (Barros et al., 2020).

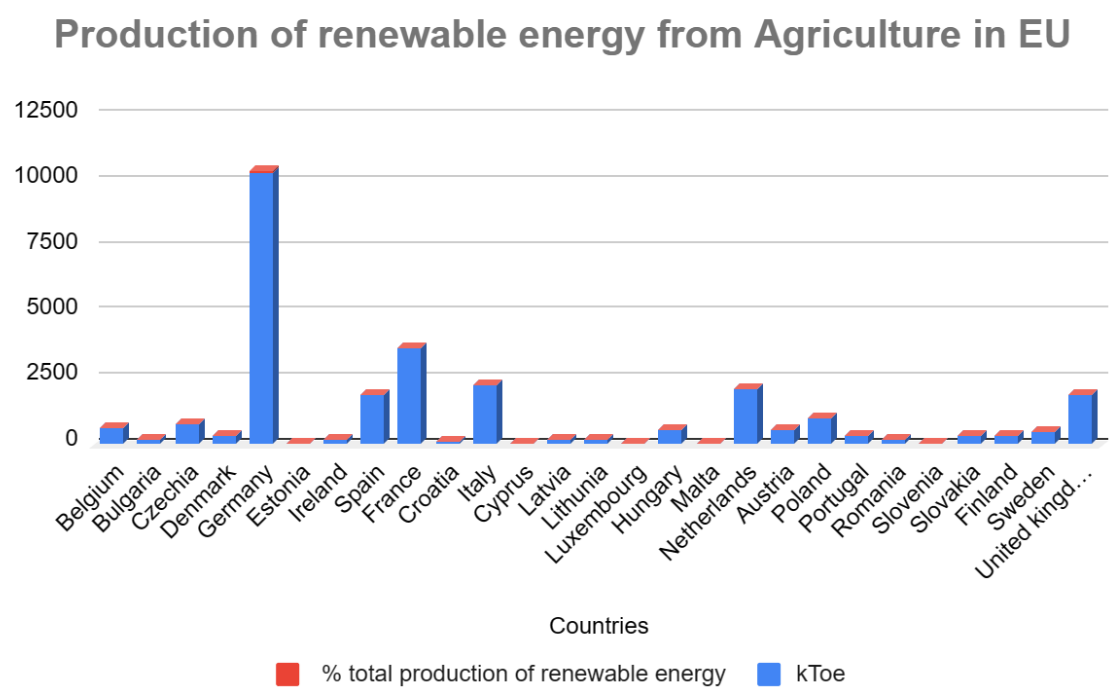

Figure 1. Production of renewable energy from agriculture in Europe (Data extracted from Eurostat nrg-bal-c online data 2020: CAP context indicators)

2.5 Waste generation in Nigeria

Nigeria's population is estimated to be 218,541,212 individuals (World Bank population statistics, 2023). Nigeria is located in Western Africa on the Gulf of Guinea and is comprised of 36 states. The country classified as the 32nd largest nation in terms of land area of about 924,000 km^2. Wastes of all kinds, comprising agriculture, municipal solid waste (MSW), and sewage, are poorly managed in Nigeria, which is one of the country's most pressing environmental challenges. According to Okafor et al. (2022), Nigeria produced roughly 20.5 million tons of waste in 2020, with 50% of that waste being categorized as organic waste. As the population increases, massive volumes of wastes are produced every day and are disposed of in unhygienic way, such as burning, putting waste in an unhealthy landfill, littering streets and drains, hence, leading to the country's environmental issues. Nigeria's waste management system is inadequate, due to lack of technical know-how, a well-established legislative framework, as proper finance, substandard technology, including landfills, incinerators, and garbage vehicles (Nnaji, 2015; Ogwueleka, 2009). In Nigeria, municipal solid waste is categorized into organic and inorganic. The Organic garbage consisting of food wastes, wood or leaves, paper, plastics, textile, rubber, leather, and other undefined miscellaneous organic materials. Inorganic waste comprises glass, metal, bones, and ashes (Igoni et al. 2007; Kofoworola, 2007). Tariwari et al. (2019) reported that food waste constitutes about 39 percent of waste generated, paper (40.82 %), plastic (6 percent), wood (3%), electronics (7%), leather/nylon (13%), glass/ceramic (4%), and unclassified waste (5%) of generated waste from there study. Waste is the nation's third-largest greenhouse gas emitter (Okafor et al., 2022). As there is a dearth of data in Nigeria and even on the United Nations website, getting an estimate of the amount of waste produced in Nigeria is challenging. However, estimates of the amount of garbage produced across the nation have been provided by some studies. Table 1 shows the estimated population in various Nigerian cities, and the amount of waste generated.

Table 1.Estimate of waste generated in Nigeria

State	Population	MSW generation Kg/capital/day	Tonnes per year	Source
Uyo(Akwa ibom)	800, 000	0.54	153,300	Okey et al., 2013
Anambra	509,500	0.53	84,137	Ogwueleka, 2009
Benue(Makurdi)	249000	0.48	24,242	Ogwueleka, 2009
Enugu	100,700	0.44	12,000	Ogwueleka, 2009
Lagos	8, 029,200	0.63	255,556	Ogwueleka, 2009
Oyo	3,565,108	0.72	936,910	Ike et al., 2018
Ilorin(Kwara state)	1,154,883	1.30	477,954	Ibikunle, 2021
Kano	3,248,700	0.56	156,676	Ogwueleka, 2009
Kaduna	1,458,900	0.51	135,391	Ogwueleka, 2009
Delta	116,681	1.04	63,1013	Owamah et al., 2017
FCT(Abuja)	159,900	0.66	14,785	Ogwueleka,2009
Jos	816,824	0.73	217,642	Ike et al., 2018
Benin-city	1, 125,058	0.78	320,304	Ike et al., 2018
Kano	1,458,900	0.56	156,676	Ogwueleka, 2009
Rivers	1,363,596	0.85	423,055	Ike et al., 2018
Sokoto	563,861	0.68	139,950	Ike et al., 2018
Kebbi	128,403	0.65	30463	Ike et al., 2018
Niger(Minna)	346,524	0.68	86007	Ike et al., 2018

2.6 United Nation strategy for Waste reduction

Waste reduction is an important issue for the United Nations, as it is for many organizations in the world. The UN has implemented several strategies for waste reduction to minimize its impact and promote sustainable practices. These strategies includes;

- Reduce, Reuse and Recycle: The UN promotes the 3Rs as a key strategy for waste reduction. This approach encourages individuals and organization to reduce waste by minimizing consumption and production (SDG 12), reusing items as much as possible and recycling when necessary(UNEP, 2015). The UN also encourages the use of eco-friendly products and materials such as recycled paper and biodegradable products (UN, 2018)
- Waste to Energy: The UN also implemented waste to energy strategy to reduce waste which promote sustainable energy production as it is in the sustainable development goal(SDG 7)

2.7 Trend of pesticide use in Nigeria

Nigeria's growing population requires higher agricultural productivity, and to boost crop yield, pesticides are used control insects, weeds, etc. Erhunmwunse et al. (2012) reported that several harmful pesticides are still in use since they are cheaper than new developed safer ones. According to estimates, pesticide use in Nigeria is between 125,000 and 130,000 metric tons annually (Asogwa and Dongo, 2019).

Some of the pesticides used on crops in Nigeria includes; oriyzo-plus, Dithane M-45, Round-up, Saro set, Dexate, attacke, No pest, Betate (Rahman and Chima, 2018), Gammalin 20, aldrex 20, perenox, Cocaobre Sandoz, Copper sulphate, Basuding, Thionex and Unden (Tijani, 2017), Apron plus, atrazine, polythrine, sevin, Thiodan, Fusilade, Primextra (Hussain et al., 2021; Muhammed et al., 2020), lindane, diazinon, endosulfan, and propoxur (Sosan and Akingbohungbe, 2010). Most of the chemicals/pesticide used in Nigeria have been banned in advanced economies and classified as dangerous by the world health organization (WHO) (Oluwole and Robert, 2011; Tijani 2017; Olulakin et al., 2015; Adeniyi et al., 2016).

Exposure to pesticides cause health risks such as fever, skin issues, nausea, vomiting, eye irritation, memory loss, exhaustion and insomnia, difficulty in breathing (Sosan and Akingbohungbe, 2010; Oluwole and Robert, 2011; Tijani, 2017; Hussian et al., 2021). Inadequate pesticide education/training in Nigeria leads to widespread pesticide misuse (Asogwa and Dongo, 2009; Oluwole and Robert, 2017). For instance, Asogwa and Dongo (2009) stated that pouring pesticides into rivers to kill fish sold for human consumption, spraying Gamalin 20 on drying cocoa beans to prevent molds and maggots, and mixing distinctive pesticides to minimize the workload of spraying each differently, incorrect use of formulations and dosages, incorrect scheduling of applications, and reckless dumping of expired pesticides and pesticide containers into the environment as ordinary trash owing to a lack of appropriate disposal facilities are all factors that contribute to this problem. Studies suggested the need for proper education/ training on the use pesticides to minimize environmental foot print of these harmful chemicals (Hussain et al., 2021, Muhammed et al., 2020)

The 1988 Hazardous Waste Act (Decree 42 of 1988) was established by Nigerian government, in regard to pesticides' detrimental effects on the environment and human health. The illegal dumping of toxic waste in the port of Koko, a town in southern Nigeria, sparked this legislation. The act defines harmful waste to mean any poisonous or toxic substance that is capable of subjecting anybody to health risk. Despite the legal measures put in place by the Nigerian government to protect the country's environment from the harmful impacts of pesticides, there hasn't been any effective monitoring or enforcement to reduce these risks (Tijani, 2017). Furthermore, poor level of information, understanding, and awareness regarding the hazards associated with the use and disposal of pesticides is particularly widespread (Hussain et al., 2021).

2.8 Agricultural Crop Waste and Its Utilization in Nigeria

In Nigeria, about 70% of households are engaged in agriculture, with rural areas having a substantially higher rate than urban areas (Nigeria National Bureau of Statistics, 2021). Vast variety of agricultural crops can be produced in Nigeria because of its incredibly diverse agro-ecological conditions (Iye and Bilsborrow, 2013). Such crops include cassava, cocoa, coconut, groundnut, millet, oil palm fruit, rice, potatoes, sugarcane, sorghum, tobacco, tomatoes, fresh vegetables, ginger, melon seed, mango, cashew, wheat, yam, plantain, onions, pineapple, okra, kola nut, citrus, pulses, cowpea, etc. and are produced in large quantities for consumption and exportation and as a result, huge amounts of waste is generated from these crops. Furthermore, the residues/ waste produced from these crops include: peels, stalks, husks, shells, cobs, bunches, fibre, leaves, stems, bagasse etc. Usman et al. (2013) stated that an estimate of 18 million tonnes of agricultural crop waste is generated yearly in Nigeria with rice and maize accounting for the most proportion of the trash generated

Most of the crop wastes generated are burned, dumped, or fed to animals (Aruya et al., 2019). Furthermore, farmers are engaged in poor management of agricultural crop residues and that this is because they are unaware of the risks to human health and environmental pollution (Aruya et al., 2019). However, over 70% of the wastes produced during agricultural harvesting and processing are often utilized for other uses such as soil cover or mulching, fuel, livestock feed (Dayo, 2007; Jibrin et al., 2013) and construction materials (Usman et al., 2013). The most often used agricultural wastes for livestock feed are cassava and yam peels, cowpea and groundnut husks, brans, oilcake, maize, millet, and sorghum stovers (Singh et al., 2011). In addition, legume crop wastes due to their superior nutritional value, digestibility, dietary protein content, and mineral composition are often chosen as animal fodder over cereal crop residues (Owen, 1994). Jibrin et al. (2013) also noted that 58% of animal feed during the rainy season comes from agricultural crop waste. In addition to crop wastes utilized for many reasons, energy could also be produced from it. Agricultural crop wastes can be a significant source of bioenergy (IRENA and FAO, 2021), specifically in Nigeria rural areas where almost everyone engages in agriculture. Some studies evaluated the energy potential of crop wastes. For instance, Kyauta (2015) discovered a renewable and sustainable energy source by converting groundnut shells and maize cobs into solid pellet fuel. In addition, research conducted by Japhet et al. (2015) looked at the production of rice husk pellets and characterized them as a potential alternative source of energy.

Crops with the potential to be used as feedstock for the production of biofuels in Nigeria include sugarcane, sweet sorghum, maize, and cassava for ethanol production, and oil palm, coconut, cotton, sunflower, soy bean, and Jatropha for biodiesel production (Agbro and Ogie, 2012). Larger proportion of the population utilizes fuel or firewood to meet their energy requirements due to lack of access to electricity (Okafor et al., 2022). Utilizing waste biomass for energy could address the problem of waste disposal and reduce the cost of energy requirements (Jekayinfa and Omisakin, 2005), and could also serve as an additional alternative to provide people with access to energy (Nwoke et al., 2020). According to Adegbulugbe and Olayiwola (2018), Nigeria has the potential to generate up to 13,000 MW of electricity from crop waste which is equivalent to about 40% of the country's current installed capacity. Although, utilizing only biomass as energy is insufficient to adequately supply energy needs (Jekayinfa et al., 2020). With abundance amount of residue produced from crops in Nigeria, the most challenging part of utilizing this wastes as a form of alternative energy includes poor handling of residues for bioenergy production processes, inconsistent or conflicting laws, and technological restrictions, inadequate management of waste (Okafor et al., 2022).

Table 2. Estimation of crop residues, feedstock and energy potential for some major crops grown in Nigeria.

Crop /feedstock	Production (tons)	Residue type	RPR	Residue (tons)	Quantity (ton)	Conversion pathway	Bioenergy Type	Estimated Energy potential
Rice	727.14	Husk Straw	0.27 0.16	194.15 1277.58	1471.74	Gasification, pyrolysis, Combustion, Briquetting	Biogas, methane, methanol, bio-oil, solid fuel	26663.93
Maize	653.50	Cobs Stover	0.27 2.00	178.41 1307.00	1485.41	Combustion, fermentation	Biogas, Bio-oil, ethanol	26998.78
Sorghum	23.77	Stalk	1.25	29.71	29.71	Gasification, pyrolysis, Fermentation	Biogas,Bio-oil, Ethanol	505.07
Soybean	843.55	Husk Straw	2.50 1.00	2108.88 843.55	2953.42	Gasification, pyrolysis, Briquetting	Biogas, methane, methanol, Bio-oil, solid fuel	53143.74
Sugarcane	283.5	Bagasse Tops/leaves	0.33 0.05	93.56 14.18	107.74	Combustion, fermentation, Anaerobic digestion, Gasification, Briquetting	Methane, Ethanol, Biogas, Bio-oil, Solid fuel	1889.48
Total					6047.02			109201.0

RPR – Residue to product ratio Source: (Alhassan et al. 2019)

2.8 Policies, Legislations and Strategies on Energy in Nigeria

One of the strategies put in place for energy in Nigeria is the integrated energy strategy, called the National Energy Policy (NEP; 2003, 2006, 2013, 2022). The NEP's primary goal is to optimize the nation's energy resources to guarantee sustainable growth by promoting the development of renewable energy sources while reducing the use of fossil fuels (non- renewable energy), this policy was developed by the ECN "Energy Commission of Nigeria" (NEP, 2022). Other national energy policies and plans developed by ECN include the Renewable Energy Master Plan (REMP, 2012) which aims to integrate renewable energy in the energy supply to buildings, the national grid, and other distribution systems. Additionally, there is also Nigerian Biofuel Policy and Incentives (NBPI, 2007) whose goal was to promote the domestic fuel ethanol sector by employing agricultural products in accordance with the federal government's order on a national automotive biomass program. In 2015, the federal Ministry of Power (FMP) developed National Renewable Energy and Energy Efficiency Policy (NREEEP) which describes the worldwide goals embedded in the laws, regulations, and programs supporting renewable energy and energy efficiency (NREEEP, 2015).

2.9 Management of Contaminated Pesticide plastic packaging waste

An estimate of 2.7 million metric tons of pesticide is used nationwide in 2020 (FAO, 2022a). Evidently, these pesticides come in containers, which means that when the chemicals have been consumed, the containers are considered to be a waste. The majority of pesticide containers/packaging used worldwide are made of non-biodegradable materials, such as high-Density Polyethylene (HDPE) (Jones, 2014).

Pesticide plastic waste is considered packaging waste and is classified as a hazardous waste under 15 01 10* of waste category named 'the Packaging containing residues or contaminated by hazardous substances (European waste catalogue, EWC 2002). An estimate developed by the Plant Protection Department suggests that around 1.8% of the chemicals are still contained inside their original container (Dien and Vong, 2016). The common methods of disposing pesticide plastic waste especially in developing countries includes burning, leaving on the field where it is been used, reusing, throwing in to waste dumps (Sosan et al., 2020) all of which poses environmental and health risks. To mitigate environmental and health concerns related to pesticide plastic waste, it was recommended to clean pesticide containers immediately after use (FAO and WHO, 2008). Triple rinsing, pressure rinsing, and integrated rinsing are the recommended cleaning methods. Georgious et al. (2022) found that contaminated pesticide plastic waste was deemed non-hazardous after three rinses as it was below the WHO's recommended threshold level. The world health organization (WHO) and food and agricultural organization (FAO) as cited by Mehmood et al. (2021) suggested that the best approach to manage empty pesticide container is to return it to the producer so that it could be destroyed through high-temperature incineration. According to Briassoulis et al. (2014), a project named “AgroChePack” was launched in Europe and its goal was to transfer knowledge from existing programs and foster synergy with the LabelAgriWaste program for the management of all agricultural plastic waste. Prior to treatment of pesticide plastic waste e.g. recycling, adequate collection system could enhance the management of this waste. For instance, in Hungary, a non-profit organization for national pesticide containers called "CSEBER" was founded in 2003 with the aim to coordinate and manage the collection and disposal of pesticide packaging material (FAO and WHO, 2008) so as to reduce its impact on the environment. Georgious et al. (2022) found that recycling is the most environmentally friendly alternative for managing pesticide plastic waste.

2.10 Energy recovery from crop waste

Crop waste is the plant material left over after harvesting crops such as rice, wheat corn, sugarcane etc. energy recovery from crop waste is the process of converting crop residues in to usable energy. This process is important because crop waste is a significant source of biomass, which can be converted into renewable energy without competing with food production (Liu et al., 2021). One of the benefits of crop waste to energy is that it can help to reduce greenhouse gas emissions. When crop waste is left to decompose in the field or burned, it releases methane and carbondioxide in to the atmosphere (Liu et al., 2021). However, by converting crop waste to energy, these emissions can be avoided and the carbon in the biomass can be stored in the form of biochar, which can improve soil fertility (Mohanty et al., 2020)

2.10.1 Methods of energy recovery from agricultural waste

A variety of treatment techniques can be used to transform agricultural wastes into energy. They are grouped into Mechanical, thermos-chemical conversion and biochemical technologies

Mechanical treatment

Pelletization is a method that converts biomass into a high density, solid energy carrier. It entails several steps, such as pre-treatment of the raw materials, pelletization, and post-treatment. The pre-treatment of the raw material involves combining it with various additives and then subjecting it to conditioning with steam in order to increase either the temperature or the moisture content. (Pak et al., 2011). Frequently utilized raw materials for this process includes sawdust, wood shavings, wood wastes, and agro-based byproducts like straw and switch grass. Pellets made of biomass have the potential to be used directly as fuel in household heating stoves, commercial heating boilers, and large-scale power plants (Chen et al., 2017)

Thermo-chemical conversion:

Thermochemical treatment referred to as the production of energy from biomass through the use of heat and chemical reactions. The three main thermochemical biomass conversion processes are combustion, pyrolysis, and gasification (Kumar et al., 2015).

Combustion is defined as the process of burning biomass in the presence of oxygen and it is applied in a variety of processes and equipment including furnaces, stoves, steam turbines, boilers, etc. in other to transform the chemical energy contained in biomass into heat energy, mechanical energy, and electricity. When biomass is burned as a fuel, a vast number of air pollutants are released into the atmosphere. Some of these pollutants include NOx, SO_2, respirable particulate matters, formaldehyde, and benzene (Albalak et al., 2001)

Pyrolysis is the thermal breakdown of lignocellulosic biomass in an inert atmosphere and the absence of oxygen. Gases, biochar, and bio-oil are the byproducts of pyrolysis. The pyrolysis products varies depending on the process's heating rates, reactor type, solid residence time, and operating temperature (Sá et al., 2020). Bio-oil is the primary byproduct of rapid pyrolysis that takes place between 500 and 650 degrees Celsius, and methane is produced above 700 degrees Celsius (Fogarassy et al., 2019)

Gasification is the process of converting biomass into syngas, a composition of CO_2, CO, and H_2 that is used to create natural gas. According to the study by Abubakar et al. (2019), it was stated that during this process, certain hydrocarbons could potentially be generated, thus the gas produced can be used to generate electricity or heat.

Biochemical Conversion

Anaerobic digestion (AD) is the method that involve the use microorganisms to break down biomass and produce biogas in the absence of oxygen, which can be used as fuel (Mohanty et al., 2020). Carbon dioxide and methane make up the majority of biogas, with small proportions of hydrogen, hydrogen sulfide, and nitrogen (Aigbodion et al., 2018). However, Bacteria metabolize biomass in an anaerobic condition, producing gas containing energy equivalent to 20–40% of the lower heating value of the material (McKendry, 2002).

Fermentation is the process by which different types of microbes transform carbohydrates, such as starch and sugar i.e., crops like sugar cane, maize wheat etc. into ethanol without the use of oxygen. Utilizing a wide variety of microorganisms in fermentation processes allows for an increase in the amount of sustainable agro-waste-derived resources that can be used in the production of ethanol (Beesley et al., 2011). In addition to being used to generate electricity, bioethanol may also be used as a chemical feedstock and as a solvent in industrial settings (Guerrero et al., 2018)

3. MATERIALS AND METHODS

This study was aimed at accessing the level of awareness and opinions of individuals in Nigeria regarding pesticides plastic waste and energy recovery from crop waste as well as investigate the management practices of pesticide plastic waste and crop waste in Hungary. Mixed method of analysis was used for this research (interview and questionnaire). The targeted population for the survey part of the research study were individuals who lived in Nigeria. And the interview part of the research was targeted to companies in Hungary.

The inclusion criteria for this study were individuals who were at least 18 years old and had some level of knowledge about agriculture. Likert-type questions (ranging from very aware to not aware and very familiar and not familiar) was used to determine the respondents' level of awareness and familiarity with energy recovery from crop waste and multiple choice options was used for the remaining part of the survey questions

3.1 Data collection

A total of 203 participants were surveyed using an online based questionnaire (lime survey) to collect information from Nigeria. The questionnaire contains series of questions that addresses: the socio-demographic variables such as age, level of education, and income; awareness and the opinion of people on the topic. The survey consisted of 14 questions with closed-ended questions. For the Hungarian part of the research, an online interview was done with Executive Director of CSEBER (Packaging Collection System nonprofit limited company which collects and clean/dispose of empty agricultural chemical packaging materials) and the Chief executive officer of Biogas Union, private limited company that sets up biogas plants across in Hungary. Data collection took place in April 2023.

3.1.1 Data Analysis

The data generated from the survey was exported and statistically analyzed with IBM SPSS statistics version 27. Descriptive statistics were used to analyze the demographic characteristics of the participants and other variables. Linear regression statistics was used to test for the hypothesis at significant level of 0.05

4. RESULTS AND DISCUSSION

4.1 Responses to the Survey

4.1.1 Age of the respondents

Data on the demographic characteristics: Age, presented in Table 3 showed that the majority (68.5%) of the respondents were between the age ranges of 26-40 years while 25.0% of the respondents fell within the age range of 18-25years. About 5.9% of the study participants were between 41-64years while 0.5% of the respondents were above 65years. The data on ages indicated that the majority of the respondent are youths who are expected to have some considerable level of environmental awareness. The study of social environmental concerns is greatly influenced by age because maturity may have an impact on one's knowledge of environmental and sanitation problems (Eagles and Demare, 1999 and Longe et al., 2009).

Table 3: Age distribution of respondent

Age	Frequency	Percentage (%)
18-25	51	25.1
26-40	139	68.5
41-64	12	5.9
Over 65	1	0.5
Total	203	100%

4.1.2 Level of education

Data on level of education of the selected population is presented in Table 4. This characteristic was taken into account in this study to ascertain respondents' comprehension and awareness of the waste generated from agricultural sector. The level of academic accomplishment of people ranges from vocational education to tertiary education. This result showed that the majority of the respondent (66.0%) attained BSc degree, followed by MSc. Degree (24.6 %). Few of these respondents have attained at least vocational education (2.0%), entries for Ph.D. is 1.0%, and 6.4 % of the respondent had secondary education. Education levels may also play a significant role on people's perception on agricultural waste and its management. Although only 2% had vocational education and about 6% had secondary education. Even this small percentage, could have a negative influence on their perception on management of crop waste and pesticide packaging waste. Educated people are more likely to prioritize environmental concerns (Sabah and Jamil, 2010).

Table 4: Level of education

Level education	Frequency	Percentage (%)
Vocational Education	4	2.0
Secondary education	13	6.4
BA/BSc Degree	134	66.0
MA/MSc Degree	50	24.6
Ph.D. Degree	2	1.0
Total	203	100%

4.1.3 Gross income

Data on level income of the selected population is presented in Table 5. The income level ranges from 100, 000-200, 000 Naira to over 500,000 Naira. The data showed that majority (48.8%) of the respondents are low income earners, 34.5% earn between 100,000-200,000 Naira, 8.9% earn between 300,000-400,000 Naira, 3.4% earned between 400,000-500,000 Naira and 4.4% earn above 500,000 Naira

Table 5: Income of the respondent

Income	Frequency	Percentage
< 100,000 Naira	99	48.8
100,000- 200,000 Naira	70	34.5
300,000- 400,000 Naira	18	8.9
400,000-500,000 Naira	7	3.4
>500,000 Naira	9	4.4
Total	203	100%

4.1.4 Participant's Reponses on waste generated from sectors

Figure 2 depicts the responses of the participants on waste generation capacity of different sectors i.e. industry, construction and agricultural sector. The result showed a big disparity between responses. Higher proportion of the respondents (51.1%) choose industry has the sector that generates highest volume of waste, followed by the agricultural sector with 35%, responses for all sectors to be 7.9% and construction sector, 7.5%. Data obtained for perception on waste generated by sectors showed that, the respondents are of the opinion that industry generates the highest volume of waste, followed by agriculture. This implies that individuals may view waste from industrial sector as a more significant issue than waste generated by agricultural activities, especially in urban areas where people are more exposed to industrial activities and products.

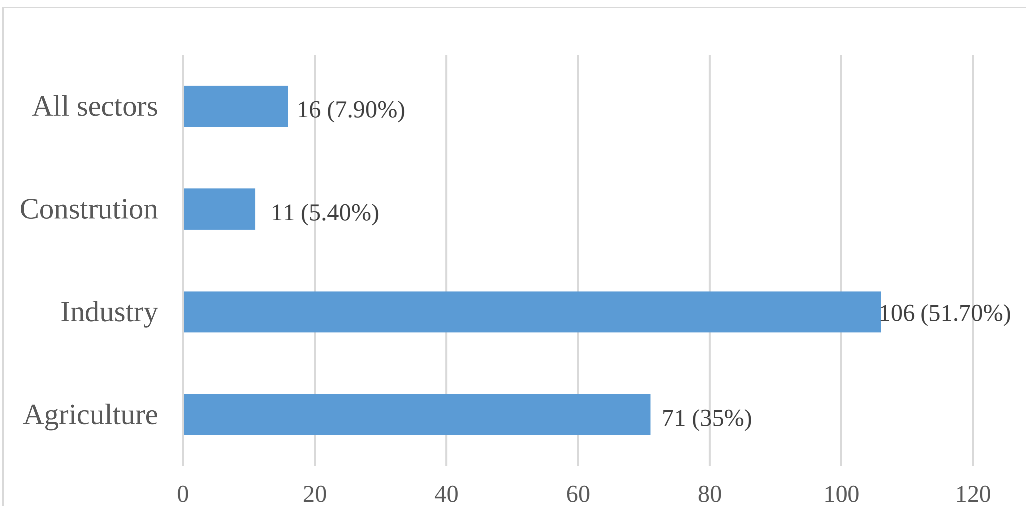

Figure 2. Waste generation by sector

4.1.5 Participant's response on Policy, plan and program for managing agricultural waste in Nigeria

The figure below depicts participant's response on policies and plans in place for managing agricultural waste. According to the result that can be found below, a large percentage of respondents (68.5%) acknowledged the existence of policies, plans, and programs for waste management, whereas 31.5% choose otherwise.

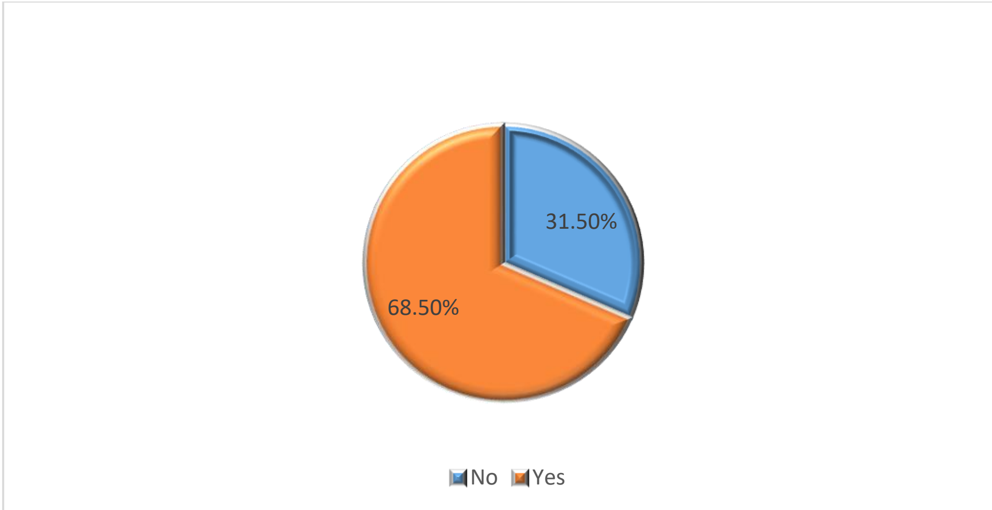

Figure 3. Policy, Plan and Programme.

4.1.6 Respondents opinion on Waste regulation adequacy on waste reduction

The data in Figure 4. Shows people's opinions on the efficiency of waste regulation in managing waste from the agricultural sector. According to the results, majority of respondents (58.6%) expressed a negative opinion, stating that the regulations in place are not effective enough in reducing agricultural waste. On the other hand, 41.4% of the respondents believe that the regulation are adequate in reducing these waste.

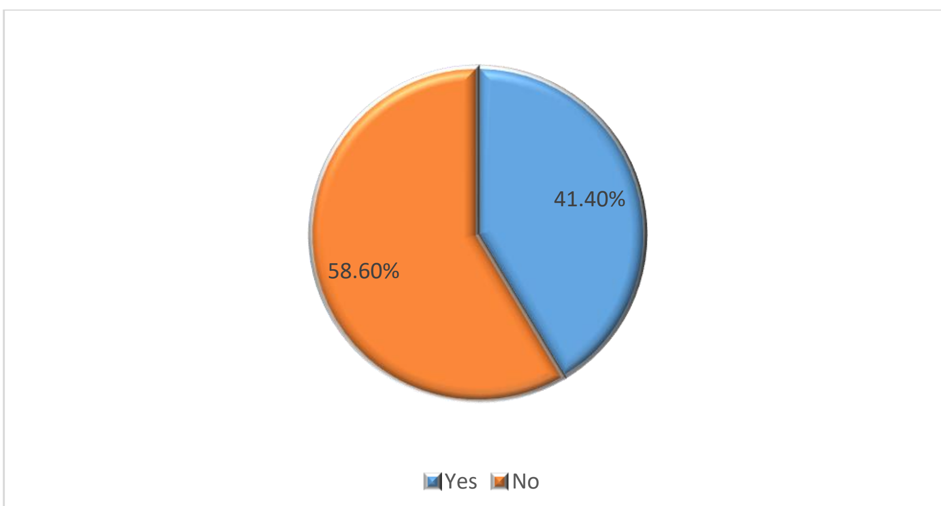

Figure 4. Waste regulation adequacy.

4.1.7 Respondents opinion on the reusability of crop waste

The data collected for the responses in this section is presented in figure.5. Based on the analysis of the data on the opinion of the respondents on crop waste reusability, the findings revealed that individuals' perspectives towards the reusing of crop waste varied ranging from 10-50%. 50.7% of the respondent are of the opinion that reusing crop waste can reduce environmental pollutions and emissions, 22.2 % are of the opinion that reusing crop waste can help to reduce waste, 10.8% for the response that it is sustainable, 16% of the respondent believe that it will still have effect on both health and the environment.

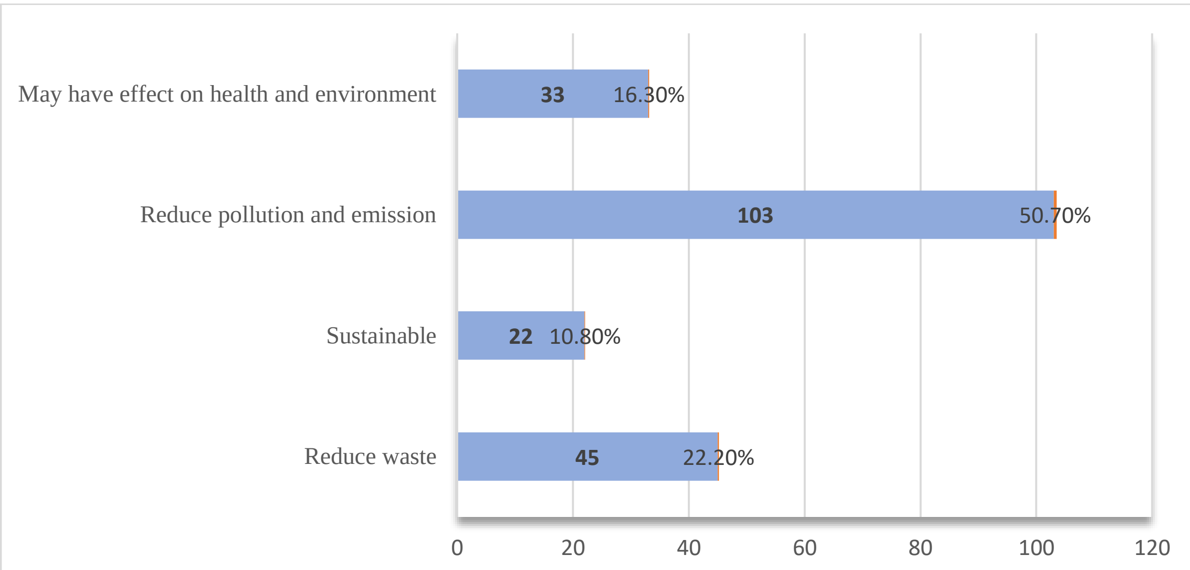

Figure 5. Opinion on crop waste reusability.

4.1.8 Level of awareness of the environmental impact of crop waste and pesticide packaging waste

The data collected for the responses on the level of awareness about the environmental impact of pesticide packaging waste is presented in figure 6. The findings revealed that individuals' level of awareness varied ranging from the highest with 46.8% (very aware), 35.6% of the respondent had limited level of awareness (somewhat aware) and the least with 16.6% (not aware).

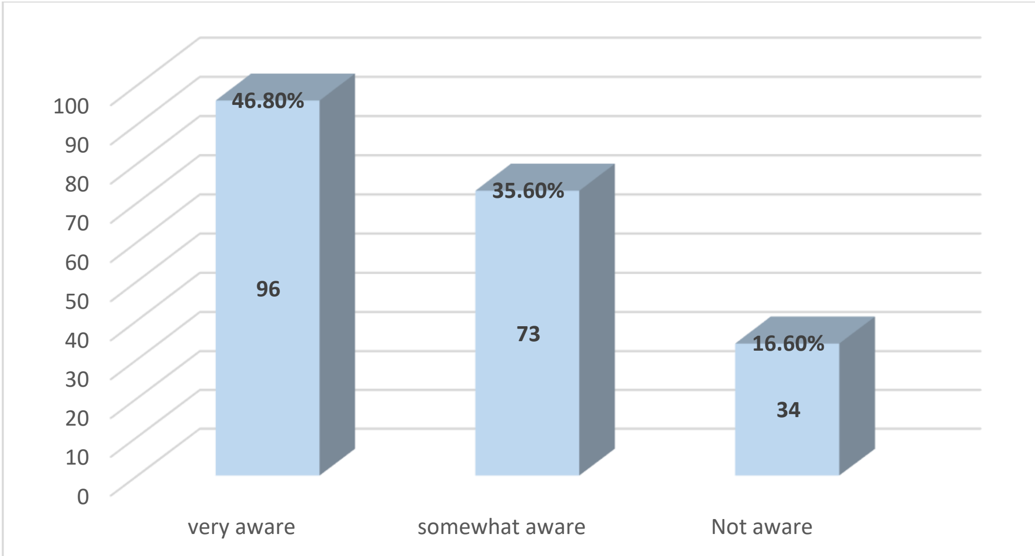

Figure 6. Level of awareness.

4.1.9 Responses on Familiarity with the concept of Crop waste utilization for energy generation

Figure 7 depicts the responses that were obtained from respondents about their level of familiarity with the concept of using agricultural crop waste as a source of energy. Based on the analysis of the survey, higher percentage of the respondents are familiar with the use agricultural crop waste in energy generation (43.3%), 37.4% for somewhat familiar and 19% of the respondent are unfamiliar with the use of crop waste to energy.

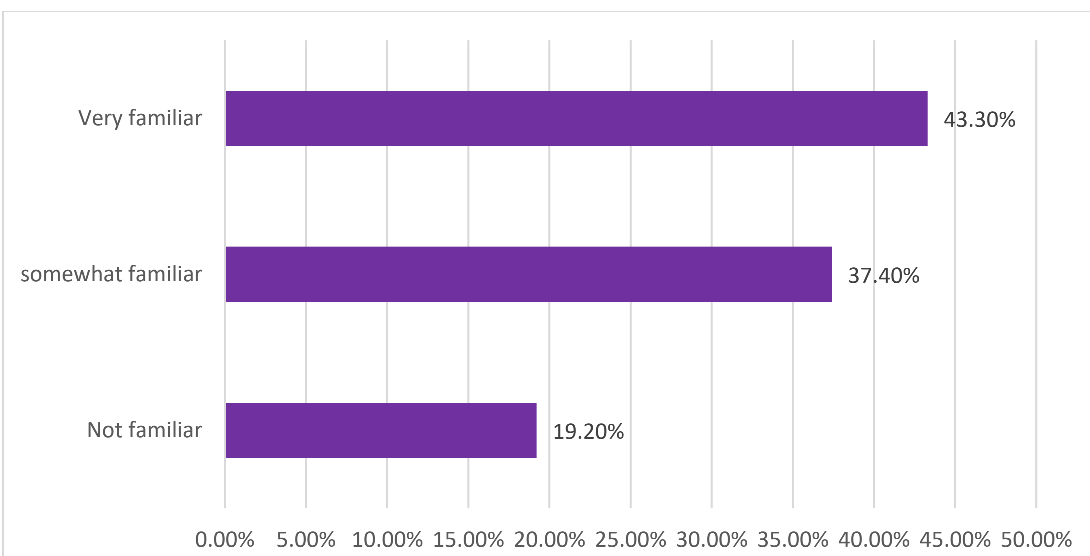

Figure 7. Respondent’s familiarity with crop waste to energy.

The study revealed high level of awareness of environmental impact of crop waste and pesticide packaging waste and crop as well as familiarity with the concept utilization of crop waste (biomass) to generate energy among the respondents (figure 6 and 7). This may likely be attributed to the fact that majority of the respondents are educated. Studies have shown that Education has a significant influence on environmental awareness (Aminrad et al., 2011). Moreover, we are in the technological age where almost everyone has access to smart phones, laptops etc. It's most likely that these individuals learned about the issue of environmental impact of agricultural waste and its potential to be used for energy generation, not just via education but probably from other sources like social media, news outlets (radio or TV), search engines like Google, articles, and so on. This may partially explain why there is high level awareness among the respondents.

4.1.10 Respondent's opinion on Energy utilization of crop waste to reduce/solve energy crisis

The information that was gathered from respondents on their viewpoints on the recycling/ conversion of agricultural crop waste into electricity in their country is depicted in Figure 8. The options provided for the responses ranges from Yes, No and Maybe. According to the analysis of the result, a higher percentage of respondents (72.2%) view it as a promising solution to the country's current energy crisis. 22.9% think it is likely to solve energy crisis, while others (4.5%) are of the opinion that it cannot provide any solution to the countries pressing issue on energy crisis.

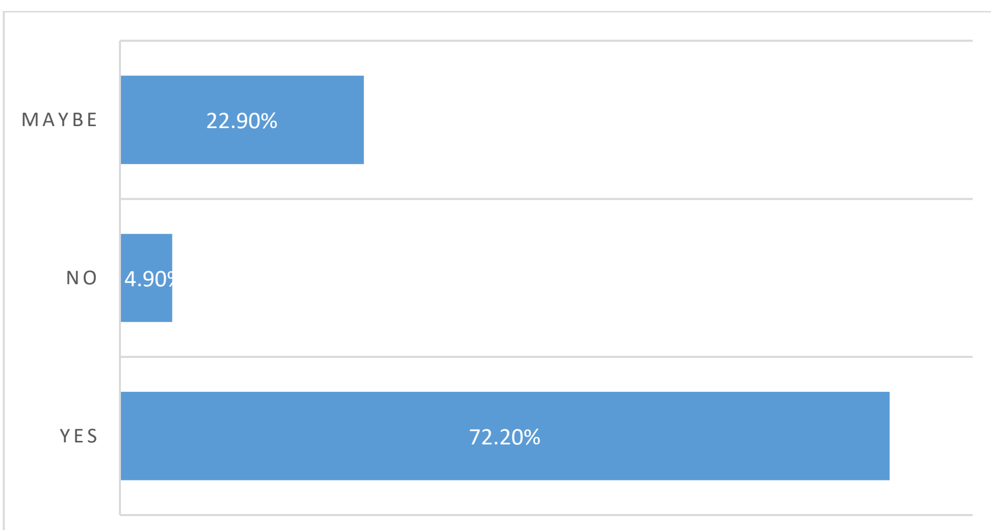

Figure 8. Opinion on crop waste energy to reduce/solve energy crisis.

The data obtained for the opinion on using crop waste for energy in solving/ reducing energy crisis. Majority of the respondent (figure 7) are positive that, using crop waste to generate energy could help in reducing the energy crisis in the country. Nigeria has been experiencing an energy crisis for some years now, and many households suffers from stable electricity leading them to turn to an alternative energy sources like generators to power their homes which is additionally a source of pollution to the environment. Beyond putting in place the necessary regulations and fostering a good attitude toward agricultural crop waste, proper implementation of plans for the exploitation of energy from crop waste could go a long way in improving the countries energy crisis.

4.1.11 Causes of improper management of crop waste and pesticide packaging waste

Table 6 showed the opinion of people on the cause of the improper management of these waste. The result showed that 12.8% of the respondent believed it is cause by ineffective waste regulation, 14.3% believed it to be cause by lack of adequate disposal facilities. 3.4 % are of the opinion that is due to lack of awareness regarding the regulation put in place to manage waste, 32.0% believed it to be lack of environmental awareness and education, 32.0% for lack of information about the potential health risk associated with improper management of these wastes, and no response from 5.4% of the respondents.

Table 6: Causes of improper crop and pesticide waste management

Parameter	Frequency	Percentage (%)
No response	11	5.4
Ineffective waste regulation	26	12.8
Lack of adequate disposal facilities	29	14.3
Lack of awareness about regulation put in place	7	3.4
Lack of environmental awareness and education	65	32.0
Lack of information regarding the potential health risks associated with improper management of these wastes	65	32.0

There is a noted divided opinion of the cause of improper management of crop waste and pesticide plastic waste among the respondents. Aside from response that it is due to inadequate waste regulation, Majority of the respondents believed it is due to lack of environmental awareness and education and lack of information on the potential health risks associated with these waste. This is in line with what was stated by Adejumo and Adebiyi (2020) that in most developing countries, inappropriate agricultural waste management is as result of lack of awareness of the potential risks and advantages of handling agricultural waste effectively. These factors are alarming, as less environmental awareness could result in increased mismanagement, which would worsen environmental quality. In Nigeria's rural areas, where there are more uneducated people, sustainable management of agricultural waste, particularly crop waste and pesticide plastic waste is likely to be a challenging task. Reduced mismanagement of these waste may be accomplished by raising awareness, probably through extension agents or environmental specialists.

4.1.12 Participants opinion on triple rinsing

Figure 9 depicts the opinion of respondents regarding the question of whether or not people/farmers can comply with the triple rinsing of pesticide containers before disposal. The result showed 66.5% of the respondents gave a positive response and 33.5% gave a negative response.

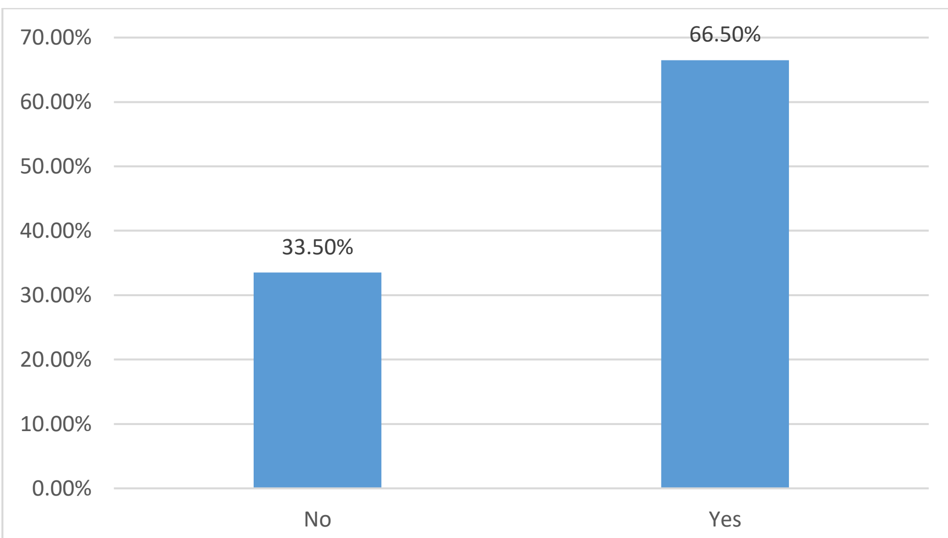

Figure 9. Participant’s opinion on triple rinsing.

4.1.13 Provision of incentives by government to farmers to reduce and waste agricultural waste

The figure below depicts the opinion of people about government providing incentives to farmers to reduce waste. This result showed 93.6% of the respondent wants the government to provide incentives to farmers to reduce agricultural waste and very few (6.4%) said otherwise. Although farmers clean pesticide containers before disposal, but majority only rinse them once (Sosan et al., 2020). However, With the positive responses from the respondents on compliance with triple rinsing of pesticide plastic waste, if proper monitoring and provision of incentives to farmers is put in place, it may likely help to reduce improper management of pesticide containers. Although prevention can be the best approach to managing waste, however, agricultural waste cannot be avoided as it is source of food production and consumption. Encouraging farmers through provision of incentives can be a key to having a good impact on the problem.

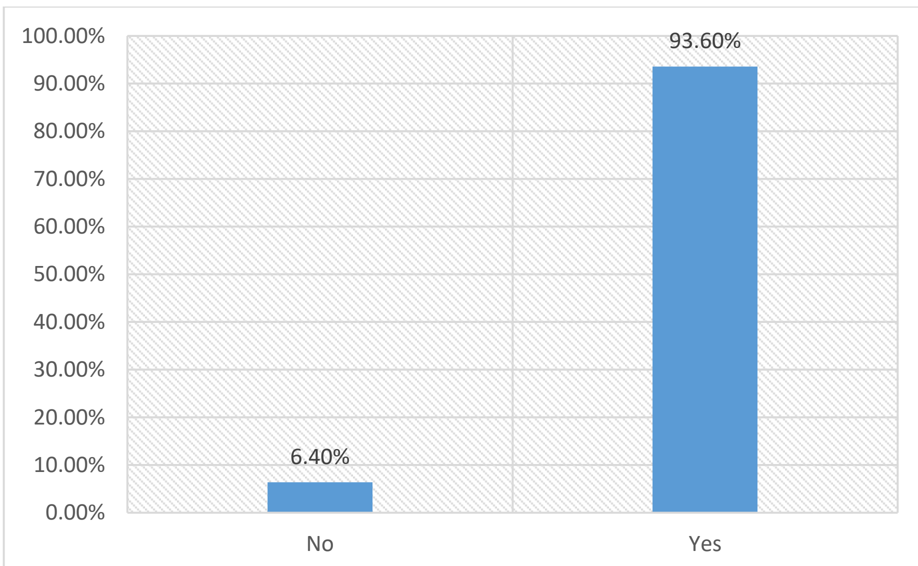

Figure 10. Provision of incentives to farmers.

4.1.14 Participant’s response on the rating of collection system in Nigeria

Figure 11 depicts the ratings of the respondent on the waste collection system in their country. The question for this section was put on a scale of 1-5 ranging from “Not effective to Very effective. Majority of the respondents rate the collection system as moderate (38.9%), 23.2% for slightly effective, 16.7% for Not effective, 8.4% for effective, and 5.9% for very effective. Based on the data from this survey about waste collection system, majority of the respondent rated the collection system as inefficient/effective enough, this corresponds with the finding of Longe et al. (2009) in their study of people’s perception on household solid waste management in Nigeria

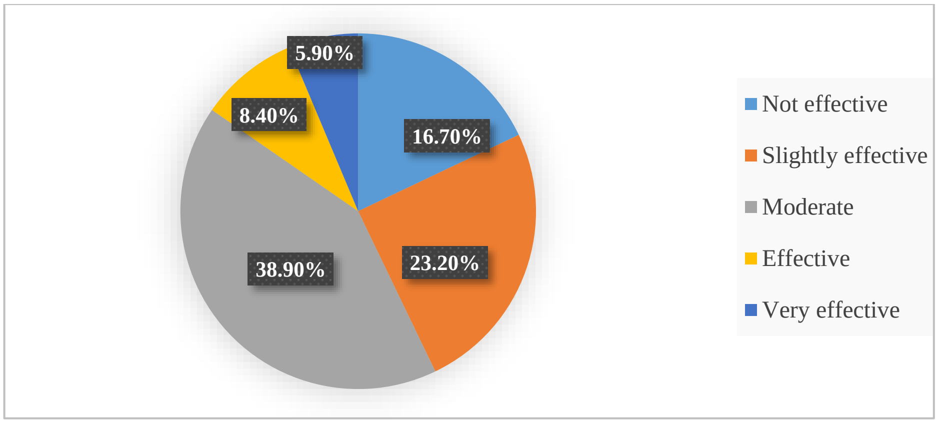

Figure 11. Waste collection effectiveness.

4.2 Interview responses from the Hungarian companies

4.2.1 CSEBER (packaging collection system, non-profit limited company)

This company is responsible for the collection of pesticide plastic waste in Hungary. Pesticide plastic waste after being used by farmers is often rinsed three times as required by CSEBER before collection. This rinsing program is titled "Harom a Margar Igazsag" where steps on how to rinse this containers are provided to the farmers. These steps includes: Pouring the pesticide into the tank and letting it drip into the spray tank for 30 seconds; Add water to the container to ¼ full! (At least 1/10 according to the Hungarian regulation); Recap the container and shake it for 30 seconds; Drain the rinse water into the spray tank, then let it drip for 30 seconds; Repeat it three times. After these steps are carried out, the farmers are required to destroy/puncture the container so that it cannot be used again and should be allowed to dry before taking to the nearest collection center. The farmers can then search CSEBER location that is closest to them and transport these containers there. In Hungary, pesticide packaging waste is classified as non-hazardous because of the strict regulation of the country, requiring that a farmer must have a license to handle/manage hazardous waste before taking it to the collection center.

The volume of pesticide plastic waste collection increases annually. For Example in 2020, the collection rate was 64.3%; in 2021, the collection rate was 67.4%; 2022 collection rate was 68.7% and in 2023 they project to collect at least 70.8% at the end of the year and in 2025, they aim to reach the target of about 75% increase in collection rate.

There are numerous organizations that CSEBER collaborates with. They pay membership fee for different organizations. The major organizations that work in partnership with CSEBER include the Plant Protection Association in Hungary (they represent Crop Life Europe in Hungary), the Environmental Service and Production Companies Association, the Packaging Companies Association, the Business Council for Sustainable Development in Hungary, the Ministry of Agriculture, the Food Chain Safety Office, the Cereal Producers and Seed Association. This organizations are the key partners and they assist in reaching out to farmers, which improves the country's collection rate.

They work with local farmers and other stakeholder to encourage proper disposal of these materials and to educate them about the importance of environmental sustainability. This is often accomplished through the annual CSEBER conference, which usually takes place during sustainable development week in November. The major/big partners, agricultural media, news publications, and others are usually invited to this conference. Additionally, the company's partners are frequently requested to inform and educate farmers and their clients about the significance of collecting this waste during the conference.

CSEBER is one of the members of the crop life Europe, therefore they are required to recycle the collected pesticide plastic waste. Recycling of pesticide plastic waste contributes to the EU circular economic goals. The granulate and end use product made from CSEBER can be used make for example protection pipes for underground internet cables which are usually installed underground to prevent direct contact with Human. It is prohibited to make packaging materials for consumables such as food, drinks etc. from this recycled plastics.

An initiative called "Close the Loop" by Crop Life Europe, aimed at promoting and facilitating the recycling of pesticide packaging waste. It recognizes the importance of proper disposal and recycling of pesticide containers to minimize their impact on the environment. The initiative encourages all it European members e.g. pesticide manufacturers, distributors, farmers, and other stakeholders to actively participate in the recycling process. The goal is to establish a closed-loop system where the packaging waste is collected and recycled to create new packaging materials e.g. pesticide packaging material.

4.2.2 Biogas Union (private limited company)

This biogas union is a private limited company that sets up biogas plants across the country. Biogas is typically generated through fermentation, firing, or combustion, using agricultural waste such as straw, grasses, food waste, dietary waste, pig manure; also human sewage sludge can be used in biogas production. Grains with high sugar and fat content are also a viable source of biogas. However, straw with high fiber content is not typically used for biogas production due to its complex carbohydrate and lignin content, which are difficult for microorganisms to break down. Biogas production is most effective with waste that has high cellulose and moisture content, typically between 60 to 70%. The end product produced from biogas is digestate which serves as a manure that contains other nitrogen sources and can be used as used as a fertilizer in a crop field.

They work with farmers by proposing a project to build a biogas plant near the farm. For example, a small town in Hungary called Kisber, where a livestock farm with about 100 cattles is located. By building a biogas plant there, the farmers can provide the organic waste material required for the biogas production process. The biogas plant will in turn supply renewable energy in the form of electricity and heat energy, which is necessary for livestock production on the farm. Additionally, the biogas plant can reduce the amount of waste and odour emissions from livestock waste, making it a more sustainable and environmentally friendly option.

This company works also with regulatory bodies who play an important role in overseeing the construction and operation of biogas plants. These regulatory bodies work to ensure that biogas plants are built and operated in a safe, environmentally sustainable, and socially responsible manner. The company works with them by providing the necessary information on the construction of any biogas plant project. And there has not been any legal issues pertaining to this.

4.3 Test for hypothesis

LE: level of education, LAEPP: Level of awareness about environmental impact of pesticide plastic waste, OCWR: opinion on crop waste reusability

Table 7. Test for hypothesis

Hypothesis	Regression weight	Beta coefficient	R^2	F	p-value	Level of significance
H1	LE-LEAPP	0.069	0.017	3.472	0.064	P > 0.05
H1	Age-LEAPP	0.091	0.010	2.012	0.158	P > 0.05
H2	Age-OCWR	0.189	0.007	1.423	0.234	P > 0.05

The hypothesis test 1, if age and education have impact on environmental awareness. The dependent variable Environmental awareness was regressed on predicting variable age and level of education to test the hypothesis H1. Age and education is not statistically significantly on Level of awareness about environmental impact of pesticide plastic waste at 0.05 level of significance.

The hypothesis test 2: if age has significant impact on the opinion of people on crop waste reusability. The result also showed positive but no significance at 0.05 level of significant.

5. CONCLUSION AND RECOMMENDATION

Level of awareness and opinion of people on the treatment of contaminated packaging and energy recovery from crop wastes was determined in this study, result revealed high level of awareness among the participants. Additionally there is high perception of crop waste to energy been the possible solution to energy crisis in Nigeria. The management of crop waste and pesticide packaging waste in Nigeria is hampered by problems like inadequate waste regulation, a lack of environmental awareness and education, lack of information on the potential health risks associated with these waste, inadequate disposal facilities, and an insufficient and ineffective waste collection system. Environmental regulations governing how people should treat waste/agricultural waste are generally not enforced effectively. This study also revealed that Hungary has made a significant progress in the management of pesticide packaging waste and biogas (energy) production from agricultural waste and challenges still exist in Nigeria. Based on these findings it is recommended that government of Nigeria should provide adequate information on environmental awareness through campaigns or programs etc. about the benefits of managing agricultural waste efficiently just like it is done in Hungary where conferences are organized yearly to educate farmers on why it is important to manage for example pesticide packaging waste efficiently. Additionally, there should also be strict regulations, proper implementation of policies, and law enforcement, provision of adequate waste transportation and collection systems similar to those used in Hungary.

6. SUMMARY

Agricultural crop waste and pesticide plastic waste is a major environmental concern due to their potential to release pollutants, greenhouse gases and pathogens to the environment. The management of these wastes has drawn attention recently in many parts of the world in effort to lessen their negative effect on the environment.

This research aimed to investigate the level of awareness and opinions of individuals in Nigeria regarding the treatment of pesticide packaging waste and energy recovery from crop waste, and to examine agricultural waste management (e.g. pesticide plastic waste and energy recovery from crop waste) practices in Hungary. A mixed-methods approach was used, involving an online survey of 203 participants in Nigeria and online interviews with two companies in Hungary. The survey data was analyzed using IBM SPSS statistics version 27, with descriptive statistics used to analyze the responses.

The findings of the study showed that respondents in Nigeria had a high level of awareness regarding the environmental impact of agricultural waste and energy recovery from crop waste, and expressed strong support for converting crop waste to energy in reducing the country's energy crisis. However, the study also identified several barriers to proper waste management in Nigeria, including inadequate disposal facilities, weak law enforcement, and a lack of environmental education. In contrast, the study also found that Hungary has made significant progress in managing pesticide packaging waste and producing biogas from waste.

Overall, this study highlights the need for improved environmental awareness and education in Nigeria, particularly among less-educated individuals, in order to promote more sustainable waste management practices. The study also underscores the importance of policy implementation, law enforcement, and investment in waste infrastructure to protect the environment and promote sustainable agricultural practices

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List of Appendixes

Appendix 1: Demographic characteristics and respondents perspective on waste from sector and waste regulation

Questions and Responses	Frequency
Age	
18-25	51
26-40	139
41-64	12
0ver 65	1
Level of Education	
Primary Education	0
Vocational	4
Secondary	13
BA/BSc	134
MA/MSc	50
Ph.D. Degree	2
Which sector generates the highest volume of waste	
Industry	105
Agriculture	71
Construction	11
All sectors generates the same volume of waste	16
Does your country has a plan, policy or programme to manage agricultural waste	
Yes	139
No	64
Do you think the regulation is adequate enough to reduce these waste	
Yes	119
No	84

Appendix 2: Level of awareness and opinion of respondents on crop waste and pesticide packaging waste

Question and Responses	Frequency
What is your opinion about the reusability of crop waste	
It can help to reduce waste	45
It is sustainable	22
It may still have negative effect on the environment	33
It reduces environmental pollution and emission	103
How familiar are you with the concept of utilizing crop waste to generate energy	
Not Familiar	39
Somewhat Familiar	76
Very familiar	88
How aware are you about the environmental impact of pesticide packaging waste	
Not aware	34
Somewhat aware	73
Very Aware	96
In your opinion, what do you think is the cause of improper management of these wastes	
Ineffective waste regulation	26
Lack of adequate disposal facilities	29
Lack of awareness about regulation put in place	7
Lack of environmental awareness and education	65
Lack of information regarding the potential health risks associated with improper management of these wastes	65

DECLARATION

on authenticity and public assessment of final essay/thesis/master's thesis/portfolio[1]

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