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Effect of Starch Composition on the Strength of Compression Moldable Starch-Wood Bio-Composite Materials.

AU Birnin-Yauri[1]*, and AP Abbot[2].

[1]Department of Pure and Applied Chemistry, Kebbi State University of Science and Technology, Aliero
[2]Department of Chemistry, University of Leicester United Kingdom.

Research Article

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*For Correspondence

Department of Pure and Applied Chemistry, Kebbi State University of Science and Technology, Aliero

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ABSTRACT

This research reported the effect of different starch compositions on the strength of Starch-wood biocomposites plasticized using borax-glycerol systems. These compression moldable materials have benign nature and biodegradability and could be employed as alternative to MDF which uses environmentally non-benign adhesive i.e. urea-fomaldehyde. Cornstarch together with Wood flour were assayed using different mixing ratio viz. 100% Wood flour, 100% Starch flour, 80% - 20% Wood- Starch, 70% -30 % Wood – Starch, 60% - 40 % Wood –Starch and 50% -50% Wood –Starch. The pure wood composite was found to be weak while the strength of the starch-wood composites was found to increase with increasing starch component.

INTRODUCTION

It is evident that the oil-based polymers have dominated materials science for many decades. But the current challenge now associated with the use of the petro-based materials includes economic and environmental problems. [1] A large amount of investigation carried out for biodegradable polymers from a renewable source has been directed on the use of polylactic acid, PLA, which is derived from starch and has found use in biomedical applications, packaging and disposable items such as cutlery and cups etc. However, the disadvantage of PLA is the high cost when compared with petroleum-based materials in terms of the numerous processing steps required for its production from starch.[2]

A more attractive option to the use of petro-based polymers is the use of thermoplastic starch (TPS) which is produced by the incorporation of small polar organic compounds such as glycerol, urea, water etc. These compounds help to plasticise the starch by breaking the internal hydrogen bonding between the glucose rings in the starch decreasing its crystalline and making the structure more amorphous. The incorporation of these polar compounds into the Starch structure is often achieve by extrusion, compression molding, melt processing etc. [2,3] However, the strength of the starch-based composites depends largely on the composition of starch, plasticizer and filler reinforcement. Hein, the effect of varying compositions of starch as thermoplastic component and wood as filler reinforcement in the development of starch-wood composites is assayed, plasticized using saturated aqueous borax solution.

METHOD

Preparation of samples.

Saturated aqueous borax solution

500 ml of deionised water was obtained in a beaker equipped with a magnetic stirrer and placed on a thermostatically controlled hot plate set at 50^{o}C. The sodium tetraborate decahydrate (Sigma Aldrich > 99%) was continuously added into the deionised water in the beaker and stirring was maintained. The saturated solution was formed at the point when a spatula was added and could not dissolve in the solution. Stirring was stopped and solution was allowed to cool to room temperature. The undissolved borax solute was then filtered and the collected filtrate was kept in a storage bottle.

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Starch and Wood flour

Corn starch and wood were dried in an oven for 24 hours at 70 °C before use. The various formulations and their codes of the samples are outline in the table 1 below:

Sample mixing and homogenization

Appropriate amount of the powdered cellulose materials were blended with a given quantity of the corn starch (Weik field brand, used as received), mixed with a particular plasticiser (as prepared above), homogenized in a Kenwood FP 120 food processor and the resulting mixtures (sandwich) were allowed to stay for 60 minutes at room temperature in a clean, sealed, airtight plastic bags before compression molding.

Table 1: Different composition of Starch-Wood samples.

S/N	Starch (%)	Wood (%)	Code
1	100	-	S100
2	-	100	W100
3	50	50	S50W50
4	40	60	S40W60
5	30	70	S30W70
6	20	80	S20W80

Procedure for compression-molding

The mixture (sandwich) was then placed in oven at 70°C for one hour. The mixture was then placed between two copper plates lined with silicone sheet and with a 2 mm copper separator with a 10 cm square aperture (figure 1). The sandwich was then placed in a Fortune TH 400 hydraulic press (figure 2) and a force of 100 kN was placed on the sample for 10 minutes at 140 °C. The sample was then cooled back to room temperature in 5 minutes in the press with the force still applied.

Figure 1: Sample laden plate frame

Figure 2: Fortune TH 400 hydraulic press

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Procedure for mechanical properties test.

After compression molding, a Ceast 6051 punch press was used to cut out 10 dogbone-shaped specimens from the thin sheets and measured their thickness and a 2mm min-1 extension rate was set. The stress/strain tests were employed to test the mechanical properties of the thin sheet materials using an Instron 3343 tensiometer fitted with a 500N load cell. All measurements were conducted at room temperature. The data obtained were used to assay the mechanical properties of each of the samples such as maximum tensile stress. The average of the results for the ten specimens was estimated to obtain the maximum tensile strength given in mega Pascal (MPa).

RESULTS AND DISCUSSION

RESULTS

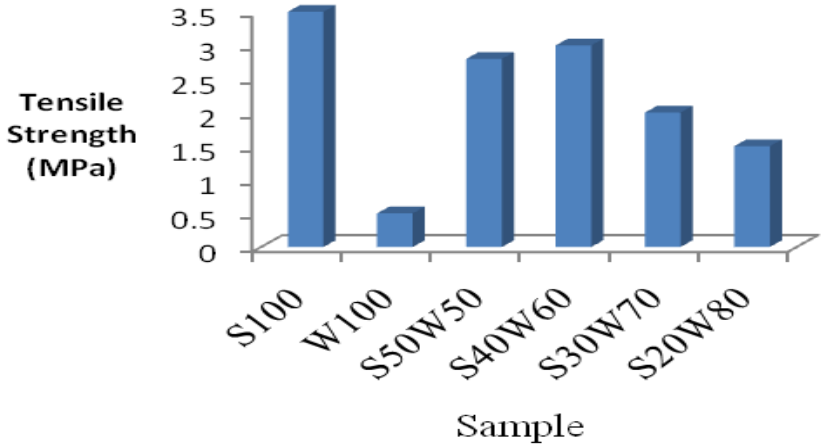

Figure 3: Tensile strength of various samples

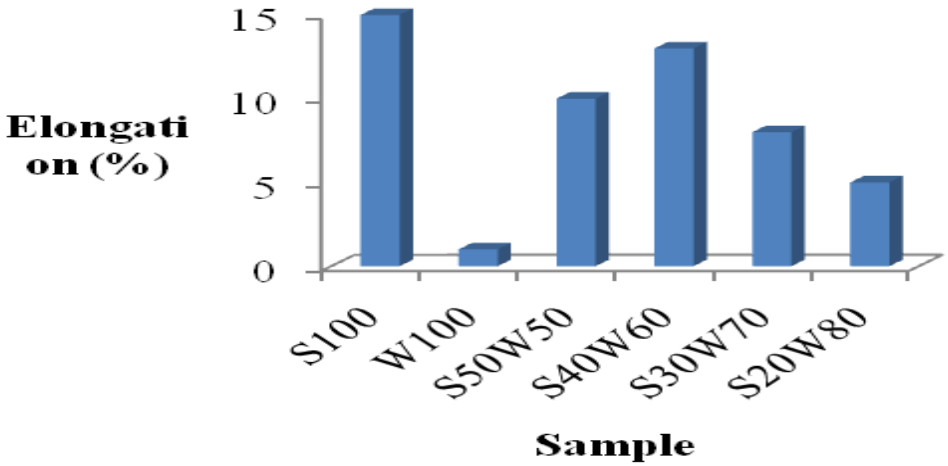

Figure 4: Percentage elongation of various samples

DISCUSSION

Initially, 50 g of solutions of the borax (*i.e.* Sodium borate decahydrate) in the form of saturated aqueous solution was employed to plasticise 100% of pure wood sample and the products obtained turn out to be very soft, brittle and weak. Therefore the amount of wood was reduced to 80% and then 20% of corn starch was introduced. The strength and the flexibility of the materials were enhanced and their respective texture in general was increased. More corn starch viz. 30%, 40% and 50% was added while reducing further the content of wood flour viz. 70%, 60% and 50% respectively. It was observed that strength of the composites increases further (figure 3). These observations made were expected as starch has remarkable thermoplastic properties and exhibit such properties only in the presence of a suitable plasticiser.[4] This gave the impression that wood alone may not form a thermoplastic of significant strength, implying that the thermoplasticity of pure wood is less than that of wood-starch composites. It is important to know that tensile strength is the measure of the material to failure given by the applied strength (ie load per unit area). In the wood-starch composites therefore, the starch is the thermoplastic

component while the wood is the cellulose filler reinforcement which after mixing with the starch and plasticiser upon compounding help to enhance the texture of the composites and improve their strength. [5]

Generally, the percentage elongation of the materials formed with all the plasticisers tends to have a proportionality relationships with their corresponding tensile strength irrespective of the amount of the plasticiser used. This is expected due to the weakness and brittleness of the most of the composites which could arise due to micro defect and lack of adequate sample homogeneity. Thus, the elongation of the pure wood samples was the weakest than the starch-wood composites and as such the pure wood composites have poor flexibility. The change in length prior to failure of the materials increases with increasing starch content of the composites. As can be seen from figures 4, the elongation at break of the composites decreased with increased wood filler reinforcement. This illustrates that increase in the amount of the filler loading makes the ductility of the pure wood composites to decrease. But for the composites containing starch, the wood filler component of these composites aids to reduce the ductility of the composite and increases their stiffness. [6]

CONCLUSION

The starch-wood composites developed here indicated that the pure wood sample was brittle, rough and weaker than the starch-wood composites. Strength of the starch-wood composites increases with increased starch. The elongation of the pure wood samples was the weakest than the starch-wood composites. The elongation of the starch-wood composites is low with low starch content and high wood flour reinforcement loading arising due to the poor interfacial bonding between the filler and starch biopolymer matrix causing micro cracks at the point of impact. These cracks can easily propagate in the composites causing decreased impact strength.

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