25

Egypt. J. Soil. Sci. Vol. **60**, No. 4, pp. 349-364 (2020)

Egyptian Journal of Soil Science

http://ejss.journals.ekb.eg/

Agricultural Waste and its Nano-Management: Mini Review

Hassan El-Ramady[1], Ahmed El-Henawy[1*], Megahed Amer[2], Alaa El-Dein Omara[3], Tamer Elsakhawy[3], Heba Elbasiouny [4], Fathy Elbehiry[5], Doaa Abou Elyazid[6] and Mohammed El-Mahrouk[6]

[1]*Soil and Water Dept., Faculty of Agriculture, Kafrelsheikh University, Egypt*

[2]*Soils Improvement Dept., Soils, Water and Environment Research Institute (SWERI), Sakha Station, Agricultural Research Center (ARC), Kafr El-Sheikh 33717, Egypt*

[3]*Agriculture Microbiology Department, Soil, Water and Environment Research Institute (SWERI), Sakha Agricultural Research Station, Agriculture Research Center (ARC), Kafr El-Sheikh 33717, Egypt*

[4]*Department of Environmental and Biological Sciences, Home Economy faculty, Al-Azhar University, Tanta 31732,*

[5]*Central Laboratory of Environmental Studies, Kafrelsheikh University, Kafr El-Sheikh 33516,*

[6]*Horticulture Dept., Faculty of Agriculture, Kafrelsheikh University, Kafr El-Sheikh 33516, Egypt.*

Table of contents

AGRICULTURAL wastes are considered residues resulted during the agricultural production and after harvesting fruit and vegetable and their processing, agro-industrial by/co-products from the grapes, banana, olives and milk processing. These wastes may represent a treasure when they are turning into valuable applications (i.e., composts, biochar, adsorbents for removing pollutants from the environment and organic fertilizers) instead of burning it in open fields causing several environmental problems such as soil degradation and air pollution. The landfill disposal and open dumping of agro-wastes is a common practice in the developing countries generating huge amounts of ash, which may create serious health and environmental problems, primarily due to pollution of groundwater. Under the umbrella of the green bioeconomy and based on industrial innovation and high technology, new and better approaches for the recovery of agricultural wastes have been developed. This has contributed to guaranteeing sustainable production and its consumption, resource utilizing efficiency, the conversation of these wastes into valuable products and the reduction of negative environmental impacts.The common management of Agro-wastes may include a lot of suggested uses such as the production of biosynthesis of nanoparticles, biotechnological products, composting and biofuel production. Furthermore, a lot of bioactive compounds could be produced from the agro-wastes, which have many application possibilities such as functional food, pharmaceutical and cosmetic approaches. The nano-management of agro-wastes may include using nanotechnology to convert the agro-wastes into a valuable product. This topic still has several open questions, particularly under sustainable and green bioeconomy prespective.

Keywords: Vegetables and fruits, Banana peels, Biochar, Nanomaterials, Bioeconomy.

*Corresponding author: aelhenawy@agr.kfs.edu.eg .

Authors Emails: hassan.elramady@agr.kfs.edu.eg; megahedamer3@gmail.com, alaa.omara@yahoo.com; drelsakhawyg@gmail.com; hebaelbasiouny@azhar.edu.eg; fathyelbehiry@gmail.com; delgiar@agr.kfs.edu.eg; threemelmahrouk@yahoo.com

DOI: 10.21608/ejss.2020.46807.1397

©2020 National Information and Documentation Centre (NIDOC)

1. Introduction

The agricultural sector is considered a main driver for industrial sector inseveral countries worldwide, providing millions of job opportunities and the main source for our food, feed, fiber and fuel. Based on the increasing demand for agricultural produces, huge amounts of agricultural wastes are also expected to be generated. These agricultural wastes have a high carbon content and also loosely termed as biomass, which could be used in several products such as biofuels, biochemicals and biomaterials *via* different biological, chemical and physical approaches (Zakaria et al. 2018). Several studies including articles, books and reviews have been reported about these agro-wastes based on its evolution and alternative uses (Duque-Acevedo et al. 2020), its management (He et al. 2019; Fareed et al. 2020), its viability as green concrete (Luharet al. 2019; Mo et al. 2020), it is removing of pollutants as adsorbents (Dai et al. 2018), its applications in civil engineering (Nguyen et al. 2019), production of biodegradable polymers (Maraveas, 2020), bio-actives (Ben-Othman et al. 2020), biofuels (Ge et al. 2021), biochar (Kwoczynski and Cmelík 2021; El-Bassi et al. 2021) and biogas (Dar et al. 2021).

Agricultural wastes may include any residues resulted from agricultural activities, which need proper management (i.e., how and why should re-utilizeor recycle for otherpurposes). These agri-wastes also may include the wastes of food processing as by-products of various food industries (Gupta et al. 2019). The management of agri-wastes was and still a hot topic, which several researchers handled from different sides with main concern how convert these wastes in a healthy manner into valuable produces and at the same time minimize the ecological risks of these wastes (Maji et al. 2020). These studies focused on different approaches, which confirmed that the most important aspect of the management of agricultural wastes mainly depends on the nature of agricultural wastes (Khan and Faisal 2020). The agri-wastes could be managed byvermi-composting (Gupta et al. 2019; Rini et al. 2020), biomethanation (Dar et al. 2021), implications for the circular economy (Woodard 2021), using tool of life cycle assessment (Ahamed et al. 2021), and the effective transformation (Prasad et al. 2020). It is worth to mention that all countries are in a need for a proper management of agri-wastes for the sustainable agriculture (Khan and Faisal, 2020) and the management process of any waste and its choosing should depend on its being minimizing environmental impact and maximum safety (Prasad et al. 2020). This management process of agri-wastes, which start with the collection, may include the following processes processing, transport, disposal or recycling and checking of waste (Prasad et al. 2020).

Several applications of nanotechnology in agricultural sector have been gained a great concern from researchers particularly the nano-fertilizers and nano-pesticides as well as its role in the effective management of phytopathogens, controlled release of agrochemicals and nutrient utilization (Pramanik et al. 2020). These applications may include some approaches such as using nano-applications in remediation or removal pollutants from the environment (Akhayere et al. 2019; Handojo et al. 2020), the nano-management of agri-wastes like nano-adsorbent (Kaliannan et al. 2019), converting garlic peels into carbon nanomaterials as electrodes for supercapacitors (Bhat et al. 2020), nanocellulose as pharmaceutical ingredient (Kamel et al. 2020), fabrication of nano-silica (Singh and Endley, 2020), and converting waste-lignin into nano-biochar (Jiang et al. 2020). Therefore, this review is an attempt to highlight the agricultural wastes, its classification, applications, management and the common nanomaterials derived from agricultural wastes. The nano-management of agri-wastes also will be evaluated.

Agricultural waste: a problem or a treasure?

Any human activity like the agricultural activity, may create some wastes. The agro-wastes are the residues, which can be formed during the agricultural production and/or after crop harvesting (Prasad et al. 2020). In other words: the residues from the growing and processing of raw agricultural and allied products such as vegetables, fruits, poultry, meat, fishery, dairy, and crops (Maji et al. 2020). The sources of agricultural wastes may include the (1) crop residues, which resulted after harvesting several cultivated crops such as rice, wheat, maize, cassava, sugar cane, peanut, coconut (straw, husk, cobs, stems, cane trash,shell, respectively) as presented in Fig. 1. (2) The agro-industrial wastes, which may result from different processing of crops such as rice husks biogases, cassava peels, peanut shells, coffee husks (Elbasiouny et al. 2020). (3) Hazardous wastes that cause environmental problems such as excess pesticides and fertilizers as well as the radio-actives, nontoxic, toxic, flammable, and infectious materials (Maji et al. 2020). (4) Animal wastes that may include livestock slurry and poultry manures and slaughter house wastes such as blood and rumen as well as animal carcasses (Ardebili and Khademalrasoul, 2020). There are two types of agri-wastes may be from agro-based industries or on field as crop residues (Maji et al. 2020).

The highest amount of crop wastes was recorded as follows rice, maize, wheat/barley, cotton and sugarcane (Elbasiouny et al. 2020). The most important crops, which generate wastes after harvesting may include several crops like wheat (straw), rice (straw and husk or hull), maize (leaves and cobs), sugarcane (bagasse), vegetable wastes (leaves, peels and stems), jute and cotton (stalk), groundnut (shell) and coconut (husk) (Prasad et al. 2020). It is reported that, approximately 20% of agro-products could be damaged due to the poor post-harvest facility and 10% may be eaten by rodents (Prasad et al. 2020). The question that needs to be answered is the agri-wastes a problem or a treasure? To answer this question, it depends on the nature and composition of these agri-wastes? The wastes that rich in toxic pollutants or radio-actives represent a real problem and needs a removal of these deleterious materials from the environment. Concerning the useful agri-wastes as almost wastes, they are a real wealth and need turning or transforming into economic products (Kauldhar and Yadav, 2018).

Fig. 1. Source of chrysanthemum wastes:(A) chrysanthemum plants in a greenhouse,(B) labor harvests chrysanthemum flowers and removes leaves and roots,(C) final product of chrysanthemum plant,(D) weak plants with small flowers,(E) non-flowering plants and(F) root wastes after harvesting

Based on the intensive agriculture, huge amounts of agri-wastes may generate every year to be around 731, 354 and 203 million tons straw of rice, wheat and maize, respectively as well as 180million tons of bagasse in the world (Li and Chen, 2020). In general, the agricultural residues as materials left in agricultural fields or orchards after harvesting could be ploughed directly into the soils or convertedinto composts. The previous handling of these crop field residues is the best management, which could increase the irrigation efficiency, improve soil aeration, control soil erosion and soil health (Maji et al. 2020). The importance of crop residues might include using in composting, bioenergy or biofuel production, mineralization or release of nutrient in soils, and increase the efficiency of nutrient uptake (Elbasiouny et al. 2020; Maji et al. 2020). On the other hand, some agricultural wastes might have a negative impact on the environment and severe hazards to human health because they may contain toxic organic and/or inorganic materials and some harmful microbial species (Shaaban and Nasr, 2020). The most common practices in many developing countries towards the agri-wastes may include the landfilling of these agri-wastes and burning the crop residues on farms after harvesting. This burning of agri-wastes may generate a large amounts of greenhouse gases (e.g., CO_2, CH_4, and N_2O), air pollutants (e.g., CO, SO_2,NO_x, NH_3 and volatile organic compounds) and particulate matters (Li and Chen, 2020). The increasing of agricultural organic wastes is directly responsible for some serious environmental issues including greenhouse gas emission, ground water pollution and pathogen growth (Qi et al. 2020; Wang et al. 2020).The application of animal wastes or its over-application to saturated soils also may cause the pollution of surrounding waters through runoff (Zalewska and Popowska, 2020).

Nanomaterials derived from agricultural wastes

As mentioned before, a lot of the agricultural wastes could be found in the field after harvesting, which may protect soil from erosion or as could be considered a nutrient-providing fertilizer. However, there is another common practice for agro-wastes represents in burning or dumping in landfillsa high quantity of residues, which may cause the pollution ofsoil, groundwater and air (de Souza et al. 2020).Every year, a huge amount of agricultural waste could be generated to be about 998 million tons (Peerzada1 and Chidambaram 2020). Some agro-wastes have already been used to produce nanomaterials such as nano silica, nanocellulose, nano-adsorbent, nanocomposite and nano-cementitious additives as presented in Table 1.

Manyagro-wastes already used in synthetizing nanomaterial such as groundnut and walnut shells, banana and orange peels, and coconut husk for the biogenic synthesis of nano-silica (Peerzada1 and Chidambaram, 2020). Regarding different agro-wastes, which have been used as a nano-adsorbent in removing the pollutants from environment may include almond and walnut shells (Salem et al. 2020), leaves of *Saccharum officinarum* (Kaliannan et al. 2019), wheat and barley grass wastes (Akhayere et al. 2019). Nanocellulose also was one of the most important nanomaterials derived from agro-wastes, which was produced using many agro-wastes such as pulp of pili tree (*Canarium ovatum*) (Bongao et al. 2020), tea stalk (Guo et al. 2020), cotton residues (de Souza et al. 2020), *Nypa Fruticans* trunk, coconut husk fiber and rice husk (An et al. 2020). Many nanocomposites also were recorded as a derived from agro-wastes like maize cob biochar (Lateef et al. 2019) sawdust of tree wood *Cinnamomum camphora* (Chakraborty and Das 2020), and rice husk and olive pomace (Dakroury et al. 2020).

Nano-management of agricultural wastes

Management of agro-wastes is considered a real challenge especially in the developing countries compared to the developed ones. The management may mean the following processes production, collection, transportation, recovery and disposal of wastes,involving the supervision of such processes and the after-care of disposal sites (Elbasiouny et al. 2020; Khan and Faisal 2020). The management of agro-wastes has become a main issue during the last decades and alot of processes have been innovated for handling the organic wastes including the compost ingor organic fertilizers, biochar, and removing the pollutants from the environment. Dueto its low economic cost as well as its reductionin landfills, some agro-wastes cannot becom posted like oils. Hence, the management system of agro-wastes had changed from the last century to the development of our recent civilization (Elbasiouny et al. 2020).

Based on the circular economy, the agricultural wastes should be handled with highly effective use and consider the principle of 3Rs (i.e., reduce, reuse and recycle), which are considered low emissions, low consumption, and high efficiency (Shaaban and Nasr 2020). The reduction concept of agro-wastes means the reduction ininput of water, material and energy,the reduction in manufacturing

TABLE 1. The most important nanomaterials derived from agro-wastes and its application

Nano item	Agro-waste type	The main application of nano-item	Reference
Nano-adsorbent	Almond and walnut shells	Converting the solid agro-wastes to magnetic activatedcarbon for cationic dye adsorption wastewater treatment and rapid separation	Salem et al. (2020)
Nano-adsorbent	Leaves of *Saccharum officinarum*	Nano-adsorbent as nano-silica to remove Pb^{2+} and Zn2+ from aqueous solutions	Kaliannan et al. (2019)
Nano-adsorbent	Wheatand barley grass wastes	nano-silica in the extraction of nickel ions (Ni^{2+}) from agricultural wastewater	Akhayere et al. (2019)
Nanoagro- waste	Ash of rice husk, sugar cane bagasse and wheatstraw	Incorporation of studied nano agro-waste ashin asphalt binder and mixture is a sustainable and eco-friendly way of its disposal	Fareed et al. (2020)
Nano-silica	Walnut and groundnut shells, banana and orange peels, coconut husk	Entomo-toxic activity of studiednano-silica wasinvestigated against Sitophilus oryzaeas a common insect in stored rice and other grains	Peerzada and Chidambaram (2020)
Biogenic silica nano-structures (BSNs)	Sorghum leaves (*Sorghum bicolor*)	Sorghum leaves were used as a bio-precursor toproduce BSNs through sequential processes for food industry applications	Athinarayanan et al. (2020)
Nano-silica	Ricehusk ash	Using rice husk ash provides similar physical-chemical cementitious materials thananother commercial nano-silica	Torres-Carrasco et al. (2019)
Nano-cementitious additives	Palmoil fuel ashand rice husk ash	Production sustainable cement and concrete materials and contributing towards greener construction	Lim et al. (2018)
Nanocellulose	Pulp of pili tree (*Canarium ovatum*)	Nanocellulose is a promising alternative to mineral-based ingredients in cosmetics	Bongao et al. (2020)
Nanocellulose crystals (NCCs)	Tea stalk	NCCs are promisingbio-nanoparticles owing to their unique properties (e.g., high surface area, low cost, biodegradability and biocompatibility)	Guo et al. (2020)
Nanocellulose	Cotton residues	Nanoparticles in a biodegradable polymeric matrix of polyacid lactic	de Souza et al. (2020)
Nanocellulose	*Nypa Fruticans* trunk, coconut husk fiber, and rice husk	Value -added applications: packaging, optoelectronics, mechanically reinforced polymer composites, tissue scaffolds, environmental remediation	An et al. (2020)
Nano carbon	Garlic peels	High performance supercapacitors	Bhat et al. (2020)
Nanocomposite	Sawdust of tree wood *Cinnamomumcamphora*	Nano-silica-coated biochar can remove hexa-valent chromium under studied conditions	Chakraborty and Das (2020)
Nanocomposite	Rice husk and olive pomace	Nano-adsorbent of radionuclides (226Ra, 210Po, 228Th) admixture associated with nuclear and non-nuclear industries	Dakroury et al. (2020)
Biocharbased nano-composite	Maize cob biochar	As a potential slow release nano-fertilizer forsustainable agriculture	Lateef et al. (2019)

of products, which originally not needed, and the reduction in the people's demand not the quality of life. The concept of "Reuse" means the considering a thing multipurpose, developing with waste as raw material remanufacturing industry and using the renewable resources substitution non-renewable resources as much as possible. The concept of "Recycle" means consider the wastes of raw materials to become the initiative interior materials circulation, building technology park and constructing circular economic system differ that from traditional, recognize resource recycling utilization (Elbasiouny et al. 2020; Khan and Faisal 2020). Several studies evaluated the utilization and management of agro-wastes through different sides such as:

(1) Production of Si-nanoparticles or nano-silica (Adebisi et al. 2020; Athinarayanan et al. 2020; Peerzada and Chidambaram, 2020; Singh and Endley, 2020),

(2) Production of nanocellulose as valuable pharmaceutical ingredient (Kamel et al. 2020),

(3) Producing of biochar (Gabhane et al. 2020; Sakhiya et al. 2020; Rodriguez et al. 2020; Zhang et al. 2020; El-Bassiet al. 2021; Kwoczynski and Cmelík, 2021), and

(4) Production of high-performance supercapacitors based on porous nano carbon (Bhat et al. 2020) or graphene oxide (Tamilselvi et al. 2020).

On the other hand, several studies handled the management approaches of agro-wastes such as the following publications:

(1)The management of agriculture and food processing wastes (Pandey and Dwivedi, 2020),

(2) Agro-waste and its impact on environment and its management approaches (Maji et al. 2020),

(3)Applications agro-wastes inantimicrobial/antibiotic resistance (Zalewska and Popowska 2020),

(4) Producing agro-composite for packaging purposes (Suffo et al. 2020),

(5)Using of agro-waste ashes in producing asphalt binder (Fareed et al. 2020),

(6) The bioconversion of some agro-wastes to produce α- amylase (Bhatt et al. 2020), lignocellulolytic enzymes (Leiteet al. 2020; Naidu et al. 2020),

(7) Bioenergy production (Donner et al. 2020) like the biodiesel from raw nano-sized sugar beet agro-industrial waste (Abdelhady et al. 2020), biogas (Bolzonella et al. 2020; Dalpaz et al. 2020; Kapoor et al. 2020), pellets (Thapa and Engelken, 2020), biofuel (Ardebili and Khademalrasoul, 2020),

(8) Using agro-wastes extract (i.e., sugarcane bagasse, pineapple and banana peels) for the biogenic platinum (Ishak et al. 2020),

(9) Using the agro-wastes as substitute of natural aggregate in concrete (Mo et al. 2020),

(10) Production of adsorbents or nano- adsorbents from agri-food industry wastes for removing heavy metals from the environment (Landin-Sandoval et al. 2020),

(11) Production of composting (Gebremikael et al. 2020; Khan and Faisal 2020; Siles-Castellano et al. 2020),

(12)Application of agri-food residues or agro-industrial wastes for biorefining approaches (Kammoun et al. 2020; Koutra et al. 2021),

(13) Production of bioactive compounds from agri-food by-products (Arun et al. 2020; Ben-Othman et al. 2020; Gullón et al. 2020),

(14) Production of cementitious additives (Banu et al. 2020),

(15) Producing unfired earth blocks (Jannat et al. 2020), and

(16) Production of nanocellulose from agro-waste for cosmetic formulations (Bongao et al. 2020), for pharmaceutical ingredient (Kamel et al. 2020).

Thus, nanomaterial's derived from agro-wastes had and still have a great concern as reported by several studies and there are several other examples for nanoscale iron oxide, other metal nano-oxides and nanotubes, which could be used in the farmland wastewater treatment. There are enormous of examples where industrial waste has provided a base for replacement of fossil fuels and also acted as a source for the manufacturing of nanomaterials. The biological waste, particularly, agro-wastes could play its own role if used in a proper and environment friendly way in the same way (Javad et al. 2020). In this section, two examples of agro-wastes as a common-model will be handled and presented in more details (i.e., biochar and banana peels), whereas the rice straw will be presented only in Fig. 2.

Fig. 2. Different steps in the isolation of nano-silica from rice straw

Biochar as an agro-waste

Biochar could be defined as "a porous carbonaceous solid material with a high degree of aromatization and strong anti-decomposition ability that is produced by the thermal decomposition of biomass from plant or animal waste under oxygen free or limited oxygen conditions" (Daful and Chandraratne 2020). Biochar is mainly a product of biomass, which could be produced through thermochemical conversion processes such as torrefaction, slow or fast pyrolysis and gasification under various process parameters (Leng et al. 2019). Biochar is low-cost and renewable biomaterial with several applications C-sequestration and mitigation of greenhouse gas emissions, soil amendment, and removal of both inorganic and organic contaminants in aqueous systems (Gwenzi et al. 2021). Biochar is considered as a promising strategy to produce energy, sequester carbon, increase the productivity of soils and improve soil and environmental quality (Table 2). The main applications of biochar in agriculture may include C- sequestrationin soil, reducing the net emissions of greenhouse gases and increasing the crop productivity through improving the availability of nutrients and soil properties and reducing the loss of nutrients, sediments and pollutants (Wang et al. 2020).

The ability of biochar to removal various contaminants relies on its physical and chemical characteristicsthat greatly affected by many factors such as the feedstock type, pyrolysis technology, and pyrolysis conditions. The raw biochar has limited ability to adsorb contaminants from the environment, especially with higher concentrations. As well, it is difficult to separate the ground biochar from the aqueous solution because of its small particle sizes. To overcome these unfavorable conditions, several investigations have been performed for producing engineered biochar with special structure and surface properties such as biochar-based nano-composites. Thus, synthesizing biochar-based nano-composites is not only a method to improve the biochar properties, but also to get a new composite combining the advantages of biochar and other nano-materials. Recently, different substrates-based nanocomposites were developed to decontaminate wastewater even the nuclear wastewater. Compared with other nanocomposites,

TABLE 2. Different studies handled agro-wastes and biocharwith their applications

Agro-waste source	Agro-waste type	The main finding after application	References
Algalbiomass	Biochar	Biochar could be used as an efficient catalyst in various applications	Antoet al. (2021)
Raw jujube seeds	Agro-waste biochar	Biochar could remove metal ions (Cu, Ni, Cr and Zn) from wastewater	Gayathri et al. (2021)
Wheatstraw biomass	Agro-food biochar	Biocharimproves resistance of Mg phosphate cement in water environment	Ahmad et al. (2020)
Wastes of murumurukernel shell (MKS)	Biochar	MKS was used as the precursor biomass in synthesis of an acidbiochar, which employed as a catalyst in production of biodiesel originated from jupati oil	Bastos et al. (2020)
Wastes of rice husk, olive pit and remains	Biochar	Biochar has a potential to sequester carbon and its use assoil ameliorant	Campos et al. (2020)
Rawagricultural waste	Biochar compared to raw agricultural waste and ash	Applied biochar improved the agro-production up to 36%–64% over the experimentalfields of India and Bhutan	Dey et al. (2020)
Coconut palm biomass wastes	Biochar	Biochar enhances under humid tropic the regenerative agriculture by improving soil properties and plant yield	Gopal et al. (2020)
Agro-waste walnut shells	Biocharadsorbent	Removing of nickel (II) ions from aqueous solutions by biochar adsorbent	Georgieva et al. (2020)
Pistachio and peanut shellsand corks	Biochar-based biocatalyst (BBBs)	Immobilized BBBs applied in alcoholic fermentation of hydrolyzate generated *via* a citrus peel waste biorefinery	Kyriakou et al. (2020)
Rice husk	Agro-industrial biochar	Degradation of propylparaben as adsorbent and sono-catalyst	Nikolaou et al. (2020)
Vegetablewaste	Biochar	Biochar enhancesmaturity ofcompost during vermicomposting of vegetable waste	Paul et al. (2020)
Sugarcanestraw and sawdust	Biochar	Biochar-based hybrid materials are potentfor oxidative catalysis technology	Pierri et al. (2020)
Bean-worm skin	Phosphorus-rich biochar	Biochar enhances the adsorption of Pb through chemisorption and precipitation	Yan et al. (2020)
Sawdust wastes	Sawdustash and sawdust biochar	Remediation of polluted soil through stabilizingPb in soil	Zhang et al. (2020)

many advantages of using biochar as the substrate material for producing nano-composites are existed (Tan et al., 2016). However, it is stated that nano-biochar with the smaller sizethan 100-nm had resulted in led to increased mobility of metal icons in water and soil environment compared to micro sized biochar. As a carrier, nano-biochar could facilitate the migration of natural solutes and contaminants compared with the effects of bulk-biochar to hold nutrients and immobilize hazardous chemicals (Liu et al., 2018, Guo et al., 2020).

Banana peels as an agro-waste

Several agro-industrial wastes have been used to generate several value-added products through many processes as a source for carbon like the saccharification processand the sequential or simultaneous fermentation of the released reducing sugars (Fig. 3 and 4). These agro-industrial wastes may include fruit peels (e.g., banana, orange, etc.) vegetables, cereals and even herbs. The banana peel contains lignocellulosic compounds (lignin, pectin, cellulose, and hemicellulose). Hence, it could be regarded as an adequate source of carbohydrates; besides, this fruit is abundant and a cheap resource that could be found all over the world (Martínez-Trujillo et al. 2020). The peels of banana fruit, like many other fruit peels are usually disposed of unprocessed after the consumption of the inner fleshy fruit. The agro-wastes of banana peels may need to be converted into valuable products, which might be beneficial to humans and the environment (Bediako et al. 2019).

Banana crop is considered one of the most fruit crops, which its peel has a very high organic matter content about 91.5% and it is rich in nutrients, where each 100 g of peel contains 78.1 mg K,19.2 mg Ca, 24.3 mg Na, 0.61 mg Fe,76.2 mg Mn. The common use of banana peel may be for single-cell oil or biodiesel production or as a substrate for the production of bio-surfactant (Chaturvedi et al. 2018). It could produce the biogenic nano-silica also from banana peels (Peerzada and Chidambaram, 2020). Banana peel wastes also have a wide range of natural antimicrobial agents and could be used for therapeutic purposes to combat the multidrug resistant micro-organism infection (Saleem and Saeed, 2020). The extracted banana peel biomasses also could be applied in environmental remediation (Bediako et al. 2019). The banana plant wastes could be considered a major agro-waste and seem to be a promising for the production of bioenergy particularly in tropicaland sub-tropical countries (Bhushan et al. 2019).The ability of banana peels in sorption mercury from different aqueous solutions as biosorbent was investigated (Fabre et al. 2020). we could use banana peels, as a source of C, in producing poly-hydroxy-alkanoates by halophilic yeast isolated from marine seaweeds (*Pichia kudriavzevii*) (Ojha and Das, 2020) or production of polyhydroxy butyrate by the *Zobellella* sp., which could be used for different biomedical and agricultural applications in future (Maity et al. 2020). In India, it is reported that banana peel is considered one of the least investigated biomasses, utilized for bioethanol production using isolated cellulase from *Aspergillus Niger* (John et al. 2020). we could use banana peels as probiotic carriers for the alcoholic extraction from by-products (He et al. 2021).

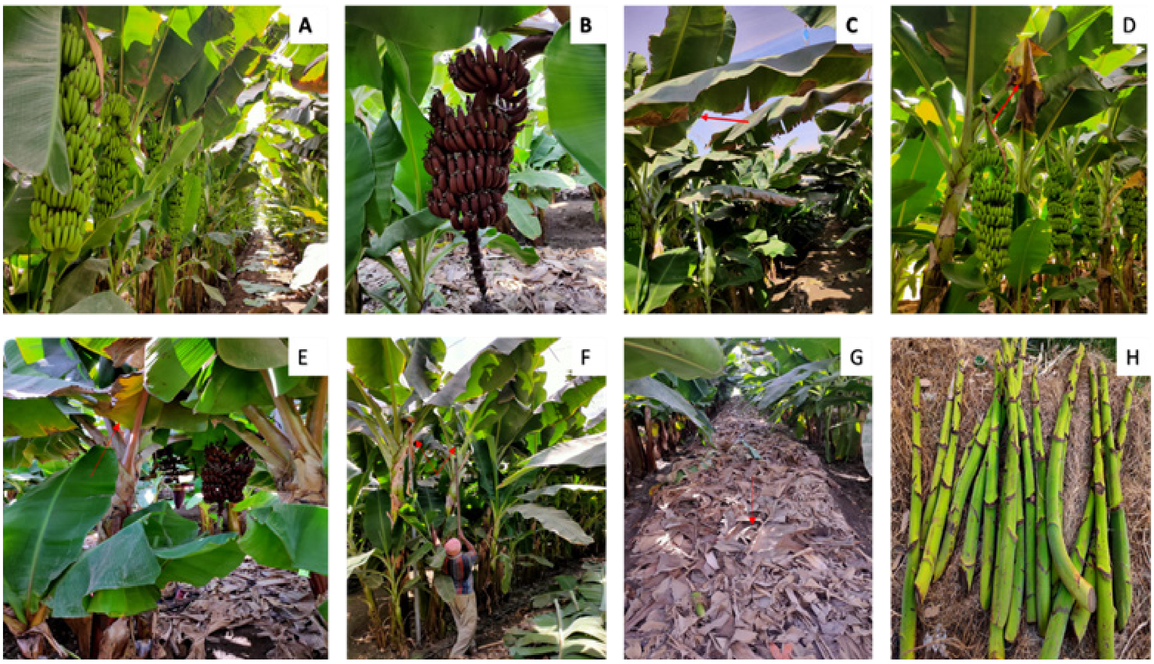

Fig. 3. Sources of banana wastes:(A) yellow banana,(B) red banana,(C and D) old leaves of yellow banana,(E) old leaves of red banana,(F) plants after harvesting,(G) dried leaves,and (H) peduncles (banana bunch without hands) of banana

Fig. 4. The most common banana wastes:peduncle base that cut at harvest (photo 1),the mother plants that cut after harvest (photo 2) and banana peels after removing (photo 3)

There are many researchers utilized banana peels for producing nano-based useful materials such as Hussein et al. (2019) reported that nano fertilizer can be extracted from banana peels containing about 80 g L^{-1} of elemental K chelated with citric acid. As well, other minerals such as Fe, Mg, Cu, Na, Ca, and Mn chelated with citric acid in a nanostructure form. Their obtained nano fertilizer has a great germination efficiency in the first planting stage of tomato and fenugreek, thus they recommended it as a biological promoter for seed germination and seedling growth performance. Thus, utilizing nanotechnology for transferring the banana peel extract from normal form to nano-form added an optimistic value for this extraction and strengthened its positive impacts for growth promoting. In addition, Ibrahim (2015) successfully utilized the banana peels for the consistent and fast synthesis of silver nanoparticles which showed good antimicrobial activity against some pathogenic microorganisms. This consider a green synthesis approach seems to be a non-toxic, cost-effective, and ecofriendly alternative to the conventional methods for reducing the microbial load.

Conclusions

To address the goals of increasing the agricultural sustainability at the food-water-energy nexus, various nutrient-rich waste streams could be exploited including biosolids, recycled water, brackish groundwater, agricultural return flows, industrial produced waters, manure, composts and others. Agro-wastesare a term could be used in description the waste material produced during any agricultural practice which may include any chemical, pesticide or fertilizer. These materials may be hazardous in nature and their use should be reduced. Agro-wastes also might include plant residues, which are not used in human foods.There are many applications could be used in handling the agro-wastes including producing bioenergy, biofertilizers, composting, and removing pollutants from the environment. Based on the global economic and environmental pollution issues, there is an increasing scientific concern in the management of the agro- and/or industrial wastes using value-added green technologies. Therefore, the biological treatment (using micro-organisms) and /or nano-management (using nanotechnology) of agro-wastes seem to be as one of the promising green biotechnologies, which may achieve less harm to the environment while balance out the agro-ecosystem. Further investigations on different agro-wastes and their sustainable management are needed in the future.

Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

Author contribution:

This study was designed and implementedby authors,where all authors contributed in writing the manuscript, interpreting information presented and have read and agreed to the version of the manuscript.

Consent for publication

All authors declare their consent for publication.

Conflicts of Interest

The authors declare that there is no conflict of interest.

Acknowledgement

The authors thank the staff members of Physiology and Breeding of Horticultural Crops Laboratory, Dept. of Horticulture, Fac. of Agric., Kafrelsheikh University, Kafr El-Sheikh, Egypt for their helping and supporting this work. .

References

Abdelhady HH, Elaza HA, Ewais EM, Saber M, El-Deab MS (2020) Efficient catalytic production of biodiesel using nano-sized sugar beet agro-industrial waste. *Fuel* 261, 116481. https://doi.org/10.1016/j.fuel.2019.116481.

Adebisi JA, Agunsoye JO, Ahmed II, Bello SA, Haris M, Ramakokovhu MM, Hassan SB (2020) Production of silicon nanoparticles from selected agricultural wastes. *Materials Today: Proceedings,* https://doi.org/10.1016/j.matpr.2020.03.658.

Ahamed A, Vallam P, Iyer NS, Veksha A, Bobacka J, Lisak G (2021) Life cycle assessment of plastic grocery bags and their alternatives in cities with confined waste management structure: A Singapore case study. *Journal of Cleaner Production* **278**, 123956. https://doi.org/10.1016/j.jclepro.2020.123956.

Ahmad MR, Chen B, Duan H (2020) Improvement effect of pyrolyzed agro-food biochar on the properties of magnesium phosphate cement. *Science of the Total Environment* 718, 137422. https://doi.org/10.1016/j.scitotenv.2020.137422

Akhayere E, Essien EA, Kavaz D (2019) Effective and reusable nano-silica synthesized from barley and wheat grass for the removal of nickel from agricultural wastewater. *Environmental Science and Pollution Research* 26:25802–25813 https://doi.org/10.1007/s11356-019-05759-x.

An VN, Nhan HTC, Tap TD, ·Van TTT, Viet PV, Hieu LV (2020) Extraction of High Crystalline Nanocellulose from Biorenewable Sources of Vietnamese Agricultural Wastes. *Journal of Polymers and the Environment* 28, 1465-1474 https://doi.org/10.1007/s10924-020-01695-x.

Anto S, Sudhakar MP, Ahamed TS, Samuel MS, Mathimani T, Brindhadevi K, Pugazhendhi A (2021) Activation strategies for biochar to use as an efficient catalyst in various applications. *Fuel* 285, 119205. https://doi.org/10.1016/j.fuel.2020.119205.

Ardebili SMS, Khademalrasoul A (2020) An assessment of feasibility and potential of gaseous biofuel production from agricultural/animal wastes: a case study. *Biomass Conversion and Biorefinery,* https://doi.org/10.1007/s13399-020-00901-z.

Arun KB, Madhavan A, Sindhu R, Binod P, Pandey A, Reshmy R, Sirohi R (2020) Remodeling agro-industrial and food wastes into value-added bioactives and biopolymers. *Industrial Crops & Products* **154**, 112621. https://doi.org/10.1016/j.indcrop.2020.112621.

Athinarayanan J, Jaafari SAAH, Periasamy VS, Almanaa TNA, Alshatwi AA (2020) Fabrication of Biogenic Silica Nanostructures from *Sorghum bicolor* Leaves for Food Industry Applications. Silicon,https://doi.org/10.1007/s12633-020-00379-4.

Banu SS, Karthikeyan J, Jayabalan P (2020) Effect of agro-waste on strength and durability properties of concrete. *Construction and Building Materials* **258**, 120322. https://doi.org/10.1016/j.conbuildmat.2020.120322.

Bastos RRC, Corrêa APL, da Luz PTS, Filho GNR, Zamian JR, da Conceição LRV (2020) Optimization of biodiesel production using sulfonated carbon-based catalyst from an amazon agro-industrial waste. *Energy Conversion and Management* 205, 112457. https://doi.org/10.1016/j.enconman.2019.112457.

Bediako JK, Sarkar AK, Lin S, Zhao Y, Song M-H, Choi J-W, Cho C-W, Yun Y-S (2019) Characterization of the residual biochemical components of sequentially extracted banana peel biomasses and their environmental remediation applications. *Waste Management* **89**, 141–153. https://doi.org/10.1016/j.wasman.2019.04.009.

Ben-OthmanS, Jõudu I, Bhat R (2020) Bioactives from Agri-Food Wastes: Present Insights and Future Challenges. *Molecules*. **25** (3), 510. doi: 10.3390/molecules25030510.

Bhat VS, Kanagavalli P, Sriram G, Prabhu BR, John NS, Veerapandian M, Kurkurie M, Hegde G (2020) Low cost, catalyst free, high performance supercapacitors based on porous nano carbon derived from agriculture waste. *Journal of Energy Storage* **32,** 101829. https://doi.org/10.1016/j.est.2020.101829.

Bhatt K, Lal S, Srinivasan R, Joshi B (2020) Bioconversion of agriculture wastes to produce α- amylase from *Bacillus velezensis* KB 2216: Purification and characterization. *Biocatalysis and Agricultural Biotechnology* 28, 101703. https://doi.org/10.1016/j.bcab.2020.101703.

Bhushan S, Rana MS, Mamta, Nandan N, Prajapati SK (2019) Energy harnessing from banana plant wastes: A review. *Bioresource Technology Reports* **7**, 100212. https://doi.org/10.1016/j.biteb.2019.100212.

Bolzonella D, Battista F, Mattioli A, Nicolato C, Frison N, Lampis S (2020) Biological thermophilic post hydrolysis of digestate enhances the biogas production in the anaerobic digestion of agro-waste. *Renewable and Sustainable Energy Reviews* 134, 110174. https://doi.org/10.1016/j.rser.2020.110174.

Bongao HC, Gabatino RRA, Arias CFH, Magdaluyo Jr ER (2020) Micro/nanocellulose from waste Pili (*Canarium ovatum*) pulp as a potential anti-ageing ingredient for cosmetic formulations. *Materials Today: Proceedings* **22**, 275–280.

Campos P, Miller AZ, Knicker H, Costa-Pereira MF, Merino A, De la Rosa JM (2020) Chemical, physical and morphological properties of biochars produced from agricultural residues: *Implications for their use as soil amendment Waste Management* **105**, 256–267. https://doi.org/10.1016/j.wasman.2020.02.013

Chakraborty V, Das P (2020) Synthesis of nano-silica-coated biochar from thermal conversion of sawdust and its application for Cr removal: kinetic modelling using linear and nonlinear method and modelling using artificial neural network analysis. *Biomass Conv. Bioref.,* https://doi.org/10.1007/s13399-020-01024-1.

Chaturvedi S, Kumari A, Bhatacharya A, Sharma A, Nain L, Khare SK (2018) Banana peel waste management for single-cell oil production.

Energ. Ecol. Environ. **3** (5), 296–303. https://doi.org/10.1007/s40974-018-0101-3.

Daful AG, Chandraratne MR (2020) Biochar Production From Biomass Waste-Derived Material. *Encyclopedia of Renewable and Sustainable Materials,* Volume **4**, doi:10.1016/B978-0-12-803581-8.11249-4, pp: 370 - 378.

Dai Y, Sun Q, Wang W, Lu L, Liu M, Li J, Yang S, Sun Y, Zhang K, Xu J, Zheng W, Hu Z, Yang Y, Gao Y, Chen Y, Zhang X, Gao F, Zhang Y (2018) Utilizations of agricultural waste as adsorbent for the removal of contaminants: A review. *Chemosphere,* **211**, 235-253. https://doi.org/10.1016/j.chemosphere.2018.06.179.

Dakroury GA, Allan KF, Attallah MF, El Aff EM (2020) Sorption and separation performance of certain natural radionuclides of environmental interest using silica/olive pomace nanocomposites. *Journal of Radioanalytical and Nuclear Chemistry,* **325**, 625–639 https://doi.org/10.1007/s10967-020-07237-y.

Dalpaz R, Konrad O, Cyrne CCS, Barzotto HP, Hasan C, Filho MG (2020) Using biogas for energy cogeneration: An analysis of electric and thermal energy generation from agro-industrial waste. *Sustainable Energy Technologies and Assessments,* **40**, 100774. https://doi.org/10.1016/j.seta.2020.100774.

Dar RA, Parmar M, Dar EA, Sani RK, Phutela UG (2021) Biomethanation of agricultural residues: Potential, limitations and possible solutions. *Renewable and Sustainable Energy Reviews,* **135**, 110217. https://doi.org/10.1016/j.rser.2020.110217.

de Souza AG, Barbosa RFS, Rosa DS (2020) Nanocellulose from Industrial and Agricultural Waste for Further Use in PLA Composites. *Journal of Polymers and the Environment,* **28**,1851–1868. https://doi.org/10.1007/s10924-020-01731-w.

Dey D, Gyeltshen T, Aich A, Naskar M, Roy A (2020) Climate adaptive crop-residue management for soil-function improvement; recommendations from field interventions at two agro-ecological zones in South Asia. *Environmental Research* **183**, 109164. https://doi.org/10.1016/j.envres.2020.109164.

Donner M, Gohier R, de Vries H (2020) A new circular business model typology for creating value from agrowaste. *Science of the Total Environment* **716**, 137065. https://doi.org/10.1016/j.scitotenv.2020.137065.

Elbasiouny H, Elbanna BA, Al-Najoli E, Alsherief A, Negm S, Abou El-Nour E, Nofal A, Sharabash S (2020) Agricultural Waste Management for Climate Change Mitigation: Some Implications to Egypt. In: A. M. Negm and N. Shareef (Eds.), *Waste Management in MENA Regions,* Springer Water, https://doi.org/10.1007/978-3-030-18350-9_8, pp: 149-169. Springer Nature Switzerland AG.

El-BassiL, Azzaz AA, Jellali S, Akrout H, Marks EAN, Ghimbeu CM, Jeguirim M (2021) Application of olive mill waste-based biochars in agriculture: Impact on soil properties, enzymatic activities and tomato growth. *Science of the Total Environment,* **755**, 142531. https://doi.org/10.1016/j.scitotenv.2020.142531.

Fabre E, Lopes CB, Vale C, Pereira E, Silva CM (2020) Valuation of banana peels as an effective biosorbent for mercury removal under low environmental concentrations. *Science of the Total Environment,* **709**, 135883. https://doi.org/10.1016/j.scitotenv.2019.135883.

Fareed A, Zaidi SBA, Ahmad N, Hafeez I, Ali A, Ahmad MF (2020) Use of agricultural waste ashes in asphalt binder and mixture: A sustainable solution to waste management. *Construction and Building Materials,* **259**, 120575. https://doi.org/10.1016/j.conbuildmat. 2020.120575.

Gabhane JW, Bhange VP, Patil PD, Bankar ST, Kumar S (2020) Recent trends in biochar production methods and its application as a soil health conditioner: a review. *SN Applied Sciences,* **2**,1307. https://doi.org/10.1007/s42452-020-3121-5.

Gayathri R, Gopinath KP, Kumar PS (2021) Adsorptive separation of toxic metals from aquatic environment using agro waste biochar: Application in electroplating industrial wastewater. *Chemosphere,* **262**, 128031. https://doi.org/10.1016/j.chemosphere.2020.128031.

Ge S, Yek PNY, Cheng YW, Xia C, Mahari WAW, Liew RK, Peng W, Yuan T-Q, Tabatabaei M, Aghbashlo M, Sonne C, Lam SS (2021) Progress in microwave pyrolysis conversion of agricultural waste to value-added biofuels: A batch to continuous approach. *Renewable and Sustainable Energy Reviews,* **135**,110148. https://doi.org/10.1016/j.rser.2020.110148.

GebremikaelMT, Ranasinghe A, Hosseini PS, Laboan B, Sonneveld E, Pipan M, Oni FE, Montemurro F, Höfte M, Sleutel S, De Neve S (2020) How do novel and conventional agri-food wastes, co-products and by-products improve soil functions and soil quality? *Waste Management* **113**, 132–144.

https://doi.org/10.1016/j.wasman.2020.05.040.

Georgieva VG, Gonsalvesh L, Tavlieva MP (2020) Thermodynamics and kinetics of the removal of nickel (II) ions from aqueous solutions by biochar adsorbent made from agro-waste walnut shells. *J Mol Liquids* **312**, 112788. https://doi.org/10.1016/j.molliq. 2020.112788.

Gopal M, Gupta A, Hameed KS, Sathyaseelan N, Rajeela THK, Thomas GV (2020) Biochars produced from coconut palm biomass residues can aid regenerative agriculture by improving soil properties and plant yield in humid tropics. *Biochar* **2**, 211–226. https://doi.org/10.1007/s42773-020-00043-5.

Gullón P, Gullón B, Romaní A, Rocchetti G, Lorenzo JM (2020) Smart advanced solvents for bioactive compounds recovery from agri-food by-products: A review. *Trends in Food Science & Technology* **101,** 182–197. https://doi.org/10.1016/j.tifs.2020.05.007.

Guo F, Bao L, Wang H, Larson SL, Ballard JH, Knotek-Smith HM, Zhang Q, Sud Y, Wang X,Hana F (2020) A simple method for the synthesis of biochar nanodots using hydrothermal reactor. *MethodsX*, **7**, 101022. https://doi.org/10.1016/j.mex.2020.101022.

Guo Y, Zhang Y, Zheng D, Li M, Yue J (2020) Isolation and characterization of nanocellulose crystals via acid hydrolysis from agricultural waste-tea stalk. *International Journal of Biological Macromolecules* **163**, 927-933. https://doi.org/10.1016/j.ijbiomac.2020.07.009.

Gupta C, Prakash D, Gupta S, Nazareno MA (2019) Role of Vermicomposting in Agricultural Waste Management. S. Shah et al. (eds.), S*ustainable Green Technologies for Environmental Management,* https://doi.org/10.1007/978-981-13-2772-8_15, pp: 283-295. Springer Nature Singapore Pte Ltd.

Gwenzi W, Chaukura N, Wenga T, Mtisi M (2021) Biochars as media for air pollution control systems: Contaminant removal, applications and future research directions. *Science of the Total Environment,* **753**, 142249. https://doi.org/10.1016/j.scitotenv.2020.142249.

Handojo L, Pramudita D, Mangindaan D, Indarto A (2020) Application of Nanoparticles in Environmental Cleanup: Production, Potential Risks and Solutions. In: R. N. Bharagava (Ed.), Emerging Eco-friendly Green Technologies for Wastewater Treatment, *Microorganisms for Sustainability,* **18**, https://doi.org/10.1007/978-981-15-1390-9_3, pp: 45-76. Springer Nature Singapore Pte Ltd.

He C, Sampers I, Raes K (2021) Dietary fiber concentrates recovered from agro-industrial by-products: Functional properties and application as physical carriers for probiotics. *Food Hydrocolloids* **111**, 106175. https://doi.org/10.1016/j.foodhyd.2020.106175.

Hussein HS, Shaarawy HH, Hussien NH, Hawash SI (2019) Preparation of nano-fertilizer blend from banana peels. *Bull Natl Res Cent.* **43**, 26.https://doi.org/10.1186/s42269-019-0058-1.

Ibrahim HMM (2015) Green synthesis and characterization of silver nanoparticles using banana peel extract and their antimicrobial activity against representative microorganisms. *Journal of Radiation Research and Applied Sciences*. **8** (3), 265-275.

Ishak NAIM, Kamarudin SK, Timmiati SN, Karim NA, Basri S (2020) Biogenic platinum from agricultural wastes extract for improved methanol oxidation reaction in direct methanol fuel cell. *Journal of Advanced Research,* https://doi.org/10.1016/j.jare.2020.06.025.

Jannat N, Hussien A, Abdullah B, Cotgrave A (2020) Application of agro and non-agro waste materials for unfired earth blocks construction: A review. *Construction and Building Materials,* **254**, 119346. https://doi.org/10.1016/j.conbuildmat.2020.119346

Javad S, Akhtar I, Naz S (2020) Nanomaterials and Agrowaste. In: S. Javad (Ed.), *Nanoagronomy,* https://doi.org/10.1007/978-3-030-41275-3_**11**, Springer Nature Switzerland AG, pp: 197-207.

Jiang C, Bo J, Xiao X, Zhang S, Wang Z, Yan G, Wu Y, Wong C, He H (2020) Converting waste lignin into nano-biochar as a renewable substitute of carbon black for reinforcing styrene-butadiene rubber. *Waste Management,* **102**, 732–742. https://doi.org/10.1016/j.wasman.2019.11.019

John I, Yaragarla P, Appusamy A (2020) Production of Bioethanol from Banana Peel Using Isolated Cellulase from *Aspergillus Niger*. In: V. Sivasubramanian and S. Subramanian (Eds.), *Global Challenges in Energy and Environment, Lecture Notes on Multidisciplinary Industrial Engineering,* https://doi.org/10.1007/978-981-13-9213-9_2, pp: 9-18. Springer Nature Singapore Pte Ltd.

Kaliannan D, Palaninaicker S, Palanivel V, Mahadeo MA, Ravindra BN, Jae-Jin S (2019) A novel approach to preparation of nano-adsorbentfrom agricultural wastes (*Saccharum officinarum* leaves) and its environmental application. *Environmental Science and Pollution Research*, **26**, 5305–5314. https://doi.org/10.1007/s11356-018-3734-z.

Kamel R, El-Wakil NA, Dufresne A, NA Elkasabgy (2020) Nanocellulose: From an agricultural waste to a valuable pharmaceutical ingredient. *International Journal of Biological Macromolecules,* **163**,1579-1590.https://doi.org/10.1016/j.ijbiomac. 2020.07.242.

Kammoun M, Ayeb H, Bettaieb T, Richel A (2020) Chemical characterisation and technical assessment of agri-food residues, marine matrices, and wild grasses in the South Mediterranean area: A considerable inflow for biorefineries. *Waste Management,* **118**, 247–257. https://doi.org/10.1016/j.wasman.2020.08.032.

Kapoor R, Ghosh P, Kumar M, Sengupta S, Gupta A, Kumar SS, Vijay V, Kumar V, Vijay VK, Pant D (2020) Valorization of agricultural waste for biogas based circular economy in India: A research outlook. *Bioresource Technology,* **304**, 123036. https://doi.org/10.1016/j.biortech. 2020.123036.

Kauldhar BS, Yadav SK (2018) Turning waste to wealth: A direct process for recovery of nano-silica and lignin from paddy straw agro-waste. *Journal of Cleaner Production,* **194**, 158e166. https://doi.org/10.1016/j.jclepro. 2018.05.136

Khan HN, Faisal M (2020) Planning and Engineering Strategies of Agricultural Wastes and Their Remediation Strategies. In: M. Naeem et al. (Eds.), *Contaminants in Agriculture,* https://doi.org/10.1007/978-3-030-41552-5_10, pp: 219-232. Springer Nature Switzerland AG.

Koutra E, Mastropetros SG, Ali SS, Tsigkou K, Kornaros M (2021) Assessing the potential of Chlorella vulgaris for valorization of liquid digestates from agro-industrial and municipal organic wastes in a biorefinery approach. *Journal of Cleaner Production* **280**, 124352. https://doi.org/10.1016/j.jclepro. 2020.124352.

Kwoczynski Z, Cmelík J (2021) Characterization of biomass wastes and its possibility of agriculture utilization due to biochar production by torrefaction process. *Journal of Cleaner Production,* **280**, 124302. https://doi.org/10.1016/j.jclepro.2020.124302.

Kyriakou M, Patsalou M, Xiaris N, Tsevis A, Koutsokeras L, Constantinides G, Koutinas M (2020) Enhancing bioproduction and thermotolerance in Saccharomyces cerevisiae *via* cell immobilization on biochar: *Application in a citrus peel waste biorefinery Renewable Energy,* **155**, 53-64. https://doi.org/10.1016/j.renene. 2020. 03.087.

Landin-Sandoval VJ, Mendoza-Castillo DI, Bonilla-Petriciolet A, Aguayo-Villarreal IA, Reynel-Avila HE, Gonzalez-Ponce HA (2020) Valorization of agri-food industry wastes to prepare adsorbents for heavy metal removal from water. *Journal of Environmental Chemical Engineering,* **8**, 104067. https://doi.org/10.1016/j.jece.2020.104067

Lateef A, Nazir R, Jamila N, Alam S, Shah R, Khan MN, Saleem M, Rehman S (2019) Synthesis and characterization of environmental friendly corncob biochar based nano-composite – A potential slow release nano-fertilizer for sustainable agriculture. Environmental Nanotechnology, *Monitoring & Management,* **11**, 100212. https://doi.org/10.1016/j.enmm. 2019.100212

Leite P, Sousa D, Fernandes H, Ferreira M, Costa AR, Filipe D, Gonçalves M, Peres H, Belo I, Salgado JM (2020) Recent advances in production of lignocellulolytic enzymes by solid-state fermentation of agro-industrial wastes, *Current Opinion in Green and Sustainable Chemistry,* https://doi.org/10.1016/j.cogsc.2020.100407.

Leng L, Huang H, Li H, Li J, Zhou W (2019) Biochar stability assessment methods: a review. *Sci. Total Environ.* **647**, 210–222.

Li S, Chen G (2020) Agricultural waste-derived superabsorbent hydrogels: Preparation, performance and socioeconomic impacts. *Journal of Cleaner Production,* **251**, 119669. https://doi.org/10.1016/j.jclepro.2019.119669.

Lim JLG, Raman SN, Lai F-C, Zain MFM, Hamid R (2018) Synthesis of nano cementitious additives from agricultural wastes for the production of sustainable concrete. *Journal of Cleaner Production* **171**, 1150-1160. https://doi.org/10.1016/j.jclepro. 2017. 09. 143.

Liu G, Zheng H, Jiang Z, Zhao J, Wang Z, Pan B, Xing B (2018) Formation and Physicochemical Characteristics of Nano Biochar: Insight into Chemical and Colloidal Stability. *Environ. Sci. Technol.* 2018, **52**, 10369–10379. DOI: 10.1021/acs.est.8b01481

Luhar S, Cheng T-W, Luhar I (2019) Incorporation of natural waste from agricultural and aquacultural farming as supplementary materials with green concrete: A review. *Composites* Part B **175**, 107076. https://doi.org/10.1016/j.compositesb.2019.107076

Maity S, Das S, Mohapatra S, Tripathi AD, Akthar J, Pati S, Pattnaik S, Samantaray DP (2020) Growth associated polyhydroxybutyrate production by the novel *Zobellellaetiwanensis* strain DD5 from banana peels under submerged fermentation. *International Journal of Biological Macromolecules* **153**, 461–469. https://doi.org/10.1016/j.ijbiomac. 2020.03.004.

Maji S, Dwivedi DH, Singh N, Kishor S, Gond M (2020) Agricultural Waste: Its Impact on Environment and

Management Approaches. In: R. N. Bharagava (ed.), Emerging Eco-friendly Green Technologies for Wastewater Treatment, *Microorganisms for Sustainability* **18**, https://doi.org/10.1007/978-981-15-1390-9_15, pp: 329-351. Springer Nature Singapore Pte Ltd.

Maraveas C (2020) Production of Sustainable and Biodegradable Polymers from Agricultural Waste. *Polymers (Basel)* **12** (5), 1127. doi: 10.3390/polym12051127.

MartínezTrujillo MA, BautistaRangel K, GarcíaRivero M, MartínezEstrada A, CruzDíaz MR (2020) Enzymatic saccharifcation of banana peel and sequential fermentation of the reducing sugars to produce lactic acid. *Bioprocess and Biosystems Engineering*, **43**, 413–427. https://doi.org/10.1007/s00449-019-02237-z.

Mo KH, Thomas BS, Yap SP, Abutaha F, Tan CG (2020) Viability of agricultural wastes as substitute of natural aggregate in concrete: A review on the durability-related properties. *Journal of Cleaner Production,* **275**, 123062. https://doi.org/10.1016/j.jclepro.2020.123062.

Naidu Y, Siddiqui Y, Idris AS (2020) Comprehensive studies on optimization of ligno-hemicellulolytic enzymes by indigenous white rot hymenomycetes under solid-state cultivation using agro-industrial wastes. *Journal of Environmental Management,* **259**, 110056. https://doi.org/10.1016/j.jenvman. 2019. 110056.

Nguyen H, Moghadam MJ, Moayedi H (2019) Agricultural wastes preparation, management, and applications in civil engineering: a review. *Journal of Material Cycles and Waste Management* **21**, 1039–1051 https://doi.org/10.1007/s10163-019-00872-y.

Nikolaou S, Vakros J, Diamadopoulos E, Mantzavinos D (2020) Sonochemical degradation of propylparaben in the presence of agro-industrial biochar. *Journal of Environmental Chemical Engineering,* **8**, 104010. https://doi.org/10.1016/j.jece.2020.104010.

Ojha N, Das N (2020) Process optimization and characterization of polyhydroxyalkanoate copolymers produced by marine *Pichia kudriavzevii* VIT-NN02 using banana peels and chicken feather hydrolysate. *Biocatalysis and Agricultural Biotechnology,* **27**, 101616. https://doi.org/10.1016/j.bcab.2020.101616.

Pandey S, Dwivedi N (2020) Utilisation and Management of Agriculture and Food Processing Waste. In: P. Mishra et al. (Eds.) *Innovations in Food Technology,* Springer Nature Singapore Pte Ltd. Pp: 269-288. https://doi.org/10.1007/978-981-15-6121-4_19.

Paul S, Kauser H, Jain MS, Khwairakpam M, Kalamdhad AS (2020) Biogenic stabilization and heavy metal immobilization during vermicomposting of vegetable waste with biochar amendment. *Journal of Hazardous Materials* **390**, 121366. https://doi.org/10.1016/j.jhazmat. 2019. 121366.

PeerzadaJG, R Chidambaram (2020) A Statistical Approach for Biogenic Synthesis of Nano-Silica from Different Agro-Wastes. *Silicon*, https://doi.org/10.1007/s12633-020-00629-5.

Pierri L, Gemenetzi A, Mavrogiorgou A, Regitano JB, Deligiannakis Y, Louloudi M (2020) Biochar as supporting material for heterogeneous Mn(II) catalysts: Efficient olefins epoxidation with H_2O_2. *Molecular Catalysis,* **489**, 110946. https://doi.org/10.1016/j.mcat.2020.11094.

PramanikP, Krishnan P, Maity A, Mridha N, Mukherjee A, Rai V (2020) Application of Nanotechnology in Agriculture. In: N. Dasgupta et al. (Eds.), *Environmental Nanotechnology,* Volume 4, *Environmental Chemistry for a Sustainable World* **32**, https://doi.org/10.1007/978-3-030-26668-4_9, pp: 317 – 348. Springer Nature Switzerland AG.

Prasad M, Ranjan R, Ali A, Goyal D, Yadav A, Singh TB, Shrivastav P, Dantu PK (2020) Efficient Transformation of Agricultural Waste in India. In: M. Naeem et al. (Eds.), *Contaminants in Agriculture,* https://doi.org/10.1007/978-3-030-41552-5_13, pp: 271-287. Springer Nature Switzerland AG.

Qi H, Zhao Y, Zhao X, Yang T, Dang Q, Wu J, Lv P, Wang H, Wei Z (2020) Effect of manganese dioxide on the formation of humin during different agricultural organic wastes compostable environments: It is meaningful carbon sequestration. *Bioresource Technology,* **299**, 122596. https://doi.org/10.1016/j.biortech.2019.122596.

Rini J, Deepthi MP, Saminathan K, Narendhirakannan RT, Karmegam N, Kathireswari P (2020) Nutrient recovery and vermicompost production from livestock solid wastes with epigeic earthworms. *Bioresource Technology,* **313**, 123690. https://doi.org/10.1016/j.biortech.2020.123690.

Rodriguez JA, Filho JFL, Melo, LCA de Assis IR, de Oliveira TS (2020) Influence of pyrolysis temperature and feedstock on the properties of biochars produced from agricultural and industrial wastes. *Journal of Analytical and Applied Pyrolysis* **149**, 104839. https://doi.org/10.1016/j.jaap.2020.104839.

SakhiyaAK, ·Anand A, Kaushal P (2020) Production, activation, and applications of biochar in recent times. *Biochar,* **2**, 253–285. https://doi.org/10.1007/s42773-020-00047-1.

Saleem M, Saeed MT (2020) Potential application of waste fruit peels (orange, yellow lemon and banana) as wide range natural antimicrobial agent. *Journal of King Saud University–Science* **32**, 805–

810. https://doi.org/10.1016/j.jksus.2019.02.013

Salem S, Teimouri Z, A Salem (2020) Fabrication of magnetic activated carbon by carbothermal functionalization of agriculture waste *via* microwave-assisted technique for cationic dye adsorption. *Advanced Powder Technology*, https://doi.org/10.1016/j.apt.2020.09.007.

Shaaban S, Nasr M (2020) Toward Three R's Agricultural Waste in MENA: Reduce, Reuse, and Recycle. In: A. M. Negm and N. Shareef (Eds.), *Waste Management in MENA Regions,* Springer Water, https://doi.org/10.1007/978-3-030-18350-9_17, pp: 337 – 353. Springer Nature Switzerland AG.

Siles-Castellano AB, López MJ, Jurado MM, Suárez-Estrella F, López-González JA, Estrella-González MJ, Moreno J (2020) Industrial composting of low carbon/nitrogen ratio mixtures of agri-food waste and impact on compost quality. *Bioresource Technology,* **316**, 123946. https://doi.org/10.1016/j.biortech. 2020.123946.

Singh SP, Endley N (2020) Fabrication of nano-silica from agricultural residue and their application. In: A. Husen and M. Jawaid (Eds.), *Nanomaterials for Agriculture and Forestry Applications.* DOI: https://doi.org/10.1016/B978-0-12-817852-2.00005-6, pp: 117-134. Elsevier Inc.

Suffo M, de la Mata M, Molina SI (2020) A sugar-beet waste based thermoplastic agro-composite as substitute for raw materials. *Journal of Cleaner Production,* **257**, 120382. https://doi.org/10.1016/j.jclepro.2020.120382.

Tamilselvi R, Ramesh M, Lekshmi GS, Bazaka O, Levchenko I, Bazaka K, Mandhakini M (2020) Graphene oxide - Based supercapacitors from agricultural wastes: A step to mass production of highly efficient electrodes for electrical transportation systems. *Renewable Energy* **151**, 731-739. https://doi.org/10.1016/j.renene.2019.11.072.

Tan X, Liu Y, Gu Y, Xu Y, Zeng G, Hu X, Liu S, Wang X, Liu S, Li J (2016) Biochar-based nano-composites for the decontamination of wastewater: A review. *Bioresource Technology,* **212**, 318-333. https//:doi.org/10.1016/j.biortech2016.04.093.

Thapa S, Engelken R (2020) Optimization of pelleting parameters for producing composite pellets using agricultural and agro-processing wastes by Taguchi-Grey relational analysis. *Carbon Resources Conversion* **3**, 104–111. https://doi.org/10.1016/j.crcon.2020.05.001.

Torres-Carrasco M, Reinosa JJ, de la Rubia MA, Reyes E, Peralta FA, Fernández JF (2019) Critical aspects in the handling of reactive silica in cementitious materials: Effectiveness of rice husk ash vs nano-silica in mortar dosage. *Construction and Building Materials* **223**, 360–367. https://doi.org/10.1016/j.conbuildmat. 2019.07.023.

Wang D, Jiang P, Zhang H, Yuan W (2020) Biochar production and applications in agro and forestry systems: A review.

Wang RX, Zhao Y, Xie XY, Mohamed TA, Zhu LJ, Tang Y, Chen YF, Wei ZM, (2020) Role of NH_3 recycling on nitrogen fractions during sludge composting. Bioresour. *Technol*. **295**, 122175.

Woodard R (2021) Waste Management in Small and Medium Enterprises (SMEs): Compliance with Duty of Care and implications for the Circular Economy. *Journal of Cleaner Production* **278**, 123770. https://doi.org/10.1016/j.jclepro.2020.123770.

Yan Y, Sarkar B, Zhou L, Zhang L, Li Q, Yang J, Bolan N (2020) Phosphorus-rich biochar produced through bean-worm skin waste pyrolysis enhances the adsorption of aqueous lead. *Environmental Pollution* **266**, 115177. https://doi.org/10.1016/j.envpol.2020.115177.

Zakaria ZA (2018) Sustainable Technologies for the Management of Agricultural Wastes. *Applied Environmental Science and Engineering for a Sustainable Future Book Series,* https://doi.org/10.1007/978-981-10-5062-6, Springer Nature Singapore Pte Ltd.

Zalewska M, Popowska M (2020) Antimicrobial/Antibiotic Resistance Genes Due to Manure and Agricultural Waste Applications. In: M. Z. Hashmi (Ed.), *Antibiotics and Antimicrobial Resistance Genes, Emerging Contaminants and Associated Treatment Technologies,* https://doi.org/10.1007/978-3-030-40422-2_6, pp: 139 – 161. Springer Nature Switzerland AG.

Zhang Q, Zhang D, Xu H, Lu W, Ren X, Cai H, Lei H, Huo E, Zhao Y, Qian M, Lin X, Villota EM, Mateo W (2020) Biochar filled high-density polyethylene composites with excellent properties: Towards maximizing the utilization of agricultural wastes. *Industrial Crops & Products* **146**, 112185. https://doi.org/10.1016/j.indcrop. 2020.112185.

Zhang Y, Wang X, Ji H (2020) Stabilization process and potential of agro-industrial waste on Pb-Contaminated soil around Pb-Zn mining. *Environmental Pollution* **260**, 114069. https://doi.org/10.1016/j.envpol.2020.114069.