Agricultural and Forestry Wastes and Opportunities for their use as an Energy Source in Nigeria- An Overview

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Abstract: The importance of agricultural residues for biomass energy generation cannot be overemphasized. This is because they are readily available and offer much potential for renewable energy sources in form of biomass. Furthermore, the energy generated through them is friendly to both human and ecology. Therefore, this paper examined uses of agricultural residues, their conversion routes and utilization systems. Various agricultural and forestry biomass convertible to energy products were identified. The paper highlighted the benefits to be derived from the use of agricultural and forestry residues as energy source in Nigeria. The paper suggested that all the techniques of conversion discussed could form an agricultural complex utilizing briquettes as a renewable energy source; using anaerobic digestion (biogas) to produce energy and fertilizer; composting for soil conditioner; pyrolysis to produce medium grade fuels and chemical preservatives and production of animal fodder through the process of pelletizing. The paper concluded that, finding practical and economic uses for the agricultural and forestry residues will create an opportunity to build a bioeconomy which will deliver sustainable economic growth with job creation and social cohesion as key outcomes.
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1. Introduction

Agricultural and forestry residues offer much potential for renewable energy sources in form of biomass. With advances in biotechnology and bioengineering, some resources, which could have been classified as waste, now form the basis for energy production (McKendry, 2002). It is estimated that, Nigeria has about 71.2 million hectares of available agricultural land, out of which about 36 million hectares of land are being currently utilized for agricultural production (FOS, 2006). The large quantities of agricultural residues produced in Nigeria can play a significant role in meeting her energy demand. Most of these residues are biomass, which contains enormous amount of energy (Fapetu, 2000a). However, it is unfortunate that these wastes are neither utilized efficiently nor properly managed effectively in all developing countries, including Nigeria (Jekayinfa and Omisakin, 2005). The current farming practice is usually to burn these wastes or leave them to decompose. This burning or decomposition, apart from amounting to a colossal waste of resources, contributes to environmental degradation and pollution and this poses hazards to both human and ecology. It also constitutes a public nuisance and an eyesore, as these wastes are left to litter almost everywhere. The type and quantity of agricultural wastes in Nigeria change from one village to another and from one year to another because farmers always cultivate the most profitable crops.

Substantial amount of agricultural wastes being generated in the country is used as fuels in rural areas by direct combustion in low efficiency traditional furnaces. The traditional furnaces are primitive mud stoves and ovens that produce large quantities of air pollution and are extremely energy inefficient.

1.1 Objective of the Study

The broad objective of this paper was to identify various sources of agricultural and forestry wastes available in the country and suggest ways of utilizing them for economic advancement of the country.

2.1 Forestry and Energy Plantation

Wood is a major source of energy in Nigeria, and the potential exists for it to become a significant renewable source. The productivity in the forest areas of Nigeria ranges between 12 to 36 MT/ha/yr as opposed to a productivity of 3-9 MT/ha/yr in the grasslands (Fapetu, 2000a). Energy and forestry crops can be grown on a large scale and it has the potential to improve agricultural productivity, conserve land and diversify economy. Forestry residues are generated by operations such as thinning, extracting stem wood for pulp and timber, and natural attrition. In sawmills, wood processing generates significant volumes of residues in the form of sawdust, off cuts, bark and wood-chip rejects.

2.2 Agricultural crops and Residues

These include residues obtained during harvesting, crop processing and food processing wastes. In Nigeria, agricultural crops are not grown specifically as energy sources because at present, it is uneconomical to do so and more so this could lead to food shortage. The agricultural crops which can be grown specifically for energy purposes include sugar-cane, maize, sorghum, eucalyptus and vegetable oil-bearing crops such as sunflower and soya. These agro-wastes abound in the country, though, not much use is made of them as energy resources. A number of agricultural and biomass studies however, had concluded that it may be appropriate to remove and utilize at least a portion of these residues for energy production, providing large volume of low cost materials (Fapetu, 2000b).

2.3 Manure Resources

Manure resources from animals account for over 92 % of such wastes (Bamigboye and Oniya, 2003). Considerable yields are obtainable from cattle and poultry farming. The rest are produced by human beings. The quality of the manure is a function of the environment from which they are recovered. In the arid regions of Nigeria, cattle wastes in form of dung are used for energy resources for domestic heating and cooking.

3.1 Advantages of Agricultural Residues for Biomass Production

There are a lot of benefits to be derived from using agricultural residues for biomass energy production. Among these benefits are:

i. They are readily available in the rural areas, where petroleum products are not always available and affordable.

ii. They serve as a useful way of waste disposal.

iii. Their use will help to reduce rate of deforestation as the rate of felling of trees in the forest will be greatly reduced (Adekoya, 1989).

iv. Their use will promote clean environment as less pollutants are deposited into the atmosphere, thereby reducing the green house effect (Wilaipon, 2008).

v. Their use will serve as additional way of generating income to farmers in rural areas, because once a market has been established, the residues may well acquire a monetary value (Oladeji, 2011).

3.2 Limitations of Agricultural and Forestry Residues as Biomass Fuel

It is observed that several kinds of agricultural residues are available and ready to be utilized as fuels. Utilization of agricultural and forestry residues is often difficult due to their uneven characteristics. This is because, it is widely accepted that the majority of the residues are not appropriate to be used as fuels directly. As compared to other kinds of fuels, agricultural residues have lower density, higher moisture content and lower energy density. Besides, the low bulk density and dusty characteristics of the biomass also cause problems in transportation, handling and storage (Husan, et al, 2002). Therefore, there is the need to transform these residues into forms that will make their combustion easy and more efficient. According to Agbontalor (Agbontalor, 20071), there are many conversion routes and these are discussed below.

4. Conversion Routes of Agricultural and Forestry Residues to Energy and Products

Biomass that can be converted into bio-fuels is of two different phytomass origin: i. convectional agricultural products and (ii) lignocellulosic products and residues (Girard, et al., 2005). Agricultural and forestry residues lend themselves to either thermo-chemical or biological conversion to energy or energy products. The process could lead to the production of solid, liquid or gaseous fuels, and in some instances agricultural residues can be converted into heat energy. Some of the conversion process include: - direct combustion, gasification, pyrolysis, and briquetting, composting and pelletizing e.t.c [3].

4.1Direct Combustion

This method of conversion is the most employed method, especially in the developing countries, Nigeria inclusive. This is a direct conversion of biomass to heat energy, where the bulk of biowaste is used in unprocessed by rural households in traditional and inefficient devices for cooking, space heating and lighting (Karekezi, 1994). The appliances employed range from the traditional three-stone fire, improved wood stove, charcoal stove with ceramic liner to sophisticated charcoal burning stoves. Realizing that most of the stoves for direct combustion of biomass give room for waste of resources, efforts are going on how to increase their efficiency (Pesambili, et al., 2003). Another way of improving efficiency of biomass is through co-combustion or co-utilization, an application of which is co-firing (Bain and Overend, 2002). A co-utilization of biomass with other fuels can be advantageous with regards to cost, efficiency and emissions (Nussbaum, 2002).

4.2 Gasification

Fapetu (2000a) defined gasification as a process by which gaseous combustible fuel (H_2, CO, CH_4, etc) termed as "producer gas" is obtained from biomass in suitably designed reactors or gasifiers and can be combusted in suitable burners. Wood gasification takes place at approximately 800- 1000^{0}C in the presence of a controlled amount of oxidizing agent. The producer gas composition depends upon the starting moisture content of the biomass raw material.

4.3 Pyrolysis of Agricultural Wastes

This is an incomplete thermal degradation of biomass (agricultural residues inclusive) into solid fuel (char), condensable liquids (tar oils and acids) and non-condensable gaseous products (Fapetu, 2000a; Bridgewater, 2002). All known biomass feed stocks could be subjected to pyrolysis, to obtain fuel and chemical products. Few researchers on renewable energy had worked on pyrolysis of agro-residues. Examples of such residues studies are oil palm waste (Guo, and Lua, 2001), maize cob (Bamigboye and Oniya, 2003; Oladeji and Ogunsola, 2010), wood residues (Fapetu, 2000b; Fapetu, 1994) and so on. Fapetu (1994) has evaluated the potential yields of some agricultural and forestry biomass (i.e. the ekki, wood coconut and palm kernel shells) during pyrolysis at temperature ranging between 960^{0}C and 1200^{0}C. The study established that coconut shells with an average yield of 29.64 % tar oil, and 30.92 % pyroligneous acid have the best overall potential for these products. However, the study concluded that ekki wood products retained the highest energy content of the parent biomass on analysis. Gaseous fuel released from pyrolysis of wood includes four main gases i.e. H2, CO, CH_4 and CO_2 (Klose, et al., 2000). There are several types of pyrolysis processes, with different heating rates: slow pyrolysis, carburization or torrefaction to produce a coal-like material and fast pyrolysis to produce a liquid similar to crude oil (Agbontalor, 2007). Recent studies have shown that vegetal wastes such as agro-residues and renewable wild-grown biomass can be pyrolyzed transforming them into green carbon, a domestic fuel that performs the same function as charcoal made from wood, and at half the cost (Pro-Natural International, 2004).

4.4 Liquefaction

The extraction of liquid from biomass for the purpose of generating energy or as a platform intermediates for production of high-value chemicals is known as liquefaction. Solid biomass can be liquefied by pyrolysis, hydrothermal liquefaction, or other thermo-chemical technologies (DOE, 2005). These liquids substances are mostly hydrocarbons and are also known as bio-oils. .Liquid fuels are principally ethanol and methanol. Methanol could be produced from wood and crops residues. Ethanol could also be produced from grass and starch contents. However, the technology of production of ethanol is different4 from the technology of methanol (Fapetu, 2000a). Four distinct steps have been recognized in the production of ethanol. These include: production of a simple sugar solution, fermentation of the sugar produced, fractional distillation of the liquor to produce 95 % ethanol solution and further chemical distillation of 95 % ethanol solution to remove the remaining water content. Methanol could be obtained via three routes. It could be distilled from the raw pyroligneous acid obtained in the pyrolysis of biomass. Methanol is also produced from natural gas. The other method is to use the hydrogen and carbon monoxide from the gasification of biomass.

4.5 Bio-gasification

This is the process of anaerobic fermentation of organic materials by micro-organisms under controlled conditions. Biomass is a mix of three basic components: lignin, cellulose and hemicelluloses. Lignin serves as a sort of glue giving the biomass fibres its structural strength, while hemicelluloses and cellulose polymers are the basic building blocks of the fibres. In order to break down the hemicelluloses and cellulose to sugars, the basic structure of the biomass must be attacked and once the structure of the biomass is disrupted the hemicelluloses and cellulose can be converted to sugars enzymatically [Dale and Moelhman, undated; Wyman, et al., 1992). Biogas is a mixture of gasses mainly methane and carbon dioxide that results from anaerobic fermentation of organic matter by bacteria. Animal manure is the major biomass feedstock, while other plant wastes could be added occasionally. Water hyacinth has been successfully used to produce biogas in Nigeria (Fapetu, 1994).

Converting biomass to ethanol fuel has gained popularity in Brazil since the mid 70’s, although, using it as a fuel in the internal combustion engine has a long history (Damen, et al., 2002; Rosa and Ribeiro, 1998). Global annual ethanol production from biomass is estimated at 18 billion litres, 80% of which is in Brazil (Turkenburg, 2008). Fuel ethanol is currently produced in Brazil, the U.S.A and several EU countries (Reith, et al., 2001).

4.6 Briquetting Process

The briquetting process is the conversion of agricultural wastes into uniformly shaped briquettes that are easy to use, transport and store (Wilaipon, 2008). The idea of briquetting is to use materials that are otherwise not stable due to lack of density, compressing them into a solid fuel of a convenient shape that can be burned like wood or charcoal (Olorunnisola, 2007). Briquetting process has been investigated by several researchers (Wilaipon, 2008: Olorunnisola, 2007; Peter, 2002; Singh, et al., 2007;

Yadong and Henry, 2000; Matti, 2004; Oladeji, et al., 2009 and so on). Process of briquetting usually transforms biomass feedstock into high quality fuel for domestic or industrial applications. The briquettes will not only help to meet the energy needs, but also solve the disposal and pollution problems often created by biomass residues. The briquettes have better physical and combustion characteristics than the initial waste (Olorunnisola, 2007). Raw materials suitable for briquettes are rice straws, maize cobs, sugar-cane waste (bagasse), sawdust, cowpea chaffs, and melon and groundnut shells among others (Oladeji, et al., 2009).

4.7 Composting

Composting is the anaerobic decomposition of organic materials by micro-organisms under controlled conditions. Agricultural waste is rich in organic matter. This matter is derived from the soil and the soil needs it back in order to continue producing healthy crops. Compositing is one of the best known recycling processes for organic waste to close the natural loop. The major factors affecting the decomposition of organic matter by micro-organism are oxygen and moisture. Temperature, which is a result of microbial activity, is also an important factor. The other variables affecting the process of compositing are nutrients (carbon and nitrogen), pH, time and the physical characteristics of the raw material such as porosity, structure, texture and particle size (El-Haggar, et al., 1998).

4.8 Pelletizing

This process is similar to briquetting. The only difference here is that the product of pelletizing is much smaller than briquette produced through briquetting. Furthermore, process of pelletizing is exclusively reserved for production of animal fodder. Agricultural wastes could be transformed into animal feedstuffs through pelletizing. Agricultural wastes have a high content of fibre that makes them not easily digestible. The size of the waste in its natural form might be too big or tough for the animals to eat. To overcome these two problems, several methods were used to transform the agricultural wastes into a more edible form with a higher nutritional value and better digestibility. The further addition of supplements can enrich the feedstuffs nutritional contents. Mechanical and chemical treatment method could be used to transform the shape of the roughage (waste) into an edible form.

Pellets are also used more in commercial applications for industrial boilers where ease of handling and burning characteristics offer a competitive alternative to coal (Wilaipon, 2009). The main advantage of pellets is the higher energy density, which reduces significantly transportation advantage, storage and handling costs per energy unit. However, the drawback of pellets is the global energy inefficiency drop and the increasing cost resulting from investment and operation. As drying is usually necessary, the energy costs may rise up to 30 % compared with wood chips (Agbontalor, 2007).

4.9 Oil Extraction from Agricultural Biomass

Oil can be extracted from a variety of biomass including sunflowers, soya-beans, oil palm and rape. The oils can be used neat or blended with diesel oil for running compression ignition engines.

5. Possible Areas of Agricultural Residues Application in Nigeria

5.1 Biofuels

The production of biofuels such as ethanol and biodiesel has the potential to replace significant quantities of fossil fuels. Ethanol can be mixed with petrol to produce gasohol for driving compression ignition engines such as tractors and harvesters in farms (Bamigboye and Oniya, 2003). Briquettes which are an improved form of charcoal and high grade solid fuel would also be useful for domestic and industrial application (Ol0runnisola, 2007).

5.2 Other Areas of Application

Electricity can be generated in small-scale from a number of agricultural residues. The combustion of agricultural residues and biogas produced can be used to generate heat and steam. The heat can be used in domestic cooking while the steam can be used to drive steam turbines and in boilers for industrial application. The biogas produced from anaerobic digestion, pyrolysis or gasification has a number of uses. It can be used in internal combustion engines and it can produce heat for industrial needs such as grass drying, running of absorption refrigeration. The ash by-product of combustion has potential for utilization as a fertilizer. The product of composting is very rich in organic matter and the soil needs it back to continue producing healthy crops. Agricultural residues provide foodstuffs for animals and this helps in overcoming deficiency in animal foodstuffs. The chemicals produced are useful as adhesive tar that can be used to bind wood particles. Some of these chemicals could be used for embalmment of dead bodies.

6. Benefits of Agricultural Residues use in Nigeria

Agricultural waste is a biomass that is renewable source of energy and its use does not contribute to global warming. In fact, it has been found to reduce the atmospheric level of carbon dioxide as it acts as a sink (Musa, 2007).

Biomass fuels have negligible sulphur content and therefore do not contribute to sulphur dioxide emissions that cause acid rain. The ash produced by combustion of agricultural residue is less than coal combustion and this ash can be used as soil additive on farmland to recycle materials such as phosphorous and potassium (Musa, 2007).

Furthermore, finding practical and economic uses for the residues will create an opportunity to build a bioeconomy, which will deliver sustainable economic growth with job creation and social cohesion as key outcomes (Oladeji, 2011). Creating such a bioeconomy involves the substitution of fossil materials with renewable carbon. As a consequence of increasing the use of renewable resources for industrial feed stocks and for energy, the bioeconomy will bring benefits in a number of areas. This will save a considerable amount of money and avoid negative environmental impacts and health hazards as a result of field burning process or decomposition of the agricultural wastes (Oladeji, 2010).

7. Conclusion

Agricultural wastes can be utilized using all the techniques mentioned above to form a complex in which valuable products such as briquettes, biogas, liquid fuels, animal fodder, fertilizer and chemical preservatives could be produced. All these do not contribute to global warming. Furthermore, finding practical and economic uses for the residues will create an opportunity to build a bioeconomy, which will deliver sustainable economic growth with job creation and social cohesion as key outcomes. However, a lot of work still needs to be done in Nigeria and other developing countries as the present state of technologies for conversion and utilization of biomass energy is appalling, more so that most of the inhabitants of developing countries, Nigeria inclusive, depend on biomass for their means of energy generation and the intensity of use is not likely to subside in the foreseeable future.

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