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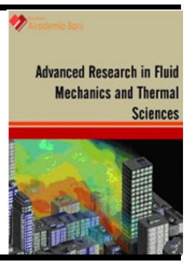

Formulating Water Based Paint with Red Natural Dyes

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ABSTRACT

The study aims to formulate and investigate the quality of water-based paint with red natural dyes. The red natural dyes was extracted from Caesalpinia sappan L. wood dissolved with water in a reactor with a capacity of 25 L. The extracted dyes were then spray dried into red powder dyes and subsequently formulated into paints by mixing them with full acrylic resin, water, dispersant, defoamer, and thickener. The powders were characterized using ultraviolet-visible spectrophotometry and Fourier transform infrared test. The results show that red powders show an absorbance spectra peak at wavelength of 400-600 nm and the functional groups of C-H, C-O-C, C-OH, C = C and C = O indicating functional groups in Brazilein dyes. The formulated paint has a viscosity, hiding power, total solid, touching drying time, hard drying time, and glossy level of 3800 mPas, 8.51 m²/kg, 54,6%, 25.09 minutes, 47.56 minutes, and 74,4 GU, respectively. The quality of the water-based paint formulated with red natural dyes has complied SNI standard 3564: 2009 for paint.

1. Introduction

The development of paint industries has increased in line with the growth in the property and housing sectors, which in 2012 it was growth of not less than 10% per year. Meanwhile, if viewed from the volume side, the annual paint production from 2010-2014 has increased from 688,770 tons to 822,804 tons [1]. Unfortunately, nearly 95% of the paint dyes are synthetic dyes. Synthetic dyes are synthesized from petroleum derivatives of low-cost and varied colors, but non-renewable. An alternative is to develop natural dyes obtained from the extraction of leaves, fruits, and trees which are renewable and have distinctive colours [2].

For environmentally friendly reason, the natural dyes used together with water-based resins are very interesting because can reduce the utilisation of surfactant. Water-based paints refer to paints in which water is used as a solvent. The common resins used in water-based paints are latex, acrylic, polyvinyl acetate, and styrene resin, all of which are soluble in water. The conventional resins for solvent-based paints, which include epoxy [3-5], alkyd, polyurethane [6,7], phenolic [8], polyester, silicates, and combinations or hybrids of these compounds [9], are derived from

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petroleum-based resources [10] and have low molecular weights. In contrast, resins for water-based paints have a high molecular weight and therefore do not need to be cross-linked in order to develop adequate film properties [11].

Natural dyes are very famous in ancient era for colouring-textiles [12-15] and nowadays have also been successfully developed for dye-sensitized solar cells (DSSCs) [16-22]. To the best of our knowledge, the application of natural dyes for paints has been increasingly [18, 23-26]. The natural dyes which are commonly explored for paint formulation include curcumine for red [25], anthocyanin for red, purple, and blue [27], and *Streptomyces* for brown, red, yellow, and black shades [28]; *Thymus serpyllum* [29] and lawsone have also been explored for brownish shades [24]. Unfortunately, there has not studies addressing to the utilisation of red natural dyes extracted from Caesalpinian sappan L wood for paint formulation yet.

The main problem with natural dyes including red Caesalpinia sappan when formulated in paints is conformity with the other components in the paint. Mixing natural dyes in paints is very important to pay attention to the quality and compatibility so that the paint produced does not experience defects and has the standard color. Whereas the natural dyes used are derived from plant consisting of various compounds with varying concentrations. Therefore, it is necessary to formulate natural dyes that can be mixed in paints to produce standardized color paint.

The quality standard of paints consists of viscosity, total solid, hiding power, drying time, gloss, toughness, and weather resistance. Generally speaking, paints are formulated by mixing [30] of the main four components, comprising resins, solvents, additives, and pigments or dyes. These components, besides having special properties, should also be compatible with one another, such that defects are avoided and the quality stadandard are fulfilled. Unfortunately, the compatibility of water-based resins, surfactants, and additives in paints which use red natural dyes is still rarely studied. Therefore, this study reports an investigation of quality stadard and defects found in water-based paints with red natural dye extracted from Caesalpinia sappan wood.

2. Methodology

The raw materials used were a full acrylic resin as a binder, propyline glycol as a surfactant, Poiz 530 as a dispersant, antifoam as a bubble or foam controller, and thickener. The dye used was the Caesalpinnia sappan powders produced from the extraction process using a reactor of 50 L capacity and followed by spray dried at a capacity of 10 L/8 h.

Formulating paints was done in two stages. The first stage was mixing dye, water, surfactant, and dispersant and stirring slowly in a magnetic stirrer. The mass concentration of dye, water, surfactant, and dispersant was 57%, 38%, 2%, and 2%, respectively. Then the second stage was mixing binder, water, surfactant, and dispersant and stirring until homogeneous. The mass concentration of binder, water, surfactant, and dispersant in solution two was 73%, 24%, 1%, and 1%, respectively. After that the first solution was poured slowly into the second solution becoming water based paint. A sufficiently amount of thickener was added to control the viscosity of paints.

UV-Vis spectrophotometry was used to examine the absorrbance spectra of red natural dyes. Meanwhile, Fourier transfrom infrared (FTIR) testing was used to identify the functional groups in red natural dyes. The viscosity of formulated paints was tested using the Brookfield viscometer. The hiding power, total solid, and drying time were done according to SNI standard 3564:2009 for paint. A microscope observation was performed to capture defects in paints and analysed by Image-J Pro software. The quality standard of formulated paints with red natural dyes would be compared with that of commercial paints (A dan B) formulated with synthetic dyes.

3. Results and Discussion

The absorbance spectra of red natural dyes were at a wide wavelength from 400 to 600 nm as shown in Figure 1 which is fit with the previous study [31]. The peak absorbance was present at a wavelength of 538 nm with an absorbance rate of 3.106.

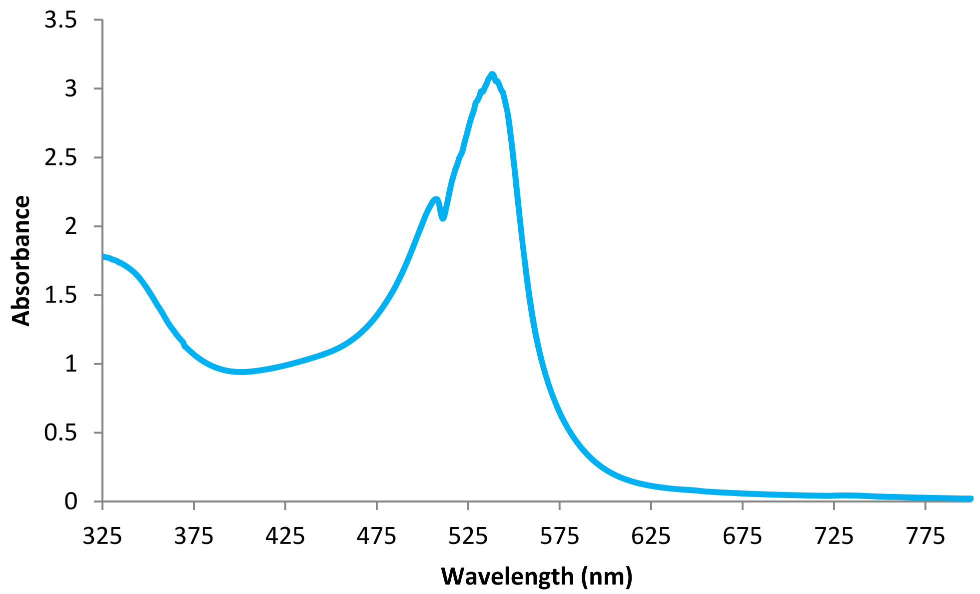

Fig. 1. UV-Vis spectra of red natural dyes

Figure 2 shows the data of wave numbers in the red natural dye detected by FTIR. The functional groups are detected, i.e. O-H hydroxyl, C-H. C=O, C=C, C-O-C, and =C-H at wavenumber of 3100-3700 cm-1, 650-1000 cm-1, 150-1870 cm-1, 1550-1650 cm-1, 1000-1300 cm-1, and 650-1000 cm-1, respectively. The functional groups indicated that the red natural dyes extracted from Caesalpinia sappan L is similar to that of the Brazillein sunstance.

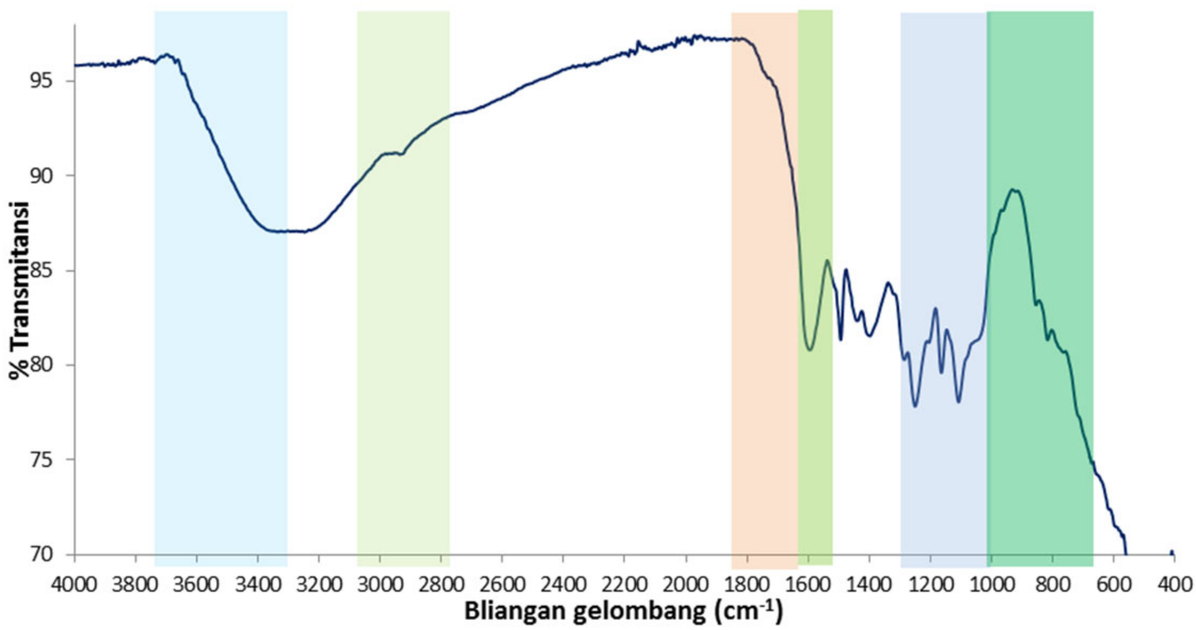

Fig. 2. FT-IR spectra of the red natural dye

Figure 3 shows the rheology property of the paint with red natural dyes compared with that of the paints with synthetic dyes. We used two commercial brands for comparison. It can be seen that the shear stress value increases gradually as the shear rate increases, indicating the non-linier effect of shear rate on shear stress. The higher the shear rate the bigger the shear stress is measured in water based paints. It also indicates that the water-based paints are non-Newtonian fluids and behave as pseudoplastic fluids meaning that there is a continuous decrease in viscosity as a function of increasing shear rate [32,33]. Paints exhibiting pseudoplastic rheology are good wetter property. A good wetting paint is usually has low surface tension as found in substances having hydrophilic polar functional groups, such as a hydroxyl or ester function combined with a hydrophobic tail (e.g. a long hydrocarbon fragment) within the same molecule [32]. The viscosity of the formulated water based paint with natural dye, commercial paint A, and commercial paint B are 3800, 5517.7, and 5816.7 mPas, respectively and fulfilling the SNI standard, i.e higher than 1150 mPas.

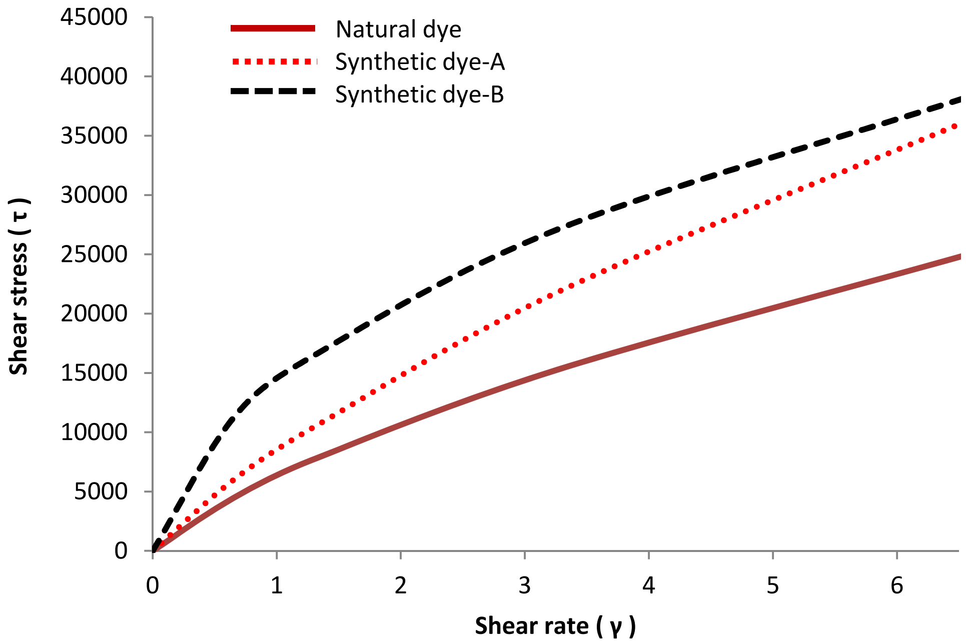

Fig. 3. The relationship between shear rate and shear stress of water based paints

Total solid and hiding power of the water based paints with natural dyes are in between than that of the commercial paint A and B as shown in Figure 4. The drying time of water based paints is shown in Figure 5. The drying time of water based paint with natural dye was close to that of commercial paint A and B as shown in Figure 5.

Defects found in the water based paints with natural dyes detected by microscope as shown in Figure 6 were crater. Crater is a surface defect in paints caused by bubbles or air trapped in paints causing imperfect drying process [34]. The air trapped is due to the high viscosity of the paint and the excessively dry time [35]. The percentage of crater is calculated using ImageJ Pro software from photographes obtained from the observer using microscope. The level of crater defect occurring in the water-based paints with natural dyes, synthetic A, and synthetic B was 1.52%, 0.11%, and 0.16%, respectively. It shows that the crater defects found in water based paints are very low.

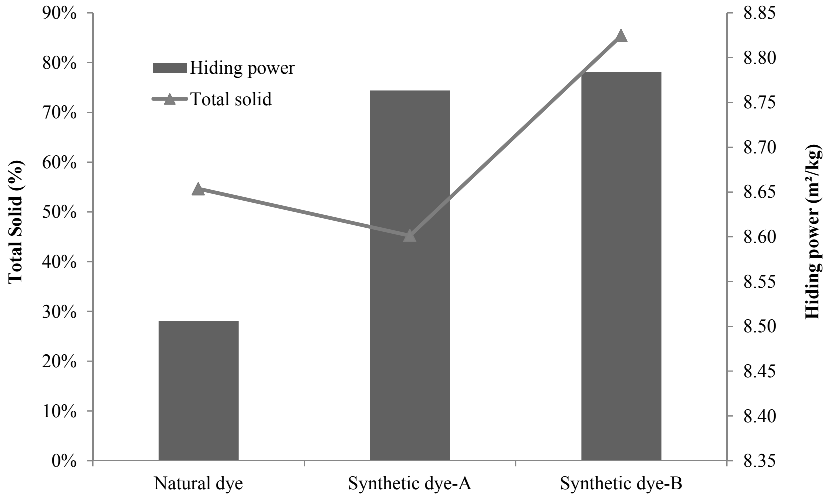

Fig. 4. Total solid and hiding power of water based paints

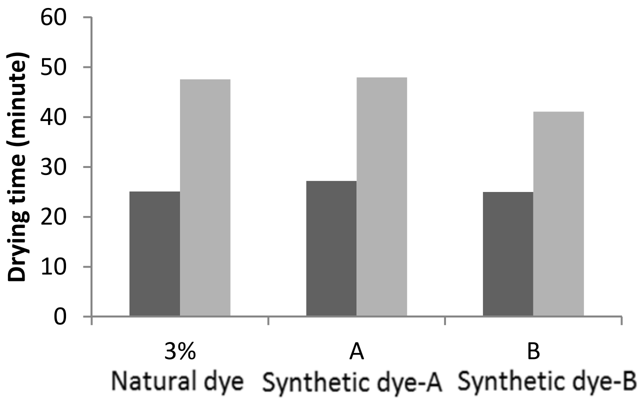

Fig. 5. Drying time of water based paints

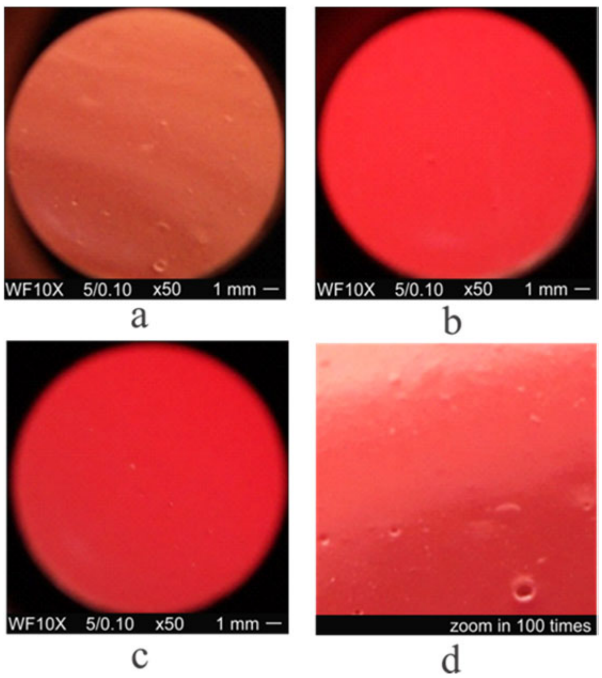

Fig. 6. Microscopice images of water based paints ; a) with natural dye, b) with synthetic commercial A, c) with synthetic commercial B, d) zoom in (100 times)

The glossy level is mainly influenced by the dispersion abbility of dyes in vehicles [36,37]. The glossy level of water based paints with natural dye, commercial paint A, and commercial paint B was 74.4, 64.1, and 0.3 GU. In commercial paint B sample, low gloss level is influenced by high total solid. Paints with a high solid content indicate that the ratio of pigment to solvent and resin is also high.

4. Conclusion

This paper has successfully formulated the water based paint using the red natural dye extracted from Caesalpinia sappan L. The formulated water based paint has been investigated its properties and compared with two commercial water based paints. The results show that red powders show an absorbance spectra peak at wavelength of 400-600 nm and the functional groups of C-H, C-O-C, C-OH, C = C and C = O indicating functional groups in Brazilein dyes. The formulated paint has a viscosity, hiding power, total solid, touching drying time, hard drying time, and glossy level of 3800 mPas, 8.51 m^2/kg, 54,6%, 25.09 minutes, 47.56 minutes, and 74,4 GU, respectively. The quality of the water-based paint formulated with red natural dyes has complied SNI standard 3564: 2009 for paint.

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References
[1] Mars, in *Perkembangan Cat Nasional* 5, 2012.
[2] Mulyanto, Subur, Suyitno, Rendy Adhi Rachmanto, Lullus Lambang Govinda Hidayat, Atmanto Heru Wibowo, and Syamsul Hadi. "Synthesis and characterization of natural red dye from Caesalpinia sappan linn." In *AIP Conference Proceedings*, vol. 1717, no. 1, p. 040032. AIP Publishing, 2016.
[3] Krishnamurti, K. "Water-soluble epoxy resins for surface coatings." *Progress in Organic Coatings* 11, no. 2 (1983): 167-197.
[4] Del Amo, B., R. Romagnoli, C. Deyá, and J. A. González. "High performance water-based paints with non-toxic anticorrosive pigments." *Progress in Organic Coatings* 45, no. 4 (2002): 389-397.
[5] Ahmetli, Gulnare, Huseyin Deveci, Ulku Soydal, Aslı Seker, and Refika Kurbanli. "Coating, mechanical and thermal properties of epoxy toluene oligomer modified epoxy resin/sepiolite composites." *Progress in Organic Coatings* 75, no. 1-2 (2012): 97-105.
[6] Papaj, Ewa A., Douglas J. Mills, and Sina S. Jamali. "Effect of hardener variation on protective properties of polyurethane coating." *Progress in Organic Coatings* 77, no. 12 (2014): 2086-2090.
[7] Wang, Yingying, Fengxian Qiu, Binbin Xu, Jicheng Xu, Yan Jiang, Dongya Yang, and Pengling Li. "Preparation, mechanical properties and surface morphologies of waterborne fluorinated polyurethane-acrylate." *Progress in Organic Coatings* 76, no. 5 (2013): 876-883.
[8] Tilak, G. Y. "Thermosetting acrylic resins-a literature review." *Progress in organic coatings* 13, no. 5 (1985): 333-345.
[9] Guyot, Alain, Katharina Landfester, F. Joseph Schork, and Chunpeng Wang. "Hybrid polymer latexes." *Progress in Polymer Science* 32, no. 12 (2007): 1439-1461.
[10] Balgude, Dinesh, and Anagha S. Sabnis. "CNSL: an environment friendly alternative for the modern coating industry." *Journal of Coatings Technology and Research* 11, no. 2 (2014): 169-183.
[11] Lambourne, R. *Paint composition and applications—a general introduction*. Cambridge, England: Woodhead Publishing, Ltd, 1999.
[12] Baid, Arun M. "Method of dyeing the textile article from medicinally rich herbs." U.S. Patent 7,485,158, issued February 3, 2009.
[13] Erkan, Gökhan, Kemal Şengül, and Sibel Kaya. "Dyeing of white and indigo dyed cotton fabrics with Mimosa tenuiflora extract." *Journal of Saudi Chemical Society* 18, no. 2 (2014): 139-148.

[14] Sachdev, Rajiv Rai. "Method for dyeing a textile product using Neem and Holy basil extract." U.S. Patent 8,697,429, issued April 15, 2014.
[15] ALKAN, Rezan, Emine TORGAN, Canan AYDIN, and Recep KARADAG. "Determination of Antimicrobial Activity of the Dyed Silk Fabrics with Some Natural Dyes." *Tekstil ve Mühendis* 22, no. 97 (2015).
[16] Zhou, Huizhi, Liqiong Wu, Yurong Gao, and Tingli Ma. "Dye-sensitized solar cells using 20 natural dyes as sensitizers." *Journal of Photochemistry and Photobiology A: Chemistry* 219, no. 2-3 (2011): 188-194.
[17] Attanayake, C. I. F., Chathuranga De Silva, B. A. J. K. Premachandra, A. A. P. De Alwis, and G. K. R. Senadheera. "Dye-Sensitized solar cells: Using Over 100 Natural Dyes as Sensitizer." In *2013 AICHE annual meeting*. 2013.
[18] Shahid, M. "Shahid-ul-Islam and F. Mohammad." *J. Cleaner Prod* 53 (2013): 310-331.
[19] Arifin, Zainal, Sudjito Soeparman, Denny Widhiyanuriyawan, Bayu Sutanto, and Suyitno. "Performance enhancement of dye-sensitized solar cells (DSSCs) using a natural sensitizer." In *AIP Conference Proceedings*, vol. 1788, no. 1, p. 030123. AIP Publishing, 2017.
[20] Agustia, Yuda Virgantara, Suyitno, Zainal Arifin, and Bayu Sutanto. "Effect of acidity on the energy level of curcumin dye extracted from Curcuma longa L." In *AIP Conference Proceedings*, vol. 1717, no. 1, p. 040005. AIP Publishing, 2016.
[21] Suyitno, Suyitno, Trisma Jaya Saputra, Agus Supriyanto, and Zainal Arifin. "Stability and efficiency of dye-sensitized solar cells based on papaya-leaf dye." *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* 148 (2015): 99-104.
[22] Suyitno, D. N. Rachmad, Z. Arifin, T. J. Saputra, M. A. Omid and M. Yusuf, *Applied Mechanics and Materials* 699, (2014).
[23] Pawlak, Katarzyna, Maria Puchalska, Agata Miszczak, Elżbieta Rosłoniec, and Maciej Jarosz. "Blue natural organic dyestuffs—from textile dyeing to mural painting. Separation and characterization of coloring matters present in elderberry, logwood and indigo." *Journal of Mass Spectrometry* 41, no. 5 (2006): 613-622.
[24] Abidin, Z. H. Z., K. M. Nasir, S. K. M. Jamari, N. Saidon, S. V. Lee, N. A. Halim, and R. Yahya. "The characteristics of a coating system containing lawsone dye colorant and PMMA-acrylic polyol blended resin." *Pigment & Resin Technology* 42, no. 2 (2013): 128-136.
[25] Abidin, Z. H. Z., N. N. Naziron, K. M. Nasir, M. S. Rusli, S. V. Lee, M. Z. Kufian, S. R. Majid *et al.,* "Influence of curcumin natural dye colorant with PMMA-acrylic polyol blended polymer." *Pigment & Resin Technology* 42, no. 2 (2013): 95-102.
[26] Usop, R., Z. H. Z. Abidin, N. A. Mazni, A. N. Hadi, N. A. Halim, R. M. Taha, M. A. Careem, S. R. Majid, and A. K. Arof. "The colour stability of natural dye coating films consisting of chlorophyll after exposed to UV-A." *Pigment & Resin Technology* 45, no. 3 (2016): 149-157.
[27] S. V. Lee, A. N. Hadi, Z. H. Z. Z. Abidin, N. A. Mazni, N. A. Halim, R. Usop, H. C. Hassan, S. R. Majid and A. K. Arof, *Pigment & Resin Technology* 44, no. 2 (2015).
[28] D. N. Sastry, T. Prabhakar and M. L. Narasu, *Pigment & Resin Technology* 45, no. 2 (2016).
[29] Cakmakçi, Emrah, Ozan Deveoglu, Ahmed Muhammed, Ali Fouad, Emine Torgan, and Recep Karadag. "HPLC-DAD analysis of Thymus serpyllum based natural pigments and investigation of their antimicrobial properties." *Pigment & Resin Technology* 43, no. 1 (2013): 19-25.
[30] A. Gürses, M. Açıkyıldız, K. Güneş and M. S. Gürses, in *Dyes and Pigments, Edited Springer International Publishing, Cham* (2016): 47-67.
[31] Fazio, E., F. Neri, A. Valenti, P. M. Ossi, S. Trusso, and R. C. Ponterio. "Raman spectroscopy of organic dyes adsorbed on pulsed laser deposited silver thin films." *Applied Surface Science* 278 (2013): 259-264.
[32] Dershem, Stephen M. "Resinless pseudoplastic bonding compositions." U.S. Patent 5,306,333, issued April 26, 1994.
[33] Colloid and interface chemistry for water quality control, *Academic Press*, (2016).
[34] L. Kornum and H. R. Nielsen, *Progress in Organic Coatings* 8, no. 3 (1980).
[35] A. Dalili, S. Chandra, J. Mostaghimi, H. C. Fan and J. C. Simmer, *Progress in Organic Coatings* 97, (2016).
[36] J. R. Costa, C. Correia, J. R. Góis, S. M. Silva, F. E. Antunes, J. Moniz, A. C. Serra and J. F. Coelho, *Progress in Organic Coatings* 104, (2017).
[37] Simpson, L. A. "Factors controlling gloss of paint films." *Progress in organic coatings* 6, no. 1 (1978): 1-30.