2) Fastness to Rubbing: Testing of rubbing fastness was done by using the Crockmeter. The rubbing fastness of the dyeing cotton fabrics are in a range from good to excellent (4-5) (Table 3). In the treatment using $Al_2(SO_4)_3$ and CaO mordant, the color fastness value is from good to excellent (4-5). The high color fastness value in the presence of mordant process occurs because the metal cations of the Ca, Fe with 2 or 3 valencies are reacted to form a metal complex bond with the dye into a large molecule. The larger the molecule size, the bigger the bonding force that occurs between the fibers and the dyestuffs. Consequently, when the fixed dye undergoes any mechanical power on the fabric surface, the dyestuffs will be more retained on the fabric fibers [24].

3) Fastness to Light: The fastness to light of the dyed fabric with natural dyes is less than others such as washing and rubbing because it is very easy to degrade by the influence of light. The color fastness value of the dyed cotton fabric as in Table 3.

Internal factors of the physics and chemistry of dyes such as dye concentration, properties of fiber, and mordant influenced the color fastness to light. Nearly 50% of the natural dyes are listed in the Color Index (CI), which derived from the flavonoid compounds, and the rest are *anthraquinone, naphthoquinone,* and indigo. The flavonoid compounds such as tannins have less color-fastness to light, but *anthraquinone* and indigo are good [41]. In the coloring process using *mordant,* the color fastness depends on the type and method of mordant. The complexity that occurs between the dye-mordant-fiber will provide the color stability to the light influence.

The loss of color in the dyed textiles by the influence of light can be attributed to degrade the natural dye *chromophore* components by photo-oxidative degradation, resulting in small molecules [41], [42]. Natural dyes tend to absorb the visible light. The radiation energy of these rays causes photochemical reactions that can damage the dyestuff structure resulting in color degradation.

TABLE II
FASTNESS TO WASHING OF THE COTTON FABRIC

Mordant Method	Kind of Mordant	Color Staining		Color Change
		Cotton	Polyester	
Pre Mordan	$Al_2(SO_4)_3$	5	4	3
	CaO	5	5	3
	$FeSO_4$	5	5	3
Simultaneous Mordant	$Al_2(SO_4)_3$	5	5	3
	CaO	5	5	3
	$FeSO_4$	5	5	3
Post Mordant	$Al_2(SO_4)_3$	4	5	4
	CaO	5	4	4
	$FeSO_4$	5	5	4
Pre and Post Mordant	$Al_2(SO_4)_3$	4	5	4
	CaO	4	5	4
	$FeSO_4$	5	4	4

In color degradation, there is a decrease in the concentration of *chromosphores* and some detected *hydroxybenzoic* acid. The color of the fabric becomes visually faded. This event is related to the oxidation process of C2-C3 atoms of the flavonoid compounds, followed by the breaking of C2-C3 and C3-C4 chains. Increased oxidation of flavonoids is caused by the effect of some activated radicals with the light on double bonds C2-C3 [43]. Metal salts in the mordant can also speed up the photo-oxidation on the dyed fabric in the dyeing process. Some mordants are catalyzed by the degradation of natural dyes and are very sensitive to the effects of light [27], [43].

TABLE III
FASTNESS TO RUBBING AND LIGHT OF COTTON FABRIC

Mordant Method	Kind of Mordant	Rubbing	Light
Pre Mordan	$Al_2(SO_4)_3$	4-5	3
	CaO	4-5	2
	$FeSO_4$	4-5	4
Simultaneous Mordant	$Al_2(SO_4)_3$	4-5	3
	CaO	4-5	2-3
	$FeSO_4$	4	> 4
Post Mordant	$Al_2(SO_4)_3$	4-5	2-3
	CaO	4-5	2-3
	$FeSO_4$	4	4
Pre and Post Mordant	$Al_2(SO_4)_3$	4-5	2-3
	CaO	4-5	3
	$FeSO_4$	4	4

D. Amount of Used Mordant Metal

The absorption of the mordant metal in dyed cotton fabrics is to evaluate the actual amount of metal ions, which has left in the fiber after the dyeing process. The result is an indication of complexity among the dyes-metal ion-fiber. Amount of the mordant metal is used to determine the color strength and the color-fastness of the dyed cotton fabrics. The test result of the mordant amount left in the fabric fibers as shown in Table 4.

Method of the post and the combined mordant averagely bind the metal more than others. The average percentage of mordant, which is absorbed, is still low (15-44%) as in Table 4. This condition indicates that the complexity that occurs among the metal ion-tannin-fiber is still low, or the number of the metal ions in the solution exceeds the quantity of complex ligament with the fibers. Another possibility is that the absorbed dyestuff is still on the fiber surface and has not penetrated in the fiber core yet, so it is easy to release into the water during the washing process.

The amount of the mordant metal contained in the dyed fabric also determines the color intensity of the resulting color (Table 1). FeSO4 in the use of CaO follows the highest amount of the used mordant metals in the combined mordant method. It corresponds to the K/S values listed in Table 1, where the high values are obtained by using of CaO and $FeSO_4$ mordant on the use of combined mordant methods.

According to [42], the increase of the mordant metal amount used in the dyeing process will not necessarily increase the metal levels in the dyed fabric. Although the mass of the metal ions in the dyeing bath is sizeable, the metal ions in the textile fibers are much lower. It is due to the unbonded metal in the fiber, which will come out with the washing after the dyeing process.

TABLE IV
THE TEST RESULT OF THE AMOUNT OF METAL MORDANT USED

Mordant Method	Mordant Kind	Metal Content (mg/L)				Mordant Used (%)
		Mordant Solution	White Fabric	Dyed Fabric	Mordant Used	
Pre Mordant	$Al_2(SO_4)_3$	980	6.99	216.25	209.25	21.35
	CaO	5607	5.78	970.24	964.46	17.20
	$FeSO_4$	8315	8.69	2364.75	2356.07	28.34
Simultaneous Mordant	$Al_2(SO_4)_3$	980	6.99	212.60	205.61	20.98
	CaO	5607	5.78	899.52	893.73	15.94
	$FeSO_4$	8315	8.69	2398.78	2390.09	28.74
Post Mordant	$Al_2(SO_4)_3$	980	6.99	219.25	212.25	21.66
	CaO	5607	5.78	2293.15	2287.36	40.79
	$FeSO_4$	8315	8.69	2390.64	2381.96	28.65
Pre and Post Mordant	$Al_2(SO_4)_3$	980	6.99	229.84	222.85	22.74
	CaO	5607	5.78	2456.05	2450.27	43.70
	$FeSO_4$	8315	8.69	2416.35	2407.66	28.96

IV. CONCLUSIONS

The main component of the *Gambier* extract identified by X-Ray Diffraction was *catechin*, *catechin anhydrous*, *pyrocatechol* including flavonoid group that could provide color with the aid of mordant. The cotton fabric was used to apply the natural dyes. Each method and type of mordant produced different and strength of color such as light brown, reddish brown to dark brown. Mordant $Al_2 (SO_4)_3$ is tended to give a lighter color than others, and high color strength obtained in the pre-mordant methods. Mordant CaO gave the color of reddish-brown, with the highest color strength on the combined and the post-mordant methods. The mordant $FeSO_4$ has produced a darker color than others have. High color intensity occurred in the combined and simultaneous mordant methods. The washing and rubbing fastness of the cotton fabric results in a range from good to excellent (4-5), while light fastness had a good enough to a reasonable value (3-4). The binding of mordant metal in coloring was still low in a range of 15-40%.

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REFERENCES

[1] D. Habip, K. Dilek, M. Nigar, and C. Seyda, "The effect of dyeing properties of fixing agent and plasma treatment on silk fabric dyed with natural dye extract obtained from Sambucus ebulus L. plant," *Procedia- Soc. Behav. Sci.*, vol. 195, pp. 1609–1617, 2015.

[2] M. J. Chan-Bacab, P. Sanmartin, J. C. Camacho-Chab, K. B. Palomo-Ascanio, H. E. Huitz-Quime, and B. O. Ortega-Morales, "Characterization and dyeing potential of colorant-bearing plants of the Mayan area in Yucatan Peninsula, Mexico," *J. Clean. Prod.*, vol. 91, pp. 191–200, 2015.

[3] N. Kusumawati, A. B. Santoso, M. M. Sianita, and S. Muslim, "Extraction, characterization, and application of natural dyes from the fresh mangosteen (Garcinia mangostana L.) peel," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 7, no. 3, pp. 878–884, 2017.

[4] M. Yusuf, F. Mohammad, and M. Shabbir, "Eco-friendly and effective dyeing of wool with anthraquinone colorants extracted from Rubia cordifolia roots: Optimization, colorimetric and fastness assay," *J. King Saud Univ. - Sci.*, vol. 29, pp. 137–144, 2017.

[5] Andasuryani, Y. A. Purwanto, I. W. Budiastra, and K. Syamsu, "Determination of catechin content in gambir powder from dried gambir leaves quickly using FT NIR PLS model," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 4, no. 5, p. 303, 2014.

[6] N. Baaka, A. Mahfoudhi, W. Haddar, M. F. Mhenni, and Z. Mighri, "Green dyeing process of modified cotton fibres using natural dyes extracted from Tamarix aphylla (L.) Karst. Leaves," *Nat. Prod. Res.*, vol. 31, no. 1, pp. 22–31, 2017.

[7] F. Giacomini, M. A. B. Menegazzo, J. C. O. dos Santos, P. A. Arroyo, and M. A. S. D. de Barros, "Eco-friendly dyeing of silk with extract of yerba mate (Ilex paraguariensis)," *Text. Res. J.*, vol. 87, no. 7, pp. 829–837, 2017.

[8] L. J. Rather *et al.*, "Ecological dyeing of woolen yarn with Adhatoda vasica natural dye in the presence of biomordants as an alternative copartner to metal mordants," *J. Environ. Chem. Eng.*, vol. 4, no. 3, pp. 3041–3049, 2016.

[9] H. Fauza, "Gambier : Indonesia leading commodities in the past," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 4, no. 6, pp. 455–460, 2014.

[10] G. Yeni, K. Syamsu, O. Suparno, E. Mardliyati, and H. Muchtar, "Repeated extraction process of raw gambiers (Uncaria gambier Robx.) for the catechin production as an antioxidant," *Int. J. Appl. Eng. Res.*, vol. 9, no. 24, pp. 24565–24578, 2014.

[11] A. Yasukawa, A. Chida, Y. Kato, and M. Kasai, "Dyeing silk and cotton fabrics using natural blackcurrants," *Text. Res. J.*, vol. 87, no. 19, pp. 2379–2387, 2017.

[12] S. Saxena and A. S. M. Raja, "Natural Dyes: Sources, chemistry, application and sustainability issues," Springer Science+Business Media Singapore 2014, 2014, pp. 41–62.

[13] Failisnur and Sofyan, "Effect of temperature and dyeing time of cotton yarn on natural dyeing with gambir extract (Uncaria gambier Roxb)," *J. Litbang Ind.*, vol. 6, no. 1, pp. 25–37, 2016.

[14] M. Yusuf, M. Shabbir, and F. Mohammad, "Natural colorants: Historical, processing and sustainable prospects," *Nat. Products Bioprospect.*, vol. 7, no. 1, pp. 123–145, 2017.

[15] M. Masae *et al.*, "Dyeing silk fabrics with stink bean pod (Parkia speciosa Hassk.) natural dye in the colorfastness and UV protection," *J. Eng. Sci. Technol.*, vol. 12, no. 7, pp. 1792–1803, 2017.

[16] M. N. Bukhari *et al.*, "Dyeing studies and fastness properties of brown naphthoquinone colorant extracted from Juglans regia L on natural protein fiber using different metal salt mordants," *Text. Cloth. Sustain.*, vol. 3, no. 1, p. 3, Dec. 2017.

[17] F. Failisnur, S. Sofyan, and R. Kumar, "Mordant effects on dyeing of gambier liquid waste and secang wood extract combination on rayon and cotton fabrics," *J. Litbang Ind.*, vol. 7, no. 2, pp. 93–100, Dec. 2017.

[18] Failisnur, Sofyan, and W. Hermianti, "Application of gambier pressing wastewater for dyeing of batik fabrics," *J. Litbang Ind.*, vol. 7, no. 1, pp. 19–28, 2017.

[19] Failisnur and G. Yeni, "Stabilization of gambier process wastewater and its application as silk dye," *Biopropal Ind.*, vol. 4, no. 1, pp. 7–16, 2013.

[20] E. Gumbira Sa'id, O. Suparno, and H. . Pransiska, "Studi pemanfaatan gambir (Uncaria gambir Roxb) dalam proses pewarnaan kain mori," IPB (Bogor Agricultural University), Bogor, 2011.
[21] S. Sofyan and F. Failisnur, "Reuse of liquid waste from textile dyeing with natural dyes gambier (Uncaria gambir Roxb.) for cotton yarn dyeing," *ARPN J. Eng. Appl. Sci.*, vol. 12, no. 18, pp. 5313–5318, 2017.
[22] V. Atika, Farida, and T. Pujilestari, "Quality of gambier extract on silk batik dyeing," *Din. Kerajinan dan Batik*, no. 7, pp. 25–32, 2016.
[23] Kumaresan, "Comparison of fastness properties and colour strength of dyed cotton fabrics with eco-friendly natural dyes," *Exp.*, vol. 8, no. 3, pp. 483–489, 2013.
[24] A. Moiz, M. Aleem Ahmed, N. Kausar, K. Ahmed, and M. Sohail, "Study the effect of metal ion on wool fabric dyeing with tea as natural dye," *J. Saudi Chem. Soc.*, vol. 14, no. 1, pp. 69–76, 2010.
[25] A. K. Samanta and A. Konar, "Dyeing of textiles with natural dyes," *Nat. Dye.*, pp. 29–56, 2011.
[26] Sofyan, Failisnur, and S. Sy, "The effect of waste treatment and mordant kind of lime, alum, and ferrous salt on dyeing quality of silk and cotton fabrics using wastewater of gambir (Uncaria gambir Roxb)," *J. Litbang Ind.*, vol. 5, no. 2, pp. 79–89, 2015.
[27] A. Ado, H. Yahaya, A. . Kwalli, and R. . Abdulkadir, "Dyeing of textiles with eco-friendly natural dyes: A review," *Int. J. Environ. Monit. Prot.*, vol. 1, no. 5, pp. 76–81, 2014.
[28] P. Pisitsak, J. Hutakamol, R. Thongcharoen, P. Phokaew, K. Kanjanawan, and N. Saksaeng, "Improving the dyeability of cotton with tannin-rich natural dye through pretreatment with whey protein isolate," *Ind. Crops Prod.*, vol. 79, pp. 47–56, 2016.
[29] S. M. Saleh, Y. A. Abd-el-hady, and K. El-badry, "Eco-friendly dyeing of cotton fabric with natural colorants extracted from banana leaves," *Int. J. Text. Sci.*, vol. 2, no. 2, pp. 36–40, 2013.
[30] P. N. Diouf, C. M. Tibirna, M. Royer, P. Dubé, and T. Stevanovic, "Structural elucidation of condensed tannin from Picea mariana bark," *J. Biomater. Nanobiotechnol.*, vol. 2013, no. 4, pp. 1–8, 2013.
[31] S. Baliarsingh, P. C. Behera, J. Jena, T. Das, and N. B. Das, "UV reflectance attributed direct correlation to colour strength and absorbance of natural dyed yarn with respect to mordant use and their potential antimicrobial efficacy," *J. Clean. Prod.*, vol. 102, pp. 485–492, 2015.
[32] P. A. G. Wanyama, B. T. Kiremire, P. Ogwok, and J. S. Murumu, "The effect of different mordants on strength and stability of colour produced from selected dye-yielding plants in Uganda," *Iaast*, vol. 1, no. 2, pp. 81–92, 2010.
[33] P. Schofield, D. M. Mbugua, and A. N. Pell, "Analysis of condensed tannins: A review," *Anim. Feed Sci. Technol.*, vol. 91, no. 1–2, pp. 21–40, 2001.
[34] G. Erkan, K. Şengül, and S. Kaya, "Dyeing of white and indigo dyed cotton fabrics with Mimosa tenuiflora extract," *J. Saudi Chem. Soc.*, vol. 18, no. 2, pp. 139–148, Apr. 2014.
[35] Q. Zhao, H. Feng, and L. Wang, "Dyeing properties and color fastness of cellulase-treated flax fabric with extractives from chestnut shell," *J. Clean. Prod.*, vol. 80, pp. 197–203, 2014.
[36] N. Punrattanasin, M. Nakpathom, B. Somboon, N. Narumol, N. Rungruangkitkrai, and R. Mongkholrattanasit, "Silk fabric dyeing with natural dye from mangrove bark (Rhizophora apiculata Blume) extract," *Ind. Crops Prod.*, vol. 49, pp. 122–129, 2013.
[37] X. Hou, X. Chen, Y. Cheng, H. Xu, L. Chen, and Y. Yang, "Dyeing and UV-protection properties of water extracts from orange peel," *J. Clean. Prod.*, vol. 52, pp. 410–419, Aug. 2013.
[38] A. Rosyida, "Pengaruh variasi pH dan fiksasi pada pewanaan kain kapas dengan zat warna alam dari kayu nangka," in *Prosiding Seminar Nasional 4th UNS SME's Summit & Awards 2015*, 2015, pp. 101–112.
[39] R. Etherington, "vegetable tannins," in *A Dictionary Of Descriptive Terminology*, 2011.
[40] L. Janani, L. Hillary, and K. Phillips, "Mordanting methods for dyeing cotton fabrics with dye from Albizia coriaria plant species," *Int. J. Sci. Res. Publ.*, vol. 4, no. 10, pp. 1–6, 2014.
[41] D. Cristea and G. Vilarem, "Improving light fastness of natural dyes on cotton yarn," *Dye. Pigment.*, vol. 70, no. 3, pp. 238–245, 2006.
[42] A. Manhita *et al.*, "Enlightening the influence of mordant, dyeing technique and photodegradation on the colour hue of textiles dyed with madder - A chromatographic and spectrometric approach," *Microchem. J.*, vol. 98, no. 1, pp. 82–90, 2011.
[43] M. P. Colombini, A. Andreotti, C. Baraldi, I. Degano, and J. J. Łucejko, "Colour fading in textiles: A model study on the decomposition of natural dyes," *Microchem. J.*, vol. 85, no. 1 SPEC. ISS., pp. 174–182, 2007.