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Editorial

Aerobic and Anaerobic Digestion of Agro-Industrial and Livestock Wastes: A Green and Sustainable Way toward the Future

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Agricultural manufacturing costs have elevated over time because of expanded land use for agricultural functions, state-of-the-art agricultural machinery, and an ever-developing population. it is anticipated that over several million tons of food are produced on average every day globally. Additionally, agriculture-based industries have thrived, which is an added benefit for the agricultural sector. However, this growth has a prominent negative impact on biotic and abiotic sources since a vast amount of waste is produced by agriculture-based industries each year, which puts pressure on the environment and its services. Several reports suggest that the waste from such industries is either burned or dumped without proper disposal procedures. Nevertheless, food waste is also a major challenge in regard to agro-waste because one-third of the food produced is wasted [1]. On considering agricultural wastes, crop residues are denoted to as a natural and valuable supply known as "black gold" since they offer a substantial amount of nutrients for crop production. The surplus material of these crops consists of lingo-cellulosic compounds that are non-edible to animals and do not decompose easily. Bearing this in mind, farmers tend to burn the surplus; this results in the expulsion of harmful gases into the environment. Crop residue production and application diverge pointedly through different provinces of the country based on the crop planted, their growth and yield. Annually, the rate of crop wastes accounts for more than 100 million tons across the globe. The highest crop wastes are a result of cereals and sugarcane farming followed my other cash crops [2,3].

Reduce, recover and reuse measure play a crucial role in the circular economy business models that aim at reducing environmental pollution, input costs and technology investments. In this regard, composting represents an effectual substitute for organic waste management, since it reduces the dumping of wastes in landfills and the usage of improper disposal techniques. Composting favours the nutrient recycling approach for a greener environment and also improves soil fertility by enhancing the macronutrient content in agricultural lands [4]. The success of generating compost from agro-wastes depends on using the suitable organic material and other factors such as controlled temperature, oxygen supply and moisture. Oxygen is a crucial determinant in this technique because this is a completely aerobic approach to degrade agro-wastes. It also favours the preparation of a biofertilizer that is phytotoxin free and enriched with humic properties. Organic matters are well homogenized and dehydrated which makes this an excellent choice for the farmers to amend the nutrient composition of their agricultural lands [5]. Amongst

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the numerous waste management routines, composting is regarded as the sustainable treatment technique for recycling agro-industrial waste into valuable by-products Employment of cheap and abundant biomass resources is an advantage of this approach making it an extensively studied approach to manage biodegradable waste for a sustainable environment. Agro-industrial waste largely entails intricate lignocellulosic materials such as cellulose, hemicellulose and lignin. In spite of being an appropriate technique for treating agricultural residues, one of the most common limitations for composting agro-waste is the difficulty of decomposing recalcitrant complexes such as cellulose, hemicellulose and lignin. This interference disturbs the yield of the composting method and the superiority of the end product. Additionally, it intensifies the cost of manoeuvres, energy and time in compost fabrication. It is vital to monitor and control the key parameters in composting such as Carbon/Nitrogen ratio [6]. To obtain a good yield, use of pre-treatment techniques such as subjecting the raw materials to thermal and chemical treatments can also increase the yield of the compost but they might not be cost-efficient. On a large scale, chemical treatments may help breaking the complex structure of the cellulose, hemicellulose and lignin biomolecules which would favour the facile and rapid degradation of the large molecules. Nevertheless, it is advisable to find alternatives without the use of sophisticated instruments and techniques that would elevate the production cost [7].

Composting is one of the most extensively and frequently employed circular economic system approach for recycling organic waste and signifies a price-effective technique for recycling vitamins. Sespite the fact that composting is taken into consideration to have a low environmental effect, it is unavoidable that the composting of manure will emit anthropogenic greenhouse gases and different gases together with ammonia and other gases such as VOCs. Composting is and acclaimed method for coping with crop residues is the need of the hour to restrain the harmful outcome of residue burning, besides the renovation of soil's natural carbon, they act as chief determinants of soil microbes, and nutrient rotation mechanisms. Compost is a pool of microorganisms with commendable degradability and physiological potentials. The duration of the system depends on Cellulolytic, amylolytic, and proteolytic microorganisms. The higher the number of microbes, the higher is the rate of decomposition. The secondary metabolites produced by the microbes in the inoculum suppresses the growth of other microbes and in turn results in composts with high nutritive value [8]. It is suggested that, humification of lignin waste which is present in excess will increase the concentrations of ligninase, protease, xylanase and urease. On the other hand, raw materials with low lignin materials showed enhanced alkaline phosphomonoesterase, cellulase and beta-glucosidase concentrations [9,10]. The global growth in population will bring about extended food production and manufacturing units that may, in turn, cause immoderate food waste. Despite the fact that composting is extensively pursued for the conversion of organic waste into value-added merchandise such as bioactive compounds that are effective in pest management [11], there are numerous obstacles, inclusive of its decreased efficiency in composting green waste without co-composting, the nonexistence of nutrients, and the emanation of greenhouse gases [3]. Subsequently, utilization of soil microbial assets is a vital venture, and compost is a completely unique niche of microbial habitat. It performs as self-heating, aerobic or anaerobic, biodegradation approach, to transform natural substances found in wastes. For the degradation of local proteins into smaller subunits (amino acids) distinctive kinds of proteases including serine protease (EC 3.4.21), cysteine (thiol) protease (EC 3.4.22), aspartic protease (EC 3.4.23), and metalloprotease (EC 3:4.24) are used. Proteases are a combination of endo-protease and exo-proteases, and in certain cases they are amidases enzymes. Nevertheless, because of its famed characteristics, biochar amendments are also used at some stage in composting to conquer those problems; each waste has to be at the correct stage to yield top best compost with excessive nutrient levels [12].

Composting agricultural biomass requires prior planning and execution since the release of carbon dioxide (CO_2) and methane (CH4) can lead to a massive decrease in the carbon concentration, similarly ammonia (NH3) volatilization results in a loss of nitrogen,

which cuts down the nutritional content of the final compost. The composting efficacy of waste is also very little due to shortcomings such as changes in its porosity, bulk density, C:N ratio and acidification issues. The final compost formed is used in agricultural lands for intensifying crop yields by refining the quality of the soil; the product generated should be of virtuous quality, which upsurges the concentration and solubility of plant nutrients such as potassium and phosphorus. This provides high water-retaining capacity and aeration. Hence, it is obligatory to get through the abovementioned complications. The co-composting of agro-waste in amalgamation with manure that has high nitrogen and low moisture contents diminishes the probable environmental effects [13,14]. Co-composting permits the aerobic breakdown of organic waste mixtures, to acquire compost that can be utilized as fertilizer. Co-composting also lessens the time and effort allied with composting and can have economic paybacks. To reduce nutrient loss, the accumulation of carbonaceous material is exceedingly favoured. For instance, sawdust is an ideal modification which is used to intensify the carbon composition and to uphold the nitrogen from waste and manure [14]. Further, organic manures, such as vermicompost and farmyard manure are exploited as organic fertilizers to escalate soil fertility and crop yield. Nevertheless, the little nutrient content, availability issues in the commercial markets, less availability in the market, dearth of awareness among farmers of their valuable effects, and challenge management of these organic manures daunt farmers from using them more regularly. The salvaging rapidity and quality of vermicompost can be amended with the amalgamation of dissimilar organic substrates such as bone meal, eggshell, banana peel and certain microbial inoculants as well as by sustaining finest temperature, pH, and moisture. The opportunity of enhancing vermicomposts with supplementary nutrient-rich organic and inorganic resources as a substitute to the poor nutrient content of organic fertilizers has been well explored. To enrich the nutritive properties of the vermicompost organic ingredients such as green manure, biomass, microbes as biofertilizer and inorganic resources including rock phosphate and fly ash are added to the vermicomposts. Conversely, mixing organic with inorganic substrates causes an over-all diminution in microbial action, which could endanger the effectiveness of the biodegradation process [15,16].

Solid waste management has become a major issue in several developing countries in recent times [8]. Nutrient retrieval from organic wastes such as kitchen litter, agro-waste, and municipal waste is crucial for waste management and environmental fortification. Yet, when these organic wastes are not disposed properly, substantial amounts of nutrients stowed in them are lost or reduced. These vital nutrients can be recovered via green-technologies such as vermicomposting and can be utilized as nutrient-rich manures in cultivated fields to recover soil fertility. For instance, eggshells, a robust and facile source of calcium, are commonly thrown out as waste from households, hotels, and food chains. On the other hand, if this calcium-rich substratum is added to the soil, it not only enhances the calcium capacity of the soil with calcium, but also neutralizes or turns the soil alkaline and suitable for the plant to grow. In the present scenario, with the upgradations in revenue and dietary reception, growing egg ingestion is noticed as eggs are known as a high-quality protein resource. However, this resulted in roughly around 58.58 MMT of eggshells waste, which are routinely dumped in landfills as waste, directing to numerous environmental glitches and therefore should be prudently managed. Similarly, banana peel is another biowaste which pollutes the environment due to improper disposal [17]. The major constituents in a banana peel are potassium, magnesium, calcium, sodium, and it also contains other minerals. From olden days, banana peel has been utilized as a biomanure to enhance soil nutrients and fertility. It is suggested that composts that contain banana peels showed elevated levels of potassium and nitrogen indicating that this agro-waste can be a good resource of plant nutrients and minerals [18]. Tea waste is another imperative biomass that is usually thrown in open space after its processing, this can lead to the expulsion of toxic gases, soil and water pollution which in turn reduces the aesthetics of the environment. Recently, this issue has been addressed in which it was suggested that tea waste can be effectively managed by vermicomposting. Employing tea

waste in in vermicomposting has shown to significantly improve the nitrogen content of the compost and it is also regarded as a key source of other minerals [19]. One of the vital wastes from which phosphorous can be obtained is the bone meal which is a complete organic resource of phosphorous. The addition of bone meal to the vermicompost not only improves its quality but when used as a fertilizer, it aids in the strong association of fungi with the roots of plants. This mycorrhizal symbiosis allows improved phosphate absorption and utilization. Rock phosphate is the major source of organic fertilizers used by the farmers; however, it was revealed that phosphates obtained from bone meals can be a better resource since their bioconversion expels a very little amount of greenhouse gas [20]. Therefore, vermicomposting of organic waste at the place of generation should be given top significance in treating the waste, which will assist in plummeting transportation costs, disease risks, greenhouse gas release, water pollution, and land space for dumping, in addition to this it helps in producing organic fertilizer that can be exploited as a soil quality enhancer. Analogous to the other wastes, a huge amount of agro-based biomass is dumped into the surroundings from the brewery industry. By-products of this industry includes spent grain, spent hops and yeast. Among these waste products expelled from the brewery, spent grains constitute about 85% of the total waste. Although it has been suggested that these spent grains can be reused for consumption purpose, they have less possibility of reaching the commercial market since the industrial arena prefers to dump or incinerate the wastes. Further, it is established that they are a good source of green energies such as bioethanol, biodiesel and biogas. This invariably reduces the production of greenhouse gases that would help in a cleaner environment as well as a circular economy. Nevertheless, it has been identified that they can be employed as a substrate for microbes and for enzyme production. Biodegradable materials including green bricks, paper, bio-covers and antifoaming agents can be produced as value added product using brewery waste. Cost-effective absorbent materials were manufactured and their efficacy in wastewater treatment was examined. The effectiveness of the biomass depends on the pre-treatment techniques such as drying [5]. The ability of compost as effective pesticide is also a vital arena to be explored since chemicals used to target pests have toxic effect on the environment as well as its components [21]. Additionally, larvicidal agents containing phytocompounds derived from plant extracts are biodegradable and less-toxic [22].

Agro-waste is the cheapest and most easily available source of carbohydrates for bioconversion and value-added product generation. Improvisation of pre-treatment and digestion techniques could revolutionize aspects of agro-waste management. It not only favors the livelihood of farmers but can be an immense benefit to both the environment and the economy of the country. Wastes of plant and animal origin have been investigated, and substantial data is available about the generation of various value-added products. However, efficient techniques for bioconversion, differences in yield, and their limitations are less emphasized. Additionally, research outcomes that involve greener approaches to a sustainable environment must be highlighted. In this context, the motive of this special issue was to stimulate further research in aerobic and anaerobic waste management strategies that include novel digesters, microbial interactions, and the generation of value-added products such as biofuels and composts from agro-waste for a sustainable environment in the future.

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