บรรณานุกรม

ยุวดี พีรพรพิศาล. 2549.   สาหร่ายวิทยา. ภาควิชาชีววิทยา คณะวิทยาศาสตร์ มหาวิทยาลัยเชียงใหม่ เชียงใหม่.

ยุวดี พีรพรพิศาล. 2546. สาหร่ายสไปรูลิน่า. สถาบันวิจัยและพัฒนาวิทยาศาสตร์และ เทคโนโลยี มหาวิทยาลัยเชียงใหม่ เชียงใหม่.

ยุวดี พีรพรพิศาล จีรพร เพกเกาะ ชยากร ภูมาศ กรองกาญจน์ จันต๊ะ และสุนิสา บุญมา. 2554.การศึกษาสายพันธุ์สาหร่ายขนาดเล็กและพัฒนาสภาวะที่ใช้เพาะเลี้ยงเพื่อหา ความเป็นไปได้ในการผลิตเป็นน้ำมันเชื้อเพลิง ภายใต้แผนงานวิจัยเรื่อง "การ พัฒนาการผลิตน้ำมันเชื้อเพลิงจากสาหร่ายขนาดเล็ก ระยะที่ 1".   สถาบันวิจัยและ พัฒนาวิทยาศาสตร์และเทคโนโลยี มหาวิทยาลัยเชียงใหม่ เชียงใหม่.

Amin, S. 2009. Review on biofuel oil and gas production process from microalgae. *Energy. Convers. Manage.*, 50: 1834–1840.

Bajpai, D. and Tyagi, V.K. 2006. Bio-oil: Source, production, composition, properties and its benefits. *Journal of Oleo Science*, 55(10): 487–502.

Banerjee, A., Sharma, R., Chisti, Y. and Banerjee, U. 2002. *Botryococcus braunii*: A renewable source of hydrocarbons and other chemicals. *Crit. Rev. Microbiol.*, 22:245–279.

Bligh, E.G. and Dyer, W.J. 1959. A rapid method of total lipid extraction and purification. *Can. J. Biochem. Physiol.*, 37:911–917.

Bollman, R.C. and Robinson, G.G.C., 1977. The kinetics of organic acid uptake by three Chlorophyta in axenic culture. *J. Phycol.*, 13: 1–5.

Borowitzka, M.A. 1999. Commercial production of microalgae: Ponds, tanks, tubes and fermentors. *J. Biotechnol.*, 70: 313–321.

BP. 2010. Statistical Review of World Energy June 2010. [online]. Available: www.bp.com/statisticalreview. [2011, Dec. 2].

Brennan, L. and Owende, P. 2010. Biofuels from microalgae – A review of technologies for production, processing, and extractions of biofuels and co-products. *Renew. Sustain. Energy Rev.*, 14: 557–577.

Cantrell, K. B, Ducey, T., Ro, K.S., and Hunt, P.G. 2008. Livestock waste-to-bioenergy generation opportunities. *Bioresource Technology*, 99: 7941-7953.

Chini Zittelli, G., Lavista, F., Bastianini, A., Rodolfi, L., Vincenzini, M. and Tredici, M.R. 1999. Production of eicosapentaenoic acid by *Nannochloropsis* sp. cultures in outdoor tubular photobioreactors. *Journal of Biotechnology*, 70: 299-312.

Chisti, Y. 2007. Bio-oil from microalgae. *Biotechnology Advances*, 25: 294-306.

Chiu, S.Y., Kao, C.Y., Chen, C.H., Kuan, T.C., Ong, S.C. and Lin, C.S., 2008. Reduction of CO_2 by a high-density culture of *Chlorella* sp. in a semicontinuous photobioreactor. *Bioresource Technology*, 99: 3389-3396.

Chun, Y.C, Kuei, L.Y., Aisyah, R., Duu, J.L. and Jo, S.C. 2011. Cultivation, photobioreactor design and harvesting of microalgae for biodiesel production: A critical review. *Bioresources Technology*, 102: 71 – 81.

Combres, C., Laliberte´, G., Sevrin Reyssac, J. and de la Nou¨ e, J., 1994. Effect of acetate on growth and ammonium uptake in the microalga *Scenedesmus obliquus. Physiol. Plantarum*, 91: 729 – 734.

Cook, J.R., 1968. The cultivation and growth of Euglena. In: Buetow, D.E. (Ed.), *The Biology of Euglena, vol. 1*. Academic Press, New York, USA, pp. 243-314.

de-Bashan, L.E. and Bashan, Y., 2010. Immobilized microalgae for removing pollutants: review of practical aspects. *Bioresources Technology*, 101: 1611-1627.

González-Fernández, C., Molinuevo-Salces, B. and García-González, M.C. 2010. Open and enclosed photobioreactors comparison in terms of organic matter utilization, biomass chemical profile and photosynthetic efficiency. *Ecological Engineering*, 36: 1497 – 1501.

Gouveia, L. and Oliveira, A.C. 2009. Microalgae as a raw material for biofuels production. *J. Ind. Microbiol. Biotechnol.*, 36: 269-274.

Gouveia, L., Marques, A.E., da Silva, T.L. and Reis, A., 2009. *Neochloris oleabundans* UTEX #1185: a suitable renewable lipid source for biofuel production. *J. Ind. Microbiol. Biotechnol.*, 36: 821-826.

Grima, E.M., Belarbi, E.H., Fernandez, F.G.A., Medina, A.R., Chisti, Y., 2003. Recovery of microalgal biomass and metabolites: process options and economics. *Biotechnol. Adv.*, 20: 491–515.

Guschina, I.A. and Harwood, J.L. 2006. Lipids and lipid metabolism in eukaryotic algae. *Progress in Lipid Research*, 45:160–186.

Heredia–Arroyo, T., Wei, W., Ruan, R. and Hu, B. 2011. Mixotrophic cultivation of *Chlorella vulgaris* and its potential application for the oil accumulation from non–sugar materials. *Biomass and Bioenergy*, 35: 2245–2253.

Huang, G.H., Chen, F., Wei, D., Zhang, X.W. and Chen, G., 2010. Biodiesel production by microalgal biotechnology. *Appl. Energ.*, 87: 38–46.

Illman, A.M., Scragg, A.H. and Shales, S.W., 2000. Increase in Chlorella strains calorific values when grown in low nitrogen medium. *Enzyme Microb. Technol.*, 27: 631–635.

Krienitza, L. and Wirth, M. 2006. The high content of polyunsaturated fatty acids in *Nannochloropsis limnetica* (Eustigmatophyceae) and its implication for food web interactions, freshwater aquaculture and biotechnology. *Limnologica*, 36: 204–210.

Kunjapur, A.M. and Eldridge, R. B. 2010. Photobioreactor design for commercial biofuel production from microalgae. *Ind. Eng. Chem. Res.*, 49: 3516 – 3526.

Lee, K. and Lee, C.G. 2001. Effect of light/dark cycles on wastewater treatments by microalgae. *Biotechnol. Bioprocess Eng.*, 6: 194–199.

Liang, Y.N., Sarkany, N. and Cui, Y., 2009. Biomass and lipid productivities of *Chlorella vulgaris* under autotrophic, heterotrophic and mixotrophic growth conditions. *Biotechnol. Lett.*, 31, 1043–1049.

Liu, Z., Wang, G. and Zhou, B. 2008. Effect of iron on growth and lipid accumulation in *Chlorella vulgaris*. *Bioresource Technology*, 99: 4717–4722.

Mata, T.M., Martins, A.A. and Caetano, N.S. 2010. Microalgae for biodiesel production and other applications: a review. *Renew. Sust. Energ. Rev.* 14: 217–232.

Matsunaga, T., Matsumoto, M. Maeda, Y., Sugiyama, H., Sato, R. and Tanaka, T. 2009. Characterization of marine microalga, *Scenedesmus* sp. strain JPCC GA0024 toward biofuel production. *Biotechnology Letters*, 31: 1367 – 1372.

Metzger, P. and Largeau, C. 2005. *Botryococcus braunii*: a rich source for hydrocarbons and related ether lipids. *Applied Microbiology and Biotechnology*, 66: 486–496.

Miao, X. and Wu, Q. 2004. High yield bio-oil production from fast pyrolysis by metabolic controlling of *Chlorella protothecoides*. *Journal of Biotechnology*, 110: 85–93.

Perez-Garcia, O., de-Bashan, L. E., Hernandez, J.P., Bashan, Y. 2010. Efficiency of growth and nutrient uptake from wastewater by heterotrophic, autotrophic, and mixotrophic cultivation of *Chlorella vulgaris* immobilized with *Azospirillum brasilense*. *J. Phycol.*, 46: 800–812.

Posten, C. 2009. Design principles of photo-bioreactors for cultivation of microalgae. *Eng. Life Sci.*, 9(3): 165 – 177.s

Rao, A. R., Dayananda, C., Sarada, R., Shamala, T. R. and Ravishankar, G.A. 2007. Effect of salinity on growth of green alga *Botryococcus braunii* and its constituents. *Bioresource Technology*, 98: 560–564.

Renaud, S.M., Parry, D.L. and Luong –Van, T. 1994. Microalgae for use in tropical aquaculture I: Gross chemical and fatty acid composition of twelve species of microalgae from the Northern Territory,Australia. *Journal of Applied Phycology*, 6: 337–345.

Richmond, A., 1986. Cell response to environmental factors. In: Richmond, A. (Ed.), *Handbook for Microalgal Mass Culture*. CRC Press, Boca Raton, FL., USA, pp. 69–99.

Rodolfi, W. L., Bassi, N., Padovani, G., Bonini, G., Zitelli, G.C., Biondi, N. and Tredici, M.R. 2007. Lipid production from microalgae: strain selection, induction of lipid sythesis and outdoor cultivation in pilot photobioreactors. In: *Proceedings of the 15th European conference and exhibition*, Berlin.

Saijo, Y., 1975. A method for determination of chlorophyll. *Japanese J. Limnol.*, 36: 103–109.

Sanchez Miron, A., A. Contreras Gomez, F. Garcia Camacho, E. Molina Grima, and Chisti, Y. 1999. Comparative Evaluation of Compact Photobioreactors for Large-Scale Monoculture of Microalgae, *J. Biotechnol.*, 70: 249–270.

Scarsella, M., Belotti, G., De Filippis, P. and Bravi, M. 2010. Study on the optimal growing conditions of *Chlorella vulgaris* in bubble column photobioreactors. Chemical engineering transactions, www.aidic.it/ibic2010/webpapers/ 58Scarsella.pdf

Schmidt, R.A., Wiebe, M.G. and Eriksen, N.T., 2005. Heterotrophic high cell–density fed-batch cultures of the phycocyanin producing red alga *Galdieria sulphuraria*. *Biotechnol. Bioeng.* 90: 77–84.

Shi, X.M., Chen, F., Yuan, J.P. and Chen, H. 1997. Heterotrophic production of lutein by selected *Chlorella* strains. *Journal of Applied Phycology*, 9(5): 445–450.

Shi, X.-M., Liu, H.-J., Zhang, X.-W. and Chen, F., 1999. Production of biomass and lutein by *Chlorella protothecoides* at various glucose concentrations in heterotrophic cultures. *Process Biochem.*, 34: 341–347.

Sierra, E., Acién, F.G., Fernández, J.M., García, J.L., González, C., Molina, E. 2008. Characterization of a flat plate photobioreactor for the production of microalgae. *Chem. Eng. J.*, 136–47.

Takagi, M., Karseno and Yoshida, T. 2006. Effect of salt concentration on intracellular accumulation of lipids and triacylglyceride in marine microalgae *Dunaliella* cells. Journal of Bioscience and Bioengineering, 101(3): 223–226.

Vazhappilly, R. and Chen, F., 1998. Eicosapentaenoic acid and docosahexaenoic acid production potential of microalgae and their heterotrophic growth. *J. Am. Oil Chem. Soc.*, 75: 393–397.

Wood, B.J.B., Grimson, P.H.K., German, J.B. and Turner, M., 1999. Photoheterotrophy in the production of phytoplankton organisms. *J. Biotechnol.*, 70: 175–183.

Xiong, W., Li, X.F., Xiang, J.Y. and Wu, Q.Y., 2008. High–density fermentation of microalga *Chlorella protothecoides* in bioreactor for microbio–diesel production. *Appl. Microbiol. Biotechnol.*, 78: 29–36.

Xu, H., Miao, X.L. and Wu, Q.Y., 2006. High quality biodiesel production from a microalga *Chlorella protothecoides* by heterotrophic growth in fermenter. *Biotechnology*, 126: 499–507.

ภาคผนวก

อาหารเลี้ยงเชื้อ (NIES, 2000 อ้างโดย ยุวดี และคณะ, 2544)

อาหารสูตรอย่างง่าย algal medium (AM) ในปริมาณ 1 L มีสูตรอาหาร ดังนี้

1. K_2HPO_4	0.25	g/L
2. $MgSO_4.7H_2O$	0.513	g/L
3. $NaNO_3$	1.0	g/L
4. $NHCl_4$	0.05	g/L
5. $CaCl_2$	0.058	g/L
6. $FeCl_3$	0.003	g/L

ผลการทดสอบทางสถิติ

1. **การเพาะเลี้ยง** *Scenedesmus* sp. AARL G022 แบบ mixotrophic โดย ใช้ glucose เป็นแหล่งคาร์บอน

   1.1 Dry weight (g.L^{-1})

ANOVA

Dry weight (g/L)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9.679	3	3.226	1270.621	.000
Within Groups	.018	7	.003		
Total	9.697	10			

Dry weight (g/L)

	glucose	N	Subset for alpha = .05				
		1	2	3	4	1	
Tukey HSD(a,b)	1.00	3	.1669				
	2.00	3		.3478			
	3.00	3			1.0723		
	4.00	2				2.7814	
	Sig.		1.000	1.000	1.000	1.000	
Duncan(a,b)	1.00	3	.1669				
	2.00	3		.3478			
	3.00	3			1.0723		
	4.00	2				2.7814	
	Sig.		1.000	1.000	1.000	1.000	

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.667.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

1.2 Total lipid (mg.L^{-1})

ANOVA

Total lipid (mg L^{-1})

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	26272.969	3	8757.656	2.670	.128
Within Groups	22958.706	7	3279.815		
Total	49231.675	10			

Total lipid (mg L^{-1})

		N	Subset for alpha = .05	
	totallipid	1	2	1
Tukey HSD(a,b)	1.00	3	22.5499	
	2.00	3	38.6049	
	3.00	3	74.0918	
	4.00	2	161.2938	
	Sig.		.098	
Duncan(a,b)	1.00	3	22.5499	
	2.00	3	38.6049	
	3.00	3	74.0918	74.0918
	4.00	2		161.2938
	Sig.		.350	.122

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.667.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

		N	Subset for alpha = .05	
	totallipid	1	2	1
Tukey HSD(a,b)	1.00	3	22.5499	
	2.00	3	38.6049	
	3.00	3	74.0918	
	4.00	2	161.2938	
	Sig.		.098	
Duncan(a,b)	1.00	3	22.5499	
	2.00	3	38.6049	
	3.00	3	74.0918	74.0918
	4.00	2		161.2938
	Sig.		.350	.122

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.667.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

1.3 Lipid (%)

ANOVA

Lipid (%)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	76.110	3	25.370	2.926	.109
Within Groups	60.699	7	8.671		
Total	136.809	10			

Lipid (%)

persen

		N	Subset for alpha = .05	
	lipid		1	2	1
	3.00	3	6.7737	
	4.00	2	8.4285	
Tukey HSD(a,b)	2.00	3	11.0701	
	1.00	3	13.4917	
	Sig.		.121	
	3.00	3	6.7737	
	4.00	2	8.4285	8.4285
Duncan(a,b)	2.00	3	11.0701	11.0701
	1.00	3		13.4917
	Sig.		.149	.098

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.667.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

1.4 จำนวนเซลล์ (colony.ml^{-1})

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	174165437779809.100	3	58055145926603.000	3.494	.070
Within Groups	132939986268717.400	8	16617498283589.680		
Total	307105424048526.600	11			

rate

	growth	N	Subset for alpha = .05		
		1	2	1	
Tukey HSD(a)	1.00	3	2546296.2967		
	2.00	3	4123456.7900		
	3.00	3	10413580.2467		
	4.00	3	11280864.1967		
	Sig.		.113		
Duncan(a)	1.00	3	2546296.2967		
	2.00	3	4123456.7900	4123456.7900	
	3.00	3	10413580.2467	10413580.2467	
	4.00	3		11280864.1967	
	Sig.		.053	.073	

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

1.5 ค่า OD $_{665}$

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.566	3	1.189	9.554	.005
Within Groups	.995	8	.124		
Total	4.561	11			

		N	Subset for alpha = .05		
	OD	1	2	3	1
Tukey HSD(a)	1.00	3	.2150		
	2.00	3	.4717		
	3.00	3	.9907	.9907	
	4.00	3		1.6400	
	Sig.		.103	.188	
Duncan(a)	1.00	3	.2150		
	2.00	3	.4717	.4717	
	3.00	3		.9907	.9907
	4.00	3			1.6400
	Sig.		.399	.109	.054

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

หมายเหตุ   หมายเลข 1.00 = control

                              2.00 = 0.01 M

                              3.00 = 0.02 M

                              4.00 = 0.05 M

2. การเพาะเลี้ยง *Scenedesmus* sp. AARL G022 แบบ mixotrophic โดย ใช้ glycerol เป็นแหล่งคาร์บอน

2.1 Dry weight (g.L^{-1})

ANOVA

weight

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.065	3	.022	2.359	.158
Within Groups	.065	7	.009		
Total	.130	10			

weight

	glycerol	N	Subset for alpha = .05
		1	1
Tukey HSD(a,b)	5.00	3	.1230
	6.00	3	.1947
	7.00	3	.2890
	8.00	2	.3230
	Sig.		.164
Duncan(a,b)	5.00	3	.1230
	6.00	3	.1947
	7.00	3	.2890
	8.00	2	.3230
	Sig.		.058

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.667.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

2.2 Total lipid (mg L^{-1})

ANOVA

mg

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1582.870	3	527.623	2.473	.146
Within Groups	1493.722	7	213.389		
Total	3076.592	10			

mg

		N	Subset for alpha = .05
	totallipid	1	1
Tukey HSD(a,b)	5.00	3	17.5810
	6.00	3	31.2363
	7.00	3	45.8603
	8.00	2	46.8545
	Sig.		.184
Duncan(a,b)	5.00	3	17.5810
	6.00	3	31.2363
	7.00	3	45.8603
	8.00	2	46.8545
	Sig.		.065

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.667.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

1.3 Lipid (%)

ANOVA

persen

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6.473	3	2.158	.680	.591
Within Groups	22.202	7	3.172		
Total	28.675	10			

persen

	lipid	N	Subset for alpha = .05
			1
		1	1
Tukey HSD(a,b)	5.00	3	14.4898
	8.00	2	14.5170
	7.00	3	15.9637
	6.00	3	16.1110
	Sig.		.727
Duncan(a,b)	5.00	3	14.4898
	8.00	2	14.5170
	7.00	3	15.9637
	6.00	3	16.1110
	Sig.		.352

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.667.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

2.4 จำนวนเซลล์ (colony.mL^{-1})

ANOVA

rate

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1262189811895.499	3	420729937298.500	1.124	.402
Within Groups	2620027422503.431	7	374289631786.204		
Total	3882217234398.929	10			

rate

		N	Subset for alpha = .05
	growth	1	1
Tukey HSD(a,b)	1.00	3	2663580.2467
	2.00	3	3012345.6800
	3.00	3	3012345.6800
	4.00	2	3685185.1900
	Sig.		.298
Duncan(a,b)	1.00	3	2663580.2467
	2.00	3	3012345.6800
	3.00	3	3012345.6800
	4.00	2	3685185.1900
	Sig.		.111

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.667.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

2.5

ANOVA

ssh

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.049	3	.016	2.196	.176
Within Groups	.052	7	.007		
Total	.101	10			

ssh

	OD	N	Subset for alpha = .05
		1	1
Tukey HSD(a,b)	1.00	3	.1477
	2.00	3	.2667
	4.00	2	.2755
	3.00	3	.3213
	Sig.		.180
Duncan(a,b)	1.00	3	.1477
	2.00	3	.2667
	4.00	2	.2755
	3.00	3	.3213
	Sig.		.064

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.667.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

2.5 ค่า OD $_{665}$

ssh

	OD	N	Subset for alpha = .05
		1	1
Tukey HSD(a,b)	1.00	3	.1477
	2.00	3	.2667
	4.00	2	.2755
	3.00	3	.3213
	Sig.		.180
Duncan(a,b)	1.00	3	.1477
	2.00	3	.2667
	4.00	2	.2755
	3.00	3	.3213
	Sig.		.064

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.667.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

หมายเหตุ   หมายเลข 1.00 = control

2.00 = 0.01 M

3.00 = 0.02 M

4.00 = 0.05 M

3. การเพาะเลี้ยง *Scenedesmus* sp. AARL G022 แบบ mixotrophic โดย ใช้ sodium acetate เป็นแหล่งคาร์บอน

3.1 Dry weight (g.L^{-1})

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.584	3	2.861	.941	.487
Within Groups	15.201	5	3.040		
Total	23.785	8			

weight

	sodium	N	Subset for alpha = .05
		1	1
Tukey HSD(a,b)	12.00	2	12.0785
	11.00	2	12.6765
	10.00	2	13.8925
	9.00	3	14.4897
	Sig.		.528
Duncan(a,b)	12.00	2	12.0785
	11.00	2	12.6765
	10.00	2	13.8925
	9.00	3	14.4897
	Sig.		.221

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.182.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

3.2 Total lipid (mg L^{-1})

mg

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	529.741	3	176.580	5.457	.049
Within Groups	161.787	5	32.357		
Total	691.527	8			

mg

	totallipid	N	Subset for alpha = .05		
			1	2	1
Tukey HSD(a,b)	9.00	3	17.5810		
	11.00	2	31.6935		
	10.00	2	33.3870		
	12.00	2	35.7255		
	Sig.		.072		
Duncan(a,b)	9.00	3	17.5810		
	11.00	2			31.6935
	10.00	2			33.3870
	12.00	2			35.7255
	Sig.		1.000		.502

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.182.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

3.3 Lipid (%)

ANOVA

persen

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.584	3	2.861	.941	.487
Within Groups	15.201	5	3.040		
Total	23.785	8			

persen

	lipid	N	Subset for alpha = .05
		1	1
Tukey HSD(a,b)	12.00	2	12.0785
	11.00	2	12.6765
	10.00	2	13.8925
	9.00	3	14.4897
	Sig.		.528
Duncan(a,b)	12.00	2	12.0785
	11.00	2	12.6765
	10.00	2	13.8925
	9.00	3	14.4897
	Sig.		.221

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.182.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

3.4 จำนวนเซลล์ (colony/ml)

ANOVA

rate

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	689005099 071.026	3	22966836635 7.009	.700	.591
Within Groups	163971765 4263.832	5	32794353085 2.766		
Total	232872275 3334.858	8			

rate

		N	Subset for alpha = .05
	growth	1	1
Tukey HSD(a,b)	2.00	2	1972222.2 250
	4.00	2	2467592.5 950
	1.00	3	2663580.2 467
	3.00	2	2671296.2 950
	Sig.		.613
Duncan(a,b)	2.00	2	1972222.2 250
	4.00	2	2467592.5 950
	1.00	3	2663580.2 467
	3.00	2	2671296.2 950
	Sig.		.271

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.182.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

ANOVA

ssh

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.041	3	.014	5.222	.053
Within Groups	.013	5	.003		
Total	.054	8			

ssh

	OD	N	Subset for alpha = .05	
		1	2	1
Tukey HSD(a,b)	1.00	3	.0347	
	2.00	2	.1325	
	4.00	2	.1805	
	3.00	2	.1955	
	Sig.		.074	
Duncan(a,b)	1.00	3	.0347	
	2.00	2	.1325	.1325
	4.00	2		.1805
	3.00	2		.1955
	Sig.		.101	.264

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.182.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

หมายเหตุ   หมายเลข 1.00 = control

2.00 = 0.01 M

3.00 = 0.02 M

4.00 = 0.05 M

4. การเพาะลี้ยง *Scenedesmus* sp. AARL G022 แบบ mixotrophic โดย ใช้ sodium acetate เป็นแหล่งคาร์บอน

4.1 Dry weight (g.L^{-1})

ANOVA

biomass

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	29.692	5	5.938	29.938	.000
Within Groups	1.984	10	.198		
Total	31.676	15			

biomass

		N	Subset for alpha = .05		
	darklight	1	2	3	1
Tukey HSD(a,b)	1.00	3	.1426		
	5.00	3		1.5620	
	6.00	2		1.9389	
	3.00	2		2.1198	
	4.00	3			3.5589
	2.00	3			4.0372
	Sig.		1.000	.716	.819
Duncan(a,b)	1.00	3	.1426		
	5.00	3		1.5620	
	6.00	2		1.9389	
	3.00	2		2.1198	
	4.00	3			3.5589
	2.00	3			4.0372
	Sig.		1.000	.205	.251

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.571.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

4.2 Total lipid (mg.L^{-1})

ANOVA

mg

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	257494.153	5	51498.831	24.629	.000
Within Groups	20909.947	10	2090.995		
Total	278404.099	15			

mg

	totallipid	N	Subset for alpha = .05			
		1	2	3	4	1
Tukey HSD(a,b)	1.00	3	22.5713			
	5.00	3	129.1563	129.1563		
	6.00	2	158.0412	158.0412	158.0412	
	3.00	2		185.0000	185.0000	
	2.00	3			297.2924	297.2924
	4.00	3				396.3475
	Sig.		.059	.735	.052	.224
Duncan(a,b)	1.00	3	22.5713			
	5.00	3		129.1563		
	6.00	2		158.0412		
	3.00	2		185.0000		
	2.00	3			297.2924	
	4.00	3				396.3475
	Sig.		1.000	.216	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.571.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

4.3 Lipid (%)

ANOVA

persen

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	142.694	5	28.539	5.160	.013
Within Groups	55.305	10	5.530		
Total	197.999	15			

persen

	lipid	N	Subset for alpha = .05	
		1	2	1
Tukey HSD(a,b)	2.00	3	7.4706	
	5.00	3	8.4259	
	3.00	2	8.4495	
	6.00	2	9.2168	9.2168
	4.00	3	11.1377	11.1377
	1.00	3		15.9819
	Sig.		.523	.069
Duncan(a,b)	2.00	3	7.4706	
	5.00	3	8.4259	
	3.00	2	8.4495	
	6.00	2	9.2168	
	4.00	3	11.1377	
	1.00	3		15.9819
	Sig.		.135	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.571.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are
not guaranteed.

4.4 จำนวนเซลล์ (colony/ml)

ANOVA

cell

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3547442466786296.000	5	709488493357259.000	6.941	.005
Within Groups	1022232167393820.000	10	102223216739382.000		
Total	4569674634180110.000	15			

cell

		N	Subset for alpha = .05			
	growth	1	1	2	3	1
Tukey HSD(a,b)	1.00	3	3212962.9633			
	6.00	2	15083333.3300			
	5.00	3	18271604.9400			
	4.00	3	25024691.3567	25024691.3567		
	3.00	2	27148148.1450	27148148.1450		
	2.00	3		49679012.3433		
	Sig.		.163	.145		
Duncan(a,b)	1.00	3	3212962.9633			
	6.00	2	15083333.3300	15083333.3300		
	5.00	3	18271604.9400	18271604.9400		
	4.00	3		25024691.3567		
	3.00	2		27148148.1450		
	2.00	3			49679012.3433	
	Sig.		.138	.235	1.000	

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.571.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are
not guaranteed.

หมายเหตุ   1.00 = phototrophic

2.00 = light all time

3.00 = L8:16D

4.00 = L16:8D

5.00 =L12:12D

6.00 = heterotrophic