

**STABILITAS PIGMEN FIKOSIANIN DARI *Spirulina platensis*
TERMODIFIKASI FORMALDEHIDA SEBAGAI KANDIDAT
SENSITIZER ALAMI**

SKRIPSI

diajukan untuk memenuhi sebagian syarat untuk memperoleh gelar
Sarjana Sains Program Studi Kimia



oleh
Meganita Marthania
NIM 1503445

**PROGRAM STUDI KIMIA
DEPARTEMEN PENDIDIKAN KIMIA
FAKULTAS PENDIDIKAN MATEMATIKA DAN ILMU PENGETAHUAN ALAM
UNIVERSITAS PENDIDIKAN INDONESIA
BANDUNG
2019**

**STABILITAS PIGMEN FIKOSIANIN DARI *Spirulina platensis*
TERMODIFIKASI FORMALDEHIDA SEBAGAI KANDIDAT
SENSITIZER ALAMI**

oleh
Meganita Marthania

Sebuah skripsi yang diajukan untuk memenuhi sebagian syarat memperoleh gelar Sarjana Sains pada Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam

© Meganita Marthania 2019
Universitas Pendidikan Indonesia
Agustus 2019

Hak Cipta dilindungi undang-undang.
Skripsi ini tidak boleh diperbanyak seluruh atau sebagian, dengan dicetak ulang,
difotokopi, atau cara lainnya tanpa ijin dari penulis.

HALAMAN PENGESAHAN

MEGANITA MARTHANIA

STABILITAS PIGMEN FIKOSIANIN DARI *Spirulina platensis*
TERMODIFIKASI FORMALDEHIDA SEBAGAI KANDIDAT SENSITIZER
ALAMI

disetujui dan disahkan oleh pembimbing:

Pembimbing I



Dr. Heli Siti Halimatul Munawaroh, M.Si.
NIP. 197907302001122002

Pembimbing II



Gun Gun Gumilar, M.Si.
NIP. 197906262001121001

Mengetahui,

Ketua Departemen Pendidikan Kimia



Dr. Hendrawan, M.Si.
NIP.196309111989011001

ABSTRAK

Penggunaan pigmen alami sebagai penangkap cahaya (*sensitizer*) dalam teknologi *photovoltaic* tengah berkembang. Salah satu pigmen alami yang berpotensi sebagai *sensitizer* adalah fikosianin dari mikroalga *Spirulina platensis*. Fikosianin memiliki sifat yang kurang stabil terhadap lingkungan, sehingga perlu dilakukan modifikasi untuk meningkatkan kestabilannya. Pada penelitian ini dilakukan upaya modifikasi untuk menstabilkan fikosianin terhadap cahaya dan termal menggunakan teknik *crosslink*. Perubahan sifat yang dianalisis meliputi karakteristik, stabilitas cahaya dan stabilitas termal. Adapun tahap penelitian meliputi modifikasi, karakterisasi, dan pengujian stabilitas cahaya dan termal. Fikosianin hasil pemurnian (PC) dimodifikasi dengan cara *crosslinking* menggunakan formaldehida, menghasilkan fikosianin-formaldehida (PC-F). Karakterisasi PC-F dilakukan menggunakan spektrofotometri UV-Vis, FTIR dan SDS-PAGE. Stabilitas terhadap cahaya putih menggunakan lampu putih 18 W, lampu kuning 14 W, lampu UV A 8 W, lampu UV B dan dilakukan pada waktu penyinaran yang berbeda. Stabilitas termal dilakukan pada suhu 25 °C, 40 °C, 50 °C, 60 °C dengan waktu inkubasi selama 30 menit. Spektra UV-Vis PC-F memiliki tiga puncak pada daerah 611 nm, 360 nm dan 273 nm yang mengalami pergeseran panjang gelombang dari spektra UV-Vis PC. Perbedaan lain antara PC dan PC-F terdapat pada spektrum FTIR yaitu hanya muncul satu puncak pada daerah 1658.78 cm⁻¹ untuk gugus amida I. SDS PAGE PC-F menunjukkan satu pita yang menandakan trimer ($\alpha\beta$)₃ fikosianin dengan berat molekul 30,56 kDa. PC dengan modifikasi formaldehida (PC-F) menunjukkan penurunan absorbansi yang lebih besar dibandingkan PC pada penyinaran cahaya putih, UV A dan UV B masing – masing sebesar 6,28%, 16,12% dan 61,90%, namun penurunan absorbansi PC-F pada cahaya kuning lebih kecil dibandingkan PC yaitu sebesar 3,95%. PC-F meningkatkan kestabilan termal, namun belum menunjukkan peningkatan terhadap kestabilan cahaya putih, UV A dan UV B.

Kata Kunci: Fikosianin, Formaldehida, *Spirulina platensis*, Stabilitas Cahaya, Stabilitas Termal.

ABSTRACT

Natural pigments as sensitizers in photovoltaic technology is developing. One of the natural pigments that has the potential as a sensitizer is phycocyanin from *Spirulina platensis* microalgae. However, phycocyanin has properties that are less stable to the environment, so it needs to be modified to improve its stability. In this study an attempt was made to modify to change the nature of phycocyanin to light and thermal stability using the crosslink technique. Changes in the analyzed properties include characteristics, light stability and thermal stability. The research phase includes modification, characterization, and testing of light and thermal stability. Purification results of phycocyanin (PC) were modified by crosslinking using formaldehyde, resulting in phycocyanin-formaldehyde (PC-F). PC-F characterization was performed using UV-Vis, FTIR and SDS-PAGE spectrophotometry. Stability to white light using 18 W white lights, 14 W yellow lights, UV A 8 W lamps, UV B lamps and performed at different irradiation times. Thermal stability is carried out at 25 °C, 40 °C, 50 °C, 60 °C with an incubation time of 30 minutes. UV-Vis PC-F spectra have three peaks in the 611 nm, 343 nm and 271 nm regions which experience wavelength shifts from PC UV-Vis spectra. Another difference between PC and PC-F is found in the FTIR spectra, namely that only one peak appears in the region of 1658.78 cm⁻¹ for the amide group I. SDS PAGE PC-F shows a band indicating the trimer ($\alpha\beta$)₃ of phycocyanin with molecular weight is 30,56 kDa. PC with formaldehyde (PC-F) modification showed a greater decrease in absorbance compared to PC in irradiation of white light, UV A and UV B respectively by 6.28%, 16.12% and 61.90%, but decreased absorbance of PC -F in yellow light is smaller than a PC which is 3.95%. PC-F increases thermal stability, but has not shown an increase in white light stability, UV A and UV B.

Keyword: *Spirulina platensis*, phycocyanin, formaldehyde, photostability, thermal stability.

DAFTAR ISI

KATA PENGANTAR	i
UCAPAN TERIMA KASIH.....	ii
ABSTRAK	iv
ABSTRACT.....	v
DAFTAR ISI.....	vi
DAFTAR TABEL.....	viii
DAFTAR GAMBAR	ix
DAFTAR LAMPIRAN.....	xi
BAB I PENDAHULUAN	1
1.1. Latar Belakang	1
1.2. Rumusan Masalah	3
1.3. Tujuan.....	3
1.4. Manfaat.....	4
1.5. Struktur Organisasi Skripsi	4
BAB II TINJAUAN PUSTAKA.....	5
2.1 Mikroalga <i>Spirulina platensis</i>	5
2.2 Fikosianin sebagai Kandidat <i>Sensitizer</i>	6
2.3 Formaldehid sebagai agen <i>Crosslink</i>	8
2.3.1 Tahapan Modifikasi Formaldehid.....	9
2.3.2 Faktor – faktor yang Mempengaruhi <i>Crosslink</i>	10
2.4 Pengujian Stabilitas pada Pigmen Alami.....	11
BAB III METODE PENELITIAN.....	12
3.1 Waktu dan Tempat.....	12
3.2 Alat dan Bahan	12
3.2.1 Alat.....	12
3.2.2 Bahan	12
3.3 Prosedur Penelitian	13
3.3.1 Ekstraksi dan Pemurnian.....	14
3.3.2 Modifikasi Fikosianin dengan Formaldehid	16
3.3.3 Karakterisasi Fikosianin dan Fikosianin-Formaldehid	17
3.3.4 Pengamatan Stabilitas Cahaya Fikosianin dan Fikosianin-Formaldehid.....	17

3.3.5 Pengamatan Stabilitas Termal Fikosianin dan Fikosianin-Formaldehid	18
BAB IV TEMUAN DAN PEMBAHASAN	20
4.1 Karakteristik Fikosianin (PC) dan Fikosianin-Formaldehid (PC-F)	20
4.2 Sabilitas Fikosianin (PC) dan Fikosianin-Formaldehid (PC-F) terhadap Cahaya	29
4.3 Stabilitas Fikosianin (PC) dan Fikosianin-Formaldehid (PC-F) terhadap Berbagai Suhu.....	36
BAB V SIMPULAN DAN REKOMENDASI	38
5.1 Simpulan	38
5.2 Rekomendasi.....	38
DAFTAR PUSTAKA	39
LAMPIRAN-LAMPIRAN.....	44

DAFTAR TABEL

Tabel 2.1. Spektrum sinar tampak (Worsfold & Zagatto, 2017).....	11
Tabel 4.1. Puncak – puncak absorbansi hasil analisis spektrofotometri UV-Vis PC dan PC-F	22

DAFTAR GAMBAR

Gambar 2.1. Spirulina platensis (Small, 2011).....	6
Gambar 2.2. Skema Struktur Fikobilisom (Fernández-Rojas, Hernández-Juárez, & Pedraza-Chaverri, 2014).	6
Gambar 2.3. Struktur Fikosianobilin (Hsieh-Lo et al., 2019).....	7
Gambar 2.4. Stabilisasi dengan cara crosslink intramolekul dan intermolekul (Wong & Wong, 1992).	8
Gambar 2.5. Tahapan Modifikasi Protein menggunakan Formaldehid (Srinivasa, Ding, & Kast, 2015).....	9
Gambar 3.1. Skema Penelitian.	13
Gambar 3.2. Tahapan Ekstraksi Fikosianin dengan Metode Maserasi.....	14
Gambar 3.3. Tahap Pemurnian Fikosianin.	15
Gambar 3.4. Tahapan Modifikasi Fikosianin dengan Formaldehid.	16
Gambar 3.5. Karakterisasi Fikosianin (PC) dan Fikosianin-Formaldehid (PC-F).	17
Gambar 3.6. Pengamatan Stabilitas Cahaya Fikosianin (PC) dan Fikosianin- Formaldehid (PC-F).	18
Gambar 3.7. Tahap Pengamatan Stabilitas Termal Fikosianin (PC) dan Fikosianin-Formaldehid (PC-F) pada berbagai suhu selama 30 menit.....	18
Gambar 4.1. Warna larutan a) larutan fikosianin (PC), b) larutan fikosianin- formaldehid (PC-F)	20
Gambar 4.2. Spektra absorbansi UV-Vis PC dan PC-F yang diukur pada daerah 240 nm – 800 nm.	21
Gambar 4.3. Spektra UV-Vis fikosianin dan fikosianin termodifikasi (Sun et al., 2006). A) spektra UV-Vis fikosianin, B) spektra UV-Vis fikosianin termodifikasi.	23
Gambar 4.4. Spektrum FTIR dari PC dan PC-F dengan perubahan hilangnya puncak.	24

Gambar 4.5. Spektrum FTIR dari PC dan PC-F dengan perubahan intensitas % transmitan.....	25
Gambar 4.6. Spektrum FTIR Formaldehid (Mirghani, 2018).....	26
Gambar 4.7. Analisis SDS-PAGE. (a) marker, (b) PC-F.	27
Gambar 4.8. Kurva regresi Log berat molekul (Log BM) dengan migrasi relatif (Rf) dari protein marker.	28
Gambar 4.9. SDS-PAGE Fikosianin termodifikasi formaldehid (Sun et al., 2006).	29
Gambar 4.10. Grafik Pengaruh Penyinaran Cahaya Kuning Warm White pada Fikosianin (PC) dan Fikosianin-Formaldehid (PC-F).....	30
Gambar 4.11. Grafik Pengaruh Penyinaran Cahaya Putih Cool Daylight pada Fikosianin (PC) dan Fikosianin-Formaldehid (PC-F).....	31
Gambar 4.12. Grafik Pengaruh Penyinaran Sinar UV A pada Fikosianin (PC) dan Fikosianin-Formaldehid (PC-F).	33
Gambar 4.13. Grafik Pengaruh Penyinaran Sinar UV B pada Fikosianin (PC) dan Fikosianin-Formaldehid (PC-F).....	34
Gambar 4.14. Grafik Pengaruh Suhu pada Fikosianin (PC) dan Fikosianin-Formaldehid (PC-F).	36

DAFTAR LAMPIRAN

Lampiran 1. Perhitungan dalam Penelitian	44
Lampiran 2. Data Karakterisasi.....	46
Lampiran 3. Pengamatan Stabilitas Cahaya.....	52
Lampiran 4. Pengamatan Stabilitas Termal	56
Lampiran 5. Dokumentasi.....	57

DAFTAR PUSTAKA

- Abd El-Baky, H. H., & El-Baroty, G. S. (2012). Characterization and bioactivity of phycocyanin isolated from *Spirulina maxima* grown under salt stress. *Food and Function*, 3(4), 381–388. <https://doi.org/10.1039/c2fo10194g>
- Bryant, D. A., Guglielmi, G., de Marsac, N. T., Castets, A. M., & Cohen-Bazire, G. (1979). The structure of cyanobacterial phycobilisomes: a model. *Archives of Microbiology*, 123(2), 113–127. <https://doi.org/10.1007/BF00446810>
- Calogero, G., Citro, I., Di Marco, G., Armeli Minicante, S., Morabito, M., & Genovese, G. (2014). Brown seaweed pigment as a dye source for photoelectrochemical solar cells. *Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy*, 117(January), 702–706. <https://doi.org/10.1016/j.saa.2013.09.019>
- Calogero, G., Yum, J. H., Sinopoli, A., Di Marco, G., Grätzel, M., & Nazeeruddin, M. K. (2012). Anthocyanins and betalains as light-harvesting pigments for dye-sensitized solar cells. *Solar Energy*, 86(5), 1563–1575. <https://doi.org/10.1016/j.solener.2012.02.018>
- Cifferi Orio, T. O. (1985). *of Spirulina*. (111).
- Edwards, M. R., Hauer, C., Stack, R. F., Eisele, L. E., & MacColl, R. (1997). Thermophilic C-phycocyanin: Effect of temperature, monomer stability, and structure. *Biochimica et Biophysica Acta - Bioenergetics*, 1321(2), 157–164. [https://doi.org/10.1016/S0005-2728\(97\)00056-X](https://doi.org/10.1016/S0005-2728(97)00056-X)
- Enciso, P., Woerner, M., & Cerdá, M. F. (2018). Photovoltaic cells based on the use of natural pigments: Phycoerythrin from red-antarctic algae as sensitizers for DSSC. *MRS Advances*, 3(61), 3557–3562. <https://doi.org/10.1557/adv.2018.533>
- Fernández-Rojas, B., Hernández-Juárez, J., & Pedraza-Chaverri, J. (2014). Nutraceutical properties of phycocyanin. *Journal of Functional Foods*, 11(C), 375–392. <https://doi.org/10.1016/j.jff.2014.10.011>

- Fox, C., Johnson, F., Whiting, J., & Roller, P. (1985). Formaldehyde Fixation. *The Journal of Histochemistry and Cytochemistry*, 33(8), 845–853.
<https://doi.org/10.1152/ajpgi.00048.2011>
- Fukui, K., Saito, T., Noguchi, Y., Kodera, Y., Matsushima, A., Nishimura, H., & Inada, Y. (2004). Relationship between color development and protein conformation in the phycocyanin molecule. *Dyes and Pigments*, 63(1), 89–94. <https://doi.org/10.1016/j.dyepig.2003.12.016>
- Glazer, Alexander N. By, L. H. (1985). Light Harvesting by Phycobilisomes. *Annual Review of Biophysics and Biophysical Chemistry*, 14(1), 47–77.
- Glazer, A. N. (1976). *Phycocyanins : Structure and Function*.
- Glazer, A. N. (1994). Phycobiliproteins - a family of valuable, widely used fluorophores. *Journal of Applied Phycology*, 6(2), 105–112.
<https://doi.org/10.1007/BF02186064>
- Gong, J., Sumathy, K., Qiao, Q., & Zhou, Z. (2017). Review on dye-sensitized solar cells (DSSCs): Advanced techniques and research trends. *Renewable and Sustainable Energy Reviews*, 68(December 2015), 234–246.
<https://doi.org/10.1016/j.rser.2016.09.097>
- Haque, F. Z., & Pandey, P. (2014). Light Harvesting in Dye-Sensitized Solar Cells with Advanced Dye Designs. *Reviews in Advanced Sciences and Engineering*, 3(4), 320–330. <https://doi.org/10.1166/rase.2014.1078>
- Hoffman, E. A., Frey, B. L., Smith, L. M., & Auble, D. T. (2015). Formaldehyde crosslinking: A tool for the study of chromatin complexes. *Journal of Biological Chemistry*, 290(44), 26404–26411.
<https://doi.org/10.1074/jbc.R115.651679>
- Hoseini, S. M., Khosravi-Darani, K., & Mozafari, M. R. (2013). Nutritional and Medical Applications of Spirulina Microalgae. *Mini-Reviews in Medicinal Chemistry*, 13(8), 1231–1237.
<https://doi.org/10.2174/1389557511313080009>
- Hsieh-Lo, M., Castillo, G., Ochoa-Becerra, M. A., & Mojica, L. (2019).

Phycocyanin and phycoerythrin: Strategies to improve production yield and chemical stability. *Algal Research*, 42(March), 101600.

<https://doi.org/10.1016/j.algal.2019.101600>

Kamble, S. P., Gaikar, R. B., Padalia, R. B., & Shinde, K. D. (2013). Extraction and purification of C-phycoerythrin from dry *Spirulina* powder and evaluating its antioxidant, anticoagulation and prevention of DNA damage activity.

Journal of Applied Pharmaceutical Science, 3(8), 149–153.

<https://doi.org/10.7324/JAPS.2013.3826>

Kathiravan, A., & Renganathan, R. (2009). Photosensitization of colloidal TiO₂ nanoparticles with phycocyanin pigment. *Journal of Colloid and Interface Science*, 335(2), 196–202.

<https://doi.org/10.1016/j.jcis.2009.03.076>

Lantz, L. M. (2001). *Protein Labeling with Fluorescent Probes*.

Lauceri, R., Chini Zittelli, G., Maserti, B., & Torzillo, G. (2018). Purification of phycocyanin from *Arthrospira platensis* by hydrophobic interaction membrane chromatography.

Algal Research, 35(August), 333–340.

<https://doi.org/10.1016/j.algal.2018.09.003>

MacColl, R. (1998). Cyanobacterial phycobilisomes. *Journal of Structural Biology*, 124(2–3), 311–334.

<https://doi.org/10.1006/jsbi.1998.4062>

Manirafasha, E., Ndikubwimana, T., Zeng, X., Lu, Y., & Jing, K. (2016).

Phycobiliprotein: Potential microalgae derived pharmaceutical and biological reagent. *Biochemical Engineering Journal*, 109, 282–296.

<https://doi.org/10.1016/j.bej.2016.01.025>

Martelli, G., Folli, C., Visai, L., Daglia, M., & Ferrari, D. (2014). Thermal stability improvement of blue colorant C-Phycocyanin from *Spirulina platensis* for food industry applications.

Process Biochemistry, 49(1), 154–159.

<https://doi.org/10.1016/j.procbio.2013.10.008>

Mirghani, M. E. S. (2018). *Detection of formaldehyde in cheese using FTIR*

spectroscopy Detection of formaldehyde in cheese using FTIR spectroscopy.

(December 2017).

- Munawaroh, H. S. H., Darojatun, K., Gumilar, G. G., Aisyah, S., & Wulandari, A. P. (2018). Characterization of phycocyanin from *Spirulina fusiformis* and its thermal stability. *Journal of Physics: Conference Series*, *1013*(1).
<https://doi.org/10.1088/1742-6596/1013/1/012205>
- Narayan, M. R. (2012). Review : Dye sensitized solar cells based on natural photosensitizers. *Renewable and Sustainable Energy Reviews*, *16*(1), 208–215. <https://doi.org/10.1016/j.rser.2011.07.148>
- Of, S., & Problem, T. H. E. (1993). * (1.1). *3*(3), 241–276.
- Puchtler, H., & Meloan, S. N. (1985). On the chemistry of formaldehyde fixation and its effects on immunohistochemical reactions. *Histochemistry*, *82*(3), 201–204. <https://doi.org/10.1007/BF00501395>
- Shalini, S., Balasundara Prabhu, R., Prasanna, S., Mallick, T. K., & Senthilarasu, S. (2015). Review on natural dye sensitized solar cells: Operation, materials and methods. *Renewable and Sustainable Energy Reviews*, *51*, 1306–1325. <https://doi.org/10.1016/j.rser.2015.07.052>
- Small, E. (2011). 37. *Spirulina* - food for the universe. *Biodiversity*, *12*(4), 255–265. <https://doi.org/10.1080/14888386.2011.642735>
- Srinivasa, S., Ding, X., & Kast, J. (2015). Formaldehyde cross-linking and structural proteomics: Bridging the gap. *Methods*, *89*, 91–98. <https://doi.org/10.1016/j.ymeth.2015.05.006>
- Sun, L., Wang, S., Chen, L., & Gong, X. (2003). Promising fluorescent probes from phycobiliproteins. *IEEE Journal on Selected Topics in Quantum Electronics*, *9*(2), 177–188. <https://doi.org/10.1109/JSTQE.2003.812499>
- Sun, L., Wang, S., & Qiao, Z. (2006). Chemical stabilization of the phycocyanin from cyanobacterium *Spirulina platensis*. *Journal of Biotechnology*, *121*(4), 563–569. <https://doi.org/10.1016/j.jbiotec.2005.08.017>
- Thavarajah, R., Mudimbaimannar, V. K., Elizabeth, J., Rao, U. K., & Ranganathan, K. (2012). Chemical and physical basics of routine formaldehyde fixation. *Journal of Oral and Maxillofacial Pathology*, *16*(3),

400–405. <https://doi.org/10.4103/0973-029X.102496>

Wang, Z., & Zhang, X. (2017). Isolation and identification of anti-proliferative peptides from *Spirulina platensis* using three-step hydrolysis. *Journal of the Science of Food and Agriculture*, *97*(3), 918–922.

<https://doi.org/10.1002/jsfa.7815>

Wong, S. S., & Wong, L. J. C. (1992). Chemical crosslinking and the stabilization of proteins and enzymes. *Enzyme and Microbial Technology*, *14*(11), 866–874. [https://doi.org/10.1016/0141-0229\(92\)90049-T](https://doi.org/10.1016/0141-0229(92)90049-T)

Worsfold, P. J., & Zagatto, E. A. G. (2017). Spectrophotometry: Overview ☆. In *Reference Module in Chemistry, Molecular Sciences and Chemical Engineering* (3rd ed.). <https://doi.org/10.1016/B978-0-12-409547-2.14265-9>