ISSN: 1672 - 6553

JOURNAL OF DYNAMICS AND CONTROL

VOLUME 10 ISSUE 01: P39-64

AGRIWASTE GENERATED IN INDIAN AGRICULTURE, DIFFICULTIES AND RESOLUTIONS FACED BY THE GOVERNMENT – A REVIEW

Mahima Jain, Sonali Pandey

Department of Botany, School of Sciences, JECRC University, Jaipur, Rajasthan, India

JOURNAL OF DYNAMICS AND CONTROL
https://doi.org/10.71058/jodac.v10i01003

AGRIWASTE GENERATED IN INDIAN AGRICULTURE, DIFFICULTIES AND RESOLUTIONS FACED BY THE GOVERNMENT – A REVIEW

Mahima Jain[1*], Sonali Pandey[2]
Department of Botany, School of Sciences, JECRC University, Jaipur, Rajasthan, India
mahimaj154@gmail.com[1] drsonali17@gmail.com[2]
Corresponding Author

Abstract: *Agricultural wastes are described as leftovers from agricultural activities which includes waste created by farming, planting, harvesting, fertilizer run off from fields, pesticides go to fields, slaughterhouse, livestock waste, post-harvest waste. Agricultural waste has the ability to harm the environment and expose personnel to biohazards, which are dangerous biological materials. Every year India produces a vast amount of agricultural waste. That abundance creates both an environmental problem (production of harmful gases during burning) and an economic opportunity (bioenergy, compost, animal feed, industrial feedstock). This review comprises the scale and sources of agricultural waste in India, the main challenges governments face in handling the waste, the preventive measures taken so far, observed rifts and problems in execution, and practical advices to ameliorate outcomes.*

1.Introduction: -

Agricultural wastes are described as remnants from agricultural operations, which include waste created by farming. Manure and other waste from farms, poultry houses, and slaughterhouses, harvest waste, fertilizer runoff from fields, pesticides that go into soils, water, or the air, and silt that drains from fields are all considered agricultural waste. Agriculture waste, also referred to as agri-waste or agricultural garbage, is any leftover material created during agricultural operations as well as any by-products [58]. Planting, harvesting, handling, and post-harvest processing are some of the agricultural production operations that generate a variety of organic and inorganic wastes [101]. Among the waste products from different agricultural processes are jute fibres, sugarcane bags, crop stalks, vegetables, wheat husk and straw, and food and vegetable waste [94]. According to estimations, 998 million tons of residual agricultural trash are produced each year [51]. The generation of garbage in agriculture is a major contributor to pollution and many forms of environmental contamination. Waste materials' properties have changed over time, presenting hazards to public health and safety [58, 109]. Approximately two tons of agri-waste are produced daily by farmers in rural areas. An abundance of fertilizers and manures, cow house waste, on average, the sugar industry generated about 20 million metric tons of waste [84]. The bulk of agricultural waste is composed of crop leftovers, which are a significant source of plant nutrients and high in organic carbon. Keeping agricultural residues after harvesting lowers soil erosion. Even though 75% of the waste is produced after harvesting by combine harvester machinery, animals are unable to eat it because of its high silica concentration [104]. Crop residues decompose physically, chemically, and biologically, which weakens the lingo-cellulose bonds and raises the nutritional value of the soil. The primary and most effective mode of decomposition is biological, in which waste products decompose more quickly in both anaerobic and aerobic conditions because of the spores of bacteria and fungi. To increase the quantity of nutrients in a finished product, microbial decomposition fixes nitrogen, phosphorous solubilizes, and breaks down cellulose [8]. Any organic substance obtained directly or indirectly through photosynthesis is referred to as biomass. Biomass and feedstock differ from each other in terms of origin, variety, and traits. They contain manure, straw, sewage, wood, rice husks, sugarcane,

https://doi.org/10.71058/jodac.v10i01003

municipal solid waste and sugar beets among other things [63]. According to India's Ministry of New and Renewable Energy (MNRE), the nation produces an average of 500 million tons (Mt) of agricultural residue every year [63]. Almost majority of this crop residue is actually used as feed and fuel for houses and businesses, according to the same research. Nonetheless, 140 Mt of excess remains, of which 92 Mt are burned each year [23]. A selection of Asian countries' agricultural waste production in Mt/year is compared in Table 1. Significantly, India burns a considerably larger amount of agricultural waste than other nations in the region [63].

Table 1. India's production of agricultural waste in comparison to a few other countries in the same region [63].

Country	Agricultural Waste Generated (Million Tons/Year)
India	500
Indonesia	55
Bangladesh	72
Myanmar	19

There are four main types of organic materials from which biomass resources can be extracted. Crop plants are one kind of first-generation biomass feedstock. However, the attention has shifted to the production of bioenergy from second-generation feedstock, such as biomass, which is composed of lignocellulosic materials, due to disruptions to the food web and supply [59]. The exploitation of the third and fourth generation feedstock from biomass that exploits the microbial community came after the drawbacks of the second generation [8]. Numerous analytical techniques can be used to study biomass, providing a wealth of information about its characteristics that can be used to improve production and recovery [44]. It is still challenging to locate and identify the mechanism that performs the conversion. The technology's inability to evaluate and identify the components of biomass that are pertinent to the production of energy from biological sources and value-added products makes it difficult to comprehend the outcomes of pre-treating biomass production and the factors influencing the chosen approach [59]. It is possible to use biomass from agricultural areas as a feedstock to produce commodities with additional value. This include biomass from crops, cultivated crops, fruits, and vegetables in addition to biomass from fisheries and animals [140]. Agricultural waste can be efficiently utilized in a variety of agro-based applications and industrial operations. However, the cost of delivery, processing, and collection may sometimes be far more than the income from the useful use of such garbage [138]. Farmers who burn their agricultural waste or leave it in the fields significantly pollute the air and soil. Farmers then start burning the leftovers, however this process produces 8.77 Mt CO_2, 141.15 Mt CO_2, 0.23 Mt NO_x, and 0.12 Mt N_2O, which contributes to air pollution and the loss of organic material, which is roughly 80–90% N, 25% P, and 20% K [63]. As a result, managing rice straw is a difficult problem in areas that grow rice. To transform this garbage into a form that may be used, an efficient waste disposal method is required. New approaches to more effectively managing agricultural waste have been made possible by recent technological developments and a growing focus on sustainable practices. Waste can be turned into useful resources like fertilizers, bioenergy, and animal feed using cutting-edge techniques like composting, anaerobic digestion, and bioconversion. Furthermore, by offering real-time data, optimizing resource allocation, and promoting improved decision-making, the integration of information and communication technologies (ICT) can improve waste management procedures [91]. The purpose of this article is to examine the difficulties in managing agricultural waste and to offer creative solutions and industry best practices for dealing with these problems. We will demonstrate the possibilities of contemporary technologies and sustainable practices in turning agricultural waste into useful resources by looking at case studies and successful

https://doi.org/10.71058/jodac.v10i01003

examples from different geo-graphical areas. Agricultural waste has the potential to harm the environment and expose personnel to biohazards, which are dangerous biological materials. Because agricultural waste can release toxic gasses that are bad for your health, storing it can increase the risks involved [62].

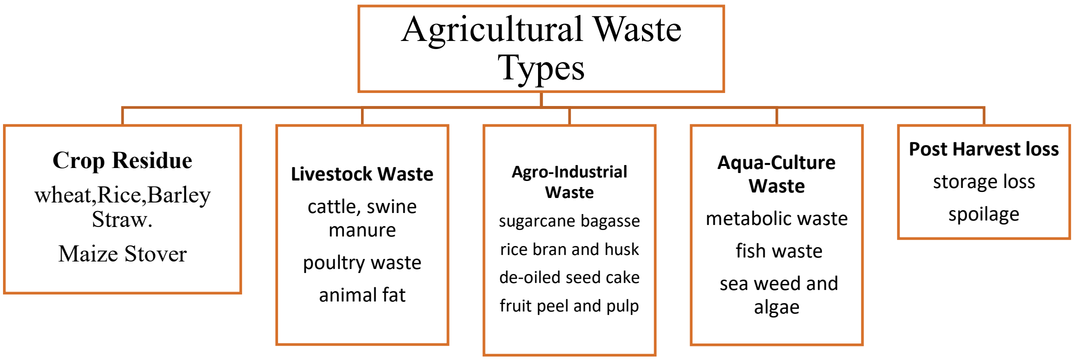


Fig 1. Agricultural Waste Types [63].

2.Production of Agricultural Waste: -

As was previously said, waste from the illogical use of intensive farming techniques and inappropriate chemical use in cultivation typically accompany agricultural expansion, having a significant impact on rural areas in particular and the environment globally in general. The kinds of agricultural operations that are conducted determine the trash that is produced.

2.1 Wastes from Cultivation: Although a tropical climate is ideal for agricultural growth, it also encourages the growth and development of weeds and insects. In order to eradicate those insects and weeds and prevent the development of epidemic diseases, this circumstance generates a high demand for pesticides, which frequently leads to farmers abusing them. Following application, the majority of pesticide bottles and packaging are dumped into ponds or fields. The Plant Protection Department (PPD) estimates that 1.8% of the chemicals are still in their packaging. Because of their potentially hazardous and long-lasting compounds, these wastes have the potential to have unforeseen environmental effects like food illness, poor food hygiene, and contaminated farmland. High production and low cost are characteristics of inorganic fertilizer. Nevertheless, a lot of farmers fertilize their crops with more fertilizer than the plants require. The properties of the land or yield, the kinds of plants, and the fertilization technique all affect how quickly fertilizer chemicals like nitrogen, phosphorous, potassium, etc. are absorbed. Some of the excess fertilizer is retained in the soil, some enters ponds, lakes, and/or rivers due to surface runoff or the irrigation system used, causing surface water to become contaminated; some enters ground water, and some evaporates or de-nitrates, causing air pollution [113].

2.2 Waste from Livestock Production: Every year, more than 3 million tonnes of animal waste, including urine and dung, are produced in India. According to FAO (2020), methane plays a major role in the yearly emissions of greenhouse gases from animal manure, which

https://doi.org/10.71058/jodac.v10i01003

totalled over 1.4 billion tons of CO_2 equivalent in 2018. One of the biggest global polluters is the cattle sector [45]. Brazil is the world's fifth-largest producer of methane, one of the primary greenhouse gases, which is generated in significant quantities. The country's agricultural sector emits the most methane, with 14.54 Mt in 2020, accounting for 71.8% of the total, according to SEEG (System of Estimates of Emissions and Removals of Greenhouse Gases) data. The management of animal waste accounts for the remaining 5.8% (0.85 Mt CH_4). According to the Climate Observatory, animal emission levels will increase by 5.6% if emission mitigation efforts are delayed until 2030 at the current rate of crop and livestock production. Brazil promised at COP26 in Glasgow, Scotland in 2021 to cut global methane emissions by 30% by 2030 compared to 2020 levels, which would be in conflict with this [45]. Trash management from an energy-use viewpoint is essential to supply chain sustainability because of the sector's yearly emissions and waste production. Therefore, the development of waste management technologies within a circular economy is being driven by the global incentive for the adoption of anaerobic digestion technology through legal measures [125].

Solid waste from farm animal activities, such as manure and organic materials in the slaughterhouse; wastewater from animal showering and cage washing; air pollutants, such as hydrogen sulphide (H_2S) and methane (CH_4), and odours are examples of waste from livestock production. Since most of them are usually built around residential areas, the pollution that comes from raising cattle is a major drawback. Odours from cages that result from the process of breaking down animal excrement are one type of air pollution. Temperature, humidity, ventilation, and animal density all affect how strong the odour is. The amounts of ammonia (NH_3), H_2S, and CH_4 change as the digestive process progresses and are also influenced by organic materials, food ingredients, microbes, and the health of the animal. This source of unprocessed and non-reusable garbage will produce greenhouse gasses in addition to harming soil fertility and causing pollution. Water makes about 75% to 95% of the total volume of livestock waste, with the remainder consisting of organic and inorganic debris as well as numerous microorganism species. These microorganisms and materials will spread illnesses to people and harm the environment in a number of ways [91].

2.3 Aquaculture Waste: As cultivation has expanded, more feeds are being used to increase production. The most important factor influencing how much trash is produced in a system is the quantity of feed used. Metabolic waste, which can be suspended or dissolved, is one of the main wastes produced during cultivation. The temperature of the surrounding environment affects feeding rates. A rise in temperature causes more people to feed, which increases the amount of garbage produced. Because proper flow can reduce the fragmentation of fish body waste and allow for quick sinking and concentration of the settleable particles, water flow patterns in production units are essential for waste management. This is crucial because a large percentage of non-fragmented bodily waste may be promptly collected, thus lowering the amount of dissolved organic waste. Aquaculture waste is classified into four categories: gases (H_2S), liquid (effluents), semisolids and solids (particulate fraction), and the latter two are called sludge or sediments [28]. There are two categories of solid waste, or sludge: suspended materials and settleable solids. In aquaculture systems, sulphur (S) is a residual chemical element that is derived from the metabolic waste that farmed species create [39]. Since S oxidizes to sulphate ($SO_4^{2-)}$ and breaks down as sulfide (S^{2-}) when suspended in aerobic sedimentary conditions, it primarily occurs as a sulfate ion. In most aquaculture systems, the food supply is the main source of water contamination and degradation [28]. The remaining nutrients must be removed and are usually discharged into the environment as effluents, which are fluids that contain liquid, gaseous, or solid waste; only 30% of the nutrients that are delivered are transformed into products. Change is brought about by suspended particles because they block light from passing through water, which prevents photosynthesis in phytoplankton and marine grasses and increases their mortality. The ensuing oxygen consumption in the

https://doi.org/10.71058/jodac.v10i01003

water brought on by the bacterial breakdown of dead plants has a negative impact on aquatic species farming. The aquatic food web at its base may be impacted by the transformation of aquatic creature profiles into sediment-tolerant species under harsh circumstances [47]. Additionally, the particle component in ponds and cultivated areas tends to biologically disintegrate as it falls to the bottom due to its organic matter concentration, making the bottom anaerobic [47].

2.4 Crop Residue: - The states that generate the most crop waste, According to National policy for management of crop residues(NPMCR), are Maharashtra (46 Mt), Punjab (51 Mt), and Uttar Pradesh (60 Mt). Out of the 500 Mt produced annually, 92 Mt are burned [74]. Combine harvesters are mainly used to harvest and thresh coarse rice, leaving behind leftover leftovers in the form of gluts or thin strips. This is particularly true if the harvesters do not have spreaders installed [57]. There is a comparatively short window for using or disposing of rice trash between the harvest of rice and the rabi season (October to November), when crops like potatoes, wheat, or vegetables are seeded [121]. Farmers consequently burn all or a portion of the 80% of rice leftovers generated each year. Crop residue burning causes a lot of environmental issues [57]. Burning crop residue has several negative effects, including raising greenhouse gas emissions that exacerbate global warming, raising smog and particulate matter levels that are bad for human health, destroying the biodiversity of agricultural lands, and lowering soil fertility [69]. Burning crop residue significantly increases air pollutants such as non-methane hydrocarbons (NMHC), volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), carbon dioxide (CO_2), and NH_3 (Reddy *et.al*, 2023). This basically explains why nutrients that would have stayed in the soil, like organic carbon and nitrogen, have vanished [61,63]. About 8.57 Mt of carbon monoxide, 141.15 Mt of carbon dioxide, 0.23 Mt of nitrogen oxides (NO), 0.12 Mt of NH_3, 1.46 Mt of NMVOC, 0.65 Mt of NMHC, and 1.21 Mt of PM were released in 2008–2009 as a result of burning 98.4 Mt of crop residue. Of these emissions, CO_2 accounted for 91.6%.

Table.2 Top 5 CO_2 Equivalent Emitting Countries by Crop Residues with average values during 2010-2017 [42,63]

S.no.	Country	Gigagram
1.	China mainland	4500
2.	India	3500
3.	USA	3000
4.	Brazil	1500
5.	Russian Federation	1000

2.5 Post-harvest losses: Define post-harvest losses as the losses in agricultural produce, both quantitative and qualitative, that occur between harvest and processing or consumption [79]. These losses can be caused by a variety of factors, including as inadequate storage facilities, negligent handling, transportation issues, pests, diseases, and natural calamities. In "Advancements and Challenges in Agriculture Waste Management, reducing post-harvest losses is crucial to boosting agricultural productivity, ensuring food security, and reducing financial losses for farmers and other stakeholders [129]. Effective management initiatives include enhancing transportation systems, implementing proper storage protocols, adopting state-of-the-art technology such as cold storage and drying processes, promoting better handling practices throughout the supply chain, and improving

https://doi.org/10.71058/jodac.v10i01003

infrastructure. Reducing post-harvest losses promotes sustainable agriculture, preserves food for human consumption, and lessens the impact on the environment by producing less trash [81].

The following is a list of factors that influence food loss generally, from harvest to consumer.

2.5.1 Gathering phase: A successful harvest in agriculture is the consequence of meticulous planning, a great deal of labour, and a significant financial investment [49]. Nevertheless, despite these efforts, the quantity and quality of the harvested produce can be significantly influenced by two primary factors: inadequate environmental conditions and industrial methods. Subpar production methods encompass a broad range of agricultural practices that do not adhere to the optimal standards for crop growing [72]. Using inferior seed varieties, improper irrigation techniques, insufficient fertilization, or inadequate soil preparation are a few examples of these practices. When production methods do not adhere to best standards, crops are more vulnerable to diseases, insect infestations, and nutrient shortages. All of these elements may have a detrimental effect on the crops' capacity to develop, grow, and yield the most food possible [63]. Additionally, employing suboptimal production methods may result in premature senescence or uneven ripening, thus diminishing the quality and market value of the harvested food. Environmental factors also have a big influence on crop yield and post-harvest outcomes. In addition to extreme weather events like storms, floods, droughts, and frosts, these variables encompass a broad variety of meteorological phenomena, including changes in temperature, precipitation, humidity, and exposure to sunlight [30]. By physically damaging tissues, stressing plants, and interfering with physiological processes, unfavourable environmental conditions can directly affect crop health and yield [39]. Additionally, environmental stressors might hasten degradation, promote the spread of pests and diseases, or impede harvesting due to adverse weather conditions [56,63]. Post-harvest losses could result indirectly from each of these variables. Addressing the problems caused by subpar production methods and environmental factors is necessary to improve agricultural waste management and lower post-harvest losses [43]. This necessitates the implementation of comprehensive strategies that include improved agronomic practices, increased resilience to environmental shocks, and the application of cutting-edge technologies along the entire agricultural value chain [22]. By promoting sustainable production systems, optimizing resource utilization, and enhancing crop resilience, stakeholders can minimize post-harvest losses, maximize agricultural activity efficiency, and help create a more resilient and environmentally friendly food system [127].

2.5.2 Throughout the Food storage phase: - The quantity and quality of agricultural products during this critical storage period can be significantly impacted by a wide range of factors, which also impacts the overall effectiveness of agricultural waste management programs [27]. Temperature and humidity are two of the most important factors in determining how quickly stored goods decay and perish. Inappropriate storage conditions with excessive humidity levels can lead to decay and rot in crops by creating the perfect environment for the growth of mould and fungus [55]. Conversely, abnormally low humidity levels can cause perishable goods to dry out and lose their flavour or suitability for human eating. Because temperature changes can accelerate physiological processes like respiration and ethylene production, which can result in the early phases of senescence and degradation, they can also pose a serious risk to stored crops [102]. Temperature variations, which are exacerbated by inadequate insulation and ventilation in storage facilities, can potentially compromise the integrity of the product that has been stored. Inappropriate handling practices can raise the risk of bruising, physical damage, and mechanical injury when agricultural commodities are being transported and stored. These occurrences not only reduce the produce's visual attractiveness but also act as entry routes for

https://doi.org/10.71058/jodac.v10i01003

microbiological infectious agents and spoiling organisms [9]. Additionally, improper palletization and stacking techniques can result in compression damage and air circulation restrictions, which can create hotspots and uneven ripening in storage batches [63]. Insect infestations and microbial attacks are significant risks during the food storage period. By consuming or contaminating preserved crops, pests including weevils, caterpillars, and mites can result in significant losses [32]. In a similar vein, bacterial and fungal diseases can proliferate rapidly under optimal storage conditions, leading to quality deterioration and mycotoxin accumulation, both of which pose a major risk to consumer health. A complete approach that includes state-of-the-art storage technology, stringent quality control protocols, and efficient pest management strategies is required for agricultural waste management because of these complicated concerns [76]. The use of airtight storage systems, controlled atmosphere preservation, and altered atmosphere packaging may successfully control temperature and humidity levels, thereby increasing the shelf life of preserved product and lowering post-harvest losses [61,63]. Furthermore, at every point of the chain of custody, the integrity and safety of stored commodities can be ensured by putting in place stringent sanitation protocols, employee training initiatives, and good agricultural practices, all of which can help lower the risk of contamination [87]. By proactively addressing the various factors that impact crops throughout the food storage stage, stakeholders can increase the efficacy and sustainability of agricultural waste management projects [68]. Eventually, this will result in a more robust and secure food system.

2.5.3 During Food Processing Stage: - Food loss at the food processing stage is mostly caused by the disposal of mechanically damaged food, inferior food products, items rejected only for their appearance, etc. [65]. Food that has been physically damaged throughout the harvesting, processing, and shipping processes may not be suitable for commerce or human consumption. This type of harm is known as mechanical damage. Inadequate packing, rough handling equipment, or incorrect handling can all lead to produce that is bruised, crushed, or broken (Verma *et.al,*2022). In a similar vein, discarding inferior food products is a significant contributor to food loss in the agricultural supply chain. Crops may fail to meet quality standards due to irregularities in form, size, or color, or they may have minor defects or anomalies that do not compromise their safety or nutritional value [63]. These products are usually rejected by retailers, distributors, or customers based solely on appearance criteria, even when they are entirely edible and healthful. The practice of discarding food based solely on appearance leads to significant food loss and waste across the agricultural value chain [43]. Food that does not meet the strict visual standards set by retailers may be deemed unsellable and thrown out, even when it still contains flavour and nutritional value. Both producers and vendors suffer large financial losses as a result of the waste of vital resources used in production, including as land, energy, and water, which also worsens hunger and environmental degradation [20]. The issue of food loss requires a multifaceted approach that includes improved harvesting and processing techniques, enhanced supply chain effectiveness, consumer education, and policy intervention [6]. By implementing strategies to prevent mechanical damage, optimize packing and storage conditions, and reduce rejection of produce based solely on aesthetics, stakeholders can reduce food waste, improve resource utilization, and advance a more equitable and environmentally friendly food system. Campaigns to alter consumer views about faulty product and raise awareness of the importance of preventing food waste can also mitigate the economic and environmental costs of food loss [137].

2.5.4 During the Packaging Phase: The two primary causes of inefficiency and potential food loss in the agriculture supply chain during the packaging stage of agricultural goods are inadequate packing services and packaging errors [7]. Poor Packaging Services: poor or insufficient packaging services can lead to a variety of issues that compromise the integrity and calibre of the packed items. This could entail using packing materials that aren't suitable for the product's specific requirements, like ones that don't provide enough

https://doi.org/10.71058/jodac.v10i01003

protection against moisture, oxygen, or physical damage. Using outdated, poorly maintained packing equipment that cannot efficiently handle the volume or variety of commodities is another example of inappropriate packaging help [80]. Inadequate packaging services can also lead to delays, errors, or inconsistencies in the packaging process, which can produce less-than-ideal packing outcomes and increase the risk of food contamination or rotting during storage and transit [33]. Packaging blunders are faults or omissions made during the packing process that compromise the quality, safety, or commercial viability of the items. Product separation, portioning, sealing, labelling, palletizing, and other packaging production processes can all result in these mistakes [89]. Misaligned packing materials, incorrect labelling or barcoding, improper sealing or closure of packaging containers, and wrong portion sizes are examples of common packaging errors [15]. Packaging errors can be caused by human error, equipment failure, inadequate supervision or training, or inadequate quality control processes [90]. Regardless of the cause, packaging mistakes can have major consequences, including product recalls, consumer complaints, monetary losses, and damage to a brand's reputation [61]. a plan that allocates funds for infrastructure, technology, training, and quality control methods, this could mean updating packaging equipment and infrastructure, implementing best practices and standardized packaging processes, providing continuous training and support to packaging employees, and establishing quality control systems to detect and prevent packaging issues [112]. Furthermore, to ensure that packaging criteria are understood and consistently met, collaboration and communication among supply chain actors are essential. By addressing these challenges, stakeholders may minimize food loss, enhance the efficacy and sustainability of farmed waste management programs, and maximize each packaging phase of the agricultural supply chain [70].

2.5.5 Throughout the Marketing Stage: Food loss due to poor marketing is brought on by damaged cans, improper portioning, and overextending. During the marketing stage of the supply chain for agriculture, a variety of problems, including improper division, overextending, and dented cans, can have a detrimental effect on consumer perceptions and purchase decisions and lead to food loss. Inappropriate Portioning: LIMO 2023 defines improper portioning as when food is packaged or served in larger amounts than what patrons need or expect. Customers may find it difficult to consume the entire amount before it spoils due to improper portioning, which could lead to food waste [41]. Customers may find it challenging to consume the entire quantity before it spoils, for example, if perishable foods are packaged in bulk or family-sized portions but are intended for single or smaller households. Large portions can also result in excess and food waste if patrons are unable to consume the entire meal or properly preserve the leftovers. Giving clients larger-than-average portions or package sizes, usually as part of special deals or value meals, is known as supersizing (Ali, 2023). In addition to tempting consumers searching for better offers, supersizing may inadvertently encourage overindulgence and food waste. Larger portions may exceed what a person needs to consume or what their appetite can sustain, which may lead to leftovers that spoil and are discarded [9]. Supersized portions may also normalize the practice of consuming excessive amounts of food and promote unsustainable eating habits (Kumar *et.al*,2024). Dented Cans: Dented cans pose a unique marketing challenge since consumers may perceive them as broken or of inferior quality. Even minor flaws in food packaging might make consumers doubt the product's safety and freshness and make them avoid purchasing or ingesting the affected items. Food waste may result from defective cans being left unsold on store shelves or marked down for a quick sale if they are not sold before they expire [63]. Deteriorated packaging can also shorten canned food's shelf life and eventually lead to contamination or spoiling.

2.5.6 During Consumption Phase: - Food waste at the consumer level is caused by impulsive purchases, leftovers, infrequent market outings, and other factors at the consuming stage. Several factors can contribute to food waste at the consumer level during the eating stage, such as: a) Leftovers: People sometimes prepare or serve more food than

https://doi.org/10.71058/jodac.v10i01003

they can consume, which leads to leftovers. Improper usage or storage of these leftovers before they spoil can result in waste [61,62,63].

b) Impulsive Buying: Making impulsive purchases, especially when grocery shopping, can lead to the acquisition of items that might not be used before they expire. Food waste may result if these items are stored unused and then discarded [75].

c) Regular Market Visits: People who visit the market or grocery shop infrequently may buy more food than they actually need in an attempt to keep their supplies longer. Perishable goods, such as fruits, vegetables, and dairy products, may spoil before they are consumed as a result [75].

d) Inadequate Meal Preparation: People who overestimate their meal needs and disregard portion sizes may end up cooking too much food and wasting it [63,78].

e) Misinterpretation of Expiration Dates: Even when food is still safe to eat, consumers may discard it too soon based on its expiration date. This could lead to unnecessary food waste that should be avoided [63,78].

f) Lack of Knowledge or Awareness: Some patrons may not understand how to use leftovers or store food appropriately, which could lead to waste that could have been avoided [9].

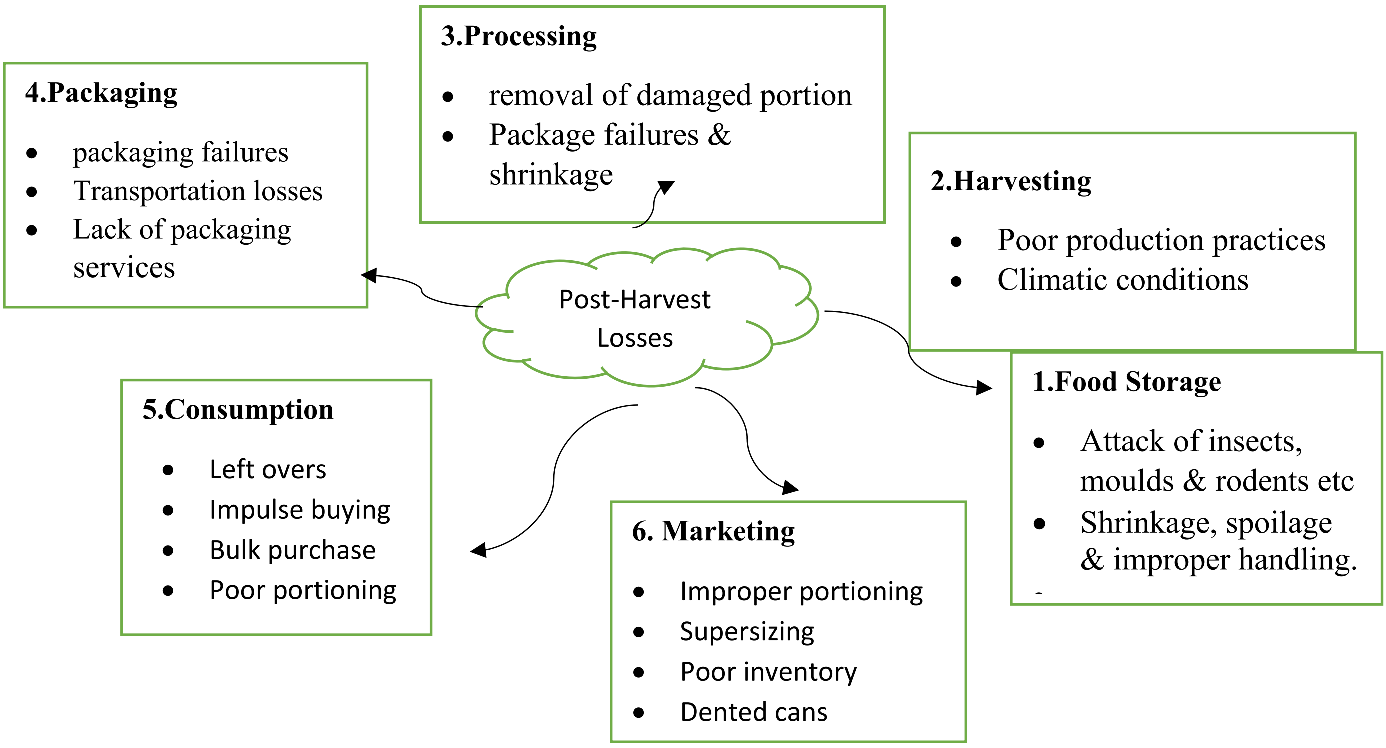


Fig.1 Post Harvest Losses [63].

3. Challenges in the Handling of Agricultural Waste:

3.1 Waste Composition Variability: Agricultural waste includes a variety of materials, including pesticide containers, manure, food waste, and crop residues [63]. The

https://doi.org/10.71058/jodac.v10i01003

unpredictable nature of waste composition hinders the development of standardized waste management methods and technology that can effectively handle a range of waste types [86].

3.2 Storage and Handling Issues: Agricultural waste needs to be handled and stored correctly to prevent environmental contamination, odours, and health hazards [10]. Since many farms lack the necessary infrastructure and storage space, improper waste management practices like open burning and negligent dumping that might damage the air and water are encouraged [119].

3.3 Variations by Season: The process of producing agricultural waste usually shows seasonal patterns, peaking during harvest seasons or periods of intensive farming [29]. Managing massive amounts of waste during these busy periods can strain the infrastructure and waste management systems currently in place, causing logistical problems and potentially endangering the environment if waste is not managed properly [60,61].

3.4 Limited Technology and Resource Access: The small-scale and resource-constrained farmers may lack the technology, resources, or instruments necessary for effective waste management [59]. This includes having access to facilities for composting, garbage collection products or services, and recycling infrastructure. To ensure equitable and sustainable waste management practices among various farming communities, these disparities must be addressed [102].

3.5 Hazards of Pollution and Contamination: Inappropriate management and disposal of agricultural waste can release harmful metals, pesticides, and viruses into the air, water, and soil [73]. Contaminated trash poses a threat to human health, environmental integrity, and food safety, underscoring the importance of implementing suitable waste management practices and assessment methods [1].

3.6 Regulatory Compliance and Enforcement: Farmers and agricultural enterprises may find it challenging to adhere to waste management standards due to complex regulatory frameworks, burdensome administrative requirements, and enforcement issues [35]. Uncertain legislation, inconsistent enforcement, and a lack of resources for compliance monitoring may hinder efforts to improve waste management practices and achieve environmental goals [60,61].

3.7 Incentives and Economic Viability: Because ecological waste management techniques sometimes require upfront investments in infrastructure, equipment, and training, farmers—especially those with small profit margins—may encounter financial challenges when putting them into practice [123]. The lack of financial incentives or market opportunities for recycled or reused agricultural waste may further deter investment in waste management solutions [64].

3.8 Cultural and Social Aspects: The following elements may influence the adoption of novel waste management practices: community norms, customs, and sociocultural attitudes on rubbish management [36]. It is necessary to remove cultural barriers, dispel myths, and include local communities in decision-making processes in order to promote acceptability and participation in farm waste management initiatives [111].

3.9 Impacts of Climate Change: Climate change alters weather patterns, increases the frequency of extreme events, and impacts crop yields, all of which exacerbate problems with agricultural waste management [86]. In addition to enhancing the systems' resistance to climate change hazards, adaptation methods are required to lessen the effects of climate change on waste generation, storage, and treatment [4].

https://doi.org/10.71058/jodac.v10i01003

3.10 Knowledge and Data Gaps: Lack of data, research gaps, and barriers to information dissemination hinder the development and implementation of evidence-based waste management techniques [38]. Funds for research, data collection, and knowledge-sharing initiatives can be provided in order to bridge these gaps and enhance decision-making for more successful and sustainable agricultural waste management [88].

4. Technological Conversion for Ecological Crop Residue Management:

Future population expansion will require more food production, which increases the possibility that crop residue development may occur soon [139]. In addition to a number of other environmental issues, the extensive usage of fossil fuels in modern times is producing massive greenhouse gas emissions. Bioenergy is becoming more and more popular as a substitute for fossil fuels in the creation of sustainable energy since it is seen as a renewable energy source [108]. Biomass is the source of bioenergy. Biofuels, which may be produced from consumable food crops including potatoes, sunflower, sugarcane, barley, and maize, are the primary sources of bioenergy [124]. However, the generation of biofuel from agricultural waste, particularly crop leftovers, has recently attracted attention in an effort to facilitate residue recovery and the development of renewable energy sources from diverse conversion processes [59,60]. Crop residues that are high in lignocellulosic materials are cheap, simple to incorporate into the food chain, and excellent sources of energy [61]. For instance, power is produced from only 12.2% of India's 500 Mt of agricultural waste annually [56].

4.1 Changes through Thermochemistry: -
Thermochemical conversion involves three steps: liquefaction, pyrolysis, and gasification. [59]. The method selection is influenced by a number of factors, including the type and quantity of leftovers, energy preferences, financial limitations, and environmental requirements [82].

4.1.1 Solidification: - This process creates a mixture of combustible gases by heating the biomass without oxygen to 500–1400 °C while maintaining an air pressure of 33 bar. The carbonaceous wastes are converted into syngas, a blend of hydrocarbons, methane, carbon dioxide, and hydrogen, by adding gasification agents during this process [118]. This syngas contains the gas hydrogen, biofuel, and biomethane as gas. Reports state that gasification is a more efficient method of producing hydrogen gas than liquefaction or pyrolysis [5]. Gasification produces large volumes of CO and CO_2, while agricultural waste has higher levels of CO_2 and CO. A gasifier with a fluidized bed is used to gasify rice straw [67]. Among the metallic elements used as catalysts to boost the production of hydrogen and methane are Ni, Ru, Cu, and Co [135].

4.1.2 Method of pyrolysis: - A further method for the thermal breakdown of biomass is pyrolysis, which occurs in anoxic environments at temperatures between 350 and 550 degrees Celsius. The process that converts organic waste into a mixture of solids, liquids, and gases is called pyrolysis. More specifically, gasification produces combustible fuel gas, whereas pyrolysis produces liquid fuel, sometimes known as bio-oil or py-oil. Three types of pyrolysis can be identified based on the operational conditions: flash, rapid, and slow pyrolysis. Because this process is cost-effective, energy-efficient, and environmentally safe. The fastest pyrolysis process is becoming more and more popular as a way to make biofuel, even if it may yield a high percentage of fuel oil (75 weight percent) [12].

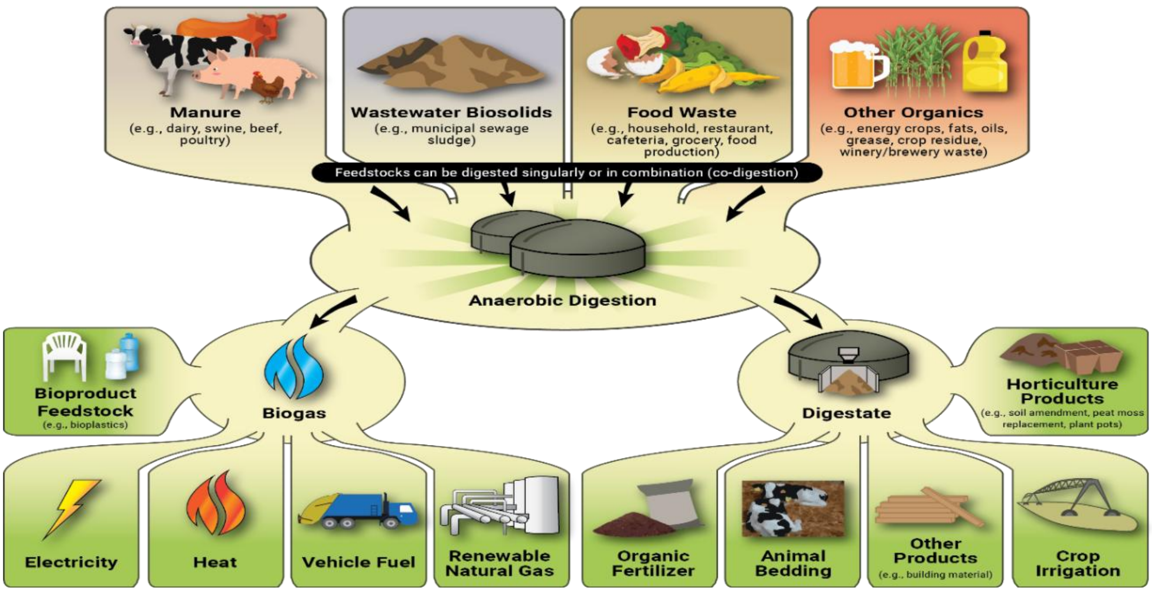
4.2. Transformation Based on Biochemistry: - In order to convert the leftovers into useable energy, some bacteria and yeast are involved in this process. In order to generate

https://doi.org/10.71058/jodac.v10i01003

sustainable energy, three biochemical transformation methods have been developed: anaerobic breakdown, alcoholic fermentation, and photobiological approaches [78].

4.2.1. Anaerobic digestion: - It is a technique that generates biogas using residual biomass and a range of microorganisms. Methane and CO_2 make up the majority of the biogas, which accounts for 20–40% of the biomass's total energy and has a poor heating value [117]. Wet biomass up to 90% in moisture content can still be used for this procedure. The three main stages of anaerobic digestion are hydrolysis, fermentation, and methanogenesis (Hou and Zhu, 2024). These simple biomolecules undergo fermentation to yield alcohol, fatty acids, acetic acids, H_2, and CO_2 after hydrolysing from complicated biomolecules. These gas combinations are broken down by methanogenesis to produce biogas, which is composed of 30–40% CO_2 and 60–70% CH_4 [110]. The process of anaerobic digestion functions as a biological mechanism. It decomposes complex organic materials such as sewage sludge, wastewater, organic waste from animals, and plant biomass. Without oxygen, this process produces digested matter and biogas. Anaerobic bacteria of several kinds carry out this function. Anaerobic digestion has been used for years to stabilize sewage sludge. This technique has become more popular recently for treating and recovering energy from various wastes. These consist of wastewater from factories, industrial organic waste, and animal waste that has been segregated from home rubbish [107]. There are numerous benefits to producing and using biogas through anaerobic fermentation. Both the participating farmers and society at large gain from it. Renewable energy sources, lower greenhouse gas emissions and less global warming, compliance with EU energy and environmental protection standards for agriculture, fewer smells from livestock and other organic waste, and a sizable boost in revenue for the agricultural sector are just a few of these social, economic, and environmental advantages.

There are two limited environmental effects of anaerobic digestion that are related to the production of biogas itself: the risk of odours, which can be mitigated by burning odorous materials in exhaust air or using other odour treatment methods, and the risk of explosion, which can be mitigated by using equipment that is explosion-proof.



https://doi.org/10.71058/jodac.v10i01003

Fig 2. Anaerobic digestion process [132].

4.2.2. Fermentation of Alcohol: - With the help of bacteria or yeast, the fermentable sugars in the leftovers can be utilized to ferment alcohol and produce bioethanol [26]. Before feeding, the hydrolysis process is used to break down complex polysaccharides into simple carbohydrates. Crude alcohol, which has an ethanol level of 10% to 15%, is then produced using drawn-out distillation procedures [130]. The residual materials are transformed into useful products through the processes of pyrolysis, gasification, and liquefaction [37].

4.2.3. Photobiological Techniques: - Plant growth and development are entirely dependent on light. Plants respond differently to different wavelengths [120]. In plants, various physiological, physical, and biological activities are regulated by distinct wavelengths [114]. Plants commonly use this method to control a variety of physiological and biological functions. Additionally, it aids in controlling the growth and development of plants [83].

4.3 Producing Bioelectric power from crop residues: - The leftover lignocellulosic crop wastes can produce bioelectricity. Burning generates heat, CO_2, and H_2O when biomass and oxygen (O_2) are combined at a high temperature [136]. During the process, chemical energy is transformed into radiation, heat, and light energy. Char and volatiles from the biomass combine with oxygen to produce heat [47]. The stream produced by this heating process subsequently powers the turbine that generates the steam required to generate energy. Recently, a promising new technology called microbial fuel cells (MFCs) was developed to use electrogenic bacteria to produce bioelectricity from organic waste without the need for an oxygen source [44]. The bioelectricity generated from agricultural waste significantly decreased greenhouse gas emissions, offsetting Australia's overall emissions by 28% and its electrical emissions by 9% [13]. Bioelectricity produced from agricultural waste is anticipated to produce 10–20% of future electricity and cut carbon dioxide emissions by around 27 million tons over a fifteen-year period. Additionally, MFC has a lot of promise for environmentally responsible and sustainable high-density energy generation.

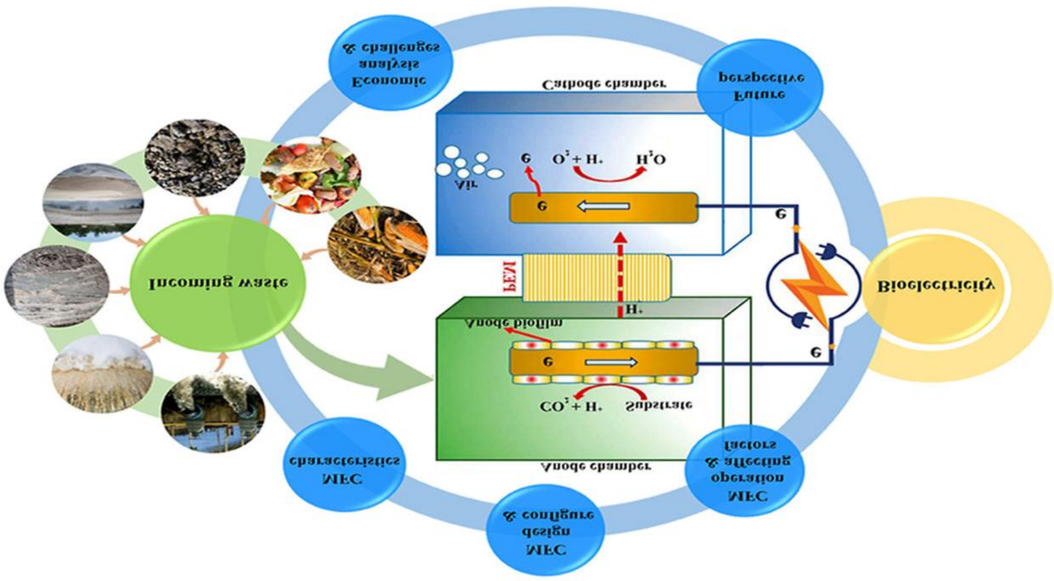


Fig 3. MFC (Microbial cell technology) [44].

4.4 Crop Residues Improve the Fertility and Productivity of The Soil: -
The importance of crop residue in international agriculture is growing. It is regarded as an excellent source of organic matter and improves soil carbon stock, water conservation,

nutrient recycling, and soil qualities. Furthermore, it reduces the likelihood of burned residue and the environmental risks associated with its retention. Cereals make up 74% of all agricultural wastes, with tubers accounting for 5%, sugar crops for 10%, oil seeds for 3%, and legumes for 8% of the total [105]. Crop residue may contain a variety of minerals in addition to C, depending on the crop and soil conditions [126]. It is widely acknowledged that crop residues first immobilize the soil's accessible nitrogen by using a high C: N ratio. As a result, it is challenging to predict how much nutrient will become available to the crops throughout the crop residue absorption period [93]. But over an extended period of time, this approach seems to be rather successful in producing better organic matter and supplying nutrients for succeeding crops, both of which raise the output of food crops. Cereals are second to legumes in terms of agricultural residue output [24]. Legume residues are known as high-quality residues rather than high-quantity residues because they provide a significant amount of soil carbon over an extended period of time.

4.5 Agro-Waste Recycling and Composting: -

The two most common conventional methods of managing agricultural wastes are flushing them out of fields soon after harvest or tilling them into the ground for disposal [73]. The chemical makeup of crop wastes can determine whether they are beneficial or harmful to an agroecosystem. The leftovers may include toxic substances or infectious microorganisms that could endanger human health. derived from a crop cultivated in polluted soil [131]. Nonetheless, there are several benefits to leaving leftovers in the field, such as improved nutrient absorption and mineralization efficiency and the release of minerals into soils [34]. Burning or trashing of agricultural leftovers is a common practice after harvesting in developing countries. Approximately 35, 85, and 45% of the nitrogen, phosphorus, and potassium that rice plants ingest remain in the vegetative sections where they can be recycled to improve the soil and support subsequent crops [48]. A microbial process that speeds up the biological breakdown, bioconversion, and disintegration of complicated elements into more easily soluble inorganic and organic components is required before agricultural waste may be composted [18]. The type of agricultural waste, its C: N ratio, and environmental factors like pH, aeration, moisture content, temperature, etc. are the primary factors affecting this process. In general, the composting process must be initiated by adding bacteria that promote plant growth or an important chemical fertilizer (NPK) [48]. It is also known as the aerobic fermentation, is a popular and practical strategy to deal with organic waste by turning it into compost for farms. Composting is widely regarded as the best way to handle organic waste. Clean organic waste from gardens and parks can now be composted in open spaces without the need for additional air. To expedite the process and prevent unpleasant odors, you can also perform it in enclosed areas. In this instance, the waste is first ground, sieved, and combined. Composting reduces the amount of garbage that ends up in landfills, which benefits the environment and helps to prevent environmental hazards. Because it lessens the likelihood that bacteria in trash can survive and spread, it is also beneficial to health [11]. The following are examples of composting technology:

1.It guarantees environmental preservation in the vicinity of cattle rearing as well as throughout the entire region where it is implemented.

2. A concentrated product that is easy to transport, odourless, pathogen-free, and easy to store takes the place of a bulky product with high humidity.

3. One product that might lessen the lack of organic matter and micronutrients in agricultural soils is compost.

4. There are major environmental advantages to using compost as a growing medium or fertilizer for agricultural land. Compost biodegradable waste no longer reaches the ecological deposit, in addition to reintegrating nutrients in the soil, which reduces the preference for chemical fertilizers. Since composting is still a relatively new activity, its

https://doi.org/10.71058/jodac.v10i01003

greenhouse gas emissions contribute little to global warming. Odour emissions are eliminated by a bio-filter in enclosed composting facilities (Montgomery,2007).

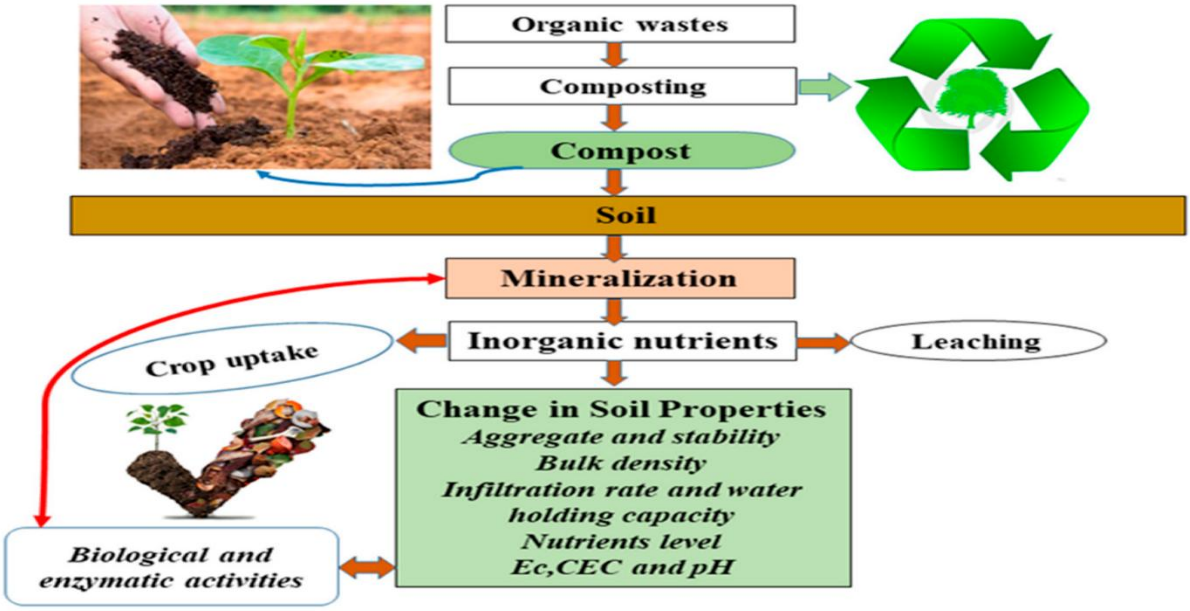


Figure 3. compost mineralization after application [48,105].

4.6 Integration of Information and Communication Technologies: By offering real-time data, enhancing resource allocation, and promoting improved decision-making, information and communication technologies (ICT) can be extremely helpful in streamlining agricultural waste management procedures. improves waste management operations' efficacy and efficiency by using data to inform decisions. enhances trash creation, collection, and processing tracking and monitoring. improves resource allocation and decision-making by facilitating coordination and communication among stakeholders, such as farmers, waste processors, and policymakers using real-time data [92,93].

4.7 Policy Support and Community engagement: - Support from policymakers and active community involvement are essential for efficient agricultural waste management because they guarantee the uptake and sustainability of creative solutions [92]. fosters the use of environmentally friendly garbage management techniques. promotes cooperation and community involvement in garbage management projects. increases the impact and scalability of waste management systems.

4.8 Production of Biogas and Bioenergy: The multi-step biological process of anaerobic digestion (AD) primarily converts organic material into the gases carbon dioxide and methane, with trace amounts of nitrogen, ammonia, hydrogen sulphide, and hydrogen vapor also being produced [96]. The AD process is a proven technique that may meet energy demands for fuel, heating, power, and other applications using cheap feedstock or even organic waste from industry and municipalities [54]. This proves that it is financially possible. Numerous studies have been carried out to look into the feasibility of producing bio-methane from different agricultural wastes, as shown in Table 3 Rice straw has an organic value of about 82%, while maize and sugarcane can have up to 92% organic content [77]. They are ideal for producing biogas due to their high content of organic matter and carbohydrates, which results in an average methane generation rate of 50–55% [140]. Because they are easily broken down, the bacteria involved in fermentation prefer the carbohydrates. Moreover, the bacteria that produce methane may use hydrogen and other intermediate products such lactic and acetic acids [99].

https://doi.org/10.71058/jodac.v10i01003

Table 3. Bio Methane Potential of Various Crop Residues

Crop residue	Bio- methane potential	Source
sugarcane	460	[63]
Potato crop	280	[63]
Cassava tuber	660	[63]
Cotton stalk hull	200	[3]
Corn waste	307	[63]
Rice straw	390	[77]

In addition to organic matter, other parameters that affect the production of biogas from various agricultural wastes include trace metals and the C/N ratio. It is evident that higher methane concentrations in maize, rice straw, and sugar cane are associated with trace metals such as calcium, iron, and chromium [106]. A 25:1 ratio has been proposed for the C/N component. Crop wastes from rice, maize, and sugarcane are particularly advantageous for the production of biogas since they naturally contain more carbon than nitrogen [50].

5. Implications for Policy and Socioeconomics: -

The socio-economic and policy outcomes of agriculture waste management are the broader societal and economic repercussions of strategies and policies which are meant to reduce waste generated from agricultural activities [31]. Social justice, environmental sustainability, economic sustainability, and regulatory frameworks are just a few of the many themes covered here. In effect Agricultural waste management can have a big impact on society and the economy.

5.1. Environmental Sustainability: Effective waste management practices help to reduce environmental deterioration by lowering pollutants, greenhouse gas emissions, and the utilization of natural resources. This promotes sustainable farming practices and the protection of the environment and biodiversity [134].

5.2. Prospects for Finance: Opportunities for business can develop because waste products can be turned profitable through effective waste management. For instance, composting organic waste can produce beneficial soil nutrients, and turning agricultural waste into bioenergy can help reduce dependency on fossil fuels and improve the availability of renewable energy sources [40].

5.3. Resource Efficiency: Implementing waste management strategies that prioritize recycling, reuse, and resource recovery can boost resource efficiency in agriculture [95]. This means improving nutrient cycling, reducing input costs, and increasing overall productivity.

5.4. Public health and Safety: - Proper waste management practices lessen the health risks associated with agricultural waste, including as exposure to dangerous chemicals, the spread of illness, and contaminating water supplies [61]. This protects agricultural workers and neighbouring communities [103].

https://doi.org/10.71058/jodac.v10i01003

5.5. Social Justice: - Policies related to waste management should consider social justice by considering potential impacts on small-scale farmers or marginalized communities living near agricultural areas, for instance. Fair access to resources and involvement in decision-making processes are essential for advancing social justice [17].

6. Policy Implications:

6.1. Regulatory Frameworks: Governments play a crucial role in developing and enforcing regulations and policies for the handling of agricultural waste [62]. These frameworks may include guidelines for trash disposal, strategies for lowering pollutants, and financial incentives for adopting sustainable behaviours [70].

6.2. **Mechanisms of Incentive**: Policy incentives such as grants, tax credits, and subsidies can be used to encourage farmers to adopt waste management practices that promote environmental objectives. Financial incentives can be used to promote the use of sustainable technology and partially offset the costs of initial investments [61,62].

6.3. Research and Innovation: Policies should support research and innovation in farm waste management to foster the development of new technologies, practices, and economic opportunities [14]. Public-private collaborations and research funding initiatives can promote innovation and information exchange [102].

6.4. Stakeholder Engagement: To execute efficient waste management plans, farmers, corporate representatives, political entities, and community organizations must collaborate [16]. Stakeholder engagement processes ensure that policies are influenced by a range of perspectives and tailored for particular communities [128].

7. Issues brought on by Agricultural Waste: -

7.1. Health Issues: When pesticides, ammonia, heavy metals, fertilizers, and oils from farms and farm equipment get up in drinking water, they can have a major negative effect on people's health. Drinking this contaminated water exposes people to these dangerous chemicals, which can result in serious health problems or even early death. According to reports, nitrates from tainted water cause blue baby syndrome, which can lead to infant deaths. Other harmful substances, such as heavy metals, can impair the neurological system, erode the immune system, and damage important organs. Additionally, farm waste can contaminate water with germs and parasites, which increases the risk of illness and death [122].

7.2. Decrease in long-term Agricultural Yields: To combat pests, weeds, and illnesses, farmers continue to use pesticides, herbicides, and other agricultural chemicals. However, many are unaware of the long-term effects these harsh chemicals have on their land. These potent substances remain in the soil for many years. They can destroy beneficial insects and microscopic organisms in the soil, as well as contaminate water and plants. This affects the quality of the crops, the soil's fertility, and the natural equilibrium of the environment. It may eventually result in decreased crop yields. Perhaps this is the reason why some farmers are returning to organic farming practices and traditional manure [58].

7.3. Impact on aquatic life: Groundwater and water systems are significantly impacted by agricultural pollution, which has a detrimental effect on aquatic life. The health and reproductive potential of fish and other aquatic animals are impacted by the absorption of

https://doi.org/10.71058/jodac.v10i01003

agricultural chemicals, herbicides, and fertilizers. Eutrophication occurs when fertilizers, manure, and animal waste contribute significant amounts of nitrogen and phosphorus to surface waters. Fish and other aquatic life are killed by this process, which depletes dissolved oxygen. Ammonia and heavy metals are two other chemical substances that can harm aquatic life and kill fish [122].

7.4. Eutrophication: When nitrogen and phosphorus from fertilizers and manure are washed into adjacent surface waters by irrigation or rainfall, eutrophication results. The dense growth of algae and plants on the water's surface, known as eutrophication, causes numerous algal blooms. Because eutrophication lowers dissolved oxygen, fish and other aquatic life may perish. Additionally, it has been connected to an increase in fatal incidences of paralytic shellfish poisoning in humans.

7.5. Depletion of soil Fertility and Soil Pollution: Chemical pesticides, herbicides, and agrochemicals used to eradicate weeds, diseases, and pests frequently contaminate the soil and can persist for years. Over time, this affects soil chemistry and microbial activity, decreasing soil fertility by eliminating soil microorganisms. According to studies, synthetic fertilizers, pesticides, herbicides, and other farming practices cause the annual loss of millions of productive soils [11].

7.6. Water Pollution: Surface runoff from farming practices, such as inadequate irrigation and management, pollutes both surface and ground water. The use of weed killers, fertilizers, pesticides, manure, and other agricultural chemicals degrades water quality and causes extensive contamination of groundwater and streams. Additionally, sedimentation and soil erosion contaminate the water, making it murky and unclean. As a result, there are adverse effects on humans, animals, plants, wildlife, and aquatic life.

7.7. Air Pollution: Fertilized fields and farm animals can emit a lot of pollutants into the atmosphere. These gases, which include ammonia and nitrogen oxides, contain nitrogen and carbon and may be involved in the greenhouse effect. Fossil fuels are used by farmers when they plough, harvest, or operate equipment like tractors. Greenhouse gas concentrations are affected by this. Additionally, a number of greenhouse gases are released by some natural soil processes [59,61,63].

7.8. Biodiversity Destruction: Soils, animals, plants, waters, and wildlife are all negatively impacted and destroyed by the continuous use of chemical products in farming. The ecosystems that sustain biodiversity are altered as a result. Additionally, beneficial insects, birds, soil microbes, and some rare tiny species, such as butterflies, can all be killed by pesticides. The impact on biodiversity is extensive. These substances have long-term effects on biodiversity because they remain in the soils [107].

8. Multifaceted Strategies as a Remedy: -

8.1. Watershed efforts: Reducing nutrient contamination requires the cooperation of numerous individuals and groups within a watershed. Successful initiatives to improve water quality involve participation from state governments, agricultural associations, nature conservation groups, educational institutions, non-profits, and neighbourhood clubs.

8.2. Management of Nutrients: Pollution can be greatly decreased by applying fertilizers in the right amounts, at the right times of year, and with the right technique.

8.3. Buffers: By absorbing or filtering out nutrients before they reach a water body, planting grass, trees, and bushes around fields—especially those that border water bodies—can aid.

8.4. Cover Crops: By recycling surplus nitrogen and preventing soil erosion, planting specific grasses, grains, or clovers can help keep nutrients out of the water.

https://doi.org/10.71058/jodac.v10i01003

8.5. Conservation Tillage: Reducing the frequency of field tilling improves soil organic matter, decreases runoff, and lessens erosion and compaction.

8.6. Managing Livestock Waste: Restoring stream banks and preventing nitrogen and phosphorus from entering waterways by keeping animals and their excrement out of lakes, rivers, and streams.

8.7. Management of the Drainage Water: Water deterioration in nearby streams and lakes can be avoided by lowering nitrogen loadings that flow from agricultural fields [10].

9. Future Prospects and Challenges: -

Although agricultural waste management has a bright future ahead of it in terms of sustainability and resource efficiency, there are also major obstacles that need to be overcome. We can overcome these obstacles and build a more sustainable future for agriculture and the environment by embracing technological advancements, incorporating the principles of the circular economy, giving climate resilience top priority, fortifying policy frameworks, raising public awareness, and encouraging cross-sector cooperation. Anticipating future directions and the issues that accompany them is essential. Sustainable farming practices, environmental preservation, and resource optimization all depend on the handling of agricultural waste. However, a number of crucial sectors become focus points for upcoming developments and problems as agricultural techniques and technology grow:

9.1. Technical Innovations: The management of agricultural waste will depend more on technical developments in the future. Future developments are anticipated to include robotics for effective collection and processing, bioreactors for the conversion of organic waste, and smart sensors for tracking trash levels. The affordability and availability of these technologies for small-scale farmers, as well as the need for ongoing research and development to increase their scalability and efficacy, are obstacles.

9.2. Bioenergy Production: Growing the production of bioenergy is a key future trend in agricultural waste management. Reducing greenhouse gas emissions and dependency on fossil fuels can be achieved by using agricultural residues, such as food waste, animal dung, and crop remnants, to produce biofuel. Nonetheless, issues like the requirement for sustainable feedstock management and the competition for land use between the production of food and fuel must be resolved.

9.3. Integration of the Circular Economy: One of the main goals for agricultural waste management in the future will be to transition to a circular economy model. Reusing, recycling, and repurposing agricultural waste to produce goods with added value is part of closing the loop. Developing effective trash collection and recycling systems, establishing markets for recycled goods, and guaranteeing the financial sustainability of circular economy projects are some of the challenges.

9.4. Climate Resilience Strategies: As the effects of climate change worsen, climate resilience will need to be prioritized in farm waste management programs moving forward. This involves implementing conservation tillage, cover crops, and agroforestry to improve soil health and water retention, which reduces the quantity of agricultural waste generated. The difficulties are in adapting these methods to a range of agroecological conditions and ensuring their long-term sustainability in the face of changing climatic trends.

9.5. Policy and Regulatory Frameworks: Improving agricultural waste management techniques will require strengthening policy and regulatory frameworks. Future directions can involve creating rules, incentives, and subsidies to promote recycling, proper disposal,

https://doi.org/10.71058/jodac.v10i01003

and trash minimization. Among the difficulties are coordinating policies at various governmental levels and resolving socioeconomic inequalities that could make it more difficult for people to follow waste management laws [97].

9.6. Public Education and Awareness: Increasing public awareness of the importance of managing agricultural waste will be essential to bringing about change. Future initiatives should concentrate on informing farmers, consumers, legislators, and the public at large about the benefits of sustainable waste management practices for the economy, society, and environment. Overcoming misunderstandings regarding trash management and making sure that educational initiatives are both accessible and culturally appropriate are challenges.

9.7. Cross-Sector Collaboration: To effectively handle the intricate problems associated with agricultural waste management, cooperation between sectors will be crucial. Future directions might entail establishing partnerships to share best practices and resources among government agencies, academic institutions, non-governmental organizations, and commercial sector stakeholders. Overcoming institutional obstacles, fostering trust among many stakeholders, and guaranteeing fair involvement in decision-making processes are among the difficulties [97].

10. Conclusion: -

Developments in agricultural waste management offer encouraging alternatives for lowering environmental impact, boosting resource efficiency, and promoting sustainable farming methods. However, before these advancements can realize their full potential, a number of issues must be resolved, such as financial constraints, infrastructure limitations, and behavioural factors. To solve these issues and accomplish the worldwide sustainable agricultural waste management targets, more research, collaboration, and policy support are essential.

11. References: -

[1] Abatan, A., Jacks, B.S., Ugwuanyi, E.D., Nwokediegwu, Z.Q.S., Obaigbena, A., Daraojimba, A.I. and Lottu, O.A., The role of environmental health and safety practices in the automotive manufacturing industry. *Engineering Science & Technology Journal*, *5*(2), **(2024)**. pp.531-542.

[2] Achinas, S., Achinas, V. and Euverink, G.J.W., A technological overview of biogas production from biowaste. *Engineering*, *3*(3), **(2017)** pp.299-307.

[3] Adl, M., Sheng, K. and Gharibi, A. Technical assessment of bioenergy recovery from cotton stalks through anaerobic digestion process and the effects of inexpensive pre-treatments. *Applied energy*, *93*, **(2012)** pp.251-260.

[4] Aggarwal, B. and Gupta, A.K., Managing Disaster Waste in the Aftermath of Emergencies: Addressing Future Climate Risk-Integrating Adaptation. In *Disaster Risk and Management Under Climate Change,* Singapore: Springer Nature Singapore **(2024)** (pp. 263-280).

[5] Aimikhe, V.J., Ogali, O.I.O. and Okoro, E.E., Natural gas production from sewage. In *Advances in Natural Gas* **(2024)** (pp. 309-347). Elsevier.

[6] Akinci, O.S. and Kumcu, S.Y., *Towards Resilient and Sustainable Food Systems: Integrating Agricultural Production Efficiency and Food Security* ***(2024).***

[7] Akkerman, R. and Cruijssen, F., Food loss, food waste, and sustainability in food supply chains. In *Sustainable supply chains: a research-based textbook on operations and strategy* Cham: Springer International Publishing ***(2024)*** (pp. 219-239).

[8] Alegbeleye, O., Odeyemi, O.A., Strateva, M. and Stratev, D., Microbial spoilage of vegetables, fruits and cereals. *Applied Food Research*, *2*(1), ***(2022)*** p.100122.

https://doi.org/10.71058/jodac.v10i01003

[9] Aloysius, N., Ananda, J., Mitsis, A. and Pearson, D, why people are bad at leftover food management? A systematic literature review and a framework to analyze household leftover food waste generation behavior. *Appetite*, *186*, ***(2023)*** p.106577.
[10] Amin, Q.A., Wani, T.A., Amin, T., Nahvi, A.I., Mukhtar, T., Rafique, N. and Bashir, S., Basic and Modern Environmental Management Practices for Food and Agricultural Waste Management. In *Integrated Waste Management Approaches for Food and Agricultural Byproducts* ***(2023)*** (pp. 113-140). Apple Academic Press.
[11] Amruddin, A., Dinar, F., Sulandjari, K., Tanur, E.A. and Andriyani, L.Y., Sustainable Agricultural Practices and Environmental Stewardship: A Global Analysis of Farmer Adoption and Impact. *Global International Journal of Innovative Research*, *2*(3), ***(2024)*** pp.595-603.
[12] Arif, Z. and Kumar, P., Recycling of Agricultural Waste for Biohydrogen Production. In *Emerging Trends and Techniques in Biofuel Production from Agricultural Waste* ***(2024)*** (pp. 223-239). Singapore: Springer Nature Singapore.
[13] Ascher, S., Gordon, J., Bongiovanni, I., Watson, I., Hermannsson, K., Gillespie, S., Sarangi, S., Biakhmetov, B., Bhargava, P.C., Bhaskar, T. and Krishna, B.B., Trigeneration based on the pyrolysis of rural waste in India: Environmental impact, economic feasibility and business model innovation. *Science of The Total Environment*, *921*, ***(2024)*** p.170718.
[14] Azmi, F.R., Roni, M. and Sa'at, M., Circular Supply Chain Management in Developing Countries: Challenges, Opportunities and Pathways to Sustainability. *Information Management and Business Review*, *16*(1 (I)) ***(2024)*** pp.105-115.
[15] Bauer, A.S., Dörnyei, K.R. and Krauter, V., Consumer complaints about food packaging. *Frontiers in Sustainable Food Systems*, *7*, ***(2023)*** p.1047451.
[16] Baumgarten, S., Aarts, N., Fliervoet, J.M. and Krabbenborg, L., Dynamics and Dependencies in Regional Collaboration for Biodiversity Restoration: Reflections from the Netherlands. *Environmental Management*, ***(2024)*** pp.1-16.
[17] Bennett, N.J., Alava, J.J., Ferguson, C.E., Blythe, J., Morgera, E., Boyd, D. and Côté, I.M., 2023. Environmental (in) justice in the Anthropocene ocean. *Marine policy*, *147*, p.105383.
[18] Bhattacharyya, P., Bisen, J., Bhaduri, D., Priyadarsini, S., Munda, S., Chakraborti, M., Adak, T., Panneerselvam, P., Mukherjee, A.K., Swain, S.L. and Dash, P.K., Turn the wheel from waste to wealth: economic and environmental gain of sustainable rice straw management practices over field burning in reference to India. *Science of the Total Environment*, *775*, ***(2021)*** p.145896.
[19] Bhuvaneshwari, S., Hettiarachchi, H. and Meegoda, J.N., 2019. Crop residue burning in India: policy challenges and potential solutions. *International journal of environmental research and public health*, *16*(5), p.832.
[20] Bukhari, S.R.H., Khan, A.U. and Noreen, S., Optimizing Water Resource Governance for Sustainable Agricultural and Hydroelectric Development in Pakistan: An In-Depth Examination and Policy Prescriptions. *Journal of Development and Social Sciences*, *5*(2), ***(2024)*** pp.280-293.
[21] Bzai, J.S.A., *Enhancing performance of big data applying similarity over detected community* (Doctoral dissertation, University of Belgrade (Serbia) ***(2023).***
[22] Camel, A., Belhadi, A., Kamble, S., Tiwari, S. and Touriki, F.E., Integrating smart Green Product Platforming for carbon footprint reduction: The role of blockchain technology and stakeholders influence within the agri-food supply chain. *International Journal of Production Economics*, *272*, ***(2024)*** p.109251.
[23] Chakravarty, K.H., Sadi, M., Chakravarty, H., Andersen, J., Choudhury, B., Howard, T.J. and Arabkoohsar, A., Pyrolysis kinetics and potential utilization analysis of cereal biomass by-products; an experimental analysis for cleaner energy productions in India. *Chemosphere*, *353*, ***(2024)*** p.141420.
[24] Chandel, R., Raj, R., Kaur, A., Singh, K. and Kataria, S.K., Energy and yield optimization of field and vegetable crops in heavy crop residue for Indian conditions-climate smart techniques for food security. *Energy*, *287*, ***(2024)*** p.129555.
[25] Channab, B.E., Idrissi, A.E., Ammar, A., Dardari, O., Marrane, S.E., El Gharrak, A., Akil, A., Essemlali, Y. and Zahouily, M., Recent advances in nano-fertilizers: synthesis, crop yield impact, and economic analysis. ***(2024)*** *Nanoscale*.
[26] Chatli, A.S., E-Waste Management and Bioethanol Production. *Sustainable Management of Electronic Waste*, ***(2024)*** pp.67-78.
[27] Chen, Z., Li, X., Si, W., Xie, S. and Xia, X., Individual self-regulation, external monitoring, and farmers' safe production behavior: Evidence from the Kuan-chung Plain, China. *Journal of Environmental Management*, *354*, ***(2024)*** p.120474.
[28] Chiquito-Contreras, R.G., Hernandez-Adame, L., Alvarado-Castillo, G., Martínez-Hernández, M.D.J., Sánchez-Viveros, G., Chiquito-Contreras, C.J. and Hernandez-Montiel, L.G., Aquaculture—Production System and Waste Management for Agriculture Fertilization—A Review. *Sustainability*, *14*(12), ***(2022)*** p.7257.
[29] Crippa, M., Solazzo, E., Huang, G., Guizzardi, D., Koffi, E., Muntean, M., Schieberle, C., Friedrich, R. and Janssens-Maenhout, G., High resolution temporal profiles in the Emissions Database for Global Atmospheric Research. *Scientific data*, *7*(1), ***(2020)*** p.121.
[30] Dalezios, N.R., Petropoulos, G.P. and Faraslis, I.N. Concepts and methodologies of environmental hazards and disasters. *Techniques for Disaster Risk Management and Mitigation*, ***(2020)*** pp.1-22.

https://doi.org/10.71058/jodac.v10i01003

[31] De Laurentiis, V., Caldeira, C., Sala, S. and Tonini, D., Life cycle thinking for the assessment of waste and circular economy policy: status and perspectives from the EU example. *Waste Management*, *179*, ***(2024)*** pp.205-215.

[32] Demis, E., *Assessment and Efficacy of Botanicals Against Rice Weevil (Sitophilus Oryzae L.) on Rice (Oryza Sativa L.) Under Storage Condition in Fogera District, North-Western Ethiopia* (Doctoral dissertation) ***(2022).***

[33] Ding, J.F., Weng, J.H. and Chou, C.C., Assessment of key risk factors in the cold chain logistics operations of container carriers using best worst method. *International Journal of Refrigeration*, *153*, ***(2023)*** pp.116-126.

[34] El-Ramady, H., El-Henawy, A., Amer, M., Omara, A.E.D., Elsakhawy, T., Elbasiouny, H., Elbehiry, F., Abou Elyazid, D. and El-Mahrouk, M., Agricultural waste and its nano-management: Mini review. *Egyptian Journal of Soil Science*, *60*(4), ***(2020)*** pp.349-364.

[35] Engle, C.R. and Senten, J., US hybrid Striped Bass and Red Drum farms: Economic effects of the US regulatory framework. *North American Journal of Aquaculture*, *85*(4), ***(2023)*** pp.293-310.

[36] Ezeudu, T.S. and Chukwudubem, E.K., Exploring Socio-Cultural Factors in the Context of Urban Environmental Management in Nigeria. *International Journal of Research and Innovation in Social Science (IJRISS)*, *7*, ***(2023)*** pp.282-300.

[37] Fan, L., Zhang, H., Li, J., Wang, Y., Leng, L., Li, J., Yao, Y., Lu, Q., Yuan, W. and Zhou, W., Algal biorefinery to value-added products by using combined processes based on thermochemical conversion: a review. *Algal research*, *47*, ***(2020)*** p.101819.

[38] Garavito, G.A.A., Moniz, T., Mansilla, C., Iqbal, S., Dobrogowska, R., Bennin, F., Talwar, S., Khalid, A.F. and Vindrola-Padros, C., Activities used by evidence networks to promote evidence-informed decision-making in the health sector–a rapid evidence review. *BMC Health Services Research*, *24*(1), ***(2024)*** p.261.

[39] Guo, G., Zhou, S., Chen, Y. and Li, Y.Y., Phosphorus recovery coupling with one-stage partial nitritation/anammox process for the treatment of high-nutrient permeate from anaerobic membrane bioreactor treating concentrated organic sludge. *Chemical Engineering Journal*, *484*, ***(2024)*** p.149474.

[40] Gürdil, G.A.K., Demirel, B. and Cevher, E.Y., The conceptualization of agricultural residues: unlocking potential for sustainability. In *BIO Web of Conferences* Vol. 85, ***(2024)*** p. 01068). EDP Sciences.

[41] Hanis, M.H. and Fernando, Y., SMART LOGISTICS SOLUTIONS FOR REDUCING FOOD WASTE: A CASE OF D NIPAH CATERING. *International Journal of Industrial Management*, *18*(1), ***(2024)*** pp.11-21.

[42] He, J., Kawasaki, S. and Achal, V., The utilization of agricultural waste as agro-cement in concrete: A review. *Sustainability*, *12*(17), ***(2020)*** p.6971.

[43] Heydari, M., Cultivating sustainable global food supply chains: A multifaceted approach to mitigating food loss and waste for climate resilience. *Journal of Cleaner Production*, *442*, ***(2024)*** p.141037.

[44] Hoang, A.T., Nižetić, S., Ng, K.H., Papadopoulos, A.M., Le, A.T., Kumar, S. and Hadiyanto, H., Microbial fuel cells for bioelectricity production from waste as sustainable prospect of future energy sector. *Chemosphere*, *287*, ***(2022)*** p.132285.

[45] Hollas, C.E., do Amaral, K.G.C., Lange, M.V., Higarashi, M.M., Steinmetz, R.L.R., Mariani, L.F., Nakano, V., Sanches-Pereira, A., de Martino Jannuzzi, G. and Kunz, A., Livestock waste management for energy recovery in Brazil: a life cycle assessment approach. *Environmental Science and Pollution Research*, *31*(3), ***(2024)*** pp.4705-4720.

[46] Hou, H. and Zhu, H., Effects of MgCl2 on sludge anaerobic digestion: Hydrolysis, acidogenesis, methanogenesis, and microbial characteristics. *Journal of Water Process Engineering*, *57*, ***(2024)*** p.104624.

[47] Huang, S., Chen, Y., Wang, J., Lao, A., Huang, H., Wang, Z., Luo, X. and Zheng, Z., Understanding the dynamics of Microcystis bloom: Unraveling the influence of suspended solids through proteomics and metabolomics approaches. *Science of The Total Environment*, *908*, ***(2024)*** p.168079.

[48] Imran, A., Sardar, F., Khaliq, Z., Nawaz, M.S., Shehzad, A., Ahmad, M., Yasmin, S., Hakim, S., Mirza, B.S., Mubeen, F. and Mirza, M.S., Tailored bioactive compost from agri-waste improves the growth and yield of chili pepper and tomato. *Frontiers in Bioengineering and Biotechnology*, *9*, ***(2022)*** p.787764.

[49] Jun, T., Arshad, U., Xue, J. and Yan, W., Transformative Potential: A Comprehensive Analysis of China-Pakistan Agricultural Cooperation under CPEC. *Journal of Peace and Diplomacy*, *4*(1), ***(2023)*** pp.28-60.

[50] Kabeyi, M.J.B., Olanrewaju, O.A. and Akpan, J., Biogas production and process control improvements. In *From Biomass to Biobased Products*. IntechOpen ***(2024)***.

[51] Kallapiran, K.A. and Kannan, R., A review on the agricultural waste residues management by different microbes. *Journal of Agriculture and Ecology Research International*, ***(2022)*** pp.93-113.

[52] Kalogiannidis, S., Kalfas, D., Chatzitheodoridis, F. and Papaevangelou, O., Role of crop-protection technologies in sustainable agricultural productivity and management. *Land*, *11*(10), ***(2022)*** p.1680.

[53] Kar, S.K., Sharma, A., Kar, S. and Dey, A., Impact on Agricultural Crop Production Under Climate Change Scenario. In *Technological Approaches for Climate Smart Agriculture* ***(2024)*** pp. 109-132. Cham: Springer International Publishing.

https://doi.org/10.71058/jodac.v10i01003

[54] Kathi, S. and Prasad, M.N.V., Phytomass gasification for energy recovery from aquatic plants. In *Bioremediation and Bioeconomy* ***(2024)*** pp. 147-186, Elsevier.

[55] Khadiri, M., Boubaker, H., Laasli, S.E., Farhaoui, A., Ezrari, S., Radouane, N., Radi, M., Askarne, L., Barka, E.A. and Lahlali, R., Unlocking Nature's Secrets: Molecular Insights into Postharvest Pathogens Impacting Moroccan Apples and Innovations in the Assessment of Storage Conditions. *Plants*, *13*(4), ***(2024)*** p.553.

[56] Khan, S., Anjum, R., Raza, S.T., Bazai, N.A. and Ihtisham, M., Technologies for municipal solid waste management: Current status, challenges, and future perspectives. *Chemosphere*, *288*, ***(2022)*** p.132403.

[57] Korav, S., Yadav, D.B., Yadav, A., Rajanna, G.A., Parshad, J., Tallapragada, S., Elansary, H.O. and Mahmoud, E.A., Rice residue management alternatives in rice–wheat cropping system: impact on wheat productivity, soil organic carbon, water and microbial dynamics. *Scientific Reports*, *14*(1), ***(2024)*** p.1822.

[58] Koul, B., Yakoob, M. and Shah, M.P., Agricultural waste management strategies for environmental sustainability. *Environmental Research*, *206*, ***(2022)*** p.112285.

[59] Kumar, J.A., Sathish, S., Prabu, D., Renita, A.A., Saravanan, A., Deivayanai, V.C., Anish, M., Jayaprabakar, J., Baigenzhenov, O. and Hosseini-Bandegharaei, A., Agricultural waste biomass for sustainable bioenergy production: Feedstock, characterization and pre-treatment methodologies. *Chemosphere*, *331*, ***(2023)*** p.138680.

[60] Kumar, P., Fiori, L., Subbarao, P.M.V. and Vijay, V.K., Development of an efficient method to blend forest biomass with agricultural residue to produce fuel pellets with improved mechanical properties. *Biofuels*, ***(2024)*** pp.1-12.

[61] Kumar, P., Raj, A. and Kumar, V.A., Approach to Reduce Agricultural Waste via Sustainable Agricultural Practices. In *Valorization of Biomass Wastes for Environmental Sustainability: Green Practices for the Rural Circular Economy* ***(2024)*** (pp. 21-50). Cham: Springer Nature Switzerland.

[62] Kumar, R., Goyal, M.K., Surampalli, R.Y. and Zhang, T.C., River pollution in India: exploring regulatory and remedial paths. *Clean Technologies and Environmental Policy*, ***(2024)*** pp.1-23.

[63] Kumar, R., Kaur, A., Sharma, S., Bharti, H. and Kumar, R., Advancements and Challenges in Agriculture Waste Management: A Comprehensive. *Educational Administration: Theory and Practice*, *30*(5), ***(2024)*** pp.7253-7273.

[64] Kurniawan, T.A., Meidiana, C., Goh, H.H., Zhang, D., Othman, M.H.D., Aziz, F., Anouzla, A., Sarangi, P.K., Pasaribu, B. and Ali, I., Unlocking synergies between waste management and climate change mitigation to accelerate decarbonization through circular-economy digitalization in Indonesia. *Sustainable Production and Consumption*, *46*, ***(2024)*** pp.522-542.

[65] Lagerkvist, C.J., Edenbrandt, A.K., Bolos, L.A. and Nayga Jr, R.M., Consumer acceptance of aesthetically imperfect vegetables–The role of information framing and personal values: Evidence from the United States. *Food Quality and Preference*, *104*, **(2023)** p.104737.

[66] LIMO, M.J., *INFLUENCE OF HEALTHY EATING CONCERNS ON MENU CHOICE DECISIONS AMONGST CUSTOMERS IN STAR-RATED HOTELS IN NAKURU COUNTY, KENYA* (Doctoral dissertation, University of Eldoret) ***(2023)***

[67] Liu, L., Huang, Y., Cao, J., Liu, C., Dong, L., Xu, L. and Zha, J., Experimental study of biomass gasification with oxygen-enriched air in fluidized bed gasifier. *Science of the Total Environment*, *626*, ***(2018)*** pp.423-433.

[68] Loboguerrero, A.M., Campbell, B.M., Cooper, P.J., Hansen, J.W., Rosenstock, T. and Wollenberg, E., Food and earth systems: priorities for climate change adaptation and mitigation for agriculture and food systems. *Sustainability*, *11*(5), ***(2019)*** p.1372.

[69] Lohan, S.K., Jat, H.S., Yadav, A.K., Sidhu, H.S., Jat, M.L., Choudhary, M., Peter, J.K. and Sharma, P.C., Burning issues of paddy residue management in north-west states of India. *Renewable and Sustainable Energy Reviews*, *81*, ***(2018)*** pp.693-706.

[70] Luo, J., Pan, Z. and Zhang, S., Greening the economy: Techniques and regulations to promote natural resource efficiency. *Resources Policy*, *90*, **(2024)** p.104686.

[71] Luo, N., Olsen, T., Liu, Y. and Zhang, A., 2022. Reducing food loss and waste in supply chain operations. *Transportation Research Part E: Logistics and Transportation Review*, *162*, p.102730.

[72] Magableh, G.M., Evaluating wheat suppliers using fuzzy MCDM technique. *Sustainability*, *15*(13), ***(2023)*** p.10519.

[73] Maji, S., Dwivedi, D.H., Singh, N., Kishor, S. and Gond, M., Agricultural waste: Its impact on environment and management approaches. *Emerging eco-friendly green technologies for wastewater treatment*, ***(2020)*** pp.329-351.

[74] Mehta, C.R., Badegaonkar, U.R., Singh, P.L. and Singh, K.K., Integrated straw management in India ***(2023).***

[75] Melati, I., Purwanto, B.M., Caturyani, Y., Olivia Irliane, P. and Widyaningsih, Y.A., The mediation effect of the urge to buy impulsively on grocery online impulse buying decisions. *Cogent Business & Management*, *11*(1), ***(2024)*** p.2316941.

[76] Mishra, R., Tripathi, P., Kumar, P., Rajpoot, P.K., Verma, S. and Aman, A.S., Innovations and Future Trends in Storage Pest Management. *Journal of Experimental Agriculture International*, *46*(5), ***(2024)*** pp.155-165.

https://doi.org/10.71058/jodac.v10i01003

[77] Misri, B., Hay and crop residues in India and Nepal. *Food Agric Organ. http://www. fao. org/docrep/005/x7660e/x7660e0q. htm.* ***(2020)*** *Accessed*, *12*.

[78] Mohanty, A., Mankoti, M., Rout, P.R., Meena, S.S., Dewan, S., Kalia, B., Varjani, S., Wong, J.W. and Banu, J.R., Sustainable utilization of food waste for bioenergy production: A step towards circular bioeconomy. *International Journal of Food Microbiology*, *365*, ***(2022)*** p.109538.

[79] Musonda, L. and Mwila, N., Factors influencing Post-Harvest Losses of Fresh Tomato in the Distribution Channel in Lusaka Markets. *African Journal of Commercial Studies*, *4*(2), ***(2024)*** pp.104-112.

[80] Nguyen, V., Nguyen, N., Schumacher, B. and Tran, T., Practical application of plan–do–check–act cycle for quality improvement of sustainable packaging: a case study. *Applied Sciences*, *10*(18), ***(2020)*** p.6332.

[81] Ninama, N., Gangal, L., Khayum, A., SB, H., HM, S. and Singh, A., Post-harvest Biotechnology or Genetic Engineering Solutions: Extending Shelf Life and Reducing Food Waste. *Journal of Advances in Biology & Biotechnology*, *27*(4), ***(2024)*** pp.1-26.

[82] Nkhoma, R., Mwale, V.D. and Ngonda, T., Socioeconomic indicators and their influence on the adoption of renewable energy technologies in rural Malawi. *International Journal of Energy Sector Management* ***(2024)***.

[83] Noori, A., Hasanuzzaman, M., Roychowdhury, R., Sarraf, M., Afzal, S., Das, S. and Rastogi, A., Silver nanoparticles in plant health: Physiological response to phytotoxicity and oxidative stress. *Plant Physiology and Biochemistry*, ***(2024)*** p.108538.

[84] Odejobi, O.J., Ajala, O.O. and Osuolale, F.N., Review on potential of using agricultural, municipal solid and industrial wastes as substrates for biogas production in Nigeria. *Biomass Conversion and Biorefinery*, *14*(2), ***(2024)*** pp.1567-1579.

[85] Oke, E.A. and Potgieter, H., Discarded e-waste/printed circuit boards: a review of their recent methods of disassembly, sorting and environmental implications. *Journal of Material Cycles and Waste Management*, *26*(3), ***(2024)*** pp.1277-1293.

[86] Oke, O.E., Akosile, O.A., Uyanga, V.A., Oke, F.O., Oni, A.I., Tona, K. and Onagbesan, O.M., Climate change and broiler production. *Veterinary Medicine and Science*, *10*(3), ***(2024)*** p.e1416.

[87] Okpala, C.O.R. and Korzeniowska, M., Understanding the relevance of quality management in agro-food product industry: From ethical considerations to assuring food hygiene quality safety standards and its associated processes. *Food Reviews International*, *39*(4), ***(2023)*** pp.1879-1952.

[88] Olita, T., Stankovic, M., Sung, B., Jones, M. and Gibberd, M., Growers' perceptions and attitudes towards fungicide resistance extension services. *Scientific Reports*, *14*(1), ***(2024)*** p.6821.

[89] Pålsson, H. and Hellström, D., Packaging innovation scorecard. *Packaging Technology and Science*, *36*(11), ***(2023)*** pp.969-981.

[90] Pan, W., Yi, L., Hu, T., Huang, J. and Huang, Y., An action research study of quality improvement in instrument packaging procedures for the central sterile supply department. *Scientific Reports*, *14*(1), ***(2024)*** p.3764.

[91] Pareek S. Addressing agricultural waste management challenges: Innovative approaches and best practices. AGBIR;40(4) ***(2024)***, p. 1229-1231.

[92] Pareek S. Comprehensive analysis of the sensors used in precision agriculture. AGBIR. 39(6), ***(2023)*** p. 740-744.

[93] Parent, L.E., Vegetable Response to Added Nitrogen and Phosphorus Using Machine Learning Decryption and the N/P Ratio. *Horticulturae*, *10*(4), ***(2024)*** p.356.

[94] Prasad, M., Ranjan, R., Ali, A., Goyal, D., Yadav, A., Singh, T.B., Shrivastav, P. and Dantu, P.K., Efficient transformation of agricultural waste in India. *Contaminants in agriculture: sources, impacts and management*, ***(2020)*** pp.271-287.

[95] Preethi, B., Karmegam, N., Manikandan, S., Vickram, S., Subbaiya, R., Rajeshkumar, S., Gomadurai, C. and Govarthanan, M., Nanotechnology-powered innovations for agricultural and food waste valorization: A critical appraisal in the context of circular economy implementation in developing nations. *Process Safety and Environmental Protection* ***(2024).***

[96] Rahimi, E., Liu, S. and Wang, M., Investigation of methane-rich gas production from the co-bioconversion of coal and anaerobic digestion sludge. *Fuel*, *357*, ***(2024)*** p.129565.

[97] Reddy, A & Kasa, Vara & Samal, Biswajit & Dubey, Brajesh & Yadav, Vinay & Pandey, Daya. Sustainable agricultural waste management in India: Innovations, challenges, and future perspectives. Biomass and Bioenergy. 202. 108261. 10.1016/j.biombioe ***(2025),***108261.

[98] Rai, S., Gurung, A., Sharma, H.B., Ranjan, V.P. and Cheela, V.R.S., Sustainable solid waste management challenges in hill cities of developing Countries: Insights from eastern Himalayan smart cities of Sikkim, India. *Waste Management Bulletin*, *2*(2), ***(2024)*** pp.1-18.

[99] Rani, P., Yadav, D.K., Yadav, A., Bishnoi, N.R., Kumar, V., Ram, C., Pugazhendhi, A. and Kumar, S.S., Frontier in dark fermentative biohydrogen production from lignocellulosic biomass: Challenges and future prospects. *Fuel*, *366*, ***(2024)*** p.131187.

[100] Reddy, K.J. and Goudra, S., A review on crop residue burning: Impact and its management. *J. Pharm. Innov*, *12*, ***(2023)*** pp.2457-62.

[101] Rifna, E.J., Dwivedi, M., Seth, D., Pradhan, R.C., Sarangi, P.K. and Tiwari, B.K., Transforming the potential of renewable food waste biomass towards food security and supply sustainability. *Sustainable Chemistry and Pharmacy*, *38*, ***(2024)*** p.101515.

[102] Roy, D., Biswakarma, N., Ghosh, T., Bag, K., Sarkar, A., Paul, K., Das, B., Chowdhury, S. and Hari Krishna, B., Climate Change on Seeds Physiology. In *Climate Change Impacts on Soil-Plant-Atmosphere Continuum*, ***(2024)*** pp. 347-382. Singapore: Springer Nature Singapore.

[103] Saha, F., 2024. Land governance ambiguity and protected area degradation in Cameroon: the case of the Ottotomo reserve. *Tropical Ecology*, pp.1-13.

[104] Sarkar, S., Kumar, R., Kumar, A., Singh, D.K. and Hans, H., Retention Vs Incorporation of Cereal Residues on Soil Health: A Comprehensive Review. *Communications in Soil Science and Plant Analysis*, *55*(12), ***(2024)*** pp.1883-1902.

[105] Sarkar, S., Skalicky, M., Hossain, A., Brestic, M., Saha, S., Garai, S., Ray, K. and Brahmachari, K., Management of crop residues for improving input use efficiency and agricultural sustainability. *Sustainability*, *12*(23), ***(2020)*** p.9808.

[106] Satpathy, P. and Pradhan, C., Biogas as an alternative to stubble burning in India. *Biomass Conversion and Biorefinery*, *13*(1), ***(2023)*** pp.31-42.

[107] SEN, A., JINDAL, N., KARTHIK, S., PILLI, D. and CHANDNANI, M., Examining the Adoption of Sustainable Management Techniques in Agriculture to Balance Economic Viability. *Journal of Environment & Bio-sciences*, ***(2023)*** *37*(2).

[108] Sethumadhavan, A., Shah, S.R., Jayakumar, M., Nirmala, G. and Rangaraju, M., Food Process Industry Waste Biomass as a Promising Alternative for Green Energy Production. In *Value Added Products from Food Waste* ***(2024)*** pp. 275-290. Cham: Springer Nature Switzerland.

[109] Sevak, P. and Pushkar, B., Arsenic pollution cycle, toxicity and sustainable remediation technologies: A comprehensive review and bibliometric analysis. *Journal of Environmental Management*, *349*, ***(2024)*** p.119504.

[110] Shahzad, H.M.A., Almomani, F., Shahzad, A., Mahmoud, K.A. and Rasool, K., Challenges and opportunities in biogas conversion to microbial protein: a pathway for sustainable resource recovery from organic waste. ***(2024)*** *Process Safety and Environmental Protection*.

[111] Shaikh, M. and Birajdar, F., Harmony in Hydroinformatics: Integrating AI and IEC for sustainable groundwater conservation in Solapur. *International Journal of Science and Research Archive*, *11*(1), ***(2024)*** pp.2163-2175.

[112] Sharma, A., Gamta, V. and Luthra, G., Regulatory Compliance in the United States: A Comprehensive Analysis of USFDA Guidelines and Implementation Strategies. *Journal of Pharmaceutical Research International*, *35*(17), ***(2023)*** pp.41-50.

[113] Sharma, A., Manpoong, C., Sharma, H., PANDEY, H., SONI, G., SHARMA, S., KUMARI, N. and RAGHAVAN, M., Removal of heavy metals and agrochemicals residues through plants. *Asian J. Microbiol. Biotechnol. Environ. Sci.*, *24*(1), ***(2022)*** pp.20-24.

[114] Sharma, A., Raghavan, M., Shi, Z. and Bang, N.T.H., Utilization of protected cultivation for crop production and preservation in India. *Environment Conservation Journal*, *22*(1&2), ***(2021)*** pp.13-17.

[115] Sharma, A., Singh, G. and Arya, S.K., 2020. Biofuel from rice straw. *Journal of Cleaner Production*, *277*, p.124101.

[116] Sharma, D. and Mishra, A., Synergistic effects of ternary mixture formulation and process parameters optimization in a sequential approach for enhanced L-asparaginase production using agro-industrial wastes. *Environmental Science and Pollution Research*, *31*(12), ***(2024)*** pp.17858-17873.

[117] Sharmila, V.G., Shanmugavel, S.P. and Banu, J.R., A review on emerging technologies and machine learning approaches for sustainable production of biofuel from biomass waste. *Biomass and Bioenergy*, *180*, ***(2024)*** p.106997.

[118] Sieradzka, M., Mlonka-Mędrala, A., Błoniarz, A. and Magdziarz, A., Experimental study of biomass waste gasification: Impact of atmosphere and catalysts presence on quality of syngas production. *Bioresource Technology*, *394*, ***(2024)*** p.130290.

[119] Sikder, S., Toha, M. and Mostafizur Rahman, M., An overview on municipal solid waste characteristics and its impacts on environment and human health. *Technical Landfills and Waste Management: Volume 1: Landfill Impacts, Characterization and Valorisation*, ***(2024)*** pp.135-155.

[120] Singh, G., Saha, P., Kanwar, P. and Singh, J., Enhancing Plant Growth: Harnessing the Effectiveness of Artificial Light. *Journal of Advances in Biology & Biotechnology*, *27*(4), ***(2024)*** pp.59-72.

[121] Singh, K., Singh, S., Kumar, V., Khandai, S., Kumar, A., Bhowmick, M.K., Kumar, V., Srivastava, A. and Hellin, J., Rice straw management: energy conservation and climate change mitigation. In *Handbook of Energy Management in Agriculture* ***(2023)*** pp. 451-475. Singapore: Springer Nature Singapore.

[122] Sharma, A., Raghavan, M., Shi, Z. and Bang, N.T.H., 2021. Role of Mushroom in the bioremediation of heavy metals and biodegradation of dyes.

[123] Slayi, M., Zhou, L. and Jaja, I.F., Constraints inhibiting farmers' adoption of cattle feedlots as a climate-smart practice in rural communities of the eastern cape, South Africa: An In-Depth Examination. *Sustainability*, *15*(20), ***(2023)*** p.14813.

[124] Sungur, Ş., Biofuels. In *Handbook of Emerging Materials for Sustainable Energy* ***(2024)*** pp. 399-417. Elsevier.

[125] Tahiru, A.W., Cobbina, S.J., Asare, W. and Takal, S.U., Unlocking Energy from Waste: A Comprehensive Analysis of Municipal Solid Waste Recovery Potential in Ghana. *World*, *5*(2), ***(2024)*** pp.192-218.

[126] Tang, Q., Wang, J., Cao, M., Chen, Z., Tu, X., Elrys, A.S., Jing, H., Wang, X., Cai, Z., Müller, C. and Daniell, T.J., Awakening soil microbial utilization of nitrate by carbon regulation to lower nitrogen pollution. *Agriculture, Ecosystems & Environment*, *362*, ***(2024)*** p.108848.

[127] Thangamani, R., Sathya, D., Kamalam, G.K. and Lyer, G.N., AI Green Revolution: Reshaping Agriculture's Future. In *Intelligent Robots and Drones for Precision Agriculture* ***(2024)*** pp. 421-461. Cham: Springer Nature Switzerland.

[128] Tjilen, A.P., Tambaip, B., Dharmawan, B., Adrianus, A., Riyanto, P. and Ohoiwutun, Y., Engaging stakeholders in policy decision-making for food security governance: Identification, perception, and contribution. *Corporate Governance and Organizational Behavior Review*, *8*(1), ***(2024)*** pp.144-154.

[129] Totobesola, M., Delve, R., Nkundimana, J.D.A., Cini, L., Gianfelici, F., Mvumi, B., Gaiani, S., Pani, A., Barraza, A.S. and Rolle, R.S., A holistic approach to food loss reduction in Africa: food loss analysis, integrated capacity development and policy implications. *Food Security*, *14*(6), ***(2022)*** pp.1401-1415.

[130] Tse, T.J., Wiens, D.J., Chicilo, F., Purdy, S.K. and Reaney, M.J., Value-added products from ethanol fermentation—A review. *Fermentation*, *7*(4), ***(2021)*** p.267.

[131] Ugoeze, K., Alalor, C., Ibezim, C., Chinko, B., Owonaro, P., Anie, C., Okoronkwo, N., Mgbahurike, A., Ofomata, C., Alfred-Ugbenbo, D. and Ndukwu, G., Environmental and Human Health Impact of Antibiotics Waste Mismanagement: A Review. *Advances in Environmental and Engineering Research*, *5*(1), ***(2024)*** pp.1-21.

[132] Unites states environmental protection agency https://www.epa.gov/agstar/how-does-anaerobic-digestion-work. How does anaerobic digestion work? ***(2024)***

[133] Verma, A.K., Umaraw, P., Kumar, P., Mehta, N. and Sazili, A.Q., Processing of red meat carcasses. In *Postharvest and Postmortem Processing of Raw Food Materials* ***(2022)*** pp. 243-280. Woodhead Publishing.

[134] Wang, J. and Azam, W., Natural resource scarcity, fossil fuel energy consumption, and total greenhouse gas emissions in top emitting countries. *Geoscience Frontiers*, *15*(2), ***(2024)*** p.101757.

[135] Wei, C., Ding, H., Zhang, Z., Lin, F., Xu, Y. and Pan, W., Research progress of bimetallic catalysts for CO2 hydrogenation to methane. *International Journal of Hydrogen Energy*, *58*, ***(2024)*** pp.872-891.

[136] Yi, B., Chen, M., Gao, Y., Cao, C., Wei, Q., Zhang, Z. and Li, L., Investigation on the co-combustion characteristics of multiple biomass and coal under O2/CO2 condition and the interaction between different biomass. *Journal of Environmental Management*, *325*, **(2023)** p.116498.

[137] Young, A., Sima, H., Luo, N., Wu, S., Gong, Y. and Qian, X., Ugly produce and food waste management: An analysis based on a social cognitive perspective. *Journal of Retailing and Consumer Services*, *79*, **(2024)** p.103829.

[138] Zargar, R.N., Bhagat, G., Singh, M., Kumar, R., Singh, P.S. and Dwivedi, S. Converting crop residue waste to wealth: A review. *RASSA Journal of Science for Society*, *5*(1), **(2023)** pp.1-12.

[139] Zhang, S., Lin, S., Wang, C. and Shahbaz, P. Towards energy sustainability: Exploring the nexus between global value chain participation and energy security in developing and developed countries. *Plos one*, *19*(1), **(2024)** p.e0296705.

[140] Zhu, C., Li, R., Qiu, M., Zhu, C., Gai, Y., Li, L., Yang, N., Sun, L., Wang, C., Wang, B. and Yan, G., High spatiotemporal resolution ammonia emission inventory from typical industrial and agricultural province of China from 2000 to 2020. *Science of The Total Environment*, *918*, **(2024)** p.170732.

[141] Zhu, Y., Lyu, T., Li, D., Zhang, Z., Guo, J., Li, X., Xiong, W., Dong, R. and Wang, S. Process mechanisms of nanobubble technology enhanced hydrolytic acidification of anaerobic digestion of lignocellulosic biomass. *Chemical Engineering Journal*, *480*, **(2024)** p.147956.