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Performance of Organic Dyes for Textile Cotton Fabric

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ABSTRACT

This research was focus on optimum dye concentration for self-cleaning properties for uncoated and coated dyed cotton fabrics through physical and mechanical properties. The dyed cotton fabrics were coated with aqueous emulsion C6-fluorocarbon. C6-fluorocarbon is an organic coating consisting of solid particles where it will dissolve in a specific formulated solvent. Cotton fabrics have cellulose and abundant hydroxyl groups structure where it will make hydrophilic properties where the fiber can provide an appropriate environment for microorganism growth in contact with water and sweats. Therefore, aqueous emulsion C6-fluorocarbon was coated as a hydrophobic coating to overcome the problem of dyed cotton fabric. Moreover, this research was aim to find the optimum concentration of dye with superhydrophobic layer and the comparison of natural dyes with synthetic dye, Golden Yellow with physical and mechanical tests. The test involved were water contact angle, crocking, weather resistance of fabric, washing, abrasion and bursting test. It was found that F (wt/wt%) was the optimum dye concentration and has the highest contact angle. The coated dyed fabric has higher mechanical and physical properties compared to the uncoated dyed fabric which can replace the usage of synthetic dye.

Keywords: Cotton, Hydrophobic Coating, Physical, Mechanical and Optimum.

1. INTRODUCTION

The advent of nanoscience and nanotechnology introduces the use of antimicrobial properties of metallic nanoparticles [1]. Nanoparticles can be classified into different types by size, morphology, physical and chemical properties. Some of them are carbon-based nanoparticles, ceramic nanoparticles, metal nanoparticles, semiconductor nanoparticles, polymer nanoparticles and lipid-based nanoparticles. The antibacterial properties of these nanoparticles are due to the presence of a large volume-to-volume ratio and a small size that provides a good surface for contact with a microbial membrane. Nanoparticles made of inorganic matter exhibit novelty and enhanced chemical, physical and biological characteristics and functionality due to their nano scale [2]. The concept behind the superhydrophobic nanotech imitates the lotus leaf. The substance involves the assembly of aluminum oxide nanoparticles filled with carboxylic acids. The water repellent content is non-toxic and can be added to surfaces through spray coating or spin coating. Superhydrophobic coating has attracted attention in the previous decade owing to prospective applications of self-cleaning, anti-corrosion, anti-fouling, petroleum water separation or treatment and field drag reduction [3]. In addition, zinc oxide nanoparticles are secure for human use as a superhydrophobic layer because they are white and can be used in personal care products, UV sensors, optoelectronic devices and solar cells owing to cost-effective benefit [4]. Furthermore, coating technology has appeared as a strategy to alter surfaces in a straightforward manner where it has appealing performances such as UV-proof, antibacterial

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properties and can be acquired in food, textile and paper packaging through coating technology [5][6].

On the other hand, cotton fabrics have cellulose and abundant hydroxyl groups available on cotton fiber structure make cotton fabric hydrophilic where it provides a suitable environment for microorganism growth upon contact with water and sweat [7]. In addition, water-repellent fabrics are essential in certain applications such as rainwear, self-cleaning coatings, anti-fouling, anti-corrosion coatings and bandages [8][9][10]. For the production of environmental friendly coating, therefore, the formation of super hydrophobic surfaces at low temperature is essential [11]. Super hydrophobicity can thus provide protection against a liquid, prolong the lifetime of the fabrics due to the prevention of water wetting from degradation and UV protection that can safeguard individuals from sun exposure induced by UV [12]. Textile products are primarily from synthetic colours generated from non-renewable and non-biodegradable petrochemical materials [13]. Approximately 30 million tons were estimated for worldwide textile consumption and projected to develop up to 3 per cent per year while 70,000 tons of dyes were released into the atmosphere [14][15]. Natural colours become an option to industry when synthetic colours caused serious issues such as visible effluent residues [16] and poisonous amines [17] were produced. In 1856, W.H Perkins found synthetic dye, providing a broad variety of colors and producing lighter shades. As a consequence, in today's globe, dye implementation has become a huge sector [18]. Natural colours, when synthetic colors caused serious issues such as visible effluent residues [19] and toxic amines, become an option to industry. In addition, synthetic dyes has moderate to great luminosity while natural coloring has poor to mild luminosity [20]. These synthetic colors and fibers can have long-term adverse effects on the setting [21]. Researchers are interested in natural colorants because they are more eco-friendly compatible and also have antibacterial and ultraviolet protective functions [22]. In addition, natural coloring was one of the promising alternatives for creating a greener textile dyeing method [23]. The benefits of natural coloring are that other fabrics do not stain except turmeric and have a broad range of colors that can be created from mixing and matching processes with different shades of colours.

Customers become more aware of their health and are demanding from manufacturers and companies for the products [24]. In this research, natural resources such as neem (*Azadirachta Indica*), turmeric (*Curcuma Longa*) and henna (*Lawsonia Inermis*) were used to replace the synthetic dye where synthetic dye can affect human health and create toxic environment. A superhydrophobic coating is added to the cotton fabric to improve self-cleaning properties and keep the dye from fading out. The superhydrophobic coating based on aqueous emulsion C6-fluorocarbon was used in this research to enhance the physical and mechanical properties of the dyed cotton fabrics as compared to the uncoated dyed fabrics. The uncoated dyed cotton fabrics have low physical and mechanical strength and tend to fade easily as compared to the coated dyed fabrics.

2. MATERIAL AND METHODS

2.1 Dyeing Process

The natural resource that was used to dye on cotton fabric were *Azadirachta Indica*, *Curcuma Longa* and *Lawsonia Inermis*. Moreover, Azadirachtin was the dye pigment that produce a green colour, Curcumin produce yellow and Lawsonia produce red colour on cotton fabric [25]. Then, all the leaves were plucked from the plant and cleaned with distilled water. The leaves were dried in the oven for 57^{0}C for 24 hours. The dried leaves were pounded into powdered form with grinder for efficient extraction. Particulate size for powdered dye was 0.05 μm±0.01. The powdered specimens were sieved with a sieve of 0.05μm and 250 meshes to remove some stalk that is not well pounded [26]. Apart from that, cold water extraction was the technique to extract dye from the powdered dye. Then, the powdered dye was weighed to 10g up to 80g and was added with 40 ml of distilled water. Hence, it is equivalent to A – 0.25 g/ml, B – 0.50 g/ml, C – 0.75 g/ml, D – 1.00 g/ml, E- 1.25 g/ml, F – 1.50 g/ml and H – 2.00 g/ml. Finally, the water-based dye was filtered using Whitman No 1, 6±1 μm filter paper. The dyeing technique was hot water dyeing process. The measuring cylinder consists of 80 ml of dye concentrations of A, B, C, D, E, F, G and H of the water soluble dye. Then, the cotton fabrics were trimmed into 11 cm x 14 cm and immersed into the dyeing pot. The dyeing pot was closed with the cover and the dyeing machine was switched on. Next, dyeing pots were put inside the dyeing machine at 90^0 for 45 minutes. Cotton fabrics were subsequently removed from the dyeing tub and dyeing pot and allowed to dry. Normal text of the paper, again first paragraph is without indentation. Second and following paragraphs are not indented either, normal text of the paper. Normal text of the paper, again first paragraph is without indentation. Second and following paragraphs are not indented either, normal text of the paper. Normal text of the paper, again first paragraph is without indentation. Second and following paragraphs are not indented either, normal text of the paper.

2.2 Process of Superhydrophobic Coating

The superhydrophobic coating consists of three phases of synthesis reaction. Alcohol-lysis is the first step to synthesis coating. It consists of 50.3% composition of C6-fluorocarbon and 20 weight by weight based on polyols. Then the crosslinking with glycerol of 50 wt/wt% at 140°C for 2 hours with calcium carbonate of 0.8% wt/wt% takes place. Second phase was condensation step where the eco-resin will form at room temperature and eco-resin was mixed with ethanol [27]. Purification was the third phase in synthesizing of the superhydrophobic coating. The solutions will continuously stir for 3 hours. Process of coating is spraying method. This is an incredibly quick coating technique and one of the most economical and efficient methods used when big amounts of coating are used in contrast to tiny amounts typical of repair maintenance activities. The dyed cotton fabric size 11 cm x 14 cm for *Azadirachta Indica*, *Curcuma Longa* and *Lawsonia Inermis* was coated with superhydrophobic coating. The spraying method required the normal drying time environment of air dry 23±20°C, whereas relative humidity about 50±5% under diffused sunlight. The angle for spray gun and coated fabric was 450 by swinging the gun back and forth across the surface, Moreover, the coating layer was 3 layers for each dyed cotton fabrics.

2.3 Water Contact Angle (ASTM D7334-08)

Water contact angle was used to assess the water droplet angle on coated dyed fabric. The standard method for this test was ASTM D7334-08: Standard Practice for Surface Wettability of Coatings, Substances and Pigments by Advancing Contact Angle Measurement. Fabric size was 2.5 cm x 2.5 cm according to the test [25]. The fabric was attached to the water contact angle machine. Water droplet was permitted to fall on the fabrics from a set height to evaluate the water contact angle (WCA) on the fabrics. The water contact angle machine as shown in Figure 1 and the schematic diagram for water contact angle in Figure 2.

Figure 1. Water contact angle machine.

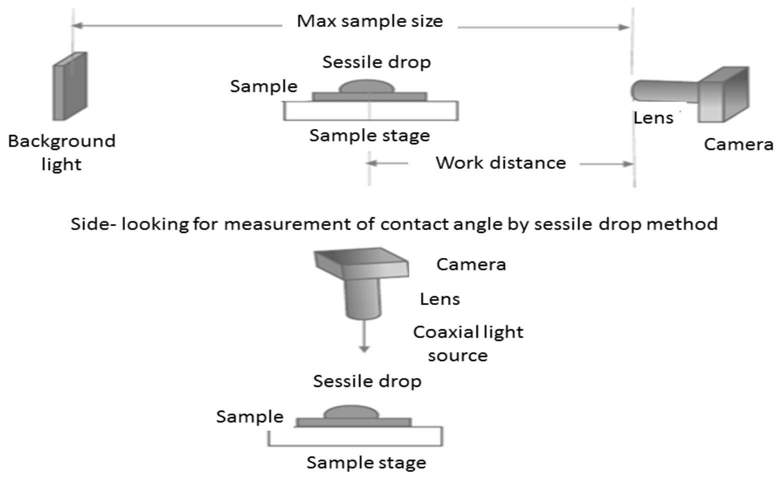

Figure 2. Schematic diagram for water contact angle [25].

2.4 Crocking test (AATCC Test Method 8)

Colour fastness is the resistance of a material to change its colour characteristics and to transfer its colorants to adjacent materials or both resulting from the exposure of the material to any environment encountered during the processing, testing, storage or use of the materials. Colour fastness test was applied in accordance to the AATCC Test Method 8: Colour fastness to crocking (Crockmeter Method). Prior to testing, the pre-condition of the test samples and the crock square for dry crock testing followed the ASTM D1776, conditioning textiles for testing. The condition of eight different concentrations of *Lawsonia Inermis*, *Azadiractha Indica*, *Curcuma Longa* dyes and Golden Yellow vat dye followed the standard process for a minimum of 4 hours in atmospheric conditions at temperature of 21 ± 1˚C and 65 ± 2% relative humidity by placing each test specimen or crock square separately on the panel. The cotton cloth was cut into 50 mm x 50 mm size. Then, the coated cotton fabric and the uncoated cotton fabric dyed with eight different natural dyes concentrations and synthetic dye were cut into size of 200 mm x 110 mm. There were 8 samples and 24 specimens for each concentration of *Lawsonia Inermis*, *Azadirachta Indica* and *Curcuma Longa* dye, and 3 specimens for Golden Yellow dye.

2.5 Weather Resistance of Fabric (AATCC Test Method 111)

The purpose of this test is to determine the weather resistance of the textile materials. This test can be applied to fibres, yarns, fabrics and products, including coated fabrics, natural, coloured, finished and unfinished. Moreover, the exposures may be calculated by calendar days, months and years. The standard method of weather resistance of textiles was AATCC Test Method 111 of Weather Resistance of Textiles: Daylight and Weather. Eight different concentrations of *Lawsonia Inermis*, *Azadiractha Indica*, *Curcuma Longa* dyes and Golden Yellow vat dye which followed the standard process were cut into 3 cm x 6 cm size. Test specimens were then conditioned at the standard atmosphere of 21 ± 1˚C temperature and 65 ± 2% relative humidity for textile testing. The specimens were exposed to the UV light from the sun. The fabrics were positioned to prevent shadowing and curling at the edges of the specimens. Temperature of samples was measured using a Black Panel Thermometer with a remote sensor attached to the black aluminium panel. The thermometer was positioned in the centre of the exposure areas. During UV exposure, the selected equilibrium temperature was maintained within 3˚C.

2.6 Washing Test (AATCC LPI 2018)

Washing test is important to examine the fading of the original sample and the dyed samples based on gray scale. The washing test was applied to the faded and discoloured dyed textiles during soaping using the fastness tester machine. The machine can change the temperature for the laundry test. The test was conducted in accordance to Home Laundering: Washing machine (AATCC LP1 2018). The standard temperature for this test was 44.2 ± 4.2°C with a total wash time of 16 ± 2 minutes. Eight fabrics with different concentrations of *Lawsonia Inermis*, *Azadiractha Indica*, *Curcuma Longa* dyes and Golden Yellow vat dye, were cut into size of 5 cm x 5 cm using appropriate cutter. There were 8 samples and 24 specimens for each concentration of *Lawsonia Inermis*, *Azadirachta Indica* and *Curcuma Longa* dye and 3 specimens for Golden Yellow dye. Each concentration was tested in triplicates and the average value was recorded. The washing pot was used as washing apparatus to pour detergent, softener and cold water. The solutions were mixed together using standard measurements. The fabrics were then put inside the washing pot and placed in the rotary machine which rotated for 16 ± 2 minutes at a temperature of 44.2 ± 4.2°C. Upon completed, the fabrics were rinsed with cold water and washed in the washing machine for 12 ± 6 minutes. Washing test was carried out for 50 cycles.

2.7 Abrasion Test (ASTM 4966-98)

The standard method for abrasion test is ASTM 4966-98, representing the Standard Abrasion Resistance Test Method for Textile Fabrics (Martindale Abrasion Tester Method). This test method evaluates the abrasion resistance of textile fabrics. This method is applicable to all types of fabrics including woven, dyed, nonwoven and industrial fabrics. The abrasion test was performed on 36 pieces of abrasive material cut to 140 mm in diameter. The coating, uncoated and synthetic dyed fabrics were then cut to a diameter of 38 mm using appropriate cutter as shown in Figure 3.23. The fabrics were then placed in the sample holders with the regular foam ring behind the fabric was checked. It is essential to position the samples flat against the mounting block. Sample holders were placed on the fabric device next to the abradant. The spindle was inserted through the top plate and the right weight at 12 kg was placed on top of it. The machine was run according to the number of cycles. Before starting each experiment and after 50,000 cycles, the normal aberrant should be substituted. While the aberrant was removed, it was held flat by weight as the retaining ring was tightened. The rubbing cycle was 5000 and 20,000 times.

2.8 Bursting Test (ASTM 3786)

The bursting strength was determined according to the Standard Test Procedure for Bursting Strength of Textile Fabrics (Diaphragm Bursting Tester Method) ASTM 3786. This test method defines the measures of resistance to bursting of cotton fabrics using a hydraulic diaphragm bursting tester. The speciments were prepared in circular dimensions of 8 cm in diameter for eight different concentrations of *Lawsonia Inermis*, *Azadiractha Indica*, *Curcuma Longa* dyes and Golden Yellow dye following the standard process. The specimens were then conditioned in accordance with Practice D1776at 20 ± 1°C and 65 ± 2% relative humidity as the standard condition. Bursting test was conducted using the diaphragm burster model Goodbrand-Jeffreys England. The samples were placed at the top of the rubber diaphragm. The pressure was then allowed to pass through the hole to extend the rubber diaphragm to break the tissue sample. The latch was swung as far as it can go to bring the operating handle to an idling position at the moment of the rupture of the fabric sample.

3. RESULTS AND DISCUSSION

3.1 Water Contact Angle

Water contact angle was used to assess the water droplet angle on coated dyed fabric. The standard method for this test was ASTM D7334-08: Standard Practice for Surface Wettability of Coatings, Substances and Pigments by Advancing Contact Angle Measurement. Figure 3 shows the water droplet test of water contact angle (WCA) of different loading ratio of Azadirachta

Indica dye of A, B, C, D, E, F, G and H. Moreover, the water contact angle for different dyes concentrations of 0.25 g/ml (A), 0.50 g/ml (B), 0.75 g/ml (C), 1.00 g/ml (D), 1.25 g/ml (E), 1.50 g/ml (F) and 2.00 g/ml (F) of the coated dyed fabrics were tested to determine the superhydrophobic characteristics.

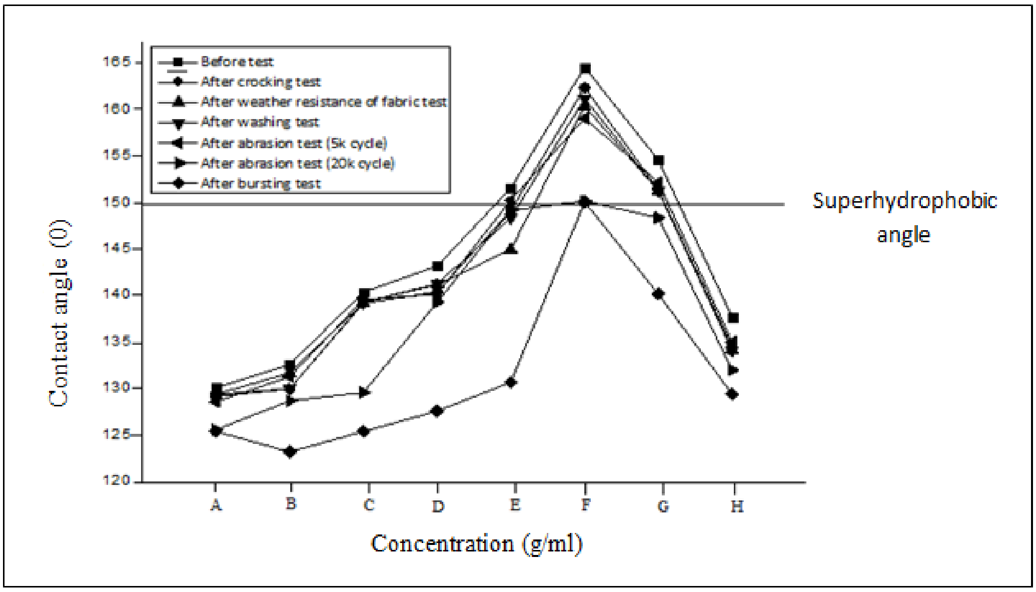

Figure 3. Water contact angle for *Azadiractha Indica*; A – 0.25 g/ml, B – 0.50 g/ml, C – 0.75 g/ml, D – 1.00 g/ml, E- 1.25 g/ml, F – 1.50 g/ml, G- 1.75 g/ml and H – 2.00 g/ml.

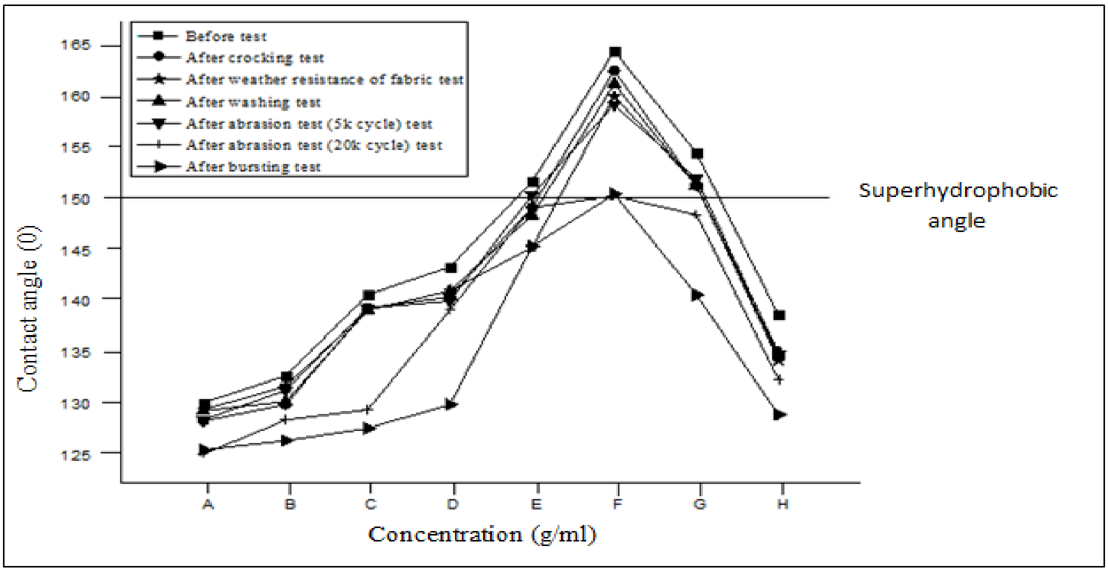

Figure 4. Water contact angle for *Curcuma Longa*; A – 0.25 g/ml, B – 0.50 g/ml, C – 0.75 g/ml, D – 1.00 g/ml, E- 1.25 g/ml, F – 1.50 g/ml, G- 1.75 g/ml and H – 2.00 g/ml.

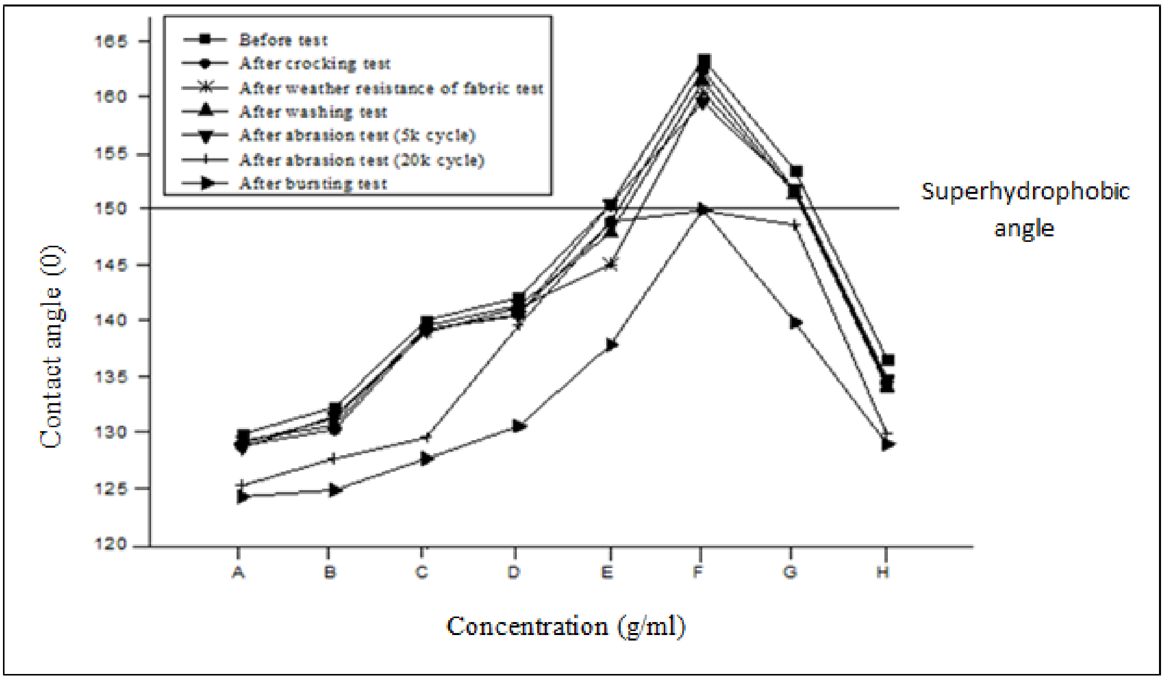

Figure 5. Water contact angle for *Lawsonia Inermis*; A – 0.25 g/ml, B – 0.50 g/ml, C – 0.75 g/ml, D – 1.00 g/ml, E- 1.25 g/ml, F – 1.50 g/ml, G- 1.75 g/ml and H – 2.00 g/ml.

Moreover, the water contact angle for different dyes concentrations of 0.25 g/ml (A), 0.50 g/ml (B), 0.75 g/ml (C), 1.00 g/ml (D), 1.25 g/ml (E), 1.50 g/ml (F) and 2.00 g/ml (F) of the coated dyed fabrics were tested to determine the superhydrophobic characteristics. The water contact angle results of the coated dyed fabrics with 3 layers of Lawsonia *Inermis* were 130.1° (A), 132.5° (B), 140.3°(C), 142.3° (D), 150.7° (E), 163.7° (F) and then decreased to 153.7°(G) and 136.8° (H). The water contact angles for *Azadiractha Indica* dye were 130.2° (A), 132.7° (B), 140.7° (C), 143.3° (D), 151.7° (E), 164.7° (F), 154.7° (G) and 137.8° (H), whereas for *Curcuma Longa* are 130.3° (A), 132.9° (B), 140.8° (C), 143.5° (D), 151.8° (E), 164.5° (F), 154.6° (G) and 138.8° (H). The optimum dye concentration obtained for *Lawsonia Inermis*, *Azadirachta Indica* and *Curcuma Longa* was 1.50 g/ml (F), revealing the development of superhydrophobic characteristics of self-cleaning properties. The particles of dye and coating with fluorine and titanium dioxide particles have reached a balance state on the cotton fabrics. Nevertheless, the uncoated fabrics contained no titanium dioxide and fluorine particles. Dyes were easily removed when the concentration of the dyes increased and decreased.The water contact angle decreased after conducting the tests as the first coating layer broke off and followed by the next layers. On hydrophilic surface, a water droplet wets as large a surface as possible, likely entering the pores of the material and completely saturating it [4]. Surface roughness is, therefore, the second critical factor for obtaining a superhydrophobic surface. High surface roughness combined with a low surface energy is required to achieve a superior contact angle and superhydrophobicity [5]. The water contact angles of *Lawsonia Inermis*, *Curcuma Longa* and *Azadiractha Indica* after undergoing bursting strength, abrasion, crocking, weather resistance of the fabric and washing tests based on were lower than those of before undergoing the all tests. The fibre tensile strength with high elongation increases the fabric bursting strength. The coated fabrics have higher elasticity than the fabrics without coating as the bursting strength of the coated fabric was higher than fabric without coating as similarly found [28]. In addition, the first layer of the fabrics could be easily swept away when external force acted on it.

On the other hand, the coated dyed fabrics represented by G and H showed the decrease of water contact angle due to high composition of *Azadirachta Indica*, *Curcuma Longa* and *Lawsonia Inermis* pigment incompatible with the coating [29]. It was revealed that the concentration of dyes represented by F gave a good quality of coating. The development of superhydrophobic characteristics was due to the low energy-based fibre pigment and curing agent of the fabrics. Besides that, the coating particles penetrated inside the fibre and attached with the fabrics. The *Azadirachta Indica*, *Lawsonia Inermis* and *Curcuma Longa* dyes formed intermolecular attraction between the hydrogen structure and hydroxyl bond in the coating particles with slightly high water contact angle. The concentration became more concentrated and the particles in the liquids became more compact [30]. Therefore, free hydroxyl groups in the *Azadirachta Indica* may promote high concentration where it decreased the covalent bond between the coating particles and fibres. Moreover, the dye molecules and superhydrophobic coating will make the fibres to become more compact by creating covalent bonds and crosslinking between the fibres, dyes and particles of the superhydrophobic coating [31]. This study focuses on the superhydrophobic coating using coconut oil as a protection layer to prevent colour fading from the fabrics and self-cleaning fabric. The previous study reported on nanofibrous mat for biomedical use using *Azadirachta Indica* and polyvinyl alcohol (PVA). Nanofibrous mat made from the PVA and *Azadirachta Indica* acted as a good water repellent fabric as it has poor one-way transport and low overall moisture control ability [32].

3.2 Comparison of Physical and Mechanical Tests between Natural and Synthetic Dyes

Figure 6 shows a comparison between natural dyes, which were the Lawsonia Inermis, Azadiractha Indica and Curcuma Longa, and synthetic Golden Yellow dye. Mechanical properties such as abrasion strength, bursting strength and colourfastness, were determined. The mechanical strength of the synthetic dyes and natural dyes was not significantly different. Only natural dyes concentration represented by F was compared with the synthetic dye.

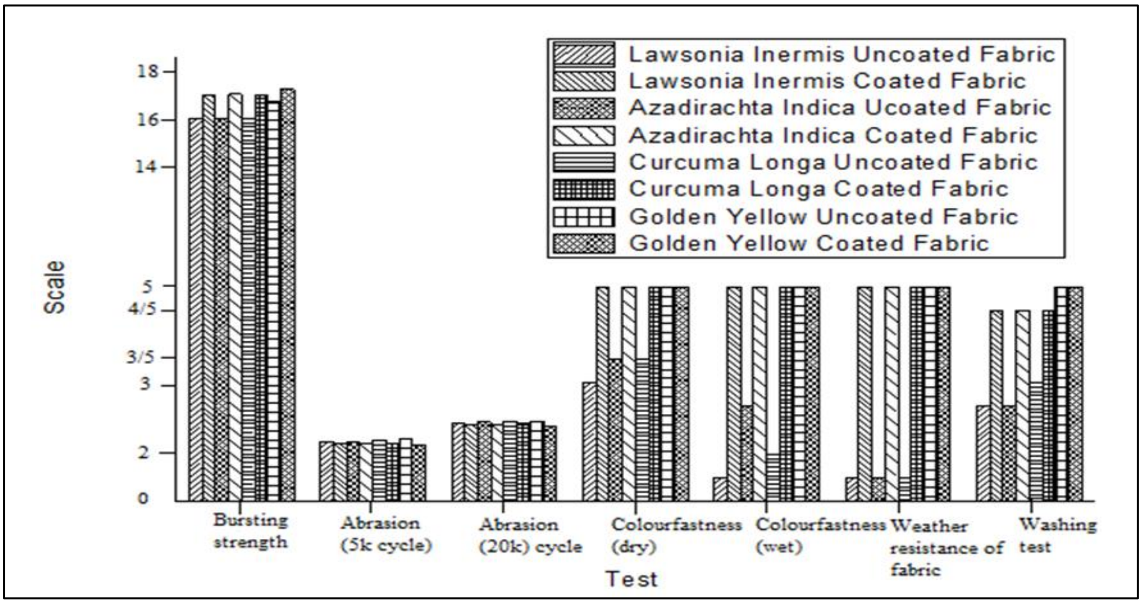

Figure 6. Comparison between coated, uncoated dyed fabric and synthetic dye.

From Figure 6, the physical and mechanical properties of natural dyes and synthetic dye were comparable without significant difference. The coated dyed fabrics have good mechanical strength compared to the uncoated dyed fabrics of *Lawsonia Inermis*, *Azadirachta Indica* and *Curcuma Longa*. The highest physical and mechanical strength of the uncoated and coated fabrics of *Lawsonia Inermis*, *Azadirachta Indica* and *Curcuma Longa* were represented by F at dye concentration of 1.50 g/ml. Both strengths were equivalent to those of the synthetic vat dyes, the Golden Yellow. The coated fabrics dyed with the *Lawsonia Inermis* indicated 5 (excellent) for weather resistance of the fabric, 5 (good) for washing test, 17.07 kPa for bursting strength, 2.41%

weight loss for 5,000 cycles and 3.21% weight loss for 20,000 cycles, abrasion strength of 5 (excellent) for dry and 5 (excellent) for wet colour strength testing while the uncoated fabrics obtained scale of 1 (very poor) for weather resistance, 2/3 (poor) for washing, 16.07 kPa for bursting strength, 2.51 % weight loss for 5,000 cycles and 3.31% for 20,000 cycles, scale of 3 (moderate) for dry and 1 (very poor) for wet colour loss. The coated fabrics dyed with *Azadirachta Indica* showed 5 (excellent) for weather resistance of the fabric, 4/5 (good) for washing test, 17.09 kPa for burst strength, 2.43% weight loss for 5,000 cycles and 3.23% for 20,000 cycles for abrasion cycle and 5 (excellent) for dry and wet colour fastness test, whereas the uncoated fabric has 1 (poor) for weather resistance, 2/3 (moderate) for washing test, 16.09 kPa for bursting strength, 2.53%weight loss for 5,000 cycles, 3.33% weight loss for 20,000 cycles of abrasion strength and 3/4 (moderate) for dry and 2/3 (poor) for wet colour loss. On the other hand, the coated fabric dyed with the *Curcuma Longa* obtained 5 (excellent) for weather resistance of the fabric, 4/5 (good) for washing, 17.08 kPa for bursting strength, 2.46% weight loss for 5,000 cycles and 3.23% weight loss for 20,000 cycles of abrasion strength and 5 (excellent) for dry and wet colour loss. Meanwhile, the uncoated fabrics dyed with *Curcuma Longa* had the lowest weather resistance, wash sample, bursting strength, abrasion strength and color resistance. Synthetic dye (Golden Yellow) was obtained 2.65% for 5,000 cycles and 3.35% for 20,000 cycles, 5 (excellent) for crocking test, 5(excellent) for washing test, 5 (excellent) for weather resistance of fabric and 16.76 kPa for bursting strength. Thus, it can be concluded that the natural dyes are able to replace the synthetic dye in textile industry. Nevertheless, the natural dyes can disappear quickly but it can be solved by adding superhydrophobic coating. Coated fabric with superhydrophobic coating was performed higher mechanical and physical properties compared to the uncoated dyed fabric. Synthetic dye also needs mordants and other additives are currently manufactured but they are relatively expensive [33]. In addition, the immense use of synthetic dyes and chemicals in the clothing, food, cosmetic and pharmaceutical industries has resulted in the production of large quantities of effluents containing high levels of dyes and toxic materials. The presence of these contaminants in effluents can pose environmental problems due to their non-degradable and persistent nature. Furthermore, the potential or real harmful effects of some synthetic dyes on human health, such as skin cancer and allergic reactions, have raised a great deal of concern. It is therefore necessary to replace environmentally harmful chemical dyes with cost-effective natural and environmentally friendly dyes or pigments. On the other hand, the raw materials for the production of natural dyes are abundantly available. Natural dyes do not pose harm and risk to human skin [34]. Some of the natural dyes act as health cure [35,36]. In addition, the extraction efficiency of colouring compounds present in plants and microbes on the basis of media pigment, such as aqueous, organic solvents, acid or alkali, pH of the media and extraction conditions such as temperature, play major role in the dyeing process [37].

4. CONCLUSION

In conclusion, the use of natural dyes extracted from the *Lawsonia Inermis*, *Azadirachta Indica* and *Curcuma Longa* coated with aqueous emulsion C6-fluorocarbon on the cotton fabric as green dyeing technology has been successfully elucidated. All the objectives in this research were successfully achieved. The highest bursting, abrasion, washing test, weather resistance of fabric, crocking and water contact angle of the coated fabrics of *Lawsonia Inermis*, *Azadirachta Indica* and *Curcuma Longa* were represented by F at dye concentration of 1.50 g/ml. The self-cleaning propertie was achieved at F (1.50 g/ml). The coated fabrics dyed with the *Lawsonia Inermis* at F indicated 5 (excellent) for weather resistance of the fabric, 5 (good) for washing test, 17.07 kPa for bursting strength, 2.41% weight loss for 5,000 cycles and 3.21% weight loss for 20,000 cycles, abrasion strength of 5 (excellent) for dry and 5 (excellent) for wet colour strength testing, coated fabrics dyed with *Azadirachta Indica* showed 5 (excellent) for weather resistance of the fabric, 4/5 (good) for washing test, 17.09 kPa for burst strength, 2.43% weight loss for 5,000 cycles and 3.23% for 20,000 cycles for abrasion cycle and 5 (excellent) for dry and wet colour fastness test and coated fabric dyed with the *Curcuma Longa* obtained 5 (excellent) for weather resistance of the fabric, 4/5 (good) for washing, 17.08 kPa for bursting strength, 2.46% weight loss for 5,000 cycles and 3.23% weight loss for 20,000 cycles of abrasion strength and 5 (excellent) for dry and wet colour loss The coated dyed fabrics have good physical and mechanical strength compared to the uncoated dyed fabrics of *Lawsonia Inermis*, *Azadirachta Indica* and *Curcuma Longa*. Both strengths were equivalent to those of the synthetic vat dyes, the Golden Yellow. The findings from this research make several contributions to the current literature. Further experiments and studies that involved natural dyes and natural super hydrophobic coating are strongly recommended. It would be interesting to assess the effect of UV exposure on the uncoated and coated dyed cotton fabrics. For future works, it is recommended that soil, oil and the chemical self-cleaning properties of the *Lawsonia Inermis*, *Azadiractha Indica* and *Curcuma Longa* dyes should be studied.

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