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On-Campus Solar Energy: A Review Towards Green Technology

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Abstract: *This review paper discusses renewable energy, specifically solar photovoltaic (PV) energy, which provides benefits in selecting the proper technology for campuses. This study aims to direct scholarly attention to the processes that underpin strategic renewable energy investment decisions, as well as how these decisions are influenced by national energy policy. It discusses three (3) common PV technologies that could be adopted by universities and colleges in support of the renewable energy in the Philippines. Different benefits and drawbacks in using solar energy were also discussed. The proposed approach framework was presented. Finally, the status of solar energy in the Philippines and the innovative initiatives of higher education institutions in the Philippines were highlighted.*

Keywords: Renewable Energy, Solar Photovoltaic, Thin film Solar Cells Technology, Mono Silicon Solar Cells Technology, Polysilicon Solar Cells Technology.

I. INTRODUCTION

Solar energy is solar radiation that can produce heat, cause chemical processes, or generate electricity. The overall amount of solar energy incident on Earth exceeds the world's current and projected energy needs by a large margin. This highly distributed source has the ability to meet all future energy needs if properly exploited. Solar energy, in contrast to the finite fossil fuels coal, petroleum, and natural gas, is predicted to become increasingly popular as a renewable energy source in the twenty-first century due to its limitless supply and nonpolluting nature [1]. New renewable energy has gotten a lot of attention as a potential future energy source that might play a big role in developing a long-term energy supply system [2].

In the Philippines, Republic Act (RA) No. 9513 also known as Renewable Energy Act of 2008, has been crafted to accelerate the exploitation and development of renewable energy resources such as, but not limited to, biomas, solar, wind, hydro, geothermal and ocean energy through the adoption of sustainable energy development strategies to reduce the country’s exposure to price fluctuations in the international markets, the effects of which spiral down to almost all sectors of the economy, to increase the utilization of renewable energy by institutionalizing the development of national and local capabilities in the use of renewable energy systems, and promoting its efficient and cost-effective commercial application by providing and nonfiscal incentives, to establish the necessary infrastructure and mechanism to carry out with the protection of health and the environment; and to establish the necessary infrastructure and mechanism to carry out the mandates specified in this Act and other existing laws [3].

Universities and Colleges in the Philippines continue to expound the development of renewable energy by installing solar panels in their respective campuses. Strategic adoption and implementation of solar energy in higher education institution is a big challenge not only on financial budget.

Renewable energy technology investments are becoming increasingly popular as a way to boost growth and speed up the recovery from the recent financial crisis. Despite their popularity and the numerous policies enacted to encourage these technologies, the adoption of RE projects has lagged behind predictions. This low adoption is attributable to a lack of adequate funding as well as a reluctance to invest in these technologies [4].

Renewable energy sources (RES) have a large potential to contribute to the sustainable development (SD) of specific territories by providing them with a wide variety of socioeconomic and environmental benefits. However, the existing

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literature has put much emphasis on the environmental benefits (including the reduction of global and local pollutants), while socioeconomic impacts have not received a comparable attention. These include diversification of energy supply, enhanced regional and rural development opportunities, creation of a domestic industry and employment opportunities. With the exception of the diversification and security of energy supply, these benefits have usually been mentioned, but their analysis has been too general (i.e., mostly at the national level) and a focus on the regional and, even more so, the local level, has been lacking. At most, studies provide scattered evidence of some of those regional and local benefits, but without an integrated conceptual framework to analyze them [5].

The management and exploitation of renewable energy sources is now recognized as central to sustainable development. Environmental concerns, recurring oil crises and market weaknesses, combined with the availability of power from natural resources and resulting possibilities for job creation and energy independence, have all pushed developed and developing countries towards new energy [6].

Electric energy security is essential, yet the high cost and limited sources of fossil fuels, in addition to the need to reduce greenhouse gasses emission, have made renewable resources attractive in world energy-based economies. The potential for renewable energy resources is enormous because they can, in principle, exponentially exceed the world's energy demand; therefore, these types of resources will have a significant share in the future global energy portfolio, much of which is now concentrating on advancing their pool of renewable energy resources. Accordingly, this paper presents how renewable energy resources are currently being used, scientific developments to improve their use, their future prospects, and their deployment. Additionally, their paper represents the impact of power electronics and smart grid technologies that can enable the proportionate share of renewable energy resources [7].

Electricity market is undergoing a tremendous transformation throughout the world. A drastic reduction of carbon emission cannot be realized if renewable energy resources are not increased in share of generation mix. Currently, most of the traditional mechanisms, including regulatory policies, fiscal incentives and public financing, are initiated from and heavily relied on policymakers and governments. However, not only these schemes do not necessarily align with business interests of investors, but also the motivations for renewable energy developments are always initiated by governments. In order to realize the full potential of renewable energy investment, an innovative approach is necessary to motivate investors and lessen government expenditures [8].

Major developments, as well as remaining challenges and the associated research opportunities, are evaluated for three technologically distinct approaches to solar energy utilization: solar electricity, solar thermal, and solar fuels technologies. Much progress has been made, but research opportunities are still present for all approaches. Both evolutionary and revolutionary technology development, involving foundational research, applied research, learning by doing, demonstration projects, and deployment at scale will be needed to continue this technology-innovation ecosystem. Most of the approaches still offer the potential to provide much higher efficiencies, much lower costs, improved scalability, and new functionality, relative to the embodiments of solar energy-conversion systems that have been developed to date [9].

II. PHOTOVOLTAIC SOLAR SYSTEM

Solar photovoltaic (PV) systems are semiconductor devices that convert sunlight into DC power by the transfer of electrons. They are a mature technology with a life expectancy of 20–30 years. The energy conversion process is divided into two stages: the generation of an electron-hole pair through light absorption in semiconductor material, and the subsequent separation of the electron to the negative terminal and the hole to the positive terminal by the device's structure to supply electricity [10].

Figure 1 illustrates how the electrical energy generated by such a solar system can be supplied into the electrical network while maintaining pre-defined quality and reliability criteria and without causing disruption to the network's normal operation. An inverter connects the PV array to the network by converting the DC output of the array PV panels to an AC output waveform that matches the voltage and frequency of the local network. It's worth noting that the system depicted in Figure 1 lacks any energy storage capability; this is the typical architecture of many contemporary grid-connected photovoltaic systems [11].

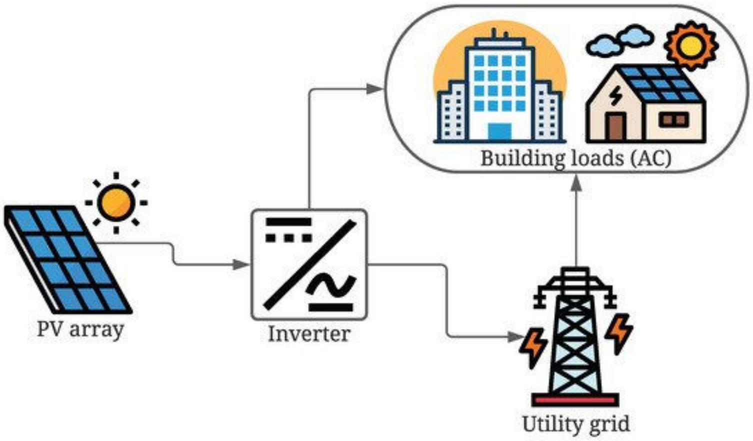

Figure 1: Layout of the grid-connected photovoltaic system [11]

III. COMMON TYPES OF SOLAR PANELS

3.1 Thin Film Solar Cells Technology

Cells Thin film solar cells are made up of micron-thick photon-absorbing material layers placed on a flexible substrate to convert light energy into electrical energy (via the photovoltaic effect). Thin-film solar cells were first developed in the United States in the 1970s by researchers at the University of Delaware's Institute of Energy Conversion. As technology advanced, the worldwide thin-film photovoltaic market grew at an unprecedented rate in the early twenty-first century, and was expected to continue to rise. Several types of thin-film solar cells are widely used because of their relatively low cost and their efficiency in producing electricity [12].

There are three main types of thin-film solar cells, depending on the type of semiconductor used: amorphous silicon (a-Si), cadmium telluride (CdTe) and copper indium gallium diselenide (CIGS). Amorphous silicon is basically a trimmed-down version of the traditional silicon-wafer cell. As such, a-Si is well understood and is commonly used in solar-powered electronics [13].

Thin-film solar cells made of amorphous silicon are the most developed. The duality is commonly p-i-n (or n-i-p), with the p-layer and n-layer mostly employed for producing an internal electric field (i-layer) made of amorphous silicon. The i-layer is typically 0.2–0.5 m thick due to the high absorption capacity of amorphous silicon. It has an absorption frequency of 1.1 to 1.7 eV [14].

A thin-film cell efficiency of 16.5 percent in cadmium telluride (CdTe) has been obtained, whereas the current record module efficiency is 10.6 percent. In 2002, CdTe accounted for 0.7 percent of global cell manufacturing, the majority of which was for indoor usage in consumer products. The efficiency of commercial modules is often less than 7%. A glass superstrate and a layer of transparent conducting oxide (TCO) as front contact, a near-transparent n-type cadmium sulphide (CdS) window layer, p-type CdTe, and a metallic rear contact make up the fundamental structure. The module is divided into cells by scribing the contact films, which are then connected in series to provide the needed voltage [15]. Cu (In1-x Gax) Se2 nanocrystalline bulk semiconductor is used as the absorber material in copper-indium-gallium-diselenide (CIGS) thin-film solar cells, which are multilayer thin-film devices. In compared to silicon wafer-based solar cells, CIGS thin film solar cells have a low-cost substrate and monolithic interconnection of individual cells in a module. CIGS have a good energy band gap, which is another advantage of this compound semiconductor. The band gap of the absorber should theoretically be between 1.0 and 1.8 eV, with 1.5 eV being the ideal value [16].

3.2 Mono Silicon Solar Cells Technology

Monocrystalline silicon solar cells, which are produced from pure silicon on thin silicon wafers, are the most common and oldest technology. Monocrystalline silicon is formed up of organized crystal formations in which each atom is perfectly aligned [17].

These cells are comprised of monocrystalline silicon in its purest form. Silicon has a single continuous crystal lattice structure in these cells, with nearly no flaws or impurities. Monocrystalline cells' main advantage is their high efficiency, which is typically around 15%. The disadvantage of these cells is that monocrystalline silicon requires a sophisticated production process, resulting in slightly higher costs than alternative technologies [18].

3.3 Polysilicon Solar Cells Technology

Polycrystalline silicon (polysilicon) is a substance made up of tiny silicon crystals that convert sunlight into electricity and is used to make crystalline silicon PV modules. Because the cells are formed in a huge block of numerous crystals rather than individually, polycrystalline panels are slightly less expensive and less efficient than monocrystalline panels. Polycrystalline has a mosaic or shattered-glass appearance due to the crystals. To construct the individual cells that make up the solar panel, the block of silicon is split into wafers, just as monocrystalline cells [19].

IV. COMMON BENEFITS OF SOLAR ENERGY

4.1 Solar Power Is Good for the Environment

Solar energy has numerous environmental advantages. Switching to solar energy will help conserve important resources, reduce air pollution, and safeguard our environment from global warming's destructive consequences. Solar panels and systems allow us to utilize the sun's clean, renewable energy while also protecting the environment [20].

Furthermore, solar energy is particularly environmentally friendly because it may decrease 40 million tons of CO2 emissions per year with the establishment of solar grids that only meet 1% of global electric energy demand [21].

4.2 Solar can Drastically Reduce or Eliminate Your Electric Bills

Solar power systems could reduce, if not eliminate, office building's electric. This money saving can have an enormous effect on large and small enterprises. Installing a solar power system means that you pay a prepayment of nearly 40 years of energy, but only a fraction of the electricity you currently pay for. Your current energy bills are probably significantly more expensive per unit than what you would spend on solar electricity [22].

These incentives reduce the effective cost of a rooftop solar panel installation for the average homeowner. A targeted discount scheme in one U.S. county resulted in 47 people installing rooftop solar panels, saving each home an estimated average of $1250 per year on their power bills and resulting in a total effective reduction of 206 metric tons of carbon dioxide emissions [23].

4.3Versatile installation

Solar energy is inexhaustible, more reliable, requires less maintenance, is silent and is more versatile as it can be installed in cities as well as in rural areas [24]. This feature, combined with the system's simplicity and adaptability, makes it easier to construct small-scale solar projects, with the added benefit of being able to scale up depending on the demands at any given time [25].

V. COMMON DRAWBACKS OF SOLAR ENERGY

5.1 Location and Sunlight Availability

The season has an impact on solar efficacy. During summer or dry season, more electricity is generated than what people really need because the earth is oriented such that the sun is closer to the Earth [26]. It is also noted that during cloudy days solar panels normally generate 30 % – 50 % of their optimum generation and during heavy rain solar panels generate 10 % – 20 % of their optimum generation [27].

5.2 High Initial Cost

The high initial cost of installation is one of the major hurdles in the development of renewable energy [28]. Solar panels would provide significant long-term benefits, but the initial expenses can be prohibitive. It could cost an arm and a leg to buy solar panels, depending on the business you choose. It is even more difficult to estimate the total cost of

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installation without the assistance of manufacturers. It could take anything from 10 to 15 years to break even on your initial investment [29].

VI. APPROACH FRAMEWORK

The proposed approach is a three-step framework. By applying the approach, renewable energy global market leaders and trends will be identified and analyzed based on: (1) economics and renewable energy policy, (2) specific renewable energy sectors that presents the most attractive investment opportunity, (3) and finally the most promising renewable energy investment vehicles for investors. Other stakeholders can also use the developed framework, such as consumers and policymakers, to make socio-economic decisions and assess renewable energy investments [8].

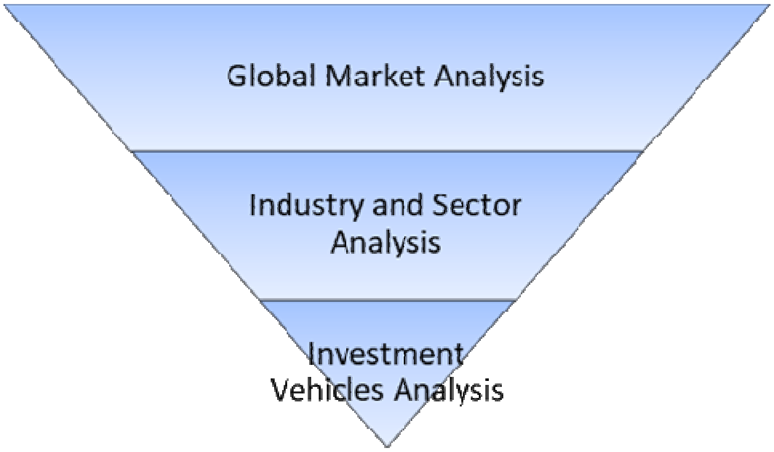

Figure 2: The proposed approach is a three-step framework [8]

VII. STATUS OF SOLAR ENERGY IN THE PHILIPPINES

According to a study by Ateneo de Manila University, renewables already account for 30% of national power generation capacity, with hydropower accounting for 16% of the total and geothermal energy accounting for 8%. However, in 2018, they accounted for 23.4 percent of total generation. Renewable Portfolio Standard guidelines, enacted in 2017, require energy companies to source or create at least 35% of their electricity needs from renewable sources by 2030, in order to meet the Renewable Energy Act's requirement that renewables account for 35% of capacity [30].

Industry appears to be moving in the same direction as these goals. AC Energy, the energy division of Philippine conglomerate Ayala Corporation, said in April 2020 that it would phase out coal investments entirely by 2030, delivering a strong message to the rest of the industrial sector about the necessity of sustainable energy. Meralco announced four months later that it would increase its energy capacity by 3000 MW over the next five to seven years, with renewables accounting for one-third of that capacity. MG D Renewable Energy is working on a 50-MW solar farm in Bulacan that is expected to be completed in early 2021 [30].

VIII. SOLAR ENERGY INITIATIVES OF PHILIPPINE HIGHER EDUCATION INSTITUTIONS

There are a few initiatives of Philippine higher education institutions in terms of solar energy implementation that could be identified. The Philippine government has also been supportive of this cause in order to advocate for access to modern energy services and renewable energy.

The La Consolacion College Manila (LCCM) has initiated its Solar Photovoltaic (PV) Net Metering Facility in 2014. The LCCM Solar Facility is the Department of Energy's first solar project for academic institutions. The installed capacity of Phase I is 42.84kW, while Phase II of the project would add 90.27kW, bringing the total capacity to 133.11kW [31]. The project aims to underscore the country's goal of energy sustainability.

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Other universities and colleges have also followed the lead of LCCM. Manuel Luis Quezon University (MLQU), St. Scholastica's College – Manila, St. Scholastica's Academy – Marikina, University of Perpetual Help, and Miriam College are among the other academic institutions that have indicated interest in a Solar PV net-metering facility on their campuses [31].

The Urdaneta City Campus, Sta. Maria Campus, Binmaley Campus, and Infanta Campus of Pangasinan State University (PSU) use more than 590,000-kilowatt hours (kWh) of electricity each year. The PSU is looking for ways to reduce the cost of their activities as well as their environmental impact. Solar energy is one viable option for generating electricity on the four (4) campuses. Both financial and non-financial benefits from the university's usage of solar were assessed through discussions and meetings. A solar photovoltaic rooftop system has been demonstrated to be the cheapest option, with a payback period of nine and a half (9.5) years and a cost of ten PHP (Philippine Peso) per kWh. From the 3,360 square meters of rooftop space that is now accessible, up to 336,000 kWh, or 57 percent of the four (4) campuses' power demand, might be produced with solar energy in 2018 [32].

Moreover, the Mariano Marcos State University has a project entitled “Renewable Energy Park Model for Education, Research and Extension Towards Agro-Industrialization and Inclusive Development”, this is to establish a feasible and viable RnE Park through R&D integration of biomass, hydro, solar and wind energy innovative technologies for a sustained, cleaner and greener agricultural productivity, strengthen MMSU faculty and staff to pursue 6P’s (product, publications, people and services, partners, process and policy) metrics deliverables on R&D under the Republic Act No. 10055-The Technology Transfer Act of 2009, To create an interactive life-long learning RETs live laboratory for students, faculty, researchers, farmers, industries, collaborators and other stakeholders; and To showcase the socio-cultural and techno-economic viabilities of RETs optimum designs, low-cost, efficient and life-cycle and impact assessment (LCIA)-based smart RETs model structures that sustain the promotion and development of institutional knowledge exchange, capacitation and development of sustainable partnerships [33].

Meanwhile, solar energy devices that use nanostructures are being pursued through collaborative approach by research groups from the University of the Philippines, Ateneo de Manila University, and De La Salle University. It focuses on solid state-based and dye sensitized-based solar cells [34].

Lastly, the Tarlac Agricultural university uses solar street lights and solar pumps for irrigation. This helps the university observe austerity measures in consuming electricity power. The establishment of solar farm in the university through public-private partnership is also in review.

IX. CONCLUSION

The sources of energy play vital roles and are required to support quality of life in practically every practical system. The speed of production of energy is a driving factor for industry and progress and a major indicator in society's improvement. It is very important to note that different types of solar panel must be identified to know the capability of each technology.

The three-step framework identified in the study is an acceptable approach in the implementation of solar energy projects and programs. However, the need to adhere to all the steps is emphasized for its effective and efficient application.

Finally, the support of government and the proactive involvement of its agencies such as the Department of Energy and the Department of Science and Technology are critical in the successful implementation and adoption of solar energy in the campuses of various Philippine higher education institutions.

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BIOGRAPHY

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Biochar from Corn Waste as Biofilter in a Recirculating Aquaculture System

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Abstract: The use of biofilter with the application of biochar technology for the improvement of water in a recirculating aquaculture system (RAS) provides a lot of advantages in aquaculture production. The research aimed to devise a biofilter system for the enhancement of TAN and un-ionized ammonia levels in a RAS using biochar from corn cobs for Nile tilapia Oreochromis niloticus production. It has five main parts: fish tank, biochar filtration tank, sediment filter, sludge filter and pump. The fish tank used is a 1 m^3 plastic cubical tank. The biochar filtration tank with a height of 85 cm and a diameter of 30 cm. The sludge filter has a height of 52 cm with a diameter of 13 cm. An electric water pump was used to recirculate the water. The system was fabricated and were able to effectively enhance the level of total ammonia nitrogen (TAN) at a rate of 0.56 ppm per hour for every 1kg biochar and 0.72 ppm per hour for the reduction of un-ionized ammonia. The devised biofilter proved to reduce the level of TAN by 9.45 ppm and un-ionized ammonia levels by 2.18 ppm in 6 hours and 30 minutes using corn cob biochar.

Keywords: Biochar, Biofilter, Recirculating Aquaculture Systems (RAS), Total Ammonia Nitrogen (TAN), Un-ionized ammonia

I. INTRODUCTION

Research and studies about biochar technology are vastly growing over the years because of its multidisciplinary approach and different applications. Biochar is a carbon- rich solid material produced by thermal decomposition of organic material or biomass in the absence or under limited supply of oxygen (Lehman and Joseph, 2009).

Ammonia and nitrite are toxic to fish. Ammonia in water occurs in two forms: ionized ammonium (NH_4^+) and un-ionized ammonia (NH_3). The latter, NH_3, is highly toxic to fish in small concentrations and should be kept at levels below 0.05 mg/l. The total amount of NH_3 and NH_4^+ remains in proportion to one another for a given temperature and pH, and a decrease in one form will be compensated by conversion of the other. The amount of un-ionized ammonia in the water is directly proportional to the temperature and pH. As the temperature and pH increase, the amount of NH_3 relative to NH_4^+ also increases. The ammonia poisoning of fish is as imminent danger in a RAS (Helfrich and Libey, 2019). With this, a biofiltration system plays a vital role in maintaining a good aquaculture water quality.

Recirculating Aquaculture Systems (RAS) has been in existence, in one form or another, since the mid-1950s. However, only in the past few years has its potential to grow fish on a commercial scale been realized. New water quality technology, testing and monitoring instrumentation, and computer enhanced system design programs, much of it developed for the wastewater treatment industry, have been incorporated and have revolutionized our ability to grow fish in tank culture. Nevertheless, despite its apparent potential, RAS should be considered a high-risk, experimental form of agriculture at this time. It can be used to culture high densities of fish annually, but its ability to do so economically remains to be demonstrated, conclusively and repeatedly (Helfrich and Libey, 2019).

With these characteristics, a potential to develop biochar from corn cobs for improving TAN and un-ionized ammonia levels in a RAS shows a potential researchable area since corn cobs are abundant in supply, low-cost, and readily available in the area. With the expansion of tilapia culture, together with the shortage of freshwater and competition of the water use into different applications, and with the growing number of human populations through the years, tilapia farming has been shifted from traditional semi-intensive systems to more intensive production systems such as the production in fish tanks and fish cages with the use of a RAS.

RAS is characterized by its ability to support extremely high stocking densities and high net production with a limited volume of water requirements. However, high stocking density will result in high fish wastes which are toxic ammonia compounds in the form of TAN and un-ionized ammonia excreted into the water and uneaten feed particles that need to be removed.

Biochar has the potential role in improving aquaculture water quality in fish culture by lowering the level of TAN and un-ionized ammonia in a RAS.

Also corn cobs has a potential media in improving aquaculture water. The use of charcoal for water purification to remove unwanted dissolved organic pollutants is well established. However, there has been limited research on the potential of biochar to improve the quality of aquaculture water in RAS for fish production. Therefore, the project will contribute to the aquaculture sector by establishing the potential of biochar filtration in improving the quality of aquaculture water specifically in reducing the TAN concentration.

II. MATERIALS AND METHODS

A. Preparation and Carbonization of Corn Cobs

Corn cobs samples were collected. Impurities and other foreign materials were removed to attain the uniformity of the samples. A pyrolytic converter was used to carbonize the corn cobs. For each batch of the biomass samples, ten kilograms (10 kg) of samples were loaded inside the kiln. Rice hulls were fed around the fuel feeder every 20 min and when the fire reached the top feeder until the samples were fully carbonized.

The biomass samples were subjected to heat with minimum presence of oxygen at an average of five hours. Carbonized samples were left inside the kiln overnight to release the heat inside the kiln and to make sure that it would not become ash when in contact with air. After carbonization, samples were crushed to achieve uniformity then sieved manually within wire mesh sizes of 1 and 5 mm to attain a 1-5 mm biochar sample size. Figure 1 shows biochar production and utilization method.

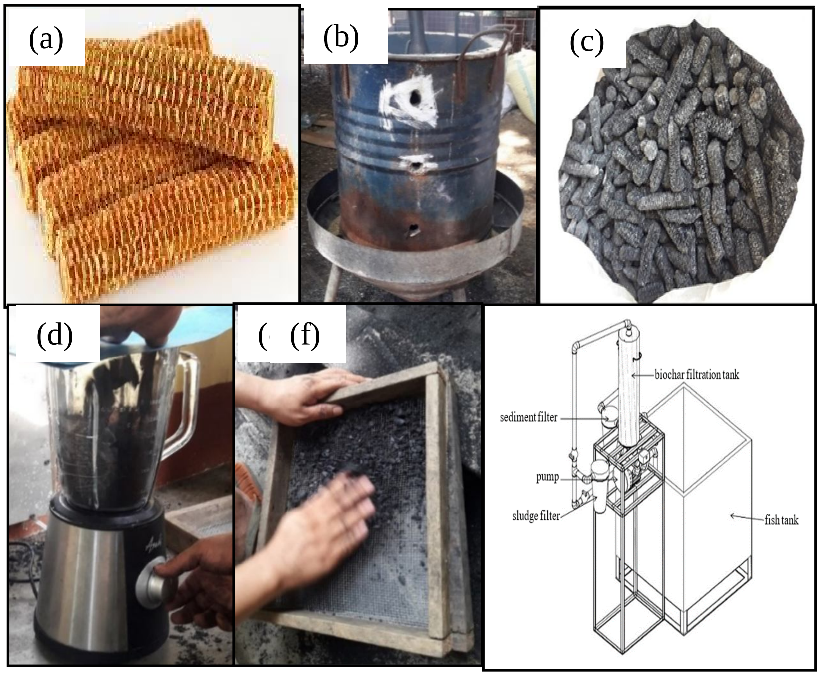

Fig 1. Biochar production and utilization (a) corn cobs (b) pyrolytic converter (c) carbonized biochar from corn cobs (d) crushing of samples (e) sieving (f) biochar filtration system

B. Devising a Biochar Filtration System in RAS

A biochar filtration system for the reduction of TAN and un-ionized ammonia, removal of the feed residues, and aeration in grow out tank was devised. The system was devised from the principle of operation of a commercial water filtration system (Figure 2). The first stage of the system aimed to remove the feed residues by suctioning the bottom layer of the tank using a water pump. After the residues were filtered, the water was then transported to the biochar container wherein the TAN was adsorbed and reduced. To avoid the black coloring of the water in the biochar container, another filter system was installed. Lastly, the filtered water was released back to the fish tanks.

The flow of water into the tank was then used as aeration in the fish tanks during the biochar filtration process. With this, there was no need for an aerator to provide for the desired dissolved oxygen level during the operation of the biochar filtration system.

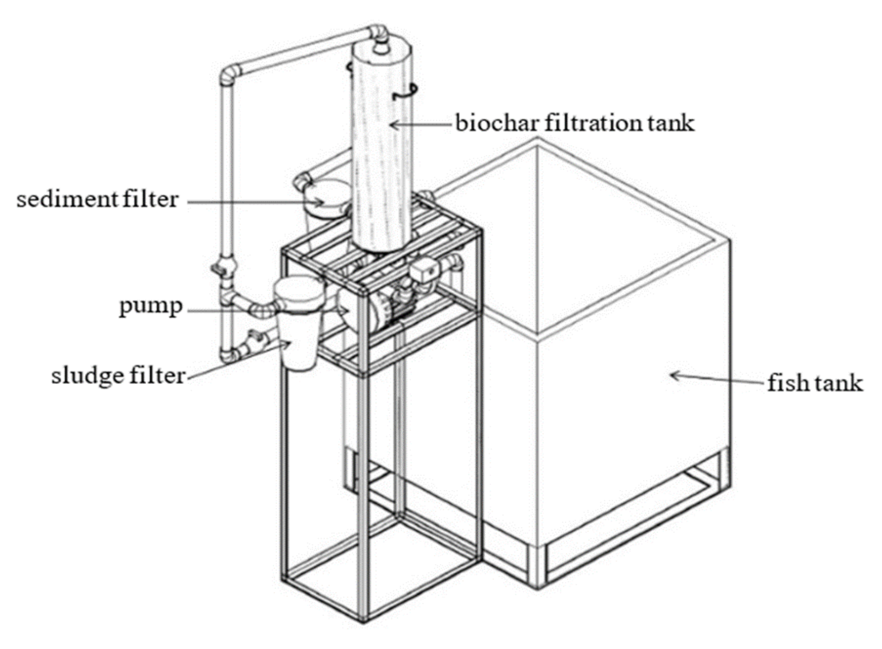

Fig 2. The biochar filtration system

C. Un-ionized Ammonia Adsorption Capacity of Biochar

Un-ionized ammonia (NH_3) which was more toxic to fish than ionized ammonia (NH_4^+) was calculated from total ammonia readings (Emerson *et al*., 1975). Total ammonia is the sum of ammonia (NH_3) and ammonium (NH_4^+) concentrations. A multi-parameter tester was used to determine the adsorption capacity of biochar in terms of the total ammonia.

D. Amount of TAN Adsorbed and Removal Efficiency using Biochar

The amount of TAN adsorbed and removal efficiency of using biochar was computed using Equation 1.

$$q_e = V/W \text{ x } (C_f - C_i) \qquad \text{(Equation 1)}$$

where: q_e - the amount of TAN and un-ionized ammonia removed ($mg \cdot g^{-1}$)
C_f - final TAN concentration, ($mg \cdot L^{-1}$)
C_i - initial TAN concentration, ($mg \cdot L^{-1}$)
V - volume of the aquaculture water in tank, L
W - weight of the biochar, g

Two basic approaches were used in interpreting the experimental results for adsorptive capacity. Nameni et al (2008) computed the percent of MB adsorbed (adsorption efficiency, %) using the formula in Equation 2.

$$\% \text{ TAN adsorbed} = [(C_i - C_f) / C_i] \text{ x } 100 \qquad \text{(Equation 2)}$$

where: C_i - initial concentration,
C_f - final concentration

E. Statistical Analysis

Paired t-test was performed for the validation of the results in an actual RAS using the devised biochar filtration systems. Comparison among treatment means was analyzed using Duncan Multiple Range Test (DMRT) at 5% level of significance.

III.RESULTS AND DISCUSSION

A. *Corn Cob Properties*

Corn cobs properties were determined by performing proximate analysis. Properties such as percent moisture, volatile combustible matter, ash and carbon content were determined to assess its quality. The higher the fixed carbon from biomass, the higher the biochar yield.

Proximate analysis revealed that the percent moisture of the corn cobs samples was 4.43 percent. Results revealed that the amount of water in biochar is within the acceptable value and much lower than the accepted moisture content of 10%. The moisture content has no effect on the adsorptive property of the biochar. Hence, if the moisture content is high, the more susceptible is the carbon to fungi growth, thus, the shelf life is reduced.

The carbon, oxygen and hydrogen component of corn cobs also known as the volatile combustible matter revealed a 14%. The result of the volatile matter is considered excellent which means that the carbonization is prolonged and at a high temperature. This also signifies that the corn cobs used is of good quality. The ash content of the biochar samples revealed that corn cob has only 6.65% which was within the acceptable values. The desirable value of ash content of activated carbon ranges from 1-20 % as mentioned by Abdul (2007). Ash content dictates the quality of an activated carbon since it reduces its mechanical strength. Corn cob has fixed carbon content of 80.3%.

The amount of TAN adsorbed and removal efficiency using biochar was attributed to thermolysis of cellulose. This cellulose or lignin is considered as the main component of biochar which formed carboxyl groups. This functional groups were the basis for the effective adsorption of ammonia (Asada, *et.al*. 2002).

B. *Biochar Filtration in a Recirculating Aquaculture Systems*

The devised biochar filtration system in RAS (Figure 3) aimed to enhance the TAN and un-ionized ammonia level in RAS. It also served as a device to take in the sludge and sediment particles from grow out tank; filter the accumulated sludge, solid particles, and sediments; and for additional aeration inside the tank during the biochar filtration process.

The biochar filtration system was composed of five main parts, namely: fish tank, pump, biochar filtration tank, sediment filter, sludge filter and pump. The fish tank used for Nile tilapia production was a 1 m^3 plastic cubical tank. The biochar filtration tank with a height of 85 cm and a diameter of 30 cm was filled with 5-9 mm gravel at the bottom, 1 kg of 5-10 mm corn cob above the gravel, and then followed by 1-5 mm of sand on top of the corn cob (Figure 4).

Fig 3. The devised biochar filtration system

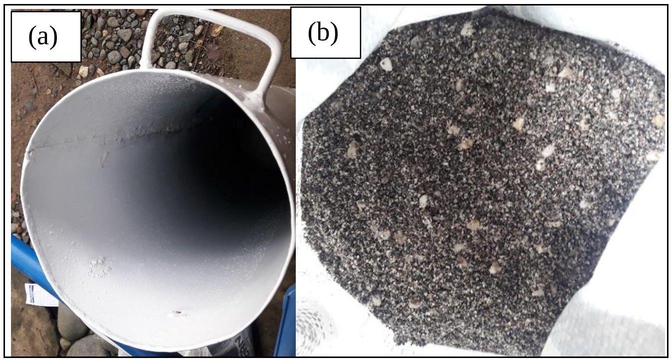

Fig 4. The biochar container (a) the biochar container (c) fine sand

The sediment filter aims to filter the sediments as well as the black coloring of the water when mixed with biochar (Figure 5). The sludge filter was used to filter the accumulated sludge and other solid particles inside the tank such as unconsumed feeds and fish excreta that settled at the bottom part of the tank (Figure 6). A sweeper/ suction pipe was connected to the filter to suck the sludge particles below the experimental tank. Also, this served as a first stage filtration so that the sludge particles were not transported to the biochar container. The sludge filter has a height of 52 cm with an inside diameter of 12 cm and an outside diameter of 13 cm.
An electric water pump was used to circulate the aquaculture water from the experimental tank, passing it through the sludge/solid filter, to the biochar filtration tank, to the sediment filter tank and lastly, to transport back the water to the experimental tank;

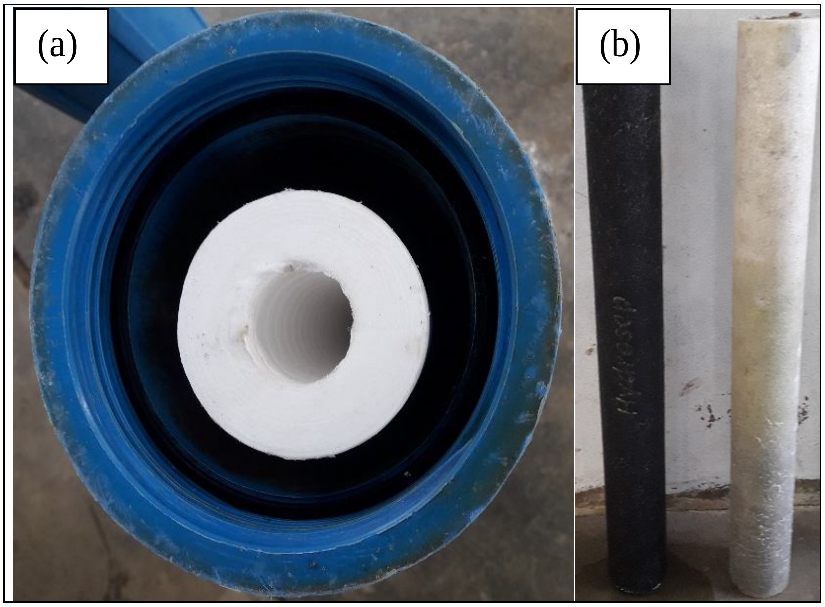

Fig. 5. The sediment filter (A) top view (B) filter media

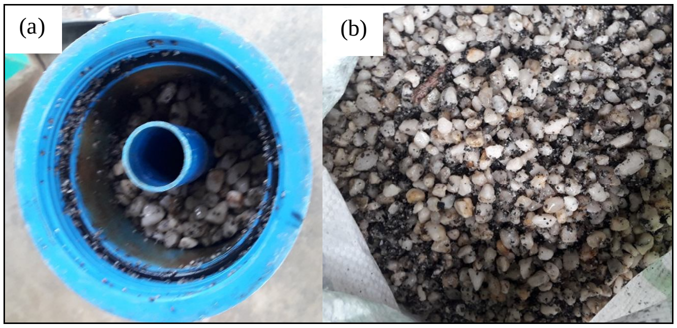

Fig. 6. The sludge filter (a) top view (b) gravel particles

C. Operation of a Biochar Filtration System

The biochar filtration system was operated by pumping the water from the RAS tank passing to the sludge filter then filled up to the biochar container wherein biochar filtration takes place. The aquaculture water was then pass through to the sediment filter then flows back to the RAS tank (Figure 7).

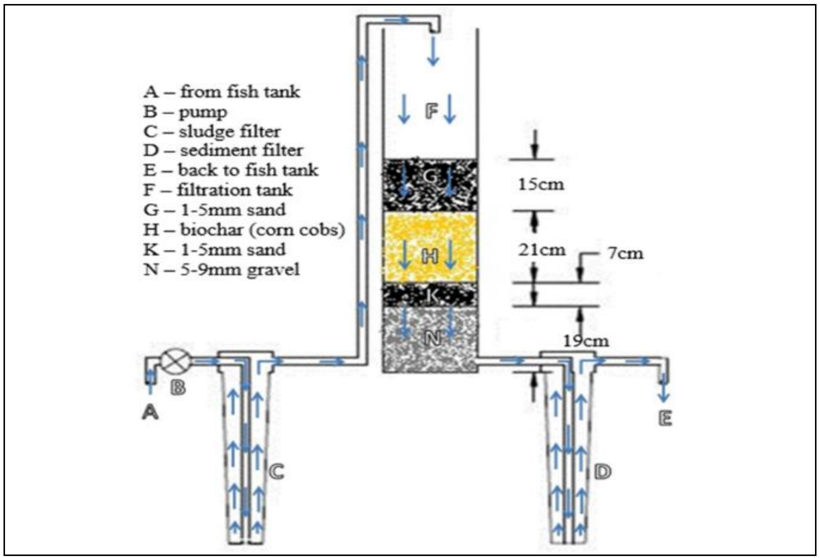

Fig. 7. Flow diagram of the biochar filtration system

D. Performance of the Devised Biochar Filtration System in a RAS

The performance of the devised biochar filtration system was evaluated through actual validation of the TAN and un-ionized ammonia reduction in an actual fish production environment (fish tank) in a RAS and was compared to the fish tank without biochar filtration.

E. TAN Reduction using the Biochar Filtration System

Results of the TAN reduction using the biochar filtration system revealed that for eight hours of operating the biochar filtration system, there is an evident enhancement of TAN in the grow-out tank. First run showed a decrease of 4.48 ppm from 6.12 ppm to 1.64 ppm. Another run showed a 4.47 ppm decrease from 5.8 to 1.33 ppm and lastly, a decrease of 3.35 ppm from the initial reading of 4.97 to 1.43 ppm (Figure 8).

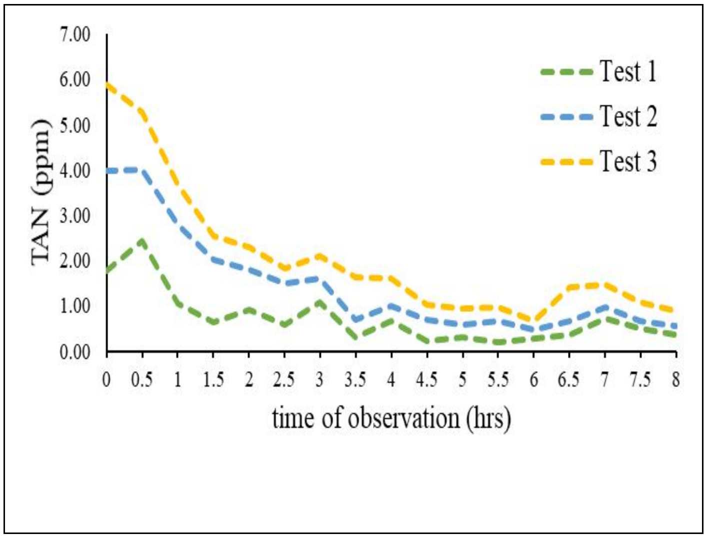

Fig.8. TAN reduction using biochar filtration system

F. Un-ionized Ammonia Reduction using Biochar Filtration System

Un-ionized ammonia reduction using biochar filtration system was calculated from total ammonia readings (Emerson, et al., 1975). Data showed that the average un-ionized ammonia levels were above the desirable level (Figure 11). The ideal un-ionized ammonia level for fish production was 0.01 ppm.

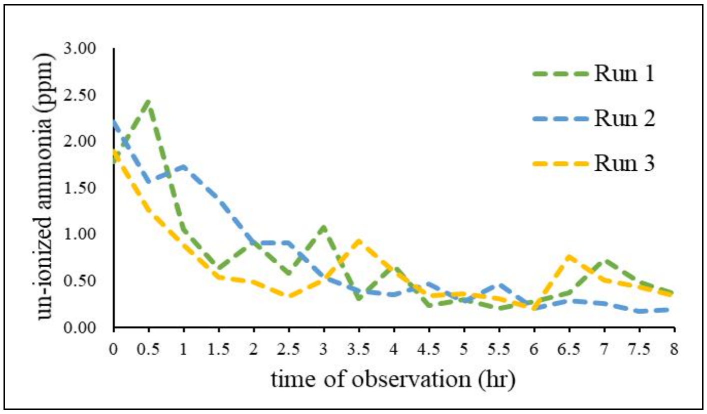

Fig. 9. Un-ionized ammonia reduction using the biochar filtration system

G. TAN Reduction at Different Stages of Biochar Filtration

The amount of TAN reduced at different filter stages was measured and evaluated. Results revealed that RAS tank had the lowest TAN reduction of 3.45 ppm after seven-hours of observation at a rate of 0.49 ppm per hour.

Time of observation (hr)	RAS Tank (ppm)	Filter 1 (Sludge Filter) (ppm)	Filter 2 (Biochar Filter) (ppm)	Filter 3 (Sediment Filter) (ppm)
0.0	4.97	5.20	5.35	5.17
0.5	5.03	4.80	3.09	3.72
1.0	4.73	4.56	3.94	3.93
1.5	4.26	4.19	3.77	3.78
2.0	4.01	3.97	2.80	3.01
2.5	3.55	3.22	2.08	2.23
3.0	2.87	2.66	1.90	1.86
3.5	2.43	2.33	1.71	1.65
4.0	2.09	1.98	1.53	1.57
4.5	2.01	1.92	1.23	1.42
5.0	1.86	1.70	1.15	1.11
5.5	1.67	1.75	1.09	1.03
6.0	1.73	1.64	1.26	1.15
6.5	1.55	1.71	1.05	1.08
7.0	1.52	1.43	1.12	1.10

Table 1. TAN reduction at different stages of biochar filtration

Biochar filtration (biochar filter) tank had the highest TAN reduction of 4.23 ppm with a rate of 0.60 ppm per hour, followed by the sediment filter of 4.07 ppm at a rate of 0.58 ppm per hour. Next was the sludge filter with 3.77 ppm at a rate 0.54 ppm per hour (Table 2). Results revealed that at the first filter (sludge), there was no significant difference on the reduction of TAN after passing through it while there was a significant difference on the second filter (biochar filter) before and after the biochar filtration. On the last filter, (sediment filter) results showed that there was no significant difference before and after passing.

IV. CONCLUSIONS

Results indicated that biofilter using corn cobs has a potential for the enhancement of TAN and un-ionized ammonia levels in RAS. It can be concluded that the percent moisture of the corn cobs samples was 4.43 percent, volatile combustible matter of 14%, ash content of 6.65% and fixed carbon content of 80.3%. The biochar filtration system successfully reduced the level of TAN at a rate of 0.56 ppm per hour for every 1kg biochar and 0.72 ppm per hour for the reduction of un-ionized ammonia in a 1 cubic meter fish tank under RAS. These results indicated that unutilized corn cobs in a biofilter can be used to mitigate the negative effect of un-ionized ammonia in a RAS.

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