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A Preliminary Investigation Of Cassava Starch Potentials As Natural Polymer In Bioplastic Production

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ABSTRACT

Starch consists of two types of molecules namely, amylose and amylopectin. Amylose, a linear chain polymer constitutes about 20% of starch. It is more soluble in water, soluble in hot water but does not form gel while amylopectin is a branched chain polymer that constitutes about 80% of the starch. It is less soluble in water, soluble in hot but forms gel, hence the need for modification. In this study, Cassava starch was modified with distilled water, glycerol and vinegar. The cassava starch, distilled water, vinegar and glycerol were all weighed in required proportions into the beaker. 50g of cassava starch was weighed into a beaker, 10mls of vinegar was added. 20mls of glycerol was also added. The resulting mixture was thoroughly stirred to form a uniform suspension, the suspension was heated, and it was continuously stirred to avoid coagulation with increasing viscosity until gelatinization was achieved at about 100°C. The gel was spread on a smooth, hard surface and mechanically pressed to form sheets. The sheets were air dried to cure for 72hrs to 5% moisture content. The sheet was subjected to tensile test. Water was used as a solvent to first get the biopolymer (starch) into solution. When the solution was heated, the water helped the starch molecules to become disrupted and disordered (denatured). The reduction of starch hydrogen bonding was achieved in the presence of water. Water diffused into the starch granules and hydrogen bonds breaking down the intermolecular bonds of the starch molecules. Water helped the starch molecules to become disrupted and disordered. When the starch was heated with water, water interacted with hydroxyl

groups in the starch, thereby reducing hydrogen bonding among the starch molecules. This phenomenon allowed individual molecules to move freely relative to each other, thereby allowing the starch to be melt-processed.

KEYWORDS

Natural Polymer, Tensile strength, modification, synthetic polymer, bioplastic, cassava starch.

INTRODUCTION

Plastics are simply chains of like molecules linked together. These chains are called polymers. This is why many plastics begin with “poly,” such as polyethylene, polystyrene, and polypropylene. Polymers often are made of carbon and hydrogen and sometimes oxygen, nitrogen, sulfur, chlorine, fluorine, phosphorous, or silicon. The term “plastic” encompasses all these various polymers. Plastics are synthetic or semi synthetic materials made from organic polymers. In other words, while other elements might be present, plastics always include carbon and hydrogen. While plastics may be made from just about any organic polymer, most industrial plastics are petroleum based and are made from petrochemicals.

The world production of plastics is estimated to be more than 100millions times per year. The need for such quantities of conventional plastics and their dominance over other materials is due to their excellent long life properties. These properties includes: resistance to chemical reactions, especially enzymatic reactions. For example, it can take up to one hundred years to degrade only a few grams of plastic(such as polyethylene) under normal environmental conditions. Degradation at high temperature such as in pyrolysis (burning) tends to cause emission

of toxic fumes. Plastic accumulations in the environment thus create tremendous problems for the world, presently and in the future. Environmental problems caused by plastics includes: changes to the carbon dioxide cycle, problems in composting and increased toxic emissions stimulated by environmental concerns, scientists are now concentrating on ways to develop plastics use more efficiently.

Thermoplastic starch currently represents the most widely used bioplastic, constituting about 50 percent of the bioplastics market. Simple starch bioplastic films and sheets can be made by modifying starch with plasticizers such as glycerol, glycol, and sorbitol and can also be added so that the starch can also be melt processed thermo-plastically. In this work, glycerol ,vinegar (acetic acid) and distilled water were used in starch modification to produce boi plastic sheets.

However, plastics made from petrochemicals do not degrade easily; they can be in the environments for several thousands of years constituting environmental nuisance and challenges. When these plastics are recycled and reused, they still find their way into the environment. Even when they are burnt at landfills, toxic fumes are released into the environment posing health threat to humans

and there are currently limited spaces for landfill, hence the need for bioplastics production. Bioplastics are plastics derived from renewable biomass sources such as vegetable fats and oils, cassava starch, food waste etc. In principle they could replace many applications for petroleum-derived plastics, Biodegradable plastics are degradable plastic in which the degradation results from the action of naturally occurring microorganisms such as bacteria, fungi and algae. Bioplastics save more nonrenewable energy than conventional plastics and emit less GHG compared to conventional plastics.

There has been a widespread interest in plastics made from renewable and natural polymers which can degrade naturally and more rapidly than the petroleum-based plastics. Among all biopolymers, starch is

being investigated as a potential material for biodegradable plastics. The main interest in 'biodegradable' plastics is that they break down into simpler components sooner than traditional plastics.

Starch is renewable, readily biodegradable, easily modified and available in bulk in all parts of the world at low cost (estimated global production > 70 millions tones in 2011, making it a very attractive raw material for "green" plastics production (Jeffry Grotto, 2013). The "Cradle-To-Grave" concept has been designed by the Michigan Biotechnology Institute (1994). As the end use of products from biodegradable plastic is composting, it can serve as a reserve for carbon dioxide and as a means to return nutrients back to the soil (as compost).

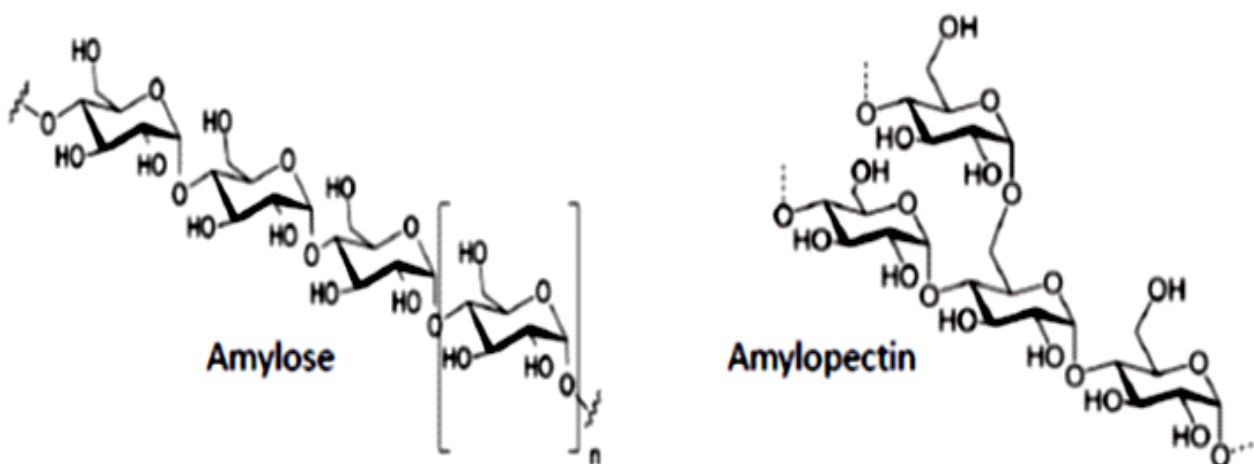


Fig 1: Structures of Amylose and Amylopectin of Cassava Starch

From 2003 to the end of 2007, the global average annual growth rate was about 38% (Shen et al., 2009) considering the promising of bio-based plastics to replace their

petrochemical counter parts, the bioplastic industry has a huge market.

According to (Weber 2000), starch-based packaging will continue developing with the support of their niches of traditional non-food

markets. Later, starch biopolymers should enter the food market, after that resistance to humidity and cost-related problems are solved

The use of starch in the manufacturing of bioplastics began in the 70's (Curvelo et al., 2001). Among its advantages, starch is cheap, abundant and renewable. Besides, it is found in several forms due to the origin of its raw material (Lawter and Fischer, 2000).

To plastify the starch, it is necessary to use a large quantity of plasticizers or destructuring compounds (glycerol, etc.) with hydrophilic properties. Thermoplastic starch currently represents the most widely used bioplastic, constituting about 50 percent of the bioplastics market. Simple starch bioplastic film can be made at home by gelatinizing starch and solution casting. The properties of starch bioplastic is largely influenced by amylose/amylopectin ratio. Generally, high-amylose starch can result in better mechanical properties. However, high-amylose starch has less processibility because of its higher gelatinization temperature and higher melt viscosity.

MATERIALS AND METHODS

The Study Area

The study was conducted at the Federal Institute Of Industrial Research Oshodi Lagos Nigeria. The bioplastic production was done at the Packaging Technology Division of the Institute. Material characterization was done at the department of Polymer Science, Yaba College of Technology, Lagos, Nigeria.

The Modification and Plasticization Process

Modification of Starch requires the disruption of starch granules and their super molecular

Structures. Starch in its native form cannot be melt-processed because the hydrogen bonds that hold the starch molecules together have to be reduced (disrupted or disordered) to melt-process native starch, the glass temperature (Tg) of pure, dry starch is above the decomposition temperature point, so it does not soften and flow. However, starch can be plasticized by materials (molecules) that are capable of hydrogen bonding with the starch hydroxyl groups, such as water, glycerol or sorbitol. The materials used in this study were cassava starch, distilled water, glycerol and vinegar. The cassava starch, distilled water, vinegar and glycerol were all weighed in required concentrations into the beaker. 50g of cassava starch was weighed into a beaker, 10mls of vinegar was added. 20mls of glycerol was also added. The resulting mixture was thoroughly stirred to form a uniform suspension, the suspension was heated, and it was continuously stirred to avoid coagulation with increasing viscosity until gelatinization was achieved at about 100°C. The gel was spread on a smooth, hard surface and mechanically pressed to form a sheet. The sheet was air dried to cure for 72hrs to 10% moisture content. Tensile strength of the sheet was determined. Water was used as a solvent to first get the biopolymer (starch) into solution. When the solution was heated, the water helped the starch molecules to become disrupted and disordered (denatured). The reduction of starch hydrogen bonding was achieved in the presence of water. Water diffused into the starch granules and hydrogen bonds breaking down the intermolecular bonds of the starch molecules. Water helped the starch molecules to become disrupted and disordered. When the starch was heated with water, water interacted with hydroxyl groups in the starch, thereby reducing hydrogen bonding among

the starch molecules. This phenomenon allowed individual molecules to move freely relative to each other, thereby allowing the starch to be melt-processed.

Vinegar contains acetic acid which forms hydrogen ions and acetate ions, the vinegar's

free Hydrogen ions interacted with the starch molecules which made them more easily disrupted and disordered. Vinegar helped the starch to dissolve better, so vinegar was used to increase starch solubility.

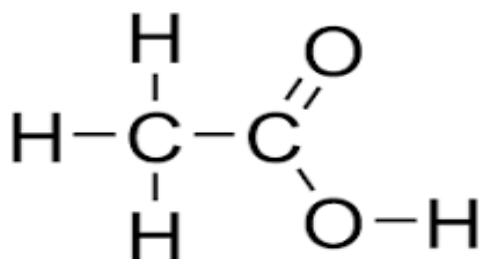


Fig 2: Structure of Vinegar

Glycerol (Propan-1, 2, 3-triol) → It is a hygroscopic liquid with a high viscosity. It has three hydroxyl groups which makes it soluble in water. It increased the flexibility and workability of the plastics. With the hydroxyl groups, it has the affinity to form hydrogen

bonds with water molecules. Glycerol made a very useful plasticizer in the formulation. Glycerol made the polymer chain molecules to bend and slide past each other more easily, which added to the flexibility and durability of the plastic.

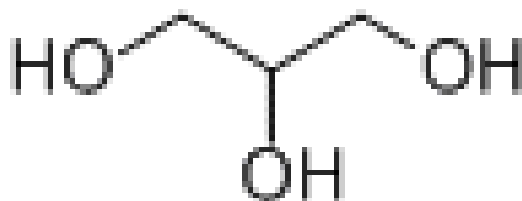


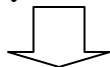
Fig 3: Structure of Glycerol

Methodology flow chart

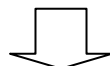
Collection of Materials



Analysis of materials



Modification



Plasticization



Plastic Production



Plastic Characterization

Table 1: Specimen Geometry of Analyzed Bioplastic Sample

S/N	PARAMETERS	VALUES	UNIT
1	Thickness	1.00	Mm
2	Length	80.00	Mm
3	Width	30.00	Mm

Table 2: Tensile Properties of Analyzed Bioplastic Sample

S/N	SPECIFICATION	VALUE	UNIT
1	Yield load	1.10	Kgf
2	Yield Elongation	0.60	Mm
3	Tensile Strength at Yield Load	3.67	Kg/cm ²
4	Breaking Load	3.70	Kgf
5	Elongation at Break Load	4.10	Mm
6	Tensile Strength at Breaking Load	12.33	Kg/cm ²
7	Tenacity at Breaking Load	0.00	Gms/Denier
8	Elongation % at Break	5.13	%
9	Maximum Load	5.20	Kgf
10	Elongation at maximum Load	2.80	Mm
11	Tensile Strength at Maximum Load	17.33	Kg /cm ²
12	Tenacity at Maximum Load	0.00	Gm /Denier
13	Elongation % at maximum Load	3.50	%
14	Modulus Elasticity	488.89	Kgf cm ²
15	0.1% Offset Yield Strength	0.00	M.Pa

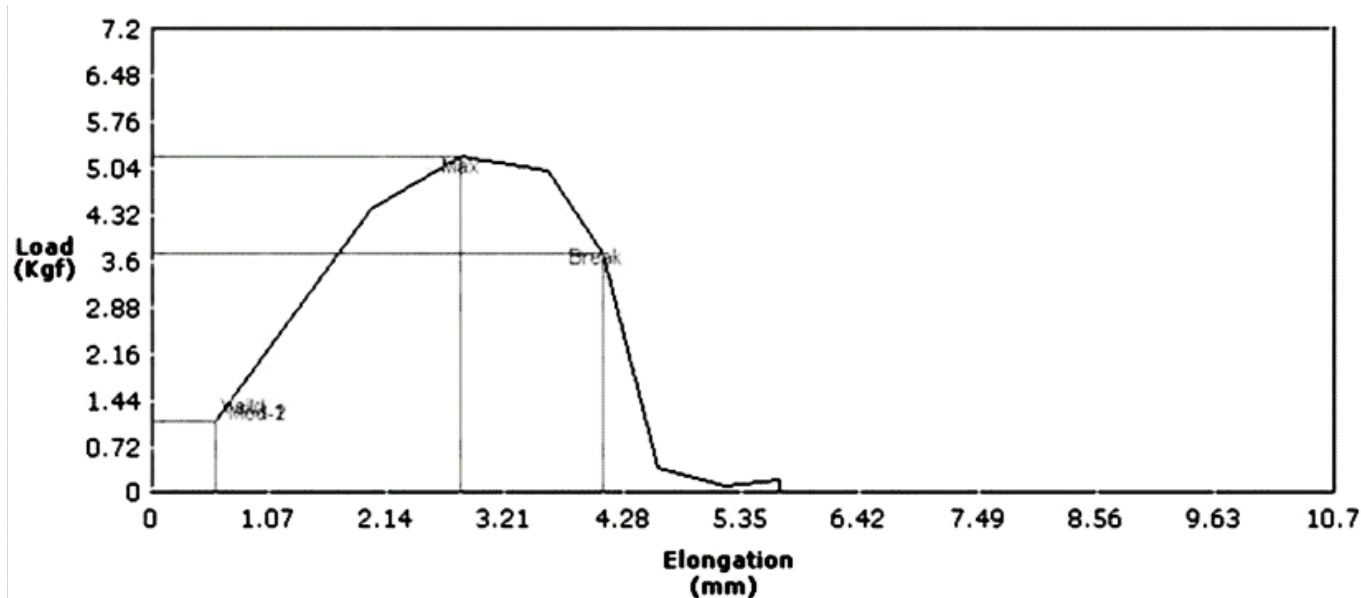


Fig 4: Load –Elongation Graph

RESULTS AND DISCUSSION

Tensile strength is measured by the maximum stress that a material can withstand while being stretched or pulled before breaking. It is an intensive property; therefore, its value does not depend on the size of the test specimen. However, It is dependent on other factors, such preparation of the specimen, the presence or otherwise of surface defect, and the temperature of test environment and the materials. From table 1 above, the specimen geometry shows that the bioplastic sample analyzed has 1.00mm 80.00mm and 30.00 for thickness, length and width respectively. Results from table 2 and the load-elongation graph show that the sample was able to withstand the maximum load of 5.20kgf with 2.80mm elongation at maximum load and tensile strength of 17.33kg/cm² at maximum load. The values above are good for a 100% bioplastic sheet. The results of the study show

that cassava starch as a natural polymer has potentials in bioplastic production.

CONCLUSION

The investigation of cassava starch as a natural polymer in bioplastic production, show that starch as a natural polymer can replace petroleum based polymers mostly used in plastic production The bioplastic produced from 100 percent cassava starch was found to possess good tensile properties acceptable for bioplastic. This is as a result of proper starch modification with water glycerol and vinegar. The result also show that the bioplastic sheet produced exhibited plastic behavior

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