Table S1. Gene accession numbers and primer sequences for transcript targets

Gene	Forward Primer	Reverse Primer	Accession Number	Product length
sod1	TGGTCCTGTGAAGCTGATTG	TTGTCAGCTCCTGCAGTCAC	AF469663.1	201
sod2	TCCCTGACCTGACCTACGAC	GGCCTCCTCCATTAAACCTC	CA352127.1	201
gpx1a	AATGTGGCGTCACTCTGAGG	CAATTCTCCTGATGGCCAAA	HE687021	131
gpx1b1	CGAGCTCCATGAACGGTACG	TGCTTCCCGTTCACATCCAC	CA357669.1	183
gpx1b2	TCGGACATCAGGAGAACTGC	TCCTTCCCATTCACATCCAC	HE687023	121
cat	TGATGTCACACAGGTGCGTA	GTGGGCTCAGTGTTGTTGAG	BX087110.3	195
gr	CTAAGCGCAGCGTCATAGTG	ACACCCCTGTCTGACGACAT	CA368976.1	108
gst	TCGCTGACTGGACGAAAGGA	CGAAGGTCCTCAACGCCATC	BX302932.3	196
b-actin	GCCGGCCGCGACCTCACAGACTAC	CGGCCGTGGTGGTGAAGCTGTAAC	AF157514	73
elf1a	TTAAGCAACCATGGGAAAGG	TACCTGCCGGTCTCAAACTT	NM_001124339	264

Abbreviations: sod: superoxide dismutase; gpx: glutathione peroxidase; cat: catalase, gr: glutathione reductase; gst: glutathione S-transferase; b-actin: beta-actin; elf: elongation factor.

Table S2. Correlations between astaxanthin concentrations and MDA and GSH concentrations and antioxidant enzyme activities in the muscle and liver of rainbow trout

	Diets[1]		MDA[3]	GSH	GST	GPX	GR	SOD
Muscle	PM SA	AST[2]	R -0.29	R 0.25	R 0.042	R -0.053	R 0.46	R 0.39
			P 0.45	P 0.52	P 0.92	P 0.89	P 0.22	P 0.30
	PM AA	AST	R 0.46	R -0.55	R 0.87	R 0.51	R 0.76	R 0.74
			P 0.21	P 0.13	P 0.002**	P 0.17	P 0.018*	P 0.023*
	FM SA	AST	R 0.28	R 0.70	R 0.35	R -0.39	R 0.45	R 0.21
			P 0.46	P 0.035*	P 0.36	P 0.30	P 0.23	P 0.59
	FM AA	AST	R 0.096	R 0.44	R 0.64	R 0.241	R 0.059	R -0.57
			P 0.81	P 0.24	P 0.066	P 0.53	P 0.88	P 0.11
Liver	PM SA	AST	R -0.83	R -0.40	R 0.39	R 0.14	R -0.11	R 0.818
			P 0.005**	P 0.29	P 0.30	P 0.73	P 0.78	P 0.007**
	PM AA	AST	R -0.40	R 0.062	R 0.72	R 0.66	R -0.20	R 0.65
			P 0.29	P 0.87	P 0.030*	P 0.055	P 0.61	P 0.057
	FM SA	AST	R -0.11	R -0.58	R -0.24	R 0.26	R 0.30	R 0.44
			P 0.78	P 0.11	P 0.54	P 0.49	P 0.43	P 0.24
		AST	R 0.12	R 0.27	R 0.031	R 0.67	R 0.37	R 0.90

	FM AA		P 0.77	P 0.48	P 0.94	P 0.048*	P 0.33	P 0.001**

[1]PM: plant protein meal based diets, FM: fishmeal based diets; SA: synthetic astaxanthin, AA: microalgal astaxanthin.

[2]AST: tissue concentrations of astaxanthin.

[3]MDA: malondialdehyde; GSH: glutathione; GST: Glutathione S-transferase; GPX: Glutathione peroxidase; GR: Glutathione reductase; SOD: Superoxidase dismutase.

*, **Positive or negative R and $P < 0.05$ represents a positive or negative correlation between the concentration of AST and concentrations of MDA or GSH or activities of GST, GPX, GR, and SOD in a given tissue. *$P < 0.05$; ** $P < 0.01$.

Table S3. Stepwise regression analysis of tissue redox biomarkers as dependent variables and dietary AST and DHA concentrations as independent variables in rainbow trout

Dependent variables (Y)[1]	Significant independent variables (X)[2]	Equations
	Plant meal-based diet	
Muscle	**Dietary AST & DHA concentrations**	
M[3]-MDA (μM/g protein)	/	/
M-GSH (μM/mg protein)	/	/
M-GST (mU/mg protein)	X_0: D-DHA (mg/g diet)	$Y=0.55+0.25X_0$
M-GPX (mU/mg protein)	/	/
M-GR (mU/mg protein)	/	/
M-SOD (mU/mg protein)	X_0: D-DHA (mg/g diet)	$Y=10+8.7X_0$
Liver	**Dietary AST & DHA concentrations**	
L-MDA (μM/g protein)	/	/
L-GSH (μM/mg protein)	/	/
L-GST (mU/mg protein)	/	/
L-GPX (mU/mg protein)	/	/
L-GR (mU/mg protein)	/	/
L-SOD (mU/mg protein)	X_0: D-DHA (mg/g diet)	$Y=79+35X_0$
	Fishmeal-based diet	
Muscle	**Dietary AST & DHA concentrations**	

M-MDA (μM/g protein)	/	/
M-GSH (μM/mg protein)	/	/
M-GST (mU/mg protein)	X_0: D-DHA (mg/g diet)	$Y=0.71+ 0.76X_0$
M-GPX (mU/mg protein)	/	/
M-GR (mU/mg protein)	X_0: D-DHA (mg/g diet)	$Y=0.149+ 0.045X_0$
M-SOD (mU/mg protein)	/	/
Liver	**Dietary AST & DHA concentrations**	
L-MDA (μM/g protein)	/	/
L-GSH (μM/mg protein)	/	/
L-GST (mU/mg protein)	/	/
L-GPX (mU/mg protein)	X_0: D-DHA (mg/g diet)	$Y=4.4+ 5.5X_0$
L-GR (mU/mg protein)	/	/
L-SOD (mU/mg protein)	/	/

[1]Dependent variables (X, tissue concentrations or activities): MDA: malondialdehyde, GSH: glutathione, GST: glutathione S-transferase, GPX: glutathione peroxidase, GR: glutathione reductase, SOD: superoxide dismutase.

[2]Independent variables (Y, dietary concentrations): AST, astaxanthin; DHA, docosahexaenoic acid (refer to reference 15).

[3]D: diets; L: liver; and M: muscle.

Table S4. Stepwise regression analysis of tissue redox biomarkers as dependent variables and tissue AST and DHA concentrations and antioxidant enzyme gene mRNA levels as independent variables in rainbow trout

Dependent variables (Y)[1]	Significant independent variables (X)[2]	Equations
	Plant meal-based diet	
Muscle	**Tissue AST & DHA concentrations and gene expression**	
M[3]-MDA (μM/g protein)	X_0: L-GR (relative mRNA level)	$Y=2.1-0.008X_0$
M-GSH (μM/mg protein)	/	/
M-GST (mU/mg protein)	X_0: L-CAT (relative mRNA level)	$Y=0.078+0.005X_0$
M-GPX (mU/mg protein)	/	/
M-GR (mU/mg protein)	X_0: L-CAT (relative mRNA level)	$Y=0.01+ 0.002X_0$
M-SOD (mU/mg protein)	X_0: L-CAT (relative mRNA level)	$Y=-4.7+0.18X_0$
Liver	**Tissue AST & DHA concentrations and gene expression**	
L-MDA (μM/g protein)	X_1: L-GST (relative mRNA level) X_2: L-SOD1 (relative mRNA level)	$Y=2.5+0.011X_1-0.012X_2$
L-GSH (μM/mg protein)	X_0: L-GR (relative mRNA level)	$Y=53+0.19X_0$
L-GST (mU/mg protein)	X_0: L-SOD2 (relative mRNA level)	$Y=-1.6+0.051X_0$
L-GPX (mU/mg protein)	X_0: L-GPX1b2 (relative mRNA level)	$Y=21+0.06X_0$
L-GR (mU/mg protein)	X_0: L-GST (relative mRNA level)	$Y=1.2+0.006X_0$
L-SOD (mU/mg protein)	X_0: L-DHA (mg/g tissue)	$Y=17+401X_0$
	Fishmeal-based diet	

Muscle	**Tissue AST & DHA concentrations and gene expression**	
M-MDA (μM/g protein)	/	/
M-GSH (μM/mg protein)	X_0: L-GPX1a (relative mRNA level)	$Y=210-0.67X_0$
M-GST (mU/mg protein)	X_1: L-GPX1a (relative mRNA level)	$Y=1.1-0.004X_1+0.004X_2$
	X_2: L- GPX1b1 (relative mRNA level)	
M-GPX (mU/mg protein)	/	/
M-GR (mU/mg protein)	X_0: L-GPX1a (relative mRNA level)	$Y=1.3-0.001X_0$
M-SOD (mU/mg protein)	X_0: L-SOD2 (relative mRNA level)	$Y=52-0.221X_0$
Liver	**Tissue AST & DHA and gene expression**	
L-MDA (μM/g protein)	/	/
L-GSH (μM/mg protein)	X_0: L-AST (μg/g tissue)	$Y=71+64X_0$
L-GST (mU/mg protein)	X_1: L-SOD1 (relative mRNA level)	$Y=14-0.095X_1+0.016X_2$
	X_2: L- GR (relative mRNA level)	
L-GPX (mU/mg protein)	X_0: L-GPX1a (relative mRNA level)	$Y=29-0.13X_0$
L-GR (mU/mg protein)	X_1: L-DHA (mg/g tissue)	$Y=3.7+1.4X_1-0.032X_2$
	X_2: L-SOD1 (relative mRNA level)	
L-SOD (mU/mg protein)	X_0: L-CAT (relative mRNA level)	$Y=-73+1.2X_0$

[1]Dependent variables (X, tissue concentrations or activities): MDA: malondialdehyde, GSH: glutathione, GST: glutathione S-transferase, GPX: glutathione peroxidase, GR: glutathione reductase, SOD: superoxide dismutase.

[2]Independent variables (Y): tissue concentrations of AST (astaxanthin) and DHA (docosahexaenoic acid, refer to reference 15) and mRNA levels of 8 antioxidant enzyme genes including catalase (CAT) gene.

[3]L: liver, M: muscle.