***Table 1SM****: Raw data for carotenoids and vitamins (nmol/ml) in plasma throughout the study. The effects were provided by the models (see Table 2). TxC: Time x carotenoid interaction; ns: No significant differences (P> 0.10). Sample size: time 0: n= 173; time 48: n= 173; and time 82: n= 86 (in time 82, diquat birds were discarded, see Methods).*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Time** | **Control (mean ± SD)** | **Ast (mean ± SD)** | **LutZea (mean ± SD)** | **ZeaLut (mean ± SD)** | **Effect** |
| ***Lutein*** |  | 0 | 22.57 ± 5.45 | 21.52 ± 5.54 | 20.34 ± 6.42 | 20.16 ± 6.38 | TxC |
| 48 | 10.68 ± 2.87 | 6.56 ± 1.48 | 16.09 ± 6.10 | 12.65 ± 3.98 |
| 82 | 9.48 ± 1.69 | 6.52 ± 0.75 | 16.86 ± 3.55 | 13.74 ± 2.45 |
| ***Zeaxanthin*** |  | 0 | 10.96 ± 2.32 | 10.64 ± 1.74 | 10.33 ± 2.46 | 10.06 ± 2.30 | TxC |
| 48 | 7.64 ± 1.99 | 6.25 ± 1.58 | 13.37 ± 5.13 | 24.37 ± 9.20 |
| 82 | 6.74 ± 1.07 | 6.59 ± 0.93 | 13.56 ± 3.28 | 25.88 ± 5.07 |
| ***Tocopherol*** |  | 0 | 22.35 ± 9.67 | 22.73 ± 6.66 | 21.18 ± 8.15 | 21.37 ± 9.49 | TxC |
| 48 | 9.08 ± 3.29 | 9.30 ± 3.24 | 10.50 ± 4.65 | 11.83 ± 4.70 |
| 82 | 11.02 ± 2.68 | 11.02 ± 2.56 | 12.60 ± 3.63 | 14.91 ± 3.99 |
| ***Retinol*** |  | 0 | 23.89 ± 3.22 | 24.05 ± 4.21 | 24.08 ± 4.45 | 22.92 ± 3.57 | ns |
| 48 | 22.11 ± 3.42 | 23.32 ± 3.62 | 23.78 ± 4.56 | 23.80 ± 4.49 |
| 82 | 25.74 ± 4.71 | 27.59 ± 4.44 | 27.01 ± 3.94 | 27.42 ± 4.38 |



***Table 2SM:*** *Raw data for carotenoids and vitamins (nmol/g) in ornaments after the diquat exposure. The effects were provided by the models (see Tables 3 and 4). C: Carotenoid supplement group; DxC: Diquat x carotenoid interaction; D: Diquat treatment; S: Sex.*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | ***Control* (mean ± SD))** | ***Ast* (mean ± SD)** | ***LutZea* (mean ± SD)** | ***ZeaLut***  **(mean ± SD)** | ***Effect*** |
| ***Eye rings*** | *Astaxanthin* | Control | 2671.7 ± 1000.6 | 2929.98 ± 1029.1 | 3987.5 ± 1635.3 | 5012.2 ± 2032 | DxC |
| Diquat | 2716.2 ± 956.1 | 2400.80 ± 1037.1 | 3638.7 ± 1901.8 | 6213.2 ± 2702.5 |
| *Papilioerythrinone* | Control | 36.09 ± 33.51 | 28.92 ± 29.43 | 71.93 ± 57.09 | 76.36 ± 66.32 | C, S |
| Diquat | 30.63 ± 22.42 | 19.88 ± 13.40 | 66.37 ± 61.52 | 86.04 ± 88.14 |
| *Tocopherol* | Control | 61.25 ± 68.85 | 62.12 ± 23.49 | 45.10 ± 18.32 | 54.61 ± 20.44 | DxC |
| Diquat | 39.21 ± 15.31 | 50.25 ± 16.65 | 45.48 ± 14.22 | 58.56 ± 19.50 |
| ***Bill*** | *Astaxanthin* | Control | 3456.1 ± 1404.6 | 2513.1 ± 1154.3 | 6999.7 ± 2873.8 | 8237.01 ± 4124.8 | DxC |
| Diquat | 3538.3 ± 1948.3 | 2564.01 ± 1333.2 | 4968.8 ± 2440.3 | 9686.5 ± 4264.1 |
| *Papilioerythrinone* | Control | 28.77 ± 20.77 | 13.55 ± 16.87 | 118.48 ± 92.03 | 62.54 ± 47.37 | C, S |
| Diquat | 24.75 ± 15.26 | 10.64 ± 10.28 | 64.66 ± 54.81 | 71.31 ± 49.58 |
| *Tocopherol* | Control | 84.42 ± 20.90 | 88.06 ± 23.40 | 91.98 ± 26.96 | 82.22 ± 26.64 | DxC |
| Diquat | 65.46 ± 25.05 | 87.06 ± 28.84 | 71.20 ± 30.59 | 89.90 ± 28.68 |
| ***Legs*** | *Astaxanthin* | Control | 1965.7 ± 1044.1 | 1896.8 ± 876.1 | 2282.23 ± 836.22 | 3070.7 ± 1386.6 | C, S |
| Diquat | 1707.6 ± 781.76 | 1666.6 ± 1103.5 | 2212.7 ± 864.2 | 3057.5 ± 1605.02 |
| *Papilioerythrinone* | Control | 46.89 ± 32.64 | 42.68 ± 40.96 | 56.58 ± 23.59 | 52.29 ± 37.38 | C, S |
| Diquat | 33.22 ± 18.10 | 38.19 ± 44.72 | 69.77 ± 55.15 | 64.08 ± 109.1 |
| *Tocopherol* | Control | 28.74 ± 10.48 | 31.20 ± 7.18 | 25.95 ± 8.06 | 32.52 ± 12.26 | C, S |
| Diquat | 23.98 ± 9.32 | 26.34 ± 10.74 | 26.80 ± 13.98 | 34.71 ± 15.80 |

***Table 3SM****: Raw data for carotenoids and vitamins in plasma (nmol/mL), liver and fat (nmol/g) after the diquat exposure. The effects were provided by the models (see Tables 3 and 4). C: Carotenoid supplement group; DxC: Diquat x carotenoid interaction; S: Sex; ns: No significant differences.*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | **Control (mean ± SD)** | **Ast (mean ± SD)** | **LutZea (mean ± SD)** | **ZeaLut (mean ± SD)** | **Effect** |
| ***Plasma*** | *Lutein* | Control | 9.48 ± 1.69 | 6.52 ± 0.75 | 16.86 ± 3.55 | 13.74 ± 2.45 | C |
| Diquat | 9.45 ± 1.66 | 6.55 ± 0.77 | 15.03 ± 4.23 | 12.80 ± 2.67 |
| *Zeaxanthin* | Control | 6.74 ± 1.07 | 6.59 ± 0.93 | 13.56 ± 3.28 | 25.88 ± 5.07 | C |
| Diquat | 6.79 ± 1.09 | 6.82 ± 1.31 | 12.66 ± 4.46 | 24.52 ± 6.12 |
| *Retinol* | Control | 25.74 ± 4.71 | 27.59 ± 4.44 | 27.01 ± 3.94 | 27.42 ± 4.38 | ns |
| Diquat | 24.71 ± 4.41 | 26.07 ± 3.94 | 26.86 ± 3.02 | 27.45 ± 4.19 |
| *Tocopherol* | Control | 11.02 ± 2.68 | 11.02 ± 2.56 | 12.60 ± 3.63 | 14.91 ± 3.99 | C, D |
| Diquat | 9.46 ± 3.65 | 11.14 ± 4.04 | 11.97 ± 3.95 | 13.71 ± 3.89 |
| ***Liver*** | *Lutein* | Control | 5.75 ± 0.49 | 4.86 ± 0.36 | 8.31 ± 1.54 | 8.82 ± 1.99 | C |
| Diquat | 5.70 ± 0.63 | 4.83 ± 0.39 | 8.14 ± 1.80 | 8.20 ± 2.22 |
| *Zeaxanthin* | Control | 4.16 ± 0.34 | 4.11 ± 0.48 | 6.52 ± 1.23 | 14.21 ± 3.80 | DxC |
| Diquat | 4.11 ± 0.38 | 4.12 ± 0.53 | 6.29 ± 1.35 | 12.84 ± 4.45 |
| *Total vitamin A* | Control | 389.28 ± 245.49 | 1392.40 ± 490.99 | 679.07 ± 237.45 | 814.33 ± 325.32 | C, S |
| Diquat | 449.32 ± 297.65 | 1374.66 ± 682.11 | 618.66 ± 269.50 | 765.81 ± 399.72 |
| *Tocopherol* | Control | 6.02 ± 1.69 | 6.67 ± 2.67 | 6.75 ± 2.66 | 9.03 ± 2.52 | DxC |
| Diquat | 4.71 ± 1.05 | 6.45 ± 2.68 | 6.65 ± 2.63 | 8.10 ± 3.76 |
| ***Fat*** | *Lutein* | Control | 17.74 ± 12.92 | 21.78 ± 13.77 | 25.31 ± 12.53 | 18.54 ± 13.63 | C |
| Diquat | 18.19 ± 11.16 | 19.95 ± 9.77 | 20.79 ± 16.24 | 21.46 ± 13.70 |
| *Zeaxanthin* | Control | 11.56 ± 8.25 | 15.37 ± 9.46 | 16.30 ± 7.63 | 16.07 ± 11.12 | C |
| Diquat | 11.98 ± 7.17 | 14.43 ± 6.98 | 13.89 ± 10.51 | 18.75 ± 11.71 |
| *Retinol* | Control | 87.09 ± 64.70 | 196.73 ± 108.90 | 149.17 ± 79.36 | 108.26 ± 86.98 | C |
| Diquat | 98.36 ± 65.76 | 179.52 ± 99.98 | 116.00 ± 99.21 | 131.30 ± 90.95 |
| *Tocopherol* | Control | 381.21 ± 392.46 | 489.32 ± 599.44 | 328.65 ± 297.64 | 319.61 ± 260.11 | ns |
| Diquat | 267.97 ± 283.51 | 396.92 ± 341.49 | 318.61 ± 378.15 | 373.70 ± 384.49 |

***Table 4SM****: Raw data for oxidative stress biomarkers in blood and other tissues at the end of the study after diquat treatment. The effects were provided by the models (see Tables 3 and 4). C: Group of carotenoid supplement; D: Diquat treatment; DxCxS; Diquat x carotenoid x sex interaction; DxS: Diquat x Sex interaction.*

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Sex** |  | **Control (mean ± SD)** | | | **Ast (mean ± SD)** | | | **LutZea (mean ± SD)** | | | **ZeaLut (mean ± SD)** | | | **Effect** |
| ***Resistance to oxidative stress***  ***in erythrocytes (min)*** |  | Control | 60.05 | ± | 9.63 | 64.25 | ± | 17.04 | 61.50 | ± | 11.78 | 57.89 | ± | 11.38 | D |
|  | Diquat | 60.69 | ± | 14.32 | 56.18 | ± | 12.11 | 54.37 | ± | 10.39 | 55.87 | ± | 9.23 |
| ***Plasma MDA (µM)*** | Male | Control | 3.195 | ± | 0.617 | 3.048 | ± | 1.007 | 3.501 | ± | 0.774 | 3.340 | ± | 1.509 | DxS |
| Diquat | 3.262 | ± | 0.988 | 4.067 | ± | 0625 | 3.472 | ± | 0.780 | 3.812 | ± | 0.934 |
| Female | Control | 3.783 | ± | 1.632 | 3.270 | ± | 0.910 | 3.075 | ± | 1.176 | 3.129 | ± | 1.123 |
| Diquat | 4.329 | ± | 1.958 | 4.399 | ± | 2.436 | 4.880 | ± | 3.599 | 5.206 | ± | 3.912 |
| ***PLAOX (mmol/L)*** | Male | Control | 0.531 | ± | 0.218 | 0.650 | ± | 0.181 | 0.580 | ± | 0.260 | 0.651 | ± | 1.509 | DxCxS |
| Diquat | 0.510 | ± | 0.116 | 0.785 | ± | 0.164 | 0.548 | ± | 0.151 | 0.605 | ± | 0.255 |
| Female | Control | 0.499 | ± | 0.171 | 0.530 | ± | 0.215 | 0.601 | ± | 0152 | 0.568 | ± | 0.161 |
| Diquat | 0.546 | ± | 0.254 | 0.575 | ± | 0.213 | 0.564 | ± | 0.214 | 0.517 | ± | 0.144 |
| ***Liver MDA  (µmol/g)*** | Male | Control | 0.026 | ± | 0.007 | 0.023 | ± | 0.010 | 0.026 | ± | 0.005 | 0.024 | ± | 0.005 | DxCxS |
| Diquat | 0.023 | ± | 0.006 | 0.023 | ± | 0.007 | 0.025 | ± | 0.007 | 0.026 | ± | 0.007 |
| Female | Control | 0.025 | ± | 0.007 | 0.034 | ± | 0.010 | 0.033 | ± | 0.014 | 0.028 | ± | 0.004 |
| Diquat | 0.032 | ± | 0.006 | 0.030 | ± | 0.012 | 0.024 | ± | 0.007 | 0.028 | ± | 0.010 |
| ***Heart MDA (µmol/g)*** |  | Control | 0.025 | ± | 0.005 | 0.023 | ± | 0.007 | 0.027 | ± | 0.01 | 0.026 | ± | 0.011 | C |
|  | Diquat | 0.024 | ± | 0.005 | 0.027 | ± | 0.005 | 0.023 | ± | 0.006 | 0.024 | ± | 0.005 |