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ENGINEERING PROPERTIES OF WALL PANELS PRODUCED FROM WASTE PAPERS AND CHICKEN FEATHER (DOWN) FIBRES

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ABSTRACT

A great number of wastes are generated globally. Traditional disposal strategies have a detrimental effect on the environment as they are often burned in incineration plants or buried in landfills, adding to CO_2 emissions and can be potentially carcinogenic. In a bid to repurpose waste products and ultimately reducing pollution, this study explores the use of waste paper and chicken feather fibres (CFF) in the production of wall panels. Wall panels are functional as well as decorative, providing insulation and soundproofing with some measure of durability and ease of replaceability. Waste papers (WP) were reduced into a slurry and mixed with varying ratios (0%, 5%, 10%, 15%, and 20%) of chicken feather fibres and formed into decorative panels. The panels were tested for physical and mechanical strength. The results obtained show medium impact and mechanical resistance with the optimum values obtained at 5% CFF inclusion while the optimum results for water absorption and thickness swelling were obtained 15%CFF. There was a gradual decrease in the thermal conductivity of the wall panels with increasing CFF.

KEYWORDS: Wall panels production, impact energy, poultry waste, paper fibres, recycling

1. INTRODUCTION

A high volume of solid wastes is generated globally from different sources such as residential, institutional, agriculture, construction, municipal services, manufacturing to mention a few. Waste papers are generated from institutions such as schools, libraries, and government centres while chicken feathers are generated from poultry activities of the agricultural sector. In recent times, paper wastes as a proportion to solid wastes have increased (Binici et al., 2013) due to the globally increasing demand for paper and paper products. It is estimated that a global volume of 419.7million metric tons of paper and board were produced globally in 2017 (Garside, 2019). The feathers generated each year by commercial slaughterhouses amount to billions of kilograms creating a serious solid waste problem in many countries (Bartels, 2003). These wastes are often left to decompose or dumped in landfills, emitting greenhouse gases resulting in global warming, climate change, and pollution of underground water (Akinyemi et al, 2019). This has prompted studies into the development of technologies that either produce less waste or find a reuse for the wastes generated. Proper waste management is necessary to save the environment from pollution and annihilation. The recycling of waste materials appears to be a reasonable alternative to waste disposal where wastes are converted into new products with some economic gain. This has been on the increase globally. More often than not, the new material has little or no resemblance to the original waste product from which it is produced. Office paper, toilet papers, paper towels, and napkins, greeting cards, cardboards, magazines, and newspapers are all products that have been made from recycled papers.

It is reported that a ton of recycled newsprint saves about a ton of wood while a ton of recycled bleached grade paper saves more than two tons of wood (Dibakar and Mohammed, 2014). Waste papers have been used in the development of composites for building materials. Amiandamhen and Osadolor (2020) produced kenaf reinforced waste papers and cement composite panels. A composite containing waste papers and cement was also developed by Samgrutsamee et al (2012) into blocks for building construction as a replacement for masonry blocks. The blocks were shown to satisfy the basic requirements for an insulating building material.

Chicken feather fibres may be recycled into low-quality animal feed or buried in landfills. Currently, the 4 billion pounds of chicken feathers produced annually in the United States are principally consumed by the feather meal industry, which utilizes the feather material in livestock feed (Winandy et al., 2003), where the feathers are hydrolyzed, dried, and converted to powdery feed supplement for a variety of livestock, primarily pigs (Park et al., 2000). This process is fairly expensive and results in a protein product of low quality which also has low demand. The development of alternative industry consumers of chicken feathers may increase the value of these feathers, which are currently valued at approximately $250/ton when sold for feather meal (Gentry et al., 2004). The utilization of chicken feathers as pillow filler, duster, and accessories material has begun. They have also been used in the production of diapers as the absorptive layers that were formally made out of the wood pulp, also called fluffy pulp (Ansarullah et al., 2018). Chicken feathers contain more than 13% nitrogen content (Tesfaye et al., 2017) and possess unique properties which include low relative density, good thermal and acoustic insulating properties, which could be used advantageously in many applications. The structure and properties of chicken feathers fibres make them unique fibres preferable for several applications such as in the production of wall panels, as they have low density, excellent compressibility, and resilience, ability to dampen sound, warmth retention, and distinctive morphological structure (Chinta et al., 2013).

In 2010, M. N. Acda introduced chicken feather fibres into the cement-bonded composite as a reinforcing material. The results showed comparable strength and dimensional stability to wood fibre-cement composites of similar density. Uzun et al (2011) also used chicken feathers as reinforcement in cement-bonded composites to improve the impact strength properties of the composite. This fact was also reported by Adetola et al (2014). Reddy et al (2014) concluded that chicken feather can be used as a matrix in the development of biodegradable composites. This view was supported by Amieva et al (2015), stating that the inclusion of chicken feather in a composite matrix could enable the development of low cost completely biodegradable composites.

The use of recycled materials in the production of wall panels is not new. Although most of the wall panels are produced from vinyl gypsum, natural wood, chipboards, fibreboard, glass, hardboards, and polyvinyl chloride, they have also been produced from recycled materials such as polystyrene wastes (Suprapto et al., 2017), paper waste tapioca (Bambang et al., 2018), bamboo (Fransisco et al., 2015) and plastics (Purwanto and Darmawan, 2017). However, the use of waste papers and chicken feather fibres is a novel development that aims to harness the lightweight, low-density properties of paper fibres with the insulative, sound absorption, and compressibility of chicken feather fibres in the production of decorative wall panels.

The development of wall panels using waste paper and chicken feather fibres is geared towards repurposing waste products and ultimately reducing the pollution caused by the disposal of these waste products. The main objective of this study is to investigate some physical, mechanical, and thermal properties of wall panels produced from chicken feather fibre and waste papers.

2. Materials and Methods

2.1. Materials

The 3D wall panel is produced from bleached grade waste papers, chicken fibres (down feathers), and water using a moulding machine that was designed and constructed for the purpose. The moulding machine is a manually operated, comprising of the mould, counter mould, screw shaft lowering mechanism and a support frame. The moulds are removable and can be changed to the dimension and shape of the desired moulded products. The counter mould, also removable is imprinted with the pattern that is transferred to the wall panels for aesthetics (Kolajo et al., 2020).

2.2. Waste paper slurry

The materials preparation and production of the wall panels are described in a flow chart (Fig. SM1). Waste papers were of the bleached grade collected from a local printing press. They were sorted, and foreign matter such as staple pins was removed. The waste papers were weighed and shredded, using a paper shredder for ease of disintegration into pulp slurry. The disintegration was done using a predetermined amount of water to achieve 5% fibre slurry consistency in a hydro pulper. The slurry was refined to ensure better inter-fibre bonding since no external binding agent is introduced into the composite. Refining allows the fibres in suspension to have increased contact area (Fig. SM2).

2.3. Chicken feather fibres

The chicken feathers were collected from a private farm in Ibadan, Western Nigeria. The feathers were cleaned, air-dried and the down feathers were separated manually by removing the quill from the mix (Fig. 1). Cleaning was done to eliminate contaminating materials which could include bloodstains, chicken flesh, feeds, and other contaminants present in the chicken feathers. The cleaned feathers were air-dried for about 72hours.

2.4. Wall panel production

The wall panels were produced using varying ratios of bleached grade waste papers (WP) to Chicken Feather Fibres (CFF) (Table 1). The refined waste paper slurry and the weighed down-feathers were mixed until there are no clusters of the feather in the mixture. The CFF content of the mix was varied by 0%, 5%, 10%, 15%, and 20% of the composite mass. AEKMS are the codes assigned to each variation of the wall panels produced. 3 replicates for each composition were produced, given a total of 15samples. The dimension of the wall panels produced is $300 \times 300 \times 13mm$ from which $175 \times 160 \times 13mm$ were obtained for Impact test, water absorption, and thickness swelling tests; $300 \times 20 \times 13mm$ for thermal insulation and resistance.

Fig. 1: Chicken feather (down) fibres

Table1: Experimental ratios of CFF to WP and WP to Water

CODE	CFF (grams)	WP (grams)	CFF:WP	Water:WP
A	0	550.0	0:100	1:45.5
E	27.5	522.5	5:95	1:47.8
K	55	495.0	10:90	1:50.5
M	82.5	467.5	15:85	1:53.5
S	110	440.0	20:80	1:56.8

2.5. Test procedures

Mechanical Properties

Modulus of Rupture and Modulus of Elasticity was carried using ASTM D1037 Standard on Instron 5500R-1132 universal test machine and strain measured using an extensometer (Model 3542, Epsilon Technology Corp.). Data were processed using Bluehill Version 2 software (Instron). Impact strength test was conducted using the Instrumental Falling Weight impact testing principle. The apparatus is equipped with various specimen fixtures for loading flat laminate and cylindrical specimens. The impact strength is calculated by dividing impact energy by the thickness of the specimen

Physical Properties

The density of the wall panels produced was determined according to ASTM D792-20 while water absorption and thickness swelling tests were conducted according to modified ASTM D570-98 standards. Test samples of dimensions 50 x 50mm2 while measurements for thickness swelling were made at the centre of the specimen facing suing a digital venier caliper with ±0.01mm accuracy.

Thermal Property

The thermal conductivity was measured of the samples using the Model TC48AC Hot Disk Thermal Constants Analyser, which uses the transient plane source method. The sensor was sandwiched between two sample pieces. All sample variations A, E, K, M, and S were analyzed. Proper contact between the samples and the sensor was ensured to obtain accurate results.

3. Results and Discussion

3.1. Mechanical Properties

The wall panel E has the highest impact strength (3193.84J/m) while the least strength (1436.93J/m) was obtained from S (Table 2). The impact strengths from wall panels E to M have higher values than A. This shows that the presence of CFFs up to about 15% inclusion increases the impact strength of the wall panels. A similar observation was made by Akinyemi and Omoniyi (2017), where it was reported that the inclusion of fibres in a bamboo and cement composite mix increased the compressive strength of the composite up to a percentage. The difference in the impact strengths is attributable to the pore spaces caused by the presence of the chicken feather in the mixture. Khalil *et al.* (2007) posit that fewer void spaces in the mix could result in an improvement in the impact strength of composites. This position is supported by Chen *et al.* (2014) who recorded the highest impact strength at 10% fibre loading in the production of oil palm mesocarp fibre reinforced biodegradable composites.

Table 2: Physical and Mechanical tests

CODE	Thickness of board (m)	Density (kg/m^3)	Impact Energy (J)	Impact Strength (J/m)	MOE* (N/mm^2)	MOR** (N/mm^2)	Thermal conductivity(W/mK)
A	0.013	380.3	22.83	1756.15	2.1	30.6	0.170
E	0.013	363.3	41.52	3193.84	3.0	33.0	0.168
K	0.013	354.7	26.99	2076.15	1.8	29.4	0.166
M	0.013	380.3	26.99	2076.15	1.2	30.8	0.157
S	0.013	384.6	18.68	1436.93	1.4	30.5	0.154

*MOE= Modulus of Elasticity, **MOR=Modulus of Rupture

3.2. Physical properties

The average density obtained was 372.64kg/m^3 (Table 2). The weight of all samples increased as the initial rate of the water absorption process increased which is as a result of the accelerated water uptake at the initial stage. This observation is similar to that of Radzi et al., (2013) where it was observed that the water uptake was faster in the early stages of immersion and became slower as the immersion time increased. The percentage of water absorbed by the samples is ranged between 239.5% and 336.7% (Fig. 2). The hydrophilic properties of paper fibres contribute to the high absorption rate of the samples. The absorption rate for E and M were minimal which is a result of the 5%CFF and 15%CFF present in the samples respectively. The excess pores and voids caused by the chicken feathers in S are assumed to be the reason for the high absorption rate recorded at S. The highest water uptake for all samples occurred at the 16th hour of immersion. At this point, the samples were saturated with water after which dissolution of the samples started to occur, which resulted in the reduction in weights. The thickness swelling of M was the highest (Fig. 3) and it retained its original structure throughout the experiment. The increase in both the percentage water absorption and thickness swelling is suspected to be due to the absence of either an adhesive (binder) or surface coat which would have served as a moisture barrier. Generally, the high affinity of natural fibres for moisture absorption is due to the presence of the hydroxyl groups and this has been reported as a significant drawback in natural fibre reinforced composites (Sreekala and Thomas 2003; Shinoj et al., 2011 and Mohammed et al., 2015).

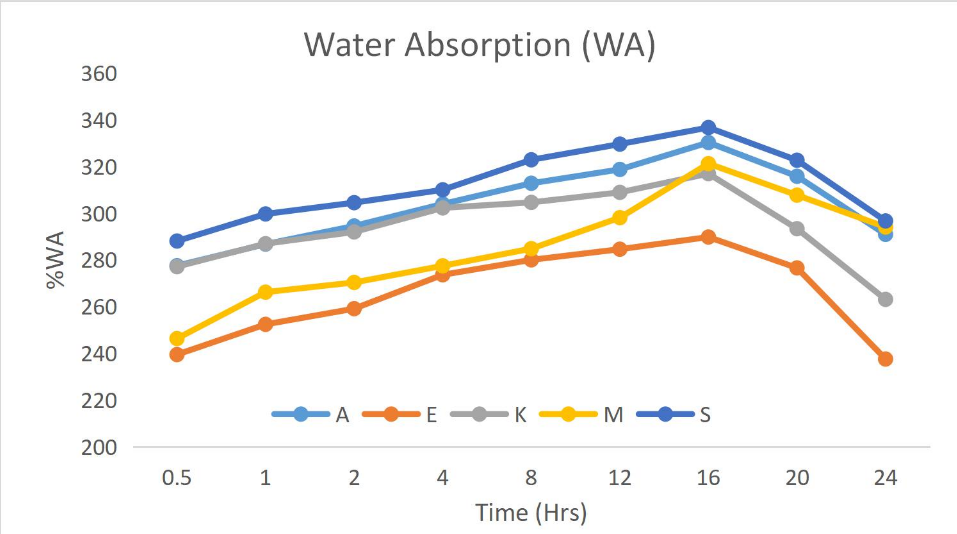

Fig. 2: Percentage of water absorption of the tests samples

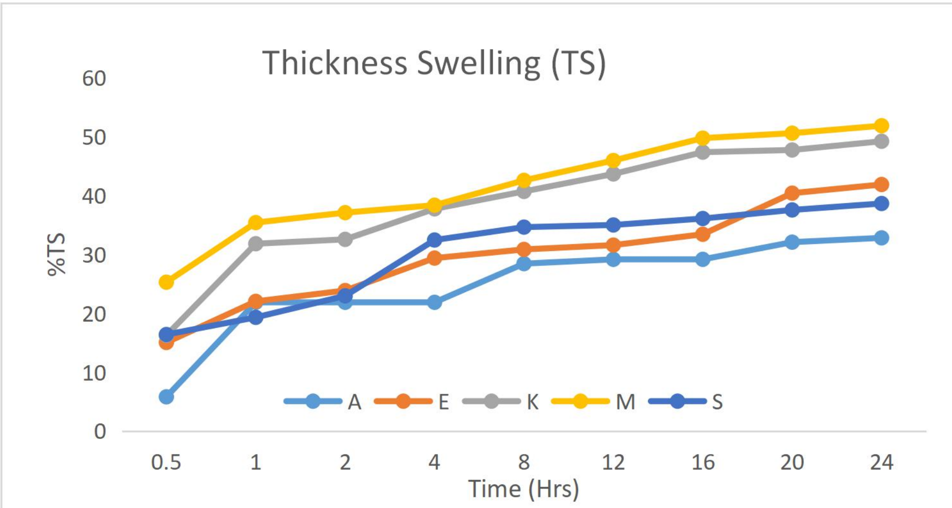

Fig. 3: Percentage of thickness swelling of the test sample.

3.3. Thermal property

According to Table 2, the thermal conductivities obtained decreased from A to S. The highest conductivity at A (0.170W/mK) and the lowest at S (0.154W/mK). As the inclusion of CFF from E to S increases, the insulating ability of the wall panels also increased. This implies that the chicken feather fibres increased the insulating property of the wall panels. Natural fibres have been reported to have a high insulating property which is a result of their low conductivities. It was observed that there was a reduction in thermal conductivity with the inclusion of bamboo fibres in a cement composite mix in the production of acrylic polymer modified mortar reinforced with fibres (Akinyemi and Omoniyi, 2017). This is in agreement with Cristel *et al.* (2010) who reported that higher bagasse fibres caused low thermal conductivity in bagasse fibre concrete. Mounika *et al.* (2012) also obtained low thermal conductivity when the fibre content in a bamboo fibre reinforced polyester composite was increased. Therefore, it could be stated that the higher the volume of the natural fibres included, the more insulating the wall panels. The presence of void and pores within the wall panels created by the quills of the chicken feathers may also be responsible for the low thermal conductivity as these have a potential for reducing heat transfer (Belhadj et al., 2012; Akinyemi and Omoniyi, 2017).

4. Conclusion

In this study, wall panels were produced from waste paper and chicken feather down fibres. The sorption properties, impact strength, moduli of rupture, and elasticity were evaluated. Thermal property of the wall panels was also determined. The inclusion of CFF up to 5% content improved the mechanical properties. Thermal properties were improved as the CFF content increased. The resistance of the panels to water absorption and thickness swelling is low. The addition of an adhesive binder or a surface coat could serve as a moisture barrier, especially in exterior applications where there is exposure to moisture. In summary, the wall panels possess good thermal, mechanical, and sorption properties suitable for interior applications.

Credit authorship and contributions

Kolajo T.E: Conceptualization, Methodology, Supervision, Writing, reviewing, and editing. Odule O.E: Investigation, Data curation, Writing- original draft.

Declaration of Competing Interest

The authors declare no conflict of interests that could have appeared to influence the work reported in this paper.

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