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LITERATURE REVIEW

# Proficient Management of Agricultural waste: Sustainable Wealth from Waste

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## Abstract

*This review emphasises the convergence of environmental sustainability and economic feasibility, highlighting the transformative potential of turning agricultural waste into value-added products. Even though they are frequently viewed as waste, agricultural residues can be rethought and repurposed through creative methods to produce valuable goods like biofuels, organic fertilisers, and biodegradable materials. It examines the various uses of agricultural waste, an asset that is often disregarded, across a range of industries, with an emphasis on the generation of bioelectricity, medicinal uses, and the extraction of anti-oxidant and anti-cancer substances. Using cutting-edge technologies to generate bioelectricity from agricultural waste not only solves environmental issues but also provides a sustainable energy source. Concurrently, the pharmaceutical industry gains from the separation of bioactive elements from agricultural waste, which acts as a replenishable supply of antioxidants and possible antitumor agents. This multidisciplinary strategy promotes improvements in pharmaceutical research while both reducing waste and demonstrating the adaptability of agricultural waste in fulfilling energy requirements. By addressing the issues of waste management, this paradigm shift towards the use of agrowaste also advances the creation of a circular economy. In order to fully realise the potential of agrowaste and promote a more resource-efficient and sustainable agriculture industry while opening up new opportunities for economic growth that hold promise for major positive effects on the environment and human health, the abstract emphasises the significance of continued research, technological advancements, and cooperative initiatives.*

## Keywords

*Agriculture Waste, Waste Valorisation, Bioactive Compounds, Bio fuel, Bio electricity*

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## 1. Introduction:

A major component of India's economy is agriculture. Over 70% of India's population lives in rural areas, where agriculture is the main industry. A large amount of agricultural waste has been produced over time, dumped, and left unutilized. Every day, a vast amount of agricultural wastes (AWs) are produced worldwide in order to meet the ever-increasing needs of the rapidly expanding population. By 2050, there could be 2.25 billion more people on the planet than there are now, or 9.15 billion people. It is predicted that agricultural production and consumption worldwide would increase by 60% by 2050. The growing global population need a greater supply of food and fodder, which raises the output of biomass from agricultural waste. Solid organic waste is growing quickly at the same time that the global population is growing, particularly in urban areas. Solid waste management has therefore drawn a lot of interest from throughout the globe. In India, the percentage of organic matter in urban Municipal Solid Waste (MSW) varies between 75 and 85% *(Sarkar & Chourasia, 2017).*

According to *Gupta B & Arora SK (2016)*, the amount of municipal solid waste generated annually in urban India is about 68.8 million tonnes. This amount is expected to increase to 200 million metric tonnes by 2041*(https://www.statista.com/statistics/1009110/india-msw-generation-amount/).* Despite the agriculture sector's historical ability to meet such demand, the perceived limit to producing food for a growing global population remains a topic of discussion and concern *(Alexandratos N & Bruinsma J, 2012)*. From 3.7 billion in 1970 to 7.9 billion in 2021, there will be more people on the planet. By 2050, it is expected to reach 9 billion, and by 2100, it will reach 11 billion. Food security will therefore be a difficult task in the years to come.

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A considerable increase in crop and livestock production has been necessary to meet the high demands of feeding millions of people, and this has added to the production of agricultural wastes (AWs). China, India, and Africa have had tremendous demographic and economic growth during the past century, along with an increase in their ability to produce AW. India generates a significant amount of solid waste annually, with AW accounting for the majority at 350–990 Mt/y. India is the second-biggest producer of agricultural waste in the world, behind China. The country generates more than 130 million tonnes of paddy straw, of which half is thrown away and used as fodder. Furthermore, burning rice residue, or parali, is a practice that poses serious health risks to the public and significantly pollutes the air in the northwest. Crop residue that is not properly disposed of produces greenhouse gases (GHGs) such as carbon dioxide ($CO_2$), nitrous oxide ($N_2O$), and methane ($CH_4$), which are harmful to both people and the environment *(Koul B et al., 2022)*.

## *2.* Agricultural Waste

One of the biggest biological sectors with the highest biomass production is agriculture, which can provide a significant bioeconomy input. Animals, aquaculture, agro-industries, and crop leftovers are some of the sources from which AWs are produced. Crop residues, which include seed pods, leaf litter, stems, stalks, husks, straws and weeds; livestock wastes, which include urine, dung, wash water, leftover milk and waste feed; poultry wastes, which include spilled feed, feathers, droppings and bedding material; abattoir wastes, which include blood, hair, hides, flesh and bones; agro-industrial wastes, which include bagasse, molasses, peels (cassava, potato, orange), pulps (tomato, apple, pineapple, papaya, orange, guava etc.) and cakes made with oil-seeds (groundnut, soybean, coconut, mustard, palm kernel, etc.) and aquaculture wastes (faeces, uneaten feed) have alarmed the public and jeopardised the long-term viability of agricultural systems *(Koul B et al., 2022)*.

## 3. Practice of Disposing off Agricultural Waste

Agricultural pollution contaminates soil by killing soil microorganisms, which lowers soil fertility and causes pollution. The chemicals found in pesticides and other agrochemicals have the potential to harm soil for a long time. Conventional agricultural practices have a minimal carbon footprint. Wastes are often treated by incinerated or disposed of in landfills. Microorganisms break down organic waste in landfills, producing a variety of gases that may have an impact on global warming. Furthermore, farmers typically use organic wastes as manures. However, because of the risk of soil pollution and the subsequent growth of plant and animal diseases, spreading or reusing their land for agricultural purposes is either forbidden or severely restricted *(Dantroliya S et al., 2022)*.

The thermal treatment of waste materials in a sealed vessel at high temperatures and pressures with limited oxygen availability to produce energy, activated carbon, and other refined products is known as pyrolysis. Another process used to treat agricultural waste is plasma gasification, which is the same process but with higher temperatures and pressures and limited oxygen availability to produce highly ionised and electrically charged syngas for the production of heat and electricity.

Burning garbage outside or in an incinerator is referred to as incinerating. These days, incinerators are used in the majority of developed nations to burn waste, turning it into energy that may be used to produce steam, heat, or electricity. Waste management is the process of gathering, moving, disposing of, recycling, and keeping an eye on waste. Two methods are used to produce organic fertilisers: vermicomposting, which involves breeding and growing earthworms, and landfilling, which involves disposing of trash in wetlands and open spaces. An outlook on anticipated development paths and constraints is created by carefully integrating the range of technical skills present throughout Food and Agricultural Organisation (FAO) FAO. This outlook is widely used for organising and framing discussions in the food and agriculture sectors on expected courses of development and restrictions. Such a lengthy look forward is necessarily laden with uncertainty *(Alexandratos N & Bruinsma J, 2012)*.

The underutilization of livestock manure and the careless or random burning of crop residues can be effectively stopped by implementing bioeconomic strategies based on agricultural waste management. This will support the sustainability of agriculture, reduce greenhouse gases, the production of value-added products from waste, farmer livelihood, youth employment, and food and health security. The majority of the AWs break down quickly and can provide plants with essential nutrients and raise soil porosity, which improves soil aeration and water retentivity. Consequently, to protect soil, biodiversity and global food security as well as to disentangle economic expansion from environmental constraints, it is imperative to reduce, reuse, and recycle agricultural leftovers *(Koul B et al., 2022)*.

## 4. Value-added products from Agriculture Waste

Research has demonstrated the enormous potential of employing organic waste as long as appropriate and stringent laws are in place—for animal feed. The growing prices and reliance on conventional feed, coupled with environmental concerns, have prompted research into the relegalization of the use of organic waste and the potential use of food waste as a sustainable animal feed. Research conducted by *Salemdeeb et al. (2017)* analysed the environmental and health effects of using food waste for pig feed and shown the benefits of doing so. They employed anaerobic digestion and composting to examine the food waste through a life cycle assessment before using it as pig feed.

Cellulose, the most prevalent biopolymer, makes up the majority of crop residue and agro-industrial waste, with lignin and hemicellulose (lignocellulosic biomass) coming in second and third. A significant portion of agricultural biomass is lignocellulosic matter, which is made up of cellulose, hemicellulose, and lignin. Since cellulose accounts for 30–50% of total biomass, it is a good resource for microbial processing. Research has shown that lignocellulosic biomass can be strategically managed and valorized to produce a variety of important domestic and commercial products. They can be utilised to lessen the problems associated with climate change and the scarcity of fossil fuels. These include the generation of compost, biocoal, biochar, biobricks, biohydrogen, biomethane, bioethanol, and biobutanol, as well as organic acids and bioelectricity. They could therefore have an impact on the bioeconomy by creating goods with added value. Furthermore, it has opened up new opportunities for young people from rural areas around the world who are looking for work. The public and farming communities, however, need to be more aware of the hidden advantages of the biological and biotechnological management of AWs, such as improved human health, reduced or no pollution of the soil, air, and water, and alternate sources of revenue. This would eliminate their ingrained beliefs and scare tactics regarding ambiguous information *(Koul B et al., 2022).*

### 4.1. Utilisation of Agriculture Waste in Electricity Production

Agriculture produces billions of metric tonnes of biomass annually. These waste materials from agriculture can be biotransformed into energy that can replace fossil fuels, reduce greenhouse gas emissions, and serve as a source of renewable energy. Alternative energy sources include biomass, which includes leftover stalks, straw, leaves, roots, rice husk, paddy husk, nuts or seed shells, decaying waste, bagasse and sugarcane leaves, waste wood, and animal dung for electricity generation *(Kaur N, 2014).* Anaerobic digestion or gasification are two methods used to convert crop leftovers into clean, sustainable electricity. Using gasification and combustion, agricultural biomass production yields 25–100 kW of electricity and up to 8 MW of power. To ensure a steady supply of agricultural leftovers, a private or community-based organisation can establish a small- or large-scale enterprise with strong partnerships from farmers and the agro-industries. The generated electricity can subsequently be sold for a profit or used for the good of society. Depending on the method, carbon credits and other by-products, such biochar, can also be acquired and exchanged.

Archean Granites, Punjab Biomass Power, Bermaco Energy, and Gammon Infrastructure Projects Limited founded the agri-waste based power project in Punjab. For the purpose of producing fuel and energy, the project uses agricultural waste that can be found locally, such as sugarcane garbage and rice straw. Through the sale of their agricultural waste, farmers can benefit financially from this enterprise. By turning agricultural waste into energy and assisting in the prevention of pollution, the project represents a significant advancement in environmental protection.

Seven power units that create energy from agricultural leftovers have been established by a private Indian power provider called Greenko Group. Greenko began operations in 2005. The 7.5 megawatt (MW) Ravikiran power project in the area of Marlanhalli, Karnataka, gathers inexpensive agricultural waste from nearby farming villages in order to produce electricity, which is then sold to the local electricity grid. The company receives special recognition for its ability to improve the local environment, emit fewer greenhouse gases, and have a minimal impact on the environment. Greenko installs its 34 MW worth of biomass energy projects in six additional places throughout India, with plant capacities ranging from 6 to 8 MW. It applies innovative methods to generate power through the use of cutting-edge technological systems and procedures *(Otoo M & Drechsel P, 2017).*

#### *4.1.1 Role of Microorganisms: Generators of Bioelectricity*

Microorganisms are fundamental to the process of converting chemical energy found in organic matter into electrical energy, which is why they are important in the production of electrical energy. The capacity of microorganisms to exchange electrons is a key component of the microbial fuel cell technology, which helps recycle organic waste *(Das KS, 2020)*. Microbial fuel cells transfer electrons that are produced when electrically active microorganisms oxidise organic matter in a closed circuit, combining with protons before being eventually taken up by an electron acceptor (often oxygen) and producing reduced compounds. According to *Almatouq A et al. (2020), Li L et ai. (2018)* and *Logan BE et al. 2019* microorganisms that absorb electrons are known as electrophytes, and those that transmit electrons to a solid anode are known as exoelectrogens. Exoelectrogenic bacteria are what produce the electricity. They can move extracellular electrons from the anode to the metabolite using pigments like pyocyanins, flavins, and cytochrome, as well as conductive pili or nanowires *(Cao Y, Mu H, et al., 2019; Kumar R et al., 2015).*

According to a research study, microbial fuel cell technology can be used to harness the high chemical content necessary for chemical oxidation-reduction reactions and the great electrostatic potential of organic waste, such as fruit waste, as a source for electrical energy production *(Rojas-Flores, S et al., 2020; Rojas-Flores S 2022).* A variety of substances, including carbohydrates, fibres, phytosterols, polyphenols, aromatic compounds, minerals, vitamins, and amino acids, are found in fruit waste. Adenosine triphosphate (ATP) and nicotinamide dinucleotide ($NAD^+$), which are produced when microbes ferment fruit waste, act as a bridge in the electron transport mechanism that connects the electrical circuit of a microbial fuel cell *(Cao Y et al., 2019; Verma M & Mishra V, 2021; Ahmad M. et al., 2018).*

Promising results have been reported by several research groups regarding the generation of bioelectricity from fruit wastes, including *R. ulmifolius* (blackberry), *H. undatus* (dragon fruit), and *M. citrifolia* (noni). These groups were able to turn on an LED spotlight for 21 days and generate a potential voltage of 1.17 ± 0.12 V (Das KS 2020; Rojas-Flores S, 2022). Potential voltages larger than 1 V are produced when waste from citrus fruits, such as *Citrus aurantiifolia, Citrus sinensis,* and *Citrus reticulata*, is used. Papaya waste has also been observed to produce potential voltages of 1.029 ± 0.131V (Flores SJR et al., 2020; Rojas-Flores S et al., 2021). The notable bioelectricity generating microorganisms are the bacteria *Achromobacter berreziniae* and *Stenotrophomonas maltophilia* and there are strains work in a mixed communities as consortia and generates large voltage potentials (Rojas-Flores S, 2022). The rise of organic waste (agricultural, municipal, industrial, chicken, plastic, and other trash), which poses serious environmental risks because it releases too much greenhouse gas (16% of global emissions, including $CO_2$, $CH_4$, $N_2O$ and others) into the atmosphere (Zhang Y et al., 2022).

### 4.2 Utilisation of Agricultural Waste in Industrial Enzyme Production

Diverse agro-industrial wastes have been effectively employed to generate important biocatalyst. A variety of substrates, including rotting fruits and vegetables, mushrooms, rice husk, wheat bran, rice straw, banana stalks, sunflower hulls, and so on, have been used to produce enzymes such as Polygalacturonase (PGase), ligninases, hemicellulases, lignin peroxidase (LiP), manganese peroxidase (MnP), amylases, cellulases, tannases, Lipases, and so forth. Bacterial strains including *B. subtilis* and *B. licheniformis* have been isolated from rotting fruits and vegetables in order to produce industrially significant polygalacturonase, according to investigations by Dharmik and Gomashe (2013) and Rehman et al.(2014). Enzymes called polygalacturonases are engaged in the breakdown of pectic materials and are widely utilised in the food industry, textile processing, plant rough fibre degumming, and pectic wastewater treatment. Additional research shows that *Trichoderma harzianum* and *Trichoderma virens* can produce polygalacturonase (PG) by utilising the rinds of cantaloupe, watermelon, oranges, and bananas. *T. harzianum* and *T. virnes* cultivated on cantaloupe and watermelon rinds, respectively, produce the most PGase (Mohamed SA et al., 2013).The cellulose, hemicellulose, and lignin found in husks, peels, pulp, and shells are examples of agro-industrial waste that can be utilised to grow mushrooms and manufacture lignocellulolytic enzymes (Kumla J et al., 2020). Both carbon and energy sources could be found in these waste materials. This kind of waste also supplies the nutrients required for the solid state fermentation process, which results in the production of lignocellulolytic enzymes necessary for the growth of mushrooms (Sánchez C, 2009; Knob A et al., 2014; Grimm D et al., 2018).

Mushrooms are important in the lignocellulose breakdown process because they produce both oxidative and hydrolytic enzymes. The breakdown of polysaccharides is carried out by hydrolytic enzymes like cellulases and hemicellulases, whereas oxidative enzymes like ligninases are known to be responsible for the modification and degradation of lignin (Kumla J et al., 2020). Lignocellulolytic enzymes are utilised in a variety of food industries, including fruit and vegetable juice, vegetable oil processing, winemaking, brewing, and baking, to aggressively break down lignocellulosic substrates (Bhat MK, 2000). *Phanerochaete chrysosporium,* a white-rot Basidiomycete, has been found to produce other lignolytic enzymes, such as lignin peroxidase (LiP) and manganese peroxidase (MnP), from sawdust and paper mill discards, grasses, waste paper, agricultural residues, including straw, stover, peelings, cobs, stalks, nutshells, non-food seeds, bagasse, and domestic wastes (Qi BC et al., 2005; Roig A et al., 2006; Munir N et al., 2015).

Many agricultural wastes have been used to produce α-amylase from *Gibberella fujikuroi*, *Bacillus subtilis* (Baysal Z et al., 2003), *Aspergillus oryzae* (Francis F et al., 2003), *Bacillus cereus* strain WN11 (Mamo G & Gessesse A, 1999), *Bacillus cereus* (Vijayaraghavan P et al., 2015), *Paenibacillus chitinolyticus* CKS1 (Mihajlovski KR et al., 2016), *Bacillus amyloliquefaciens* (Abd-Elhalem, BT et al., 2015) from rice bran, rice straw + rice bran, wheat bran, coconut oil cake, red gramme husk, molasses, and sugar beet pulp, starch processing wastewater, cow dung, orange waste powder, potato starchy waste, Sal (*Shorea robusta*) deoiled cake, jowar straw and jowar spathe. The starch molecules are hydrolyzed by amylases into polymers made of glucose units. Amylases have the potential to be used in many different industrial processes, including those in the food, fermentation, and pharmaceutical sectors.

Another crucial enzyme for industry is Protease, which is utilised in the food, pharmaceutical, detergent, silk, leather, and X-ray film industries (Jisha VN et al., 2013). It is also used to recover silver from used film. According to research done in 2008 by Mahanta N et al., deoiled Jatropha seed cake was the greatest source of lipase and protease. In 2014, Shivasharanappa, K. et al. isolated the novel strain of *Trichoderma viridiae* strain VPG 12 from agricultural soil and used different agricultural wastes, including red, green, and Bengal gramme husk, to manufacture alkaline protease from this strain. The use of wheat bran, lentil husk, defatted soy bean cake, coconut oil cake, rice bran, spent brewing grain wheat bran, rice husk, palm kernel cake, sesame oil cake, potato pulp powder, olive oil cake, jackfruit seed powder, green gramme husk, coffee pulp waste, and corncobs for the production of proteases using *Penicillium sp.*, *Bacillus sp.*, *Aspergillus oryzae*, and *Pseudomonas aeruginosa* has also been demonstrated in earlier studies (Germano S et al., 2003; Baysal Z et al., 2003; Sandhya C et al., 2005; Murthy P.S. and Kusumoto KI, 2015).

***Table 1:** Production of Industrial products from agrowaste*

| Agro waste | Enzyme produced | Organism | Application | References |
|---|---|---|---|---|
| Rotten fruits and vegetables, cantaloupe and watermelon rinds, orange and banana peels | Polygalacturonase | *B. subtilis, B. licheniformis,T.harzianum andT. virnes* | Food processing, textile manufacturing, plant rough fibre degumming, and pectic waste water treatment | *Dharmik and Gomashe, 2013; Mohamed SA et al., 2013; Jahan N et al., 2017* |
| Straw, stover, peelings, cobs, stalks, nutshells, non-food seeds, bagasse which includes cellulose, hemicelluloses and lignin | Hydrolytic enzymes,oxidative enzymeslignin peroxidase (LiP) and manganese peroxidase (MnP) | Mushrooms, *Phanerochaete chrysosporium* | Production of wine, beer, baked goods, vegetable oil, and fruit and vegetable juice | *Munir N et al 2015* |
| Wheat bran and rice husk coconut oil cake, Sal tree (Shorea robusta) | α-amylase | *Bacillus subtilis,Bacillus cereus, & Aspergillus flavus TF-8* | Food, fermentation, textile, paper, detergent, and pharmaceuticals | *Baysal Z et al., 2003; Naik B et al., 2023* |
| Rice straw, rice bran | Cellulase, endoglucanase, and β-glucosidase | *Penicillium sp., A. niger and Trichoderma sp.* | Biopolishing of fabrics and cotton;degradation of lignocellulosic complexes and plant biomass | *Singh A et al., 2021* |
| Bran made of wheat. Red gramme husk, coffee husk, green gramme husk, ground nut waste, cotton seed waste, tamarindus seed powder, rice bran, cashew apple bagasse | Tannase | *Aspergillus aculeatus* | Manufacture of gallic acid, pyrogallol, food and beverage processing, management of tannery effluents and wastewater | *Malgireddy NR & Nimma LNR. 2015* |
| Wheat bran, chickpeas, husks, red, green and black gram | Proteases | *Aspergillus parasiticus, Bacillus sp* | Detergent and pharmaceutical food industries | *Sandhya C et al., 2005* |
| Sunflower hulls, peanut shells, rice bran, wheat bran, and canola seed oil cake | Lipases | *Aspergillus melleus* | Paper, leather, textile, cosmetic, food, detergent, and pharmaceutical industries | *Amin M et al 2014* |

## 4.3 Utilisation of Agricultural Waste in the Pharmaceutical Sector

### *4.3.1 Antibiotic Production*

Agricultural wastes like sawdust, rice hulls, peanut shells, and maize cobs are rich in bioactive compounds. Studies have shown that agricultural waste can be used as a substrate to synthesise anti-oxidant and anti-cancer drugs. Furthermore, waste from the food and agriculture industries may improve the body's capacity to absorb a variety of drugs. Antibiotics are compounds that inhibit or completely destroy the growth of other bacteria when used in very small quantities. Certain microorganisms produce them. They can therefore be utilised in the industrial production of antibiotics and other high-value products.

Antibiotics derived from a range of agricultural wastes include oxytetracycline, rifamycin B, and tetracycline. Peanut (groundnut) shells, corncob, corn pomace, and cassava peels are among the substrates that *Streptomyces sp*. OXCI, *S. rimosus* NRRL B2659, *S. rimosus* NRRL B2234, *S. alboflavus* NRRL B1273, *S. aureofaciens* NRRL B2183 and *S. vendagensis* ATCC 25507 can use to make tetracyclin. Corncobs and peanut shells were the most prolific substrates for the synthesis of tetracycline *(Asagbra AE et al., 2005).* Tetracycline production was most effectively achieved by *Streptomyces sp.* OXC1 when peanut shells were utilised as the substrate for solid fermentation. Cocoyam peels, considered an agricultural waste product in homes

***Table 2 :** Bioactive compounds extracted from different agrowaste*

| Substrate | Extracted compound | Application | References |
|---|---|---|---|
| Apple seeds | Gallic acid, protocatechuic acid, ellagic acid, caffeic acid, ferrulic acid, and phenolidzin | Used as antioxidant, antimicrobial, anti-inflammatory, antiproliferative activities | *Gunes R et al., 2019* |
| Sunflower leaves | Diterpenoids, flavonoids | Used as antioxidant, anti-inflammatory immune-modulatory action anti-tumour, anti-atherosclerotic, and anti-diabetic | *Fuentes-Gandara F et al., 2018* |
| Peanut (groundnut) shells, corncob, corn pomace | Tetracycline | used preventively to stop malaria brought on by Plasmodium falciparum, a mefloquine-resistant parasite | *Asagbra AE et al., 2005* |
| Cocoyam peels | Oxytetracycline | Used to treat infections of the respiratory tract (pneumonia), urinary tract, soft tissues, and skin | *Fierascu R et al., 2019* |
| Oil-pressed cake | Rifamycin B | used as an antimycobacterial and to treat mycobacterial infections linked to AIDS, leprosy, and tuberculosis | *Vastrad BM & Neelagund SE, 2011* |
| Wheat bran, soy bean powder, cotton seed meal, and apple pomace | Neomycin | Used to treat and manage hepatic coma and perioperative prophylaxis | *Sambamurthy K & Ellaiah P 1974.* |
| Pomegranate byproductspeels, pomace, seeds | Ellagitannins, punicalagin, and punicalin, | Used as antioxidants anti-cancer agents | *Fierascu R et al., 2019* |
| Cocoa shells | Catechins, epicatechins, theobromine, and caffeine | Has anti-oxidant effects used in food and pharmaceutical industries | *Fierascu R et al., 2019* |
| Sugarcane straw and coffee husk | Xylo-oligosaccharides | Used as antioxidant,anti-hyperglycemicapplied in food, pharmaceutical and agricultural industries | *Gullon P et al., 2010* |

and kitchens, have been proven to yield oxytetracycline when incubated with the bacteria Streptomyces speibonae OXS1. Vastrad and Neelagund's research showed that extracellular rifamycin B may be produced by solid-state fermentation with oil-pressed cake, which is regarded as an industrial and agricultural waste *(Taneja A et al., 2023).*

Neomycin is a necessary aminoglycoside antibiotic that is effective against both gram-positive and gram-negative bacteria, including mycobacteria. The capacity to manufacture neomycin has been examined in a wide range of bacteria, including strains of Streptomyces such as Streptomyces fradiae *(Dulmage, H. T. 1953)* and Streptomyces marinensi *(Sambamurthy K & Ellaiah, 1974).* Nevertheless, neomycin's high cost and low yields have been the main barriers to its industrial manufacture. Neomycin has been produced from agricultural wastes such apple pomace, cotton seed meal, soy bean powder, and wheat bran by using Streptomyces fradiae in solid-state fermentation.

*4.3.2 Antioxidant and anticancer potential in agricultural byproducts*

It is obviously worthwhile to recover the many classes of natural compounds included in agro-industrial waste and byproducts, such as antioxidants and anticancer capabilities. They can be found in agricultural food wastes such as straws, pomace, peels, and seed fractions, which are rich in phytochemicals such as dietary fibres, polysaccharides, and flavour compounds. Using the pressurised liquid extraction (PLE) method, the kernels, fibre, shells, and leaves of the palm fruit are used to produce a variety of antioxidant compounds, such as tocopherols and tocotrienols, fulvic acid and humic acid, which have been shown to lower the risk of cancer *(Cardenas-Toro et al., 2015).*

*Nile et al. 2019* have employed traditional centrifugation to extract triterpenic acids and phenolic compounds from apple pomace. Utilising the PLE approach, a rich collection of antioxidant phenolic compounds categorized into four subgroups such as phenolic acids and alcohols, lignans, and flavones have also been extracted from olive wastes, including pomace, kernel, and leaves. Extracted from olive pomace, chemicals like hydroxytyrosol, maslinic acid, and oleanolic acid have been shown to have beneficial impacts on human health, including their role in preventing cardiovascular disease and cancer. Punicalagin, punicalin, and ellagitannins, three incredibly potent antioxidants with anti-cancer properties in cases of skin, lung, and prostate cancer, are found in pomegranate leftovers. Using hydrodynamic cavitation and ultrasound-assisted extraction, anticarcinogenic compounds such as epicatechins, theobromine, and caffeine can be extracted from cocoa shells. Non-digestible dietary components called xylooligosaccharides (XOS) have prebiotic and antibiotic qualities that are notably beneficial for promoting the growth of probiotics. One of the main sources of XOS is the plant biomass found in agricultural leftovers, which includes lignocellulosic materials (LCMs) like xylan. In addition to their many health advantages, they are used extensively in the food and pharmaceutical industries *(Jain I et ai., 2015).*

## 5. Conclusion

Using a possible microbial consortium, efforts were undertaken to transform vegetable waste into value-added products including compost, livestock feed, liquid biofertilizer, and an industrially significant crude enzyme mix. The study illustrated the significance of bacterial–fungal consortia as a bio-tool for converting organic waste into goods with added value. Since the great majority of agricultural wastes are now burned or buried in soil, creating contamination of the air, water, and climate, agricultural wastes and their processing are a global concern. Certain crop wastes have historically been utilised for papermaking, animal feed, roof thatching, composting, soil mulching, and burning. To sum up, transforming agricultural waste into products with additional value is a big step in the direction of sustainable and ethical farming methods. By utilising agricultural by-products to their full potential, we can create jobs and reduce environmental risks related to trash disposal. The conversion of agricultural waste into valuable products like biofuels, organic fertilisers, and biodegradable packaging materials is a prime example of how innovation can be used to solve problems related to the environment and the economy. Adopting this strategy encourages resource efficiency, lowers carbon footprint, and builds a more resilient and sustainable agriculture sector in addition to supporting a circular economy. In order to fully realise the potential of agrowaste and make a good impact on the agricultural landscape as well as the larger global environment, it will be imperative that we engage in research, technology, and cooperative efforts going forward.

**Conflicts of Interest:**

The authors declare no conflicts of interest

**References:**

*Abd-Elhalem BT, El-Sawy M, Gamal RF, & Abou-Taleb KA (2015). Production of amylases from Bacillus amyloliquefaciens under submerged fermentation using some agro-industrial by-products. Annals of Agricultural Sciences, 60(2): 193-202.*

*Ahmad M, Wolberg A & Kahwaji CI (2018). Biochemistry, electron transport chain. Europe PMC plus.*

*Alexandratos N, & Bruinsma J (2012). World agriculture towards 2030/2050: the 2012 revision.*

*Almatouq A, Babatunde AO, Khajah M, Webster G & Alfodari M (2020). Microbial community structure of anode electrodes in microbial fuel cells and microbial electrolysis cells. Journal of Water Process Engineering, 34: 101140.*

*Amin M, Bhatti HN, Zuber M, Bhatti IA, & Asgher M (2014). Potential use of agricultural wastes for the production of lipase by Aspergillus melleus under solid state fermentation. JAPS: Journal of Animal & Plant Sciences, 24(5).*

*Asagbra AE, Sanni AI & Oyewole OB (2005). Solid-state fermentation production of tetracycline by Streptomyces strains using some agricultural wastes as substrate. World journal of microbiology and biotechnology, 21:107-114.*

*Baysal Z, Uyar F & Aytekin Ç (2003). Solid state fermentation for production of α-amylase by a thermotolerant Bacillus subtilis from hot-spring water. Process Biochemistry, 38(12): 1665-1668.*

*Bhat MK (2000). Lignocellulolytic enzymes: Applications in the food industry. Critical Reviews in Food Science and Nutrition, 40(1):1-44.*

*Cao Y, Mu H, Liu W, Zhang R, Guo J, Xian M & Liu H (2019). Electricigens in the anode of microbial fuel cells: pure cultures versus mixed communities. Microbial cell factories, 18(1): 1-14.*

*Cao Y, Yang R & Martin VG (2019). Nature needs half: A new vision for global protected areas. Landscape Architecture, 26(4): 39-44.*

*Cardenas-Toro FP, Alcázar-Alay SC, Coutinho JP, Godoy HT, Forster-Carneiro T & Meireles MAA (2015). Pressurized liquid extraction and low-pressure solvent extraction of carotenoids from pressed palm fiber: Experimental and economical evaluation. Food and Bioproducts Processing, 94: 90-100.*

*Dantroliya S, Joshi C, Mohapatra A, Shah D, Bhargava P, Bhanushali S & Joshi M (2022). Creating wealth from waste: An approach for converting organic waste in to value-added products using microbial consortia. Environmentai Technology & Innovation, 25: 102092.*

*Das K S (2020). Microbial fuel cells: a path to green, renewable energy. Practices and Perspectives in Sustainable Bioenergy: A Systems Thinking Approach, 195-206.*

*Dharmik PG & Gomashe AV (2013). Bacterial polygalacturonase (PG) production from agro industrial waste by solid state fermentation. Indian journai of applied research, 3(6): 439-442.*

*Dulmage H T (1953). The production of neomycin by Streptomyces fradiae in synthetic media. Applied microbiology, 1(2): 103-106.*

*Fierascu RC, Fierascu I, Avramescu SM & Sieniawska E (2019). Recovery of natural antioxidants from agro-industrial side streams through advanced extraction techniques. Molecules, 24(23): 4212.*

*Flores SJR, Benites SM, Rosa ALRAL, Zoilita ALZAL & Luis ASL (2020). The Using Lime (Citrus× aurantiifoiia), Orange (Citrus× sinensis), and Tangerine (Citrus reticulata) Waste as a Substrate for Generating Bioelectricity: Using lime (Citrus× aurantiifolia), orange (Citrus× sinensis), and tangerine (Citrus reticulata) waste as a substrate for generating bioelectricity. Environmental Research, Engineering and Management, 76(3): 24-34.*

Francis F, Sabu A, Nampoothiri KM, Ramachandran S, Ghosh S, Szakacs G & Pandey A (2003). Use of response surface methodology for optimizing process parameters for the production of α-amylase by Aspergillus oryzae. Biochemical Engineering Journal, 15(2): 107-115.

Fuentes-Gandara F, Torres A, Fernández-Ponce MT, Casas L, Mantell C, Varela R & Macias F A (2019). Selective fractionation and isolation of allelopathic compounds from Helianthus annuus L. leaves by means of high-pressure techniques. The Journal of Supercritical Fluids, 143: 32-41.

Germano S, Pandey A, Osaku CA, Rocha SN & Soccol CR (2003). Characterization and stability of proteases from Penicillium sp. produced by solid-state fermentation. Enzyme and microbial technology, 32(2): 246-251.

Grimm D & Wösten HA (2018). Mushroom cultivation in the circular economy. Applied microbiology and biotechnology, 102: 7795-7803.

Gunes R, Palabiyik I, Toker OS, Konar N & Kurultay S (2019). Incorporation of defatted apple seeds in chewing gum system and phloridzin dissolution kinetics. Journal of Food Engineering, 255: 9-14.

Gullón P, González-Muñoz MJ, van Gool MP, Schols HA, Hirsch J, Ebringerová A & Parajó JC (2010). Production, refining, structural characterization and fermentability of rice husk xylooligosaccharides. Journal of Agricultural and Food Chemistry, 58(6): 3632-3641.

Gupta B & Arora SK (2016). Municipal solid waste management in Delhi—the capital of India. Int J Innov Res Sci Eng Technol, 5(4): 5130-5138.

https://www.iwmi.cgiar.org/Publications/wle/business-model-profiles/resource-recovery-from-waste brief-6-generating-power-from-agro-waste.pdf

Jahan N, Shahid F, Aman A, Mujahid TY & Qader SAU (2017). Utilization of agro waste pectin for the production of industrially important polygalacturonase. Heliyon, 3(6).

Jain I, Kumar V & Satyanarayana T (2015). Xylooligosaccharides: an economical prebiotic from agroresidues and their health benefits. Indian Journal of Experimental Biology 53(03): 131-142.

Jisha VN, Smitha RB, Pradeep S, Sreedevi S, Unni KN, Sajith S & Benjaminn S (2013). Versatiiity of microbial proteases, Advances in Enzyme Research, 1 (3), 39–51.

Kaur N (2014). Converting Waste Agricultural Biomass into Electrical Energy–Indian Perspective. Communication, Computing & Systems (ICCCS–2014), 264.

Koul B, Yakoob M & Shah MP (2022). Agricultural waste management strategies for environmental sustainability. Environmental Research, 206: 112285.

Knob A, Fortkamp D, Prolo T, Izidoro SC & Almeida JM (2014). Agro-residues as alternative for xylanase production by filamentous fungi. BioResources, 9(3): 5738-5773.

Kumar R, Singh L, Wahid ZA & Din MFM (2015). Exoelectrogens in microbial fuel cells toward bioelectricity generation: a review. International Journal of Energy Research, 39(8), 1048-1067.

Kumla J, Suwannarach N, Sujarit K, Penkhrue W, Kakumyan P, Jatuwong K & Lumyong S (2020). Cultivation of mushrooms and their lignocellulolytic enzyme production through the utilization of agro-industrial waste. Molecules, 25(12): 2811.

Logan BE, Rossi R, Ragab AA & Saikaly PE (2019). Electroactive microorganisms in bioelectrochemical systems. Nature Reviews Microbiology, 17(5): 307-319.

Li L, Peng X, Wang X & Wu D (2018). Anaerobic digestion of food waste: A review focusing on process stability. Bioresource technology, 248: 20-28.

Malgireddy NR & Nimma LNR (2015). Optimal conditions for production of tannase from newly isolated Aspergillus terrus under solidstate fermentation. European Journal of Biotechnology and Bioscience, 3(2): 56-64.

Mahanta N, Gupta A & Khare SK (2008). Production of protease and lipase by solvent tolerant Pseudomonas aeruginosa PseA in solid-state fermentation using Jatropha curcas seed cake as substrate. Bioresource technology, 99(6), 1729-1735.

Mamo G & Gessesse A (1999). Purification and characterization of two raw-starch-digesting thermostable α-amylases from a thermophilic Bacillus. Enzyme and Microbial Technology, 25(3-5): 433-438.

Mihajlovski KR, Radovanović NR, Veljović DN, Šiler-Marinković SS & Dimitrijević-Branković SI (2016). Improved β-amylase production on molasses and sugar beet pulp by a novel strain Paenibacillus chitinolyticus CKS1. Industrial crops and products, 80: 115-122.

Mohamed SA, Al-Malki AL, Khan JA, Kabil SA & Al-Garni SM (2013). Solid state production of polygalacturonase and xylanase by Trichoderma species using cantaloupe and watermelon rinds. Journal of microbiology, 51: 605-611.

Munir N, Asgher M, Tahir IM, Riaz M, Bilal M & Shah SA (2015). Utiiization of agro-wastes for production of ligninolytic enzymes in liquid state fermentation by Phanerochaete chrysosporium-IBL-03. IJCBS, 7, 9-14.

Murthy PS & Kusumoto KI (2015). Acid protease production by Aspergillus oryzae on potato pulp powder with emphasis on glycine releasing activity: A benefit to the food industry. Food and Bioproducts Processing, 96: 180-188.

Naik B, Kumar V, Rizwanuddin S, Chauhan M, Gupta AK, Rustagi S & Gupta S (2023). Agro-industrial waste: a cost-effective and eco-friendly substrate to produce amylase. Food Production, Processing and Nutrition, 5(1): 30.

NIle SH, Nile A, Liu J, Kim DH & Kai G (2019). Exploitation of apple pomace towards extraction of triterpenic acids, antioxidant potential, cytotoxic effects, and inhibition of clinically important enzymes. Food and Chemical Toxicology, 131: 110563.

Otoo M & Drechsel P (Eds.) (2017). Resource recovery from waste: Business models for energy, nutrient and water reuse in low- and middle-income countries. London: Earthscan/Routledge.

Qi BC, Aldrich C, Lorenzen L & Wolfaardt GW (2005). Acidogenic fermentation of lignocellulosic substrate with activated sludge. Chemical Engineering Communications, 192(9): 1221-1242.

Rehman HU, Aman A, Zohra RR & Qader SAU (2014). Immobilization of pectin degrading enzyme from Bacillus licheniformis KIBGE IB-21 using agar-agar as a support. Carbohydrate Polymers, 102:622-626.

Rodríguez G, Lama A, Rodríguez R, Jiménez A, Guillén R & Fernández-Bolanos J (2008). Olive stone an attractive source of bioactive and valuable compounds. Bioresource technology, 99(13): 5261-5269.

Roig A, Cayuela ML & Sánchez-Monedero MA (2006). An overview on olive mill wastes and their valorisation methods. Waste management, 26(9): 960-96

Rojas-Flores S, Noriega MDLC, Benites SM, Gonzales GA, Salinas AS & Palacios FS (2020). Generation of bioelectricity from fruit waste. Energy Reports, 6: 37-42.
Rojas-Flores S (2022). Generation of Electricity from Agricultural Waste. Green Energy and Environmental Technology.

Rojas-Flores S, Benites SM, De La Cruz-Noriega M, Cabaniias-Chirinos L, Valdiviezo-Dominguez F, Quezada Álvarez MA & Angelats-Silva L (2021). Bioelectricity production from blueberry waste. Processes, 9(8): 1301.

Rojas-Flores S, Pérez-Delgado O, Nazario-Naveda R, Rojaies-Aifaro H, Benites SM., De La Cruz-Noriega M & Otiniano NM (2021). Potential use of papaya waste as a fuel for bioelectricity generation. Processes, 9(10): 1799.

Salemdeeb R, Zu Ermgassen EK, Kim MH, Balmford A & Al-Tabbaa A (2017). Environmental and health impacts of using food waste as animal feed: a comparative analysis of food waste management options. Journal of cleaner production, 140: 871-880.

Sambamurthy K & Ellaiah P (1974). A new Streptomycete producing neomycin (B&C) complex-S. marinensis (part I). Hindustan antibiotics bulletin, 17(1-2): 24-28.

Sánchez C (2009). Lignocellulosic residues: biodegradation and bioconversion by fungi. Biotechnology advances, 27(2): 185-194.

Sarkar P & Chourasia R (2017). Bioconversion of organic solid wastes into biofortified compost using a microbial consortium. International Journal of Recycling of Organic Waste in Agriculture, 6: 321-334.

Sandhya C, Sumantha A, Szakacs G & Pandey A (2005). Comparative evaluation of neutral protease production by Aspergillus oryzae in submerged and solid-state fermentation. Process biochemistry, 40(8): 2689-2694.

San Martin D, Ramos S & Zufía J (2016). Valorisation of food waste to produce new raw materials for animal feed. Food chemistry, 198: 68-74.

Shivasharanappa K, Hanchinalmath JV, Sundeep YS, Borah D & Prasad Talluri VSSL (2014). Optimization and production of Alkaline Proteases from Agro byproducts using a novel Trichoderma Viridiae strain VPG 12, isolated from agro soil. International Letters of Natural Sciences, 9.

Singh A, Bajar S, Devi A & Bishnoi NR (2021). Adding value to agro-industrial waste for cellulase and xylanase production via solid-state bioconversion. Biomass Conversion and Biorefinery, 1-10.

Taneja A, Sharma R, Khetrapal S, Sharma A, Nagraik R, Venkidasamy B & Kumar D (2023). Value Addition Employing Waste Bio-Materials in Environmental Remedies and Food Sector. Metaboiites, 13(5): 624.

Vastrad BM & Neelagund SE (2011). Optimization and production of neomycin from different agro industrial wastes in solid state fermentation. International Journal of Pharmaceutical Sciences and Drug Research, 3(2): 104-111.

Verma M & Mishra V (2021). Recent trends in upgrading the performance of yeast as electrode biocatalyst in microbial fuel cells. Chemosphere, 284: 131383.

Vijayaraghavan P, Kalaiyarasi M & Vincent SGP (2015). Cow dung is an ideal fermentation medium for amylase production in solid-state fermentation by Bacillus cereus. Journal of Genetic Engineering and Biotechnology, 13(2): 111-117.

Zhang Y, Fan S, Liu T, Omar MM & Li B (2022). Perspectives into intensification for aviation oil production from microwave pyrolysis of organic wastes. Chemical Engineering and Processing-Process Intensification, 176: 108939.