Chapter 10
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The Utilization of Agro-Waste: A Nanobiotechnology Point of View

Iyabo Christianah Oladipo[1*] and Seun Barnabas Ogunsona[1]

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ABSTRACT

Aims: To review the utilization of agro-waste in the eco-friendly synthesis of nanoparticles and their biomedical, catalytic and industrial applications.
Study Design: A review.
Place and Duration of Study: This review was carried out in the interim of three weeks exploiting all relevant data, literature and publications where necessary.
Methodology: Profound gathering of literatures/publications and reviews were employed with all carefulness and professional courtesy; enough useful information were gathered over time. The introduction emphasizes the dawn of science and technology, when great ideas were still latent later leading to the advent of history changing innovations like the completion of human genome and then the birth of nanotechnology. Although, nanotechnology had been known decades been popularized by Richard Feynman in his talks in the year 1959; and in this present dispensation, nanotechnology has been a solution to many intricate challenges/ threats in science and technology. Waste/agro-waste being one out of many threats affecting the eco system has triggered the attention of great minds to exploit fresh avenues in the area of nanotechnology/nanobiotechnology and as a result turning agro waste into readily available raw materials for eco-friendly synthesis of nanoparticles capable of biomedical and industrial properties.
Results: This review has provided information on the advancement of nanotechnology and areas where agro waste have played pivotal roles in the synthesis of eco-friendly nanoparticles. With relevant literature, journals and citations, this review has provided wealth of information on what could be done with agro waste within the confines of nanobiotechnology and beyond.
Conclusion: The advancement of science in the area of nanotechnology/nanobiotechnology has given birth to many innovations the world would have decried as useless centuries back, and now the world is a better place, all thanks to nanotechnology as agro wastes are no longer threats to the eco system.

Keywords: Eco-friendly; nanotechnology; nanobiotechnology; nanoparticles; agro-wastes; synergy.

1. INTRODUCTION

The sapient nature of man has made innovation a growing phenomenon depending on the degree of necessity. Since the dawn of science, researchers have been showing feat of ingenious through discoveries, hypothesis and postulations towards the improvement of livelihood in all ramifications. Many achievements have been recorded throughout history from the discovery of antibiotics to the launch of the first spaceship; the discovery of helical structure of DNA by Crick and Watson in 1953, to the completion of human genome in 2003. All this unprecedented achievement established the advancement in science which remains insatiable. Recently, Nanotechnology, a new advancement in science has opened doors for new possibilities; lending credence to the proposition of Richard Feynman in 1959 "there is plenty of room at the bottom" [1]. Richard Feynman named father of nanotechnology gave this talk in one of his lectures many years ago and today the world is moving towards this new advancement in all areas [2].

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[1]Department of Science Laboratory Technology, Ladoke Akintola University of Technology, Ogbomoso 210214, Oyo State, Nigeria.
**Corresponding author: E-mail: xtiecoker@gmail.com;*

2. NANOTECHNOLOGY

Nanotechnology is the science that deals with the manipulation of materials within the confines of nanometer scale in order to exhibit unprecedented characteristics. According to the National Nanotechnology Initiative (NNI), Nanotechnology is the manipulation of materials, systems and devices to produce nanoparticles with at least one dimension sized from 1 to 100 nanometers [3,4]. The prefix "nano" was derived from greek word for dwarf; one nanometer (nm) is one billionth (10^{-9}) of a meter. Nanoparticles act as a bridge between bulk materials and atomic or molecular structures. Nanoparticles are of different types, they maybe synthesized naturally, unintentionally released or manufactured [5]. There are two classifications of nanoparticles; Inorganic nanoparticles i.e. metal/ metal oxides for example Au, Ag [6], Fe_3O_4, TiO_2 etc and Organic nanoparticles i.e. quaternary ammonium compound, cationic quaternary polyelectrolytes and chitosan etc.

3. PROPERTIES OF NANOPARTICLES

(i) Nanoparticles possess physical properties that established their state; the physical properties include; specific surface area, shape and size, aggregation, state of size distribution, morphology/topography, solubility, structure including crystallinity [7].
(ii) Nanoparticles possess different characteristics from their parent materials based on: The large surface area that facilitates faster chemical reaction, which as a result improve their strength and electrical conductivity [8].
(iii) They acquire quantum effects (<50 nm), provoking their optical, electrical and magnetic. This attributes can lead to high capacity for storing or transferring heat, Greater electrical conduction or resistance. Modified biological properties i.e. silver becoming bactericide having used as a precursor in the synthesis of nanoparticles [9].

Nanotechnology is a field that covers a vast and diverse array of devices derived from engineering, physics, chemistry and biology. Nanotechnology is also a multidisciplinary advancement that open the way for more innovations in all fields including medicine, electronics, foods and the environment [10]. Nano materials have been utilized in many biological applications such as biosensing, anticancer therapy, antimicrobial analysis etc. such making nanotechnology a cutting edge innovations among many. Nanotechnology is applicable in virtually all the fields in science and among all these fields is biology, the study of life forms and its environment thus establishing the term "nanobiotechnology".

4. NANOBIOTECHNOLOGY

Nanobiotechnology is a word describing the synergy between the world of engineering and molecular biology [10]. Researchers in the field of engineering have been known for decades to be working on shrinking the dimensions of fabricated structures to enable faster and higher density which have yield tremendous result as they were able to acquire the size as small as 20 nm and so also were researchers in the field of molecular biology in the domain of molecular and cellular dimensions ranging from nanometers to micrometers [10,11]. Niemeyer and Mirkin [12] stated that it is believed that a combination of these disciplines will result in a new class of multifunctional devices and systems for biological and chemical analysis. The wealth of knowledge from the two broad areas of science are embedded in nanobiotechnology, creating a vast research ground for researchers.

Nanobiotechnology provides new insight into many intricate problems in science and technology; analyses of signaling pathways into diseases processes, thus identifying more efficient biomarkers and shedding more light on the action of drugs mechanism [13], manipulation of nanomaterials in order to facilitate the binding of different biomolecules such as bacteria, toxins, proteins and nucleic acids [14], bioremediation using nanoparticles and production of nano particles from plant wastes. The use of plant materials for nanoparticles synthesis is a comparatively new and under-researched technique [15]. Using plant parts such as leaves [16], husk [6], roots [17] and stem bark [18] have been successfully used in the synthesis of metal nanoparticles.

Synthesizing a plant-based nanoparticles is very easy and cheap [19]. And also the sizes and shapes of the produced nanoparticles from plant parts can be modulated to some extent by varying the temperature, ambient conditions, reaction conditions and pH. Furthermore plant extracts contain capping agents, stabilizing agents and reducing agents so that no chemicals other than the metal source are needed [20,21,22]. Biosynthesis of metallic nanoparticles such as platinum, gold, silver, zinc, copper etc has proven to be successful and has established great attention and exploitation [23]. To avoid the use of hazardous chemicals in the synthesis of metallic nanoparticles, green chemistry has become a pivotal alternative in nanotechnology for a good deal of reasons such as less demanding, ecofriendly and low cost.

4.1 Agro-waste

The good, the bad, and the ugly side of agro waste inflict on man a deep yearn for its management and exploitation. Agro-waste are unwanted plant materials accumulated or gotten as a result of production and processing of agricultural products that may contain organic materials/macro molecules that can benefit man but whose economic values are less than cost of collection, transportation, and processing for beneficial use [24]. Over the years, agro wastes have become environmental problems and however they may also be used for several beneficial purposes [25].

4.2 The Uses of Agrowaste

Chemical adsorption: The extent at which heavy metals are being released into the atmosphere and environment through industrialization call for swift removal and elimination of these metals. Unlike plant waste that are degradable, heavy metals like copper, cadmium, mercury, zinc and lead etc. are not [26]. Agro-waste, through research has brought man lasting solutions to these pollution problems.

Agro waste such as Corn straws have shown that plant-residue-derived biochars can act as very effective sorbent as they were used in the Cu (II) and Zn (II) adsorption [27]. Also Acheampong et al. [28] reported the biosorption of Cu (II), onto coconut shell, coconut husk, saw dust and *Moring oleifera* seeds. Rice husk were also used for biosorption [29], Olive tree-pruning waste was also reported for good biosorption of Pb (II) from aqueous solution [30].

Dye adsorption: Textile industries might be doing man more harm than the benefits of covering his skin from harsh weather conditions and fashion glamour. Dyes being released into the water bodies pose a lot of threat to man and agriculture. Some agro wastes have been reported to adsorb these dyes. It was reported that methylene blue dye from aqueous solution can be absorbed onto cashew nut shell [31]. Brilliant red K-2G in aqueous solution can be removed by chestnut shells [32]. Malachite green can be removed from aqueous solution using cassava peel-based activated carbon [33].

Energy/Gas production: Agro wastes have been reported to produce gases through anaerobic digestion. Gases like methane 50-70%, CO_2 25-45%, N_2 0.5-3%, H_2 1-10% were produced [34]. Agro waste like feedstock waste [35], wood fillings, saw dust [36] can be gasified. Agro-waste can be used for bio gas production [37,38].

Biofertilizers: It was reported that banana leaf, maize cobs, wheat straw and bean straw were used as substrate to enhance crop growth and production [39], Jacinthe et al. [40] reported that biofertilizer not only increase the nutrient in the soil but also boost the soil carbon sequestration.

Construction materials: It was reported that wheat and eucalyptus fiber were used to produce fiber cement boards [41], it was also reported that luffa fibre and yarn waste could be used in combination with recycled cellulose fibers for insulation and packaging materials [42]. Palm fronds are being used by native Africans for roofing of mud houses and barns.

4.3 Agrowaste in Nanobiotechnology

Recently many researchers have exploited the replacement of plant parts with agro-industrial wastes in other to develop a fully green and sustainable methods of nanoparticle synthesis and also to make useful the agro-waste which would have otherwise being a threat to the environment one way or the other [43,44].

Over the years, many researchers have reported the usage of agro-waste as reducing/stabilizing agent in the synthesis of nanoparticles. Baiocco et al. [44] reported the usage of spent coffee grounds as reducing and capping agents in the synthesis of metallic nanoparticles. Zamare et al. [43] reviewed the usage of postharvest waste in the synthesis of nanoparticles. The postharvest wastes is almost 80% of the biomass on the agricultural fields and is often burnt in fields resulting in large amount of green gas emissions, also problems like snog arises causing serious health impact.

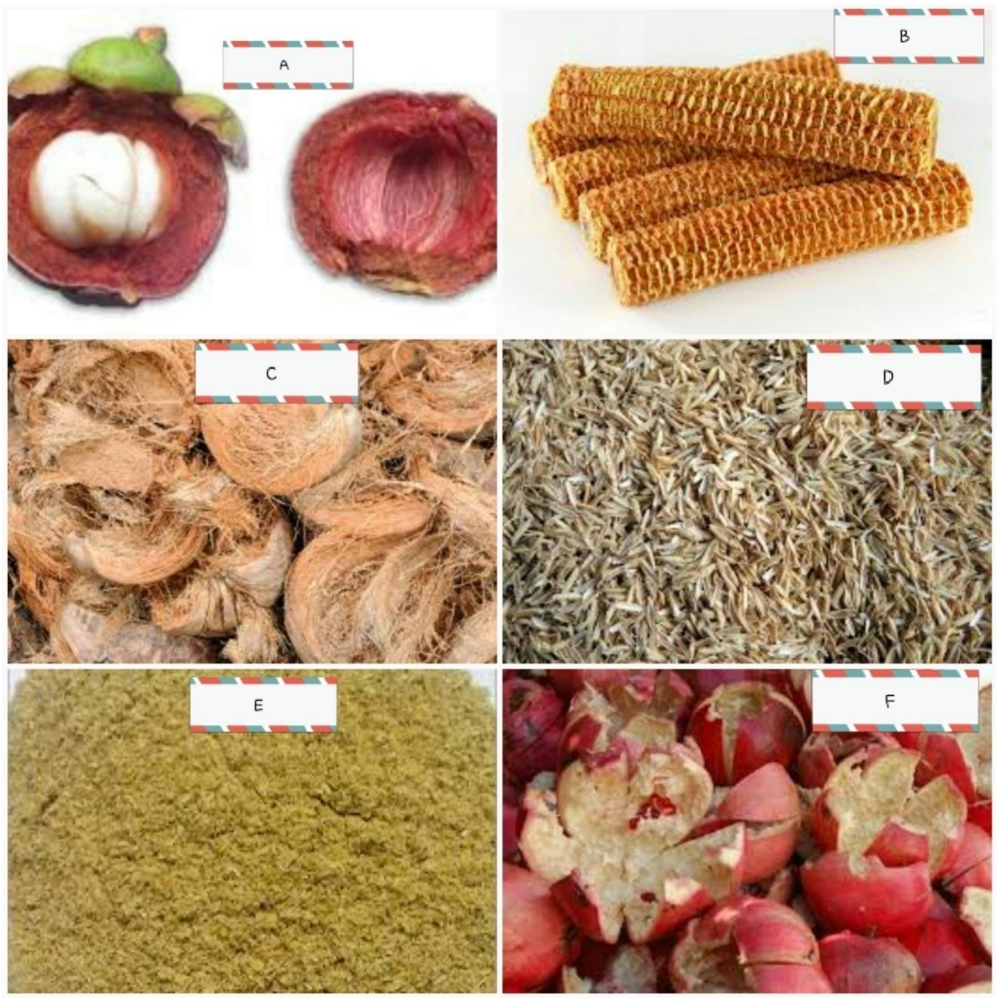

Fig. 1. Some agro-wastes used for the synthesis of nanoparticles; A: *Garcinia mangostana* fruit peels; B: corn cob; C: Coconut husk; D: Rice husk; E: Rice bran; F: pomegranate fruit peel

The waste management represents an important challenge in the agri-food based industries and demands an integrated approach in the context of recycling, reuse and recovery [45], although composting of this waste like rice bran, rice husk etc. for manure production and few for bio fuel production are been practiced but its usefulness in nanoparticles production is unprecedented. Zamare et al. [43] reported the possibility of biosynthesizing nanoparticles from agro-waste using postharvest wastes. Van et al. [9] reported the usage of rice husk in the green synthesis of silica nanoparticles.

Lee et al. [46] reported the green synthesis of gold nanoparticles using aqueous extract of *Garcinia mangostana* fruit peels. Bello et al. [47] reported the synthesis of uncarbonised coconut shell nanoparticles. To mention a few, in the field of biomedical and chemical engineering, nanoparticles synthesized from agro wastes have been reported to improve the finished products and also used in treatment of diseases related to blood. Profound exploitations have been embarked on since the dawn of nanotechnology and till now, unprecedented innovations in many areas have not seized as many researchers have brought to light the pivotal approach and applications of agro waste which had been latent before the down of nanotechnology. In the areas of microbiology, medicine, materials science, engineering, biochemistry and so on; nanotechnology has been the answer to intricate questions in science and technology.

5. BIOMEDICAL PROPERTIES OF NANOPARTICLES SYNTHESIZED FROM AGRO WASTE

5.1 Antimicrobial Activities

To plunge into the deep of intricacies in science within the confines of medicine, nanobiotechnology has been exploited in the areas of antimicrobial. Nanoparticles have been reported to have potent antimicrobial properties against super bugs that are highly resistant to antibiotics. Researchers have exploited the synergy effect of the precursor (metal) and plants (capping/reducing agent) relationship in the production of nanoparticles to create particles capable of destroying multi drug resistant bacteria and fungi.

Table 1. Antimicrobial activities of nanoparticles synthesized from agro waste

Nanoparticle synthesized	**Agro waste**	**Biomedical activities**	**Reference**
Silver nanoparticles (Ag Nps) {5-50nm}	Pomegranate peel	**Antibacterial activities** against *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Escherichia coli*	[48]
Silver nanoparticles (Ag Nps) {12 - 80 nm}	Kolanut *(Cola nitida*) Pod husk	**Antibacterial activities** against *Klebsiella granulomatis*, *Pseudomonas aeruginosa*, and *Escherichia coli* **Antifungal activities** through mycelial inhibition method against *Aspergillus niger*, *A.flavus* and *A. fumigatus*	[22]
Silver nanoparticles (Ag Nps) {4-32 nm}	Cocoa pod husk	**Antibacterial activities** against *E. coli, K. pneumoniae, Streptococcus pyogenes, Staphylococcus aureus, Pseudomonas aeruginosa*, **Antifungal activities** through mycelial inhibition method against *Aspergillus flavus, Aspergillus fumigatus and Aspergillus niger*	[6]
Silver nanoparticles (Ag Nps) {20 nm}	Waste vegetable peel	**Antibacterial activities** against *Escherichia coli, and Klebsiella pneumonae*	[49]
Silver nanoparticles (Ag Nps) {100 nm}	Root extract of *Echinops echinatus*	**Antibacterial activities** against *Escherichia coli, Staphylococcus aureus and Pseudomonas auruginosa*	[50]
Zinc Oxide Nanaparticles (ZnO Nps) {17.16nm}	Green tea leaves	**Antibacterial activities** against *Escherichia coli, Staphylococcus aureus and* **Antifungal activities** Aspergillus niger	[51]
Zinc Oxide Nanaparticles (ZnO Nps) {17.16nm}	Rice bran	**Antibacterial activities** against *Escherichia coli, Staphylococcus aureus and Pseudomonas auruginosa*	[52]

5.2 Other Biomedical Properties of Nanoparticles Synthesized from Agro Waste

Day in day out people are exposed to a lot of radiations, fumes, industrial emmisions, and dusts, all these could result in free radical generation in the body and even worse. Free radicals are electrically charged molecules with an unpaired valence electron and as a result cause them to seek out and capture electrons form other substances in order to neutralize themselves [53]. And if the initial free radicals are not neutralized in the body, it could lead to chain reaction causing thousands of free radical production. Antioxidants are capable of stabilizing free radicals before they attack cells causing more damage. It has been reported that some nanoparticles synthesized from agro waste have antioxidant properties [6]. It has also been reported that nanoparticles synthesized from agro waste have larvicidal. The ability of these nano particles to kill mosquito larva are bio medically important to man. Malaria is a life threatening parasitic disease transmitted by female anopheles mosquitoes. Furthermore, it has been reported that some nanoparticles synthesized from agro waste have thrombolytic and anticoagulant properties.

Table 2. Biomedical properties of nanoparticles synthesized from some agro waste

Nanoparticle synthesized	Agro waste	Biomedical activities	Reference
Silver nanoparticles (Ag Nps) {12 - 80 nm}	Kolanut *(Cola nitida*) Pod husk	**Antioxidant properites**: AgNps used to scavenge for free radicals afainst methanolic solution of 0.1 mM DPPH (2,2-diphenyl-1-picrylhydrazyl)	[22]
Silver-Gold alloy nanoparticles (Ag-Au Nps) {17-91nm}	Kolanut *(Cola nitida*) Pod husk	**larvicidal activities** against the larvae of Anopheles mosquito at 60, 80 and 100 µlg/ml concentration 4.0 ml **Anticoagulant** (by mixing 0.5 ml of 250 lg/ml of the nanoparticles with 5 ml of freshly collected human blood from a healthy volunteer**)** **Thrombolytic activity** in the management of blood coagulation disorder,	[6]
Silver nanoparticles (Ag Nps) {4-32 nm}	Cocoa pod husk	**Larvicidal activities** against the larvae of Anopheles mosquito at 10–100 µlg/ml concentration **Antioxidant properites**: AgNps used to scavenge for free radicals afainst methanolic solution of 0.1 mM DPPH (2,2-diphenyl-1-picrylhydrazyl)	[6]

Agro waste are rich in bio molecules although might not meet the standard of the product in which it was released from [24,25]; the properties of the agro wastes enable the nanoparticles synthesized from them to possess more properties than the bulk materials like serving as additives in some industrial products [6], catalytic and reducing agents.

Table 3. Nanoparticles from agro waste as additives, catalytic and reducing agent

Nanoparticle synthesized	Agro waste	Activities	Reference
Zinc Oxide Nanaparticles (ZnO Nps) {17.16nm}	Rice bran	**Photodegradation** and **Phtocatalytic activity** in Bromo phenol blue (BPB)	[52]
Silver-Gold alloy nanoparticles (Ag-Au Nps) {17-91nm}	Kolanut *(Cola nitida*) Pod husk	**Catalytic activities** of Ag-Au Nps at concentration of 5 µlg/ml through the decolourization of methylene blue and malachite green	[6]
Silver nanoparticles (Ag Nps) {4-32 nm}	Cocoa pod husk	**Ferric reducing activity**: 2.5 ml of potassium ferricyanide to 1 ml of Different concentrations of AgNPs prepared.	[6]
Silver nanoparticles (Ag Nps) {4-32 nm}	Cocoa pod husk	**Additive** into emulsion paint which led to effective inhibition of *E. coli, K. pneumoniae, S. pyogenes, S. aureus P. aeruginosa,* For fungal strains of *A. flavus, A. fumigatus* and *A. niger* growths	[6]
Silver nanoparticles (Ag Nps) {12 - 80 nm}	Kolanut *(Cola nitida*) Pod husk	**Additive** into emulsion paint which led to effective inhibition of *E. coli* and *P. aeruginosa.* For fungal strains of *Aspergillus flavus*, *A. fumigatus* and *A. niger* growths	[22]

6. CONCLUSION

Science is advancing, it keeps metamorphosing and liberating latent potentials in all fields. Nanotechnology as one of the fields in science is vast, pregnant with profound exploitation and full of promising future. On the evidence of already achieved advancement in the field, there are still lots of grounds to be covered. Nanotechnology has spread its tentacles towards the advancement of agro-industry through agro-waste utilization due to cutting edge researches done in the area of nanoparticles synthesis. Even though the agro-industry is just beginning to explore its applications, nanotechnology has exhibited great potential with new tools for the molecular treatment of diseases, weed control and enhancing the ability of plants to absorb nutrients [54].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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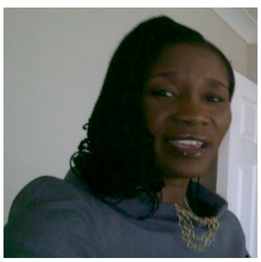
Biography of author(s)



Dr. Iyabo Christianah Oladipo
Department of Science Laboratory Technology, Ladoke Akintola University of Technology, Ogbomoso 210214, Oyo State, Nigeria.

She is a dedicated teacher and researcher, presently a senior lecturer in the Department of Science Laboratory Technology, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria. She won the 2009 TWAS-CSIR Postgraduate Fellowship, 2017 CAS-PIFI Postdoctoral Fellowship amongst others. She has published over Fourty articles in reputable journals and two book chapters. Her current research activities include synthesis and application of nanoparticles, Enterococcal bacteriocin quantification and characterization, food bio-safety and microbial toxins.