International Journal of Engineering Research and Technology.
ISSN 0974-3154 Volume 11, Number 12 (2018), pp. 2023-2033

http://www.irphouse.com

An Overview on Using the Chicken Manure (CM) Waste as a Bio-binder for Sustainable Flexible Pavement

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ABSTRACT

This paper introduces the bio-oil and bio-char by-products derived from the chicken manure (CM) waste materials as a bio-binder for flexible road construction. Chicken manure has numerous applications in the biofuel and energy using various methods of converting the chicken manure to bio-oil, biochar, and biogas. It needs more treatments for producing more efficient bio-products. Therefore, this article reviews the enhancement mechanisms for the bio-oil production and toward more sustainable bio-binder derived from chicken manure for flexible pavement constructions. It was found that chicken manure has a strong potential to be used for more sustainable and cost-effective applications. However, for road construction bio-binder, applying the chicken manure has some challenges such as the lower density; higher water content and lower adhesion performance. It is also highlighted the research gaps of bio-binder derived from the chicken manure were identified in terms of waste management, enhancement the biofuel production and toward greener and more sustainable bio-binder for flexible pavement constructions.

Keywords: Bio-binder, Bio-char, Biomass, Bio-oil, and Chicken Manure.

I. INTRODUCTION

Recently, there has been renewed interest in replacement of petroleum-based fuel and bitumen by bio-fuel and bio-binder. It is known that; the environmental resource of fuel is classified as renewable and non-renewable. However, the most current available resource is non-renewable [1]. Biomass is considered as the main source of the renewable fuel which might be the major renewable source of the bio-binder to be an alternative for the petroleum-based binder as well [2]. The biomass is also the largest sustainable energy resource in the world, which yield about 220 billion dry tones annually [3]. In China, the output of the chicken manure and livestock had reached

about 2.2 billion tons per year in 2010 which was estimated to be increased over years especially with increasing of chicken consumption [4]. Also in the USA about 35 million tons of the poultry manure were produced every year [5].

Renewable and sustainable source of fuel is one of the main interesting research aspects in the world due to the finite resources of fossil fuel and climate changes [6]. The availability of the fuel in the future is taken main concern especially in the countries where the fuel resources are limited. The conventional resources of the energy and fuel such as coal, petroleum and natural gas are increasing the environmental issues such as energy security concern and climate change [7]. It was claimed that up to 2 billion people around the world use the biomass to heat their homes and prepare their food in very poorly controlled conditions. It was also reported that out of 2 billion, over 1.6 million people annually died due to pollutions emit from the use of biomass as domestic fuel most of them children and women [8].

The production of the bio-char and bio-oil from edible resources is considered undesirable competition with the increasing of food need which will lead to increases in crop prices that is not ethically right. To avoid such ethical dilemmas and situation, inedible resources should be used such as chicken manure (CM) [7]. It was stated that poultry represents over 80% of all livestock these days. In addition to that, the conventional methods of using the poultry manure as a fertilizer are raising serious concerns about disposal and treatment of such waste. That is because the traditional uses lead to potential environmental issues due to the overuse such manure as fertilizer and emission the greenhouse gases [9]. Direct applications of the CM for farmland leads to various environmental problems such as pollution of groundwater, eutrophication in surface waters, the spread of pathogens and greenhouse emissions [2, 6, 10-15]. It was also claimed that up to 50% of the chicken industry workers suffer from upper respiratory ailments, which was justified due to the higher ammonia levels [16].The looking for a more cost-effective method for disposing the CM is an urgent necessity to convert such environmental damage waste to sustainable fuel and energy [17].

There is an urgent need to involve the poultry manure waste in producing the bio-fuel for different applications to mitigate the increase of pollution due to the continuously growing of poultry farming industry. That is because the increasing of world population demand and the land application cannot be considered as the main solution for CM disposal. Therefore, the conversion of poultry waste to bio-fuel for various applications related to the materials derived from petroleum is an effective alternative [3, 17-20]. By using such technology the stream of the waste materials will be minimized and converted into more useful resources forms [6]. The demand of the meat is expected to be 58% higher in 2050 than their demand in 2010. So that there is a very pressing need for research into technology and strategies for management and treatment of the manure toward sustainable and environmentally friendly applications [21]. Improper handling of waste produced by farms operation highly deteriorates the environment including water, air and soil [21].

In addition to reducing the consumption of fossil fuel, the introduction of biotechnology can also improve the economy, that is by providing thousands of jobs for workers in

the industries and countries that interested in green technology. For instance, only in Italy in 2010 about 100,000 workers existed in green industries which was expected to reach 250000 in 2020. Also, the estimations of 2010 indicated that about 8.5 million workers in Europe are involved in green jobs [22].

Bio-binder for road constructions produces through fast pyrolysis, thermo-chemical reactions and liquefaction process [23]. Biomass-derived from human, animal and plants wastes is the common raw materials of the bio-binder production that include swine manure, palm oil, soybean oil, vegetable oil, engine oil residue and so forth [24]. Petroleum base binder can be partially replaced in road constructions by bio-binder., providing with environmental, social and economic benefits. More research was recommended for investigating the bio-binder derived from different resources, that have not been investigated before [24]. Therefore, the aim of this overview is to introduce CM waste materials for pavement engineers and researchers toward improving the biotechnology and waste management applications in pavement engineering through using the bio-binder derived from CM for utilizing as a green alternative for the petroleum-based binder for flexible road construction.

II. METHODS OF CONVERTING OF CHICKEN MANURE TO BIO-OIL, BIO-CHAR AND BIO-GAS

There are many ways for conversion of biomass such as CM waste to the biogas, bio-oil, and bio-char [2]. There are four main thermochemical methods: pyrolysis, gasification, liquefaction, combustion and anaerobic digestion [2]. Anaerobic digestion is one of common methods used for producing the biogas from the organic materials by bacteria, but it needs a long time. Conversely, pyrolysis processing need for higher heating energy but no more time consuming [25]. Pyrolysis is considered the most common method used for converting biomass waste materials to bio-oil and bio-char [3]. It was claimed that pyrolysis processing of converting the biomass to bio-oil, bio-gas and biochar is relatively simple and inexpensive [26]. It is also claimed that pyrolysis method can solve the waste disposal issue and create new revenue for the poultry industries. Pyrolysis processing is considered the most efficient method for achieving the purpose of conversion of biomass to biofuel [2]. Pyrolysis technology is considered the most promising technology not only for solving the waste disposal and water pollution but also conversion such waste to bio-oil and bio-char to be used for different biofuel applications [27]. The utilize of pyrolysis for production of bio-oil and biochar showed to be an effective, practical and environmentally sustainable for its producing the higher amount of biofuel and reducing the greenhouse gases emissions at the same time [26]. Pyrolysis is also considered as economically marginal due to the higher competitive among the markets of bio-oil and biochar [26]. Another recent study claimed that the microwave pyrolysis technique has gained a serious attention in the research community for its advantages which summaries in its applicable, flexible, controllable, efficient, rapid and uniform [5]. Fig. 1 illustrates the pyrolysis process of converting biomass to bio-char, bio-oil and bio-gas.

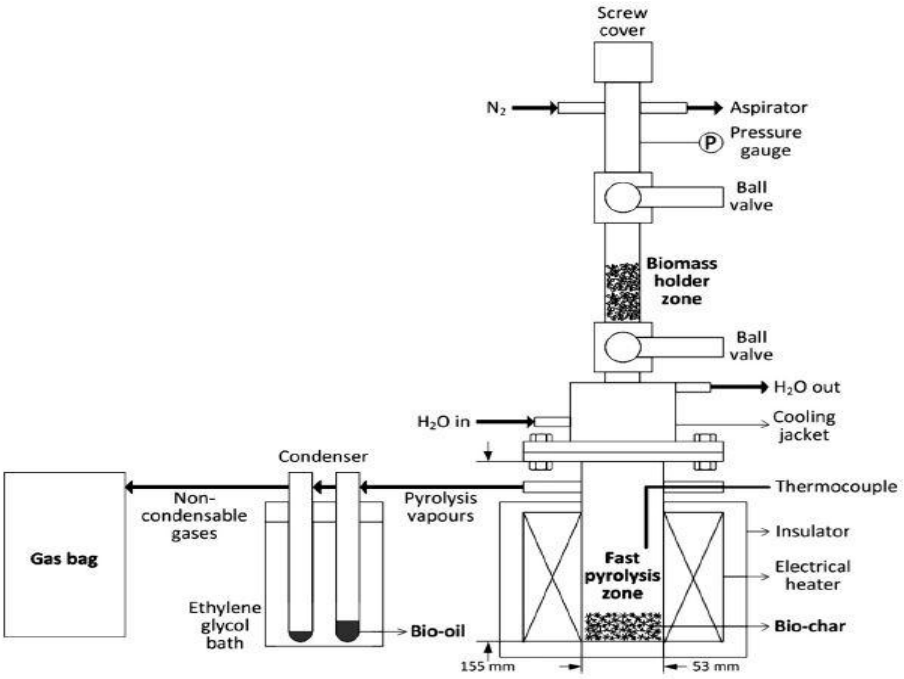

Fig.1. Schematic diagram of the fixed bed drop-type pyrolyzer [28]

Select the right conversion method depends on the purpose of the bio-oil and biochar applications. The existing technologies are combustion, anaerobic digestion, pyrolysis, gasification and hydrothermal. Direct combustion cannot be used because high water and nitrogen content in the bio-oil and biochar yield using this method, also using of anaerobic digestion results on high nitrogen bio-oil and biochar. It can be implied that the water content, chemical component and chemical, physical and rheological properties of the bio-oil and biochar will be changed based on the biomass sources, type of the conversion process and the situation of the conversion such as the temperature [29]. Current study proved that even the bio-digester shape has an effect on the biogas produced from the CM, cow waste, and piggery waste which recommended that the cylindrically shaped bio-digester showed the best performance [13]. Table 1 shows the basic elements composition of chicken manure; the lower water content makes it one of the best candidates to be used as a biomass material for production of bio-fuel and bio-binder materials.

III. ADVANTAGES AND DISADVANTAGES OF CHICKEN MANURE WASTE

Chicken manure waste is one of the organic waste materials that have many advantages and disadvantages. One of the advantages of the biochar of the chicken manure is the utilize such materials for enhancing the agriculture; that will help in developing the food security. In addition to contributing to the eco-friendly environment. But in case of using higher amount of it for the soil that will have a reverse effect by penetrating the extra materials to the surface and underground water which lead to very dangerous pollution of water [30]. Therefore, production of bio-oil from animal manure to be used

for other applications such as pavement will contribute to mitigating such pollution problem. It was reported that the generated poultry waste from the chicken farms in Pakistan can produce 280 MWh/day of electricity by converting that waste to biogas which considers as a good enhancement of the renewable resources energy in the country which suffers from lacking of the renewable energy [31]. A study was conducted to evaluate the short-term pollution of soil and water due to using of bio-oil and biochar produced from CM. It was found that bio-oil can be used as the alternative for raw materials due to the lower phosphoric materials in bio-oil which is a toxic material. Nitrogen can be easily released from the biochar to be used in a safe manner as a fertilizer to protect the soil and water pollution [8].

Table 1. Characteristics of chicken manure wastes [9]

Proximate analysis (wt. %)	
Moisture	8.2
Volatile matter	60.2
Ash	15.4
Ultimate analysis (dry basis, wt. %)	
C	40.00
H	5.4
N	5.6
S	0.1
O	33.5
Protein	33.1
Higher heating values (HHV) (MJ/kg)	16.0

It was stated that upgrading of the bio-oil produced from poultry manure is very important due to the high amount of the water and nitrogen content in such waste [9]. Another recent study was conducted in Singapore to investigate the possibility of conversion of poultry manure to gas energy. It was noted that there were two main issues due to the CM one is there is not enough space in Singapore and another one is the environmental damage due to the greenhouse gas emission. They suggested that this type of the waste should be sustainable, and green used toward reducing the carbon footprint. On the other hand, The Singapore Lim Chu Kang Company of the chicken succeed to produce 1 MW of electricity generation from conversion CM to biogas [6]. The chicken litter generated from the chicken industry could significantly contribute to air, soil and water pollution by releasing greenhouse gases, ammonia, pathogens, excess nutrients and other substances can increase the health risk of humans, animals and environment [5, 16, 27].

IV. MOTIVATION OF USING CHICKEN MANURE AS A BIO-BINDER

One of the most encouraging factors for using poultry manure for producing renewable biofuel and energy such for flexible pavement is the economic perspective. It was reported that two main benefits can be gained in term of power generation and cleanliness of the environment. The two main benefits were the fixed installation cost

then long term cost analysis which showed the more feasible to be used [1]. Current study was carried out in Brazil for evaluation of the potential energy and emission avoided by conversion of seven organic wastes (poultry manure one of the seven wastes used) using digestion technology. It was found that the potential power can be used in Brazil with respect the volume of waste annually between 4.5 and 6.9 GW which will reduce the greenhouse gas emission by 4.93% per year. Furthermore about 180000 buses will be powered by biogas produced [32]. Also, another motivation for using biofuel and renewable energy derived from CM is to reduce the import of fuel from other countries especially the countries have high biomass resources [33]. Any enhancement in the quality, quantity and cost production of the bio-fuel especially bio-oil and biochar has the direct positive effects on the bio-asphalt materials can be applied for flexible road construction since the asphalt is one of the fuel derived materials, that will reduce the higher cost of the asphalt pavement such as stone mastic asphalt which its higher cost is one of its disadvantages compared to other asphalt mixtures [34].

Singapore adopted a zero-waste policy to reduce the air pollution and waste stream, only from CM waste-fueled of the biogas power plant 50 tons per day. The biogas produced used in generating electricity and heat for the farms [6]. In the case of bio-binder derived from CM, it can be used that waste materials for green pavement even at the beginning for roads inside the campuses of Universities and Government facilities before its applying for main highways. Current study was conducted to analyze the technical and economic generating of biochar produced from poultry manure waste. It was estimated that the collection and transportation then the conversion process until the producing of the energy from the poultry manure in Britain cost only five (5) Pound MWh_{th} [35]. Another new study was conducted in Korea to investigate the possibility of producing biodiesel from biochar derived from CM and waste cooking oil. It was found that the biochar produced at temperature 350°C highly recommended to be used for yield better performance [7]. It was stated that the raw materials contain the 75% of the total cost of producing biofuel, therefore the using of such inexpensive poultry waste will enhance the economic feasibility forward more cost-effective biofuel and then bio-binder [7]. It was also found that the biochar produced from poultry manure could be promising materials for biodiesel producing which showed extraordinary performance due to the presence of the Calcium species in poultry manure [7]. From that, it can be implied that this waste could be promising materials for bio-binder as the alternative for the petroleum-based binder.

It was stated that the raw bio-oil produce from the CM is very high viscosity [36]. So that it will be more suitable for use as a bio-binder which required higher viscous properties materials. Also, this point proves that the bio-oil extracted from CM is the most suitable among the bio-oil from other domestic animal wastes for bio-binder applications. It was also claimed that the higher viscosity of the bio-oil derived from poultry waste due to the toluene soluble and hexane fractions which have relatively low nitrogen content and high alkyl functional group [27]. However, it was found that the biochar produced from CM has the alkenes amount higher than the bio-oil which make it good in adhesion but not necessary higher strength [37]. Another study showed that

the carbon content of CM is more closed to the swine manure which one of the good biomaterials for bio-binder [38].

V. CHALLENGES OF USING CHICKEN MANURE AS A BIO-BINDER

One of the most current challenges around the world is availability of sufficient, friendly environmentally and affordable energy [31]. Also, the general challenge these days is how can we recycle waste materials into different life applications such as energy, paving and other value- added products to overcome the harms raised by the animal waste [30, 39]. The safe and economical disposal of CM is becoming a major problem for the chicken industry around the world [17, 27]. It was also stated that disposal of CM is a serious problem facing the chicken industry because of the health concern and environmental pressures [2, 40]. Another general challenge in current decade is the demand of energy increases, so that looking for energy generation system to meet the requirements and for environmental safety is one of the priority of the world [31, 38]. Increasing poultry farms day by day which results in a huge amount of waste which make the waste recycling and management more complicated is considered one of the challenges that need to be solved [31].

Another main challenge is the identification of chemical behavior of bio-oil and biochar produced from CM due to the chemical complexity of their components. However with the availability of most advanced chemical analysis methods such as gas-chromatography and mass spectrometry (GC/MS) and fourier-transform infrared spectroscopy (FTIR) can give an obvious indication about the chemical behavior of such materials [37]. It is also known that using bio-oil produced from biomass is the lower densities of petroleum based binders which consider one of the major challenges need to be solved for producing bio-oil for more widely acceptable applications especially where the high density bio-oil is required such as in case of bio-binder [11]. It was also found that the bio-oil produced from the poultry manure is more viscous than the bio-oils derived from woody biomass [27]. That makes it a strong candidate to be upgraded to bio-binder applications for road construction. However, it was found that it is rapidly aged which considered as one of the serious challenges to be used in road applications which need to be mitigated for acceptable performance.

VI. CONCLUSION

There is a significant attention from researchers, policy makers and enterprises around the world for environmental control and management of toxic waste materials. The main problem is the huge waste such in the case of chicken manure which is very dangerous and filling wide area of land which causes soil and water pollution. For disposal of such waste, government will spend a lot and the health of the humans, animals and plants may be in danger. That will also affect the environment around the world. On the other hand, there is an urgent need for greener and more sustainable biofuel to cover the human needs with safe pollution affects. An extensive research should be conducted toward disposal such waste materials and convert them for more useful applications. Therefore, we are looking to be one of that interested researchers

in contribution to protecting this world from that toxic waste by studying their applicability of using the bio-oil and biochar derived from CM to be used as a bio-binder in flexible pavement engineering with consider the motivations, and challenges were declared in this article.

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