SAWDUST: SUSTAINABLE UTILITY FOR CLIMATE CHANGE MITIGATION, A REVIEW

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ABSTRACT
This comprehensive review explores the utilization and importance of sawdust, an essential wood residue litters, which can be turned into a valuable commodity for industrial and agricultural use. Among other materials manufactured from sawdust is a producer gas, which consists primarily of CO and H_2, artificial graphite (anode in lithium-ion batteries), activated carbon for water treatment, a base for spore culture in cultivating edible mushrooms, pyrolytic oil as an alternative to crude oil. Sawdust and other biomass materials are blended in specific quantities palletized into briquettes and mixed with animal digestion or wood ashes and calcium carbonate to make fertilizers were also considered for composting. Sawdust and wood shavings can both be used to make particle boards and other decorative household items. This review hereby showcased the utilization of waste for a profitable business venture and eradicating improper disposal of waste and also proffering innovative solutions for climate mitigation.
Keywords: Activated carbon, Pyrolytic oil, briquettes, compost, waste to wealth

INTRODUCTION

Wood residue has been a long term concern in the environment (Rominiyi, Adaramola, Ikumapayi, Oginni, & Akinola, 2017), they are tiny flakes obtained in sawmilling, and wood industries, notably in southern part of Nigeria, in enormous quantities in the form of heaps that are generally burned off, resulting in pollution (J. A. Adesina, Jiangang, & Xiaolan, 2022). Sawdust is commonly thought of as a polluting timber-industrial waste (Assiamah, Agyeman, Adinkrah-Appiah, & Danso, 2022), but it may be converted to a valuable raw material in the fabrication of notice boards, wall and roof sheets, and shelves, (Di Cori, Robert, Franceschinis, Pettenella, & Thiene, 2022). In energy sectors, sawdust can be utilized as a biofuel (Weiss, Emery, Corradini, & Živojinović, 2020), briquettes (Charis, Danha, & Muzenda, 2019), pellets, artificial graphite for lithium-ion batteries (Y. Yu et al., 2021) and other products like insulator for refrigerators systems and in clean up technology for bioremediation of pollutants from wastewater (K. Adesina *et al*., 2022). Sawdust has features similar to wood, however some structural properties have been altered because it is in particles (Soimakallio, Saikku, Valsta, & Pingoud, 2016). Some characteristics of the technology employed to accomplish the aforementioned will be discussed in this paper.

1.1 Briquette

Over the last few years, depleting energy, rising costs, and crisis have reignited the focus of researchers in developing alternative energy. Gases, flowing water, and nuclear energy were the world's energy requirements many years ago. Although, majority of conventional energy are non-renewable, it is also obvious that it will not be sufficient to supply the world's growing demand in the present and future. As a result, more emphasis has been dedicated to the creation of wood gas that would supposedly be a waste. Briquettes are an excellent alternative to using wood as a fuel due to technological advancements in sawdust (Umar & Academy, 2016). Wood waste has a competitive specific energy content of 16,795.96 kJ/kg while charcoal has a specific energy content of 18,711.70 kJ/kg (Y. Yu et al., 2021). Due to the presence of cellulose, it can also be transformed to bitumen by improvising it with chemical reactions of carbon (II) oxide (CO), sodium carbonate, and water at high temperatures between 250ºC and 400ºC (Weiss *et al*., 2020). Sawdust can also be used as an insulating material in the refrigeration system and for cold storage.

Interestingly, sawdust's heating value compared to other fuels when used as a source of energy has low thermal conductivity, reason why it is been utilized insulator to lower conductor's heat losses. Sawdust's bulk density could be as low as 150 - 200 kgm^3 (Harshwardhan & Upadhyay, 2017). Sawdust's positive application has been proven by technological development; for example, it is often used as prerequisite for enhancement in various materials, such as production of methanol (Isabirye *et a*l., 2012); it can be burned to create heat in three different methods to produce fuel (Sacchelli, Borghi, Fratini, & Bernetti, 2021):

i. As a home fuel energy source for cooking and space heating, using specific stones for household cooking and fire pits heat.
ii. In the agriculture industry, to produce heats to brood chickens, drying and curing.
iii. In industrial sector, to produce heat used in blacksmithing, brickmaking, and poultry production.

Most studies believed that the industry could absorb all readily recovered trash currently being generated for energy or being used as supplementary raw material for chipboard or board production (Mangi, Jamaluddin, Memon, & Bin Wan Ibrahim, 2019).

1.2 Sawdust utilization for Ionic liquid-modified biochar for enhanced Li^+ storage

Every year, hundreds of thousands of tons of sawdust are produced by forestry logging and wood processing, which is either dumped or burned. As a result of these unfriendly behaviors, there are some issues with greenhouse gas emissions through its use as fuel or filler, waste (Rajapaksha *et al*., 2016). Waste resources have garnered a lot of interest for producing LIB anodes because of their reduced cost and long-term material sustainability, thanks to a growing demand for synthetic graphite which is the anode material in lithium-ion batteries (LIBs) derived from petroleum-based materials (Dai, Zhang, Xing, Cui, & Sun, 2019). A long lasting carbon material produced thermochemically by decomposing biomass in a low-oxygen or zero-oxygen environment is called **Biochar** (Fuja, Ostrem, Probst-Fuja, & Titze, 2006). Recent research breakthroughs have enabled biochar designs to three-dimensional levels, resulting in features such as distinct pore structures, and surface dynamics that are ideal for storing energy (Arana Juve, Christensen, Wang, & Wei, 2022; Gupta, Ganjali, Nayak, Bhushan, & Agarwal, 2012; Xu *et al*., 2019). Sawdust being rich in lignin with significant amount of cellulose during pyrolysis can be modified into graphitic carbon while lignin forms an absolutely robust carbonaceous matrix with distinct pores following pyrolysis (Del Bubba *et al*., 2020; Muddemann, Haupt, Sievers, & Kunz, 2019). Utilization of wood residue to create graphitic carbon for LIBs, on the other hand, normally necessitates a high-temperature carbonization process of above 2600 °C (Selvam S & Paramasivan, 2022). Due to titaniumdioxide (TiO_2) environmental friendliness, high durable functionality, low cost, and strong performance, making it suitable as anode material (Ghadikolaei, Hosseinzadeh, Yassari, Sadeghi, & Ganji, 2017; Ghadikolaei, Yassari, Sadeghi, Hosseinzadeh, & Ganji, 2017; Zhang & Chu, 2022). However, the fundamental disadvantage of using TiO_2 in LIBs is its weak conductivity (Tobaldi *et al*., 2021).

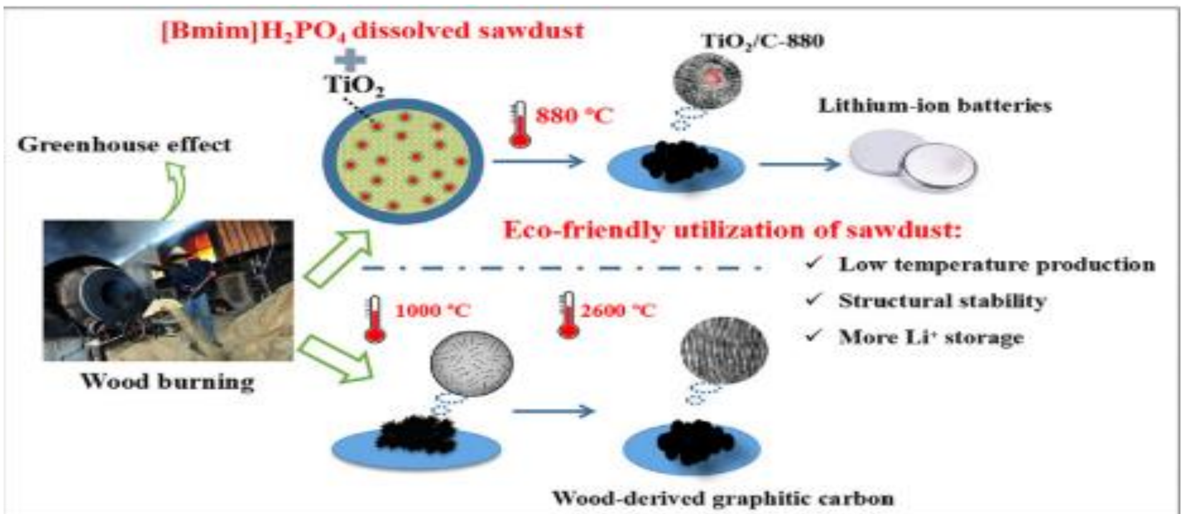

Fig 1: Modified sawdust for lithium-ion storage (J. Yu *et al*., 2021)

1.3 Water Treatment

Adsorption is the term used to describe the ability of lignocellulosics to absorb pollutants and impurities. The efficiency of biosorption technology in decreasing the concentrations of heavy metal ions, dyes, antibiotics, anti-inflammatory, and surfactants, as well as the utilization of readily available materials are two of its main advantages. Other advantages include biosorbent regeneration, adsorbate recovery, cheap cost, effective, and biosorbent regeneration (Ioannidou & Zabaniotou, 2007). Because binding occur through phenolics, amino or carboxyl, while raw lignocellulosic materials are being treated in various ways to boost their sorption capabilities. Recently, a lot of effort has gone into developing new adsorbents and improving current ones. Many researchers have looked into the possibility of utilising low-cost agricultural waste products (Adegoke, Adeleke, Adesina, Adegoke, & Bello, 2022; Eniola, Kumar, & Barakat, 2019; Ngah, W. S.Wan and Hanafiah, 2008; Patel, 2021) in place of traditional approaches for pollutants removal in wastewater treatment (Saravanan & Ravikumar, 2015; Sundararaman *et al.*, 2021; Suteu, Zaharia, & Blaga, 2012). In some circumstances, these approaches fail at low concentrations and are expensive. As a result, economy friendly adsorbents to remediate pollutants from aqueous solutions have been investigated (Varghese, Paul, & Latha, 2019). Elimination of zinc, lead, +3 and +6 chromium using modified lignin derived from lignocellulosic materials is utilized (Ofomaja & Naidoo, 2010; Salleh, Mahmoud, Karim, & Idris, 2011; Yang *et al*., 2020). Many heavy metal ions are known to bind to lignin. (Abdolali *et al.,* 2014*)*.

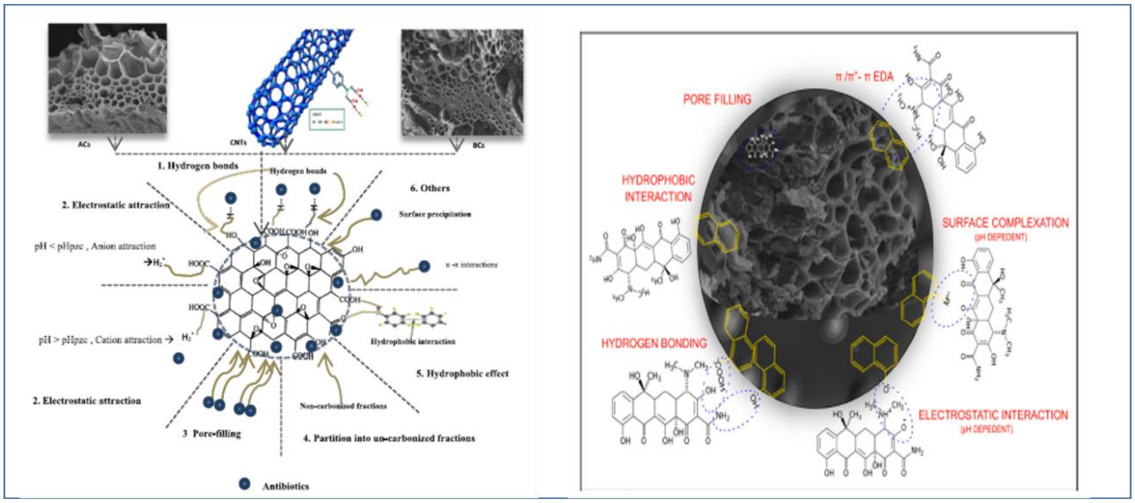

Fig. 2: A detailed scheme of mechanism involved in sorption of pollutant molecules on a biochar material (Del Bubba *et al*., 2020; Wu, 2019).

1.4 Composting

Sawdust is used in the agriculture business to make saw dust compost fertilizer. Southwest Nigeria produces tons of sawdust and other wood leftovers each year. While the majority of it is burned, a growing proportion were utilized for nurserymen, mulches, small fruit farmers while becoming more popular as barn and feedlot litter. Sawdust can induce a nitrogen shortage in soils while tannins and other extractives found in certain woods and barks may have a harmful effect on plants and soil microbes. However, mulching is well known for increasing crop yields using low-cost, commonly available materials. Wherever it is economically feasible, wood remains should be used for humus management. Although sawdust is the focus, it reacts similarly to shavings, bark and chips, with the exception that it decompose rapidly in fine material while mulches made of sawdust expand the aeration structure, water penetration and its absorption were increased. Reduce evaporation and weed control to conserve moisture.

1.5 Oxygen Sawdust gasification

This is the process of burning sawdust with a restricted amount of oxygen. CO, CO_2, H_2, and CH_3 make up sawdust gas. Except for carbon (iv) oxide, combustible liquid and gas can be used as fuel or fuel feedstock. Table 1 shows the normal composition of gasification in air, excluding water vapor. Although there are significant differences, the gas composition is mainly independent to feedstock composition owing to the fact that the final product is a combination of simple gases. If the feedstock contains a substantial amount of sulfur, hydrogen sulfide may be produced. By passing the gas, this can be simply removed across the water because when air source is substituted with oxygen, nitrogen will be removed, and the energy will reach 9 MJ/m^3. Hydro gasification, in which H_2 is introduced to react with CO to form hydro carbons, is another way to produce greater BTU gas.

$$CO + 3H_2 \rightarrow CH_4 + H_2O$$

Table 1. Sawdust gasification in air

Compounds	Percentage by volume (%)
H_2	20
CO	25
CO_2	10
CH_4	3
Higher hydrocarbon	1
N_2	40

Others	1
Total	100

1.6 Pyrolysis of sawdust for Bio-oil

Pyrolysis is the heat degradation of materials when there is no oxygen present. It is critical to distinguish between gasification and pyrolysis. By carefully managing the amount of oxygen available, gasification converts biomass to syngas. Pyrolysis is difficult to quantify properly, particularly when it comes to biomass. Pyrolysis is often confused with carbonization, which produces a solid char as the primary result. The word pyrolysis is now commonly used to describe operations in which oils are the preferred end product. Pyrolysis has a significantly shorter time span than the latter phase. Below are the list of general variation usually occur during pyrolysis (Mohan, Pittman, & Steele, 2006)

- Heat transmission raising the internal temperature of the fuel;
- Hot volatiles flowing toward unpyrolysed cooler solids resulting to heat transfer;
- Secondary reaction as a result of condensed volatiles in the cooler parts of the fuel producing tar;

Basic research on flash pyrolysis revealed carbonaceous feedstocks can provide superior yields of gases and liquids, with important compounds, petrochemicals, chemical intermediates, over the previous two decades. As a result, typical slow pyrolysis solid char can be substituted with fuel oil, chemicals or fuel gas produced.

Because sawdust primarily composed of hemicellulose and cellulose, CO and hydrogenation technologies can easily be applied to convert it to oil. Cellulose conversion to a liquid necessitates high-pressure hydrogenation, while cellulose to a bitumen necessitates treatment at high pressure and temperatures. Sawdust, catalyst, and water were heated in an autoclave with CO to about 250°C to 400°C (Galhetas *et al*., 2014).Water is required for both process and also serves as a solvent and reaction medium.

1.7. **Composite Panels**

Sawdust can be used to make particleboard, plywood, water board, and other wood panels, and the strength is highly influenced by particle size of sawdust.

Shavings, chips, and flakes are mixed together with binding chemicals and resin are further poured into hot-pressed mat for increment in density and adhesive curing. To fortify its potency dynamics, sawdust flakes can be directed to some extent in the panels to enhance exterior characteristics thereby creating a more sophisticated output (Rominiyi *et al*., 2017).

Consolidation of the board to an appropriate texture and compactness can be employed to achieve material stability because of its direct impact on finishes product efficacy and quality (Jasmani, Rusli, Khadiran, Jalil, & Adnan, 2020). When compared to multi-opening presses, improved panel aesthetics, regulated solidity, and reduced trimming losses are guaranteed (Joshi *et al*., 2020).

1.8 Sawdust Utilization for Feed Meal, Compost and Mushrooms Production

To absorb surplus moisture in wet compost, unadulterated sawdust and wood shavings are useful to dampen them and prevent them from air flow restriction in the heap. Alternatively, more moisture is supplied when adding sawdust preventing the heap from complete dry out.). As long as the animal is vegetarian, sawdust can be applied as animal beddings e.g rabbits or poultry droppings can be composted together. Beneficial symbiotic interaction with microbes in the rumen region of ruminant animals digestive tract allows them to eat cellulose materials. During times of national emergency, cattle and horses were fed with wood residues as maintenance meals. Feeding trials with wood residue was conducted on cattle and sheep, they were undertaken by utilizing a formula that include sawdust and oyster shell. A purified experimental chick ration using an inexpensive supply of cellulose resulted in a considerable boost in growth was also considered while compared to the control set, 20.2% wood flour fed to chicks had no negative influence and caused small growth improvements at 28 weeks of age.

Conclusions

Sawdust, which is normally a hazard at sawmills, can be used to make animal feed stocks, biogas, particle board, briquettes, activated carbon and Li^{+} ion anodes. Internal combustion engines can benefit from the flame-purified gas. In addition, for safety and health reasons, plywood and particle boards products are preferred over other materials for wall sheathings and roofing. Finally, composting sawdust with cattle droppings has the potential to improve soil quality.

Future perspective

The government should create an atmosphere that encourages the local manufacture of pressing and briquetting machinery. More money can be made in forex if briquetting and pressing machinery were built for export and local consumption. Sensitization through sponsored seminars and workshops across the country for indiscriminate sawdust burning should be projected. Kerosene and firewood should be replaced by sawdust briquettes as an alternative fuel for climate control. Also, sawdust biochar and modified biochar for waste water treatment and lithium-ion storage will create a massive industrial growth and also boost our economy.

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