A RESEARCH JOURNAL ON THE PRODUCTION OF NON- WOOD PAPER FROM AGGREGATE OF PALM AND COCONUT HUSKS

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Abstract----

The waste materials from the palm oil and coconut oil production from the palm tree and coconut tree respectively are the husks which is an embodiment of the fibre and the kernel which is the hard portion of the seeds. These waste materials are used essentially as sources of fuel, cellulosic value addition to food supply chain, combustion agents, forages, mulching agents and in the making of industrial substrates or feedstock for production processes and as such is the pulp synthesis from these wastes for the manufacture of paper in the pulp and paper industry.

The Collection of palm and coconut husks is realized from the local market in Mkpat Enin Local Government area, Akwa-Ibom state, Nigeria where they are widely grown especially in Ukam and Ete communities in the region. The palm and coconut husks are collected as wastes after the processing of the oil palm seeds and coconut to palm oil and coconut fruits respectively and they are left as agricultural wastes. The husks are properly washed and fed for milling of the feedstock so as to allow the bulkiness of the fibre to be exposed and moisture content to flow out so as to enhance extraction of the pulp from the feedstock. The method introduced in the extraction process in a bid to address the heterogeneity of the material is the depithing technique whereby the fibre extraction is improved for effective grades of paper to be realizable on the long run in the production process.

The Extraction process is going to be a synergy of crushing using a crusher so as to allow the feedstock to have a larger surface area and then steaming in a hot pot where it is partitioned for the steam to pre-treat and decontaminate it and after that where screening takes so as to remove the unwanted materials for the pulping operation in a bid to enhance its quality.

Bio-pulping is adopted in this research where lignin degrading fungi (oyster mushroom) is introduced into the chamber where so as to promote the degradation of the lignin contents of the pre-treated palm and coconut husks and expose the abundant cellulosic value of the feedstock and get it ready for high quality paper production.

As a finishing step to the pulp making, chlorine is applied to bleach the pulp produced to set it up as an intermediate product which is required in the making of paper since the pulp is an intermediate for paper making from raw materials required in the pulp and paper industry. Further steps will be done in the industry as electricity will be used to refine the pulp in the refiner unit when chemical pulping processing is adopted while mechanical pulping processing only involve subsequent steps like stock preparation (using steam and electricity), forming (using electricity), pressing (using steam and

electricity) and drying (using steam and electricity) to produce the end product called paper.

Introduction

1.1 Research Background

The demand for more sources of organic waste streaming into technological growth and development is gaining momentum on a daily basis and as such the raw materials sourced from the food supply chain is being reduced and channelled to non-edible sources to be sourced as feedstock for the diverse processes.

The palm oil and coconut oil production is vital for food chain sustainability and telling from the increasing need for food conservation for the growing populace of people across the globe which has triggered global food supply shortfall cry which has led to the need to cut down the use of food sources for industrial activities. Going by the scheme of things, calls for converting wastes to valuable products have been on the rise and one way this can be attended to is by using the husks of palm tree and coconut tree fruits to generate an industrial revolution through the production of fine grade pulp.

The production of pulp which is essential for paper making is very essential as it is the intermediate product needed to be further processed to yield paper which is the necessary item for the printing and manufacturing industries. It is required that the pulping process should take into account the residual oil in the pulp being formed at each point of production and treatment being engaged by using alkaline pre-treatment step to eradicate the oil from the pulp so that the pulp grade will be a product of high pulping efficiency.

In Nigeria, there are diverse means pulp is produced notably mechanical and chemical processes with which raw materials are usually wood based materials which have cellulosic contents that when processed will yield pulp and then paper while the lignin present in them will be removed along the line of the processing of the raw material to the final product. These lignin is termed an impurity which the depithing technique such as wood preparation like barking and chipping will expose for treatment by methods that will remove it from the feedstock using pulping methods such as bivis process for high-yielding pulping, alkaline peroxide pulping, mild acid pulping, soda-oxygen pulping and bio-pulping.

1.2 Problem Statement

With the advent of pulp and paper technology, there have been significant consumption of biomass of the ecosystem with so many terrestrial and arboreal animals being threatened occasioned by the felling of trees thereby cutting off tree barks, roots and stems which by implication causes a disruption in the population and communities of living organisms. The felling of these trees to be processed to timber and subsequently wood also calls for concern as it deprives living organisms of their shelter and nutrients. It also disrupts the carbon cycle whereby the carbon (iv) oxide in the surrounding is not utilized by these plants for photosynthesis to occur thereby reducing the oxygen available for the survival of living organisms. The atmosphere's ozone layer is further depleted by the greenhouse gases such as carbon (iv) oxide due to deforestation thereby leading to greenhouse effect. These challenges are enormous and this spurred up the need for this research to be carried as it will conserve the ecosystem and utilize the wastes of palm and coconut production.

1.3 Main Research Objective

The main research objective is to use environmental-friendly approach to produce high quality pulp for paper production in the industry using palm and coconut husks as the feedstock.

1.3.1 Research sub-objectives

The following are the sub-objectives of the research:

(a) to apply economically viable treatment steps in the processing of the feedstock to the pulp of high quality.

(b) to use feasible extraction techniques in separating the fibres for processing to pulp.

(c) to process the cellulosic content of the feedstock to pulp by degrading the lignin content using bio-pulping method.

(d) to enhance the produced pulp by bleaching it using a bleaching agent thereby giving the pulp a good surface finish.

(e) to produce paper of high quality from the aggregate's pulp.

1.4 Main Research Question

The main research question is why the fungi (oyster mushroom) is used compared to bacteria (bacillus) in the degrading of lignin from the feedstock?

1.4.1 Research sub-question

(a) Why is the steam generated by the boiling water supplied to the feedstock in the treatment vessel so as to decontaminate the feedstock of germs and microbes?

(b) Why is the depithing technique in this research done after the crushing of the palm and coconut husks and not before?

(c) What are the assurances that the oyster mushroom will effectively degrade the lignin and establish the cellulosic value of the feedstock for conversion into pulp?

(d) Will using sulphur (iv) oxide as bleaching agent of the pulp be more effective than the use of sodium hypochlorite as the bleaching agent?

1.5 Significance Of The Research

This research is to employ environmental-friendly approach in the processing of palm and coconut husks to obtain a high quality pulp for use in the pulp and paper industry. There will be a significant global warming containment and improved biodegradable effect of the pulp and paper produced using palm and coconut husks which is cheaper when compared to the conventional wood to pulp and paper that has negatively impacted the environment by increasing rate of deforestation which by implication leads to depletion of ozone layer and greenhouse effect. This research work will promote afforestation by encouraging planting of palm trees and coconut trees which will provide the much needed mechanism for the protection of the ozone layer as the greenhouse gas, carbon (iv) oxide will be effectively absorbed from the surrounding during photosynthesis. The paper quality that will be produced is of high grade and quality due to the fineness and smoothness of the palm and coconut husks thereby being a tool of economic value and consideration by these merits.

1.6 Aim(s) Of The Research

The aims of this research:

(a) To use biodegradable materials in the production of pulp for paper making.

(b) To enhance depithing technique by crushing the feedstock which is an aggregate of palm and coconut husks.

(c) To derive a lignin-free and of high cellulosic value pulp from palm and coconut husks.

(d) To employ an environmental-friendly approach such as bio-pulping method in the pulp producing process in line with the conservation of the surrounding.

(e) To enhance the produced pulp by bleaching with chlorine so as to give it an excellent surface-finish.

The hypothesis of this research:

This research is to produce a high quality pulp from agricultural wastes such as the palm and coconut husks obtained from palm tree and coconut tree respectively. The pulp that will be produced can now be sold as an intermediate product for the pulp and paper industry thereby generating income/revenue in the waste to paper concept of this research.

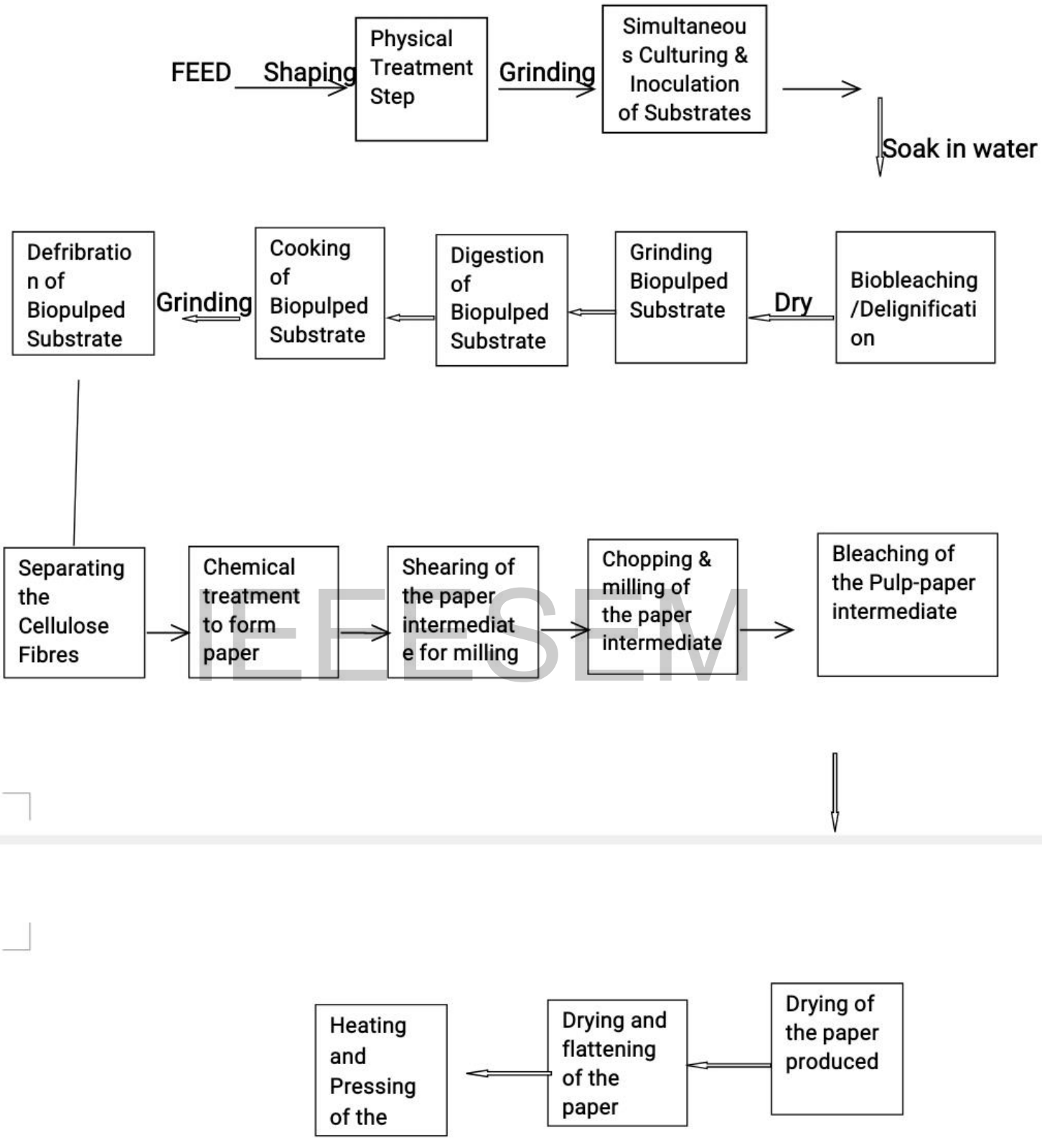
1.7 Limitations Of The Research

This research is limited to Nigeria where the cultivation of palm tree and coconut tree is prevalent and as such the continuous production of pulp from the feedstock made up of palm and coconut husks is guaranteed for the growth of pulp and paper industry.

1.8 De-Limitations Of The Research

This research is de-limited to bio-pulping method whereby the palm and coconut husks are acted upon by fungi isolates in a bid to degrade its lignin content and upgrade its cellulosic content so as to enhance the pulp quality that can be realized for the pulp and paper industry in a Nigeria.

2.2.1 Conceptual framework



BLOCK DIAGRAM OF THE PROCESS (15 PROCESS STAGES)

Materials And Methods

3.1 Materials Required:

The materials that are required for this research are as follows:

(1) Palm Husks

(2) Coconut Husks

(3) Water

(4) Containers

(5) Culture media – Garri

(6) Mushroom Spp & 7 Fungi Isolates

(7) Bleaching agent – Chlorine

(8) Four Ceramic Tiles
(9) Sodium Hydroxide (NaOH)

(10) Silica Gel

(11) Starch (Cold Water Starch)

(12) Cold Water Starch

(13) Calcium trioxocarbonate (IV)

(14) Chlorine Dioxide/Sodium Hypochlorite ($NaClO_3$)

(15) Distilled Water

(16) Cotton Material

(17) White Dye

(18) Filler

The equipment that are needed for this research are as follows:

(1) Crusher/ Mortar and Pestle/ Mallet

(2) Bunsen Burner/ Gas Cooker Cylinder

(3) Process Tank/Aluminium Container

(4) 5 Blade Chopping Device

(5) Paper Deckle

(6) Paper Mould

(7) Shearing Scissors

3.2 Method:

The Research is carried out following the underlisted steps:
Feed: The feed in this research being two coconut fruits and ninety-six palm fruits.

A. Physical Treatment Steps: The palm fruit and coconut fruit husks are obtained from the fruits by the peeling of the epicarp of the fruits using matchet and knife. Separate the coconut husk from the coconut fruit by peeling the epicarp (outermost skin) and mesocarp which is the middle portion containing coconut hard shell that encloses the edible coconut fruit and coconut water.

The palm husk is separated from the fruit by boiling water and thereafter, placing the palm kernels/fruits in the hot boiling water and boiling them together so as to soften the palm fruits squeezing the palm oil and edible portion of the palm fruits out after pounding them in a mortal using pestle. The remnants are palm fibre and palm kernel seeds. The palm kernel seeds are left behind while the palm fibre (husk) is then collected being the desired portion of the palm fruit for this research.

The coconuts epicarp and mesocarp are further treated physically by separating the epicarp from the coconut's mesocarp while the epicarp of the coconut is used as fuel or compost for economic reasons meeting the waste to wealth generation initiative.

B. Mixing of the Feed: The coconut husk is mixed with the palm husk to form an aggregate. The mixture is pounded using a mortar and pestle while 2 packs of sponge (Mushroom sponge) are transferred to an empty bowl of which hot water is added to it with the volume of the water being 2 litres of hot water. Leave for about 2 hours, remove the sponge, add 2 litres of hot water to the substrate (Coconut husk + palm husk) and leave for two hours, remove the substrate, mix the sponge and substrate together in a stainless steel plate of about 5 litres capacity. Spray randomly to the combination a handful of garri and allow for uniformity by turning the feed continuously.

C. Perforation of the Feed & Culturing: Get a thick nylon bag and make holes of about 5cm apart all through 50% volume from its middle downward, this will aid aeration and promote microbial growth within the feedstock while preparing for the culture media to be introduced into the set-up. Transfer the combination into the set-up and this combination of sponge, coconut and palm husks aggregate is now the substrate of the culture from where the microbes (fungi isolates) that are expected will use as source of nutrient. The establishment of this set-up paves way for the culturing to begin which will signal the beginning of the biopulping process of the aggregate of coconut and palm fruit husks.

D. Inoculation of the Fungi Isolates: Culturing and inoculation simultaneously begins on the set-up. On a daily basis and sometimes in-between two days, 100 millilitres of water composed of shaft of garri will be poured into the substrate while on another culture media, garri is used to make a little bit of eba meal that is tapped off and transferred to the substrate. In a time frame of 5 days, mold isolates appeared on the culture media/inoculated stream after these preparations. Appearances of the fungi isolates being brown strains, white strains, white creams, light grey strains, dark grey strains, velvet white strains of fungi – mold isolates which are the cultured mycodegradation agents that are active on the sites for inoculation that will yield to the biopulping and delignification of the feedstock.

3.3 Culturing The Fungi

Prepare garri substrate by mixing garri one cup or three handful of the garri with half steel cup (small) of water turn for effective mixing, and place on a dish for 3-4 days. Colonies of fungi will surface on the substrate.

Light grey coloured colonies	-	Rhizopus spp (Largest surface area colonies)
White then velvet with bordered white	-	Penicilium spp
White to cream mealy looking like yeast	-	Cladosporium spp
Dark grey colored Colonies	-	Alternaria spp
Woody aerial mycelium brownish	-	Mucor spp
Light blue to Light green	-	Fusarium spp

Inoculation of the substrate for paper/pulp production in the pulp/paper making Research focused dissertation

Transfer the cultured media into the substrate which is composed of palm kernel, palm fibre & small quantities of palm oil that was pulped out of the mesocarp of the palm fruit.

Mycodegradation of palm husk (135 Palm kernel recovered) to enhance pulp & paper quality from the production of the pulp/paper of which two coconut fruits and 96 Palm kernels/fruits were used to form the aggregates initially.

From the 2 Coconut fruits & 96 Palm fruits, additional palm fruits were added to aid a tougher aggregate formation bring the number of palm fruits to 135 for the biopulping process. The processed product for pulp/paper making has been synthesized using the BTMP model which is an innovative model to ensure the objective of making a scheme that will be of huge importance in paper production in an environmental-friendly way that is at the same time economically viable. The next stage will be to combine the 135 palm fruits husks that will be similarly processed using the BTMP model to get the final processed product in the combined form after which the pulp/paper making final stages will be implemented.

During the course of this research the following terminologies are adhered to in meeting standard practices such as Bio bleaching that is also the delignification process that removes the components of the feedstock that contains pigments that contains their noticeable colours that they are well known for by their consumers. Chlorine Dioxide, Sodium Hydroxide (Caustic Soda), Sodium hypochlorite, Filler composed of Calcium Trioxocarbonate(iv) will be employed to give the feedstock a whitish colour on completion of the processes involved in the research.

Factors that have been put into consideration in the research are as follows:
1.) Environmental bleaching method adopted for paper production
2.) Thermal Pulping -Huge energy requirement outlook.
3.) Chemical Pulping -Lessing Alkali with the attendant environmental concern.
4.) Mechanical Pulping -GW (Ground wood), RMP – Refiner Mechanical pulping (Suitable measures that are suited to the environmental concern raised across the globe).
5.) Bio Pulping- Culturing & Inoculation of microbes (Fungi/Micro agents) to pulp / delignify wood or non-wood plant sources which are affordable and readily available for use with the laudable biodegradable nature of the substrates.

The fungal isolates served as a good alternative & replacement to purchasing a large quantity of mushroom strains or spores which would have impacted greatly on the economy of the process as the research is geared towards having a technical economic consideration of the entire processing of the agrowastes to pulp & paper.

3.4 Paper milling operation processes.

1. Sheeting stage of the pulp
2. Chemical Additives stage

3. Drying operation to form paper intermediate
4. Shearing using a scissors to give a reduced surface area of the cellulose fibres.
5. Chopping and milling of the cellulose fibres using a five blade chopping device.
6. Forming the solution for action of the paper mould and deckle.
7. Sheeting of the paper on a cotton material
8. Leaving to dry in room temperature for three days in a bid to enhance the texture of the paper formed.
9. Treatment with sodium hypochlorite in a bid to bleach some of the papers produced.
10. Addition of a mixture of cold water starch dissolved in a solution of white bleach to give the paper a desirable whitish colour.

Modalities to achieve these operations:

- Beat the cellulose fibres + Add chemicals and sheet on tiles that act as fibreboards to dry and press with Iron so as to flatten it.
- Adopt multi-level chopping device that is a 5 blade chopping device that will give the pulp a good feed rate to the paper mould and deckle from the solution it will be made to form.
- Add chemicals & sheet on tiles, leave to dry and press using Iron for good surface finish for the paper production.
- Adopt and employ chopping, milling and paper sedimentation devices for meeting stage 3 modalities.
- Adopt and employ sheeting & pressing machine where the drying & heating operation will take place in an environment with temperature above 27^{o}C as room temperature where Nigeria is 29^{o}C to 30^{o}C.

17g of cold water starch was dissolved in 300ml of water to form a starch solution in which the cellulose fibres in the pulp are made to bind and clump together in a bid to form paper intermediates of tough and durable quality which one way to ascertain this is to establish facts telling from the porosity test that was carried out by following the procedures stated below.

- 75ml of solution was added to tiles A, B, C & D while the binding/clumping of the pulp/paper intermediates were duly observed.
- The resulting pulp is dried in the sun for heat transfer by radiation to uniformly remove the moisture.

- The drying process took about three days after which 5ml of water was poured upon the surfaces of the pulps in the four different tiles so as to establish a porosity test for the pulps in the different tiles.
- The wettability factor is drawn from the water retention rate and drying rate factor after the water upon the surfaces of the pulps.
- Pour test on the tiles is ascertained as the spread on the tiles by the water poured into the paper intermediates is observed with noticeable differences in the tiles with the tiles containing a lower water retention paper intermediates showing a heavy presence of the water spread across the surfaces of the tiles.

3.8 Refining Of Pulp:

The Pulp made from the composite of the husks of coconut and palm fruit is of short fibre make and not long fibre readily available in the conventional wood pulp both soft wood and hardwood pulp. Going by this challenge, the pulp developed from the Biopulping process

which is the novelty of this research is subjected to a refining process to smoothen, soften and elongate the fibres for paper production.

The machining (Mechanical process) for the refining of pulp in the pulp and paper industry is a huge and capital intensive one as the pulp refiner employed in the kraft and sulphite chemical process for making paper and the mechanical treatment processes is alternated with the introduction of aerobic and anaerobic fermentation of the pulp to achieve the refining of the pulp for a satellite paper production.

3.8.1 Aerobic Fermentation Of Pulp:

The pulp is poured into a 10 litre capacity stainless steel plate where the open-air fermentation of the pulp occurs in 14 days as the fermentation process was evident with foams and froths that formed due to the carbon(iv)oxide released as a result of the microbes acting on the pulp of which the fungi isolates spores leftover during the biopulping process continually promote the fermentation of the pulp with the control being the increased moisture content of the substrate leaving behind a more refined pulp which is smoother, slurry lile and elongated fibre of the pulp as the outlook at this point had a good interface for the paper production from the pulp obtained from the agrowaste feedstock. The aerobic fermentation aids the microbial actions on the surface of the pulp making it gain an advantage in terms of smootheness thereby enhancing the pulping, texturing and productivity of the paper.

3.8.2 Anaerobic Fermentation Of Pulp:

The entire plate is then covered with a circular stainless steel plate of a flat surface to enclose the substrate to now ferment anaerobically in the

absence of air which gave the already bleached pulp then change in colour from white to brownish black finish due to the intense microbial action upon the substrate.

The Anaerobic fermentation of pulp occurred in a time span of 14 days after on, the substrate was now well packed together, moisty, slurry, sticky and of longer fibre chains good enough for the making of paper going by the fact the longer fibres give better quality of paper when compared with shorter fibres of pulp that can be used also for the making of paper. The noticeable change and measure of control is the pouring of the moisture produced in the feed with the slurry being sticky and observable binding effect which is very much essential in the manufacture of paper.

For paper making, the more the pulp flows, the better the quality of paper tensile strength, capacity, binding, smoothness and texture of the paper.

3.8.3 Biochemical Treatment of the Aggregate

200ml of sodium hypochlorite $NaClO_3$ is added alongside 68g of starch that is dried to the fermented pulp for paper making. The mixture is then mixed using a stirring rod and allowed for 24 hours for the bleaching action of chlorine from $NaClO_3$ to effectively take place. After the 24hours timeline, the pulp is now bleached and at this stage becomes whitish in colour with the starch interlocking pores that might have surfaced if not for the addition of the starch with the resulting effect leaving an enclosed and non porous surface finish for the pulp-paper intermediate that is set to be transformed to paper. The temperature is maintained at room temperature, atmospheric pressure and a relative humidity that is moderate and then turned into cotton material for the cotton material to act as the paper mould as the paper will bind and form on the cotton material.

3.9 PAPER MOULDING

A cotton material is laid on a flat table, the cotton material being of 50cm by 30cm in dimension to receive the pulp and to serve as a mould.

The pulp is poured in the surface of the cotton material which is then evenly distributed across by the use of a paper deckle and filter board which makes the paper smoothening in the surface with the cotton material which turns the paper mould. The deckle and filter board are continually used to smoothen and press the paper mould and pulp together thereby resulting in a fine surface finish of the pulp-paper intermediate. The paper is left to dry for three days so as to detain off and dry the paper so as to have a thin sheet of paper left.

3.9.1 PAPER SEPARATION FROM MOULD:

The paper is detached carefully from the cotton material that is employed as the paper mould the paper is picked at the edges and then slowly raised from the

Lower part of the paper that is the portion in contact with the cotton material. The paper produced at the point is not having a perfect surface finish as there are skirmishes interlocking the layers of the paper formed across the paper fiber making the paper.

While detaching the paper from the cotton material in which there was adhesion of the paper fiber board and the cotton material. The vertical sections are raised across the four corners of the paper later on, the hand is slotted under the fiber board till all the paper are fiberboard.

Fibers are clumpy peeled off the cotton material.

3.9.2 FINISHING OF PAPER SURFACE:

The paper is placed on a flat board and sundried further for 3 days to ensure the moisture in the paper is completely dried off leaving a tougher thicker and strengthened paper. Upon drying in the sun, the paper is then transmitted in a stainless steel flat plate and placed on the top of a heating mantle for the remaining moisture to be evaporated away with care not to burn the paper so the cooked portion is immediately turned to the uncooked portion till there is an even distribution across the paper. The paper is then pressed under a pressing iron so as to smoothen the paper with the structure and texture of the paper being adequately arranged and aligned to meeting the standard of paper.

The hydraulic press is deployed on the paper with the sheeting on the paper being reinforced as the paper fiberboard getting thinner and flattened than the previous outlook of the paper formed. When the paper is fixed on the 10^{th} ends of the hydraulic press and then the adjustments begins. The desired flattening of the paper is achieved in a duration of 3 hours then the heavy masses of bodies placed on the paper for another one day duration to ensure the caking of the paper does not occur, the caking of the paper will occur while the paper is taking shape and form after the heating and pressing had taken place and this will as a result ensure the flattening of the paperpaper is maintained.

Upon receiving the paper from the press, the paper is now adequately in a desirable sheet, meeting industrial standard for paper qualityquality as it also passed passed the writing and inking test as the ink is not drained out but absorbed and pen can be used to write on it alongside correcting pen can be used to clean a writing at this point.

4. Results and Discussion

In this research, the production of pulp and paper from the aggregate of coconut and palm fruit husks which are agrowastes using starter biological method to pulp out the composite in a classical model known as BTMP (Bio-Thermo-Mechanical Pulping) model where the B stands in for Biological treatment, T represents Thermal treatment, M signifies Mechanical treatment and P stands in for Pulping in the BTMP model adopted in this dissertation. Here, the biopulping occurred after about 21 days, then the conversion to paper intermediate began with the fibreboarding/tiling of four sets of paper intermediates after the implementation of the BTMP model on the feedstock with the formation of the four fibreboards/tiles that were used for the analytical and performance index tool for the research.

The four fibreboards/tiles gave insights into the statistical performance and experimental data analytics of the study with concise reporting in a stepwise means to give information on the biopulping process of the feedstock that can be adopted for the production of pulp and paper as the industry metrics for the production line of such a magnitude of production were factored in with due consideration given to the environmental implication of the process, the costing, applicability, technical requirement, energy demand and beneficiation of the entire process.

The fibreboards/tiles were labelled Tile A, B, C and D with Tile A being reserved for the highest organic character with insight and priority given to producing a paper that will be very environmental-friendly with natural origin conservation of the paper intermediate meant for the production of paper on the tile with the chemicals added to the pulp on tile A being only starch. Tile B deviated from the organic origin conservation of tile A paper intermediate as it contained chemicals such as starch, sodium hydroxide, calcium trioxocarbonate (iv), silica gel and sodium hypochlorite with the sodium hydroxide being 10g and sodium hypochlorite being 5g in this paper intermediate, tile C paper intermediate contained starch, sodium hydroxide, calcium trioxocarbonate (iv), silica gel and sodium hypochlorite with its variation from tile B paper intermediate being sodium hydroxide with a mass of 15g instead of 10g and sodium hypochlorite being 10g instead of 5g while tile D contained starch, sodium hydroxide, calcium trioxocarbonate (iv) and silica gel with tile D containing the highest concentration in grammes per weight of sodium hydroxide with its mass being 20g and does not contain sodium hypochlorite.

After the analysis, the paper intermediates on the four tiles were subjected to further treatment as they all come out with diverse degrees of pores which is an impediment to good quality paper production and these treatments of which the paper intermediates were subjected to brought about the closure of the pores with the whitish finishing coming about by the introduction of filler that is actively composed of calcium trioxocarbonate (iv) which aided the whitening to the highest pedigree while the sodium hypochlorite bleached the paper

intermediates that it was applied on. Then the shredding of the paper intermediates followed in a bid to ensure that the spinning rate and cutting accuracy of the chopping device that ensured the milling of the paper intermediate to give the final solution in which the paper was obtained from the paper deckle and paper mould. The cotton material that served as an adsorbent to recover the paper from the paper mould was of huge significance to the study as it ensured the paper was separated from the paper mould by a chemical engineering unit operation known as adsorption which in this case, the adsorption is a solid-semi solid adsorption where the the solid medium is the cotton material while the semi solid medium being the pulp-paper solution that binded to the surface of the cotton material with the water present in the pulp-paper solution draining of the set-up thereby leaving the paper obtained to dry and the finishing process was carried with the filler application, final bleaching action and starch application to the paper obtained.

After the culturing of the fungi isolates, the inoculation stage was the successive stage whereby the delignification process began whereby data above showed how the impact of the inoculation applied on the feedstock whereby in this case, the feedstock is the aggregate of coconut and palm fruit husks reaching a significant goal of removing the lignin that binded the cellulose, hemicellulose and cellulose fibres together with the water soluble and water insoluble ends of the feedstocks to be readily discovered after the delignification process which is the biopulping itself.

Here it is ascertained that on a daily basis, the inoculation yielded the delignification of the feedstock thereby meeting the biopulping objective. The magnitude is on the strength of how much of the lignin weighted constituent was being realized on the moisture formed in the media for the biopulping, the lignin had a reddish brown outlook and was stainy in action meaning it could stain any surface due to its lubricating, binding and sticking effect.

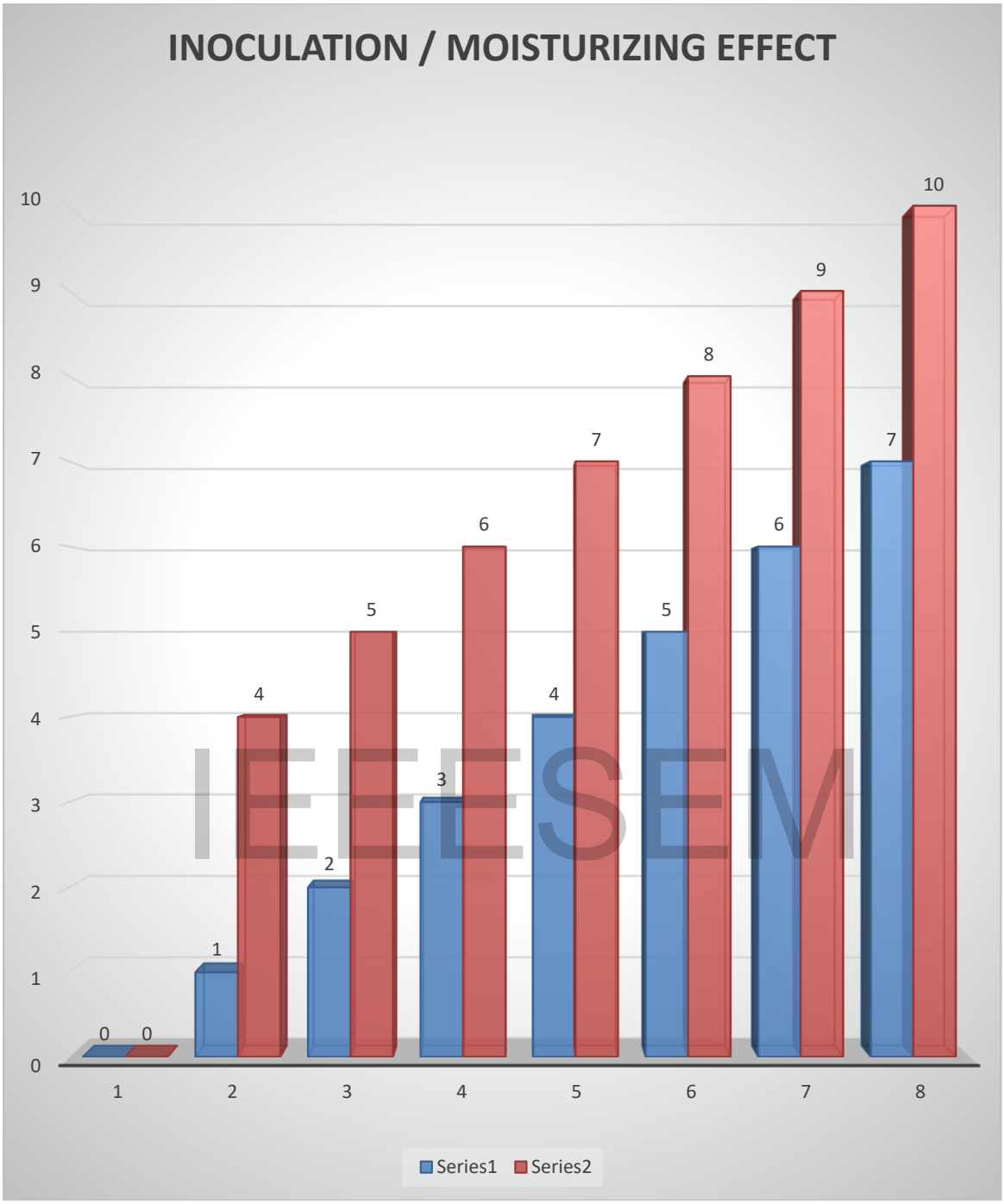


Figure 4.1: Graph showing the relationship between the Inoculation/Moisturizing effect against the Number of Days

Table 4.1: Table showing the relationship between the Biopulping Magnitude Index against the Number of Days.

Biopulping Magnitude Index	Number of Days
0	0
2	11
4	15
6	19
8	23

The Biopulping Magnitude Index is measured based on the amoung of lignin recovered after a specific number of days as the medium was perforated and the volume collected in a factor of 10 meaning 20 millilitres of the lignin recovered is shown on the graph as 2 in terms of magnitude and same goes for the other data against the days whereby it was evaluated. Thereby on the 11th day, 20 millilitres of lignin was recovered which goes as a biopulping magnitude of 2, on the 15th day, 40 millilitres of lignin was recovered which goes as a biopulping magnitude of 4, on the 19th day, 60 millilitres of lignin was recovered which goes as a biopulping magnitude of 6, on the 23rd day, 80 millilitres of lignin was recovered which goes as a biopulping magnitude of 8.

The lignin recovered indicates the efficacy of biopulping process whereby, the more the lignin collected, the more the delignification achieved which doubles as a biobleaching action as well as the pigment of the agrowastes which is containing high sulphur and phosphorus contents with the structure being densely of carbohydrate make owing to the fact that the hemicellulose, cellulose and cellulose fibres are polysaccharides just that the hemicellulose is a weaker component unlike the stronger component which is the cellulose but the lignin basically contains sulphur and phosphorus owing to its yellowish and reddish outlook respectively which on oxidation when exposed to the surrounding for

about 6 hours or more, it turns brownish and tans any object in which it is placed on.

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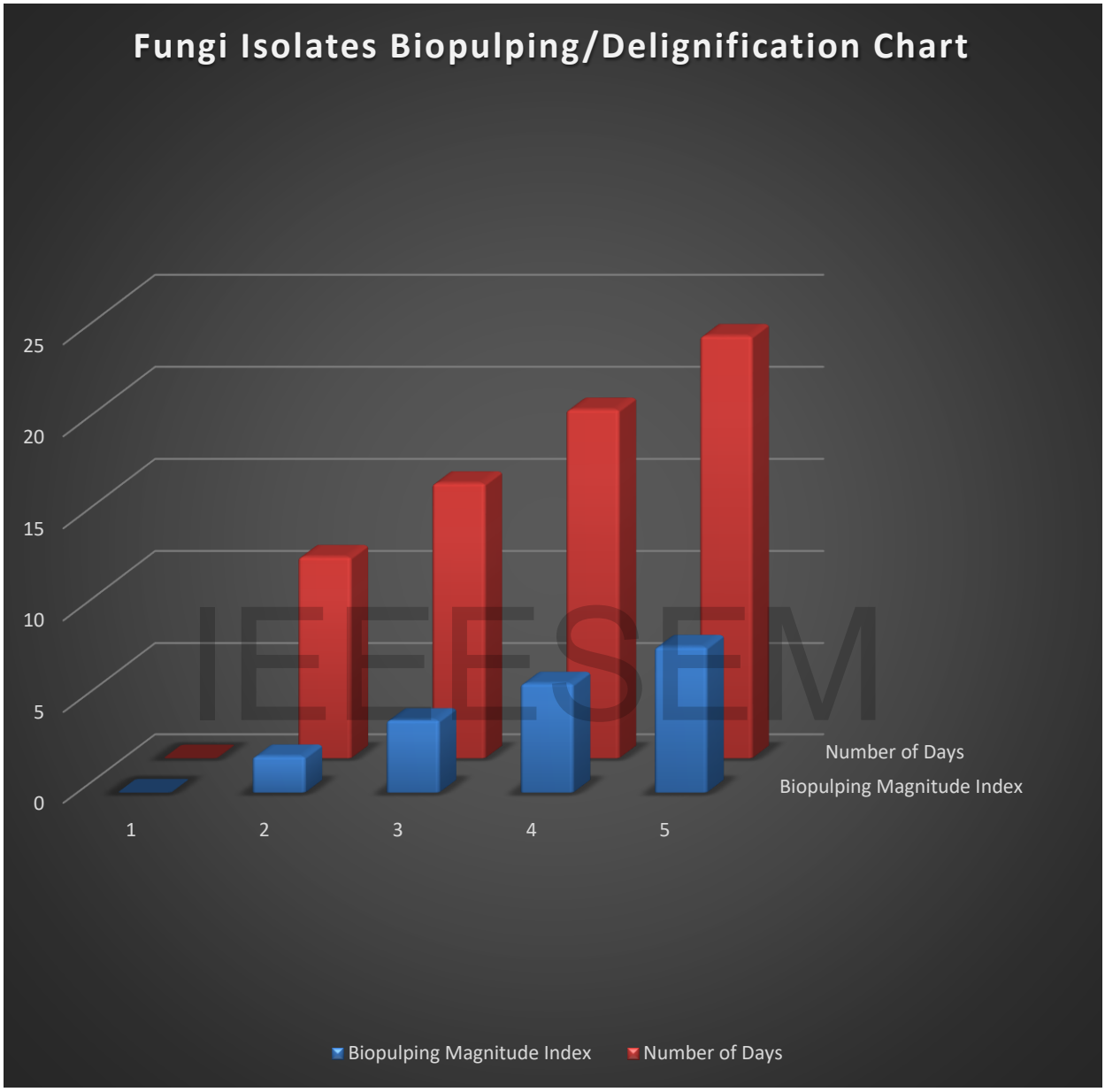


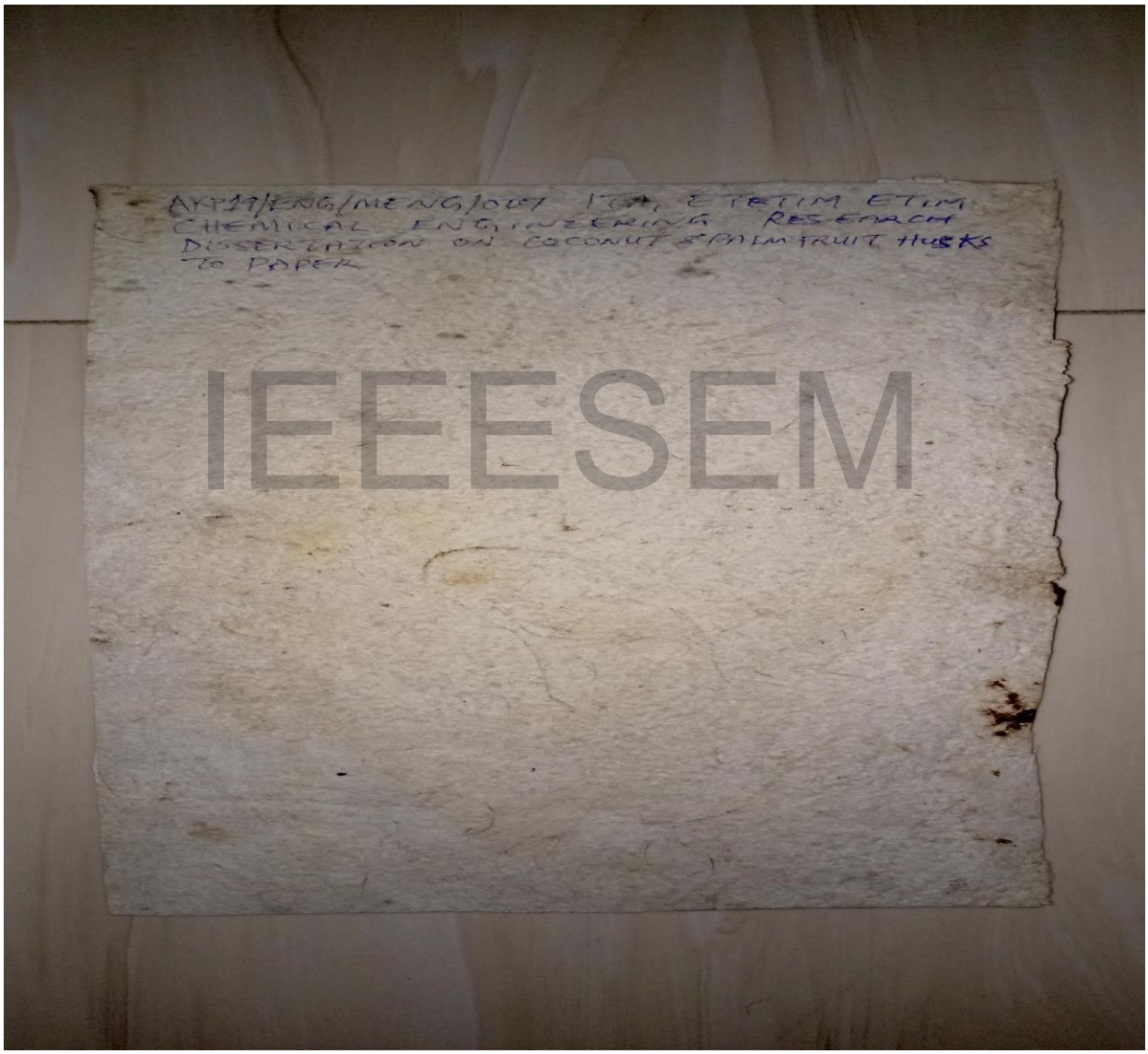
Figure 4.2: Graph showing the relationship between the Biopulping Magnitude Index against the Number of Days

The Figure above shows the biopulping effect with days serving as the performance indicator of which on the 11th day, 20 millilitres of lignin was recovered which goes as a biopulping magnitude of 2, on the 15th day, 40 millilitres of lignin was recovered which goes as a biopulping magnitude of 4, on the 19th day, 60 millilitres of lignin was recovered which goes as a

biopulping magnitude of 6, on the 23rd day, 80 millilitres of lignin was recovered which goes as a biopulping magnitude of 8.

This indicates that while the inoculation was expedited, the fungi isolates and mushroom spp serving as the mycopulping microbes were feeding on the lignin, the moisture added drained the lignin down the perforated body of the medium enclosing the media thereby giving a progressive increase in lignin formation and biopulping action witnessing a steady increase in magnitude or effect as the days were increasing for the biopulping of the feedstock to occur.

The paper produced is as shown below:



CHAPTER FIVE

5. Conclusion and Recommendation

The production of Pulp and Paper from agrowastes is a worthwhile technological advancement in that it is a waste to wealth initiative which is patterned towards tapping into the recycling and reuse drive towards technical-economic advancement of production lines as carried out in this dissertation. The agrowastes used in this study was coconut and palm fruit husks which were blended together to form a composite which served as the feedstock for the process with novel pulp and paper technology in chemical engineering innovative measures with which the conventional pulping methods such as chemical pulping, thermal pulping and mechanical pulping or their combinations were not applied in parallel or directly in this study as the biological method in the pulping which is known as biopulping was implemented with the use of fungi isolates derived from a culture medium with the nutrient being few quantities of garri. The fungi isolates were mixed with mushroom spp. so as to achieve an efficient delignification and biobleaching process where the lignin of the feedstock is broken down and separated without following the conventional means as highlighted above.

The paper produced met the standards of paper making quality as it passed the opacity, bend & fold, tensile strength, smoothness and texture tests having a positive outlook in the entirety of the papers produced with the initial porosity test laying a structure for the further treatment with filler and starch that gave an excellent pore finish with the porosity test giving a positive index as there was no observable pore after the finishing of the papers produced in the research.

The Recommendations for this dissertation are as follows:

1.) There can be another means of carrying out the biopulping process as the one done in this research was mycobiopulping since fungi isolates were used thereby other micro-organisms such as bacteria, protozoa etc can be used and checked for the degree of delignification that can be realized while considering the cost and operational impact of the means. The operational cost and time constraint of the research can be optimized in future studies pertaining to the production of the pulp and paper as carried out in this dissertation.

2.) The entire process can be experimented with a pilot plant from the raw materials physical pre treatment stage to the paper synthesis stage and a positive outcome can be adapted to the development of a non-wood engineering design and fabrication of equipment that can will be used to run processes involved in this dissertation for a non-wood sources to paper production era thereby conserving the ecosystem and ensuring that the bionass is not threatened consequently reducing global warming effect of deforestation that largely contributes to greenhouse effect as greenhouse like carbon (iv) oxide is not trapped for photosynthesis when plants are destroyed during deforestation.

REFERENCES

1.) FDA (2014). ‘‘Code of federal regulations title 21,’’ Food and Drug Administration, (http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm?fr=176.170).

2.) Mohamad Jani, S.,and Rushdan,I.(2014). ‘‘The effect of bleaching on coconut coir pulp and paper properties,’’ Journal of Tropical Agriculture and Food Science 42(1), 51-61.

3.) Nor Mazlana, M.,Rosnita, T.,Rushdan, I., Russly, A.R., and Ainun Zuriyati, M (2014). ‘‘Suitability of coir fibers as pulp and paper,’’Agriculture and Agricultural Science Procedia 2, 304-311.

4.) Nurul Husna, M.H., Suhaimi, M., and Rushdan, I. (2013). ‘‘Effect of soda-anthraquinone pulping conditions and beating revolution on the mechanical properties of paper made from gigantochloa scortechinii (semantan bamboo),’’The Malaysian Journal of Analytical Sciences 17(1), 75-84.

5.) Yao, J., Hu, Y., and Lu, W. (2012). ‘‘Performance research on coir fiber and wood debris hybrid board,’’BioResources 7(3), 4262-4272. DOI:10.15376/biores.7.3,4262-4272.

6.) B.Agbor, V.et al.,2011. Biomass pretreatment: Fundamentals toward application. Biotechnology Advances, pp. 675-685.

7.) BillerudKorsnas, 2015. BilleruKorsnas. [Online] Available at: http://billerudkorsnas.com/About-Us/ [Accessed 11 02 2006].

8.) Fonseca, M.I.et al.,2014. Biopulping of wood chips with Plebia brevispora reduces lignin content and improves pulp quality. International biodeterioration and biodegradation, Volume 90, pp. 29-35.

9.) K.Via, B.et al ., 2014. Near Infrared Spectroscopy Calibration for wood chemistry: which chemometric technique is best for prediction and interpretation?. Sensors, Volume 14, pp.13532-13545.

10.) Kong, Q.et al., 2015. Near Infrared detection of straw cellulose by orthogonal signal correction and Partial Least Squares. International journal of multimedia an ubiquitous engineering, 10(5), pp. 255-262.

11.) L.M., Hayes, D.G., Wmac, A.R & Labbe, N.,2010. Simplified determination of lignin content in hard and soft woods via UV-spectroscophometric analysis of biomass dissolved in ionic liquids. Bioresources, 5(3), pp. 1366-1383.

12.) Laftah, W.A & Rahaman, W.A.W.A., 2015. Chemical pulping of waste pineapple leaves fiber for kraft paper production. Journal of materials research and technology, 4(3), pp.254-26.

13.) Metrohm NIR System, 2016. Application of lignin in wood pulp, s.l.: Metrohm NIR System.

14.) Rinnan, A., 2014. Pre-processing in vibrational spectroscopy- when, why and how. The Royal society of chemistry, Volume 6, pp.7124-7129.

15.) Shuttleworth, M., 2016. Explorable. [Online] Available at: https://explorable.com/different-research-methods [Accessed 12 02 2016]