# CHAPTER IV

# RESULTS

## Experiment I

### 4.1 Effect of crude palm oil on hen performance and egg quality

It is demonstrated that there were no significant difference in daily feed intake of layers received crude palm oil (CPO) compared to control (data not shown). The hen-day basis percentage (%HD) of control and CPO groups was not different. The average egg weights of CPO group were significantly greater ($P<0.05$) than control group at weeks 3 and 6 of the trial. There was no difference in egg weight among weeks of experiment in both control and CPO groups as shown in Table 4.1.

The specific gravity, Haugh unit and yolk color of egg were not different in both control and treatment groups during time intervals (Table 4.1). There was also no difference in yolk color in both control and CPO groups, although there was a trend toward an increase in CPO group.

### 4.2 Effect of crude palm oil on egg yolk cholesterol concentration

The cholesterol concentration (mg/yolk weight and mg/g yolk) of control and CPO group were not different (neither various time interval nor treatment groups) as shown in Table 4.2.

Table 4.1 Effects of crude palm oil on hen performance and egg quality in experiment I.

| Parameter / Treatment group | Week No. 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| **Hen-Day Basis (%)** | | | | | | |
| Control | 88.57 ± 2.86 | 88.57 ± 1.77 | 94.29 ± 1.60 | 85.71 ± 1.87 | 84.29 ± 3.09 | 81.43 ± 2.84 |
| CPO | 85.00 ± 9.48 | 84.29 ± 2.34 | 94.29 ± 1.60 | 85.71 ± 2.71 | 91.43 ± 5.71 | 91.43 ± 1.96 |
| **Egg Weight (g/egg)** | | | | | | |
| Control | 64.70 ± 0.72 | 64.38 ± 1.38 | 63.77 ± 0.27$^{y}$ | 64.05 ± 0.81 | 65.20 ± 0.58 | 64.17 ± 0.44$^{y}$ |
| CPO | 64.28 ± 1.53 | 66.78 ± 0.38 | 66.07 ± 1.51$^{x}$ | 65.51 ± 1.03 | 65.30 ± 0.86 | 66.97 ± 0.89$^{x}$ |
| **Specific Gravity** | | | | | | |
| Control | 1.088 ± 0.000 | 1.100 ± 0.000 | 1.089 ± 0.005 | 1.095 ± 0.003 | 1.087 ± 0.003 | 1.085 ± 0.001 |
| CPO | 1.088 ± 0.000 | 1.100 ± 0.000 | 1.080 ± 0.002 | 1.085 ± 0.004 | 1.081 ± 0.003 | 1.083 ± 0.001 |
| **Haugh Unit** | | | | | | |
| Control | 76.59 ± 7.22 | 77.95 ± 1.38 | 72.72 ± 4.15 | 77.43 ± 5.67 | 76.25 ± 1.63 | 75.35 ± 1.56 |
| CPO | 74.70 ± 6.41 | 78.60 ± 1.93 | 76.28 ± 4.05 | 74.50 ± 7.49 | 75.26 ± 2.27 | 75.57 ± 1.83 |
| **Yolk Color** | | | | | | |
| Control | 6.00 ± 0.33 | 5.00 ± 0.33 | 4.00 ± 0.00 | 5.00 ± 0.00 | 4.00 ± 0.33 | 4.00 ± 0.33 |
| CPO | 7.00 ± 0.33 | 6.00 ± 0.88 | 6.00 ± 0.00 | 5.00 ± 0.58 | 5.00 ± 0.00 | 5.00 ± 0.33 |
| **Yolk Weight (g)** | | | | | | |
| Control | 17.85 ± 1.14 | 15.40 ± 0.40 | 14.98 ± 0.65 | 15.97 ± 0.92 | 14.01 ± 0.14$^{y}$ | 14.06 ± 0.05$^{y}$ |
| CPO | 16.19 ± 1.11 | 15.45 ± 0.61 | 15.74 ± 0.35 | 15.58 ± 0.58 | 15.64 ± 0.32$^{x}$ | 15.76 ± 0.23$^{x}$ |

* Mean ± SD, n=3 (except %HD, n=5)

$^{x,y}$ Means within column (different group) with no common superscript differ significantly ($P<0.05$).

Control = lard 2% in diet, CPO = crude palm oil 2% in diet

Table 4.2 Effect of crude palm oil on egg yolk cholesterol concentration in experiment I

| Parameter | Week 4 | | Week 5 | | Week 6 | |
|---|---|---|---|---|---|---|
| | Control | CPO | Control | CPO | Control | CPO |
| Cholesterol Conc. (mg/yolk weight) | 301.75±12.81 | 283.11 ± 10.42 | 275.22 ± 20.77 | 283.86 ± 3.81 | 277.00 ± 7.05 | 278.54 ± 5.16 |
| Cholesterol Conc. (mg/g yolk) | 18.89 ± 0.61 | 18.17 ± 0.75 | 19.64± 1.74 | 18.15 ± 0.19 | 19.70 ± 0.28 | 17.67 ± 0.29 |

Mean ± SD, n=3

Control = lard 2% in diet, CPO = crude palm oil 2% in diet.

Cholesterol Conc. = cholesterol concentration

## Experiment II

### 4.3 Effect of crude palm oil on hen performance

Hen performances are shown in Tables 4.3 and 4.4. Weight gain, average daily gain (ADG) and hen-day basis (HD) percentage (80.81-84.82%) were not significantly different in both times of study and treatment groups. Daily feed intake (DFI), egg weight overall and feed conversion ratio (FCR) are shown in Table 4.5. It is depicted that there was no significant change in DFI of hens fed control diet and among CPO diets.

From week 3 to week 6 of the study, the overall egg weight were significantly increased in hens fed on CPO2 and CPO3 compared to the control and CPO1 supplemented group. There was no change in overall egg weight in the first two weeks of the trial. In hens fed on CPO2 and CPO3, overall egg weight in weeks 4, 5 and 6 were significantly ($P<0.05$) higher than other weeks. In Table 4.5, it is demonstrated that the FCR of hen receiving CPO3 was significantly better than control (2.04 g diet/g egg) and CPO1 (2.00 g diet/g egg) at week 3 of the trial. There was no difference in FCR of the hen in all groups during different time intervals except in the CPO3 group (improved at week 3 to week 6).

**Table 4.3** Effect of crude palm oil on weight gain and average daily gain (ADG) (week 0- week 6) in experiment II.

| Parameter | Control | CPO1 | CPO2 | CPO3 |
|---|---|---|---|---|
| Weight Gain (g) | 7.19 ± 0.77 | 6.25 ± 0.51 | 7.19 ± 0.60 | 6.88 ± 0.36 |
| ADG (g/d) | 0.17 ± 0.019 | 0.15 ± 0.012 | 0.17 ± 0.014 | 0.16 ± 0.008 |

Mean ± SD, ($P<0.05$)

Control = lard 2%, CPO1 = crude palm oil 2%, CPO2= crude palm oil 3%, CPO3 = crude palm oil 4%.

**Table 4.4** Effect of crude palm oil on hen-day basis percentage (%HD) in experiment II.

| Treatment group | Week No. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Control | 84.13 ± 2.90 | 82.14 ± 1.26 | 82.14 ± 1.26 | 81.25 ± 0.51 | 80.75 ± 0.47 | 83.04 ± 3.42 | 82.14 ± 2.25 |
| CPO1 | 82.94 ± 5.24 | 82.14 ± 1.63 | 82.59 ± 1.34 | 83.04 ± 1.55 | 82.59 ± 1.98 | 80.81 ± 2.25 | 82.14 ± 5.65 |
| CPO2 | 82.94 ± 2.00 | 80.46 ± 1.46 | 81.70 ± 1.98 | 82.15 ± 1.03 | 82.59 ± 1.53 | 80.81 ± 2.25 | 82.59 ± 2.68 |
| CPO3 | 83.34 ± 0.92 | 84.38 ± 1.52 | 83.04 ± 1.15 | 83.93 ± 0.73 | 83.93 ± 1.26 | 83.03 ± 1.79 | 84.82 ± 1.03 |

Mean ± SD, ($P<0.05$)

Control = lard 2%, CPO1 = crude palm oil 2%, CPO2= crude palm oil 3%, CPO3 = crude palm oil 4%.

Table 4.5 Effect of crude palm oil on hen performance in experiment II.

| Parameter / Treatment group | Week No. 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| **DFI (g/d)** | | | | | | | |
| Control | 108.57 ± 0.60 | 107.02 ± 0.05 | 107.99 ± 0.49 | 108.13 ± 0.67 | 106.60 ± 0.64 | 107.65 ± 0.23 | 107.00 ± 0.37 |
| CPO1 | 108.27 ± 0.22 | 106.95 ± 0.41 | 108.23 ± 0.25 | 107.86 ± 0.23 | 108.04 ± 0.20 | 107.68 ± 0.16 | 107.17 ± 0.31 |
| CPO2 | 109.50 ± 0.72 | 106.63 ± 0.85 | 107.76 ± 0.28 | 107.84 ± 0.22 | 107.47 ± 0.10 | 107.84 ± 0.27 | 107.81 ± 0.22 |
| CPO3 | 108.61 ± 0.26 | 107.83 ± 0.19 | 107.96 ± 0.10 | 107.83 ± 0.33 | 107.97 ± 0.34 | 107.84 ± 0.18 | 108.24 ± 0.37 |
| **Average Egg Wt.* (g/egg)** | | | | | | | |
| Control | 65.27 ± 0.15 | 65.11 ± 0.03 | 65.15 ± 0.06 | $65.19 \pm 0.08^{z}$ | $65.11 \pm 0.04^{z}$ | $65.25 \pm 0.07^{y}$ | $65.30 \pm 0.13^{y}$ |
| CPO1 | 64.78 ± 0.33 | 64.91 ± 0.70 | 64.97 ± 0.19 | $65.04 \pm 0.11^{z}$ | $65.27 \pm 0.22^{z}$ | $64.95 \pm 0.23^{y}$ | $64.60 \pm 0.23^{z}$ |
| CPO2 | $64.97 \pm 2.29^{b}$ | $64.60 \pm 0.38^{b}$ | $65.48 \pm 0.17^{b}$ | $65.68 \pm 0.07^{y\,b}$ | $66.54 \pm 0.22^{y\,a}$ | $67.25 \pm 0.20^{x\,a}$ | $67.00 \pm 0.28^{x\,a}$ |
| CPO3 | $65.40 \pm 0.20^{b}$ | $65.14 \pm 0.12^{b}$ | $65.39 \pm 0.07^{b}$ | $67.16 \pm 0.25^{x\,a}$ | $67.45 \pm 0.13^{x\,a}$ | $67.51 \pm 0.18^{x\,a}$ | $67.60 \pm 0.05^{w\,a}$ |
| **FCR (g diet/g egg)** | | | | | | | |
| Control | 1.98 ± 0.03 | 2.00 ± 0.03 | 2.03 ± 0.04 | $2.04 \pm 0.03^{x}$ | 2.01 ± 0.18 | 1.99 ± 0.04 | 2.00 ± 0.04 |
| CPO1 | 2.02 ± 0.06 | 2.01 ± 0.05 | 2.02 ± 0.04 | $2.00 \pm 0.03^{x}$ | 2.01 ± 0.05 | 2.05 ± 0.03 | 2.04 ± 0.07 |
| CPO2 | 2.03 ± 0.03 | 2.01 ± 0.05 | 2.01 ± 0.05 | $2.00 \pm 0.03^{xy}$ | 1.95 ± 0.03 | 1.99 ± 0.03 | 1.95 ± 0.03 |
| CPO3 | $2.03 \pm 0.03^{a}$ | $1.97 \pm 0.04^{ab}$ | $1.99 \pm 0.03^{ab}$ | $1.91 \pm 0.14^{y\,b}$ | $1.91 \pm 0.03^{b}$ | $1.92 \pm 0.12^{b}$ | $1.89 \pm 0.02^{b}$ |

Mean ± SD, n=8,Control = lard 2%, CPO1 = crude palm oil 2%, CPO2= crude palm oil 3%, CPO3 = crude palm oil 4%.

$^{a,b}$ Means within row (different time) with no common superscript differ significantly (P<0.05).

$^{w,x,y,z}$ Means within column (different group) with no common superscript differ significantly (P<0.05).

* Average egg weight = total of egg weight / number of eggs

## 4.4 Effect of crude palm oil on egg quality

It is demonstrated that there was no significant difference in specific gravity and Haugh unit in both different treatment groups and periods of study as shown in Table 4.6. From weeks 3 to 6, hens receiving CPO3 produced eggs with significantly ($P<0.05$) greater yolk color than other groups. There was no difference in yolk color of the hen in all groups during time intervals except in CPO3 group that egg yolk color was significantly ($P<0.05$) increased from week 3 to week 6 compared to week 0 (Figure 4.1). At the last week of trial, all hens in treatment groups fed on crude palm oil had significantly greater yolk color ($P<0.05$) than control group. From week 4 to week 6 of the study, egg weight of hens fed on CPO2 and CPO3 were significantly ($P<0.05$) greater than control and CPO1 group (approximately 1.7-2.2 g higher) as shown in Table 4.7. The egg weight and yolk weight were not different in both control and CPO1 during time intervals as shown in Table 4.7. In CPO2 and CPO3 group, egg weight started to increase significantly ($P<0.05$) in week 4 to week 6 of the trial (Figure 4.2). In CPO2 group, yolk weight started to increase significantly ($P<0.05$) in week 4 to week 6 of the trial while yolk weight of CPO3 group was significantly increased ($P<0.05$) in the week earlier (week 3) (Figure 4.3). There were no significant difference in albumin weight and egg shell weight in different treatment groups and different times of study.

Percentages of egg yolk and albumin were not different in both control and CPO1 groups during time intervals as shown in Table 4.8. From week 4 to week 6 of study, percentage of egg yolk in hens fed on CPO2 was significantly ($P<0.05$) greater than control and CPO1 group and in CPO3 group started to be higher ($P<0.05$) than other groups from week 3 to week 6. From week 4 to week 6 of study, the percentage of albumin of hens fed on CPO2 group was significantly ($P<0.05$) less than control and CPO1 groups and percentage of albumin in CPO3 group was less ($P<0.05$) than other groups from week 3 to week 6 (Table 4.8). There was no significant difference in percentage of egg shell in different treatment groups and difference time of the study.

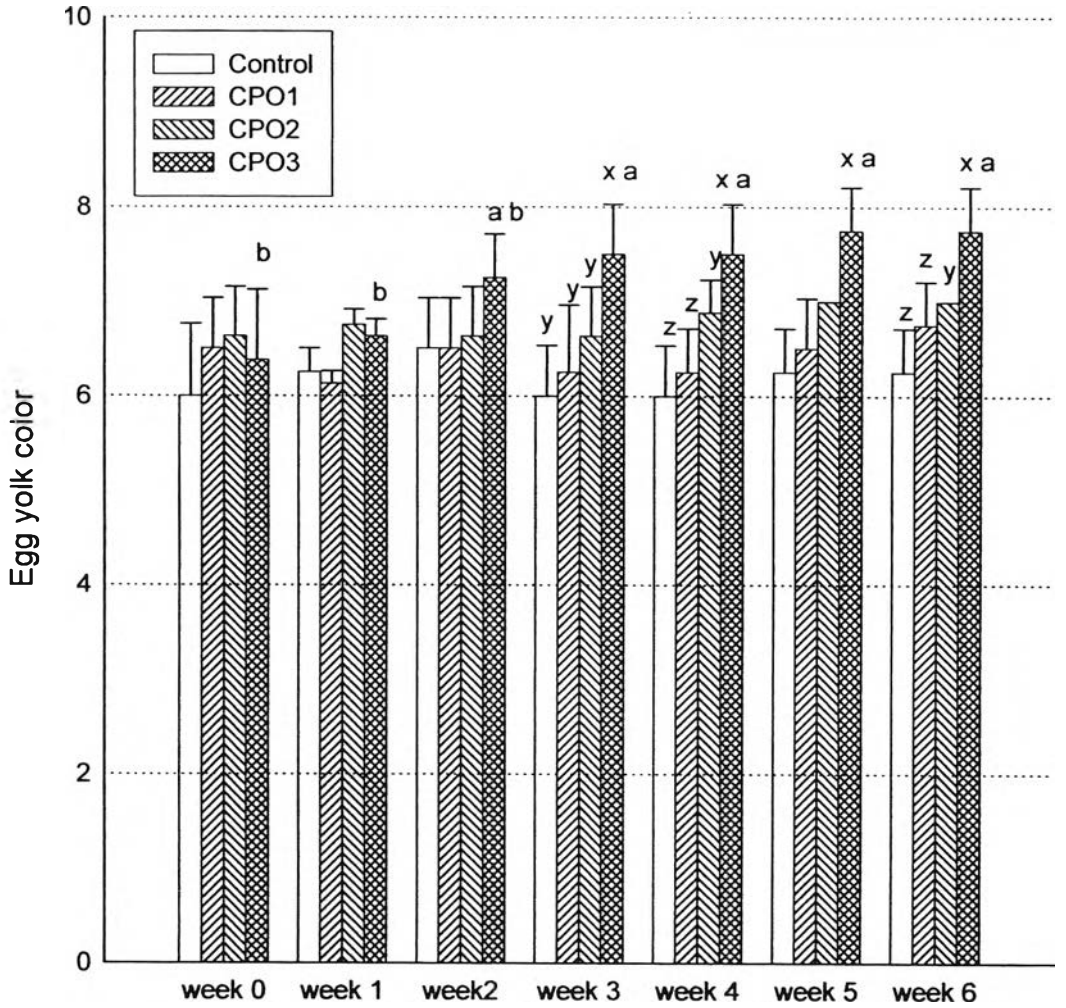
Table 4.6 Effect of crude palm oil on specific gravity, Huagh unit and egg yolk color.

| Parameter / Treatment group | Week No. 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| **Specific Gravity** | | | | | | | |
| Control | 1.084 ± 0.004 | 1.081 ± 0.001 | 1.082 ± 0.004 | 1.084 ± 0.007 | 1.082 ± 0.003 | 1.085 ± 0.005 | 1.085 ± 0.004 |
| CPO1 | 1.083 ± 0.006 | 1.083 ± 0.002 | 1.083 ± 0.005 | 1.084 ± 0.005 | 1.080 ± 0.003 | 1.084 ± 0.004 | 1.085 ± 0.003 |
| CPO2 | 1.082 ± 0.004 | 1.083 ± 0.001 | 1.080 ± 0.006 | 1.084 ± 0.006 | 1.083 ± 0.003 | 1.085 ± 0.005 | 1.083 ± 0.004 |
| CPO3 | 1.084 ± 0.003 | 1.084 ± 0.002 | 1.081 ± 0.006 | 1.084 ± 0.007 | 1.083 ± 0.002 | 1.085 ± 0.008 | 1.084 ± 0.006 |
| **Haugh Unit** | | | | | | | |
| Control | 75.93 ± 5.77 | 79.79 ± 2.07 | 80.49 ± 1.38 | 81.36 ± 1.75 | 80.56± 2.71 | 80.44 ± 2.01 | 79.81 ± 1.92 |
| CPO1 | 75.62 ± 4.77 | 77.98 ± 1.65 | 80.02 ± 1.54 | 81.47 ± 1.24 | 79.56 ± 3.79 | 78.92 ± 2.38 | 80.81 ± 0.83 |
| CPO2 | 75.62 ± 4.46 | 82.58 ± 0.83 | 81.27 ± 1.81 | 81.37 ± 1.55 | 81.07 ± 3.28 | 80.97 ± 1.58 | 79.16 ± 1.60 |
| CPO3 | 73.99 ± 6.17 | 77.35 ± 1.95 | 80.70 ± 1.61 | 79.79 ± 2.10 | 82.17 ± 5.69 | 81.08 ± 1.18 | 78.66 ± 2.22 |
| **Egg Yolk Color** | | | | | | | |
| Control | 6.00 ± 0.76 | 6.25 ± 0.25 | 6.50 ± 0.53 | $6.00 \pm 0.53^{y}$ | $6.00 \pm 0.53^{z}$ | $6.25 \pm 0.46^{z}$ | $6.25 \pm 0.46^{z}$ |
| CPO1 | 6.50 ± 0.53 | 6.13 ± 0.13 | 6.50 ± 0.53 | $6.25 \pm 0.71^{y}$ | $6.25 \pm 0.46^{z}$ | $6.50 \pm 0.53^{z}$ | $6.75 \pm 0.46^{y}$ |
| CPO2 | 6.63 ± 0.52 | 6.75 ± 0.16 | 6.63 ± 0.52 | $6.63 \pm 0.52^{y}$ | $6.88 \pm 0.35^{y}$ | $7.00 \pm 0.00^{y}$ | $7.00 \pm 0.00^{y}$ |
| CPO3 | $6.38 \pm 0.74^{b}$ | $6.63 \pm 0.18^{b}$ | $7.25 \pm 0.46^{ab}$ | $7.50 \pm 0.53^{x a}$ | $7.50 \pm 0.53^{x a}$ | $7.75 \pm 0.46^{x a}$ | $7.75 \pm 0.46^{x a}$ |

Mean ± SD, n=8, Control = lard 2%, CPO1 = crude palm oil 2%, CPO2= crude palm oil 3%, CPO3 = crude palm oil 4%.

$^{a,b}$ Means within row (different time) with no common superscript differ significantly ($P<0.05$).

$^{x,y}$ Means within column (different group) with no common superscript differ significantly ($P<0.05$).




[x, y, z] Different superscripts of means in the same week are significantly different ($P<0.05$).

[a, b] Different superscripts of means in the same group in various weeks are significantly different ($P<0.05$).

**Figure 4.1** Effect of crude palm oil on egg yolk color.

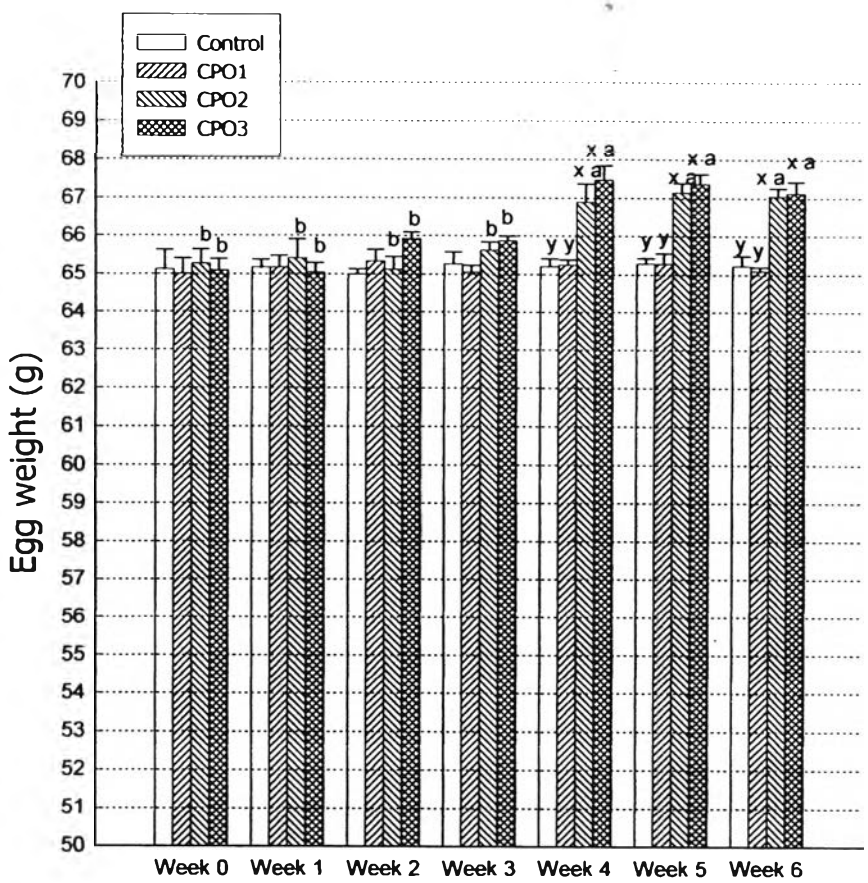
**Table 4.7** Effect of crude palm oil on egg weight, yolk weight, albumin weight and egg shell weight.

| Parameter | Week No. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| **Egg Wt. (g)** | | | | | | | |
| Control | 65.12 ± 0.50 | 65.17 ± 0.20 | 64.99 ± 0.14 | 65.26 ± 0.31 | 65.20 ± 0.20$^{y}$ | 65.28 ± 0.14$^{y}$ | 65.22 ± 0.26$^{y}$ |
| CPO1 | 65.01 ± 0.36 | 65.17 ± 0.30 | 65.33 ± 0.30 | 65.05 ± 0.18 | 65.25 ± 0.13$^{y}$ | 65.28 ± 0.27$^{y}$ | 65.10 ± 0.10$^{y}$ |
| CPO2 | 65.27 ± 0.37$^{b}$ | 65.41 ± 0.49$^{b}$ | 65.12 ± 0.33$^{b}$ | 65.62 ± 0.21$^{b}$ | 66.90 ± 0.47$^{x a}$ | 67.15 ± 0.24$^{x a}$ | 67.05 ± 0.21$^{x a}$ |
| CPO3 | 65.10 ± 0.29$^{b}$ | 65.04 ± 0.25$^{b}$ | 65.92 ± 0.17$^{b}$ | 65.87 ± 0.12$^{b}$ | 67.47 ± 0.38$^{x a}$ | 67.37 ± 0.25$^{x a}$ | 67.13 ± 0.30$^{x a}$ |
| **Egg Yolk Wt. (g)** | | | | | | | |
| Control | 16.69 ± 0.16 | 16.24 ± 0.13 | 16.28 ± 0.12 | 16.33 ± 0.20$^{y}$ | 16.18 ± 0.43$^{y}$ | 16.52 ± 0.14$^{y}$ | 16.19 ± 0.18$^{y}$ |
| CPO1 | 16.65 ± 0.30 | 16.51 ± 0.17 | 16.38 ± 0.18 | 16.09 ± 0.23$^{y}$ | 16.22 ± 0.25$^{y}$ | 16.63 ± 0.27$^{y}$ | 16.17 ± 0.13$^{y}$ |
| CPO2 | 16.69 ± 0.26$^{b}$ | 16.26 ± 0.42$^{b}$ | 16.16 ± 0.28$^{b}$ | 16.46 ± 0.18$^{y b}$ | 17.72 ± 0.91$^{x a}$ | 18.09 ± 0.21$^{x a}$ | 17.83 ± 0.27$^{x a}$ |
| CPO3 | 16.61 ± 0.21$^{b}$ | 16.37 ± 0.30$^{b}$ | 16.78 ± 0.20$^{b}$ | 17.70 ± 0.19$^{x a}$ | 18.35 ± 0.93$^{x a}$ | 18.26 ± 0.26$^{x a}$ | 18.28 ± 0.31$^{x a}$ |
| **Albumin Wt. (g)** | | | | | | | |
| Control | 41.95 ± 0.49 | 42.63 ± 0.16 | 42.21 ± 0.42 | 42.43 ± 0.21 | 42.54 ± 0.28 | 42.28± 0.18 | 42.36 ± 0.41 |
| CPO1 | 41.84 ± 0.35 | 42.29 ± 0.29 | 42.29 ± 0.58 | 42.30 ± 0.17 | 42.58 ± 0.43 | 42.20 ± 0.25 | 42.68 ± 0.48 |
| CPO2 | 41.96 ± 0.22 | 42.78 ± 0.21 | 42.73 ± 0.55 | 41.84 ± 0.14 | 42.50 ± 0.57 | 42.38 ± 0.18 | 42.66 ± 0.95 |
| CPO3 | 42.00 ± 0.15 | 42.44 ± 0.30 | 42.52 ± 0.71 | 41.55 ± 0.16 | 42.23 ± 0.79 | 42.22 ± 0.23 | 42.11 ± 0.43 |
| **Egg Shell Wt. (g)** | | | | | | | |
| Control | 6.48 ± 0.12 | 6.30 ± 0.17 | 6.50 ± 0.13 | 6.50 ± 0.13 | 6.48 ± 0.10 | 6.48 ± 0.10 | 6.67 ± 0.13 |
| CPO1 | 6.52 ± 0.13 | 6.37 ± 0.12 | 6.66 ± 0.11 | 6.66 ± 0.11 | 6.45 ± 0.17 | 6.45 ± 0.17 | 6.25 ± 0.13 |
| CPO2 | 6.62 ± 0.22 | 6.37 ± 0.18 | 6.32 ± 0.11 | 6.32 ± 0.11 | 6.68 ± 0.15 | 6.68 ± 0.15 | 6.56 ± 0.22 |
| CPO3 | 6.49 ± 0.19 | 6.23 ± 0.18 | 6.62 ± 0.23 | 6.62 ± 0.23 | 6.89 ± 0.17 | 6.89 ± 0.17 | 6.74 ± 0.13 |

Mean ± SD, n=8, Control = lard 2%, CPO1 = crude palm oil 2%, CPO2= crude palm oil 3%, CPO3 = crude palm oil 4%.

$^{a,b}$ Means within row (different time) with no common superscript differ significantly ($P<0.05$).

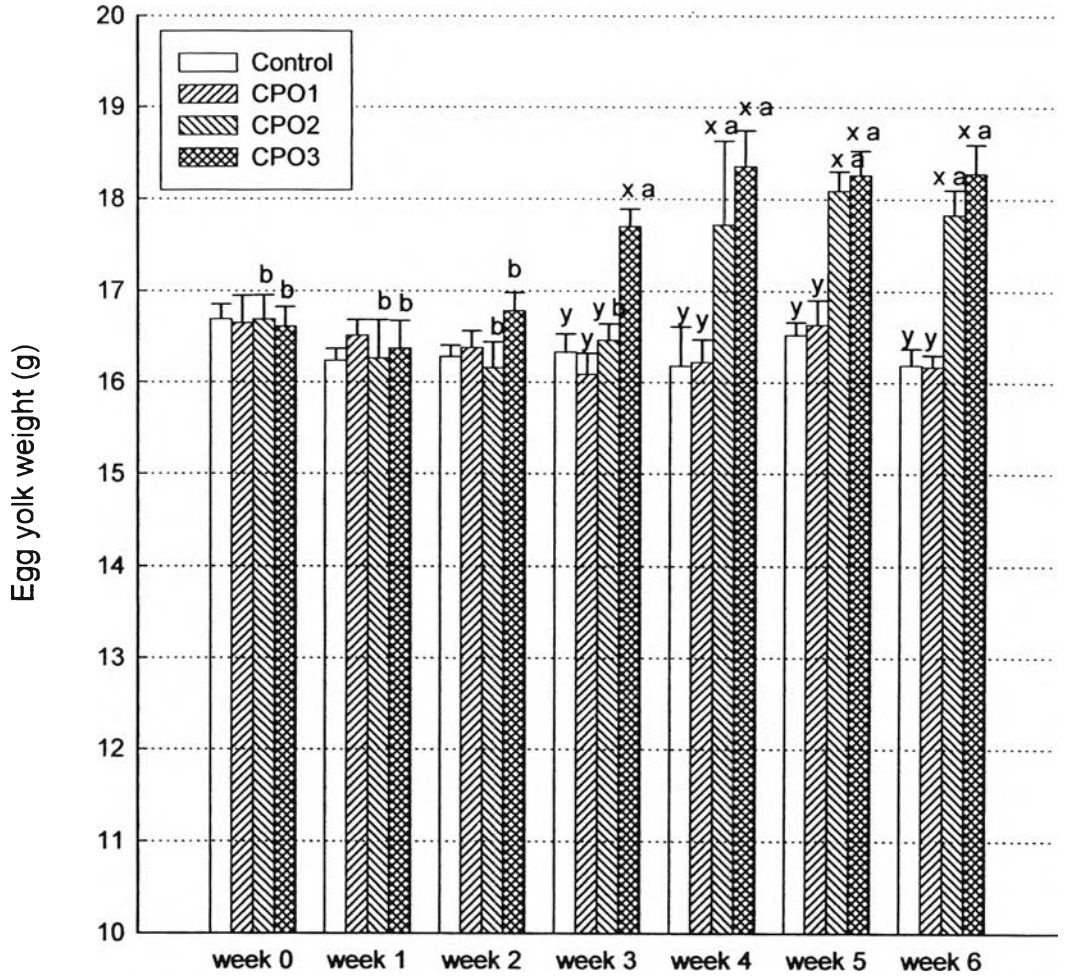
$^{x,y}$ Means within column (different group) with no common superscript differ significantly ($P<0.05$).




$^{x, y}$ Different superscripts of means in the same week are significantly different ($P<0.05$).

$^{a, b}$ Different superscripts of means in the same group in various weeks are significantly different ($P<0.05$).

**Figure 4.2** Effect of crude palm oil on egg weight.




[x, y] Different superscripts of means in the same week are significantly different (P<0.05).

[a, b] Different superscripts of means in the same group in various weeks are significantly different (P<0.05).

**Figure 4.3** Effect of crude palm oil on egg yolk weight.

Table 4.8 Effect of crude palm oil on percentage of egg yolk, albumin and egg shell.

| Parameter / Treatment group | Week No. 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| **Egg Yolk (%)** | | | | | | | |
| Control | 25.64 ± 0.25 | 24.92 ± 0.22 | 25.05 ± 0.15 | 25.02 ± 0.24$^{y}$ | 24.81 ± 0.51$^{y}$ | 25.30 ± 0.19$^{y}$ | 24.81 ± 0.23$^{y}$ |
| CPO1 | 25.61 ± 0.41 | 25.33 ± 0.27 | 25.06 ± 0.19 | 24.73 ± 0.29$^{y}$ | 24.86 ± 0.26$^{y}$ | 25.47 ± 0.34$^{y}$ | 24.83 ± 0.17$^{y}$ |
| CPO2 | 25.57 ± 0.32$^{b}$ | 24.84 ± 0.47$^{c}$ | 24.81 ± 0.33$^{c}$ | 25.08 ± 0.22$^{y\,c}$ | 26.47 ± 0.85$^{x\,abc}$ | 26.94 ± 0.25$^{x\,a}$ | 26.59 ± 0.34$^{x\,ab}$ |
| CPO3 | 25.51 ± 0.23$^{b}$ | 25.16 ± 0.38$^{b}$ | 25.46 ± 0.26$^{b}$ | 26.46 ± 0.27$^{x\,ab}$ | 27.20 ± 0.15$^{x\,a}$ | 27.10 ± 0.31$^{x\,a}$ | 27.22 ± 0.34$^{x\,a}$ |
| **Egg Shell (%)** | | | | | | | |
| Control | 9.95 ± 0.22 | 9.66 ± 0.23 | 10.01 ± 0.19 | 9.91 ± 0.28 | 9.94 ± 0.13 | 9.79 ± 0.22 | 10.23 ± 0.17 |
| CPO1 | 10.02 ± 0.18 | 9.78 ± 0.17 | 10.19 ± 0.18 | 9.64 ± 0.18 | 9.88 ± 0.25 | 10.11 ± 0.18 | 9.59 ± 0.18 |
| CPO2 | 10.13 ± 0.29 | 9.73 ± 0.27 | 9.71 ± 0.17 | 10.04 ± 0.18 | 10.25 ± 0.21 | 9.88 ± 0.16 | 9.79 ± 0.32 |
| CPO3 | 9.96 ± 0.27 | 9.57 ± 0.26 | 10.04 ± 0.33 | 10.06 ± 0.15 | 10.21 ± 0.22 | 10.11 ± 0.17 | 10.05 ± 0.19 |
| **Albumin (%)** | | | | | | | |
| Control | 64.41 ± 0.28 | 65.43 ± 0.25 | 64.94 ± 0.27 | 65.07 ± 0.40$^{x}$ | 65.25 ± 0.26$^{x}$ | 64.91 ± 0.29$^{x}$ | 64.96 ± 0.26$^{x}$ |
| CPO1 | 64.37 ± 0.49 | 64.89 ± 0.29 | 64.75 ± 0.22 | 65.63 ± 0.38$^{x}$ | 65.27 ± 0.31$^{x}$ | 64.42 ± 0.49$^{x}$ | 65.58 ± 0.33$^{x}$ |
| CPO2 | 64.30 ± 0.49$^{a}$ | 65.43 ± 0.48$^{a}$ | 65.48 ± 0.39$^{a}$ | 64.88 ± 0.26$^{x\,a}$ | 63.28 ± 0.40$^{y\,b}$ | 63.18 ± 0.29$^{y\,b}$ | 63.63 ± 0.59$^{y\,b}$ |
| CPO3 | 64.54 ± 0.40$^{a}$ | 65.27 ± 0.60$^{a}$ | 64.50 ± 0.46$^{a}$ | 63.48 ± 0.24$^{y\,b}$ | 62.59 ± 0.48$^{y\,c}$ | 62.79 ± 0.44$^{y\,c}$ | 62.74 ± 0.37$^{y\,c}$ |

Mean ± SD, n=8, Control = lard 2%, CPO1 = crude palm oil 2%, CPO2= crude palm oil 3%, CPO3 = crude palm oil 4%.

$^{a,b,c}$ Means within row (different time) with no common superscript differ significantly ($P<0.05$).

$^{x,y}$ Means within column (different group)with no common superscript differ significantly ($P<0.05$).

## 4.5 Effect of crude palm oil on egg yolk cholesterol concentration

Egg yolk cholesterol concentrations (mg/yolk weight and mg/g yolk) were not different in both control and all treatment groups in week 0. In control group, egg yolk cholesterol concentrations (mg/yolk weight and mg/g yolk) started to be higher ($P<0.05$) than treatment groups in week 4 to week 6 of the trial are shown in Table 4.9. The egg yolk cholesterol concentration (mg/yolk weight and mg/g yolk) of CPO3 group was lowest ($P<0.05$) compared to other groups (Figure 4.4). It is demonstrated that on weeks 5 and 6, all hens in treatment groups fed on crude palm oil had significantly lower ($P<0.05$) egg yolk cholesterol concentrations (mg/yolk weight and mg/g yolk) than control.

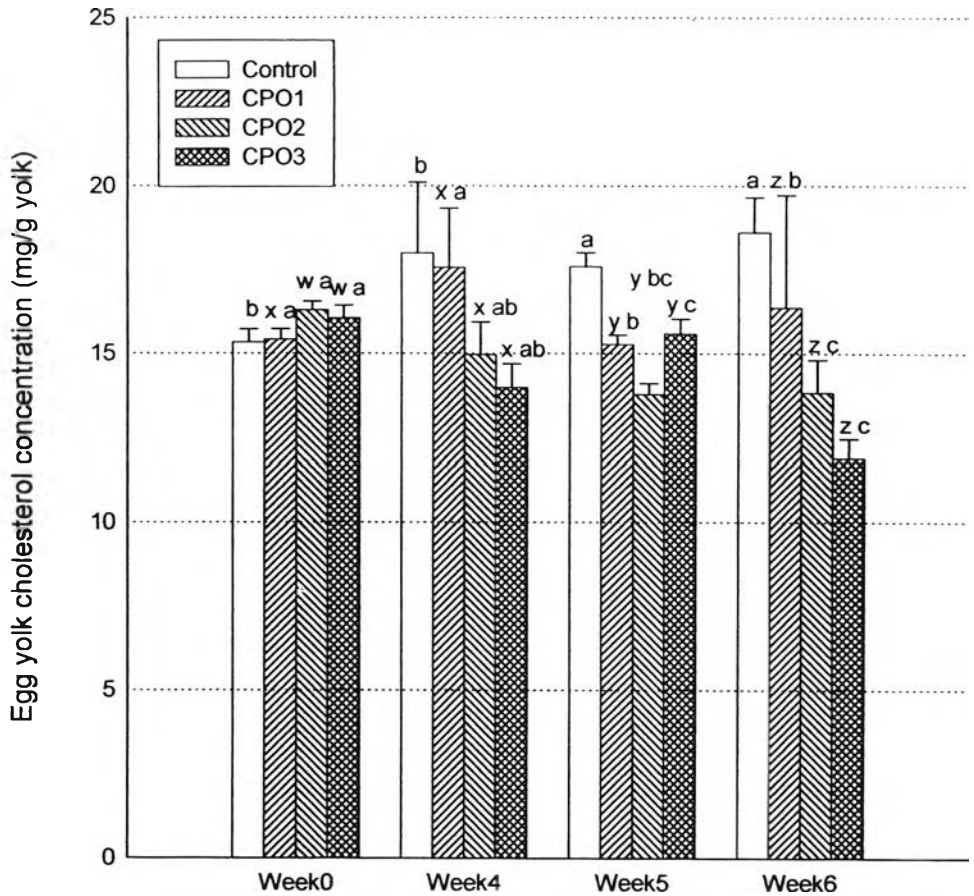
Table 4.9 Effect of crude palm oil on egg yolk cholesterol concentration in experiment II.

| Parameter / Treatment group | Week NO. | | | |
|---|---|---|---|---|
| | Week 0 | Week 4 | Week 5 | Week 6 |
| **Cholesterol concentration (mg/yolk weight)** | | | | |
| Control | $265.11 \pm 5.71^{b}$ | $324.76 \pm 14.57^{x\,a}$ | $347.60 \pm 14.22^{w\,a}$ | $312.27 \pm 10.42^{x\,a}$ |
| CPO1 | $251.19 \pm 4.94$ | $276.65 \pm 10.56^{y}$ | $302.19 \pm 11.50^{x}$ | $271.30 \pm 16.39^{y}$ |
| CPO2 | $244.33 \pm 8.64^{a}$ | $274.09 \pm 5.84^{y\,a}$ | $261.33 \pm 11.99^{y\,a}$ | $220.78 \pm 7.62^{z\,b}$ |
| CPO3 | $251.22 \pm 13.36^{a}$ | $256.12 \pm 7.6s^{y\,a}$ | $219.65 \pm 11.34^{z\,b}$ | $202.68 \pm 5.31^{z\,b}$ |
| **Cholesterol concentration (mg/g yolk)** | | | | |
| Control | $15.33 \pm 0.39^{b}$ | $17.99 \pm 2.11^{x\,a}$ | $17.59 \pm 0.42^{w\,a}$ | $18.61 \pm 1.05^{w\,a}$ |
| CPO1 | $15.41 \pm 0.32^{b}$ | $17.56 \pm 1.77^{x\,a}$ | $15.27 \pm 0.28^{x\,ab}$ | $16.37 \pm 2.35^{x\,ab}$ |
| CPO2 | $16.30 \pm 0.26^{a}$ | $14.96 \pm 0.98^{y\,b}$ | $13.78 \pm 0.33^{y\,bc}$ | $13.84 \pm 0.98^{y\,c}$ |
| CPO3 | $16.06 \pm 0.38^{a}$ | $13.97 \pm 0.72^{z\,b}$ | $11.59 \pm 0.45^{z\,c}$ | $11.89 \pm 0.58^{z\,c}$ |

Mean $\pm$ SD. Control = lard 2%, CPO1 = crude palm oil 2%, CPO2= crude palm oil 3%, CPO3 = crude palm oil 4%.

$^{a,b,c}$ Means within row (different time) with no common superscript differ significantly ($P<0.05$).

$^{x,y}$ Means within column (different group) with no common superscript differ significantly ($P<0.05$).




[w, x, y, z] Different superscripts of means in the same week are significantly different ($P<0.05$).

[a, b, c] Different superscripts of means in the same group in various weeks are significantly different ($P<0.05$).

**Figure 4.4** Effect of crude palm oil on egg yolk cholesterol concentration.

## 4.6 Effect of crude palm oil on tocopherol and tocotrienol concentrations in liver

Hens fed on control diet had higher ($P<0.05$) α-tocopherol and γ-tocopherol concentrations in liver than other groups at the end of experiment (Table 4.10). In contrast, the highest concentration ($P<0.05$) of δ-tocopherol was found in hens fed on 4% CPO at the same time interval (Figure 4.5). Total tocopherol (α-, γ- and δ- tocopherol) concentrations of control group was highest ($P<0.05$) compared to other groups. The total tocopherol concentrations of control, CPO1, CPO2 and CPO3 were 144.88, 69.04, 42.23 and 67.23 μg/g liver, respectively (Table 4.10). It is demonstrated that γ-tocopherol was a major form of vitamin E deposited in liver.

α-Tocotrienol concentration in liver of hens fed 4% CPO were significantly lower ($P<0.05$) than other groups. γ-Tocotrienol (34.42 μg/g liver) concentration in hens fed on control diet was highest ($P<0.05$) compared to other groups (Figure 4.6). δ-tocotrienol (6.40 μg/g liver) concentration in hens fed on 4% CPO was highest ($P<0.05$) compared to other groups. Total tocotrienol concentrations of control and CPO1 groups were significantly higher (61.86 and 61.81 μg/g liver, respectively) other groups. Hens in CPO2 group had the lowest total tocotrienol concentrations in liver ($P<0.05$). It is shown that α- and γ-tocotrienol were major forms of vitamin E deposited in liver.

Tabe 4.10 Effect of crude palm oil on tocopherol and tocotrienol concentrations in liver (μg / g)

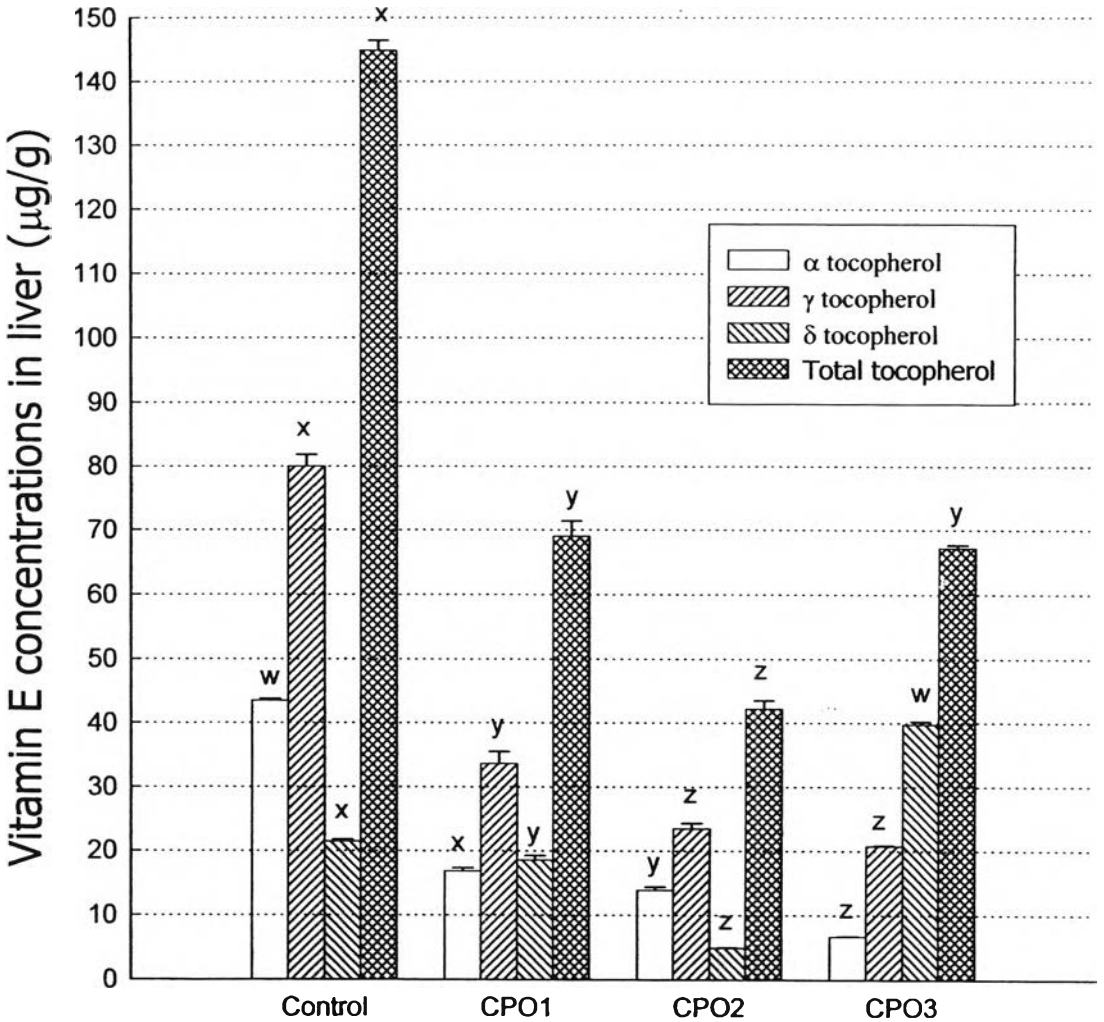
| Treatment | α-T* | γ-T | δ-T | Total-T | α-T3# | γ-T3 | δ-T3 | Total-T3 |
|---|---|---|---|---|---|---|---|---|
| Control | 43.47 ± 0.28$^{w}$ | 79.96 ± 1.85$^{x}$ | 21.44 ± 0.29$^{x}$ | 144.88 ± 1.57$^{x}$ | 23.16 ± 0.22$^{x}$ | 34.42 ± 4.49$^{w}$ | 4.27 ± 0.41$^{y}$ | 61.86 ± 4.38$^{x}$ |
| CPO1 | 16.83 ± 0.51$^{x}$ | 33.66 ± 1.84$^{y}$ | 18.54 ± 0.71$^{y}$ | 69.04 ± 2.39$^{y}$ | 31.60 ± 5.42$^{w}$ | 25.64 ± 1.68$^{x}$ | 4.55 ± 0.21$^{y}$ | 61.81 ± 6.84$^{x}$ |
| CPO2 | 13.88 ± 0.47$^{y}$ | 23.41 ± 0.86$^{z}$ | 4.93 ± 0.06$^{z}$ | 42.23 ± 1.30$^{z}$ | 8.29 ± 0.51$^{y}$ | 5.20 ± 0.34$^{z}$ | 3.82 ± 0.16$^{z}$ | 17.32 ± 0.86$^{z}$ |
| CPO3 | 6.72 ± 0.09$^{z}$ | 20.71 ± 0.10$^{z}$ | 39.79 ± 0.46$^{w}$ | 67.23 ± 0.50$^{y}$ | 6.93 ± 0.11$^{z}$ | 9.57 ± 0.14$^{y}$ | 6.40 ± 0.10$^{x}$ | 22.91 ± 0.32$^{y}$ |

Mean ± SD, n=4, Control = lard 2%, CPO1 = crude palm oil 2%, CPO2 = crude palm oil 3% and CPO3 = crude palm oil 4% in diet.

$^{w, x, y, z}$ Means within column (different group) with no common superscript differ significantly (P<0.05).

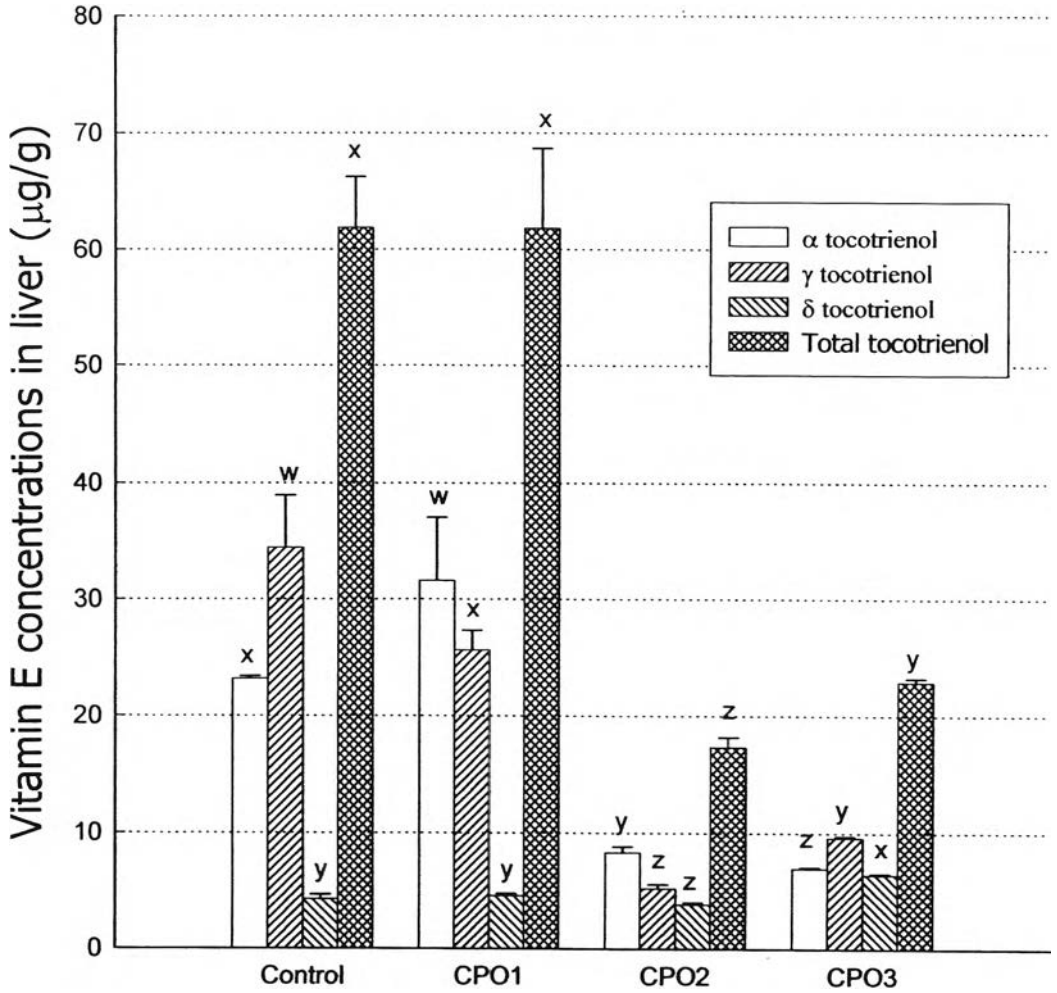
* Tocopherol

# Tocotrienol




$^{w, x, y, z}$ Different superscripts of means in different groups are significantly different ($P<0.05$).

**Figure 4.5** Effect of crude palm oil on tocopherol concentrations in liver.




w, x, y, z Different superscripts of means in different groups are significantly different (P<0.05).

**Figure 4.6** Effect of crude palm oil on tocotrienol concentrations in liver.

## 4.7 Effect of crude palm oil on tocopherol and tocotrienol concentrations in plasma

In week 6 of experiment, hens fed on 2% CPO had higher ($P<0.05$) α-tocopherol concentration in plasma than other groups (Table 4.11). γ-Tocopherol (30.21 μg/ml) and δ-tocopherol (10.73 μg/ml) concentrations of CPO2 group was highest when compared to other groups (Figure 4.7). Total tocopherol concentrations of CPO1 group was highest ($P<0.05$) compared to other groups. The total tocopherol concentrations of CPO1, CPO2, control and CPO3 groups were 98.48, 75.87, 50.55 and 33.59 μg/ml, respectively. It is shown that α-tocopherol was a major form of vitamin E in plasma.

α-Tocotrienol (11.03 μg/ml) concentration in plasma of CPO2 group was significantly higher ($P<0.05$) than other groups (Table 4.11). γ-Tocotrienol (30.28 μg/ml) concentration in hens fed on 4% CPO was highest ($P<0.05$) compared to other groups (Figure 4.8). δ-Tocotrienol (4.77 μg/ml) concentration of hens fed on control diet was significantly higher than hens fed on CPO. Total tocotrienol concentrations of CPO3 group were highest (34.19 μg/ml) when compared to other groups.

Table 4.11 Effect of crude palm oil on tocopherol and tocotrienol concentrations in plasma (μg / ml)

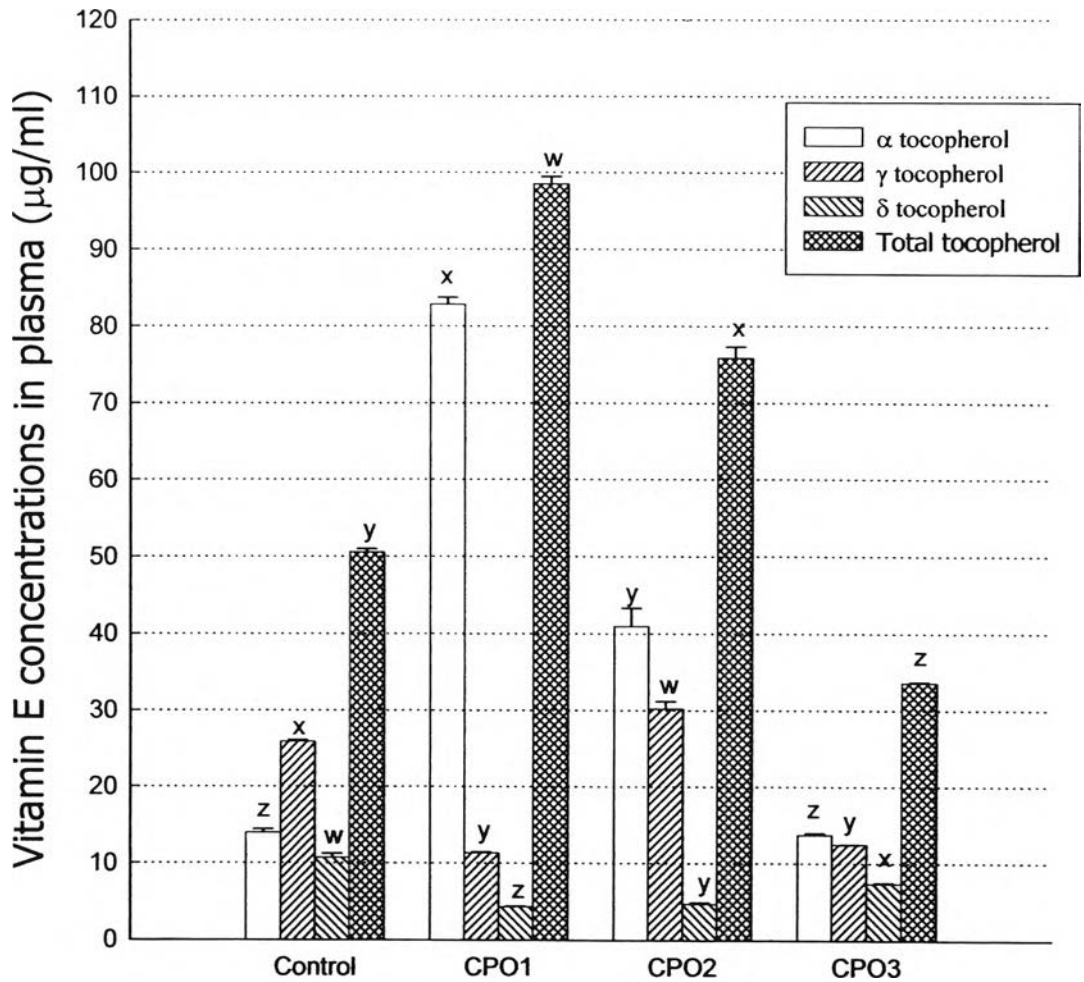
| Treatment | α-T* | γ-T | δ-T | Total-T | α-T3# | γ-T3 | δ-T3 | Total-T3 |
|---|---|---|---|---|---|---|---|---|
| Control | 13.98 ± 0.46$^{z}$ | 25.83 ± 0.22$^{x}$ | 10.73 ± 0.54$^{w}$ | 50.55 ± 0.46$^{y}$ | 3.66 ± 0.09$^{y}$ | 14.64 ± 0.20$^{x}$ | 4.77 ± 0.08$^{w}$ | 23.07 ± 0.25$^{x}$ |
| CPO1 | 82.81 ± 0.94$^{x}$ | 11.33 ± 0.14$^{z}$ | 4.33 ± 0.08$^{z}$ | 98.48 ± 0.96$^{w}$ | 8.02 ± 0.33$^{x}$ | 4.40 ± 0.04$^{z}$ | 1.67 ± 0.02$^{x}$ | 16.83 ± 0.24$^{z}$ |
| CPO2 | 40.94 ± 2.36$^{y}$ | 30.21 ± 0.93$^{w}$ | 4.71 ± 0.21$^{y}$ | 75.87 ± 1.48$^{x}$ | 11.03 ± 0.30$^{w}$ | 8.99 ± 0.06$^{y}$ | 0.84 ± 0.13$^{z}$ | 20.87 ± 0.21$^{y}$ |
| CPO3 | 13.73 ± 0.25$^{z}$ | 12.48 ± 0.01$^{y}$ | 7.38 ± 0.11$^{x}$ | 33.59 ± 0.12$^{z}$ | 2.67 ± 0.01$^{z}$ | 30.28 ± 0.20$^{w}$ | 1.23 ± 0.03$^{y}$ | 34.19 ± 0.21$^{w}$ |

Mean ± SD, n=4, Control = lard 2%, CPO1 = crude palm oil 2%, CPO2 = crude palm oil 3% and CPO3 = crude palm oil 4% in diet.

$^{w, x, y, z}$ Means within column (different group) with no common superscript differ significantly ($P<0.05$).

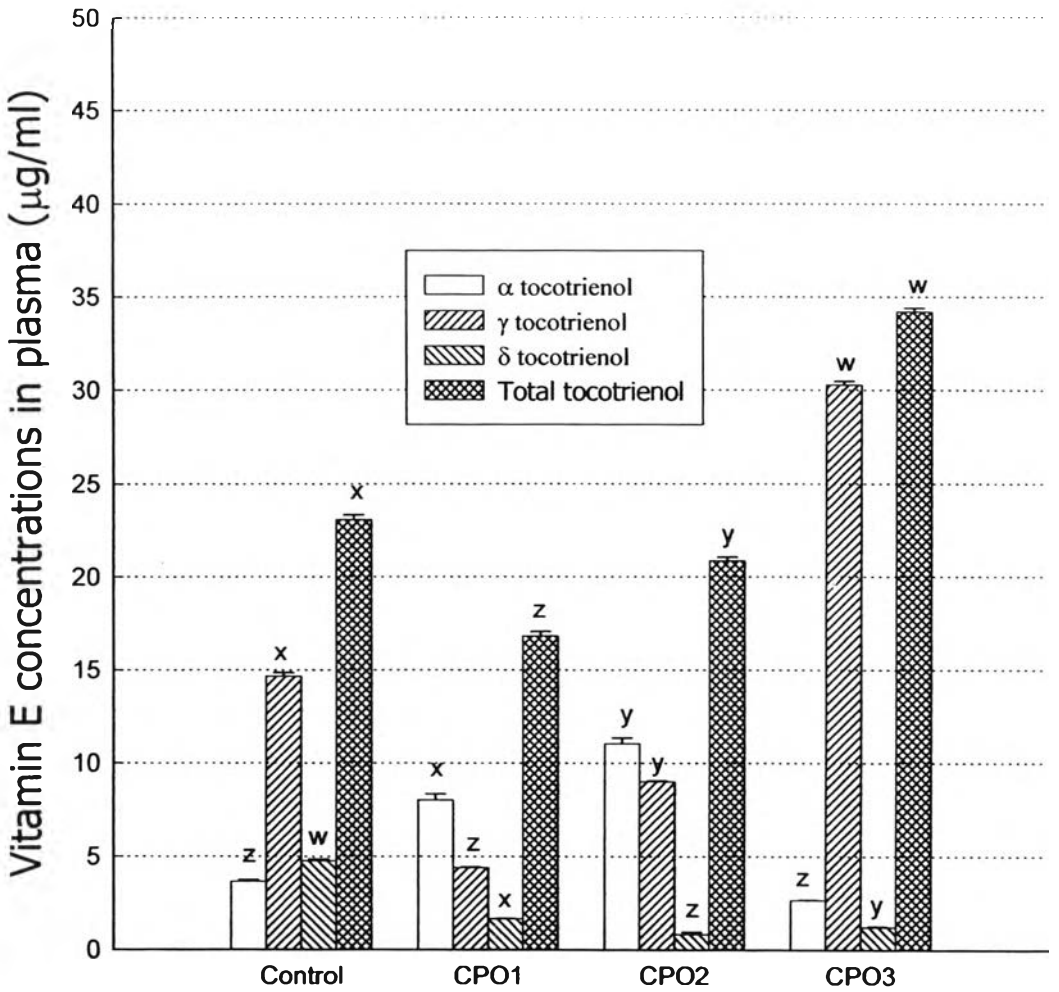
* Tocopherol

# Tocotrienol




$^{w, x, y, z}$ Different superscripts of means in different groups are significantly different ($P<0.05$).

**Figure 4.7** Effect of crude palm oil on tocopherol concentrations in plasma.




$^{w, x, y, z}$ Different superscripts of means in different groups are significantly different ($P<0.05$).

**Figure 4.8** Effect of crude palm oil on tocotrienol concentrations in plasma.

## 4.8 Effect of crude palm oil on tocopherols and tocotrienols in egg yolk

Hens fed on 4% CPO had higher ($P<0.05$) α-tocopherol and δ-tocopherol concentrations in egg yolk than other groups in week 6 of the experiment (Table 4.12). However, the lowest concentration ($P<0.05$) of γ-tocopherol was found in hens fed on CPO at the same time interval (Figure 4.9). Total tocopherol (α-, γ- and δ- tocopherol) concentrations of CPO2 group were highest ($P<0.05$) compared to other groups. The total tocopherol concentration of control, CPO1, CPO2 and CPO3 were 436.11, 484.21, 443.65 and 428.26 μg/g yolk, respectively. It is shown that γ-tocopherol was a major form of vitamin E deposited in egg yolk.

α-Tocotrienol concentration in egg yolk of hens in all treatment groups fed on CPO was significantly greater ($P<0.05$) than hens fed on lard (control group). γ-Tocotrienol (141.51 μg/g yolk) and δ-tocotrienol (2.01 μg/g yolk) concentrations in hen fed on 3% CPO were highest ($P<0.05$) compared to other groups (Table 4.12). Total tocotrienol concentrations of control group were significantly ($P<0.05$) lowest (290.86 μg/g yolk) when compared to other groups. Hens in CPO2 group had the highest total tocotrienols concentration in egg yolk ($P<0.05$), but its was not different from CPO3 group (Figure 4.10). It is shown that α-tocotrienol was a major form of the vitamin E deposited in egg yolk.

Table 4.12 Effects of crude palm oil on tocopherols and tocotrienols concentration in egg yolk (μg / g yolk).

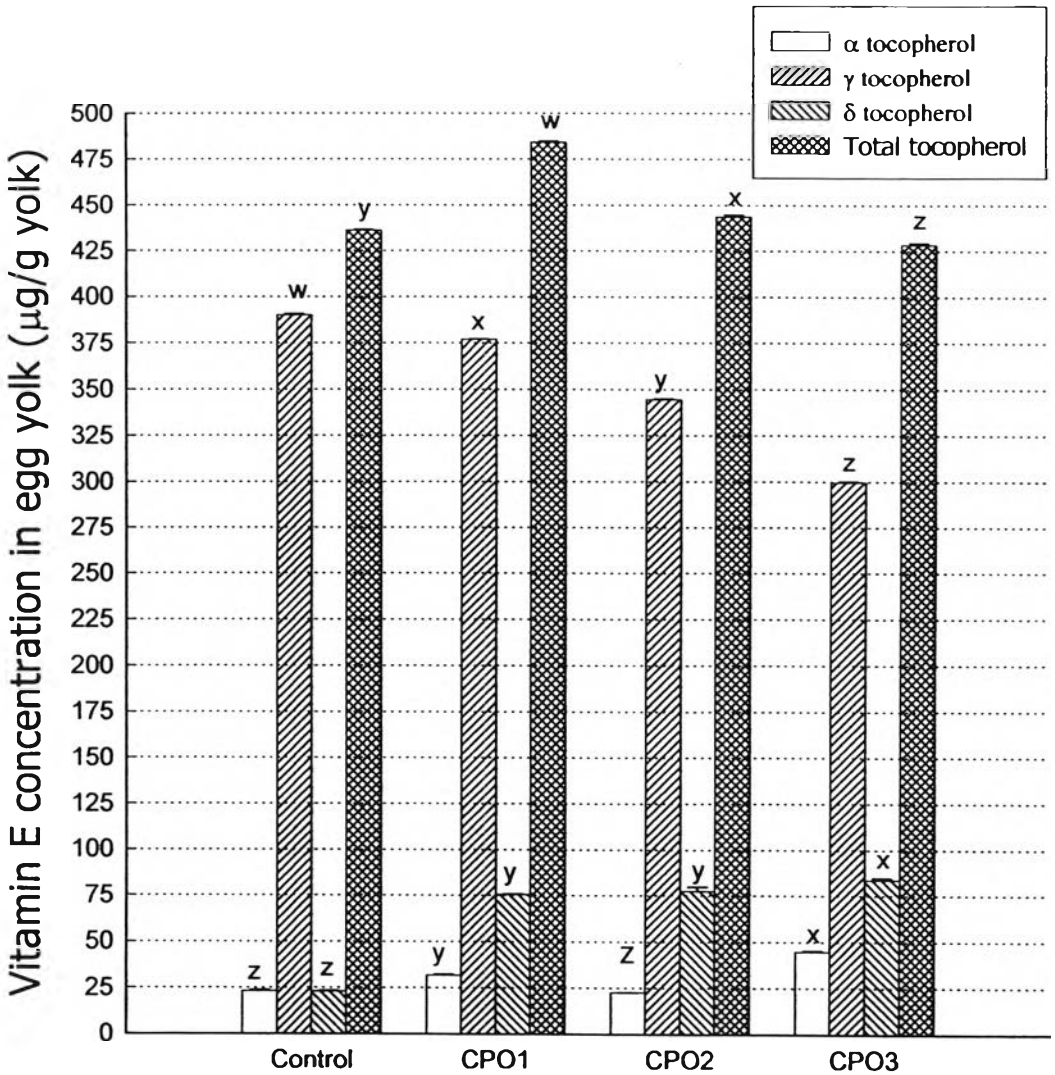
| Treatment | Alpha-T* | Gamma-T | Delta-T | Total-T | Alpha-T3# | Gamma-T3 | Delta-T3 | Total-T3 |
|---|---|---|---|---|---|---|---|---|
| Control | 23.02 ± 0.65$^{z}$ | 390.09 ± 0.44$^{w}$ | 22.89 ± 0.34$^{z}$ | 436.11 ± 0.38$^{y}$ | 164.45 ± 2.00$^{y}$ | 88.27 ± 0.46$^{z}$ | 0.83 ± 0.01$^{z}$ | 290.86 ± 1.95$^{z}$ |
| CPO1 | 31.77 ± 0.52$^{y}$ | 376.83 ± 0.25$^{x}$ | 75.56 ± 0.12$^{y}$ | 484.21 ± 0.44$^{w}$ | 210.70 ± 0.80$^{x}$ | 112.65 ± 0.13$^{y}$ | 1.21 ± 0.08$^{y}$ | 324.48 ± 0.68$^{y}$ |
| CPO2 | 22.54 ± 0.05$^{z}$ | 344.43 ± 0.46$^{y}$ | 77.33 ± 2.36$^{y}$ | 443.65 ± 1.02$^{x}$ | 216.09 ± 1.77$^{x}$ | 141.51 ± 0.20$^{w}$ | 2.01 ± 0.02$^{w}$ | 359.46 ± 1.38$^{x}$ |
| CPO3 | 44.64 ± 0.50$^{x}$ | 299.56 ± 0.58$^{z}$ | 83.54 ± 1.01$^{x}$ | 428.26 ± 1.06$^{z}$ | 221.36 ± 1.78$^{x}$ | 125.34 ± 0.33$^{x}$ | 1.68 ± 0.09$^{x}$ | 348.00 ± 1.54$^{x}$ |

Mean ± SD, n=4, Control = lard 2%, CPO1 = crude palm oil 2%, CPO2 = crude palm oil 3% and CPO3 = crude palm oil 4% in diet.

$^{w,x,y,z}$ Means within column (different group) with no common superscript differ significantly ($P<0.05$).

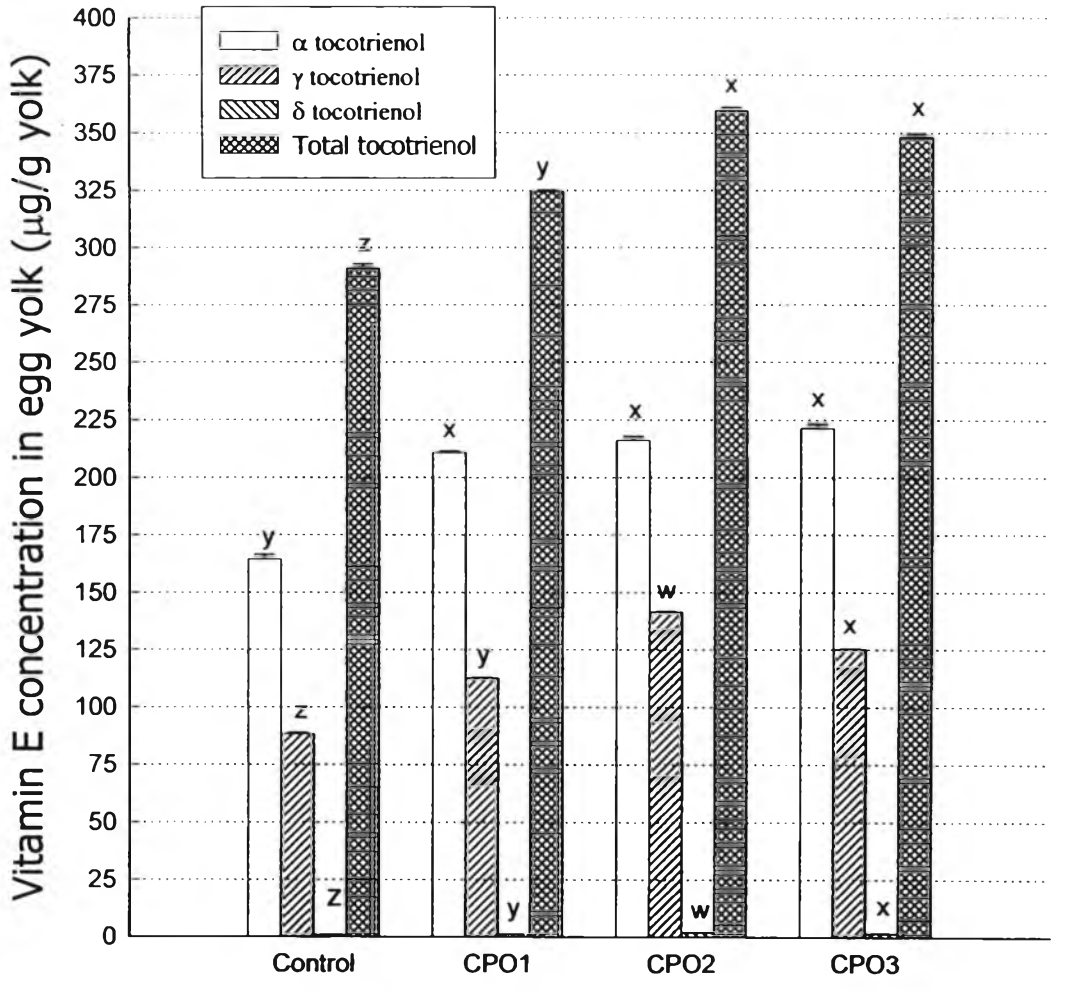
* Tocopherol

# Tocotrienol




[w, x, y, z] Different superscripts of means in different groups are significantly different (P<0.05).

**Figure 4.9** Effect of crude palm oil on tocopherol concentrations in egg yolk.




$^{w, x, y, z}$ Different superscripts of means in different groups are significantly different ($P<0.05$).

**Figure 4.10** Effect of crude palm oil on tocotrienol concentrations in egg yolk.

## 4.9 Effect of crude palm oil on tocopherol and tocotrienol concentrations in adipose tissue

α-Tocopherol and δ-tocopherol concentrations in hens fed on CPO were higher ($P<0.05$) than hens fed on control diet (Table 4.13). α-Tocopherol concentration in adipose tissue of hens in CPO2 group was significantly higher than other groups. δ-Tocopherol concentration in adipose tissue of CPO1 group was highest ($P<0.05$). γ-Tocopherol concentration (860.58 μg/g adipose tissue) in adipose tissue of hens fed on control diet was significantly higher than hens fed on CPO (Figure 4.11). Total tocopherol (α-, γ- and δ-tocopherol) concentration of control group was highest ($P<0.05$) compared to other groups. The total tocopherol concentrations of control, CPO1, CPO2 and CPO3 groups were 931.43, 828.45, 648.34 and 640.81 μg/g adipose tissue, respectively. It is demonstrated that γ-tocopherol was a major form vitamin E deposited in adipose tissue.

Hens fed on 4% CPO had higher ($P<0.05$) α-, γ- and δ- tocotrienol (1,275.10, 1,500.31 and 303.67 μg/g adipose tissue, respectively) concentrations in adipose tissue higher ($P<0.05$) than other groups at the end of experiment (Table 4.13). In contrast, the lowest concentrations ($P<0.05$) of α-, γ- and δ- tocotrienol (63.63, 180.46 and 33.87 μg/g adipose tissue, respectively) were found in hens fed on control diet at the same time interval. Total tocotrienol concentrations of CPO3 group were highest (3,079.80 μg/g adipose tissue) when compared to other groups. It is shown that γ-tocotrienol was a major form of the vitamin E deposited in adipose tissue (Figure 4.12).

Table 4.13 Effect of crude palm oil on tocopherol and tocotrienol in adipose tissue (μg/g).

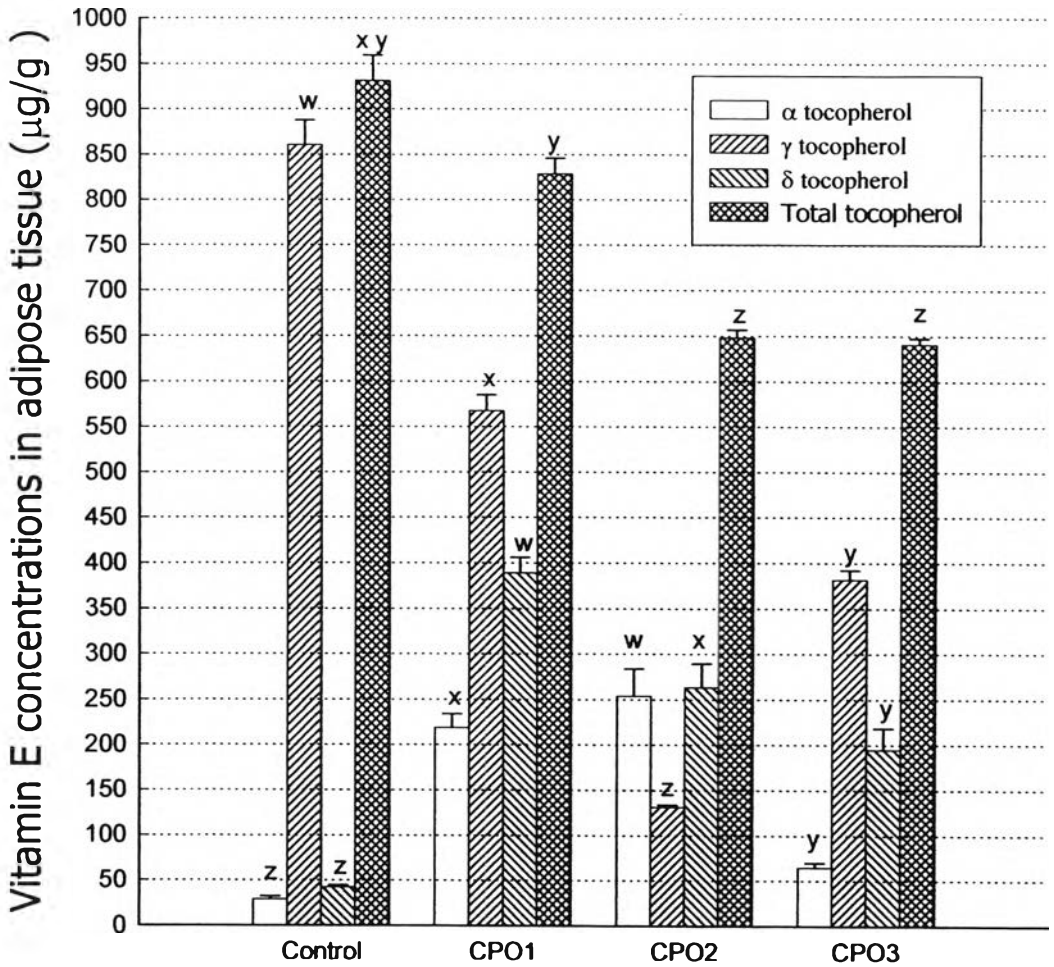
| Treatment | α-T* | γ-T | δ-T | Total-T | α-T3# | γ-T3 | δ-T3 | Total-T3 |
|---|---|---|---|---|---|---|---|---|
| Control | 28.61 ± 3.74$^{z}$ | 860.58 ± 26.93$^{w}$ | 42.24 ± 2.29$^{z}$ | 931.43 ± 27.91$^{x}$ | 63.63 ± 1.67$^{z}$ | 180.46 ± 2.58$^{z}$ | 33.87 ± 1.87$^{z}$ | 277.97 ± 4.32$^{z}$ |
| CPO1 | 218.70 ± 15.24$^{x}$ | 567.51 ± 17.33$^{x}$ | 388.83 ± 17.11$^{w}$ | 828.45 ± 17.37$^{y}$ | 774.01 ± 12.14$^{x}$ | 647.60 ± 5.16$^{x}$ | 254.76 ± 2.17$^{x}$ | 1676.38 ± 8.37$^{x}$ |
| CPO2 | 253.83 ± 29.98$^{w}$ | 131.21 ± 2.45$^{z}$ | 263.29 ± 26.01$^{x}$ | 648.34 ± 8.30$^{z}$ | 629.71 ± 40.56$^{y}$ | 507.86 ± 5.71$^{y}$ | 117.142 ± 4.23$^{y}$ | 1254.72 ± 27.59$^{y}$ |
| CPO3 | 64.50 ± 5.16$^{y}$ | 381.58 ± 10.60$^{y}$ | 194.73 ± 23.53$^{y}$ | 640.81 ± 6.47$^{z}$ | 1275.10 ± 6.34$^{w}$ | 1500.31 ± 16.69$^{w}$ | 303.67 ± 6.11$^{w}$ | 3079.08 ± 15.88$^{w}$ |

Mean ± SD, n=4, Control = lard 2%, CPO1 = crude palm oil 2%, CPO2 = crude palm oil 3% and CPO3 = crude palm oil 4% in diet.

$^{w, x, y, z}$ Means within column (different group) with no common superscript differ significantly ($P<0.05$).

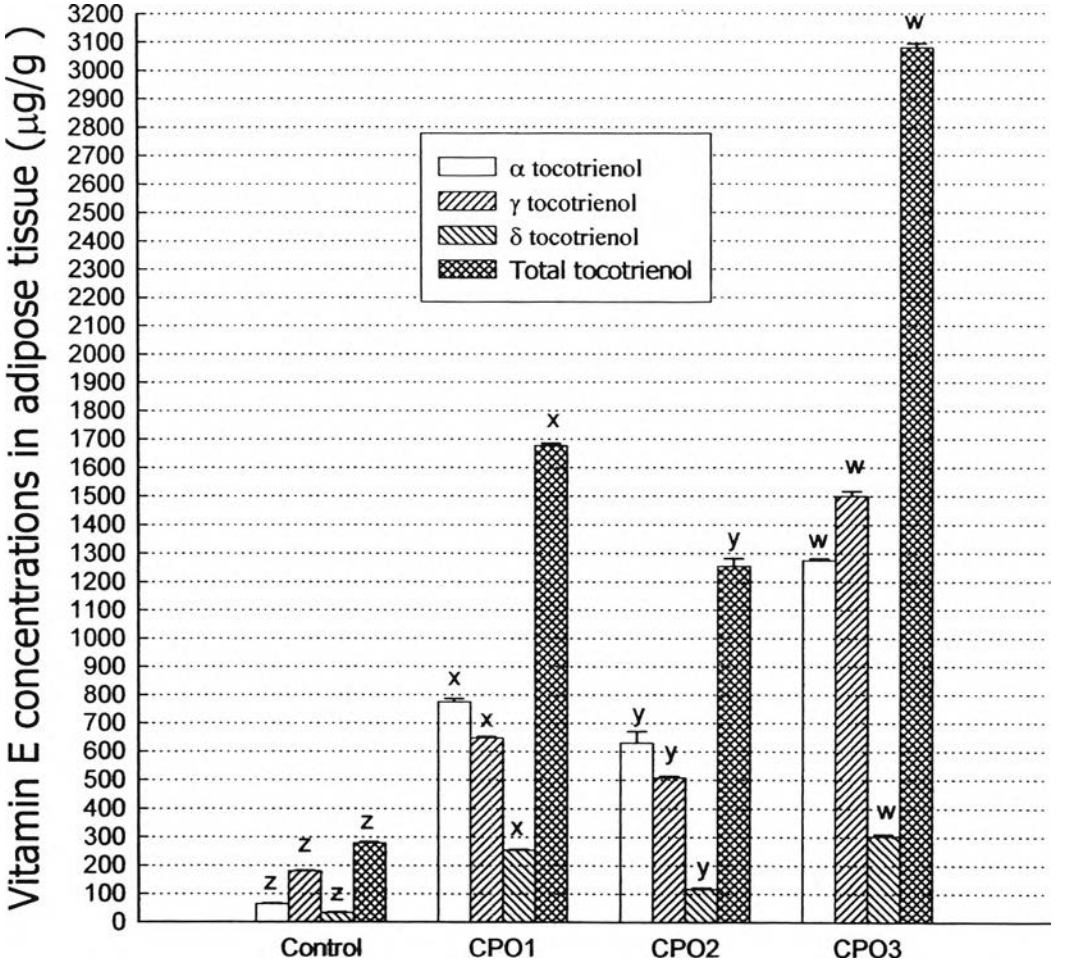
* Tocopherol

# Tocotrienol




[w, x, y, z] Different superscripts of means in different groups are significantly different ($P<0.05$).

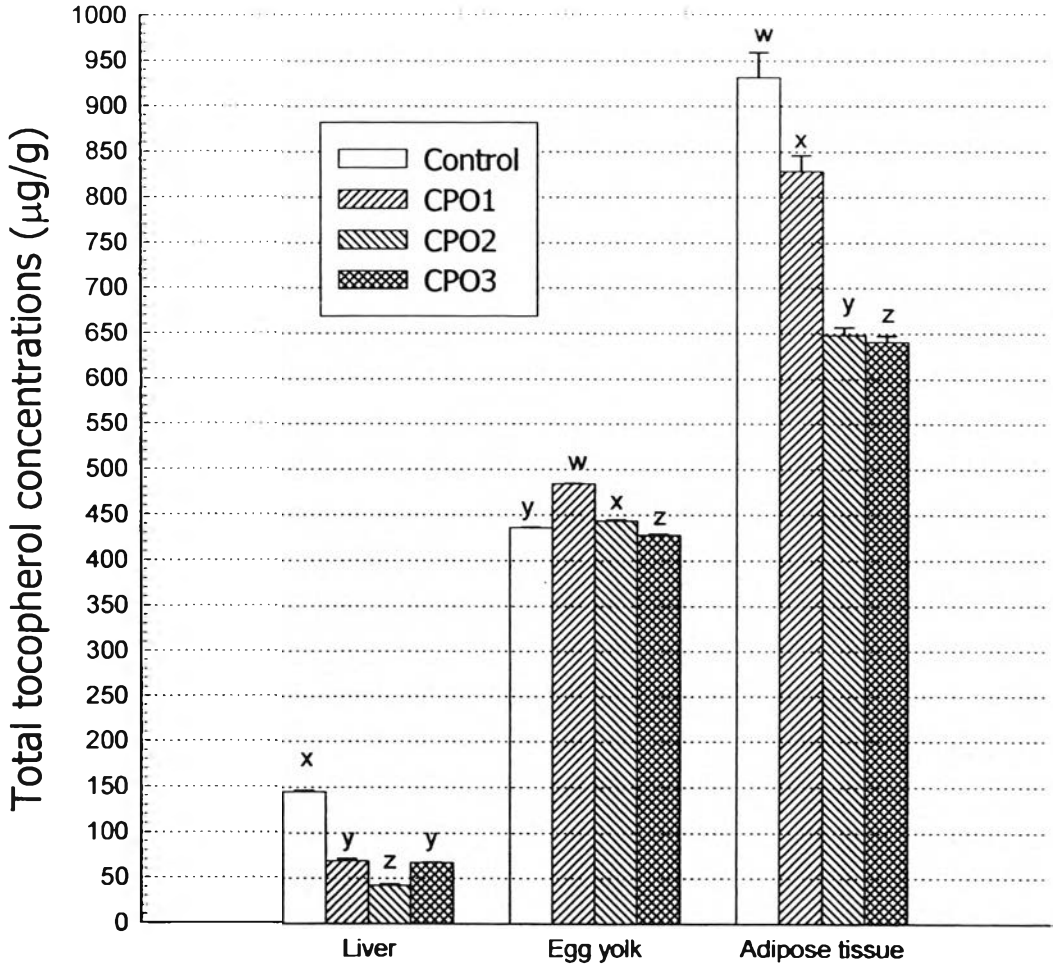
**Figure 4.11** Effect of crude palm oil on tocopherol concentrations in adipose tissue.




$^{w, x, y, z}$ Different superscripts of means in different groups are significantly different ($P<0.05$).

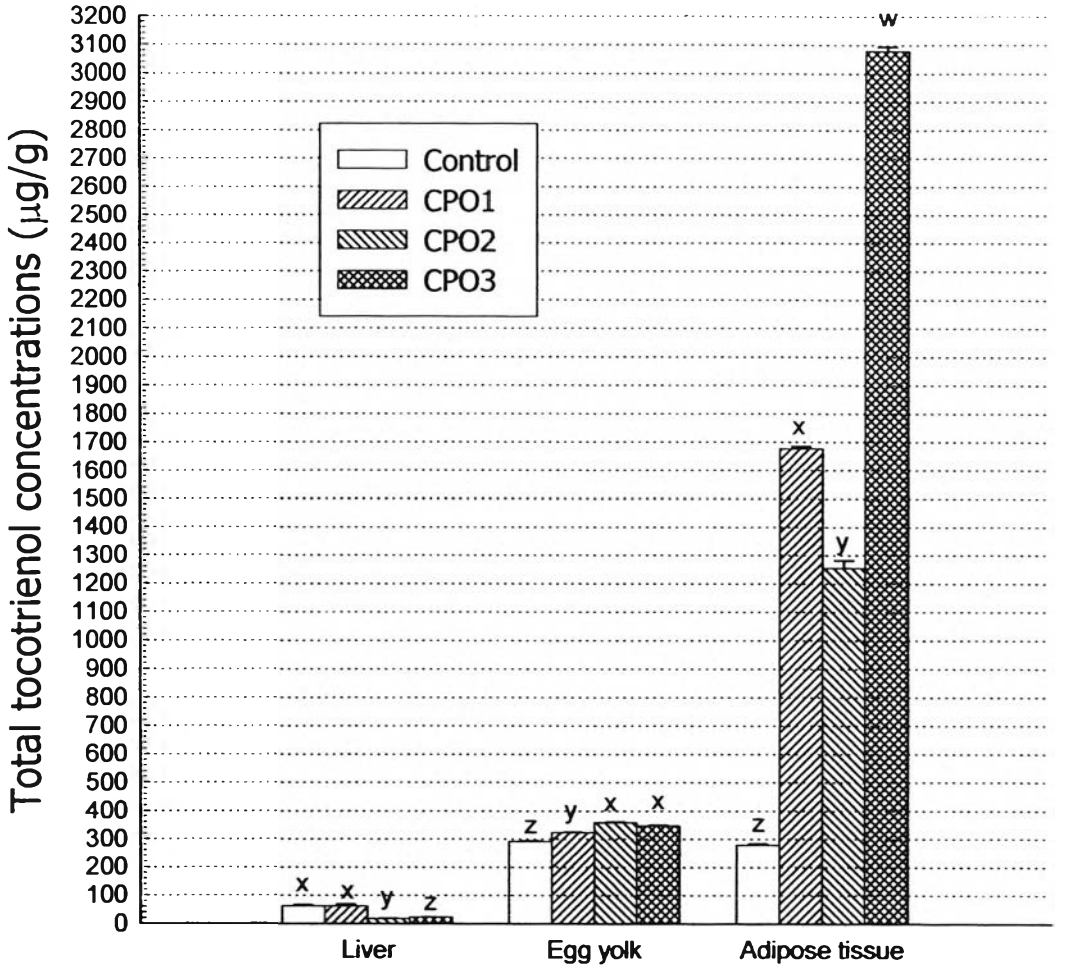
**Figure 4.12** Effect of crude palm oil on tocotrienol concentrations in adipose tissue.

The result in this study demonstrated that total tocopherol concentrations of all groups were deposited highest in adipose tissue, egg yolk and liver, respectively as shown in Figure 4.13. Total tocotrienol concentrations were highest deposited in both egg yolk and adipose tissue but found in the lowest amount in liver of hen fed on CPO diets (Figure 4.14).




$^{w, x, y, z}$ Different superscripts of means in different groups are significantly different ($P<0.05$).

**Figure 4.13** Effect of crude palm oil on tocopherol concentrations in egg yolk and tissues.




$^{w, x, y, z}$ Different superscripts of means in different groups are significantly different ($P<0.05$).

**Figure 4.14** Effect of crude palm oil on tocotrienol concentrations in egg yolk and tissues.