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APPENDIX

APPENDIX A

LIST OF PUBLICATION

International conference

1. Oi-jai Limpanyalert, Sorawit Powtongsook, and Prasert Pavasant “ENHANCING SCHEME FOR INDUCTION AND ACCUMULATION OF ASTAXANTHIN FROM HAEMATOCOCCUS PLUVIALIS NIES144” , Extended Abstract for 15th Regional Symposium on Chemical Engineering In Conjunction With 22nd Symposium of Malaysian Chemical Engineering, Malaysia, 2 - 3 December 2008, Paper ID BIO021-O.

APPENDIX B

CALCULATIONS

1. Calculation of astaxanthin mass

$$\text{mg astaxanthin} = \frac{AV}{E_{1cm}^{1\%} \times 100} \times 1000 \quad (\text{A.1})$$

where A = light absorbance at wavelength of maximum absorption

$$\begin{aligned} E_{1cm}^{1\%} &= \text{mass extinction coefficient at wavelength of maximum absorption} \\ &= 2306.6 \text{ (100ml/g cm)} \end{aligned}$$

2. Calculation of astaxanthin concentration (mg/l)

$$\text{astaxanthin concentration (mg/l)} = \frac{\text{mg astaxanthin}}{V} \quad (\text{A.2})$$

where V = volume of sample for extraction
= 0.006 L

3. Calculation of astaxanthin productivity (mg/day.l)

$$\text{astaxanthin productivity} = \frac{\text{astaxanthin concentration}}{\text{time}} \quad (\text{A.3})$$

4. Calculation of astaxanthin content (mg/10⁶ cells)

$$\text{astaxanthin content} = \frac{\text{astaxanthin concentration}}{\text{average cell concentration}} \quad (\text{A.4})$$

5. Calculation of %astaxanthin (%g astaxanthin/g cell)

$$\% \text{astaxanthin} = \text{astaxanthin content} \times \text{dry weight} \quad (\text{A.5})$$

where dry weight = 0.0164 g/10⁶ cells

6. Calculation of %astaxanthin accumulation rate (%g astaxanthin/day g cell)

$$\% \text{astaxanthin accumulation rate} = \frac{\% \text{astaxanthin}}{\text{time}} \quad (\text{A.6})$$

Example of Calculation for % astaxanthin accumulation rate

The sample at Day 2 had O.D. (at 477 nm) = 0.689

$$\begin{aligned} \text{mg astaxanthin} &= \frac{0.689 \times 10}{2306.6 \times 100} \times 1000 \\ &= 0.0149 \text{ mg} \end{aligned}$$

$$\begin{aligned} \text{astaxanthin concentration} &= \frac{0.0149 \text{ mg}}{0.006 \text{ l}} \\ &= 2.45 \text{ mg/l} \end{aligned}$$

$$\begin{aligned} \text{astaxanthin productivity} &= \frac{2.45 \text{ mg/l}}{2 \text{ days}} \\ &= 1.24 \text{ mg/l day} \end{aligned}$$

$$\begin{aligned} \text{astaxanthin content} &= \frac{2.45 \text{ mg/l} \cdot 10^6}{12.0 \times 10^7 \text{ cell/l}} \\ &= 0.021 \text{ mg}/10^6 \text{ cells} \end{aligned}$$

$$\begin{aligned} \% \text{astaxanthin} &= \frac{0.021 \text{ mg}/10^6 \text{ cells}}{0.0164 \text{ g}/10^6 \text{ cells}} \times \frac{100}{1000} \\ &= 0.13\% \text{ g astaxanthin/g cell} \end{aligned}$$

$$\begin{aligned} \% \text{astaxanthin accumulation rate} &= \frac{0.13\% \text{ g astaxanthin/g cell}}{2 \text{ days}} \\ &= 0.065 \% \text{g astaxanthin/ day g cell} \end{aligned}$$

4. Economical analysis for astaxanthin production

Example of calculation:

Conditions: no diluted cell concentration and 0.65 klux

$$\begin{aligned} \text{cultivation volume [II]} &= \text{cultivation volume per time / g astaxanthin} \\ &= 1 / 0.00985 \\ &= 101.52 \text{ L} \end{aligned}$$

$$\begin{aligned} \text{cultivation time [III]} &= \text{cultivation time per time / g astaxanthin} \\ &= 14 \text{ days} / 0.0985 \text{ kg} \\ &= 1,421.32 \text{ day} \end{aligned}$$

$$\begin{aligned} \text{total volume of water [VIII]} &= \text{volume of water [V]} \times \text{cultivation volume [IV]} \\ &= 0.9 \times 101.52 \text{ L} \\ &= 91.37 \text{ L} \end{aligned}$$

$$\begin{aligned} \text{total volume of nutrient [IX]} &= \text{volume of nutrient [VI]} \times \text{cultivation volume [IV]} \\ &= 0.1 \times 101.52 \\ &= 10.15 \text{ L} \end{aligned}$$

$$\begin{aligned} \text{total volume of cells [X]} &= \text{volume of cell per time [VII]} \times \text{cultivation volume [IV]} \\ &= 0.25 \text{ L} \times 101.52 \\ &= 25.38 \text{ L} \end{aligned}$$

$$\begin{aligned} \text{Cost of water [XI]} &= 0.06 \text{ THB / L} \times \text{total volume of water [VIII]} \\ &= 0.06 \times 91.7 \\ &= 5.48 \text{ THB} \end{aligned}$$

$$\begin{aligned} \text{Cost of nutrient [XII]} &= 1 \text{ THB/L} \times \text{total volume of nutrient [IX]} \\ &= 1 \times 10.15 \\ &= 10.15 \text{ THB} \end{aligned}$$

$$\begin{aligned} \text{Cost of cell [XIII]} &= 564 \text{ THB/L} \times \text{total volume of cells [X]} \\ &= 564 \times 25.38 \\ &= 14,314.72 \text{ THB} \end{aligned}$$

$$\begin{aligned} \text{Power of air compressor [XIV]} &= 0.8 \times \text{number of cultivation [IV]} \\ &= 0.8 \times 101.52 \\ &= 81.22 \text{ W} \end{aligned}$$

$$\begin{aligned}
 \text{Power of light source [XV]} &= 20 \times \text{number of lamps} \\
 &= 20 \times 0 \\
 &= 0 \text{ W}
 \end{aligned}$$

$$\begin{aligned}
 \text{Total electrical unit [XVI]} &= (\text{Power of light source [XV]} + \text{Power of air compressor} \\
 &\quad \text{[XV]}) \times [(\text{cultivation time [III]} \times 24) / 1000] \\
 &= (81.22 + 0) \times [(14 \times 24) / 1000] \\
 &= 27.29 \text{ W}
 \end{aligned}$$

$$\begin{aligned}
 \text{Electrical cost [XVII]} &= \text{Total electrical unit [XVI]} \times 3 \text{ THB} \\
 &= 27.29 \times 3 \\
 &= 81.87 \text{ THB}
 \end{aligned}$$

$$\begin{aligned}
 \text{Cost of pump [XIX]} &= 0.0132 \times \text{number of cultivation [IV]} \times \text{cultivation time [III]} \\
 &= 0.0132 \times 101.52 \times 14 \\
 &= 18.76 \text{ THB}
 \end{aligned}$$

$$\begin{aligned}
 \text{Cost of lamps [XX]} &= 0.1644 \times \text{number of cultivation [IV]} \times \text{cultivation time [III]} \\
 &= 0.1644 \times 101.52 \times 14 \\
 &= 2.30 \text{ THB}
 \end{aligned}$$

$$\begin{aligned}
 \text{Total operation cost [XXI]} &= \text{cost of water [XI]} + \text{cost of nutrient [XII]} \\
 &\quad + \text{cost of cell [XIII]} + \text{electrical cost [XVII]} + \\
 &\quad \text{cost of pump [XVIII]} + \text{cost of lamp [XIX]} \\
 &= 5.48 + 10.15 + 14,314.72 + 81.87 + 18.76 + 2.3 \\
 &= 14,430.98 \text{ THB}
 \end{aligned}$$

Table A-1 Economical analysis for astaxanthin production from *Haematococcus pluvialis* per one time of cultivation by diluted initial cell concentration

| | | Ambient | | | | Light 2 | | | |
|--|-----------------------------------|---------|--------|--------|--------|---------|--------|--------|--------|
| | | DCC | DC10 | DC20 | DC25 | DCC | DC10 | DC20 | DC25 |
| Cultivation volume per reactor (l) | [I] | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Cultivation time (days) | [II] | 14.00 | 14.00 | 12.00 | 14.00 | 14.00 | 12.00 | 14.00 | 10.00 |
| Astaxanthin concentration (mg/l) | [III] | 9.85 | 4.45 | 2.24 | 2.66 | 17.94 | 4.18 | 4.79 | 4.39 |
| Number of cultivation | [IV] | 1.00 | 10.00 | 20.00 | 25.00 | 1.00 | 10.00 | 20.00 | 25.00 |
| Total astaxanthin (kg) | [V = (IIIxIV)+1000] | 0.00 | 0.04 | 0.04 | 0.06 | 0.01 | 0.04 | 0.09 | 0.10 |
| Volume of water (l) | [VI] | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| Volume of nutrient (l) | [VII] | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Volume of cell (l) | [VIII] | 0.25 | 0.02 | 0.01 | 0.01 | 0.25 | 0.02 | 0.01 | 0.01 |
| Total volume of water (l) | [IX = VIxIV] | 0.90 | 9.00 | 18.00 | 22.50 | 0.90 | 9.00 | 18.00 | 22.50 |
| Total volume of nutrient (l) | [X = VIIxIV] | 0.10 | 1.00 | 2.00 | 2.50 | 0.10 | 1.00 | 2.00 | 2.50 |
| Total volume of cell (l) | [XI = VIIIxIV] | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Cost of water, 0.06 THB/l (THB) | [XII = IXx0.06] | 0.05 | 0.54 | 1.08 | 1.35 | 0.05 | 0.54 | 1.08 | 1.35 |
| Cost of nutrient, 1 THB/l (THB) | [XIII = Xx1] | 0.10 | 1.00 | 2.00 | 2.50 | 0.10 | 1.00 | 2.00 | 2.50 |
| Cost of cell, 564 THB/l (THB) | [XIV = XIx564] | 141.00 | 141.00 | 141.00 | 141.00 | 141.00 | 141.00 | 141.00 | 141.00 |
| Power of air compressor (W) | [XV = IVx0.8] | 0.80 | 8.00 | 16.00 | 20.00 | 0.80 | 8.00 | 16.00 | 20.00 |
| Power of light source (W) | [XVI] | 0.00 | 0.00 | 0.00 | 0.00 | 20.00 | 200.00 | 400.00 | 500.00 |
| Total electrical unit (units) | [XVII = (XV+XVI)x(IIx24)+1000] | 0.26 | 2.68 | 4.60 | 6.72 | 6.98 | 59.90 | 139.77 | 124.80 |
| Electrical cost, 3 THB per unit (THB/time) | [XVIII = XVIIx3] | 0.80 | 8.06 | 13.82 | 20.16 | 20.96 | 179.70 | 419.32 | 374.40 |
| Cost of pump ^a (BTH/time) | [XIX = 0.0132xIIxIV] | 0.18 | 1.84 | 3.16 | 4.62 | 0.18 | 1.58 | 3.69 | 3.30 |
| Cost of lamp ^b (BTH/time) | [XX] | 0.00 | 0.00 | 0.00 | 0.00 | 2.30 | 19.72 | 46.03 | 41.10 |
| Total operating cost (THB/time) | [XXI = XII+XIII+XIV+XVIII+XIX+XX] | 142.14 | 152.45 | 161.07 | 169.63 | 164.60 | 343.56 | 613.13 | 563.65 |

Table A-1 (continued) Economical analysis for astaxanthin production from *Haematococcus pluvialis* per one time of cultivation by diluted initial cell concentration

| | | Light 4 | | | | Light 6 | | | |
|--|---|---------|--------|---------|---------|---------|--------|---------|---------|
| | | DCC | DC10 | DC20 | DC25 | DCC | DC10 | DC20 | DC25 |
| Cultivation volume per reactor (l) | [I] | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Cultivation time (days) | [II] | 18.00 | 8.00 | 14.00 | 10.00 | 14.00 | 8.00 | 14.00 | 10.00 |
| Astaxanthin concentration (mg/l) | [III] | 16.19 | 4.77 | 3.13 | 3.29 | 21.23 | 9.20 | 2.53 | 4.11 |
| Number of cultivation | [IV] | 1.00 | 10.00 | 20.00 | 25.00 | 1.00 | 10.00 | 20.00 | 25.00 |
| Total astaxanthin (kg) | [V = (IIIxIV)+1000] | 0.01 | 0.04 | 0.06 | 0.08 | 0.02 | 0.09 | 0.05 | 0.10 |
| Volume of water (l) | [VI] | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| Volume of nutrient (l) | [VII] | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Volume of cell (l) | [VIII] | 0.25 | 0.02 | 0.01 | 0.01 | 0.25 | 0.05 | 0.01 | 0.01 |
| Total volume of water (l) | [IX = VIxIV] | 0.90 | 9.00 | 18.00 | 22.50 | 0.90 | 9.00 | 18.00 | 22.50 |
| Total volume of nutrient (l) | [X = VIIxIV] | 0.10 | 1.00 | 2.00 | 2.50 | 0.10 | 1.00 | 2.00 | 2.50 |
| Total volume of cell (l) | [XI = VIIIxIV] | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Cost of water, 0.06 THB/l (THB) | [XII = IXx0.06] | 0.05 | 0.54 | 1.08 | 1.35 | 0.05 | 0.54 | 1.08 | 1.35 |
| Cost of nutrient, 1 THB/l (THB) | [XIII = Xx1] | 0.10 | 1.00 | 2.00 | 2.50 | 0.10 | 1.00 | 2.00 | 2.50 |
| Cost of cell, 564 THB/l (THB) | [XIV = XIx564] | 141.00 | 141.00 | 141.00 | 141.00 | 141.00 | 141.00 | 141.00 | 141.00 |
| Power of air compressor (W) | [XV = IVx0.8] | 0.80 | 8.00 | 16.00 | 20.00 | 0.80 | 8.00 | 16.00 | 20.00 |
| Power of light source (W) | [XVI] | 40.00 | 400.00 | 800.00 | 1000.00 | 60.00 | 600.00 | 1200.00 | 1500.00 |
| Total electrical unit (units) | [XVII = (XV+XVI)x(IIx24)+1000] | 17.62 | 78.33 | 274.17 | 244.80 | 20.42 | 116.73 | 408.57 | 364.80 |
| Electrical cost, 3 THB per unit (THB/time) | [XVIII = XVIIx3] | 52.87 | 235.00 | 822.52 | 734.40 | 61.28 | 350.20 | 1225.72 | 1094.40 |
| Cost of pump ^a (BTH/time) | [XIX = 0.0132xIIxIV] | 0.23 | 1.05 | 3.69 | 3.30 | 0.18 | 1.05 | 3.69 | 3.30 |
| Cost of lamp ^b (BTH/time) | [XX] | 5.91 | 26.30 | 92.04 | 82.20 | 6.90 | 39.45 | 138.00 | 123.30 |
| Total operating cost (THB/time) | [XXI = XII+XIII+XIV+XV+XVI+XVII+XVIII+XIX+XX] | 200.18 | 404.90 | 1062.36 | 964.75 | 209.53 | 533.26 | 1511.60 | 1365.85 |

Table A-2 Economical analysis for astaxanthin production from *Haematococcus pluvialis* per one time of cultivation by diluted spent medium concentration

| | | Ambient | | | | Light 2 | | | |
|--|-----------------------------------|---------|--------|---------|---------|---------|--------|---------|---------|
| | | DMC | DM5 | DM10 | DM15 | DMC | DM5 | DM10 | DM15 |
| Cultivation volume per reactor (l) | [I] | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Cultivation time (days) | [II] | 18.00 | 18.00 | 12.00 | 16.00 | 18.00 | 18.00 | 12.00 | 18.00 |
| Astaxanthin concentration (mg/l) | [III] | 2.77 | 1.80 | 0.71 | 0.24 | 4.36 | 2.15 | 2.75 | 0.64 |
| Number of cultivation | [IV] | 1.00 | 5.00 | 10.00 | 15.00 | 1.00 | 5.00 | 10 | 15.00 |
| Total astaxanthin (kg) | [V = (IIIxIV)+1000] | 0.0027 | 0.009 | 0.0071 | 0.0036 | 0.0043 | 0.0107 | 0.0275 | 0.0096 |
| Volume of water (l) | [VI] | 0.00 | 0.80 | 0.90 | 0.93 | 0.00 | 0.80 | 0.90 | 0.93 |
| Volume of nutrient (l) | [VII] | 1.00 | 0.20 | 0.10 | 0.06 | 1.00 | 0.20 | 0.10 | 0.06 |
| Volume of cell (l) | [VIII] | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Total volume of water (l) | [IX = VIxIV] | 0.00 | 4.00 | 9.00 | 13.95 | 0.00 | 4.00 | 9.00 | 13.95 |
| Total volume of nutrient (l) | [X = VIIxIV] | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Total volume of cell (l) | [XI = VIIIxIV] | 0.25 | 1.25 | 2.50 | 3.75 | 0.25 | 1.25 | 2.50 | 3.75 |
| Cost of water, 0.06 THB/l (THB) | [XII = IXx0.06] | 0.00 | 0.24 | 0.54 | 0.83 | 0.00 | 0.24 | 0.54 | 0.83 |
| Cost of nutrient, 1 THB/l (THB) | [XIII = Xx1] | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Cost of cell, 526 THB/l (THB) | [XIV = XIx564] | 131.50 | 657.50 | 1315 | 1972.50 | 131.50 | 657.50 | 1315.00 | 1972.50 |
| Power of air compressor (W) | [XV = IVx0.8] | 0.80 | 4.00 | 8.00 | 12.00 | 0.80 | 4.00 | 8.00 | 12.00 |
| Power of light source (W) | [XVI] | 0.00 | 0.00 | 0.00 | 0.00 | 20.00 | 100.00 | 200.00 | 300.00 |
| Total electrical unit (units) | [XVII = (XV+XVI)x(IIx24)+1000] | 0.34 | 1.72 | 2.30 | 4.60 | 8.985 | 44.92 | 59.90 | 134.78 |
| Electrical cost, 3 THB per unit (THB/time) | [XVIII = XVIIx3] | 1.03 | 5.18 | 6.91 | 13.82 | 26.95 | 134.78 | 179.71 | 404.35 |
| Cost of pump ^a (BTH/time) | [XIX = 0.0132xIIxIV] | 0.23 | 1.18 | 1.58 | 3.16 | 0.23 | 1.18 | 1.58 | 3.56 |
| Cost of lamp ^b (BTH/time) | [XX] | 0.00 | 0.00 | 0.00 | 0.00 | 2.95 | 14.79 | 19.72 | 44.38 |
| Total operating cost (THB/time) | [XXI = XII+XIII+XIV+XVIII+XIX+XX] | 133.77 | 665.11 | 1325.03 | 1991.32 | 162.65 | 809.50 | 1517.56 | 2426.64 |

Table A-2 (continued) Economical analysis for astaxanthin production from *Haematococcus pluvialis* per one time of cultivation by diluted spent medium concentration

| | | Light 4 | | | | Light 6 | | | |
|--|-----------------------------------|---------|--------|---------|---------|---------|---------|---------|---------|
| | | DMC | DM5 | DM10 | DM15 | DMC | DM5 | DM10 | DM15 |
| Cultivation volume per reactor (l) | [I] | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Cultivation time (days) | [II] | 10.00 | 18.00 | 16.00 | 8.00 | 18.00 | 18.00 | 6.00 | 18.00 |
| Astaxanthin concentration (mg/l) | [III] | 2.35 | 6.18 | 4.85 | 2.76 | 3.88 | 5.00 | 1.50 | 0.92 |
| Number of cultivation | [IV] | 1.00 | 5.00 | 10.00 | 15.00 | 1.00 | 5.00 | 10.00 | 15.00 |
| Total astaxanthin (kg) | [V = (IIIxIV)+1000] | 0.0023 | 0.0309 | 0.0485 | 0.0414 | 0.0038 | 0.0200 | 0.0100 | 0.0138 |
| Volume of water (l) | [VI] | 0.00 | 0.80 | 0.90 | 0.93 | 0.00 | 0.80 | 0.90 | 0.93 |
| Volume of nutrient (l) | [VII] | 1.00 | 0.20 | 0.10 | 0.06 | 1.00 | 0.20 | 0.10 | 0.06 |
| Volume of cell (l) | [VIII] | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Total volume of water (l) | [IX = VIxIV] | 0.00 | 4.00 | 9.00 | 13.95 | 0.00 | 4.00 | 9.00 | 13.95 |
| Total volume of nutrient (l) | [X = VIIxIV] | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Total volume of cell (l) | [XI = VIIIxIV] | 0.25 | 1.25 | 2.50 | 3.75 | 0.25 | 1.25 | 2.50 | 3.75 |
| Cost of water, 0.06 THB/l (THB) | [XII = IXx0.06] | 0.00 | 0.24 | 0.54 | 0.83 | 0.00 | 0.24 | 0.54 | 0.83 |
| Cost of nutrient, 1 THB/l (THB) | [XIII = Xx1] | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Cost of cell, 526 THB/l (THB) | [XIV = XIx564] | 131.50 | 657.50 | 1315.00 | 1972.50 | 131.50 | 657.50 | 1315.00 | 1972.50 |
| Power of air compressor (W) | [XV = IVx0.8] | 0.80 | 4.00 | 8.00 | 12.00 | 0.80 | 4.00 | 8.00 | 12.00 |
| Power of light source (W) | [XVI] | 40.00 | 200.00 | 400.00 | 600.00 | 60.00 | 300.00 | 600.00 | 900.00 |
| Total electrical unit (units) | [XVII = (XV+XVI)x(IIx24)+1000] | 9.79 | 88.12 | 156.67 | 117.50 | 26.26 | 131.32 | 87.55 | 393.98 |
| Electrical cost, 3 THB per unit (THB/time) | [XVIII = XVIIx3] | 29.37 | 264.38 | 470.01 | 352.51 | 78.79 | 393.98 | 262.65 | 1181.95 |
| Cost of pump ^a (BTH/time) | [XIX = 0.0132xIIxIV] | 0.13 | 1.18 | 2.11 | 1.58 | 0.23 | 1.18 | 0.79 | 3.56 |
| Cost of lamp ^b (BTH/time) | [XX] | 3.28 | 29.59 | 52.60 | 39.45 | 8.87 | 44.38 | 29.59 | 133.16 |
| Total operating cost (THB/time) | [XXI = XII+XIII+XIV+XVIII+XIX+XX] | 165.29 | 953.90 | 1841.27 | 2367.88 | 220.41 | 1098.30 | 1609.58 | 3293.01 |

BIOGRAPHY

Ms. Oi-jai Limpanyalert was born on 24th February, 1984 in Bangkok. She finished her higher secondary course from Sawanananwittaya School in March, 2002. After that, she studied in the major of Biotechnology in Faculty of Science at King Mongkut's Institute of Technology Ladkrabang. She continued her further study for Master's degree in Chemical Engineering (Biochemical Engineering research group) at Chulalongkorn University in 2006.