Chapter

The Use of Waste Management Techniques to Enhance Household Income and Reduce Urban Water Pollution

*Olayiwola A. Akintola, Olufunmilayo O. Idowu,
Suraju A. Lateef, Gbenga A. Adebayo, Adekemi O. Shokalu
and Omolara I. Akinyoola*

Abstract

Appropriate waste management options are major concerns in the developing world. Current methods include incineration in the open and accumulation of wastes in designated places where they constitute nuisance to the environment. Apart from air pollution from the incinerators, leachates from decomposed wastes are either washed off where they serve as source of pollutants to the adjourning streams and rivers or contaminate groundwater through deep percolation. We present viable options for managing agricultural wastes in this chapter. The options presented are so simple and sustainable such that it can be managed by individuals. Hence, they are independent of the government bureaucratic bottlenecks that have been the bane of the previous government interventions. If embraced, it will also serve as sources of income for the concerned household, hence enhance their livelihood.

Keywords: environmental pollution, water pollution, waste management, waste-to-wealth

1. Introduction

Nigeria is reputed to be the largest black nation in the world, blessed with abundance of natural resources such as nickel, gold, tin, iron ore, bauxite, precious stones, bitumen, crude oil and vast agricultural land. Of all the natural resources, crude oil exploration is well developed. The nation depends on it for more than 70% of her income [1]. Due to instability and recent steady downward fall in crude oil price globally, the government of Nigeria seems to be seeking for diversification of her economy via increase in agricultural production. Several programmes have also been put in place to encourage Nigerians to get involved in agricultural production.

Due to poor infrastructural development in rural areas in developing nations of the world, there is the usual migration of people, especially youths, into the cities where they hope to get a “white-collar job” for a decent life. Unfortunately, the migration continues and the “white-collar job” is more of a mirage than reality. In an attempt to find a means of sustenance, some of these youths end up getting involved in one vice or the other. Due to land tenure system, poverty, lack of incentives, etc., more than 70% of farmers in Nigeria and other developing nations of the world are considered small-scale farmers (land holding of less than 10 ha) [2]. Continuous cultivation of the land has also led to depletion in the nutrient status of the soil. Unfortunately, cost of soil amendments such as mineral fertilizer is gradually getting beyond the reach of average farmer. Hence, if urgent steps are not taken to address the downward trend, developing world will soon be faced with food crises of unimaginable magnitude.

One of the ways of mitigating against this is the step already being experimented by the Nigerian government whereby incentives are provided to encourage women, unemployed youth and other stakeholders to get actively involved in agriculture. This is a right step in the right direction, if pursued to a logical end. However, there must be a holistic approach towards solving this problem. Such approach must include alternative source of input (fertilizer, etc.) that is affordable. It will also be necessary to find a way of forming the farmers into clusters so that processing facilities will be acquired and maximized. The government also must look into the area of packaging and transportation of agricultural produce so as to minimize loss. In a recent survey conducted in selected fruits and vegetable market in Oyo State, Nigeria, the traders complained of losing at least 5% of the purchased products between the farm gate and market due to the way the produce are stacked together during transportation and bad road network. Due to the perishable nature of these produce, a large percentage of the produce will also go into waste. If the traders must break even, they will have no other choice than to increase the price of the remaining items. Hence, buyers will be forced to pay not only for the items bought but also for the spoilt ones. The spoilt ones are usually stacked in designated places within the market community where they serve as breeding ground for disease vectors (**Figure 1**). When it rains, leachates from these dumping grounds are either washed to adjourning streams and rivers where they serve as contaminants to the water bodies or leached down the soil via deep percolation where they serve as contaminants to groundwater. Creating farm clusters will definitely boost agricultural production and encourage siting of medium- to large-scale processing plants that will add value to agricultural produce, thus enhancing the profitability of their products. It will

Figure 1.
Some horticultural waste from Odo-Oba, near Ogbomosho in Oyo State, Nigeria, West Africa.

however lead to generation of large volume of wastes which will serve as nuisance to the communities unless alternative uses have been provided long before they are generated to avoid outbreak of diseases in an epidemic magnitude.

Under normal circumstances, industrial wastes are to be treated to meet some prescribed minimum standards before discharge. The standards are clearly stated by regulating bodies. Unfortunately, most of the industries scattered all over Nigeria, as well as other developing environments, have been reported not to comply with these standards because the enforcement of the prescribed standard is weak and the penalties are too light to serve as deterrent to others [3–5]. These also pose a great risk to waterbodies. Other sources of contamination to waterbodies include leachates from agrochemicals, industrial discharge, etc. In this chapter, however, we will limit ourselves to agricultural wastes and its management.

Poverty thrives in Nigeria, as it is in other developing nations of the world. Nigeria is rated as one of the poorest countries of the world and occupies the 152nd position out of 188 countries on Human Development Index (HDI) ranking [6]. About 80% are reported to be living below poverty line [7]. Pipe-borne water is non-existent in most cities due to the breakdown of public water supply. Hence, several households depend on shallow wells and streams for their potable water. Some are dying of avoidable diseases. Unfortunately, others are ill but are too poor to be able to access health facility. On the contrary, the wastes that litter the place, serving as breeding ground for disease vectors and contaminating the streams and shallow wells, could be turned into income-generating ventures via waste-to-wealth programmes. The government structures are failing in the developing world due to the combinations of factors. Empowering households through waste-to-wealth programme will not only rid the environment of debris, etc. but will also take care of major source of contaminants to waterbodies (surface- and groundwater). Hence, our world will be a better place to live in and pollution will be minimized. Some of the ways of converting the menace of indiscriminate dumping of wastes into money-spinning ventures include but are not limited to:

2. Mushroom production

Across the globe, wastes are being generated from agriculture, industries, etc. To combat food security, efforts are being made to increase agricultural productivity and economic yield with little or no attention given to its disposal. When wastes are poorly managed or disposed, it may result in outbreak of disease and untidy environment, characterized with offensive odors, resulting into increase in the population of rodents and insects that could constitute threat to lives and properties. Over time, what has been considered as wastes in some enterprises, especially in agro industries, is found to be useful, thereby adding value to the supposed wastes.

Mushrooms are a group of fungi and are distinct from green plants because they lack chlorophyll and therefore cannot manufacture their own food as other plants do but rather produce extracellular enzyme which digest various kinds of dead organic matter on which they grow [8]. It contains all the essential amino acids (for humans) as well as most commonly occurring non-essential amino acids and amines. These include phenylalanine, valine, theanine, tryptophan, isoleucine, methionine and leucine [9, 10].

Mushrooms are a good source of protein that can enrich human diets, especially in some developing countries where meat may be rare or expensive. Many mushrooms are considered to be healthy food because they contain large amounts of qualitatively good protein, vitamins (B_1, B_2, B_3, C and D) and minerals (potassium and phosphorus) in addition to folic acid, an ingredient known for enriching the blood stream and preventing deficiencies. They have a low fat content ranging from 0.6 to 3.15%. The protein content ranges between 19 and 37%, depending on the variety [11, 12]. They are conventionally grown on agro-industrial wastes containing lignin, cellulose and hemicelluloses. In Nigeria and other parts of the world, tons of these wastes are generated annually which, if not managed, will constitute a menace to the environment. Different agro-industrial wastes singly and in combination have been used for the cultivation of different mushrooms such as *Volvariella volvacea*, *Pleurotus* species, *Agaricus* species, etc. [13–15]. The waste used in mushroom production includes banana leaves, water hyacinth, sawdust, rice straw, maize stover, corn cob, cassava peels, grass straws, oil palm processing wastes, etc.

The first step in mushroom growing is the choice of which mushroom species to grow. The culture of the choice mushroom can be obtained and prepared into the planting spawn, or the spawn is purchased directly from a mushroom laboratory. The second step is sourcing for a readily available substrate within the grower's immediate environment to cut down production cost. This step is followed by the preparation of the growing medium or substrate which may include chopping, breaking, soaking or moistening, depending on the type of substrate. They can be used fresh (rice straw, maize cob, banana leaves, etc.) or composted (sawdust). Some (straws, vines and wood) may require chopping into smaller sizes of 3–5 cm, while others can be used directly (e.g. sawdust) [16]. It is also required that the growth materials are disinfected to rid them of other inherent micro-organisms and insects by applying heat or chemical treatments [17, 18]. The third step in mushroom growing process is the transfer of the spawn or inoculum (planting material) to the growth medium after disinfection. This is done using a standard method in a laminar flow chamber or a locally fabricated inoculation hood, to avoid contamination of the disinfected substrate by unwanted micro-organisms. After inoculation or planting, the substrates are then moved to a dark room or incubation chamber and left for a period depending on the mushroom species that is being grown; it is a time during which the mushroom mycelium ramifies the entire substrate. After incubation, the substrates are subjected to a fruiting condition where the mushroom fruiting body initials or primordia begin to appear and are harvested after maturity. Mushroom cultivation processes are presented in **Figure 2**.

Figure 2.
Mushroom cultivation processes. (a)–(g) represent substrate preparation, mixing and bagging, actively growing mushroom planting material (spawn), inoculation/spawning of substrate bags, Volvariella volvacea growing on banana leaves, and Calocybe indica (milky mushroom) growing on sawdust substrate and freshly harvested mushrooms, respectively.

Mushrooms are a high-value niche product; its production is a viable source of livelihood and food security. Cost–benefit analysis of different aspects of mushroom production was investigated by [19]. The authors reported a cost–benefit ratio of 2.30, 3.13 and 1.8 on mushroom spawn production, substrate preparation and mushroom fruiting body production, respectively. Celik and Peker [20] and Basanta et al. [21] also reported the profitability of mushroom fruiting body production in Bulgaria and Bangladesh, respectively.

3. Composting

Compost fertilizers are organic fertilizers made from plant and animal leftover that have been decomposed by the existing micro-organism [22, 23]. The main objective of making compost manure is to recycle these nutrients in plants and animal leftover back to the soil for plant growth. The practice improves the soil physical, chemical and biological activities, improving crop yields and nutritional values. It also maximizes the use of available organic resources on the farm and minimizes the use of costly inorganic agrochemicals [24, 25]. Process involved in making compost is referred to as composting. Composting is defined as a biological process in which a micro-organism converts organic materials such as manure, sludge, leaves, peels, animal waste and food waste into a soil-like material called compost in the presence of water and air [26]. It is the main process used to produce stable, high-quality organic fertilizers from organic waste [27]. Composting is done to transform and stabilize organic materials into stable, usable products, to produce uniform organic fertilizer suitable for soil amendment and to remove offensive odors, to kill weed seeds and pathogenic organisms [28]. Compost can be made from crop residues, husks, stovers and agricultural, domestic and industrial wastes that are accessible and available, combined with animal manures. Human wastes can also be composted for crop production, but it is not encouraged due to disease and pathogen transmission [29].

Nigeria is the leading producer of cassava in the world, producing 37 million tons/year on 2.5 million hectares of land [30]. Accompanied with this output is the large volume of cassava peels being released as waste by processing centres all over Nigeria. It is usually burnt or used to feed livestock (most especially small ruminants) as source of protein and roughages. However, not more than 10% of the cassava peels produced is utilized in feeding livestock. The remaining is commonly found in farm and other processing sites as heap that are generally perceived as a nuisance [28]. These materials, however, could be utilized more effectively and sustainably through recycling rather than being destroyed through burning as commonly practiced by many leading to air pollution. Wastes such as cassava peels are rich in crude protein (5.29%) and fat (1.18%) [31]. Utilization of the peels and other agricultural wastes is limited by its low digestibility. Composting will not only reduce toxicity but also convert the resistant lignocellulose material into a more digestible substrate. Preparing compost from wastes offers many advantages. It provides incentive for communities to recover locked nutrients in the wastes, eliminate the problem of waste disposal and increase the manurial values of the materials [32].

Compost can be prepared throughout the year. Three common methods of preparing composts include on the earth/flat surfaces, the use of compost pits and preparation in boxes. Methods adopted are dependent on availability and access to space (**Figure 3**).

Compost manure will regulate soil structure, softens hard soil and improves the water holding capacity of the sandy soil, thus increasing soil aeration and the soil's ability to withstand erosion by wind or water [25]. It requires little or no technical

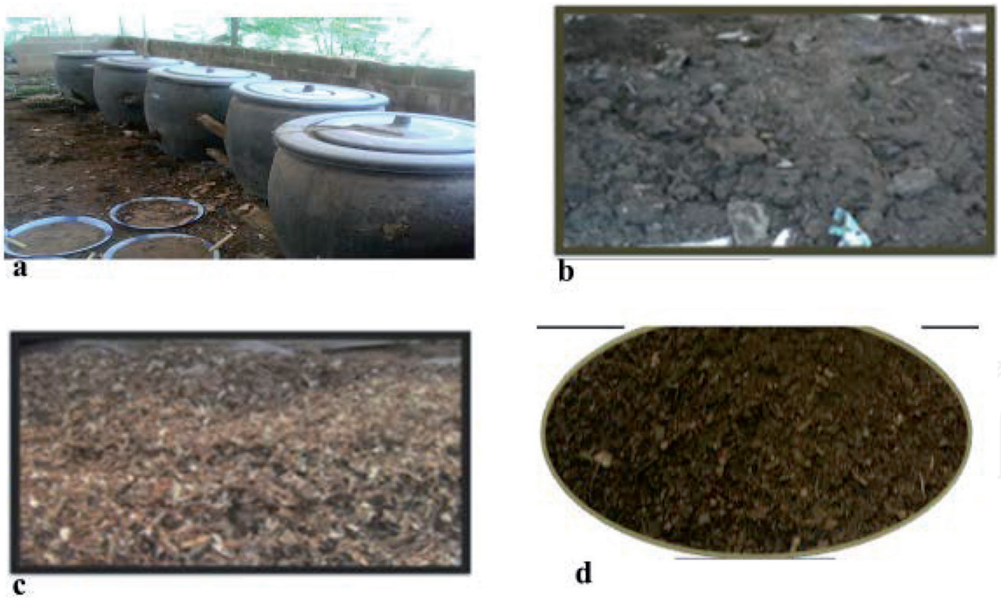

Figure 3.
Composting materials and matured compost; a, b, c and d are composting using bins, poultry manure, cassava peels and finished compost, respectively.

know-how. It is cheap and can be made on-site where wastes are deposited, thus reducing cost of transport. As an organic fertilizer, it has the ability to release nutrient slowly into the soil, thereby making the effect to last longer, even to the succeeding crops. It creates a good environment for soil microbes, by providing carbon compounds which serve as nutrients for soil micro-organisms and other soil habitats. Compost manure due to its composition is the storehouse of all essential macro- and micronutrients required by plants. When composts are fortified with other amendments, it can be used to control plant diseases and reduce crop losses on the field. [30]'s report indicated that this type of product significantly reduced the need for pesticide, fungicide and nematode application, which could cause environmental pollution. Matured compost should conform to at least one of the four tests outlined below: (i) The carbon to nitrogen ratio (C: N) must be less than 25:1, and seed germination using radish in the compost is at least 90% of control. (ii) The compost is cured and does not reheat to 20°C above ambient temperature. (iii) The compost is cured and there is a 60% weight reduction of organic material. (iv) The material is cured under aerobic conditions without reheating.

4. Biochar production

Biochar is known as "biological charcoal" which is produced from large biomass of organic materials in the presence of little or no oxygen "at relatively low temperature (<700°C)" [33]. It is the carbon-rich product obtained when biomass, such as wood, manure or leaves, is heated in a closed container with little or no available air. It is also known to be of tremendous benefits to soil microbial population, improve growth of crops and soil functions. It is very helpful in environmental protection. Biochar, when used as a soil amendment, has been reported to boost soil fertility and improve soil quality by raising soil pH, increasing water holding capacity, attracting beneficial organisms like fungi and microbes, improving cation exchange capacity (CEC) and retaining nutrients in soil [34–36]. Another major benefit associated with the use of biochar as a soil amendment is its ability to sequester carbon from the atmosphere-biosphere pool and transfer it to soil [37, 38]. It may also decrease emissions of other more potent greenhouse gases (GHG) such as N_2O

and CH_4. It may persist in soil for a long period of time because it is very resistant to microbial decomposition and mineralization.

One of the challenges in characterizing biochar as a class of materials is that it is new and unique [33]. Nevertheless, the defining property is that the organic portion of biochar has a high carbon (C) content which comprises the so-called aromatic compounds characterized by rings of six C atoms linked together without oxygen (O) or hydrogen (H).

Some essential nutrients can be depleted in biochar due to the pyrolysis method used in its production. Some materials are heat labile, especially at the surface of the material, while other nutrients become concentrated in the remaining biochar. Individual elements are potentially lost to the atmosphere, fixed into unavailable forms or released as soluble oxides during pyrolysis. For wood-based biochar, carbon (C) volatizes around 100°C, N above 200°C, S above 375°C and K and P between 700 and 800°C, while volatilization of magnesium (Mg), calcium (Ca) and manganese (Mn) occurs at a temperature above 1000°C. Biochar additions to soil do provide a modest contribution of nutrients depending, in part, upon the nature of the feedstock (wood versus manure) and the temperature under which the material is formed.

Much of the current understanding of the properties of biochar is derived from studies centred on the phenomenon known as "Terra Preta". Terra Preta (meaning black in Portuguese) refers to the expanse of very dark, fertile soils mostly found in the Amazon Basin of Brazil. The majority of the biochar applied and incorporated within the soil in this region of the Amazon over countries underwent various changes and became microscopically unrecognizable while enriching the soil with nutrients and changing soil properties. This implies that biochar, when added to soil, undergoes changes slowly but surely over the years. Change in soil properties has been recorded in different soils to which biochar was added. Increase in cation exchange capacity and pH of soil as a result of biochar addition has been documented.

Biochar can be produced from a variety of biomass materials, otherwise known as feedstock. These include biological, decomposable materials like wood and wood-based waste materials, municipal waste, domestic wastes, agricultural/industry wastes, etc., depending on its availability and abundance. The production of biochar from materials with high economic benefits and other competing uses will however not be sustainable. Biochar can be produced at almost any pH between 4 and 12 [32, 33] and can decrease to a pH value of 2.5 after short-term incubation of 4 months at 70°C. The pyrolysis temperature of biochar production and its pH are directly proportional. The burning and natural decomposition of biomass and particular agricultural waste adds large amounts of CO_2 to the atmosphere. Biochar that is stable, fixed and recalcitrant carbon are known to be capable of storing large amount of greenhouse gases; hence, it has the potential of reducing or stalling the increase in atmospheric greenhouse gas levels. It can also be used to improve water quality, increase soil fertility and raise agricultural productivity. Biochar, like coal, can sequester carbon in the soils for hundreds to thousands of years; hence, it has the potential of helping the withdrawal of CO_2 from the atmosphere while producing and consuming energy. It is estimated that the sustainable use of biochar could reduce the global net emissions of carbon dioxide (CO_2), methane and nitrous oxide by up to 1.8 pg. $CO_{2-}C$ equivalent (CO_2—C_C) per year. Biochar is a high-carbon, fine-grain residue which can be produced through modern pyrolysis processes. Pyrolysis is the direct thermal decomposition of biomass in the absence of oxygen to obtain an array of solid (biochar), liquid (bio-oil) and gas (syngas) products. The specific yield from the pyrolysis is dependent on the type of process, temperature, feedstock and other conditions that it is subjected to.

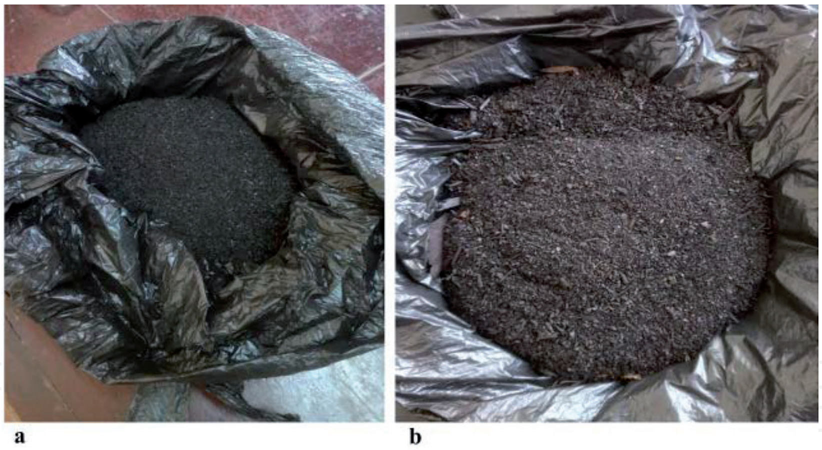

Figure 4.
Biochar made from sawdust; a and b represent milled biochar and biochar in granular form respectively.

Biochar application to soil has the potential to positively improve the soil health and increase availability of both macro- and micronutrient elements in the soil. The application of biochar can decrease the Al saturation of acid soils which often is a major constraint for productive cropping in highly weathered soils of the humid tropics. Biomass production to obtain biofuels and biochar for carbon sequestration in the sol is a carbon-negative process, i.e. more CO_2 is moved from the atmosphere than released, thus enabling long-term sequestration. A recent study indicated that appropriate combinations of these feed stalks will produce good fertilizer blends with optimum nutrient availability. For example, a feed stalk with plantain peels/wastes contains high content of potassium [39], while citrus waste-based biochar has higher N and P content. Biochar made from sawdust is presented in **Figure 4**.

5. Biogas production

In recent years, interest in anaerobic digestion as a management option for the disposal of organic wastes has grown considerably because of its major role in an effort to reduce greenhouse gas emission and protect the environment. The continuing use of fossil fuels is universally regarded as the principal contributor to global anthropogenic emission of GHG. It also anticipated that the fossil fuel reserves, which provide the bulk of world energy need, will be depleted in foreseeable future. In addition, the challenge of unstable fuel prices and security of the energy supply makes the call for alternative source of energy imperative. Anaerobic digestion, a proven technology for conversion of various organic wastes to biogas, is widely regarded as a source of renewable energy and technology for achieving pollution reduction.

For any nation to be self-sufficient in food production, there is the need to encourage the stakeholders to go from subsistence level where they are to intensive farming. This however has the challenge of high waste generation, particularly organic waste. The farmer/processor, etc. are therefore faced with the challenge of proper disposal of waste. However, proper management of these wastes through anaerobic digestion process could serve as an income generation venture for the stakeholders as well as cheap source of methane gas for cooking and biofertilizer from the slurry. This will save the women long hours previously spent in search of fire wood, hence, more time for their husbands and to breastfeed their children. With appropriate biogas digester for household use, agricultural and other wastes could be channeled towards generating biogas and other by-products that could be used for other purposes.

Properly designed biogas digester will accept highly digestible organic materials such as kitchen waste and other starchy/sugary feedstock (waste/spoilt grain, over-ripe/rotten fruits and vegetables, nonedible seeds, fruits and rhizomes, etc.). Biogas digester takes organic material (feedstock), with animal waste as an inoculant, into an air-tight tank carefully designed container where bacteria break down the material and release biogas—a mixture of mainly methane (CH_4) (50–70%) and carbon dioxide (CO_2) (30–40%) with low amount of hydrogen sulphide (H_2S). The biogas can be burned as a fuel, for cooking or other purposes (the calorific value of biogas has been estimated to be about 6 kWh/m^3 (20 mega joule), which corresponds to about half a liter of diesel oil), and the solid residue (effluent) can be used as organic compost. The impurities (CO_2 and H_2S) should be eliminated so as to get good quality methane gas for cooking.

Biogas yields from substrates largely depend on the substrates' composition and biodigester conditions. For biodigestion of horticultural wastes on individual farm, the available designs of biodigesters that have been widely disseminated in developing countries could be employed. The available designs of biodigester unit include fixed-domed digester, floating-drum digester and low-cost bag/balloon biodigester. A fixed dome biodigester consists of a closed, dome-shaped digesting unit with a non-movable, rigid gasholder and a "compensation tank" which serves as a reservoir for displaced slurry (**Figure 5**). The gas is stored in the upper part of the digester, and the gas pressure is determined by the difference between the levels of the slurry in the digester and compensating tank. Given the high rates of biogas production from some horticultural wastes, fixed dome digesters could be an ideal option for internal storage of large volume of biogas (estimated to store up to 20 m^3). It also requires less space for construction and less maintenance, offers self-agitation of slurry and is durable. Some of its demerits include special skills required for its construction and challenge of maintaining a stable gas pressures.

Floating-drum digester consists of an underground digester and a moving gasholder. The gasholder floats either directly on the fermentation slurry or in a water jacket of its own. The gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored. Though it is durable, easy to maintain and offers steady gas pressure, floating-drum digester may not be an ideal option for large farms where the rate of waste generation may inappropriately be higher than the handling capacity of floating dome digester (the digester volume is generally accepted not to exceed 20 m^3 as compared with the volume of fixed dome digester which could be between 6 and 124 m^3) [41] (**Figure 6**).

A balloon biodigester consists of a digester bag with the upper part of the bag serving as gas holder. The inlet and outlet are attached to the skin of the balloon. The desired gas pressure is achieved by the elasticity of the bag or by placing a

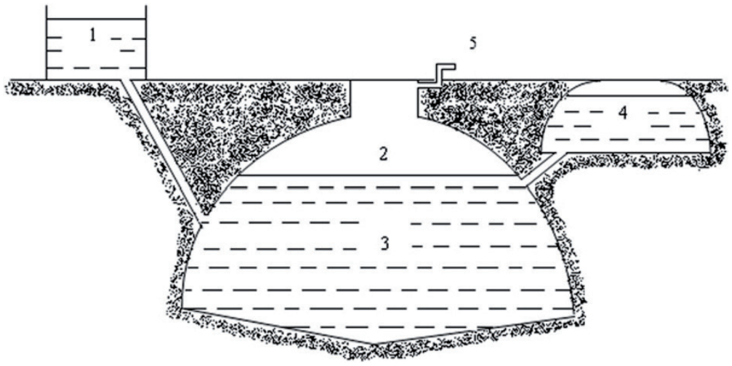

Figure 5.
Fixed dome digester. (1) Mixing tank with inlet pipe. (2) Gasholder. (3) Digester. (4) Compensation tank. (5) Gas pipe. Source: Arthur et al. [40].

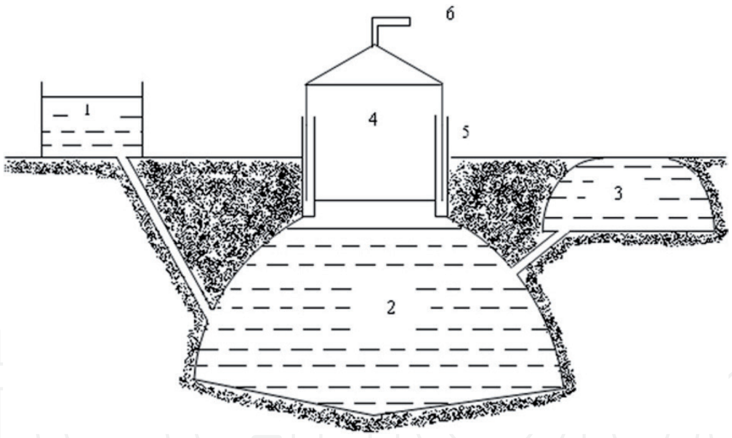

Figure 6.
Floating-drum digester. (1) Mixing tank with inlet pipe. (2) Digester. (3) Compensation tank. (4) Gasholder. (5) Water jacket. (6) Gas pipe. Source: Arthur et al. [40].

weight on the balloon. The useful life span of balloon digester is usually between 2 and 5 years. This type of digester seems to be ideal for farm-based management of horticultural wastes due to its low installation and operational costs, low construction sophistication and versatility in treating different waste materials.

Biogas digesters described above are simple and easy to construct from locally available materials, and their operations do not require special skills. Therefore, these reasons provide technical justification for adoption of anaerobic digestion for farm-based management of horticultural wastes. The construction of biogas digesters can also help to create new jobs and help stimulate the rural economy. Biogas technology in developing countries has been based on animal dung as the only viable biogas digester feedstock. Given the higher biogas potentials of various horticultural wastes, animal dung could be co-digested with horticultural wastes, thereby promoting the paradigm shift from mono-feedstock digestion to multi-feedstock digestion. This will also improve the economics of biodigester operation.

The biodigester could be operated as a batch-fed or continually fed system. For batch-fed digesters, the digesters are usually filled with substrate and left to digest over a period of time (which can be considered to be their retention) until gas production ceased. Thereafter, the digesters are emptied and fresh substrate added. Though simple in operation, the major drawback is that the process of emptying and filling is laborious. Alternatively, the digesters could be operated as continually fed system. Effluent from an existing biogas plant mixed with carefully prepared substrate can be used. The feeding of the biogas digester should be built up over a few weeks until it provides a steady supply of gas, and thereafter fresh substrate is added and digested slurry added at interval. For greater efficiency, feedstock with large lumps (more than 20 mm) should be broken up or cut to pieces to produce large surface area for bacteria to act on.

A common challenge with biogas digester that uses highly digestible organic materials is that it can become acidic and fail if it is overfed. This however can be recovered by causing feeding to cease and then start building up the feed rate slowly. An important design parameter for biogas digester is the overall loading rate. These are commonly expressed as the number of days of retention time or the quantity of organic matter applied to a given tank volume. This largely depends on the type of feedstock and digester system. Common detention times for farm-based manure digesters are roughly 20–30 days. More complex wastes that include fats and proteins will usually have retention times higher than 30 days.

The digestion process is commonly designed at one of the three different temperature zones, i.e. phsychrophilic (15–20°C), mesophilic (30–40°C) and thermophilic (50–60°C). Each of these temperature zones relies on a different species of bacteria that thrives at their given temperatures. The choice of appropriate temperature zone to operate is a function of the available feedstock, project site logistics, costs for heating and intended use of the digestate. Although, higher temperature systems will achieve additional pathogen destruction, more energy will be required to provide the required temperature. Lower-temperature, mesophilic systems, on the other hand, can provide the benefit of a faster-growing, more robust bacteria population than thermophilic which have slower-growing bacteria. Nigeria annual temperature is forecast to be in the range of 16–25°C in Jos Plateau area and can be as high as 44°C in the far north [42]; this indicates that most biogas digesters in Nigeria will operate well within mesophilic temperature conditions.

Methane, the major constituent of biogas, is an environmentally friendly cooking system that burns with a blue flame, without producing any smoke or soot. Hence, the introduction of simple, efficient and low-cost biogas system would not only help households in finding alternative use for agricultural and other wastes but also help in preventing the hazards caused due to indoor air pollution as a result of smoke and soot from burning fuelwood in traditional cooking methods (firewood, kerosene stove, etc.), especially by women and children in rural households. The replacement of fossil fuels with environmentally friendly alternative presented by promoting biogas use will reduce the emission of greenhouse gases. The adoption of biogas production from horticultural waste will also help to promote sanitation by turning wastes that are potential public nuisances and threats to public health into useful organic fertilizer and feed material.

6. Local soap production

Plantain/banana is a major staple food in sub-Saharan Africa [43]. It is majorly planted in the southern part of Nigeria due to the favorable growing condition of the area. It has numerous economic values. It can be eaten raw, cooked/fried/baked or processed into other secondary products such as plantain/banana flour. It is reported to have several health benefits. Hence, there is the need to encourage its production in large quantity.

In order to maximize the potential of plantain/banana in meeting the need of farmers and also take them beyond subsistence to commercial level of production, cultivation of large hectarage is required. In the alternative, farmers could be encouraged to form clusters (growers and processors). One of the "disadvantages" of mass production of plantain/banana is the enormous waste generation (the peels, stalk and the pseudo stem). Plantain/banana peels could be fed to livestock. However, in places where it is produced in large quantities, the "supply" is usually greater than the "demand". Hence, they are usually piled up at dumpsites where they serve as menace to the society. Apart from odor generation, it could also serve as breeding ground for vectors. These "wastes" are also very rich in potash; hence they could be used in local soap production.

Soap is a new substance produced by the interaction of oils and alkali solution through a process known as saponification. Care must be taken to ensure that no free alkali or excessive, free oil remains in the finished product. Virtually, all wastes that are rich in potash can be used for local bath soap production. In cocoa-producing area (e.g. south-western part of Nigeria) where cocoa pods are generated in large quantities, they constitute nuisance to the environment. These can also be used for local soap production.

Waste from different cultivars of plantain/banana, viz. peels and stalks, as well as cocoa pods could be collected, shredded and dried. Potassium hydroxide can be

Figure 7.
Stages in local soap production from agricultural waste. (a)–(d) represent ashing of dried cocoa pods/plantain waste in a carefully constructed metal drum, the soap production process, finished product in solid form and finished product in liquid form, respectively.

extracted from the dried waste via ashing, i.e. burning in a partially closed environment (e.g. in a drum) so as to minimize oxygen (**Figure 7**). Clean water is used to extract potassium hydroxide from the ash. It is then concentrated and used for local soap production.

Most people prefer to make single oil soaps. Due to its relatively cheaper cost, palm kernel oil is commonly used. However, it is possible to mix two or more oils, e.g. blending 80% palm oil and 20% palm kernel oil or using 75% palm oil, 20% palm kernel oil and 5% vegetable oil so as to improve the soap quality. It is believed that the higher the ratio of palm oil and vegetable oil to that of palm kernel oil, the better the quality of the soap. The oil is poured into a steel drum and placed on a gentle fire, starting towards a slow boil. Potassium hydroxide solution is to be added gradually while keeping the heat steady for about 2–6 hours (depending on the quantity and the intensity of the applied heat). The mixture is to be stirred continually in a predetermined direction (depending on the convenience of the one doing the stirring), until it begins to solidify. At this point, the intensity of the heat should be reduced and the content removed from the fire to finish off slowly. Essential oils and/or colorant could be added as desired once the soap is finished cooking. The soap could be "picked" to release the air trapped in it from stirring. It can then be taken out and spread on a flat wooden board to dry in a cool, well-ventilated place for up to 8 hours.

The process of local soap making is very simple, straightforward and easy to understand by stakeholders (unemployed youths, women, etc.). It does not require technical details, and the method could be mastered by people who do not have formal education. More so, it could serve as a means of enhancing their livelihood and improving household income. It is generally believed to be eco-friendly, being a natural product and also friendly to the skin. Hence, the demand for the product is very high.

7. Conclusion

In this chapter, we present the possibilities of using simple waste management techniques in farms and rural set-ups, especially in developing countries.

Agricultural wastes, rather than constituting menace to the society via serving as breeding ground for vectors as well as contamination of water sources, can be turned into wealth, thereby empowering stakeholders through specialized trainings. The use of agricultural wastes for the production of mushrooms, composting, biochar, biogas and soap production was discussed in this chapter. Procedures for turning these wastes into wealth were presented. They were simplified such that anyone, irrespective of their background, can easily learn and adopt these methodologies. These will not only serve as a means of purifying our environment but will also serve as a means of household empowerment. It is concluded that if any of these methods is used, agricultural wastes could also be an avenue for sustainable income generation as well as the preservation of the environment. The methods proffered are not only simple but are also easy to adopt and transfer.

Conflict of interest

The authors declare that they have no conflict of interest.

Author details

Olayiwola A. Akintola[1]*, Olufunmilayo O. Idowu[1], Suraju A. Lateef[2], Gbenga A. Adebayo[1], Adekemi O. Shokalu[1] and Omolara I. Akinyoola[1]

1 National Horticultural Research Institute, Ibadan, Oyo State, Nigeria

2 Department of Environmental Health Sciences, Faculty of Public Health, College of Medicine, University of Ibadan, Oyo State, Nigeria

*Address all correspondence to: akinbolanle97@yahoo.co.uk

References

[1] OPEC 2019. Available from: https://www.opec.org/opec_web/en/about_us/167.htm Accessed [18th January, 2019]

[2] Mgbenka RN, Mbah EN. A review of smallholder farming in Nigeria: Need for transformation. International Journal of Agricultural Extension and Rural Development Studies. Published by European Centre for Research Training and Development UK (www.eajournals.org). 2016;**3**(2):43-54. Print ISSN: ISSN 2058-9093 Online ISSN: ISSN 2058-910

[3] Akintola OA, Sangodoyin AY, Agunbiade FO. Evaluation of environmental pollution effects on domestic roof-harvested rainwater in Southern part of Nigeria using impact indices. Water Practice & Technology. 2013;**8**(2):244-255. DOI: 10.2166/wpt.2013.026

[4] Akintola OA, Sangodoyin AY, Agunbiade FO. Fuzzy logic modelling of the effects of pollution on domestic roof-harvested rainwater quality in residential and industrial environments. Archives of Environmental Contamination and Toxicology (AECT). 2016;**71**(1):113-121. DOI: 10.1007/s00244-016-0278-4

[5] Akin AO, Yisau SA, Oyedotun AF. Anthropogenic activities impact on atmospheric environmental quality in a gas-flaring community: Application of fuzzy logic modelling concept. Environmental Science and Pollution Research. 2018;**25**(22):21915-21926. DOI: 10.1007/s11356-018-2295-5

[6] Ewubare DB, Okpani AO. Poverty and Income Inequality in Nigeria (1980-2017). International Journal of Advanced Studies in Ecology, Development and Sustainability. ISSN Print: 2354-4252 | ISSN Online: 2354-4260. 2018;**5**(1):138-151

[7] CIA 2018. Central Intelligence Agency (US). Available from: https://www.cia.gov/library/publications/the-world-factbook/fields/2046.html Accessed [18th January, 2019]

[8] Oei P. "Manual of Mushroom Cultivation Techniques, Species and Opportunities for Commercial Cultivation in Developing Countries", CTA, 21-26. 1991

[9] Zakia B, Srinivasan KS, Stravastava HC. Amino acid composition of the protein from mushroom (*Pleurotus sp.*). Applied Microbiology. 1963;**11**(3):184-187

[10] Anakalo KG, Shitandi AA, Mahungu MS, Khare KB, Harish KS. Water hyacinth, wheat straw and corn cob substrates. Journal of Agriculture and Biological Sciences. 2008;**4**(4):321-326

[11] Bonatti M, Karomopp P, Soares HM, Furlan SA. Evaluation of Pleurotus ostreatus and P sajor-caju nutritional characteristics when cultivated on different lignocellulosic wastes. Food Chemistry. 2004;**88**:425-428

[12] Akindahunsi AA, Oyetayo FL. Nutrient and antinutrient distribution of edible mushroom *Pleurotus tuber-regium* (Fries) Singer. Swiss Society of Food Science and Technology. 2005;**10**:1016

[13] Fasidi IO. Studies on Volvariella esculenta (Mass) Singer: Cultivation on agricultural wastes and proximate composition of stored mushrooms. Food Chemistry. 1996;**55**:161-163

[14] Idowu OO, Otunla CA, Oke AO, Adelaja BA. Efficiency of different concentrations of water hyacinth (*Eichornia crassipes*) (Mart.) Solms and sawdust as substrate for the cultivation of *Pleurotus ostreatus* (Jacq. Ex.Fr.) Kummer (oyster mushroom.). The Journal of Biological Chemistry. 2015;**32**(2):565-572

[15] Otunla CA, Jonathan SG, Idowu OO, Olawuyi JO. Mycelia growth and sclerotia production of Pleurotus tuber-regium (Fries) Singer on four sawdust types at three composting intervals. Agronomsky Glasnik. 2018;**2**:79-90

[16] Quimio TH, Chang ST, Royse DJ. "Technical guidelines for mushroom growing in the tropics". In: FAO Plant Production and Protection Paper 106. 1990. pp. 160-170

[17] Stamets P. Materials for formulating fruiting substrates. In: Growing Gourmet and Medicinal Mushrooms. 3rd ed. Berkeley, Toronto: Ten Speed Press; 2000. pp. 140-180

[18] Idowu OO, Otunla CA. Influence of heat treatment methods of bulk substrate treatment on the growth and sclerotia yield *Pleurotus tuber-regium*. In: Proceedings of the 35th Annual Conference of Horticultural Society of Nigeria. 2017

[19] Adeoye IB, Idowu OO, Alabi OO. Cost and benefit analysis pf mushroom production. Nigerian Journal of Horticultural Science. 2018;**2**:104-108

[20] Celik Y, Peker K. Benefit/cost analysis of mushroom production for diversification of income in developing countries. Bulgarian Journal of Agricultural Science. 2009;**15**(3):228-237

[21] Basanta KB, Imrana S, Parvez KA, Al M. Economics of mushroom (Agaricus bisporus) production in selected Upazila of Bangladesh. The Agriculturist. 2012;**10**(2):77-89

[22] Yinda GS, Adeoye GO. A comparative study of two composting methods. In: Proceedings 3rd African Soil Science Society Conference, University of Ibadan, August 20-26 1995. 1995

[23] Adebayo AG, Shokalu AO, Akintoye HA. Effect of compost mixes on vegetative development and fruit Yield of Okra. IOSR Journal of Agriculture and Veterinary Science. 2013;**3**(1):42-49

[24] Manral HS, Saxena SC. Plant growth, yield attributes and grain yield of soybean as affected by the application of inorganic and organic sources of nutrients. Bioresource Technology. 2003;**92**:110-118

[25] Ghosh PK, Ajay KK, Manna MC, Mandal KG, Mistra AK, Hati KM. Comparative effectiveness of cattle manure, poultry manure, phosphocompost and fertilizer NPK on three cropping systems in Ventisols of semi-arid tropics. II. Dry matter yield, nodulation, chlorophyll content and enzyme activity. Bioresource Technology. 2004;**95**:85-93

[26] Rynk R, editor. On-Farm Composting Handbook: Northeast regional Agricultural Engineering Service, Cooperative and Extension, NRAES-54. Vol. 47. Ithaca. U.S.A: The Production of *Ceriodaphnia cornuta*. Bioresearch Technology; 1992. pp. 1036-1040

[27] Kiyonori H. Production of compost from organic waste. In food and fertilizer. Technology Centre Extension Bulletin. 1990;**311**:1-17

[28] Akanbi WB, Adebayo TA, Togun OA, Adeyeye AS, Olaniran OA. The use of compost extract as foliar spray nutrient source and botanical insecticide in *Telfairia occidentalis*. World Journal of Agricultural Sciences. 2007;**3**(5):642-652

[29] University of Illinois Extension Service. 2013 Composting for the Home Owner. Available from: http://web.extension.illinois.edu/homecompost/materials.cfm

[30] Adediran JA, Taiwo LB, Akande MO, Lawal BO. In: Adeoye GA, Akinsolotu TA, editors. Working

Manual on Composting Technology and Utilization. A Guide for Extension Agents, Farmers' Compost Makers and Users. Ibadan, Nigeria, West Africa: Institute of Agricultural Research and Training. 2006. pp. 1-21

[31] Oyenuga VA. Nigerian Foods and Feeding-Stuffs. Their Chemistry and Nutritive Value. Ibadan, Nigeria, West Africa: Ibadan University Press; 1968

[32] Ashutosh S, Raja MR, Rina C. Effects of Four Different Doses or Organic Manures in Environment and Development and Earthscan, USA and UK. 2006

[33] Lehmann J, Joseph S. For Environmental Management. USA and UK: International Institute of Environment and Development and Earthscan; 2009

[34] Lehmann J, Gaunt J, Rondon M. Bio-char sequestration in terrestrial ecosystems-A review. Mitigation and Adaptation Strategies for Global Change. 2006;**11**:403-427

[35] Lehmann J. A handful of carbon. Nature. 2007;**447**:143-144

[36] Lehmann J. Bio-energy in the black. Frontiers in Ecology and the Environment. 2007;**5**:381-387

[37] Winsley P. Bioenergy production for climate change mitigation 2007. New Zealand Science Review. 2007;**64**:5-10

[38] Woolf D, Amonette JE, Street-Perrott FA, Lehmann J, Joseph S. Sustainable biochar to mitigate global climate change. Nature Communications. 2010;**1**:56-64

[39] Olufunmi OO, Akintola OA, Okafor M, Dixon UG, Ajoba FB, Adawa AA, et al. Elemental characterization of biochar of some horticultural crop wastes. In: Proceedings of the 36th Annual Conference of Horticultural Society of Nigeria (Hortson), Lafia 2018 Faculty of Agriculture Shabu-Lafia Campus. Keffi, Nasarawa State, Nigeria: Nasarawa State University; 2018

[40] Arthur R, Baidoo MR, Antwi E. Biogas as a potential renewable energy source: A Ghanaian case study. Renewable Energy. 2011;**36**:1510-1516

[41] Akinbami JFK, Ilori MO, Oyebisi TO, Akinwumi IO, Adeoti O. Biogas energy use in Nigeria: Current status, future prospects and policy implications. Renewable & Sustainable Energy Reviews. 2001;**5**:97-112

[42] Wikipedia. 2019. https://en.m.wikipedia.org/wiki/Geography_of_Nigeria Accessed [25th February, 2019]

[43] Akinyemi SOS, Aiyelaagbe IOO, Akyeampong E. Plantain (Musa spp.) cultivation in Nigeia: A review of its production, marketing and research in the last two decades. Acta Horticulturae. 2010;**879**:211-218. DOI: 10.17660/ActaHortic.2010.879.19