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Research Article

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Evaluation of the Use of Carbon Black from Waste Materials for the Production of Erasable White Board Ink

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Abstract The use of Carbon black from locally sourced carbonaceous waste such as lampblack, spent tyre and coconut shell was explored in the formulation of erasable white board ink. The formulated ink from lampblack demonstrated good physical properties which include viscosity, opacity, adhesion, eligibility and erasability. These properties were optimized in this study by varying the concentrations of Arabic gum, pigment and the solvent ratios. It is hoped that this work introduces an economically viable means for the production of erasable ink from local sources as well as contribute to sustainable waste management.

Keywords Carbon Black, Waste Materials, Erasable White Board Ink

Introduction

Inks are colloidal systems of fine pigment particles coloured or uncoloured dispersed in an aqueous or organic solvent. These are primarily composed of pigments, binders, solvents and additives [1]. One of the relatively new products flooding the Nigeria market today is the crucial educational material called "erasable white board marker" or" temporary marker" used on white board which has now almost replaced the traditional chalk used on black board. This product is in high demand at all level of education. However, all the temporary marker currently in circulation in Nigeria are imported, current techniques employ synthetic materials which drives the costs. This practice drains our economy and hence the drive for finding sustainable methods of producing various components of inks locally.

Carbon black (soot) which is the pigment explored in this study is a form of elemental carbon produced by the incomplete combustion or thermal decomposition of hydrocarbons [2]. Its high tinting strength has seen it widely used as a coloring for ink and paint. Other properties such as chemical inertness, ease of functionalization, low cost and ease of disposability have also been applicable for electrochemical sensing and energy storage [3]. Commercially available carbon black is produced mainly from furnace black. However, thermal black, lampblack, acetylene black and channel black have all been explored [4,5]. Therefore, the use of carbon black (soot) from waste materials to produce non-porous white board marker ink can also be explored. Characterization and parameter optimization are done to fully determine the quality of the produced ink and its suitability for use in white board markers. Furthermore, the proportions of ink components also influence critical properties like the flow and appearance of the ink. Hence, the importance of optimizing the production conditions of the ink. Primary components to be optimized include pigment, resin and solvent ratios which are raw materials for ink production [6].

The pigment colours the ink and makes it opaque while resins bind the ink and the surface into a film [7]. The solvents make the ink flow so that it can be transferred to the printing surface. Other additives could also be incorporated to alter the physical properties of the ink if necessary. Arabic gum is natural resin rich in non-viscous soluble fiber [8,9,10] widely used industrially as a stabilizer, thickener, emulsifier and to a lesser extent in textiles, ceramics, lithography, cosmetic and pharmaceutical industry. Because of the compact, branched structure and therefore small hydrodynamic volume, gum Arabic solutions are characterized by a low viscosity, allowing the use of high gum concentrations in various applications. Solutions exhibit Newtonian behavior at concentrations up to 40% and become pseudo plastic at higher concentrations [11]. These properties are exploited in this study to optimize the production of inks.

Indiscriminate disposal of waste and unused materials which include synthetic and bio-based waste materials on roads, canals and drainages which may be due to poor waste management by the citizen and government need to be curbed. Therefore, this research seeks to produce temporary ink from waste materials such as used tyres, kerosene and coconut shell char soots. This is hoped will reduce or possible eliminate the importation of temporary ink marker into Nigeria. However, these inks have demonstrated greater stability and flow which are vital for the application of the inks.

Ink, also called masi, is a mixture of several chemical components, which has been used in India since at least the 4th century BC. In the late 19th century, logwood ink was made from extract of the logwood (haematoxylononcampecheartzim) tree mixed with crystalized sodium carbonate and potassium chromate and potassium chromate. The wood was cut into pieces and then steeped in boiled water to extract the dye [12]. They used fine particles of carbon (lampblack) as the colorant and gum, saps or glues as the vehicles or bonding agents [4]. Lampblack is soot collected from oil lamps; however, the lampblack used was created by partially burning tar with a little vegetable oil, the pigment (i.e. lampblack) was suspended in gum or other glue to ensure that it adhered to the writing surface. The erasable ink or dry ink was invented in 1975 by Jerry Woolf of Techform laboratories; however dry erase markers and boards became popular in the mid-1990 and these markers are better than chalk in so many different ways especially that they are easy to erase, they can be applied to the board with less pressure and they are unaffected by water. It is worthy of note to say that this type of markers is made basically for non-porous surfaces such as mirrors, metals, and opaque glass materials. The ink is made from color pigments, chemical solvents and a polymer also called a release agent [7]. Therefore, this research seeks to solve economic and environmental problems which includes;

1. Creation of employment and boosting the nation’s economy
2. Reducing health hazard caused by pollution
3. Minimizing the rate of foreign exchange and maker pen importation
4. Waste management

2. Materials and methods

Materials

Ethanol (99.5% Analytical grade), Magnesium sulphate salt were obtained from Fisher Scientific. Distilled water, Arabic gum.

Carbon Soot Pigments

The protocol for the preparation of carbon soot pigments from lampblack, coconut shell and spent tyre are briefly described. For lampblack, a kerosene lamp was used to make a very sooty flame by interrupting the flame with a non- combustible pan suspended just above the flame known as lid. The soot deposited on the lid is swept over a wide container using a feather. The lid is closed on the flame again and this process continues until the oil is finished. The coconut shell char was collected from the local market in Yola. The procured shell char sample was cleaned and sub-divided to smaller lump sizes and activated with direct fired with wood in a close steel pot at a controlled condition to obtain granulated carbon. Shredded piece of spent automobile tyre was washed and dried. It was charged into the reactor after which flame was ignited to initiate combustion. A fluffy black residue after the completion of combustion was recovered in a ready-made form of fine particles sizes.

Ink Preparation

50 mL distilled water is used to dissolve 20 g of Arabic gum in a beaker and stirred for 45 minutes while 4.5 g of the lamp soot pigment is dissolved in 20 mL of distilled water. 40 mL of ethanol is added to the soot solution and 2 mL of the Arabic gum solution are added and stirred for 3 minutes to form a homogeneous solution. To dry the ink sample, 0.30 g of Magnesium sulphate is added to about 30 mL and the sample is stored in an air-tight container for analysis. This procedure was repeated for tyre soot and coconut shell char soot respectively.

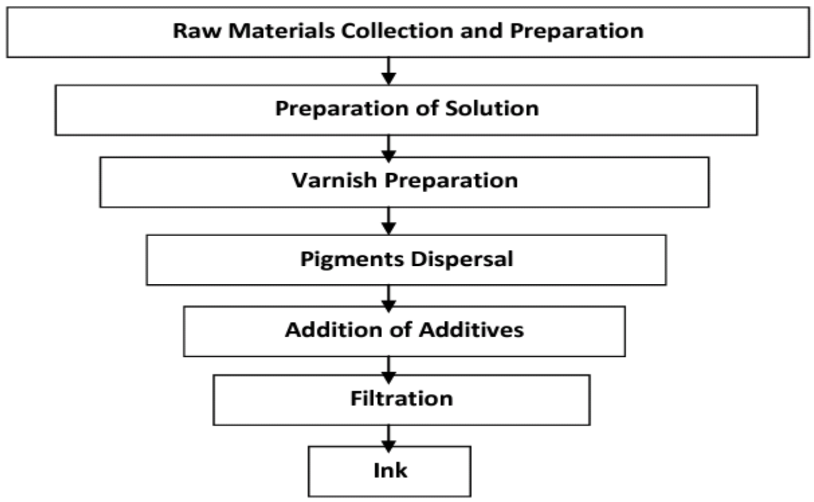

Figure 1: Block diagram for ink manufacturing process

Physical Properties Characterization

Visual comparison was used to determine opacity while the viscosity was determined using a syringe and stopwatch. The ink was used to write on a whiteboard and the drying time was measured. The erasability of the ink was also determined after 5 mins and 24 hrs while a 5 m distance was used to test the eligibility of the ink. Adhesion property of ink was carried out by applying on a whiteboard and allowed to dry for 24 hours. Two sets of lines, one crossing perpendicularly over the other was drawn on the board. An adhesive tape was pressed firmly with the thumb covering all the interactions of the perpendicular line. The adhesive tape was held at its loose ends and forcibly removed from the surface. Removal of more than 50% of the square lines of the ink sample indicates a poor adhesion and erasability. All physical characterizations were done in triplicates. The parameters for the best ink was then optimized.

Method Optimization

Lampblack produced best initial physical properties hence the soot pigment, Arabic gum and solvent ratios were varied to determine optimum conditions for suitable ink production. Table 1 below shows the variation quantity of the three (3) components of ink.

Table 1: Mixture design of the ink component

Concentration (ml) of A.G	Pigment(g)	Ethanol (ml)	Water (ml)
0.4	1.5	5	25
0.6	1.8	10	20
0.8	2.0	15	15
1.0	2.25	20	10
1.4	2.5	25	5

3. Results and Discussion

Pigment Physical Properties

Physical properties of the inks from various starting materials are given in table 2 below.

Table 2: Physical Property Characterization

Physical test	Lampblack	Spent tyre	Coconut shell
Viscosity (mm/s)	18.76	36.11	9.85
Drying time (s)	6.25	2.31	15.49
Erasability	Poor	Very poor	Very poor
Eligibility	Good	Good	Poor
Opacity	Fair	Good	Poor
Adhesion	Good	Good	Poor

The coconut shell ink has poor properties which can be attributed to the low viscosity resulting from weak inter molecular forces [13]. The effect is an increase in the drying time which results in very poor erasability. The low cross-linking density of the binder to the pigment leads to poor adhesion of the coconut shell ink [14].

The lampblack and Spent tyre soot inks demonstrate comparatively good adhesion, opacity and eligibility however, erasability is poor due to binder-pigment interaction [15]. It is also observed that there is an increase in viscosity which decreases the drying time. Therefore, the lampblack soot was further evaluated as pigment of choice for optimum conditions determination.

Effect of Arabic Gum concentration on the Viscosity of Lampblack Ink

Viscosity measures the resistance of the fluid to flow and its relationship with the Arabic gum volume is given in figure 2 below.

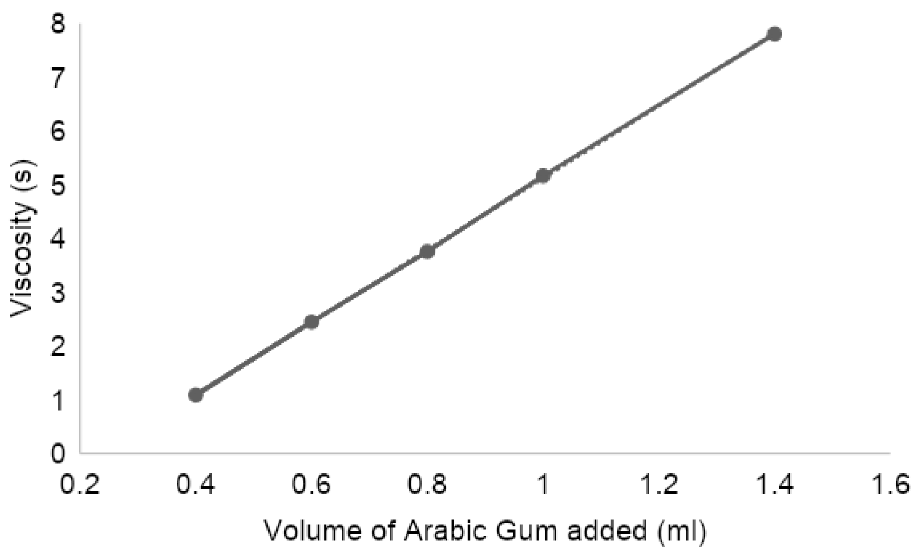

Figure 2: Relationship between Viscosity and Volume of Arabic gum added

The viscosity of the solution increases as the more Arabic gum is added. Higher cross-linked networks are formed as the Arabic gum volume is added resulting in less solvent molecules thus the correlating increase in the viscosity [16,17,18]. This viscosity also affects the drying time as it is reported that the higher the viscosity, the lower the drying time and our experiments confirm this.

Effect of Arabic Gum concentration on drying time of Lampblack Ink

Drying time of a substance implies the time that a liquid or semi liquid substance hardens or the vaporization of the solvent leaving the colorant and the binder so that the ink is attached to the surface and absorbed by it. As illustrated in figure 3 below, there is a decrease in the drying time when an increase in the concentration of binder results in increased cross-linkage between the particle chains thus the escape of the moisture becomes difficult [19]. This leads to a decreased in diffusion rate of the solvent molecule through the surface correlating with a decrease in the viscosity.

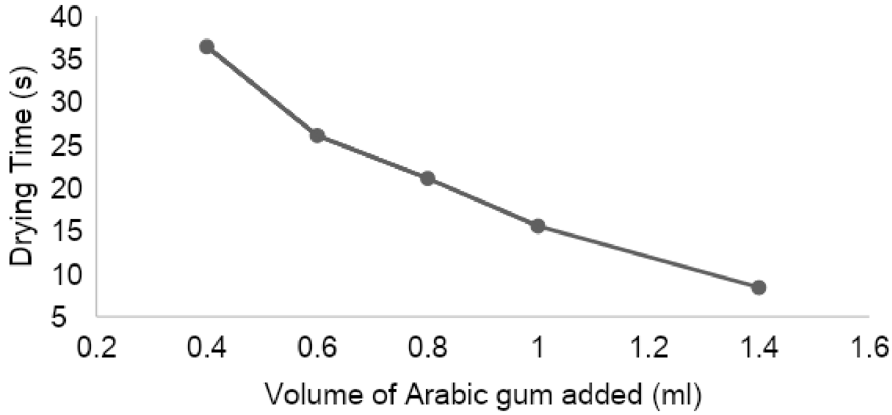

Figure 3: Effect of Arabic gum volume on the drying time of lampblack ink

Effect of Arabic Gum volume added on the physical properties of Lampblack Ink

To optimize physical properties of the ink, various volumes of Arabic gum solution were used to prepare the inks and the physical properties are given in table 3 below.

Table 3: Effect of Arabic Gum on the Physical properties of Ink from lampblack

Parameter	**Volume of Gum Arabic Solution**					**Remark**
	0.4	**0.6**	**0.8**	**1.0**	**1.4**	
Erasability	Fair	Good	Good	Poor	Poor	Good
Opacity	Fair	Fair	Good	Good	Good	Good
Eligibility	Fair	Fair	Good	Good	Good	Good
Adhesion	Poor	Fair	Good	Good	Good	Good

Evaluation of the physical properties illustrate that when 0.8 mL of the solution is added, the physical properties were good which could be attributed to lower cross-linking density of the binder to the pigment hence indicating their ability to stabilize pigment dispersion [14].

Pigment mass and Viscosity of Lampblack Ink

Varying starting masses of the soot pigment from lampblack were used to determine the corresponding effect on the viscosity of the Ink.

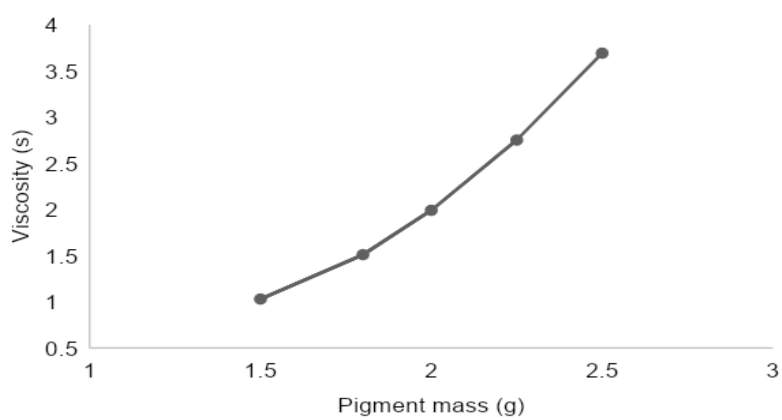

Figure 4: Effect of varying pigment amount on viscosity of Ink from lampblack

It is observed that viscosity increases with an increase in pigment quantity because particle size quantity possesses greater inertia such that on interaction, the particles are momentarily retarded and then accelerated. In both these stages their inertia affects the amount of energy required. This dissipation of energy is what may appear as extra "viscosity [20]. This could be attributed to stronger intermolecular or inter particles forces caused by increased in molecular weight of the pigment size [13]. An ink that has more pigment, more binder and less solvent will be more viscous while the ink that contain less pigment, less resin and more solvent will be less viscous which implies fast flow sample.

The effect of pigment concentration on drying time

The drying time of the ink is a function of its viscosity. The relationship between the mass of pigment used and the drying time is illustrated in figure 5. The presence of more particles results in a higher mass per unit of volume and therefore a higher density lower rate of evaporation [13].

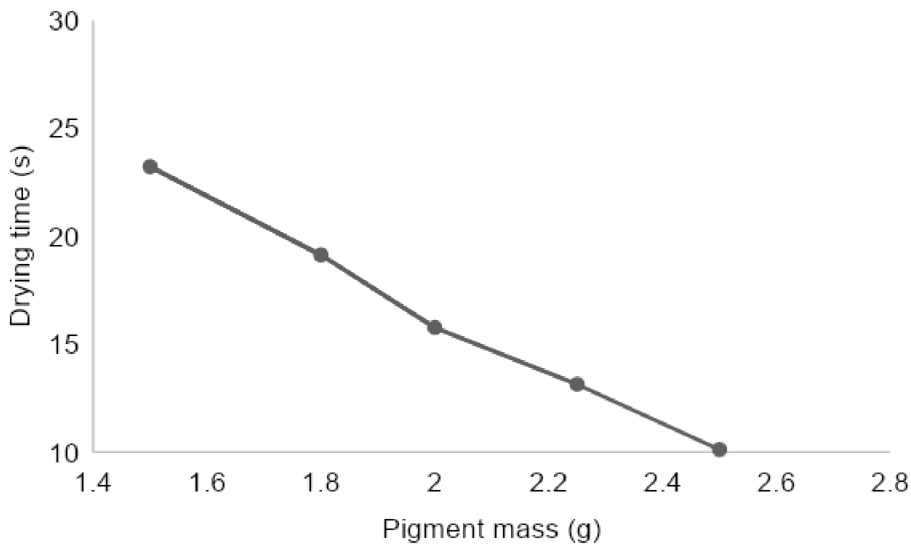

Figure 5: Relationship between pigment mass and the drying time of the Ink

Effect of pigment mass on the Physical Properties of lampblack

Table 4: Effect of pigment mass on Physical properties of Ink from lampblack

Parameter	**Mass of pigment**					**Remark**
	1.5	**1.8**	**2.0**	**2.25**	**2.5**	
Erasability	Fair	Good	Fair	Poor	Poor	Fair
Opacity	Fair	Good	Good	Good	Good	Good
Eligibility	Poor	Good	Good	Good	Good	Good
Adhesion	Poor	Good	Good	Good	Good	Good

From the table above, it was observed that optimized mass for the ink production was 1.8g which demonstrated good erasability, adhesion, eligibility and opacity.

Solvent ratio effect on Lampblack Ink Formulation

To optimize the solvent ratio for the ink production, varying volumes were used and table 4 below illustrates the resultant effect on the viscosity and drying time of the ink.

Table 5: Effect of solvent ratio on Physical properties of Ink from lampblack

Sample	Ethanol (ml)	Water (ml)	Binder (ml)	Pigment (g)	Drier (g)	Viscosity (s)	Drying time(s)
A	5	25	0.8	1.8	0.15	7.50	54.09
B	10	20	0.8	1.8	0.15	5.08	35.61
C	15	15	0.8	1.8	0.15	1.85	23.20
D	20	10	0.8	1.8	0.15	1.51	13.41
E	25	5	0.8	1.8	0.15	1.21	10.23

It can be seen from the results that viscosity decreases with increase in diluent (ethanol) concentration which can be explained as a result of decrease in molecular weight resulting to more free volume between liquid particles hence solvent evaporate easily [19]. Sample A has the ratio quantity of 1:5 of ethanol to water hence it gave the highest viscosity as a result of higher intermolecular forces between the liquid particles, rate of evaporation decreases. This happens because intermolecular forces make it less likely for the solvent molecules on the surface to escape thereby increasing drying time while sample E is of the least viscosity resulting to free volume caused by rate of diffusion [21].

6. Conclusion

In this work, we have demonstrated the production of Carbon black from locally sourced carbonaceous waste such as lampblack, spent tyre and coconut shell as pigment in the formulation of erasable ink. The resulting erasable ink addressed the problem associated with overdependence on imported materials such as the white board marker and waste management hence converting waste to wealth. The formulated ink from lampblack demonstrated a high degree of compliance to the imported ink in terms of viscosity, opacity, adhesion, eligibility and erasability test but poor drying time. These properties were optimized in this study by varying Arabic gum, soot pigment and solvent ratios. It is hoped that this work introduces an economically viable means for the production of erasable ink from local source.

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