Agricultural Waste as Raw Materials for the Production of Activated Carbon: Can Tanzania Venture into this Business?

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Abstract: *Activated Carbon (AC) can be produced from a variety of carbonaceous materials. Traditionally, they are produced from coal, lignite, coconut shells and wood peat thus raising the cost of commercial activated carbons. Agricultural wastes and by-products are considered good alternative source materials for production of activated carbons because of their abundance, high carbon content and cheap availability. In this review, an extensive list of agricultural wastes and by-products from vast literature has been assessed and properties of activated carbons produced from them evaluated. The potential of Tanzanian agricultural wastes for production of activated carbons is also discussed. Among the variety of agricultural wastes studied, nut shells, stones, seed hulls/husks, plant straws/stalks, sugar cane bagasse and agro-forestry residues such as sawdust have drawn much interest. The review also reveals that indeed agricultural wastes can produce activated carbons with properties comparable to commercial ones. In this case, Tanzania stands a chance of benefitting both economically and environmentally if it utilises the agrowastes for large scale production of activated carbons.*

Keywords*:* Activated carbons, physical activation, chemical activation, agricultural wastes.

INTRODUCTION

Activated carbons are broadly defined to include a wide range of amorphous carbon-based materials prepared in such a way that they exhibit a high degree of porosity and an extended interparticle surface area (Bansal and Goyal, 2005). They are obtained as residues after volatile components within source materials are removed. Typically they have surface areas ranging from 250 to 2400 m^2/g and pore volumes up to 91.4 cm^3/g (Ioannidou and Zabaniotou, 2007). Their pore size distribution is often multimodal ranging from micro to macropores. Various carbonaceous materials of animal, vegetable or mineral origin can be used to produce activated carbons (Smisek and Cerny, 1970). However, for economical reasons, source materials are required to have high carbon content and should be obtainable cheaply and abundantly.

Traditionally, coal, lignite, coconut shells and wood peat have been the main raw materials in production of commercial activated carbon (Bansode *et al*., 2002). However, the cost of the commercial activated carbon has remained high, limiting its applicability (Bansal *et al*., 1988). The use of low cost source materials such as agricultural wastes for the production of activated carbon can go a long way towards reducing the cost of commercial activated carbons. Moreover, transforming agricultural wastes into valuable end products may lead to crops value addition as well as reducing problems of solid waste management.

Tanzania has an agro-based economy and most of its agricultural waste and by-products, such as rice husks and fruit shells (coconut shells, cashew nut shells and palm fruit shells), are presently being discarded. The disposal procedures are haphazard and sometimes pose a threat to the environment. From an 'environ-economics' point of view, the disposal of the agrowastes is not only hazardous to the environment but it also leads to wastage of, otherwise very useful resources. Agricultural wastes and by-products have long been recognised as good sources of activated carbon (Ioannidou and Zabaniotou, 2007). At present all activated carbons used for different industrial processes in Tanzania are imported. The country stands a chance of benefitting economically and environmentally from investing in production of activated carbon using agricultural wastes and by-products. With the introduction of *Kilimo Kwanza* initiative (MAFC, 2012), more and more agriculture produce is expected and so are the associated agricultural wastes. It is therefore worthwhile exploring the possibility of venturing into the business of commercial activated carbon production.

The present review is aimed at evaluating and compiling the work that has been done over the last few decades on the use of various agricultural wastes and by-products for the production of activated carbons. The potential of Tanzanian agricultural wastes for the production of commercial activated carbons is also assessed.

A HISTORICAL PERSPECTIVE OF ACTIVATED CARBON

The use of Activated Carbon (AC) has a long history dating back to ancient times. The Egyptians used charcoal for reduction of ores in the manufacture of bronze and for medicinal applications as early as 3750 BC (Inglezakis and Poulopoulos, 2006). On the other hand, the Hindu documents dating from 450 BC show the use of sand and charcoal filters for the purification of drinking water. Activated carbon in form of char is also reported in keeping drinking water fresh in recent studies of the wrecks of Phoenician trading ships (University of Kentucky, 2012). In the time of Hippocrates (*ca*. 460 - 370 BC) and Pliny the Elder (AD 23 - 79) wood chars were employed for medicinal purposes (Hassler, 1963). During the time of Columbus (15th century) sailors put drinking water in wooden barrels that were blackened in the insides with fire to keep the water fresh.

The specific adsorptive properties of charcoal were first observed by Scheele in 1773 in the treatment of gases. However, it was Lowitz in 1786 who provided the first systematic account of the adsorptive power of charcoal in the liquid phase. The charcoal was used for decolorizing raw sugar syrups in sugar refining industry. The use of activated carbon in form of charcoal for decolourization in sugar refineries was later patented in England in 1812 (Inglezakis and Poulopoulos, 2006). It was later realised that bone char had an even higher decolorizing ability, hence a switch took place from wood charcoal to bone char in the sugar industry in 1817. Later in the nineteenth century, systematic studies were carried out on the manufacture and regeneration of bone chars by Schatten in Germany and the application of charcoal air filters for removing vapours and gases in London sewers by Stenhouse (University of Kentucky, 2012).

Activated carbon was first produced on an industrial scale at the beginning of the twentieth century, and major developments then took place in Europe. The Swedish chemist von Ostreijko obtained two patents, in 1900 and 1901, covering the basic concepts of chemical and physical activation of carbon with metal chlorides and carbon dioxide and steam, respectively (Sontheimer, 1988). In 1909, a plant named 'Chemische Werke' was built to manufacture, for the first time on a commercial scale, the powdered activated carbon Eponits and Norits (Dabrowski, 1998). There were similar developments in the United States at the same time. The first activated carbon was produced from black ash, a waste product of soda production, for decolorizing liquids (Hassler, 1963). The first commercial production of activated carbon in the United States took place in 1913 (Hendricks, 2006).

The use of poisonous gases in the First World War paved way for the development and large-scale production of Granular Activated Carbon (GAC). These carbons were used in gas masks for the adsorption of poisonous gases. Subsequently, they were used for water treatment, solvent recovery and air purification. Later, in 1935 - 1940, pelletized carbons were produced from sawdust by zinc chloride activation for the recovery of volatile solvents and the removal of benzene from town gas. Nowadays, the zinc chloride process of chemical activation has been largely superseded by the use of phosphoric acid (University of Kentucky, 2012).

At present, activated carbon finds wide application in many areas. It is used especially in environmental pollution control as well as in industry for various liquid and gas phase adsorptions (Bansal and Goyal, 2005). Among liquid phase applications, one can list food processing, preparation of alcoholic beverages, decolorization of oils and fats, product purification in sugar refining, purification of chemicals (acids, amines, glycerine, glycol, etc.), enzyme purification, decaffeination of coffee, gold recovery, refining of liquid fuels, purification in electroplating operations, purification in the clothing, textile, personal care, cosmetics, and pharmaceutical industries, applications in the chemical and petrochemical industries. Gas phase applications include; recovery of organic solvents, removal of sulphur-containing toxic components from exhaust gases, biogas purification, and use in gas masks, among others. Activated carbon is also used in medical and veterinary applications, soil improvement, removal of pesticide residues, and nuclear and vacuum technologies.

ACTIVATED CARBONS PRODUCED FROM AGRICULTURAL WASTE

Almost any organic matter with a large percentage of carbon could theoretically be activated to enhance its adsorption capacity. In practice, however, the best sources of activated carbon should have a high carbon content, a long storage life, are hard enough to maintain their properties under usage conditions, are obtainable at a low cost, and capable of producing a high-quality activated product when processed (Bansal *et al.*, 1988). Of all these parameters, cost is very important when comparing sorbent materials. Unfortunately, cost information is seldom reported, and the expense of individual sorbents varies depending on the degree of processing required and the local availability of raw materials. In general, an adsorbent can be termed as of low cost if its source requires limited processing, is abundant in nature, or is a by-product or a waste material from another industry. Considering the aforementioned aspects, there has been a switch of interest from the use of traditional raw materials to agricultural wastes and by-products as precursors for AC. Production of AC from agricultural waste and by-products has potential economic and environmental advantages especially for countries like Tanzania where agriculture is the main economic activity. This is because, firstly, it converts unwanted, low-value agricultural waste to useful high-value adsorbents. Secondly, it provides an excellent method for the agricultural solid waste management thereby reducing environmental pollution. Thirdly, it can reduce the importation of activated carbon and thereby increasing the economic base in the country.

Agricultural waste and by-products can be used for the production of AC with a high adsorption capacity, considerable mechanical strength, and low ash content (Savova *et al.*, 2001). A literature survey reveals a huge amount of information on the potential of agricultural wastes as raw materials for the production of commercial activated carbon (Ioannidou and Zabaniotou, 2007). Various types of agricultural wastes and by-products have been studied depending on their local availability. Materials that have drawn much interest include nut shells and stones, seed hulls/husks, plant straws/stalks, sugar cane bagasse, agro-forestry residues such as saw dust, etc. Table 1 gives a summary of agricultural wastes and by-products that have been studied widely in the production of AC. Furthermore, the Chemistry Department at the University of Dar es Salaam, has for about 2 decades, explored ways of developing activated carbons from local agricultural wastes (Mkayula and Matumbo, 1994; Mbwette 1994;Sadala and Mkayula, 1995; Mdoe and Mkayula, 1996; Mkayula and Mdoe, 1999; Mdoe and Mkayula, 2002; Mdoe *et al.*, 2003; Raymond and Mdoe, 2008). Results from these studies indicate that, it is possible to produce activated carbons from agricultural waste that have properties comparable to commercial ones.

As seen from Table 1, a variety of agricultural waste has been studied for production of activated carbons. Of all reported raw materials, coconut shells, rice residues (husks and straws), sugar cane bagasse and corn residues have received the most attention by various researchers. Coconut shells are already used as source materials for production of commercial activated carbons (Basal *etal.*, 1988). The other materials given in the table also proved to be good source materials for activated carbons. The fact that they are the most frequently studied tells us that, there is enough information on how to process them in order to produce AC with optimal properties. Coconut shells, rice residues, sugar cane bagasse and corn residues are some of the agricultural wastes that are abundantly available in Tanzania. With introduction of the *Kilimo Kwanza* policy (MAFC, 2012), it is anticipated that more of these agricultural wastes will be available to satisfy any viable industrial production of activated carbons.

Table 1: Agricultural waste that have been used for production of activated carbons

Raw material	Reference
1. Nut shells/stones	
Stones (cherry, date, olive and peach stones)	Tsai *et al.* 1997; Minkova *et al.* 2000; Minkova *et al.* 2001;Savova *et al.* 2001;Galiatsatou *et al.* 2002; Foo and Hameed, 2011
Nut shells (coconut, cashew nut, Macadamia, hazelnut, almond, walnut, apricot, pecan, oil palm)	Mdoe and Mkayula 1996; Ahmadroup and Do 1997; Ahmedna *et al.* 2000; Chipofya and McConnachie, 2000; Marcilla *et al.* 2000; Kadirvelu *et al.* 2001; Savova *et al.* 2001; Mdoe and Mkayula 2002; Aygun *et al.* 2003; Khan *et al.* 2003; Yang and Lua 2003; Ahmedna *et al.* 2004; Lua *et al.* 2004; Ash *et al.* 2006; Singh *et al.* 2008; Soleimani and Kaghazchi 2007; Aworn *et al.* 2008; Gimba and Muyiwa 2008; Fuadi *et al.* 2012; Olafadehan *et al.* 2012; Yusuf *et al.* 2012
2. Hulls/husks/seed coat	
Seeds (*Caricapapaya,* Rapeseed and grape seeds)	Predel and Kaminsky, 1998; Savova *et al.* 2001; Haykiri-Acma *et al.* 2005; Ayeni, 2012
Chickpea	Hayashi *et al.* 2002
Jatropha curcas fruit pericarp and seed coat	Ramakrishnan and Namasivayam, 2009; Okeola *etal.* 2012
Hulls (Kapok seed, oat, peanut, sunflower seed and wheat hulls and rubber seed coat)	Lanzetta and Di Blasi 1998; Chipoya and McConnachie, 2000; Girgis *etal.*, 2002; Fan *et al.* 2004; Zhang *etal.* 2004; Haykiri-Acma *etal.* 2005; Mohanty *etal.* 2008; Rao *etal.* 2008; Borhan and Kamil, 2012
Moringa oleifera seed husks	Chipofya and McConnachie, 2000
Rice residues (husks, straws)	Suemitsu *etal.* 1986; Tan et al., 1993; Mdoe and Mkayula 1996; Munaf and Zein, 1997Srinivasan *etal.* 1998; Ahmedna *etal.* 2000, Yalcin and Sevinc 2000;Mdoe and Mkayula 2002; Oh and Park 2002; Ajmal *etal.* 2003; Malik 2003; Aworn *etal.* 2008; Sharma *etal.* 2009; Foo and Hameed, 2011; Pandharipande *etal.* 2012
3. Agro-forestry residues	
Neem (*Azadirachta indica*) bark	Ayub *etal.* 2001
Sawdust	Ajmal *etal.* 1996; Selvi *etal.* 2001; Kadirvelu *etal.* 2003a; Aworn *etal.* 2008; Pandharipande *etal.* 2012
Woody materials	Mbwette, 1994;Mdoe and Mkayula, 1996; Minkova *etal.* 2001; Cetin *et al.*, 2004; Yusufu *etal.* 2012
4. Others	
Banana pith	Kadirvelu *etal.* 2003
Cane pith	Tseng and Tseng 2006
Cassava peel	Sudaryanto *etal.* 2006
Coconut residues (various parts: husk, coir, sawdust)	Chand *etal.* 1994; Kadirvelu *etal.* 2001; Kadirvelu *etal.* 2003; Kadirvelu and Namasivayam 2003; Bhatnagar *etal.* 2010; Foo and Hameed 2012
Corn residues (cobs, stover, straw)	Tsai *etal.* 1997; Lanzetta and Di Blasi 1998; Tsai *etal.* 1998;El-Hendawy *etal.* 2001; Tsai *etal.* 2001; Kadirvelu *etal.* 2003; Fan *etal.* 2004; Zhang *etal.* 2004; Alam and Bangash 2007; Aworn *etal.* 2008
Cotton and olive residues	Kadirvelu *etal.* 2003, Putun *etal.* 2005
Pine rayed	Cetin *etal.*, 2004
Sugar cane bagasse	Chand *etal.* 1994; Ayub *etal.* 1998; Ahmedna *etal.* 2000; Ayub *etal.* 2001a; Ayub *etal.* 2001b; Khan *etal.* 2001; Minkova *etal.* 2001;Mohan and Singh 2002; Cetin *etal.*, 2004; Soleimani and Kaghazchi 2007; Aworn *etal.* 2008;Pandharipande *etal.* 2012
Tobacco stem	Jambulingam *etal.* 2007

METHODS USED IN PRODUCING ACTIVATED CARBON FROM AGRICULTURAL WASTE

Basically, there are two main steps for the preparation of AC: (1) carbonization of carbonaceous raw material below 800°C under inert atmosphere, and (2) activation of the carbonized product (char), which is either by physical or chemical method (Smisek and Cerny, 1970).The main aim of the carbonization is to reduce volatile content of the raw material in order to convert it to a suitable form for activation. By carbonization, most of the non-carbon elements, hydrogen and oxygen are first removed in gaseous form by pyrolytic decomposition of the starting material. In the process, the freed atoms of elementary carbon are grouped into elementary graphitic crystallites (Balci, 1992). On the other hand, activation is the development of pores in a non-porous carbonized char by means of chemical reactions. Whereas physical activation is preceded by carbonisation of the raw material, chemical activation is not. In the latter case the carbonization and activation processes occur simultaneously.

Chemical Activation

In chemical activation the precursor is impregnated with a given chemical agent and pyrolyzed thereafter. As a result of the pyrolysis process, a much richer carbon content material with a much more ordered structure is produced, and once the chemical agent is removed after the heat treatment, the porosity is highly developed. Chemical activation offers several advantages since it is carried out in a single step, combining carbonization and activation, performed at lower temperatures and therefore resulting in the development of better porous structure. However, the use of chemicals for the activation process could raise some environmental concerns, although some of the added chemicals are recoverable at the end of the process (Tsai *etal.*, 1997; Tsai *et al.*, 1998; Zhang *etal.*, 2004).

Several activating agents have been reported for the chemical activation process. However, the commonly used ones are phosphoric acid, zinc chloride, potassium hydroxide, potassium carbonate and ammonium chloride. For instance, phosphoric acid was used for the preparation of activated carbons from peanut hulls (Girgis *etal.*, 2002), corn cobs (El-Hendawy *etal.*, 2001) and almond shells and pecan shells (Ahmedna *etal.*, 2004). The activation conditions were variable in terms of temperature and activation time. Whereas peanut hulls were activated at 500°C for 3 h, corn cobs were activated at the same temperature for only 2 h. The resulting ACs had different characteristics, the corn cob-based carbons showing better characteristics than the peanut hulls-based carbons.

Also a solution of $ZnCl_2$ (30 wt%) was used for the activation of almond shells, hazelnut shells, apricot stones (Aygun *etal.*, 2003), corncobs (Tsai *etal.*, 1997, Tsai *etal.*, 1998) and peanut hulls (Girgis *etal.*, 2002). The activation conditions were variable. Itwas also used as an activating agent for Macadamia nutshells (Ahmadroup and Do, 1997) and rice husks (Yalcin and Sevinc, 2000) at 500°C for 1 h and at 600°C for 3 h in combination with CO_2, respectively. The later kind of activation gave the best characteristics of the activated carbons than with any other agent (chemical or physical).

Carbons from Macadamia nutshells (Ahmadroup and Do, 1997), peanut hulls (Girgis *etal*., 2002), cashew nut shells, coconut shells (Mkayula and Matumbo, 1994) and rice husks (Mdoe and Mkayula, 1996; Mdoe and Mkayula, 2002) were also activated with KOH at temperatures ranging from 500 - 900°C for up to 3 h. However, the produced ACs, did not have good quality compared to the ones produced with $ZnCl_2$. In particular, corncob (Tsai *etal*., 2001) that was activated with KOH at 500 - 800°C for 1 h, did not generally give AC with good internal surface areas. Other materials that were activated using KOH include rice straw (Oh and Park, 2002), olive seed coats (Stavropoulos and Zabaniotou, 2005) and cassava peels (Sudaryanto *etal*., 2006). Generally, good porosity characteristics were obtained for these source materials. Furthermore, potassium carbonate was used in the activation process of corncob (Tsai *etal*., 2001) at 500 - 800°C for 1 h. However, the surface areas of the resulting ACs were generally less than those reported for KOH activated carbons. NH_4CI has also been used as an activating agent for almond shells and hazelnut shell (Baci *etal*., 1994]. Comparison of ACs produced using NH_4Cl and $ZnC1_2$ indicated that NH_4CI could be considered as an alternative to $ZnC1_2$ as the activating agent. It should be noted that the use of $ZnC1_2$ as an activating agent is decreasing because the residual zinc in the carbon is undesirable in some applications.

An important factor in chemical activation is the degree of impregnation (impregnation ratio). This is the weight ratio of the anhydrous activating agent to the dry materials. The effect of the degree of impregnation on the porosity of the resulting product is apparent from the fact that the volume of salt in the carbonized material is equal to the volume of pores, which are freed by its extraction. For small degrees of impregnation, a small increase in impregnation amount causes an increase in the total pore volume of the product showing an increase in the volume of smaller pores. When the degree of impregnation is further raised, the number of larger pores increases and the volume of the smaller pores decreases (Balci, 1992). However it should be noted that the porosity characteristic is also a function of the source.

Physical Activation

Physical activation of carbonised char is normally accomplished using gaseous activating agents at elevated temperatures. The most common activating agents are steam, carbon dioxide and air or their mixtures. However, CO_2 is widely preferred because it is clean, easy to handle and it facilitates control of the activation process due to the slow reaction rate at temperatures around 800°C (Zhang *etal*., 2004). During the activation process, disorganized carbon is burnt out and the closed and clogged pores between crystallites are freed. By the removal of disorganized carbon, the surface of the elementary crystallites becomes exposed to the action of the activating agent. The removal of non-organized carbon and the non-uniform burn-off of elementary crystallites leads to the formation of new pores, and to the development of the macroporous structures. This is followed by widening of existing pores or formation of larger pores by the complete burn-off of walls between adjacent micropores.

Activated carbons from rice husk, corn cob, oak, corn hulls, corn stover, rice straw, pecan shells, peanut hulls, cashew nut shells, coconut shells, almond shells (Ahmedna *etal*., 2000; Marcilla *etal*., 2000; Yalcin and Sevinc, 2000; Hendawy *etal*., 2001; Girgis *etal*., 2002; Oh and Park, 2002; El- Malik, 2003; Yang and Lua, 2003; Lua *etal*., 2004; Zhang *etal*., 2004; Haykiri-Acma *etal*., 2005), black wattle wood charcoal (Mdoe and Mkayula, 1996) and palm fruit shells (Mdoe and Mkayula, 2002) have been prepared using the physical activation method. The raw materials were carbonised under inert atmosphere and then activated at temperatures ranging from 400 to 850°C, and sometimes up to 1200°C.

TYPICAL CHARACTERISTICS OF ACTIVATED CARBONS PREPARED FROM AGRICULTURAL WASTES

The effectiveness of activated carbon as an adsorbent is attributed to its unique properties, including large surface area, a high degree of surface reactivity, universal adsorption effect, and favourable pore size (Basal *etal*., 1988). However, these properties vary depending on source material and activating conditions. Particularly, the nature of the raw material from which a given activated carbon is produced often has a large effect on its porosity properties. As a result, activated carbons produced from different raw materials may have quite different adsorption qualities despite being prepared under similar conditions. Table 2 shows some of the differences in physical properties for various raw materials used in preparing AC (Basal *etal*., 1988).

Table 2: Physical properties of some raw materials used in preparing activated carbons

Raw Material	Density (kg/L)	Texture of AC	Possible Applications
Soft wood	0.4 - 0.5	Soft, large pore volume	Aqueous phase adsorption
Nutshells	1.4	Hard, large micropore volume	Vapour phase adsorption
Hard coal	1.5 - 1.8	Hard, large pore volume	Gas vapour adsorption
Lignite	1.0 - 1.4	Hard, small pore volume	Wastewater treatment

Source: Basal *etal*., 1988

The properties of the activated carbons prepared from agricultural wastes are usually comparable to the commercial ones. However, they vary depending on the source materials and the activating conditions. Typical properties that have been obtained for activated carbons prepared from agricultural wastes obtainable in Tanzania, preparation conditions notwithstanding are exemplified in Table 3. As can be seen from the table, surface areas as high as 1400 m^2/g and pore volumes of up to 90 cm^3/g were obtained. It was observed that, materials with a greater content of lignin (grape seeds, cherry stones) develop ACs with macroporous structure, whereas raw materials with a higher content of cellulose (apricot stones, almond shells, coconut shells) produces AC with a predominantly microporous structure (Savova *etal*., 2001).

Table 3: Physical characteristics of activated carbons developed from agrowaste obtainable in Tanzania

Source Material	S_{BET} (m^2/g)	Pore Vol. (cm^3/g)	Reference
Corn cob	400 - 1410	0.1 – 0.70	Tsai *etal*., 1997, Tsai *etal*., 1998; El-Hendawy *etal*., 2001; Tsai *etal*., 2001
Corn hulls	900 - 1010	0.27 – 0.42	Zhang *etal*., 2004
Corn stover	311 - 712	0.18 – 89	Fan *etal*., 2004, Zhang *etal*., 2004
Rice husks	146 - 994		Mkayula and Matumbo, 1994; Mdoe and Mkayula, 1996; Mdoe and Mkayula, 2002
Cashew nut shells	200 - 727		Mdoe and Mkayula, 1996
Coconut shells	653 - 1031		Mdoe and Mkayula, 1996

CONCLUSION AND RECOMMENDATIONS

In this review, attempt has been made to focus on recent developments related to production of AC from agricultural wastes and by-products. Agricultural wastes and by-products are considered good alternative source materials for production of AC because of their abundance, high carbon content and cheap availability. Among the agricultural wastes reported in the literature, nut shells/stones, seed hulls/husks, plant straws/stalks, sugar cane bagasse and agro-forestry residues such as saw dust have been studied widely. The review reveals that indeed such agricultural wastes can produce activated carbons with properties comparable to commercial ones. In addition, utilization of agricultural wastes as source materials for production of activated carbons is beneficial both economically and environmentally because firstly, it converts unwanted, low-value agricultural waste to useful high-value adsorbents. Secondly, it provides an excellent method for the disposal of agricultural solid waste thereby reducing environmental pollution. Thirdly, it can reduce the importation of activated carbon wherefore increasing economic base in the country. Tanzania is endowed with an abundance of agrowastes which are presently discarded haphazardly. Thus these observations should serve as an incentive for Tanzanians to venture into commercial production of AC from agrowastes. As discussed in this review, AC has a lot of potential applications in various industries. In addition, the recent discovery of huge natural gas reserves in Tanzania suggests that there is a huge potential market for AC. Hence there is a reason for Tanzanians to venture into this business. However, there is a need for doing an extensive study to establish the actual local capability in producing activated carbons, assess the availability of the raw materials to meet industrial demand as well as establish the actual market demand in Tanzania.

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