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Experimental Study of Blended Pineapple Leaves and Elephant Grass Stems Fiber Pulp for the Production of Hard Cover Binding Papers

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Abstract

This research focuses on the production of hard cover binding papers from blended pulps of pineapple leaves fiber (PLF) and elephant grass stems fiber (EGSF). These two non-valorized Cameroon vegetable fibers were chosen because of their cellulose content being above 35%. A commercial hard cover binding papers (S com) of grammage 100 g/m^2 was bought in the market to serve as a reference paper for the required analysis. Chemical, Physical, Mechanical and Physico-chemical properties were determined for 12 specimen papers. PLF presented cellulose content 66.71%, hemicellulose 19.55%, lignin 7.75%, while EGSF presented cellulose content 43.26%, hemicellulose 9.34%, lignin 22.86%. PLF and EGSF pulp were produced using Soda Pulping method. 12 papers specimen (S1, to S12) were produced using the modified Japanese handmade paper method and tested and compared S com. S8 presented properties that were closer to S com. The physical properties of S8 presented grammage 102.00 g/m^2 which was 0.02% higher than S com, the tensile properties presented young modulus 117.23 MPa which was 0.56% lesser than S com obtained from a microcomputer electronic universal material testing machine (product model: QL-5W) and the physico-chemical properties for water test were determined 750% absorptiveness which was. 96% higher than S com and humidity test was 15.69% absorptiveness which was 0.34% lesser than S com. These results follow TAPPI T 494, T 404, T 441, T 502, T1210, and ISO 1924, 3781 norms. The study investigates whether soda-pulp blends of pineapple leaf fibres (PLF) and elephant grass stem fibres (EGSF) can replace wood pulp in hard-cover binding paper. Twelve handmade sheets (S1 - S12) with varying

PLF/EGSF ratios and $CaCO_3$ additions were fabricated and benchmarked against a commercial 100 g/m^2 paper board. Chemical composition, grammage, density, tensile properties and water/humidity absorptiveness were measured according to TAPPI and ISO standards. Specimen S8 (predominantly EGSF) showed grammage, Young's modulus and absorptiveness closest to the commercial reference, indicating technical feasibility.

Keywords

Blended PLF and EGSF Pulp, Soda Pulping Method, Cellulose, Hard Cover Binding Paper, Grammage

1. Introduction

Wood makes up about 90% of the conventional raw material used for pulp and paper production in the world according to Madakadze *et al.* (1999) [1]. However, depleting forest to obtain the wood has made an impact on the environment, according to Monhanty *et al.* 2005 [2]. Deforestation has been on the rise, causing the loss of between 40,000 to 80,000 hectares of primary forest annually between 2015 and 2018 according to http://www.euredd.efi.int/ (2022). In the case in Malaysia, the rate is accelerating faster than any other tropical countries in the world according to Harrison Rhett D, 2005 [3]. This has made the search for alternative fiber in non-wood materials imperative in pulp and paper production. Worldwide, deforestation is estimated to be responsible for about 12% of greenhouse gas emissions according to Daniel *et al.* (2013) [4]. When loggers and developers cut down forests, CO_2 escapes into the atmosphere. Furthermore, animals and indigenous people who once depended on forests for life cannot do so any longer.

The union of concerned scientists points out that "wood products" including paper account for about 10% of total deforestation according to Daniel *et al.* (2013) [4]. Owing to the environmental concerns and wood resource depletion, more attention is being paid to renewable materials such as non-wood. Conventionally, wood is the principal resource of cellulosic fiber for pulp and paper manufacture. The increase demand of paper consumption from virgin pulp is the main cause for the usage of wood species as the main raw material leading to massive deforestation and replantation according to Daud *et al.* 2014 [5]. This has consequently altered the ecological balance and contributed to the climate change.

According to some research studies on the suitability of aquatic plant fibers for handmade papermaking according to Bidin *et al.* 2015 [6] and Mejouyo *et al.* (2020) [7] in many countries, quantities of available wood are insufficient to meet the requirements and demands of pulp and paper especially in Mediterranean countries like Spain, Italy, and Greece. In Malaysia, over one million tons of papers were produced in 2005 according to Roda *et al.* [8]. This would mean that more tropical trees need to be felled to sustain papermaking industry to meet the paper requirement and demand. Cellulose being the main property needed for

paper and Pulp production [6] [9]. Some alternatives with high cellulose content have been used to replace the wood fiber with non-wood-derived fibers according to Enayat *et al.* (2009) [10] from agriculture residues such as wheat and rice straw, sorghum stalks, jute, and hemp for paper production.

The use of paper in Cameroon is predominant to all other products because of its huge applications in a very wide domain. Some applications might be in the domain of packaging or parceling of products, handwriting or printing materials, toilet tissues to hand tissues napkins, craft drawing papers to hand or machine drawing papers just to name a few. According to the report on United Nation COMTRADE data base on international trade (2024) [11] on international trade, Cameroon imports rates of paper and paperboard, articles of pulp were US$116.96 million during 2021. These products keep increasing day in day out according to reports on paper importation by National Trade House on Paper Importation (2021) [12] (chambre de commerce), stating that paper has been in a rise of 20 percent yearly. This therefore draws our attention to what would happen if wood remains the only source to which paper is produced. According to Forest Stewardship Council 2012 [13] matured wood for paper production takes 40 to 100 years to be ready. The felling of wood for this purpose causes deforestation and loss of rain forest, and thus contributes to the rise in global warming. To avoid this, alternative research on paper production which is centered in the use of non-wood has come to combat these massive cut down of trees for paper and pulp production. These research alternatives mostly focus on non-wood plants with high cellulose contents above 35%, so, Pineapple Leaves fiber (PLF) and Elephant Grass Stem Fiber (EGSF) have cellulose content above 35%. The plants pulp was combined for the production of Handmade hard cover binding paper.

2. Materials and Method

The following methodology presented below was adopted (**Figure 1**).

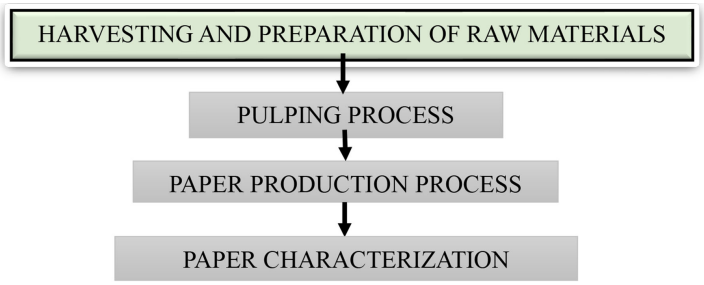

Figure 1. Methodology.

2.1. Harvesting and Preparation of Raw Materials

The materials used here were harvested in two regions of Cameroon. The Pineapple Leave Fiber (PLF) harvested in PENJA in the Littoral Region and Elephant Grass Stems Fiber (EGSF) harvested in Mile 5 Nkwen Bamenda in the North west region. These fibers were used in two forms, dried and wet depending of the

method applied. Figure 2 represent the two plants and zone of the fiber used.

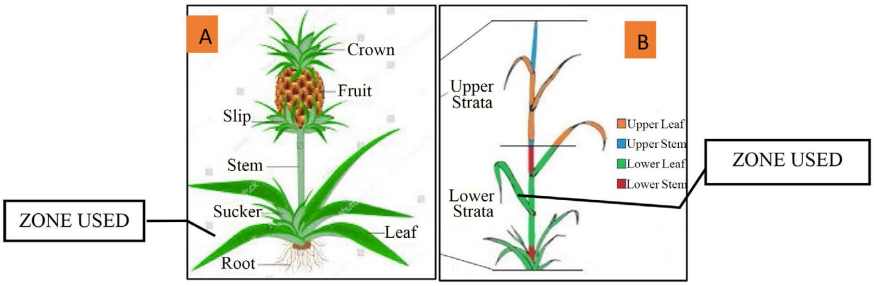

Figure 2. (A) Pineapple plant, (B) Elephant grass plant.

2.2. Method of Chemical Characterization of the Fibers

The chemical Characterization was using the dried 20 g of PLF and EGSF to determine the cellulose content which is the main properties which helps in the choice or selection of the required vegetable fibers for Pulp and Paper production. The method used for the analyses was the modified Protocol describe by Mounguengui *et al.* [14] which helps in breaking down the different chemical composition. The prepared dried fiber was measured and put in a Soxhlet round bottom flask, Sulfuric acid and Ethanol-benzene was introduce in the flask to remove extractives and then filtered to obtain compounds such as lignin, hemicellulose pectin and others. See Figure 3.

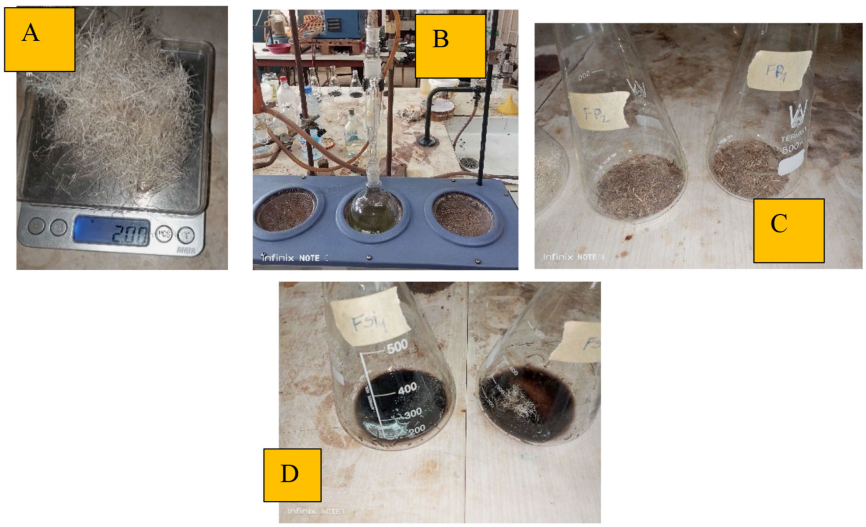

Figure 3. (A) Fiber on Digital Scale, (B) Soxhlet Round bottom Flask used for extraction of compound, (C) fiber put in round bottom Flask, (D) Round bottom Flask use for extracting Lignin (black) liquor in Chemistry Lab ENSPY Yaoundé.

2.3. Pulping Process

2.3.1. Pulp Preparation

The PLF and EGSF were chopped into 3 to 5 cm of length. 4 kg of chopped fresh PLF and EGSF then put in an open pot containing 10 L of distilled water and with

4% caustic soda solution. This mixture was then boiled for 3 to 4 hours to obtain (Soda pulping method) pulp [15]. Typically, the alkali charge is 16%, and the pulping temperature ranges from 14˚C to 170˚C.

2.3.2. Raw Materials and Soda Pulping Process (Figure 4)

Figure 4. (A) preparation of PLF; (B) preparation of EGSF; (C) 4 kg of chopped EGSF; (D) Chopped EGSF + 4% Caustic Soda + HO_2; (E) 4 kg of PLF + 4% Caustic Soda + HO_2; (F) Pot on red hot charcoal for cooking; (G) Digested Pulp mixed with black liquor.

Figure 5 below represents the different steps of Pulp Cleaning and Blending Process.

Figure 5. (A) Washing of PLF & EGSF Pulp; (B) Washed PLF & EGSF Pulp; (C) Blending of PLF & EGSF Pulp; (D) Pulp whitening Bleaching; (E) Bleach PLF & EGSF Pulp; (F) Blended unbleached PLF & EGSF Pulp.

2.3.3. Paper Production Process

Twelve (12) formulation of paper specimens of S1 - S12 were produced following the formulation of dry pulp mass ratio/additives between 1% and 2% of $CaCO_3$ represented in **Table 1** below. These paper specimens were produce using the

modified Japanese handmade paper production method. This method is a combination of the traditional Japanese handmade paper technique and a compressed lamination handmade paper technique. This technique was used in the lab to produce unsized papers sheet. The paper sheets were formed using the deckle box method for a controlled volume of pulped fibers [16]. This pulp was thoroughly combined in a 30 liter of water, poured into a custom deckle box, and gravity drained through a mesh screen mold (30/30 mesh, tergal cotton screen) for 10 to 15 min. After draining, the sheet was transferred from the mold to the pressed at 2 kN using a screw jack platen press to remove excess water and then dried for 24 hours at ambient temperature (25˚C) to have 80 to 90% dry. The paper samples were then placed between two smooth zinc sheets of 0.25 mm thickness, before placing it between two roller for lamination to have a uniform thickness with a roll pressure of 950 N/mm^2 (950 MPa) for a to and fro movement of about 5 times for 2 minutes.

Table 1. Specimens dry mass ratio formulations/additives of S1 - S12.

CODE OF SPECIMEN	FORMULATION
S1	0 g PLF: 100 g EGSF: 1% $CaCO_3$
S2	100 g PLF: 0 g EGSF: 1% $CaCO_3$
S3	0 g PLF: 100 g EGSF:1.5% $CaCO_3$
S4	100 g PLF: 0 g EGSF: 1.5% $CaCO_3$
S5	0 g PLF: 100 g EGSF: 2% $CaCO_3$
S6	100 g PLF: 0 g EGSF: 2% $CaCO_3$
S7	90 g PLF: 10 g EGSF: 1% $CaCO_3$
S8	10 g PLF: 90 g EGSF: 1% $CaCO_3$
S9	90 g PLF: 10 g EGSF: 1.5% $CaCO_3$
S10	10 g PLF: 90 g EGSF: 1.5% $CaCO_3$
S11	90 g PLF: 10 g EGSF: 2% $CaCO_3$
S12	10 g PLF: 90 g EGSF: 2% $CaCO_3$

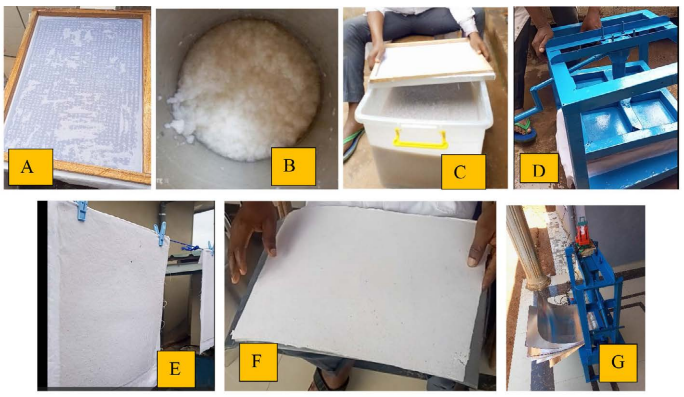

Figure 6. (A) Deckle Box; (B) Blended Pulp; (C) Carrying Pulp in Deckle box; (D) Pressing the Pulp to remove excess water from the mesh screen; (E) Drying of the mesh screen Paper; (F) Dried paper; (G) Lamination process.

The additive $CaCO_3$ was added in varied percentages of 1% to 2% of the total weight of the dried pulp to improve opacity, increases smoothness, increases brightness, and enhances printability of the paper [17] (**Figure 6**).

2.4. Paper Characterization Process

2.4.1. Physical Characterization

The Grammage and Density was determined on specimen paper S1 to S12. A commercial hard cover binding paper "**S com**" of grammage 100 g/m^2 was used to determine the density which serves as test base line for all our calculation according to TAPPI-T 410 and ISO 186 [7] [18]. Grammage and Density was calculated using the following equations

$$G = \frac{m}{A} \times 10^6, \tag{1}$$

and

$$\rho = \frac{m}{V} \times 10^9, \tag{2}$$

where G is the grammage, ρ is the density of the paper, m is the mass of the specimen paper in gram, A is the average area of the paper in square millimeters, V the average volume of the specimen paper.

2.4.2. Mechanical Characterization

The mechanical test was done according to TAPPI-T 494 to determine the tensile properties. The tensile properties determined here are the young modulus, Tensile index, Tear index and Elongation of specimen paper S1, to S12 and a commercial hard cover binding paper "**S com**" of grammage 100 g/m^2 was also tested which serves as test base line for all our tests. The test samples were shaped following TAPPI T494 and TAPPI T 404 and also ISO 1924-1, ISO 1924-2 standards. The specimen had 20 rectangular samples of (10 × 140 mm) per samples: 10 samples in Machine Direction (MD) and 10 samples in Transverse direction (TD) see **Figure 7**. The Young modulus was determined using the average values gotten from MD and TD of the Microcomputer electronic universal material testing machine (Product model: QL-5W) of loading speed 10 mm/s. According to TAPPI, the tensile index and tear index were calculated using Equation (3) and Equation (4) [19]

$$\text{Tearing index} = \frac{\text{Tearing strentgh}\left(\text{kPa}\right)}{\text{Basis weight}\left(\frac{\text{g}}{\text{m}^2}\right)} \tag{3}$$

$$\text{Tensile index} = \frac{\text{Tensile strentgh}\left(\text{kN/m}\right)}{\text{Basis weight}\left(\frac{\text{g}}{\text{m}^2}\right)} \times 1000 \tag{4}$$

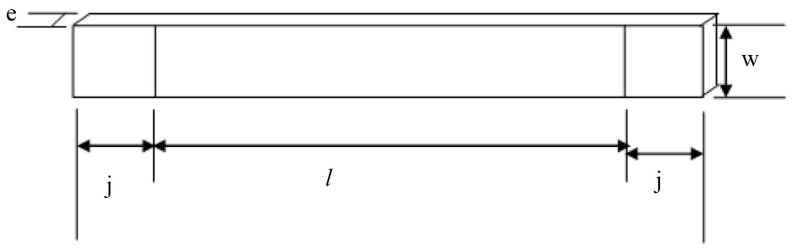

Figure 7. Rectangular tensile samples.

where:

Jaw holding length both side $(j) = 20$ mm, *Test length* $(l) = 100\ \text{mm} \le l \le 200\ \text{mm}$, *Width* $(w) = 10$ mm, *Thickness of the paper* $(e) = e(\text{mm})$ varies per specimen, Speed = 10 mm/min.

2.4.3. Physico-Chemical Characterization

The Physico-chemical test was done according to TAPPI-T 441. The absorptiveness of water or humidity was done on S1 to S12 of specimen papers and a commercial hard cover binding paper term "**S com**" of grammage 100 g/m^2 was also tested which serves as test base line for all our tests. Water absorptiveness and Humidity test was done using COBB method and T502 on the specimen paper with combination of PLF (%) + EGSF (%) of pulp fiber. The paper specimen had 10 square samples of 10 mm ×10 mm. The values to be determined here were Mass ratio (MR), Water absorption rate W_r and Humidity absorption rate H_r.

Calculated using Equations (5)-(7) according to Ndapeu *et al.* (2016) [20]

$$MR = \frac{M_t - M_i}{M_f - M_i} \tag{5}$$

$$W_r = \frac{M_f - M_i}{M_i} \times 100 \tag{6}$$

$$H_r = \frac{M_f - M_i}{M_i} \times 100 \tag{7}$$

where: MR: mass ratio; M_t: mass at time t; M_f: final stable mass during test; M_i: initial mass before test; W_r: Water absorption Rate, H_r: Humidity absorption rate.

3. Result and Discussion

3.1. Chemical Characterization

Table 2. Chemical characterization of Pineapple Leave fiber (PLF) and Elephant Grass Stem fiber (EGSF) harvested in Littoral region (Penja) and Bamenda (Mile 5 Nkwen) respectively.

Chemical Content of PLF and EGSF								
Samples	Different Chemical Content (%)							
	Humidity Content	Lignin Content	Extractive Content	Hydrosolubles sugar Content	Pectines Content	Holocellulose Content	Celullose Content	Hemicelulloses Content
PLF	15.09	7.75	13.67	11.87	2.67	72.94	61.71	15.55
EGSF	15.09	22.86	11.73	13.02	2.82	63.17	43.26	9.34

The value of the cellulose for PLF was 61.71 and that of EGSF was 43.26 which the main structural component providing strength and stability to plant cell walls and fibre. According to M. PASTER *et al.* (2003) and M. Jurarut *et al.* (2015) [21] [22], these cellulose contents are above 35% and therefore are good for paper and pulp production. So, the pulp was produced using soda method. After the production of the pulp, another test was performed to verify the quantity of lignin left in the pulp which we had PLF 0.89% and EGSF 1.02% (Table 2).

3.2. Physical Characterization

The calculated values of grammage and the density are presented in Table 3.

Table 3. Grammage and density.

SPECIMEN CODE	Thickness (mm)	AREA (cm^2)	Volume (cm^3)	Mass (g)	Density (g/cm^3)	Standard dev	Grammage (g/m^2)	Standard dev	ISO Standards (paper and paper board for Hard cover binding [23]	
									Thickness (mm)	Gammage (g/m^2)
S1	0.89	100	8.89	3.42	0.38	1.092	342.00	1.080		
S2	0.61	100	6.09	2.37	0.39	1.023	236.50	1.412		
S3	0.58	100	5.77	2.67	0.47	1.100	267.00	1.191		
S4	0.41	100	4.05	2.80	0.44	1.129	280.00	1.501		
S5	0.52	100	5.21	2.83	0.47	1.126	282.50	1.664		
S6	0.44	100	4.40	2.78	0.48	1.045	277.75	1.391		
S7	0.32	100	3.20	1.03	0.32	1.051	103.00	0.936	0.2 mm	90 ≤ 100 ≤ 170 g/m^2
S8	0.30	100	3.00	1.02	0.34	1.119	102.00	0.813		
S9	0.49	100	4.91	2.74	0.56	1.187	273.50	1.146		
S10	0.46	100	4.63	2.81	0.61	1.138	281.25	1.930		
S11	0.48	100	4.81	2.80	0.58	1.341	280.13	1.755		
S12	0.43	100	4.33	2.88	0.67	1.082	287.75	1.610		
S com	0.20	100	2.00	1.00	0.50	1.028	100.00	1.635		

The results in Table 3 represent the calculated values of Density and Grammage from Equation (1) and Equation (2) above. The commercial hard cover binding paper "S com" had grammage labels 100 gsm on its ream, so therefore S7 and S8 present 103 and 102 gsm which present a percentage values 0.03% and 0.02% slightly above S com and so therefore these two paper are in the range of hard cover binding papers [23].

3.3. The Mechanical Characterization

Table 4 below presents the values of the tensile index, tear index, young modulus and the Elongation of Specimen S1 to S12.

Table 4. Tensile index, Tear index, Young modulus and Elongation of S1 to S12.

SPECIMEN	Tensile index (TI) Nm/g		Tear index (Tin) mN·m²/g		Young modulus		Elongation	
	TI	STDEV	Tin	STDEV	E (Mpa)	STDEV	e (%)	STDEV
S1	0.14	0.036	0.025	0.372	27.08	6.31	6.61	0.84
S2	0.45	0.034	0.055	0.481	87.06	9.63	5.72	0.67
S3	0.28	0.025	0.032	0.501	64.58	6.16	7.22	2.07
S4	0.01	0.051	0.001	0.516	4.05	0.57	25.02	2.97
S5	0.02	0.042	0.002	0.339	5.97	1.06	20.69	1.68
S6	0.01	0.048	0.001	0.481	3.53	0.82	21.97	2.70
S7	0.32	0.089	0.019	0.381	54.20	2.79	15.16	1.37
S8	0.69	0.0360	0.041	0.371	117.23	5.84	7.22	2.07
S9	0.17	0.059	0.017	0.420	47.77	3.45	11.13	1.44
S10	0.29	0.005	0.027	0.403	87.62	6.64	7.41	1.39
S11	0.15	0.047	0.014	0.481	42.83	6.84	7.22	1.00
S12	0.21	0.092	0.018	0.486	69.38	4.73	7.18	1.05
S com	0.84	0.075	0.034	0.175	209.93	3.64	5.72	0.67

Figure 8 below represents the young modulus and Elongation of the specimens tested.

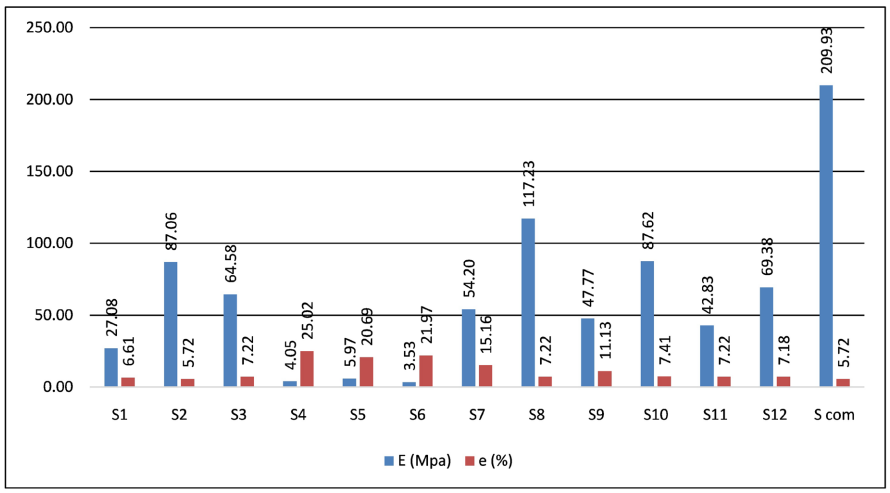

Figure 8. Young modulus (E) and elongation (e).

Figure 8 represents the young modulus and elongation of S1 to S12. These values of young modulus and elongation represent the average values of the sum of 10 different samples per specimen S1 to S12 which are gotten from the microcomputer electronic universal material testing machine presented in **Figure 7**. The specimen S8 presented young modulus of 117.23 MPa and elongation of 7.22%, while S com which is the commercial hard cover binding paper tested which is

consider as our reference had young modulus of 209.93 MPa and elongation of 5.72%, therefore we can conclude that specimen S8 present the best value as compare to the rest of the specimens so can be used as hard cover binding paper.

3.4. Physico-Chemical Characterization Results

3.4.1. Water Absorptiveness Test

The values of the water absorptiveness test obtained here are from the COBB test presented in Table 5.

Table 5. Water absorption test values.

	Time (s)	0	10	20	30	40	50	60	70	80	90
SPECIMEN	S1	2.57	2.87	3.19	3.41	3.61	3.92	4.08	4.33	4.33	4.33
	S2	3.42	4.02	4.91	5.46	5.95	6.32	6.7	7	7	7
	S3	2.37	2.8	3.11	3.33	3.59	3.81	4.18	4.76	4.76	4.76
	S4	3.00	4.48	5.09	5.58	6.07	6.47	7.08	7.6	7.6	7.6
	S5	2.89	3.69	4.97	5.56	6.25	6.65	7.19	7.73	7.73	7.73
	S6	2.68	4.43	5.43	6.38	7.4	7.98	8.59	8.79	8.79	8.79
	S7	1.03	2.91	4.79	6.67	7.77	8.32	8.66	8.89	8.89	8.89
	S8	1.02	3.01	4.44	5.57	6.57	7.67	8.43	8.67	8.67	8.67
	S9	3.58	4.04	4.55	5.16	5.68	6.14	6.49	7.18	7.18	7.18
	S10	3.69	3.98	4.59	5.20	5.69	6.20	6.44	6.97	6.97	6.97
	S11	2.47	4.05	4.85	5.57	6.60	7.90	8.23	8.55	8.55	8.55
	S12	3.40	4.79	5.61	6.33	7.09	7.91	8.53	8.98	8.98	8.98
	S com	1	2.08	2.86	3.34	3.73	4.22	4.65	4.82	4.82	4.82

The graph of water absorption rate of the specimens is presented in Figure 9.

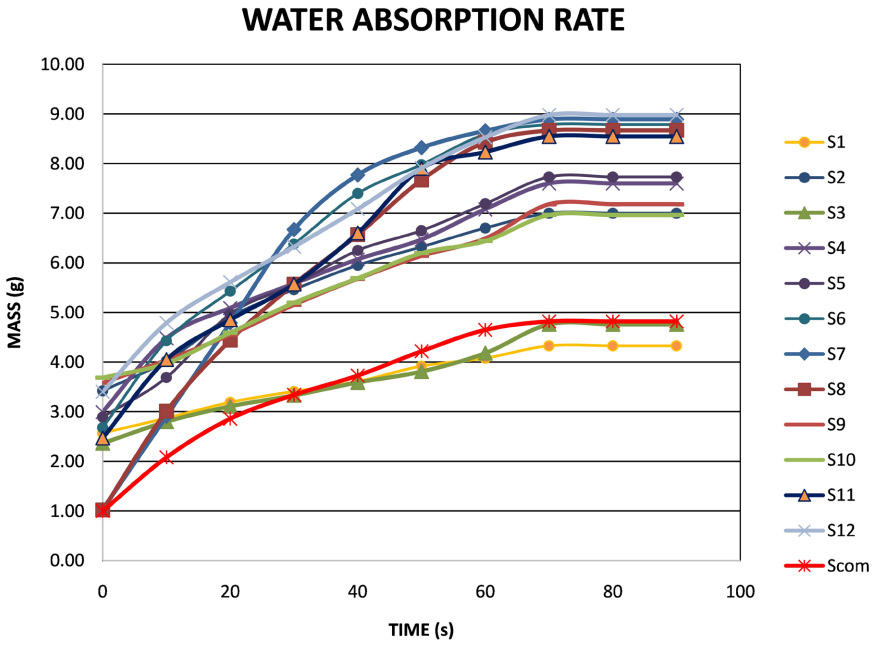

Figure 9. Water absorption mass stability of S1 to S12 within 90 s.

The graph in Figure 9 represents the rate of absorptiveness per 10 s duration for 90 s test time of the specimens. We notice that all the specimen papers had mass stability at 70 s which also conforms with that of S com tested to be the reference.

Figure 10 below represents the mass ratio of water absorptiveness of the specimens.

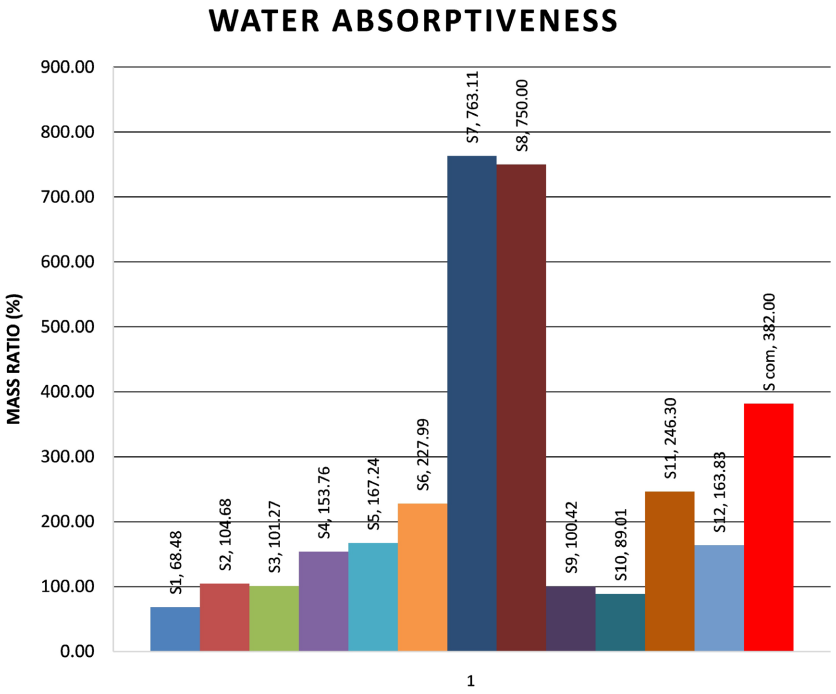

Figure 10. Mass ratio of water absorptiveness.

Figure 10 indicates the amount of water each specimen is able to absorb to get to saturation. So therefore, S1 presented least 68.48% while S7 presented the highest 763.11%. S com presented 382% less than half of S7. The S1 results indicates that there is still some percentage of lignin left in the composition of the specimen which prevent more water from getting in, while S7 indicate the contrary to S1.

3.4.2. Humidity Absorptiveness Test

The values of the humidity absorptiveness test obtained here are from saturated salt bath test at relative humidity (RH) of 50 [24]. The values of the test are presented in Table 6.

Table 6. Humidity absorptiveness test values.

	Time (hr)	0	24	48	72	96	120	144	168
SPECIMEN	S1	2.57	2.83	2.91	3.05	3.23	3.34	3.34	3.34
	S2	3.42	3.45	3.53	3.61	3.69	3.77	3.77	3.77
	S3	2.37	2.60	2.63	2.66	2.69	2.72	2.72	2.72
	S4	3.00	3.27	3.64	4.11	4.28	4.35	4.35	4.35
	S5	2.89	2.94	2.96	3.09	3.25	3.49	3.49	3.49

Continued

S6	2.68	2.90	3.05	3.14	3.38	3.68	3.68	3.68
S7	1.03	1.11	1.19	1.27	1.35	1.43	1.43	1.43
S8	1.02	1.06	1.09	1.12	1.15	1.18	1.18	1.18
S9	3.58	3.68	3.75	3.85	3.96	3.98	3.98	3.98
S10	3.69	3.79	3.89	3.99	4.19	4.39	4.39	4.39
S11	2.47	2.57	2.68	2.75	2.88	2.95	2.95	2.95
S12	3.40	3.50	3.60	3.70	3.84	3.95	3.95	3.95
S com	1.00	1.02	1.11	1.23	1.38	1.46	1.46	1.46

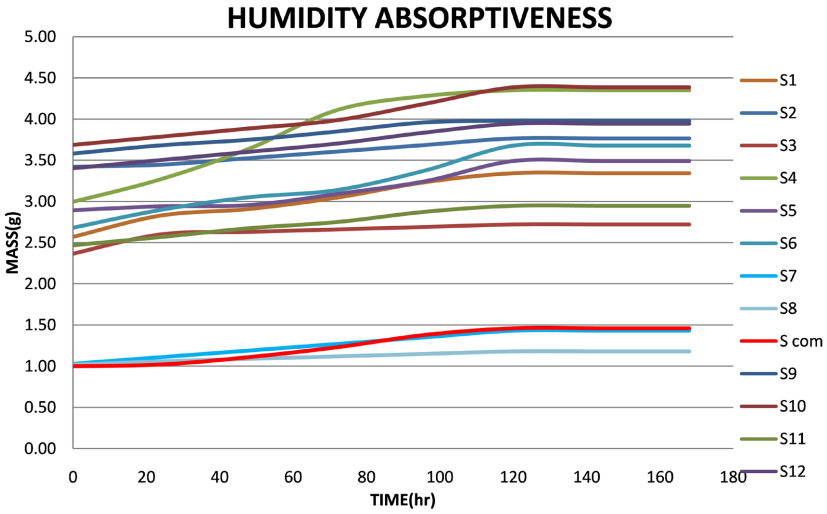

Figure 11. Humidity absorption mass stability of S1 to S12 within 168 hours.

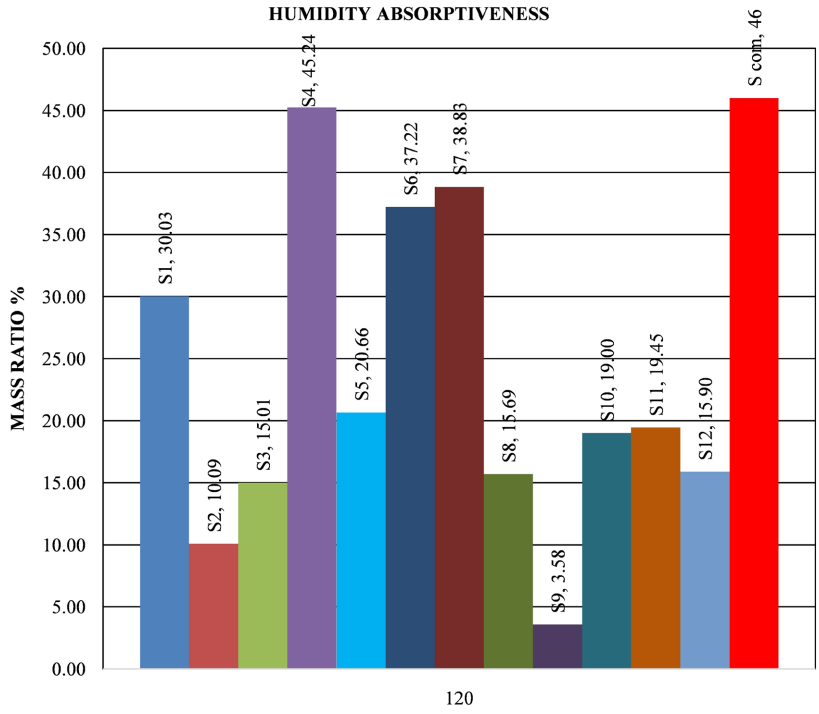

Figure 12. Mass ratio of the humidity absorptiveness.

Figure 11 represents the absorptiveness rate of 24 hours for 168 hours duration (7days)

The humidity absorption mass stability presented in Figure 11 shows that all the specimens had mass stability at 120 hours and these values correspond to that of S com which is our reference. The values of $CaCO_3$ and lignin content has a significant impact in the absorptiveness of our specimens.

Figure 12 below represents the mass ratio of the humidity absorptiveness.

The values of mass ratio of the humidity absorptiveness indicate the amount of water in the air the specimen is able to absorb at saturation. So therefore, S4 absorb 45.24% of humidity closer to S com 46%.

4. Conclusion

The study of Blended Pineapple Leaves Fiber and Elephant Grass Stems Fiber pulp for the Production of Hard Cover Binding Papers was carried out on 12 specimens (S1 - S12). A commercial hard cover binding paper (S com) 100 gsm with paper thickness of 0.20 mm was used as test base line for the 12 specimens tested. The young modulus and grammage of S8 was 117.23 MPa, and 102.00 gsm respectively which is closer to S com than the rest of the specimens. The tensile strength of S com was young modulus 209.93 MPa. The grammage of S8 is 0.02% more, young modulus is 0.56% lesser and thickness 0.10 mm more as compared with S com. We also observed that because of the 1.08% of lignin in the EGSF pulp, it significantly increases S8 toughness and thus influences the tensile properties. The presence of 1% $CaCO_3$ and 1.08%/0.8% lignin in the pulp of EGSF/PLF helps to decrease rate of humidity absorbency. Comparing these values of S8 with S com, we can conclude that according to *S. P. Preprotic et al.* 2023 [23], specimen S8 can be used for hard cover binding because of its grammage and mechanical strength.

In further findings, SEM analysis should be done to determine the fiber bonding, and the microfibril length of the specimens.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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