Chapter

Agricultural Solid Wastes: Causes, Effects, and Effective Management

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Abstract

The role of the agricultural sector in human development and economic development cannot be overemphasized. Awareness for increased agricultural production is on the increase, arising from the need to feed the ever-increasing human population. Interestingly, almost all agricultural activities generate wastes, which are generated in large quantities in many countries. However, these wastes may constitute a serious threat to human health through environmental pollution and handling them may result in huge economic loss. Unfortunately, in many developing countries where large quantities of these wastes are generated, they are not properly managed because little is known about their potential risks and benefits if properly managed. There are studies that address some of the challenges of agricultural solid wastes as well as suggestions on how they can be properly managed. In this chapter, we intend to explore the major sources of agricultural solid wastes, their potential risks, and how they can be properly managed.

Keywords: agricultural solid waste, animal feed, composting, environmental safety, recycling

1. Introduction

Increasing growth in human population has necessitated increased agricultural production. Agricultural production in the last five decades has been said to increase more than three times. Other factors responsible for increased agricultural production include technological advancement toward green revolution and expansion of soil for agricultural production [1, 2]. It has been estimated that agricultural sector provides about 24 million tons of food globally [1] with accompanying health risks and threat on ecosystems [3]. We cannot do without agriculture because food is a necessity across the globe, but the impact of agriculture on the environment is also evident. For example, it has been documented that about 21% of greenhouse gas emission comes from agriculture. The negative influence of agriculture on the environment, aquatic lives and human health have necessitated improvement in agricultural production, involving effective and efficient ways of handling agricultural solid wastes [4].

The global leaders have been mandated to prioritize production of more food and energy for increasing human population which is estimated to exceed 10 billion by 2050 as well as to tackle the impacts already caused. However, this mandate is expected to be achieved with lower emissions of pollutants, zero solid waste and less fossil fuel [5, 6]. The future prediction for increased agricultural production involves food production for human population, industrial needs, and animal feed [7]. However, every step of agricultural production, processing and consumption generates quantities of agricultural solid wastes, depending on the type of agricultural produce or product, processing techniques and purpose of use.

The agricultural sector is one of the main sectors generating the largest quantities of agricultural solid wastes, which may be allowed to accumulate indiscriminately and constitute nuisance to global health and threat to food security or used as raw materials for bio-economy [8, 9]. The benefits of recycling of agricultural solid wastes include reduction of greenhouse gas emissions and use as fossil fuel as well as contributing significantly to the development of new green markets, creation of jobs, production of bio-energy and bio-conversion of agricultural solid wastes to animal feed [10, 11].

The emphasis on the management of agricultural solid wastes cannot be over-emphasis. Agricultural solid wastes are generated from many sources. One of such sources are pesticides, including herbicides and insecticides. It has been estimated that the global food production would fall by an estimate of about 42% if the use of pesticide is completely stopped [12]. The influence of agricultural solid wastes on human health, animal health, and the environment is significant and all hands must be on deck to tackle the menace posed by mismanagement of agricultural solid wastes. Agricultural solid wastes are mismanaged largely owing to ignorance. Many of the farmers and household managers who generate these wastes do not know how to effectively manage them. Many of them do not know the health implications of what they toy with, while some who know are 'handicapped'. Year after year, large tons of agricultural solid wastes are being produced, with an annual increase of about 7.5% [13, 14]. In many parts in developing countries, agricultural solid wastes are indiscriminately dumped or burnt in public places, thereby resulting in the generation of air pollution, soil contamination, a harmful gas, smoke and dust and the residue may be channeled into a water source thereby polluting the water and aquatic environment [15–17].

2. Classification and causes/sources of agricultural solid wastes

Agricultural solid wastes are produced mainly from farming activities. However, it is not limited to the production but other activities associated with farming and food chain. Every stage and phase of the agricultural-food chain can generate significant agricultural solid wastes. The broad classification of agricultural solid wastes includes the following:

a. Animal production solid wastes;

b. Food and meat processing solid wastes;

c. Crop production solid wastes;

d. On-farm medical solid wastes;

e. Horticultural production solid wastes;

f. Industrial agricultural solid wastes;

g. Chemical wastes.

1. **Animal production solid wastes**—animal production solid wastes are solid wastes generated from the production of livestock for whatever purposes. Examples of such wastes include bedding/litter, animal carcasses, damaged feeders, and water-trough, etc.

2. **Food and meat processing solid wastes**—this class of agricultural solid wastes are produced from the processing of crop or animal products for human consumption, such as abattoir or slaughterhouses. Examples of food and meat processing agricultural solid wastes include hoofs, bones, feathers, banana peels, etc.

3. **Crop production solid wastes**—crop solid wastes are associated with agricultural solid wastes typically produced from agricultural activities involving crop production. Examples of such agricultural solid wastes are crop residues, husks, etc.

4. **On-farm medical solid wastes**—on-farm medical solid wastes refer to solid wastes that are generated from the use of drugs, insecticides or vaccines used on or animals. Examples of such wastes include vaccine wrappers or containers, disposable needles, syringes, etc.

5. **Horticultural production solid wastes**—this group of agricultural solid wastes refer to solid wastes generated from cultivation and maintenance of horticultural plants and landscape for beautification. Examples of such wastes are prunings and grass cuttings.

6. **Industrial agricultural solid wastes**—agricultural produce and livestock are not only cultivated and produced for dietary consumption. They are used for other uses and it is not unlikely that such activities result in agricultural solid wastes. Wood processing and cuttings readily come to mind as a source of agricultural solid wastes. Paper production using agricultural products as raw materials also generate some quantities of agricultural solid wastes.

7. **Chemical wastes**—chemical wastes in this context have to do with agricultural solid wastes generated from the use of pesticides, insecticides and herbicides on the farm or store, such as pesticide containers or bottles. Agricultural activities still depend on the use of pesticides, insecticides, and herbicides, being handled by many uneducated and untrained farmers in developing countries, resulting in abuse by these uneducated farmers [18, 19]. Some uneducated farmers mishandle pesticide containers, thereby resulting in unpredictable environmental hazards. It has been reported that about 2% of pesticides remain in the containers after use, which some ignorant and uneducated users may throw in the ponds or on the open field resulting in food poisoning, environmental and water pollution, causing death of many lives [20, 21].

Agricultural solid wastes are usually generated through agricultural activities involving preparation, production, storage, processing and consumption of agricultural produce, livestock and their products. Agricultural solid wastes are produced via:

i. Farming activities

ii. Poor road network

iii. Poor electricity or lack of rural electrification

iv. Inadequate drying technique and storage facilities

v. Food spoilage

vi. Kitchen-generated agricultural solid wastes

1. Farming activities—the main source of agricultural solid waste generation is agriculture. Beginning from land clearing till harvest, every phase of farming activities results in the generation of agricultural waste. From preparing the pen for the arrival of the animals to the farm, preparation of pasture/paddock till the animals are slaughtered and sold, solid wastes are generated.

2. Poor road network for transporting harvested produce from the farm to the market or storage is another avenue of generating large quantities of agricultural solid wastes. This happens largely as a result of the bad road network in some developing countries, which may result in a road accident or delay of agricultural produce from farms to markets. When road accident occurs, perishable agricultural produce result easily in wastage, and when delayed, the same result may occur. The spoilt produce is either thrown away on the road or separated to be discarded once the farmer gets to the market. **Figure 1** shows agricultural produce being transported in a city in Nigeria.

3. Poor electricity or lack of rural electrification—the epileptic power supply and lack of rural electrification in some parts of developing countries with significant agricultural activities are contributing in no small measure to the generation of agricultural solid wastes. Stable electricity could have facilitated the cold storage of the harvested produce and thereby reduce spoilage and consequently agricultural solid wastes.

4. Inadequate drying technique and storage facilities—spoilage of much agricultural produce could be prevented with adequate drying techniques. If farmers have access to adequate drying technique or moisture monitor, it would have gone a long way in militating against food spoilage and agricultural solid waste, thereby enhancing food security and reducing the impact of agricultural solid waste on human health and the environment. Many of the farmers depend largely on the unpredictable solar system to dry their produce before they are stored, as well as rely on the conventional method of moisture monitoring which is neither effective nor accurate. Inadequate monitoring of moisture content in grain before storage has been reported to result in aflatoxin infestation. Aflatoxin is produced by *Aspergillus flavus*. Aflatoxin infestation is both a cause and a product of food spoilage [23] and its contamination of food and livestock feed can lead to significant annual crop losses globally [24].

It has been estimated that about 10% of global crop harvest is destroyed by filamentous fungi through contamination of food and feed with mycotoxins. Aflatoxins have been reported to produce liver carcinogens, impair human health in

Figure 1.
Transportation of agricultural produce in Nigeria. Source: Vanguard Newspaper [22].

developing countries, and result in the huge economic losses, in the U.S. corn alone amounting to about $280 million annually. The economic losses could be as high as 1 billion dollars if other crop-infestation such as cotton, peanuts and tree nuts are included. Aflatoxins B1 and B2 which cause preharvest and postharvest crop infestation are produced by *Aspergillus flavus* [23].

1. Food spoilage is another important source or cause of agricultural solid wastes. It has been estimated that about 40% of food is wasted in the US alone annually. This waste has been estimated to cost about 162 billion dollars Natural Resources Defense Council [25]. Pest and insect infestation may also increase wastage owing to spoilage.

2. Kitchen-generated agricultural solid wastes: in most cases, the end result of agricultural activities is family consumption. Usually, the consumption of agricultural produce at the family level is not without the production of agricultural solid wastes. Some of these wastes are generated out of necessity. For example, orange peels and banana peels are discarded as agricultural solid wastes in many homes. However, agricultural solid wastes may also be generated unintentionally, arising from food spoilage. Kitchen-generated agricultural solid wastes become significant when restaurants are included as kitchens (commercial kitchens). Of all the kitchen wastes considered in cities in China, agricultural solid wastes (food wastes) constitute between 88 and 94% [26]. **Figure 2**, **Tables 1** and **2** respectively show home-generated agricultural solid wastes, the composition of kitchen wastes and nutritional characteristics of kitchen wastes in selected cities in China.

Figure 2.
Home-generated agricultural solid wastes.

Cities	Food waste	Paper	Metal	Bone	Wood	Fiber	Plastic
Guiyang	92.09	0.80	0.10	5.20	1.01	0.10	0.70
Shenyang	92.16	0.42	0.08	5.22	1.31	0.12	0.69
Chongqing	94.13	0.31	0.00	5.24	0.02	0.13	0.19
Wuhan	88.40	2.80	0.20	5.20	1.00	0.30	2.10

Source: Li et al. [26].

Table 1.
Composition of kitchen wastes in Chinese cities (unit: %).

Cities	Moisture[a]	Volatile solid[b]	Crude protein[b]	Ether extract[b]	Oil[a]	Salinity[a]
Beijing	74.34	80.21	25.86	24.77	3.12	0.36
Tianjin	70.99	85.64	24.30	25.96	2.63	0.70
Chongqing	85.07	92.66	14.45	17.02	1.96	0.24
Suzhou	84.43	82.98	21.80	29.30	3.28	0.70
Hangzhou	74.94	91.50	16.46	24.31	2.09	1.32

Source: Li et al. [26].
[a]*Wet basis.*
[b]*Dry basis.*

Table 2.
Nutritional characteristics of kitchen wastes in Chinese cities (unit: %).

3. Influence of agricultural solid waste on human health and environment

The influence of agricultural production on human, health, change in climate, animal healthy and the environment cannot be over-emphasized. For example, it has been suggested the greenhouse gas emissions need to be reduced drastically to avert the impeding threat on the planet, earth and its inhabitants to avert temperature rise by at least an average rise of 35.6°F [27]. Animal production has been indicted to produce about 37 and 65% of global methane and nitrous oxide emissions respectively [28], which are more potent than carbon dioxide. Indiscriminate burning of agricultural solid wastes produces climate-relevant emissions. Improper handling of agricultural solid wastes influence change in climate and change in climate in turn hampers food production. The effects of indiscriminate disposal of agricultural solid wastes cannot be overemphasized. Some of the effects are outlined below:

i. Flood

ii. Health and environmental implication

iii. Food security

1. Flood: One major cause of flood has been the blockage of waterways. Waterways are blocked primarily when human beings build on waterways or when the canals or waterways are blocked by solid wastes. In an agricultural environment, the indiscriminate dumping of agricultural solid wastes can result in blockage of waterways which when that happens will result in floods which may result in losses of lives and properties.

2. Health and environmental implication—arising from indiscriminate burning of generated wastes. Indiscriminate dumping and burning of agricultural solid waste have resulted in pollution, a threat to human lives as well as other environmental problems, calling for global attention, although these wastes can be recycled to improve soil fertility, being rich in nutrient required for sustainable agricultural production [13, 29, 30]. **Figure 3** shows the agricultural solid wastes being dumped in open space.

3. Food security and agricultural solid wastes: Continuous human population growth has been linked with increased agricultural activities which consequently results in increased generation of agricultural solid wastes. There are currently about 7.5 billion people around the globe and a significant portion of this population still do not have enough food to eat. **Figure 4** is a chart comparing the human population according to continents while **Table 3** shows the current human population parameters according to continents. The effects of food insecurity are enormous, ranging from poor health, slow progress in education and employment development [34]. One of the important 17 Global Sustainable Goals is to end hunger, achieve food security and improve nutrition and promote sustainable agriculture by 2030. Unfortunately, 10 years ahead of the deadline for this goal, there are still about 821 hungry people across the globe [34]. It has been argued that the main problem of food insecurity is not that we are not producing enough food, but agricultural solid wastes, mainly food wastage is responsible. Africa and Asia have been noted as the fast-growing population in the world, incidentally, these are the regions with most food insecure people

and inefficient waste management [33, 35]. It has been estimated that one-third of the food we produce annually is lost or wasted, costing about one trillion US dollars annually. Wastage occurs mostly in developing countries during the production and supply chain while it occurs mainly in developed countries on the plate [34]. Agricultural solid wastes can be recycled as nonconventional feed ingredients to enhance food security by enhancing animal protein production [36]. **Figures 5** and **6** respectively show food wastage chart in America and estimate of unconsumed food by an average American family.

Figure 3.
Dumping of agricultural solid wastes at the public. Sources: Akande and Olorunnisola [31] and Olayiwola et al. [32].

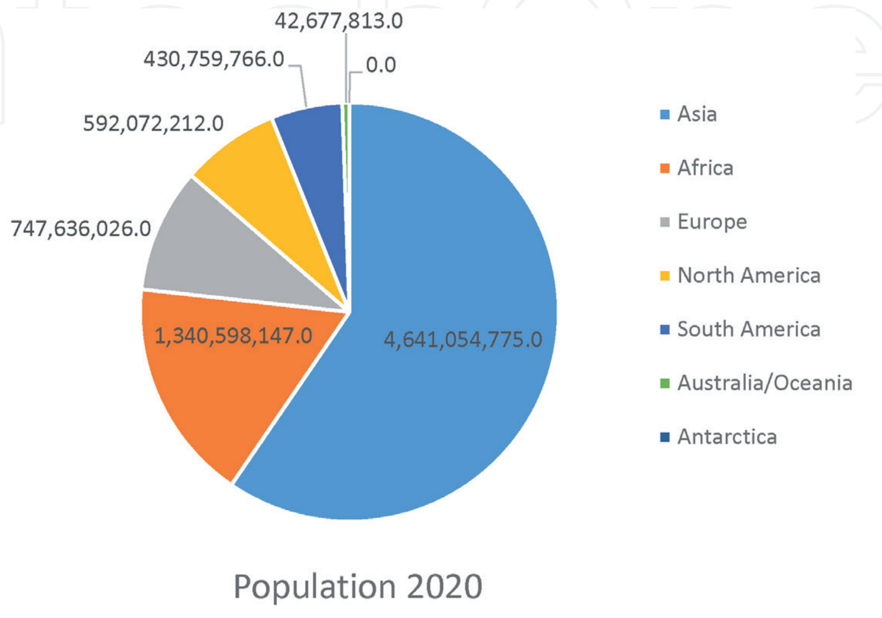

Figure 4.
Current population of the seven continents. Source: Worldometers [33].

Rank	Continent	Population	Area, km^2	Density, P/km^2	World population share, %
1	Asia	4,641,054,775	31,033,131	150	59.5
2	Africa	1,340,598,147	29,648,900	45	17.2
3	Europe	747,636,026	22,134,900	34	9.6
4	North America	592,072,212	21,330,000	28	7.6
5	South America	430,759,766	17,461,112	25	5.5
6	Australia/Oceania	42,677,813	8,486,460	5	0.6
7	Antarctica	0	13,720,000	0	0.0

Source: Worldometers [33].

Table 3.
List of continents ranked by current human population parameters.

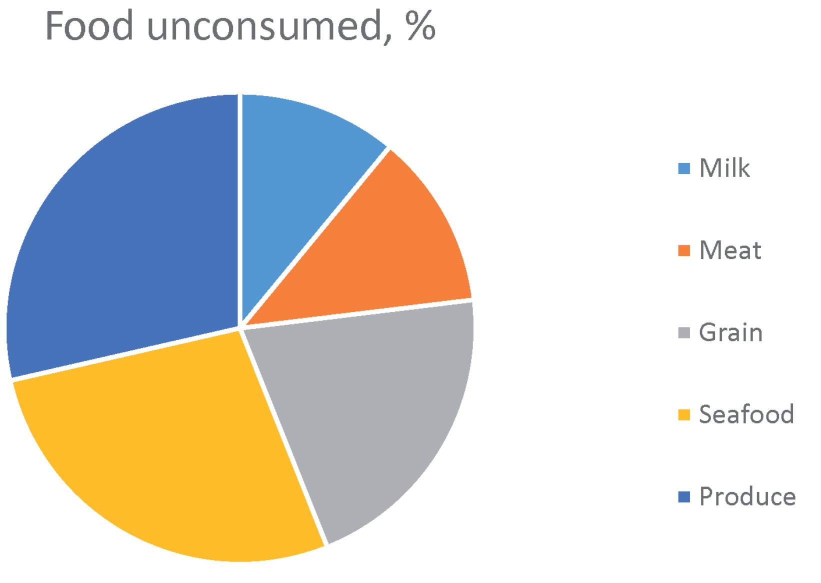

Figure 5.
Unconsumed food by an average American family. Source: Rescuing Leftover Cuisine [25].

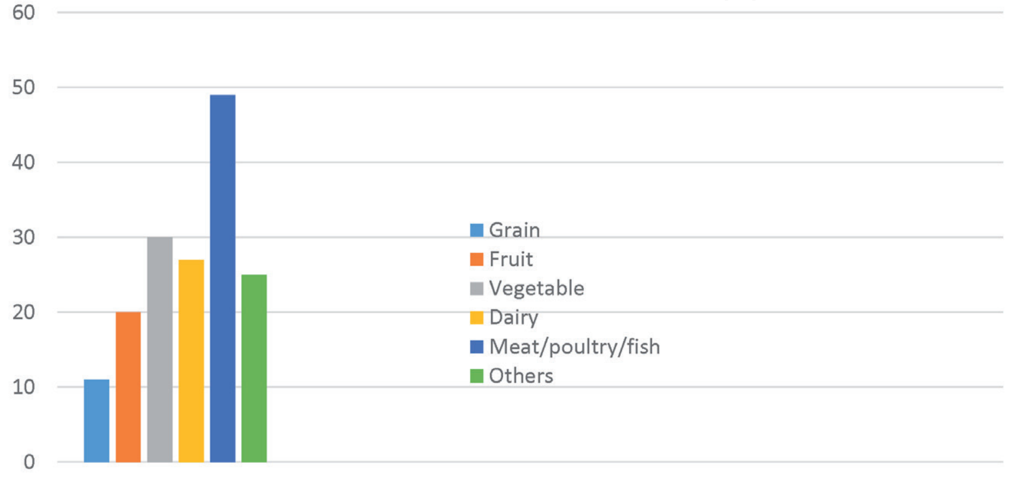

Figure 6.
Food wastage chart in America. Source: Rescuing Leftover Cuisine [25].

4. Effective management of agricultural solid wastes

There are options on how agricultural solid wastes could be handled. This chapter is necessary because of the need to focus people's attention on efficient ways of managing these wastes. Traditionally, shafts from palm oil processing could be used as fuel in fuel wood for cooking and heating. In the recent time, some of these wastes are put into better uses. Some of these agricultural solid wastes could be used as additives in cement mixes, water glass manufacturing, paper making, ethanol production, animal feed, electricity and biogas generation, heavy metal removal, mulching, organic fertilizers, and compost. An effective means of managing agricultural solid wastes is to recycle them to produce useful products. This can be achieved through:

i. Compositing/organic manure

ii. Substrates for edible fungi cultivation

iii. Nonconventional feed ingredient

iv. Traditional soap making

v. Alternative energy sources and bio-fuel production

vi. Production of silica

1. Compositing: Li et al. [26] recommended that kitchen wastes, largely agricultural solid waste from food wastage could be used as an animal feed via sterilization, fertilizer via composting and bioenergy via anaerobic digestion. These wastes are important candidates for compositing owing to their high organic matter content and nutrients, although their high salt, moisture content and oil may impair composting.

2. Substrates for mushroom cultivation: mushroom has been grown on different agricultural solid wastes as substrates [32, 37]. Steps involved in mushroom cultivation and its benefits are highlighted by Olayiwola et al. [32].

3. Nonconventional feed ingredient. Several attempts have been made to feed agricultural solid wastes to livestock as a means of recycling as well as a cheap source of feed for raising animal-source protein. A nonconventional feed ingredient, *mycomeat* has also been produced from agricultural solid wastes. The wastes served as substrate and a mixture of the substrates and the cultivated fungi (mushroom) was feed to broiler chicks, as a nonconventional feed ingredient, *mycomeat* [36–40] fed some agricultural solid wastes to albino rats and recommended processing of the wastes in order to obtain a better result. Adebiyi et al. [41] recommended the combination of 40% cassava peel +40% concentrate +20% watermelon wastes for feeding grower pigs. Poultry feathers could be used for several products instead of being indiscriminately discarded or burnt. Traditional, feathers are used for decoration, pillows and could be converted as nonconventional feed ingredients to feed livestock.

   Feathers are a group of agricultural solid wastes that are generated in large quantities annually as a by-product of poultry processing [42].

It may account for about 6% of the total live weight of a mature chicken. They are rich in a keratinous protein, which is a fibrous and insoluble protein [43]. Adejumo et al. [44] reported protein content of between 84 and 87% for feather meal, hence, effective use of feather meal as livestock feed ingredient may payoff than its use as other produce. Feathers can be used in erosion control, for diaper filling, as biodegradable composites, in the greenhouse industry, animal feeds, upholstery, artwork, paper alternatives, light-weight structural materials, water filtration fibers, fabric, aircraft, and automotive industries and thermal insulation [45, 46]. The major limitation to the use of feathers as a livestock feed ingredient is the insoluble keratinous protein, but recent studies are suggesting ways of overcoming the limitation [38, 44, 47]. It has been documented that about 80% of kitchen wastes, largely food wastage are fed to pigs in China, although direct feeding of kitchen waste has not been without restriction in China, arising from the concern of foot and mouth disease [48] Processing of agricultural solid wastes could enhance their value for feeding pigs [49, 50]. The effect of dried sweet orange (*Citrus sinensis*) peel has been tested on humoral immune response of broiler chickens [51] as well as maize replacement and its effect evaluated on growth performance and carcass qualities of broiler chickens [52], instead of allowing them to accumulate and constitute a nuisance as agricultural solid wastes.

4. Traditional soap making: traditional technology exists in Africa decades ago for turning some of the agricultural solid wastes into useful products. Cocoa pods which could turn agricultural solid wastes are usually either allowed to naturally decompose and enrich the soil or are used to make black soap, which may be used for washing dishes or bathing.

5. Alternative energy source and bio-fuel production: agricultural solid wastes can be converted to green energy through anaerobic digestion [9]. High protein and fat contents of these wastes may impair anaerobic digestion stability, as well as unavailability of efficient technology required for disposal of biogas residues [53]. However, pre-treatment techniques such as mechanical (sonication), chemical addition (acid or alkali), oxidative (ozone), biological (enzyme addition), thermal ad osmotic (freezing and sodium chloride treatment) may improve the physical and chemical properties of the wastes, thereby enhancing their solubilization of organic particles, sterilization effect as well as the promotion of their subsequent recycling (biogas production) [54, 55]. Despite many challenges confronting its production, bio-fuel and bio-energy attract many hopes as a sustainable renewable energy source, which tend to promote rural and regional development, reduction of CO_2 emission, creation of job opportunity as well as replacing the energy from nonrenewable fossil fuel with green energy [56–58]. Agricultural solid wastes (rich in cellulose, hemicellulose, starch, lipids and proteins) which are produced in large tons and burnt in open-field or allowed to accumulate in some developing countries may be channeled toward bio-fuel generation [59, 60]. Key players and political leaders, particularly in developing countries should team up with researchers to scale up the conversion of biomass to alternative energy sources or bio-fuel generation. This is expected not only to reduce the health menace

arising from open-field agricultural solid wastes burning or dumping but to improve energy production and reduce economic losses of waste disposal as well.

6. Production of silica: Production of silica: Silicon, the 2nd most abundant nonmetallic element in the earth crust with an atomic weight of 28 [61, 62] forms silica and silicates. It is rarely found in its elemental state owing to its affinity for oxygen [63]. It has been reported as a beneficial trace element, widely distributed in foods. Its health benefits include improvement of the structural integrity of nail, hair, skin, immunity, bone mineralization, bone calcification and reduces the occurrence of atherosclerosis [64–66]. In the presence of hydrochloric acid and other gastric fluids in the GIT, silicon compounds are degraded into bioavailable forms of silicic acid (ortho, meta, di, and tri-silicates) [67] and are diffused into different organs of the body [68, 69]. Silicon quantity decreases with age and tends to be more in plants than animal-sources, although dietary sources are low in silicon and may need to be supplemented in diets through other means [65, 70–72]. It does not bond with plasma proteins, hence, about 75% of plasma silicon is excreted within a few hours after ingestion [68, 73]. Agricultural solid wastes are potential sources of silica. Silica has been produced from agricultural solid wastes such as corn cob, rice husk, bagasse and rice straw using chemical, thermal, and microbial methods [74–79].

5. Conclusion

Food wastage is an important source of agricultural solid wastes. Hence, the prevention of food wastage at all levels before they are created will salvage some of these wastes and prevent unnecessary ill-health and environmental disadvantages as well as huge economic losses. This can be achieved through proper education and awareness of those involved with agricultural activities at all levels as well as being a little more generous by feeding hungry people with fresh food instead of keeping them till they are spoilt. There are hungry people everywhere in the world. Feeding animals saves food scraps and bioconversion of agricultural by-products, which may turn to agricultural solid wastes if their values are not enhanced and will go a long way in preventing such wastes as well. Composting and conversion of agricultural solid wastes to a renewable energy source is another effective way of managing agricultural solid wastes. It is high time attention is focused on turning these huge potential agricultural solid wastes to wealth, particularly in developing countries. To make our world safer for us to live, all hands must be on deck. Research activities should be geared toward commercial scaling of some productive findings made toward the efficient recycling of agricultural wastes.

Proper awareness should be made to everyone involved in agricultural activities whether at a middleman or woman, farmer, or consumer on the effects of indiscriminate disposal of agricultural solid wastes and benefits of efficient management of agricultural solid wastes. Political leaders, particularly in developing countries should be open-minded and formulate policies that ensure the efficient recycling of agricultural solid wastes and appropriate funds should be earmarked to achieving this. Attention should be focused on minimizing wastage by creating a more efficient sustainable agricultural supply chain through the development of sustainable durable markets and improving rural infrastructures such as electrification, roads, and storage [34].

It should also be noted that huge revenue could be generated from the conversion of agricultural solid wastes into useful products, as it has the potential of employing people if well-harnessed. Hence, its importance goes beyond the health implication but includes income generation for individual and governments which receive tax from companies and individual working in such establishments involved in the conversion of wastes to useful products. Also, it could contribute significantly to minimizing civil unrest plaguing some villages in developing countries. Some idle youths used to foment trouble could be scarce to find if they are gainfully employed, and that gainful employment could be companies or individuals who are efficiently engaging in turning agricultural solid wastes to wealth. Recycling of agricultural solid wastes into useful products could generate other sets of agricultural solid wastes, which may serve as raw materials for another useful products, thereby necessitating the continuous recycling of agricultural solid wastes until every potential waste is converted into wealth.

Conflict of interest

We have no conflicts of interest.

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