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 perspectve.

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

The agricultural sector is considered a main driver for industrial sector in several 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 Othman et al. 2020), biofuels (Ge et al. 2021), biochar (Kwoczynski and Cmelík 2021; El-Bassi Othman et al. 2020) 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-utilize or recycle for other purposes). 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 by vermi-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 180 million 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 converted into 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$_2$O), 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 landfills a 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 (Peerzadal 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.

Many agro-wastes already used in synthesizing nanomaterial such as groundnut and walnut shells, banana and orange peels, and coconut husk for the biogenic synthesis of nano-silica (Peerzadal 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 (Dakrouy 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 a lot of processes have been innovated for handling the organic wastes including the composting or removal, organic fertilizers, biochar, and removing the pollutants from the environment. Due to its low economic cost as well as its reduction in landfills, some agro-wastes cannot be posted like oils. Hence, the management system of agro-wastes has 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 in input of water, material and energy, the reduction in manufacturing...
TABLE 1. The most important nanomaterials derived from agro-wastes and its application

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

(4) Producing agro-composite for packaging purposes (Sufflo 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-amylose (Bhatt et al. 2020), lignocellulolytic enzymes (Leite et al. 2020; Naidu et al. 2020),

(7) Bioenergy production (Donner et al. 2020) like the biodiesel from raw nano-sized sugar beet agro-


(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 (Bau 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.

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-sequestration in 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 characteristics that 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,
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 size than 100-nm had resulted in increased mobility of metal ions 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 process and 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 (Bediako et al. 2019).

**Table 2. Different studies handled agro-wastes and biochar with their applications**

<table>
<thead>
<tr>
<th>Agro-waste source</th>
<th>Agro-waste type</th>
<th>The main finding after application</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algal biomass</td>
<td>Biochar</td>
<td>Biochar could be used as an efficient catalyst in various applications</td>
<td>Anto et al. (2021)</td>
</tr>
<tr>
<td>Raw jujube seeds</td>
<td>Agro-waste biochar</td>
<td>Biochar could remove metal ions (Cu, Ni, Cr and Zn) from wastewater</td>
<td>Gayathri et al. (2021)</td>
</tr>
<tr>
<td>Wheat straw biomass</td>
<td>Agro-food biochar</td>
<td>Biochar improves resistance of Mg phosphate cement in water environment</td>
<td>Ahmad et al. (2020)</td>
</tr>
<tr>
<td>Wastes of murumuru kernel shell (MKS)</td>
<td>Biochar</td>
<td>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</td>
<td>Bastos et al. (2020)</td>
</tr>
<tr>
<td>Wastes of rice husk, olive pit and remains</td>
<td>Biochar</td>
<td>Biochar has a potential to sequester carbon and its use as soil ameliorant</td>
<td>Campos et al. (2020)</td>
</tr>
<tr>
<td>Raw agricultural waste</td>
<td>Biochar compared to raw agricultural waste and ash</td>
<td>Applied biochar improved the agro-production up to 36%-64% over the experimental fields of India and Bhutan</td>
<td>Dey et al. (2020)</td>
</tr>
<tr>
<td>Coconut palm biomass wastes</td>
<td>Biochar</td>
<td>Biochar enhances under humid tropic the regenerative agriculture by improving soil properties and plant yield</td>
<td>Gopal et al. (2020)</td>
</tr>
<tr>
<td>Agro-waste walnut shells</td>
<td>Biochar adsorbent</td>
<td>Removing of nickel (II) ions from aqueous solutions by biochar adsorbent</td>
<td>Georgieva et al. (2020)</td>
</tr>
<tr>
<td>Pistachio and peanut shells and corks</td>
<td>Biochar-based biocatalyst (BBBs)</td>
<td>Immobilized BBs applied in alcoholic fermentation of hydrolyzate generated via a citrus peel waste biorefinery</td>
<td>Kyriakou et al. (2020)</td>
</tr>
<tr>
<td>Rice husk</td>
<td>Agro-industrial biochar</td>
<td>Degradation of propylparaben as adsorbent and sono-catalyst</td>
<td>Nikolaou et al. (2020)</td>
</tr>
<tr>
<td>Vegetable waste</td>
<td>Biochar</td>
<td>Biochar enhances maturity of compost during vermicomposting of vegetable waste</td>
<td>Paul et al. (2020)</td>
</tr>
<tr>
<td>Sugar canes straw and sawdust</td>
<td>Biochar</td>
<td>Biochar-based hybrid materials are potent for oxidative catalysis technology</td>
<td>Pierri et al. (2020)</td>
</tr>
<tr>
<td>Bean-worm skin</td>
<td>Phosphorus-rich biochar</td>
<td>Biochar enhances the adsorption of Pb through chemisorption and precipitation</td>
<td>Yan et al. (2020)</td>
</tr>
<tr>
<td>Saw dust wastes</td>
<td>Sawdustash and sawdust biochar</td>
<td>Remediation of polluted soil through stabilizing Pb in soil</td>
<td>Zhang et al. (2020)</td>
</tr>
</tbody>
</table>
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 could also 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 tropical and 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-wastes are 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 implemented by 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.

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