International Journal of Frontiers in
Engineering and Technology Research
Journal homepage: https://frontiersrj.com/journals/ijfetr/
ISSN: 2783-0497 (Online)

(Research Article)

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Influence of process variables on shoe polish viscosity

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International Journal of Frontiers in Engineering and Technology Research, 2022, 02(01), 001–007

Publication history: Received on 19 February March 2022; revised on 22 March 2022; accepted on 26 March 2022

Article DOI: https://doi.org/10.53294/ijfetr.2022.2.1.0033

Abstract

Valourisation of non-biodegradable wastes into value added products like shoe polish can indeed be an effective tool for waste management and climate change mitigation. However, having appropriate shoe polish viscosity is important for customer satisfaction as too thick or too thin shoe polish may not result in desired customer satisfaction. The aim of this study was to investigate the effects of process variables (water repellant nature, process temperature, carbon black source and particle size, as well as, composition type and quantity) on shoe polish viscosity. The viscosity values of the various samples of shoe polish produced using carbon black pigments from batteries, pyrolytic rubber tyres, plastic bottle and water sachets wastes were determined. From the results obtained, it could be observed that shoe polish samples that had almost the same value of dynamic viscosity ($\eta = 0.2389$) with that of the commercial Kiwi shoe polish included the shoe polish with used vegetable oil as water repellant and the shoe polish with dye sourced from discarded batteries and plastic bottle wastes but with particle sixe of 0.80 mm. On comparison of the viscosity values of other shoe polish samples with that of the Kiwi shoe polish, it was observed that all shoe polish samples evaluated for all the distinctive process variables except temperature had comparable viscosity with that of Kiwi shoe polish. The real difference in viscosities of the shoe polish samples was observed when the process temperature was below 60 °C. This indicates that temperature as a process variable is the main determining factor regarding the viscosity of the shoe polish samples.

Keywords: Viscosity; Shoe polish; Customer satisfaction; Wastes; Process variables

1. Introduction

Huge amount of non-biodegradable polymeric wastes including rubber tyres, pure water nylon sachets, polyethylene terephthalate (PET) bottles and batteries wastes are generated on a daily basis with unsanitary landfilling being the common disposal method of getting rid of the polymeric wastes. Unfortunately, unsanitary landfilling of wastes has associated health hazards and negative environmental impacts [1-3]. Pyrolytic conversion of non-biodegradable polymeric wastes into materials used in the production of valuable products such as shoe polish could indeed be a sustainable way for effective waste management system and global warming mitigation [4-8]. However, inclusion of the converted waste material in shoe polish production process must be done such that shoe polish with appropriate viscosity is produced. This is important for customer satisfaction as too thick shoe polish cannot be spread far on shoe surface before drying and flaking off occur while too thin shoe polish cannot stay long enough to penetrate shoe surface. Shoe polish viscosity is the thickness of shoe polish as it relates to the resistance of the polish to attempts to move through it. The resistance is due to the interaction between the molecules of the shoe polish, which usually consist of a colloidal emulsion of substances including naphtha (volatile substance), lanolin (hydrophilic grease), paraffin oil, turpentine, paraffin wax, gum Arabic, wax, ethylene glycol, and dye, among others [5].

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Naphtha is a volatile component and acts as a preservative for shoe polish and also gives shoe its shining appearance. High amount of volatile constituents of shoe polish will make the shoe polish to dry out quickly and thicken after application. Gun Arabic and paraffin wax act as thickener in shoe polish preventing the polish to be too fluid and difficult to use. Lanolin acts as a waterproof and bonding agent in shoe polish preventing the volatile substance from evaporating until the shoe polish is spread enough on the shoe surface. Turpentine, along with paraffin, is used to give shoe polish its glossy and shiny feature. Dyes are included in shoe polish production to give the polish its colour. Different brands of commercial shoe polish exist in the World market including Kiwi, Lude, Coxy, Beeswax, among others. Kiwi, however, seems to be the shoe polish brand with the major share of the World market. Meanwhile, most commercial shoe polishes are now costly and have components that are not environmentally friendly. Consequently, various research studies are now being conducted on the possibility of using waste derived materials as shoe polish components. However, for customer satisfaction, shoe polishes produced using waste derived materials must have similar or improved qualities including viscosity, gloss, rub resistance, fading resistance, dust absorption resistance and wrinkle resistance; compared to the commercial shoe polish brands.

Research studies on using waxes produced from polymeric wastes (water nylon sachets, plastic and rubber wastes, among others) as components of shoe polishes have been carried out [4, 6, 9]. There is however need for further studies on how to optimize different process variables during shoe polish production in a way to obtain improved shoe polish viscosity comparable to that of commercial shoe polish brands such as Kiwi shoe polish. Therefore, the aim of this study was to investigate the effects of different process variables on viscosities of shoe polish samples in order to determine the optimal conditions for producing shoe polish of improved viscosities comparable to commercial Kiwi shoe polish.

2. Methodology

This study was the continuation of the experiment conducted by Akinbomi et al. [10]. The materials and equipment used during the study included discarded PET bottles, rubber tyres, water sachets, batteries, fresh and used vegetable oils, isopropanol, paraffin oils, water baths, thermometer, canoe bar soap, candle was, gum Arabic, lime oranges, kerosene, carbon black, KIWI commercial shoe polish, leathered shoes, aluminum pots, stirrer, kerosene stove, shoe polish packaged containers, pouring utensils, cooling equipment for the polish to set, stop clock, thermometer, scale balance, as well as, pyrolysis system. The pyrolysis system comprised of gas-fired furnace, pyrolysis reactor, heavy oil condenser, two cyclones for light oil condensation, scrubber for gas cleaning, and gas storage bag (Figure 1). The pyrolysis reactor was a cylindrical steel vessel with thickness, internal diameter and capacity of 12 mm, 250 mm, and 25 kg of shredded polymeric waste, respectively. The reactor vessel was closed with two pairs of flanges (top and bottom). There was a hole at the center of the reactor vessel which served as the gas exit. The gas-fired furnace was made in such a way that it would provide uniform heat to the pyrolysis reactor. Solar-power temperature sensor was inserted in the reactor vessel to measure the temperature in the pyrolysis reactor (Figure 2). The discarded PET bottles, rubber tyres, water sachets and batteries were collected from dumpsites around Lagos State University, Ojo, Lagos, Nigeria. Reinforced steel materials were removed from the waste tyres before the tyres were shredded manually into chips, washed with clean water, and then spread under the sun for drying. Chemical balance, measuring cylinder, and stop clock were used during the pyrolysis experiment for measuring feedstock weight, cooling water volume, and progressing reaction time, respectively. Empty containers were also prepared for the collection of condensed liquid oil and char.

The experimental procedure involved the pyrolysis of conversion of PET bottles, rubber tyres and water sachets into carbon black for usage as pigments in the shoe polish production process. The batteries were not pyrolysed but opened up to obtain the carbon black. The pyrolysis reactor containing 9 kg each of the dried shredded polymeric wastes was placed inside liquefied petroleum (LPG) gas-fired furnace for batch pyrolysis process. Before starting the pyrolysis process, between 20 and 30 litres of clean water were measured into each of the two cyclones used for light oil condensation. The 9 kg of each of the shredded polymeric wastes was pyrolyzed separately at a temperature range between 236^{0}C and 488 ^{0}C. The temperature was maintained for about 5 hours (residence time) at 488 ^{0}C. At the end of the pyrolysis experiment, the non-condensable gas was collected in a gas storage bag while the condensable liquid oil was collected in the containers. The furnace was left to cool down to room temperature (25^{0}C) before the char left in the reactor vessel was removed. The production of the shoe polish samples involved investigation of the effects of different process variables (water repellant nature, carbon black source and particle size, process temperature, as well as, composition type and quantity) on the shoe polish viscosities.

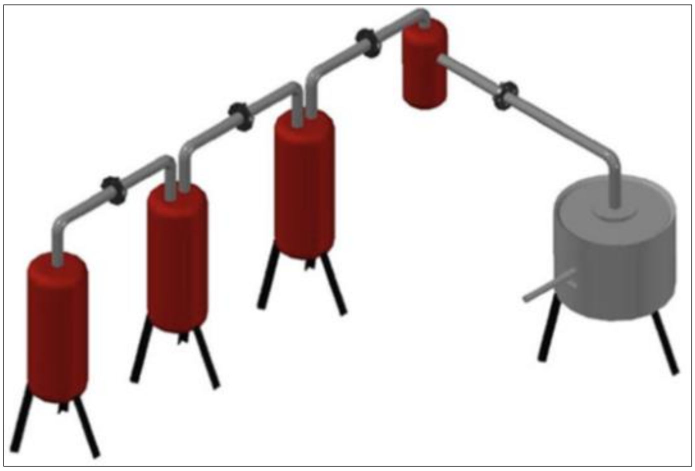

Figure 1 Pyrolysis system setup

Figure 2 Gas-fired furnace with attached solar-powered temperature sensor

Specific amounts of the required feedstock materials (including candle wax, carbon black, vegetable oil, gum, lime oranges except the flammable alcohol and kerosene) were measured into the aluminum pot placed on electric cooker. The mixture inside the aluminum pot was stirred thoroughly until the temperature reached various degrees of temperature including 10°C, 20°C, 30°C, 40°C, 50°C, 60°C, 70°C, 80°C, 90°C and 100°C. After the desired temperature was reached, the mixture inside the aluminum pot was removed from the hot electric cooker and poured into a glass beaker. Isopropanol and kerosene were introduced into the mixture while stirring. The resulting mixture was divided into two equal parts (50ml). The two equal parts were put into separate glass containers while 30ml of each mixture was poured into the customized packaging steel container and allowed to cool. The remaining 20ml of each mixture was poured into a container for various test analyses. The shoe polish produced was applied on finished black leather while physical properties such as wrinkle resistance, gloss, rub resistance; fading resistance and dust absorption resistance were evaluated and compared to KIWI commercial shoe polish.

The polished samples were examined for their gloss by comparing them with one another. To test for rub resistance, the polished leather samples were rubbed with white and clean cotton material for about 40 times. The change in hue and level of stain were examined. The polished leather samples were tested for fading resistance by exposing them to the sun for 74 hours and the change in hue and glosses were used to access the parameter. To test for dust absorption resistance, the polished leather samples were exposed to an open environment, where dust could get easy access to them for 24 hours. The level of dust adsorption was then examined. Regarding the wrinkle resistance, the polished leather samples were each held at both end and creased to see if the polish would peel off the leather. For the viscosity test; the shoe samples were sent to Kaduna Polytechnic Laboratory, Kaduna State, Nigeria, for analysis.

3. Results and discussion

The results obtained from the viscosity test, as well as the tests on gloss, rub resistance, fading resistance, dust absorption resistance and wrinkle resistance; are presented in Table 1. From the results obtained, it could be observed that shoe polish samples that had almost the same value of dynamic viscosity (η = 0.2389) with that of the commercial Kiwi shoe polish included the shoe polish with used vegetable oil as water repellant and the shoe polish with dye (carbon black) sourced from discarded Tiger head battery (1.5 V) and plastic bottle wastes but with particle sixe of 0.80 mm. On comparison of the viscosity values of other shoe polish samples with that of the commercial Kiwi shoe polish, it could be observed that all shoe polish samples evaluated for the distinctive process variables of water repellant nature, carbon black source and particle size, as well as, composition type and quantity; had dynamic viscosity values that could be approximately comparable to the viscosity of the commercial Kiwi shoe polish. The only process variable that had shoe polish samples with substantial difference in dynamic viscosity values when compared with that of commercial Kiwi shoe polish, was the process temperature. The real difference in viscosities of the shoe polish samples was observed when the process temperature was below 60°C but when the process temperature was 60°C and above, the viscosity values were comparable with the viscosity of commercial Kiwi shoe polish. This indicates that temperature as a process variable is the main determining factor regarding the viscosity of the shoe polish samples. The results are in conformity with the fundamental theory [11] that viscosity of fluid is strongly dependent on temperature.

Regarding the shoe polish physical properties including wrinkle resistance, gloss, rub resistance, fading resistance and dust absorption resistance; they were treated extensively in the previous study by Akinbomi et al. [10]. From the results obtained in the study, it was shown that there was no statistical significant difference between the physical properties of the commercial Kiwi shoe polish and that of the shoe polish samples produced using various process variables when the process temperature was 60°C and above. This indicates that the shoe polish samples produced using different process variables including water repellant nature, process temperature, carbon black source and particle size, as well as, composition type and quantity; could be compared favourably with that of commercial Kiwi shoe polish.

Table 1 Comparative analysis of shoe formulations with commercial KIWl shoe polish

S/N	Shoe polish formulation with distinctive factor	Physical Properties of Shoe Polish						
		Lustre/Gloss	**Rub Resistance**	**Fading Resistance**	**Dust Absorption Resistance**	**Wrinkle Resistance**	**Viscosity (mPa.S)**	**Viscosity Difference with reference to Standard KIWI**
	Standard:: KIWI commercial shoe polish	Very good	Very good	Very good	Very good	Very good	0.2389	
	Control: Temperature (90^{0}C); Particle size (0.250mm); **Composition*:*** Candle wax (20g); Carbon black source: Plastic (20g); Gum Arabic (5g); Fresh vegetable oil (20g); Isopropanol (20g); Fragnance: lime orange liquid (5g); Preservative: kerosene (10g)	Very good	Good	Very good	Good	Very good	0.2562	> 0.02
A	**Water repellant**							
1	Water repellant: fresh vegetable oil (Control)	Very good	Good	Very good	Good	Very good	0.2562	> 0.02
2	Water repellant: used vegetable oil	Very good	Very good	Very good	Good	Very good	0.2389	0
3	Water repellant: Paraffin oil	Very good	Good	Very good	Good	Very good	0.2644	> 0.03
B	**Carbon black source**							
4	Dye (cabon black) from pyrolytic plastic bottle wastes	Very good	Good	Very good	Good	Very good	0.2562	> 0.02
5	Dye (cabon black) from pyrolytic discarded vehicle rubber tyre	Poor	Poor	Poor	Poor	Poor	0.2540	> 0.02
6	Dye (cabon black) from pyrolytic pure water nylon sachet	Good	Good	Very good	Good	Very good	0.2553	> 0.02
7	Dye (cabon black) from discarded Tigerhead battery (1.5V)	Good	Very good	Good	Very good	Good	0.2368	0
C	**Temperature**							
8	Temperature at 100^{0}C	Good	Good	Good	Good	Very good	0.2008	< 0.04
9	Temperature at 90^{0}C	Very good	Good	Very good	Good	Very good	0.2562	> 0.02
10	Temperature at 80^{0}C	Good	Good	Very good	Very good	Very good	0.3129	> 0.07
11	Temperature at 70^{0}C	Good	Very good	Good	Very good	Good	0.3521	> 0.11
12	Temperature at 60^{0}C	Good	Very good	Good	Good	Very good	0.3974	> 0.16
13	Temperature at 50^{0}C	Very good	Very good	Good	Very good	Good	1.7200	> 1.48
14	Temperature at 40^{0}C	Good	Good	Good	Very good	Good	1.8800	> 1.64
15	Temperature at 30^{0}C	Good	Good	Good	Good	Good	2.0000	> 1.76
16	Temperature at 20^{0}C	Fair	Good	Good	Good	Good	2.1300	> 1.89
17	Temperature at 10^{0}C	Fair	Good	Fair	Good	Fair	2.4100	> 2.17

Table 1 Comparative analysis of shoe formulations with commercial KIWl shoe polish (Cont'd)

S/N	Shoe polish formulation with distinctive factor	Physical Properties of Shoe Polish						
		Lustre/Gloss	***Rub Resistance***	***Fading Resistance***	***Dust Absorption Resistance***	***Wrinkle Resistance***	***Viscosity (mPa.S)***	***Viscosity Difference with reference to Standard KIWI***
	Standard:: KIWI commercial shoe polish	Very good	Very good	Very good	Very good	Very good	0.2389	
	Control: Temperature (90^{0}C); Particle size (0.250mm); ***Composition:*** Candle wax (20g); Carbon black source: Plastic (20g); Gum Arabic (5g); Fresh vegetable oil (20g); Isopropanol (20g); Fragnance: lime orange liquid (5g); Preservative: kerosene (10g)	Very good	Good	Very good	Good	Very good	0.2562	> 0.02
D	**Carbon black particle size**							
18	Dye (Carbon black) particle size of : 0.25 mm	Very good	Good	Very good	Good	Very good	0.2562	> 0.02
19	Dye (Carbon black) particle size of : 0.45 mm	Good	Very good	Good	Very good	Good	0.2264	< 0.01
20	Dye (Carbon black) particle size of : 0.80 mm	Good	Very good	Good	Good	Very good	0.2416	0
E	**Composition type and quantity**							
21	Surfactant [canoe bar soap (5g)] added; Amount of water repellants [fresh vegetable oil (40g) and candle wax (10g)), dye [carbon black(10g)] and preservative [(kerosene (5g)] varied	Very good	Very good	Very good	Good	Good	0.4826	> 0.24
22	Surfactant [canoe bar soap (5g)] added;; Amount of water repellant [candle wax (10g)], dye [Carbon black(10g), preservative [kerosene(5g)] and softener [isopropano(40g)] varied	Very good	Very good	Very good	Very good	Good	0.4128	> 0.17
23	Surfactant[canoe bar soap (5g)] added;; Amount of water repellant [candle wax(10g)], dye [carbon black(40g)], softener [isopropano(10g)] and preservative [(kerosene (5g)] varied	poor	Poor	poor	poor	poor	0.5168	> 0,28
24	Surfactant[canoe bar soap (10g)] added;; Amount of water repellant [candle wax(10g)], dye [Carbon black (10g)] , gum Arabic (10g), and fragnance [lime orange liquid(10g)] varied	good	Good	Very good	good	good	0.8121	> 0.57

4. Conclusion

This study examined the influence of distinctive process variables of water repellant nature, process temperature, composition type and quantity, as well as, carbon black source and particle size; on the viscosities of shoe polish samples produced. The results showed that, in general, the viscosity values of shoe polish samples evaluated for the distinctive process variables, except process temperature, were favourably compared with the viscosity value of commercial Kiwi shoe polish. The real difference in viscosities of the shoe polish samples was observed when the process temperature was below 60°C. This indicates that temperature as a process variable is the main determining factor regarding the viscosity of the shoe polish samples, and that when using waste derived materials as components for shoe polish production; process temperature must be optimized to obtain appropriate shoe polish viscosity for customer satisfaction.

Compliance with ethical standards

Acknowledgment

The authors are grateful for the support given by the Lagos State University Management during the course of the research work which was carried out within the university premises.

Disclosure of conflict of interest

The authors declare that there is no conflict of interest with publication of the manuscript.

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