Journal of Materials and Environmental Science
ISSN : 2028-2508
e-ISSN : 2737-890X
CODEN : JMESCN

J. Mater. Environ. Sci., 2023, Volume 14, Issue 6, Page 656-670

http://www.jmaterenvironsci.com

Effects of polyvinyl acetate matrix composites on the mechanical behavior of water hyacinth pulps

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Received *11 May 2023,*
Revised *28 June 2023,*
Accepted *30 June 2023*

Keywords:
- *water hyacinth;*
- *polymer matrix composites;*
- *pulps loading;*
- *mechanical behavior;*
- *polyvinyl-acetate*
  Biodegradable-paperboard
  Hand lay-up method

Citation*: Wembe B. D., Djomi R., Konai N., Ntamack G. E. (2023) Effects of polyvinyl acetate matrix composites on the mechanical behavior of water hyacinth pulps. Development, J. Mater. Environ. Sci., 14(6), 656-670.*

Abstract: This project intends to refine water hyacinth (WH) paperboard with various polyvinyl acetate (PVA) percentages to create a material composite that is suited for various applications. Eichhornia crassipes, an aquatic plant with a rapid rate of development that typically covers the surface of rivers, has an effect on the environment. In order to do this, water hyacinth stalks pulp was used to create six samples of paperboard composites. In order to determine the adhesive strength of the fibers, this study intends to analyses the mechanical, physical and morphological characteristics of pulps made from water hyacinth and reinforced with white polyvinyl acetate. The composites' fiber bonding capabilities were assessed. Polyvinyl acetate glue varies in different grammes (F+0g, F+2.5 g, F+5g, F+7.5g, F+10g, and F+15g), with a 50g water hyacinth paste were kept constant. Compared to 0g PVA paperboard, the mechanical characteristics of paperboard composites were greatly enhanced. The binding strength and drying time of the composites were greatly increased by adding more polyvinyl acetate to them. At drying temperatures of 180°C, this huge improvement was especially apparent. This finding was interpreted as crucial background data for engineers working to increase the competitiveness of their biodegradable materials, particleboard, packaging, insulation materials (automotive, building), furniture made from biocomposite materials, and paper products, as well as for researchers looking to advance the state of the art. They can replace pulp production, which would otherwise result in lessening the deforestation caused by pulp production from cutting down trees. The created composite showed noteworthy mechanical and morphological qualities.

1. Introduction

The aquatic invasive plant known as water hyacinth (Eichhornia Crassipes), which is native to the Amazon,is being spread by people through horticulture in tropical and subtropical areas. (Holm L G *et al*, 1977) (Gopal, B., 1987). These plants are intriguing for a variety of applications due to their unusual mechanical characteristics. Water hyacinth, which is growing quickly in Cameroon, is encroaching on rivers. Because it results in the extinction of several flora and fauna species, it is a significant barrier to the production of power, irrigation, and biological diversity. The Cameroonian Ministry in charge of the environment integrated mechanical and chemical control in 2016 to remove water hyacinth, but the plant is still spreading. (joseph antoine njanda tchouyou, 2017) Water hyacinth for parchment paper (Erlinda, L. Mari ., (2012)). Paper is a product created from plant cellulose fibres, thus the Latin word papyrus. Each variety of paper is distinguished by its mass, gramme, water content, production, and finish, which determine its transparency, visual appeal, and other properties. (Sarah, 02-Aout-2019). Paper production and pulp making are still on the increase all over the world. (Sridash, W., 2010) Papers have a vast usage in packaging writing etc. (Ogunwusi, A. A. and Ibrahim, N. D., 2014).There are a lot of problems associated with paper making and pulp production from wood, which include deforestation, high energy consumption, increase global warming (Casey, P., 1980) (Gielen, D. and Tam, C., 9th October, 2006.) it also accounts for huge pollution of air and water (Gielen, D. and Tam, C., 9th October, 2006.) Due to the unique properties of polymers, such as their excellent damping qualities, resilience, peak strength to weight ratios, and stiffness to weight ratios, polymer composites are used in a variety of industries, including aerospace, automotive accessories, structural members, and anti-vibration applications. Typically, a polymer matrix and reinforcing filler make up a polymer composite. These are light, affordable, and readily available materials in the area. (Pickering, K.L., Efendy, M.A. and Le T.M., 2016,) (Oksman, K., Aitomäki, Y., Mathew, A. P., Siqueira, G., Zhou, Q., Butylina, S., ... & Hooshmand, S., 2016) ; (Lamhamdi et al. 2014). Natural fibers are biodegradable, renewable, environmentally friendly, non-toxic, and locally available. Besides, they have low density, high performance, and low cost. (F.Z. Arrakhiz, M. El Achaby, M. Malha, M.O. Bensalah, 2013,) Using wood extensively can result in environmental issues like deforestation, flooding, and global warming. Researchers have concentrated on locating other renewable resources to replace the usage of wood for some uses in order to address these issues. There are various non-wood resources that could be used to make pulp and other wood-based products. By substituting other cellulose source materials, such as biomass, the intensive use of wood as the primary source of cellulose can be reduced. In this study, water hyacinth, a free-floating aquatic macrophyte that typically grows to a height of 0.5 metres, was examined. During the wet season, it can develop and spread quickly. The water hyacinth is seen as an unwelcome plant and a nuisance. Water hyacinth has produced a number of issues due to its quick growth and spread, including the decline in fish populations, extensive coating of river surfaces and canals, blockage of irrigation systems, and water pollution. Due to its fast development, efforts to control or eradicate the water hyacinth are labor- and labor-intensively expensive.

Based on research conducted by (Pasaribu and Swahlita, 2007), It is well known that fresh water hyacinths have a 94.25% moisture content and a 3.6% dry pulp yield. A 1m2 area contains 28 kg of fresh water hyacinth, the majority of which (84%) is stem. Low in lignin (10%), water hyacinth has significant levels of cellulose (60%) and hemicellulose (33%). Currently, water hyacinth is utilised for compost and crafts. (Gunnarso,C,C. and Petterson,C,M. ., 2007). Recently, bio-board was successfully constructed using bagasse (waste from sugar cane production), rice straw, wheat straw, and corn straw. Water hyacinth fibre (WH) is a watery so that grows in the river Wouri area of Douala. It springs from the water's roof. It stops oxygen from entering the water, causing the level of dissolved oxygen to fall below the legal limit and resulting in water pollution. In numerous investigations, WH was employed as a reinforcing filler in a polymer matrix, such as polyester, polypropylene, and thermoplastic starch. They concluded that the composites' mechanical characteristics were improved by the low WH content. (Flores Ramirez, N., Sanchez Hernandez, Y., Cruz de Leon, J., Vasquez Garcia, S. R., Domratcheva Lvova, L., & Garcia Gonzalez, L, 2015) (M. Saha,, 2011) Poor adherence among natural hydrophilic fibers and the hydrophobic polymer matrix results in the poor compatibility of polymer matrix with fiber and minimize mechanical strengths and ductility (Maamoun A, El-Wakil A, El-Basheer TM. , 2022). Many studies can enhance the interfacial interaction between WH and polymer matrix using coupling agents and grafting polymers. (Supri A. G. and B. Y. Lim, 2009,) (A. G. Supri, S. J. Tan, H. Ismail & P. L. Teh, 2011) Aircrafts technology was the pioneer application of fiber reinforced polymers (Nickel J, Riedel U., 2003). Yet, these materials are now being used in a variety of disciplines, particularly in those that call for lightweight materials with high stiffness and strength. Natural fibre polymer composites are being used in increasingly sophisticated ways in the realm of vehicle engineering. (Ilyas RA, Sapuan SM, Ishak MR, Zainudin ES, 2019). Besides that, the rising demands for the advanced materials with tailored physical and mechanical properties made the nanocellulose, which has natural fibers origin as the most attractive nanomaterial for high-performance applications (Ilyas RA, Sapuan SM,, et al, 2019). The nanocellulose reinforced various polymer composites and their manufacturing techniques (Ilyas RA, Sapuan SM,et Al, 2018;). Biocomposites are composite materials comprising of one or multiple-phase materials that are originated from nature (A.AjithramaJ.T.Winowlin Jappesb I.et al, 2022). Plant fibres including cotton, flax, and sugar palm fibre are among these materials. Since it is a desirable option from an ecological and financial standpoint, using WH as a reinforcing material in polymer composites. One of the main goals of this work is to investigate the impact of WH on the creation of paperboard as well as to identify the physical characteristics of paperboard, such as moisture content, density, and mechanical behaviour (tensile stress & bending stress), which were confirmed with 5 different polyvinyl acetate loadings that gave rise to various mechanical properties of paperboards. Cutting, milling, and soaking pulp with varying composites of (0g, 2.5g, 5g, 7.5g, 10g, and 15g) is how WH paperboard is made, and the paperboards were successfully produced under test conditions. We came to the conclusion that WH fibre is one of the good natural fibres that can be used as a reinforced material for the creation of polymer composites for various purposes based on the qualities of the Water Hyacinth fibres that were obtained. (R.A. Ilyas,S.M. Sapuan, 2020,), while saving the cost required managing agricultural waste. (M. R. Sanjay,G. R. Arpitha,et Al, 2016)

In this study, paperboard composites were successfully created, and we now need to figure out how independent variables like density, water absorption, tensile strength, moisture content, and surface morphological traits affect the pulping of the composites made from water hyacinth.

2. Materials and Methods

2.1 Extraction of WH fiber and Elaboration of the composites (Figure 1)

2.1.1. Method of obtaining the composites specimen

Inside the Wouri Estuary (BONABERIE) area, WH plants are located and identified before being collected. The roots and leaves of those plants are taken out after collection. We harvested the plant's fibres using the stalks. The retting technique process involves the extraction of fibres. But the retting procedure cannot be carried out here. (N. Supatata, J. Buates, P. Hariyanont, 2013). Only a small number of fibres can be extracted chemically using hot water, and the quality of the fibre is greatly impacted. With the aid of a 1/2 HP electrical motor, at least one mechanical extraction machine is constructed, and plant fibre is successfully removed from the plant stalks. Below shows the steps involved in extracting papers from water hyacinth (Eichornia crassipes) (Figure 2). It is easily explained by a schematic diagram that shows the extraction of WH fibre and the chemical formula for the reinforced PVA matrix. ($C_4H_6O_2$), made in Italy under the trade name DURABOND, has the following specifications: Molar mass: 86.09 g/mol per unit; Density: 1.19 g/cm3 (25 °C); Boiling point: 112 °C (234 °F; 385 K). After conducting mechanical and absorption tests in accordance with ASTM standards.

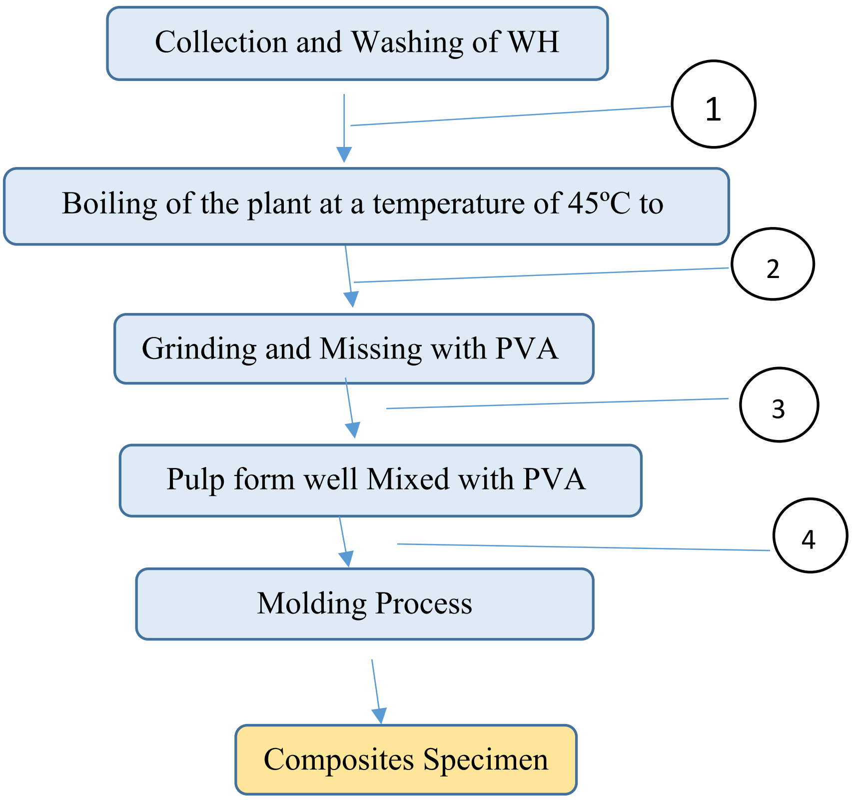


Figure 1 Schematic structure of obtaining Paperboard composite PVA[Authors]

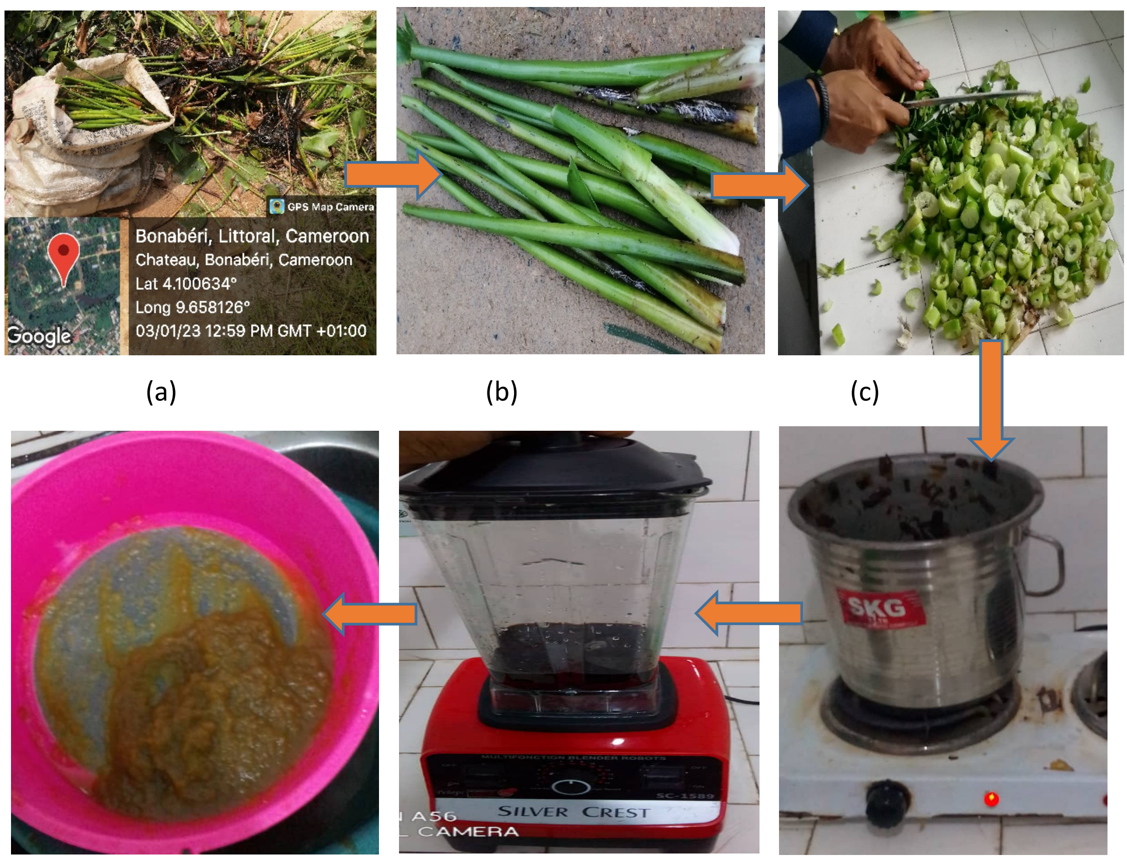


Figure 2. Process of obtaining paper from water hyacinth [Authors]

The most often used kind of wood glue is polyvinyl acetate (PVA), a vinyl adhesive also known as "white glue," "hobby and craft," or "school glue." PVA is non-toxic, PH neutral, affordable, and simple to use. Even after curing, PVA is still malleable but flows when subjected to continual strain. Because most glues (including PVA itself) do not bind well to cured PVA glue, joints that have previously been bonded with PVA might be challenging to repair. Although Type 2 PVAs are water resistant, PVA adhesives themselves are not waterproof.

2.2 Physical and Mechanical Measurement

The individual weighing operations were carried out using a 0.001mg precision balance. Each test was carried on the paperboard's composites.

2.2.1 Areal Density of paper composite

According to the ISO 536:2019 regulations, the apparent density Dp of composite papers was computed by dividing the mass by the volume as given in equation (I). These standards enable the gravimetric approach based on the Archimedes principle to evaluate bulk density. First, the mass of the fiber M_p that had previously spent 24 hours drying at 50 °C was determined. These papers' volume VP dimensions are measured in order to create the samples. The length, width, and thickness of the paper were measured in order to determine the volume of the sample Vp. The test's goal is to establish the relative thickness of the two categories of sheets made from water hyacinth stem pulp. To accomplish this, we use a micrometre to measure the thicknesses at five spots on a rectangular piece of paper that was specifically cut and drawn for this purpose. We then use equation to determine the average thickness (2).

$$Dp = \frac{Mass\ of\ paper(Mp)}{Volume\ of\ paper(Vp)} \quad \text{(Eqn. 1)}$$

$$e_m = \frac{1}{5}\sum_{i=1}^{5} e_i \quad \text{(Eqn. 2)}$$

2.2.2 Moisture content

The moisture content of paper water hyacinth (MC) was can be determined from equation (2) (Nadlene, R., Sapuan, S.M., et Al, 2015). Samples with a mass of Mt were kept at room temperature (25 2 °C) for 24 hours with a relative humidity of 75%. Moisture is a phrase used to describe a liquid's vapour phase, particularly water. After condensation, moisture might appear either distributed within a solid or on a surface. The moisture content is often relatively low. The presence of airborne water vapour is a nice illustration of wetness. Chemical titrations are one of the other techniques for figuring out how much water is in a sample. (for example the (Fischer, Karl , (1935)), determining mass loss on heating (perhaps in the presence of inert gas), or after freeze-drying. From the Annual Book of ASTM (American Society for Testing and Materials) Standards, the total evaporable moisture content in Aggregate (C 566). The hydrophilic character of these papers favors the absorption of relative humidity from the air of the paper [(Baley, C., Le Duigou, A., Bourmaud, A. and Davies, P., 2012)]. Finally, the Samples were dehumidified in an oven set for 24 hours, and the final mass M_p of each sample was measured can be calculated with the formula:

$$\%MC = \frac{(Mt - Mp)}{Mt} \times 100 \quad \text{Eqn. 3}$$

2.2.3 Effects of water absorption

Because WH fibers are hygroscopic, they easily absorb water. This makes it difficult for paper to interact with water-based liquids. This can be taken into account on a variety of scales, including the microstructure of fibers and the entry of water into disorganized pore networks. The ratio of absorbed water divided by the mass of oven-dried paper TAPPI 441 determines the paper's moisture content (2007). The moisture content of paper in equilibrium with the surrounding air relies on the relative humidity of the air and the equilibrium temperature and can be calculated using the proper thermodynamic laws. (Prahl J M, 1968).

2.2.4 Mechanical testing

There haven't been many tests done to evaluate the mechanical qualities of composites made of paperboard. The ISO standard testing procedure was used for all tests. Tests for tensile strength, burst strength, and tearing index were performed in accordance with ISO Standards 1924-2: 1994 (E), 2758: 1983 (E), and 1974: 1990 (E), respectively. The two ranges of paperboard composites manufactured from water hyacinth stalk pulps are tested to assess their Young's modulus, mechanical strength, maximum deformation, and average tensile index (Figure 3). Using a universal testing device that measures and records the tensile force as a function of the specimen's elongation, a specimen is stretched until it ruptures at a consistent speed. The average tearing force (in mN) needed to propagate the initial tear to a full rupture was recorded as the tear resistance (F_R). (Yamauchi T, Tanaka A, 2002) The tear index (T_I) was evaluated. During the test, the Test Master software plots the curves and calculates all test parameters.

$$\sigma_m = \frac{F_m}{S} \; ; \; \varepsilon_r = \frac{A_r}{L_i} \times 100 \; ; E = \frac{R_e}{\varepsilon_e} \times 100 \; ; I = \frac{F_m}{L \times G} : T_I = \frac{F_R}{G} \qquad \text{Eqn. 4}$$

With: F_m(N) is the maximum tensile force of the paper, S(mm^2) is the cross sectional area of the specimen, A_r(mm) is the measured elongation at break of the paper, L_i (mm) is the initial length of the specimen (here 150 mm),$Re = \frac{Fe}{S}$ (MPa)is the yield strength of the specimen,$\mathcal{E}e$ (%) is the elastic deformation of the specimen, G (g/m^2) is the weight of the paper (see weight report),E(MPa) is the modulus of Young's modulus,ϑm (MPa) is the mechanical tensile strength, I (N.m/g) is the tensile strength and $\mathcal{E}r$ (%) is the maximum deformation of the specimen.

Figure 3. paperboard composites prepare to measure Mechanical properties

2.2.5 Morphological Characterization

The scanning electron microscopy (SEM)was performed to examine the physical structure change of various samples using SEM model Phenom Prox, by Phenom Word Eindhoven, The Netherlands. Samples was placed double adhesive which was on a sample stub, was coated sputter coater by quorum technologies model Q150R, with 5nm of gold. Thereafter it was taken to the chamber of SEM machine where it was viewed via NaVCam for focusing and little adjustment, it was then transferred to Sem mode, was focused and brightness contrasting was automatically adjusted afterward the morphologies of different magnification was store in a USB stick.

3. Results and discussions

After the sample preparation process, six water hyacinth composites were successfully produced under experimental conditions, shown in Fig. 2, and different analysis was performed.

3.1 Areal Density or Grammage

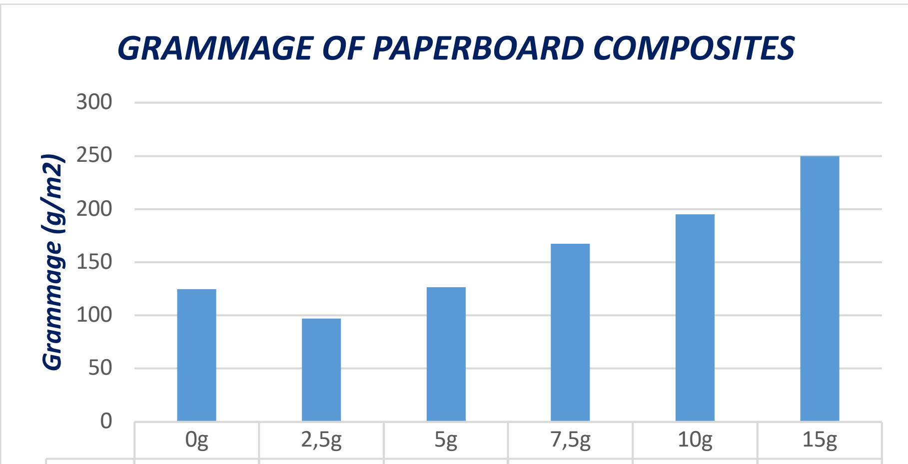
The test's objective is to establish the weight of six distinct types of paperboards manufactured using PVA and WH stem pulp. A square piece of paper is traced, then dried for 24 hours at 60°C in a ventilated oven. The samples are then placed in a hygroscopic chamber with a relative humidity set at 65%. The samples are taken out of the hygroscopic chamber after 24 hours and weighed using a 0.001 g precision balance. a sample of a standard from the ISO 536 collection

$$G = \frac{m}{S} ; \quad Eqn.\ 5$$

where m (g) is the mass of a section of paper; S (m^2) is the cross-section of the test piece and $G\ (g/m^2)$ is the weight of the paperboard composite.

Effect of WH pulps proportion on Areal Density and Thickness

The areal density and thickness of the nonwoven fabric are affected by the amount of the fibre blend, as shown in Figure 4. It is evident from the figure that an increase in the percentage of water hyacinth fibre tends to increase the areal density and thickness of the nonwoven fabric. The electronique balance clearly demonstrates a linear link between the proportion of water hyacinth fibres in the mix and the nonwoven's areal density and thickness. The increase in sample thickness combined with an increase in the water hyacinth fibre mix proportion results in a reduction in the bulk density of the nonwoven fabric. Consequently, it can be said that the physical characteristics of needle-punched nonwoven textiles that change simultaneously as a result of the needling operation are areal density, thickness, and bulk density (Nazire Dniz Yilmaz, Pamela Banks-Lee et Al , 2011). Polyvinyl is also known for its excellent removal of blue basic dye from wastewaters ()



	0g	2,5g	5g	7,5g	10g	15g
Gram	124,576012	97,3796955	126,797386	167,743791	195,198594	249,966082

Figure 4. The Values of Grammage of paperboard composites

3.2 Water Absorption

Water absorption characteristics of the paperboard composites against fiber loading are shown in Fig.5. In general, water absorption (%) increases with fiber loading (Renner Károly, János Móczó ,et Al,

2010) (Heard, T.A., Winterton, S.L. , 2000,) and the current instance also shows this pattern. Also, it has been found that after 24 hours of immersion in distilled water at room temperature, WH fibre reinforced PVA composites have a larger water content than the 0g of PVA in paperboard. As a result, even though the chemical treatment improved the composites' mechanical attributes, it was unable to reduce their capacity to absorb water.

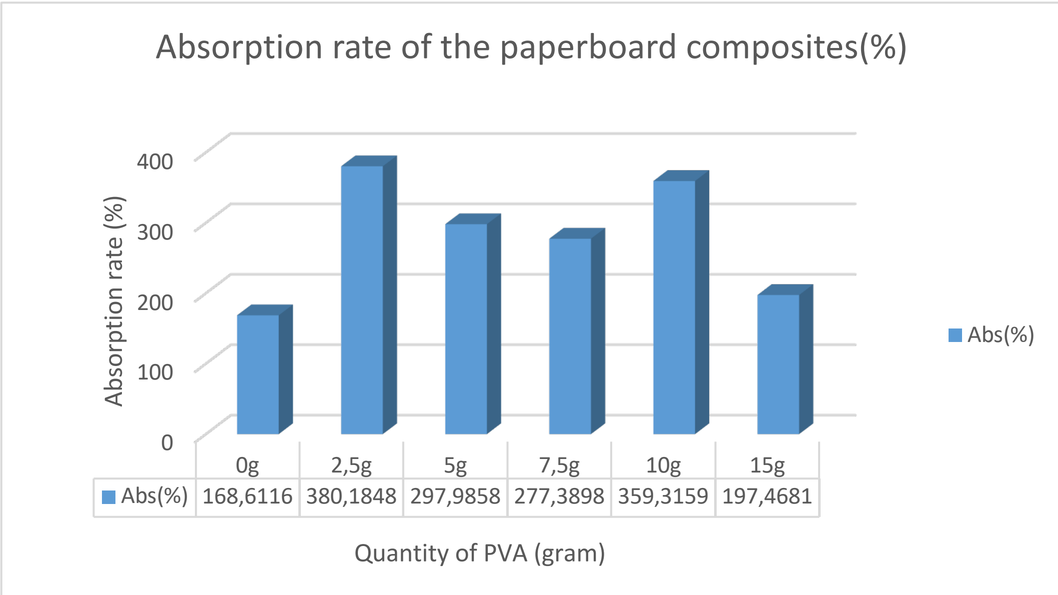


Figure 5 The values of water absorption (%) of the paperboard composites

3.3 Moisture Content

The amount of water that is measurable and present in paper and paperboard is known as its moisture content (Figure 6). This quantity will fluctuate depending on the environment and the moisture added throughout the manufacturing and conversion processes. Relative humidity and whether the moisture were adsorbed or desorbed—brought into equilibrium from a higher relative humidity—determine this (brought into equilibrium from a lower relative humidity).

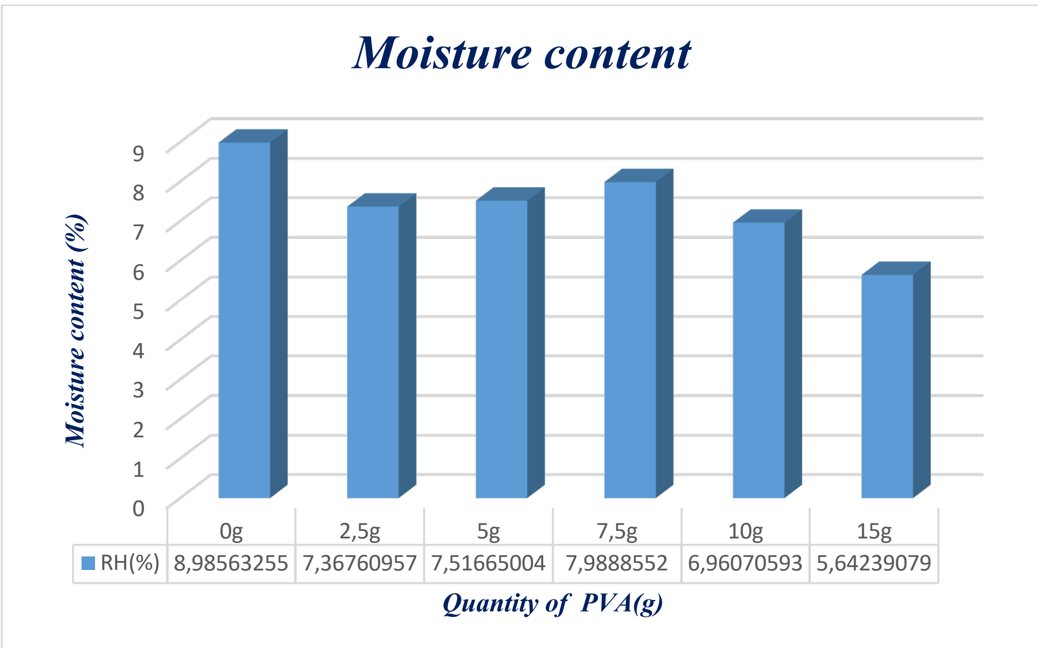


Figure 6 Changes in Moisture content

Table 1 Summary of the Physical Properties of paperboard composites

Quantity of PVA	Thickness (mm)	%Moisture Content	%Abs @30min	Density Area Grammage(g/m^2)
0g	0.13	9.98	168.61	124.57
2.5g	0.15	7.36	38018	97.37
5g	0.19	7.51	297.98	126.79
7.5g	0.25	7.98	277.38	167.74
10g	0.30	6.96	359.31	195.19
15g	0.40	5.64	197.46	249.96

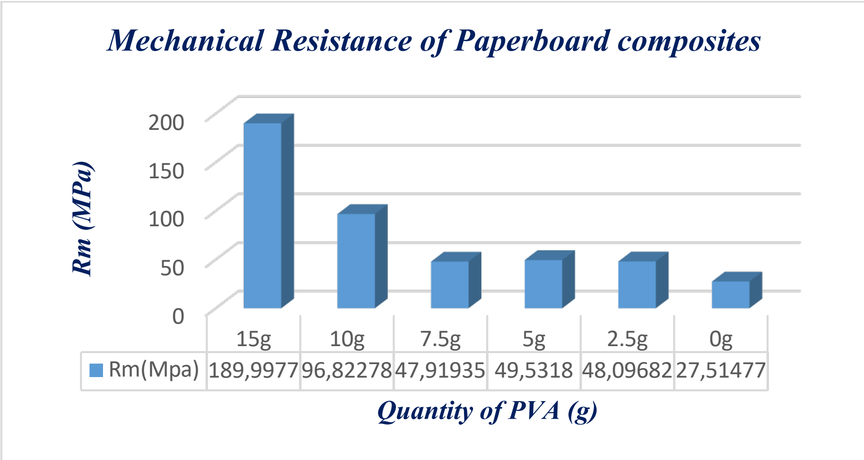
3.4 Mechanical Properties (Figure 7).

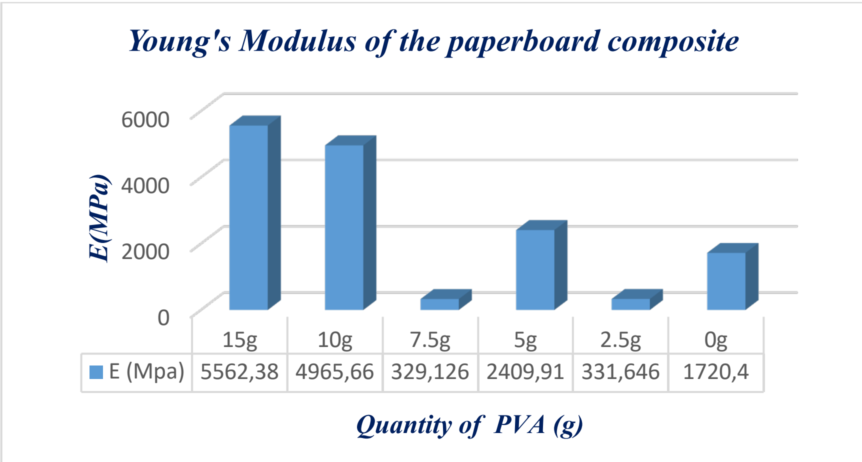
The use of PVA matrix as a reinforcing paperboard surface has improved the bond strength between the fibres in paperboard. It may therefore be stretched to great lengths before breaking. High tensile strength bonds require a lot of energy to break. A paper with a high tensile strength will consequently be less likely to break when under pressure. Table 2 shows that PVA matrix-containing paperboard composites outperformed those with 0g of PVA matrix in terms of tensile strength (control paper). PVA matrix has improved paperboard's strength as a result of deteriorating fibres. Hydrogen bonds have an impact on the tensile index, and the hydrogen bonds that formed between the fibre and the water in the paperboard enhanced the bond. The fact that VA matrix paperboard has a greater tensile strength than 0g PVA matrix composites suggests that the biopolymer coating agent has improved the strength and ductility of the paperboard (PVA matrix). The thick PVA matrix layer that was visible on the paper surface can be thought of as a reinforcing layer. In the production of boards, the burst strength and fibre bonding strength are strongly connected. The burst strength of the paperboard composite has risen by 9%. The chemical similarity between the PVA matrix and the more compatible cellulose fibres and the PVA matrix's absorption into the fibre arrangement were the causes of this. How resilient a fabric is to tearing depends on both the fibre strength and the fibre bond.

Table 2 Summary of the Mechanical Properties of paperboard composites

Mechanical props	Tensile strength (kN/m)	Burst strength (kPa)	Tearing resistant (mN)	Folding endurance (no.)
0	0.13	9.98	168.61	124.57
2.5g	0.15	7.36	380.18	97.37
5g	0.19	7.51	297.98	126.79
7.5g	0.25	7.98	277.38	167.74
10g	0.30	6.96	359.31	195.19
15g	0.40	5.64	197.46	249.96

Fiber length is one of the main elements that determines paper tearing strength. The resistance to tearing increased as the bonding degree grew. This came about as a result of the PVA matrix's strengthening activity, which improved the fibres' ability to stick together (Kuusipalo, Jurkka and Kaunisto, M. and Laine, A. and Kellomäki, Minna, 2005). In light of this, more energy is needed to cut the link than to remove the fibre. Paperboard made from those fibres has a stronger tearing resistance since it took more work to remove the longer strand. The analysis's results showed that PVA levels on paperboard composites had increased. The addition of the paperboard increased tearing resistance by 0.2%. In general, as the ripping value rises, more force is required. The greater ripping resistance of the PVA matrix necessitates the use of more force to shred the samples. Folding endurance rises along with fibre bonding and fibre strength, but falls as fibre bonding intensifies. As a result, the paper will start to crumble. Paperboard with a PVA matrix has a 19% higher folding endurance than paperboard without one, whereas paperboard mixed with a PVA matrix has a 4.87% lower folding endurance.





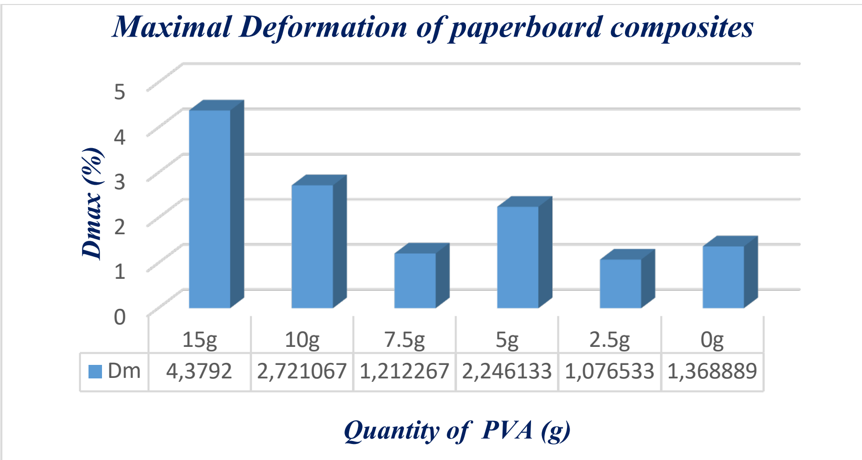


Figure 7a,7b,7c Mechanical Resistance, Youngs Modulus, Elongation at Break of Paperboard composites respectively.

The result show that tensile strength was lower than bending strength water hyacinth bio-board Based on (Suboyejo, M., 2004) The direction of the load has a significant impact on a material's ability to resist deformation. Since bio-board is formed from biomass, which contains cellulose bound by hydrogen (Van der Wall's force), it is made from biomass. This is distinct from metal substance, where the atoms are connected by stronger hydrogen bonds such as ionic, covalent, or metallic bonds. cellulose, lignin, and hemicelluloses make up natural fibres. According to (Mishra, S., et Al, 2004) Anhydro D-glucose is the basic building block of the cellulose macromolecule and contains three alcohol hydroxyls (-OH). These hydroxyls from hydrogen bonds form intramolecular (inside the macromolecules themselves) as well as intermolecular (with hydroxyl groups from the air) interactions.

3.5 Morphological Analysis

The surface of six WH paperboard composites is examined under a scanning electron microscope. The graphic below displays the WH paperboard's SEM image. The interfacial bonding to the reinforcement and matrix materials is clearly visible in the direct view of the electron pictures. It indicates that there is weak interfacial adhesion at the PVA matrix and WH pulp interface. Also apparent in the composite micrograph is the WH. This could explain why, as shown in figure 8, the tensile strength of paperboard composites charged with various grammes of PVA may be changed.

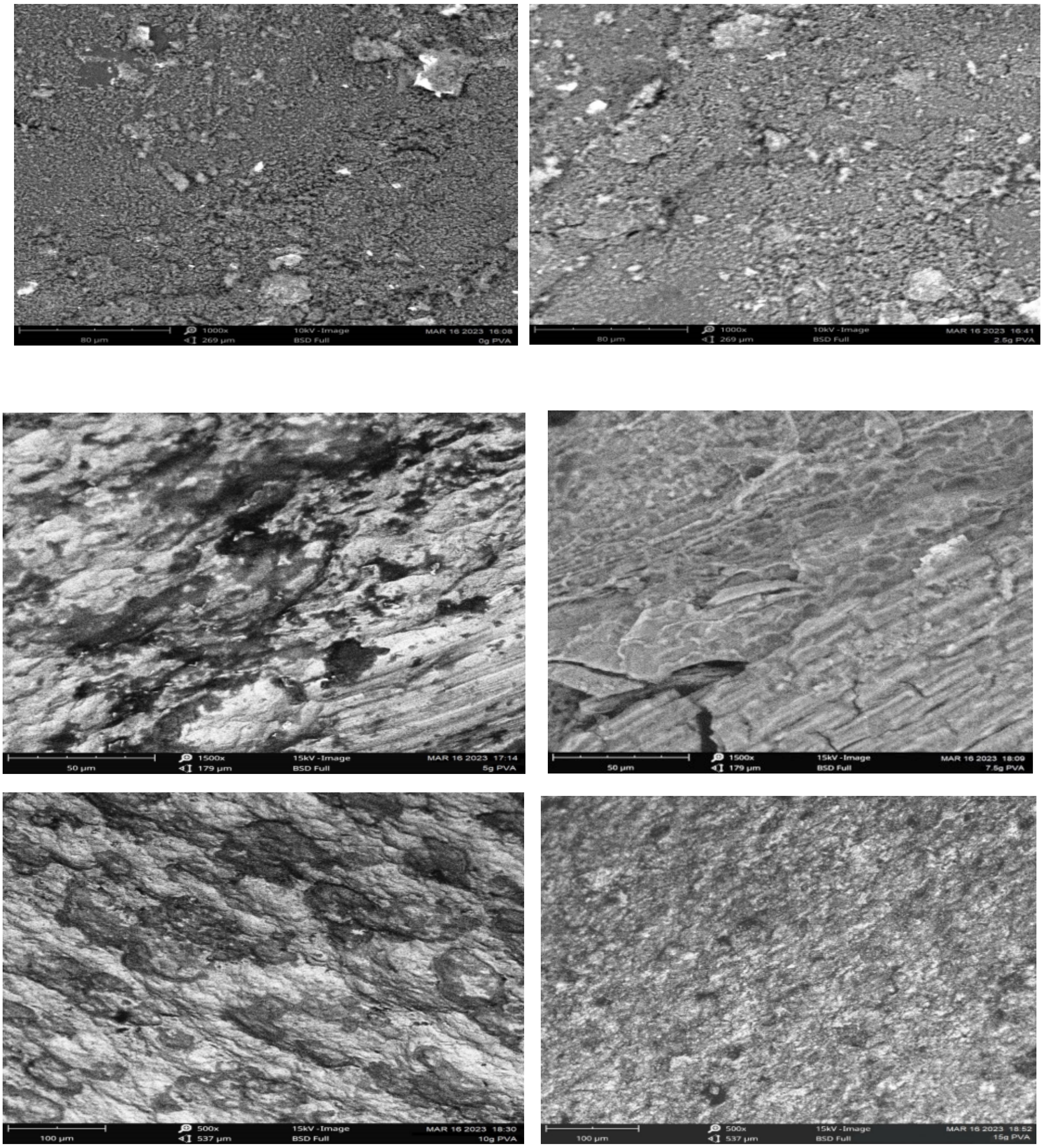


Figure 8. Surface structure of the water hyacinth paperboard composites using SEM with morphologies of the 0g,2.5g,5g,7.5g,10g,15g of PVA.

There are a few voids visible that are about 30 m in size.Also, we might have discovered that charged and uncharged water hyacinth pulps differ from one another. We can therefore conclude that WH PVA composites are superior to WH pulps without PVA. Paperboard composites were created when the hydrophilic groups (OH groups) in the 0g of WH paperboard were changed to hydroneutral groups (ester groups) during the esterification reaction. The presence of hydroneutral groups may be what makes the WH Paperboard composites' mechanical and acoustic qualities better. (Manabendra Saha and Ali Md. Afsar, 2018).

Conclusion

It was discovered that the properties gained from WH paperboard were suitable for producing pulps and composites. Although the paper becomes more rigid and less prone to water absorption as polyvinyl acetate is added, the good burst and tensile strength of paperboard made from this source raw material makes it appealing. In order to satisfy the growing demand for sustainability in the transportation industry and automotive industry as insulators or ceiling roofs, existing bio-composite materials can be replaced with renewable, recycled, and lightweight materials. This is done while taking into account the requirements of each category of transportation. By moving some of the heavier components, materials with high-performance natural fibre composites were able to reduce the transport weight, which in turn reduced fuel consumption and CO2 emissions. The paperboard's water permeability indicated that it would be ideal for additional paperboard processing, including sizing, coating, and other techniques. The air permeability of the paperboard is increased by the growth in water hyacinth and PVA diameter, which may result in significant sound absorption of the material. As a result, paperboard that has been thoroughly combined with PVA can be employed as acoustic materials in car interiors and room interiors. The findings of a morphological investigation of the fracture surface of WH-PVA composites reveal that the treated WH pulps and PVA interact favourably, minimising microvoids, promoting pulps dispersion in the matrix, and reducing pulps agglomeration and pulling out. In conclusion, water hyacinth stalks may be used to make paperboard that may be used to make items like cards, car roofs, packaging paper, newspaper, case board, and insulating materials. This would result in a more thorough use of waste while also increasing the value of WH stalks. This study demonstrates the viability of using precipitated polyvinyl acetate as a filler in paper goods. This might result in a fully biodegradable end product. However, additional effort needs to be done to produce the WH paperboard composite of uniform qualities, and more desirable to industries.

Acknowledgement, The technical data of the department of Cpeel university of Ibadan.
Disclosure statement: *Conflict of Interest***:** The author declared no potential conflicts of interest with respect to this article.

References

Ajithram A., Winowlin Jappes J.T., Siva I., Adam Khan M., Brintha N.C. (2022). Investigation of water, chemical absorption and mechanical properties of water hyacinth (Eichhornia Crassipes) aquatic plant powde, ash composites for commercial applications. 60, *Part 3,*, 1339-1346. https://doi.org/10.1016/j.matpr.2021.10.019.

Arrakhiz F.Z., M. El Achaby, M. Malha, M.O. Bensalah. (2013,). Mechanical and thermal properties of natural fibers reinforced polymer composites: Doum/low density polyethylene, *Materials and Design* , 200-205DOI: 10.1016/j.matdes.2012.06.056.

Baley C., Le Duigou A., Bourmaud, A. and Davies, P. (2012). Influence of Drying on the Mechanical Behaviour of Flax Fibers and Their Unidirectional composites. *Composites Part A: Applied Science and Manufacturing*, 43,1226-1233.

Casey P. (1980). Pulp and Paper Chemistry and Chemical Technology. *Third Edition, Vol 1. . chicago Wiley Interscience Publication*.

Erlinda L. Mari . ((2012)). Parchment-Like Paper Using Water Hyacinth Pulp. . *Philippine Journal of Science, 141 (2);* , 179-185.

Fischer, Karl . ((1935)). Neues Verfahren zur maßanalytischen Bestimmung des Wassergehaltes von Flüssigkeiten und festen Körpern". *Angew. Chem. 48 (26): . doi:10.1002/ange.19350482605.*, 394–396.

Flores Ramirez, N., Sanchez Hernandez, Y., Cruz de Leon, J., Vasquez Garcia, S. R., Domratcheva Lvova, L., & Garcia Gonzalez, L. (2015). Composites from water hyacinth (Eichhornea crassipe) and polyester resin.16, . *Fibers and Polymers*, 196-200.

Gielen D. and Tam, C. (9th October, 2006.). Energy Use, Technologies and CO Emissions in the Pulp and Paper Industry .Energy Efficient Technologies and CO2 Reduction Potentials in the Pulp and Paper Industry in collaboration with. *WBCSD, IEA, Paris,*.

Gopal B. (1987). Water hyacinth . (Aquatic Plant Studies 1). Elsevier, Amsterdam, 4 . *Journal of Tropical Ecology Elsevier Science Publishers, Amsterdam ISBN 0-444-42706-6*, 92 - 93.

Gunnarso C,C. and Petterson,C,M. . (2007). Water hyacinth as a resource in agriculture and energy production: . *A literature review. Waste Management,*, 27, 117-129.

Heard T. A., Winterton S. L. (2000). "Interactions between nutrient status and weevil herbivory in the biological control of water hyacinth", *J. Appl Ecol, 37:* , 117–127.

Holm L G et al. (1977). The world'sWorst Weeds. Distrbution and biology. *Universty Press of Hawaï. Honolulu,*, 609.

Ilyas R.A., Sapuan S.M. (2020,). Biopolymers and Biocomposites: Chemistry and Technology. *Perspectives in Analytical Chemistry Vol. 16, No. 5*, 500-502.

Ilyas RA, Sapuan SM, Ishak MR, Zainudin ES. (2019). Sugar palm nanofibrillated cellulose (Arenga pinnata (Wurmb.) Merr): Effect of cycles on their yield,physic-chemical, morphological and thermal behavior. . *International Journal of Biological Macromolecules* , 123:379-88.

Ilyas RA, Sapuan SM,, et al. (2019). . Potential of natural fibre composites for transport industry : . *Prosiding Seminar Enau Kebangsaan , Bahau, Negeri Sembilan, Malaysia: Institute of Tropical Forest and forest product*, 2-11.

Ilyas RA, Sapuan SM, et Al. (2018;). Nanocrystalline cellulose as reinforcement for polymeric matrix nanocomposites and its potential applications: . *A Review. Current Analytical Chemistry https://doi.org/10.2174/157341101*, 14:203–25.

Joseph antoine njanda tchouyou. (2017). Production de l'énergie propre et durable à moindre coût au travers de la valorisation énergétique de la jacinthe d'eau au cameroun (estuaire du wouri).

Kuusipalo, Jurkka and Kaunisto, M. and Laine, A. and Kellomäki, Minna. (2005). Chitosan as a coating additive in paper and paperboard. *Tappi Journal*, 17-21.

Lamhamdi A., Azzaoui K., Mejdoubi E., Garoiz H., Berrabah M., Elbali B., Hammouti B. (2014), Extraction of organochlorine pesticides by a matrix of calcium phosphate, *Mor. J. Chem.* 2 N°2, 90-96.

Maamoun A, El-Wakil A, El-Basheer TM. . (2022). Enhancement of the mechanical and acoustical properties of flexible polyurethane foam/waste seashell composites for industrial applications. . *Journal of Cellular Plastics.58(4) doi:10.1177/0021955X221088392*, 645-672.

Manabendra Saha and Ali Md. Afsar. (2018). Thermo-mechanical and morphological properties of water hyacinth reinforced polypropylene composites. *International Journal of Engineering Materials and Manufacture https://doi.org/10.26776/ijemm.03.03.2018.04*, 151-161.

Medjahed K., Tennouga L., Mansri A., Chetouani A., Hammouti B., Desbrières J. (2013). Interaction between poly(4-vinylpyridine-graft-bromodecane) and textile blue basic dye by spectrophotometric study, *Res. Chem. Intermed.,* 39 N°7, 3199-3208.

Mishra S., et Al. (2004). A Review On Pineapple Leaf Fibers, Sisal Fibers And Their Biocomposites. *.Macromolecul Mater Engineering, 289,* , 955-974.

Nadlene R., Sapuan S.M., et Al. (2015). . Material Characterization of Roselle Fibre (Hibiscus sabdariffa L.) as Potentiel Reinforcement Material for Polymer Composites . *Fibers and Textiles in Eastern Europe,* , 6, 23-30.

Nazire Dniz Yilmaz Pamela Banks-Lee et Al . (2011). Effects of Porosity, Fiber Size and Layering Sequence on Sound Absorption Performance of Needle punched Nonwovens. *Journal of Applied Polymer Science,* 121, 3056-3069.

Nickel J, Riedel U. (2003). Activities in biocomposites. *Materials Today*, 44–48.
Ogunwusi A. A. and Ibrahim N. D. (2014). Advances in Pulp and Paper Technology and the Implication for the Paper Industry in Nigeria. . *Industrial Engineering Letters,*, 3-4.
Oksman K., Aitomäki, Y., Mathew, A. P., Siqueira, G., Zhou, Q., Butylina, S., ... & Hooshmand, S. (2016). Review of the recent developments in cellulose nanocomposite processing. Composites , 83,. *Part A: Applied Science and Manufacturing*, 2-18.
Pasaribu and Swahlita. (2007). *(Processing of Raw Water Hyacinth As Paper Art).Key Papers on Exposure Research Results: Resource Conservation and Rehabilitation Forest. Padang,.* Indonesia.: Pengolahan Enceng Gondok Sebagai Bahan Baku Kertas Seni.
Pickering K.L., Efendy, M.A. and Le T.M. (2016,). A Review of Recent Developments in Natural Fiber Composites and their Mechanical Performance, *Composites Part A: Applied Science and Manufacturing*, 83, 98-112. https://doi.org/10.1016/j.compositesa.2015.08.038
Prahl J M. (1968). *Thermodynamics of paper fiber and water mixtures PhD thesis* . Harvard University Cambridge, MA: Harvard University Cambridge, MA.
Renner Károly János Móczó et Al. (2010). "Micromechanical deformations in PP-lignocellulosic filler composites: Effect of matrix properties". *Composites Science and Technology ,70:*, 1141–1147.
Saha M.(2011). Mechanical Characterization of Water Hyacinth Reinforced Polypropylene Composites. http://lib.buet.ac.bd:8080/xmlui/handle/123456789/96.
Sanjay M. R., Arpitha G. R. ,et al. (2016). Applications of Natural Fibers and Its Composites: An Overview. *Natural Resources,*, 108-114.
Sarah (02-Aout-2019). Les différents types de papier pour l'impression [en ligne] disponible sur <. *http : // www pixarprinting.fr.>blog>type*.
Sridash W. (2010). The environmentally benign pulping process of non wood fibers. *suranaree journal of science and technology*, 105-123.
Suboyejo M. (2004). Mechanical Properties of Engineered Material. . *Marcel Dekker. New York*.
Supatata N., J. Buates, P. Hariyanont. (2013). Characterization of Fuel Briquettes Made from Sewage Sludge Mixed with Water Hyacinth and Sewage Sludge Mixed with Sedge. *International Journal of Environmental Science and Development,* 4, 179-181. http://dx.doi.org/10.7763/IJESD.2013.V4.330 ,
Supri A. G. and B. Y. Lim. (2009,). Effect of Treated and Untreated Filler Loading on the Mechanical,Morphological, and Water Absorption Properties of Water Hyacinth Fibers-Low Density Polyethylene Composites. *Journal of Physical Science, 20(2),*, 85-96.
Supri A. G., Tan S. J., Ismail H. & Teh P. L. (2011). Effect of Poly(methyl Methacrylate) Modified Water Hyacinth Fiber on Properties of Low Density Polyethylene/Natural Rubber/Water Hyacinth Fiber Composites, DOI: 10.1080/03602559.2011.551981. *Polymer-Plastics Technology and Engineering, 50:9*, 898-906.
Tobin T. J. . (2001). The construction of the codex in classic and postclassic period of maya civilization . . *Westmoreland country college* , 56.
Yamauchi T., Tanaka A. (2002). Tearing test for paper using a tensile tester. *J Wood Sci* 48, 532-535.

(2023); http://www.jmaterenvironsci.com