Nutritional modulation of the antioxidant system of the body

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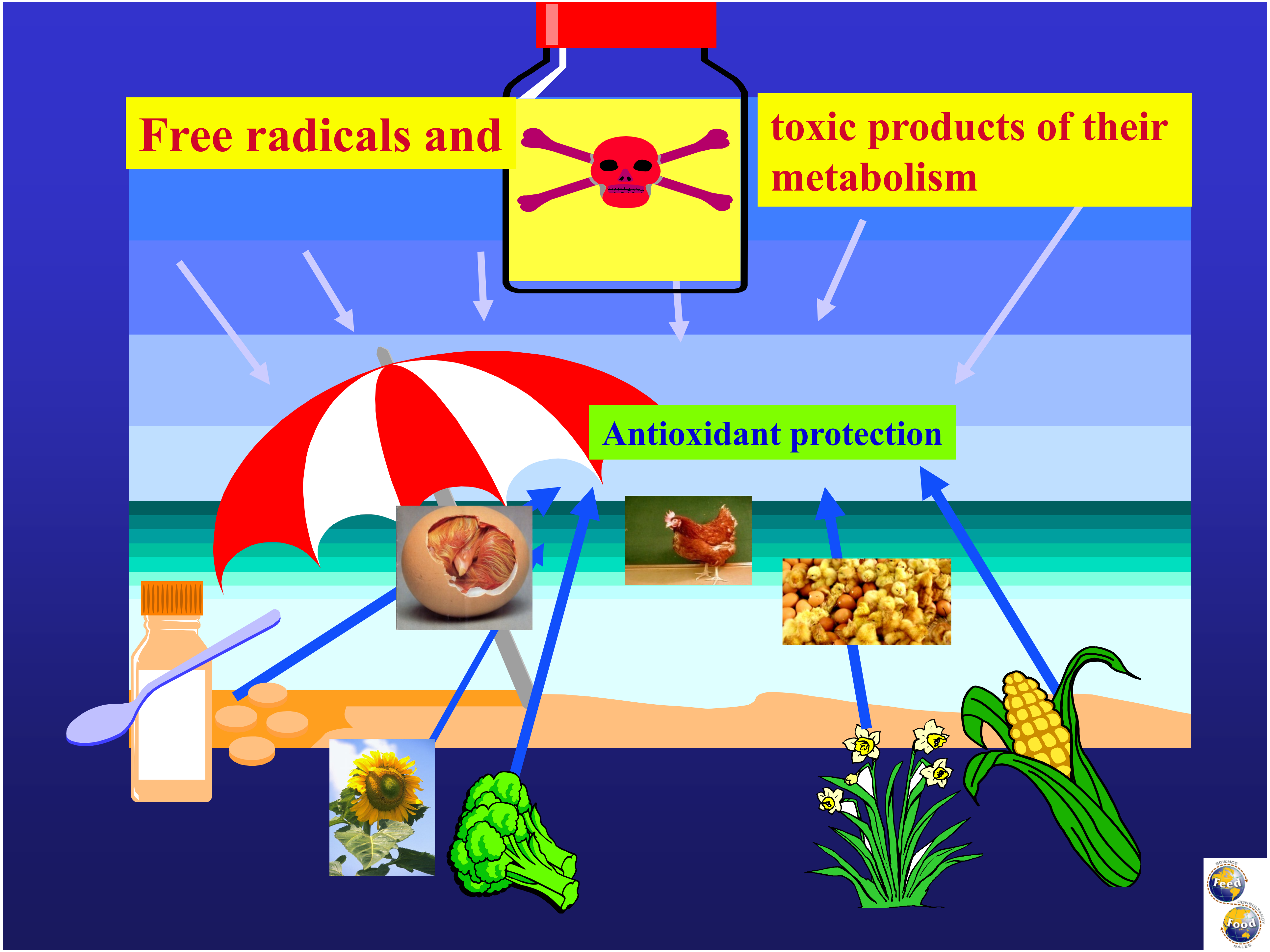
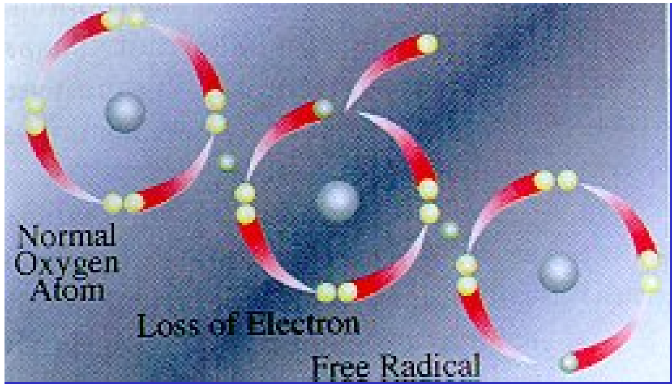

Free radicals and
toxic products of their metabolism
Antioxidant protection



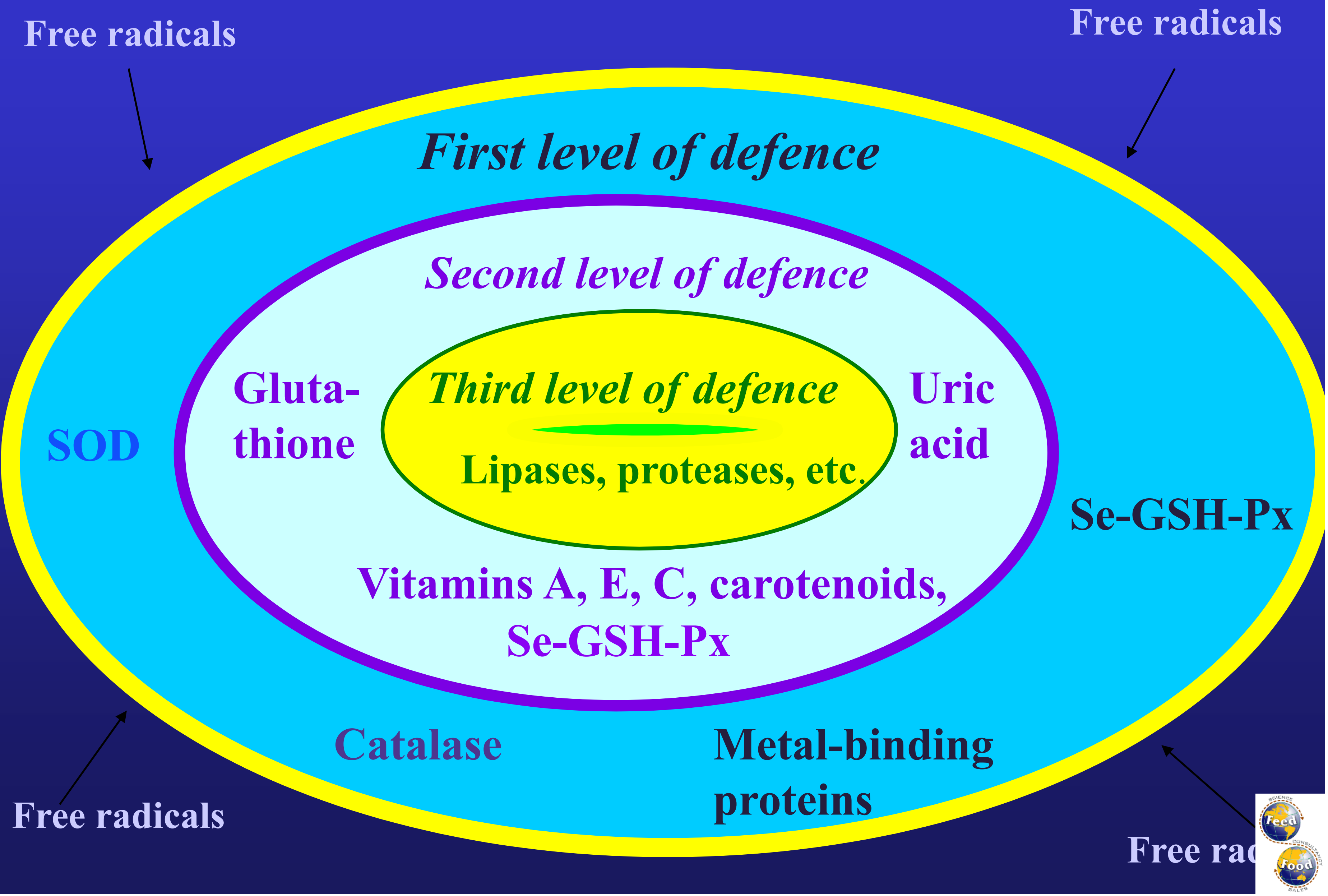
How many free radicals are produced each day?

- **About 10^{12} O_2 molecules processed by each rat cell daily and the leakage of partially reduced oxygen molecules is about 2%, yielding about** *2 x10^{10} molecules of ROS per cell per day* (**Chance B., Sies H. and Boveries A., 1979**)
- **Prof. Bruce Ames has shown that the DNA in each rat cell is hit by about 100,000 free radicals a day.**

The major cellular target for free radicals

Target	Damage	Consequence
DNA	Scission on deoxyribose ring; base damage; strand breaks; cross-linking	Mutations; translational errors; inhibition of protein synthesis
Protein	Aggregation and cross-linking; fragmentation and breakdown; modification of thyol groups	Modified ion transport; increased Ca influx; modified enzyme activity
PUFA	Loss of unsaturation; formation of reactive metabolites (e.g. MDA)	Altered membrane fluidity, permeability and activity membrane-bound enzymes

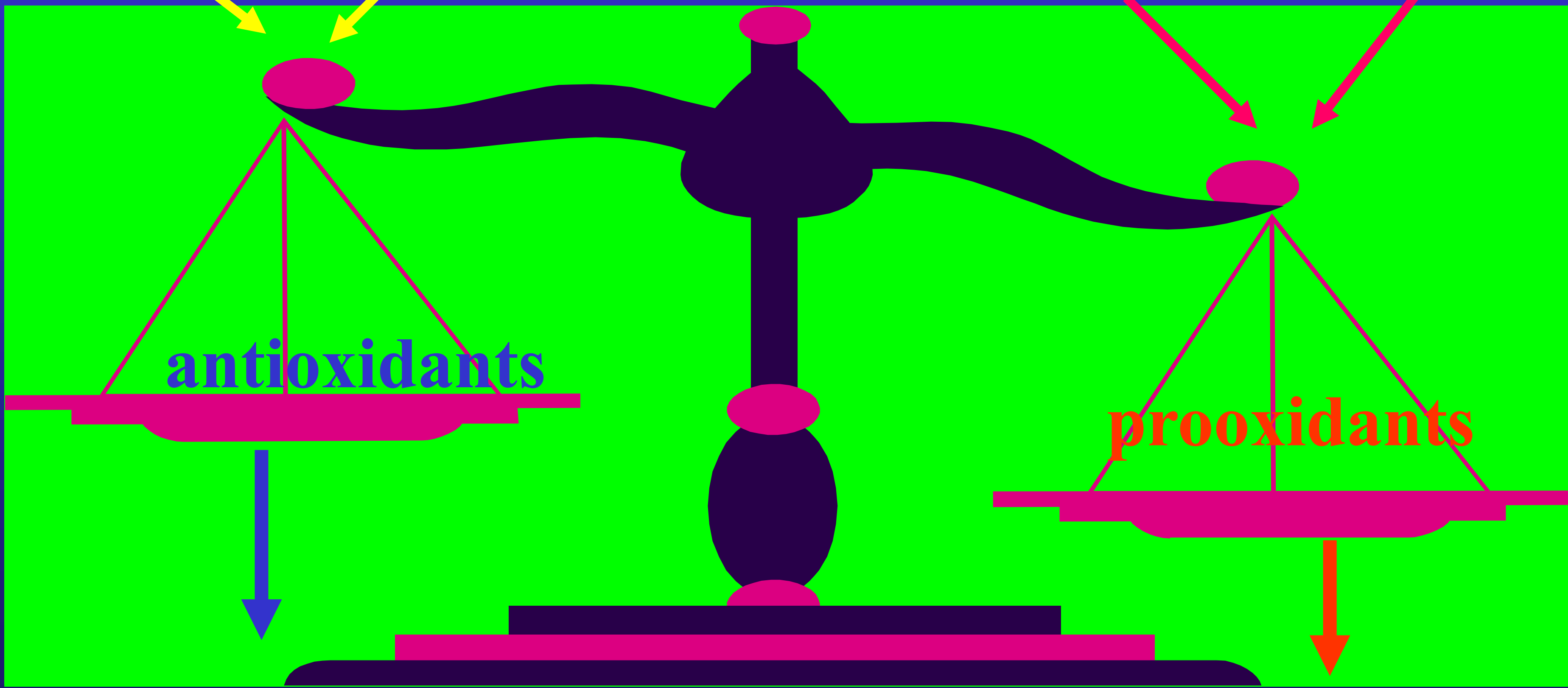
Three major levels of the antioxidant defence in the cell



Antioxidant-prooxidant balance in the cell

Diet optimization

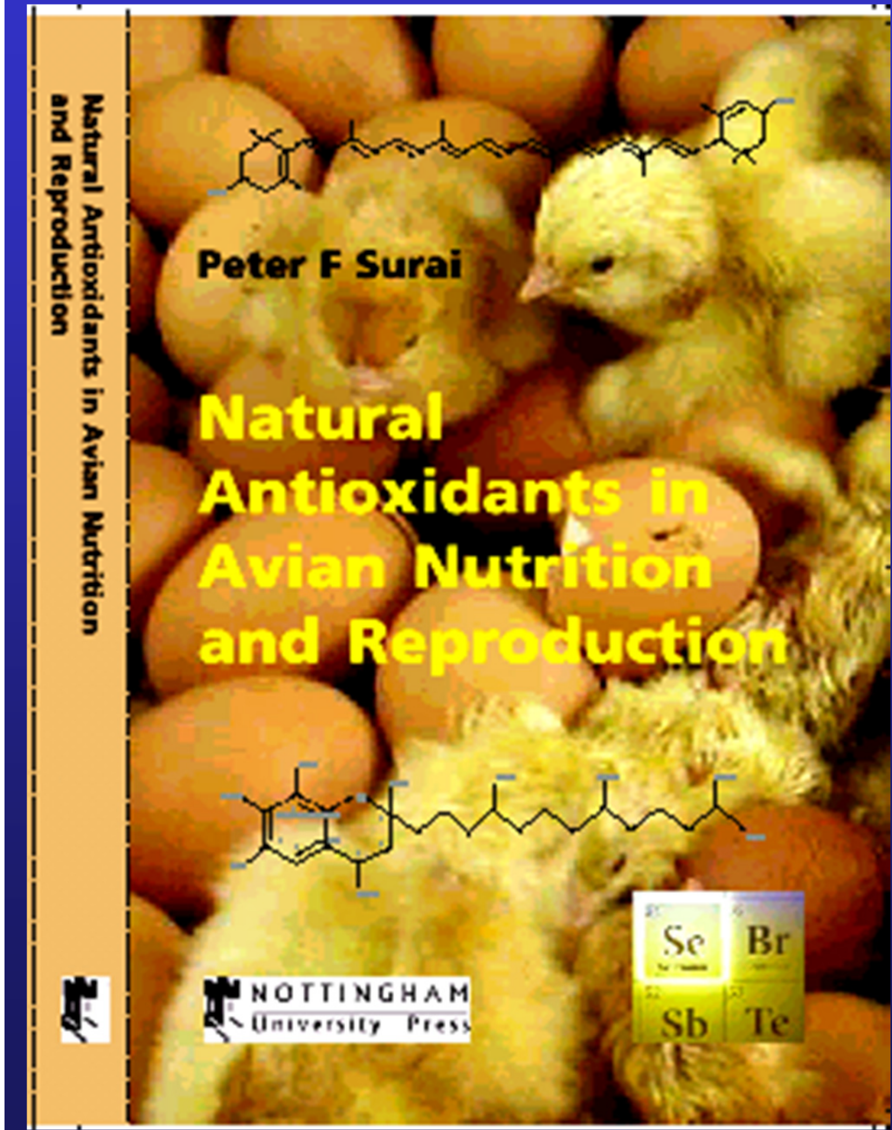
Stress conditions



Antioxidant protection and maintenance of good health

Lipid peroxidation and protein oxidation and development of different diseases

Antioxidant team



All antioxidants in the body are working together as a team (antioxidant system), responsible for prevention of damaging effects of free radicals and toxic products of their metabolism

Nutritional modulation of the antioxidant system

Modulation of the antioxidant system of the developing chicken embryo by maternal nutrition can be used as a model system

Maternal effect of antioxidants

Antioxidants in the diet:
vitamin E, carotenoids, ascorbic acid, selenium, flavonoids

Laying hen

Egg yolk:
tocopherols, tocotrienols, Carotenoids, Se

Embryo: tocopherols, tocotrienols, carotenoids, ascorbic acid, glutathione, uric acid, coenzyme Q, GSH-Px, SOD

Developing chicken: growth, immunity, disease resistance

Fatty acid composition of egg yolk and liver of newly hatched chick, %

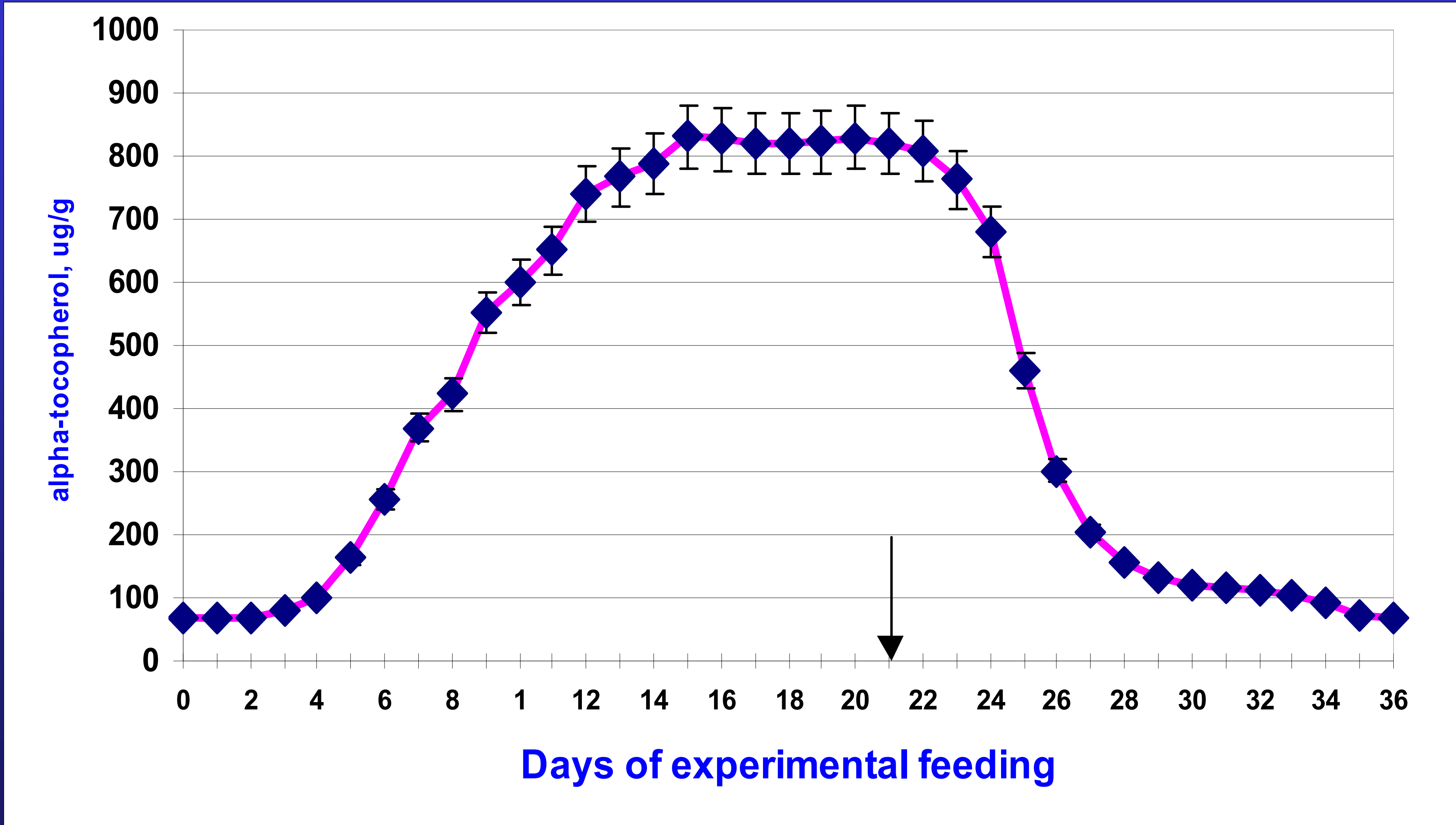
Fatty acid	Egg	Liver
16:0	25.8	16.1
18:0	8.1	27.5
18:1n-9	40.5	7.5
18:1n-7	1.6	0.7
18:2n-6	14.7	14.6
20:4n-6	1.7	21.9
22:6n-3	1.6	10.4
Total PUFA	18.0	46.9

Surai et al., 1999

Major feed-derived antioxidants

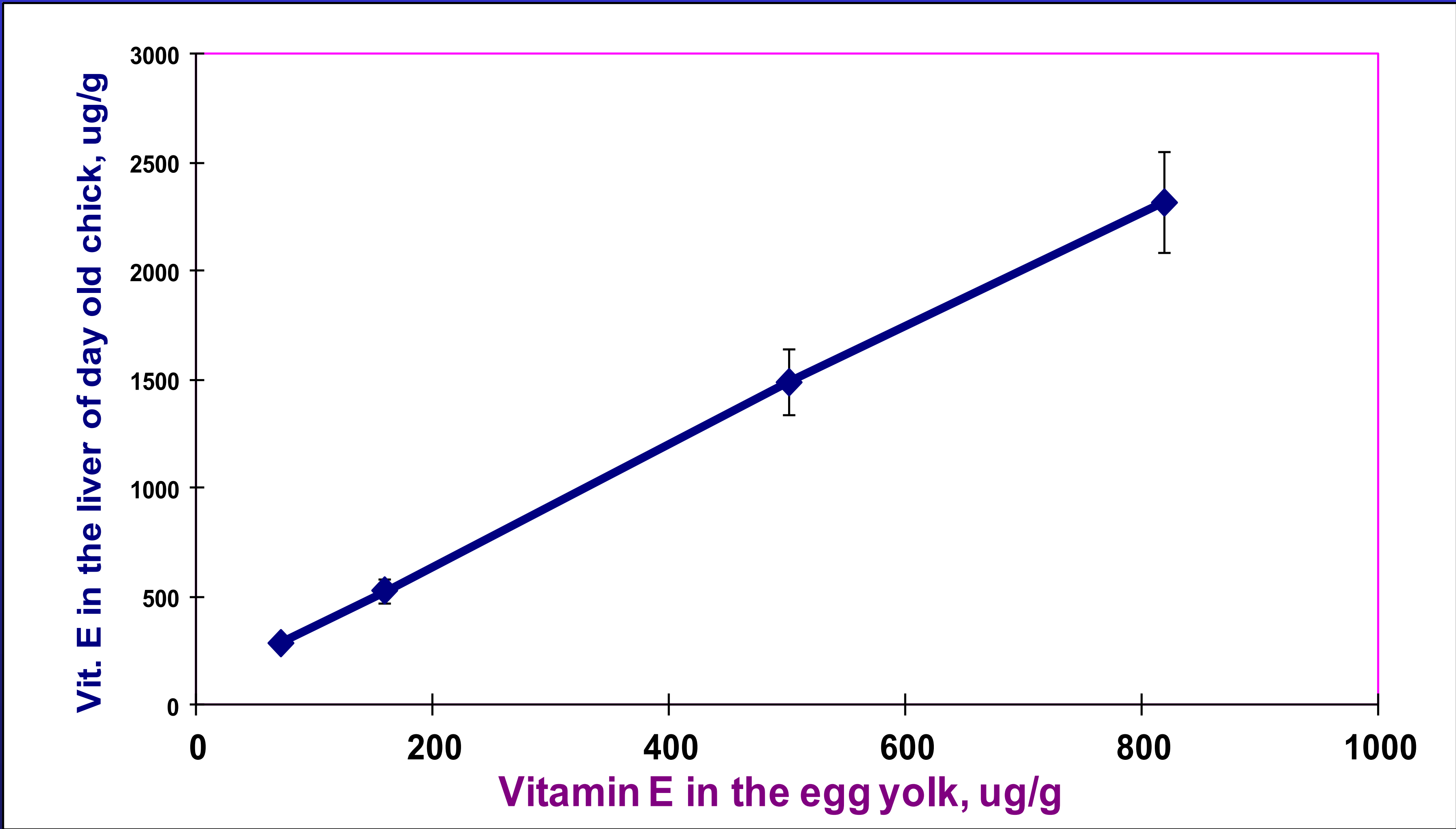
- Vitamin E
- Carotenoids
- Selenium
- Vitamin C
- Flavonoids
- Essential oils
- Other minerals (Mn, Zn, Cu, Fe)

Vitamin E Transfer From Feed to Egg Yolk



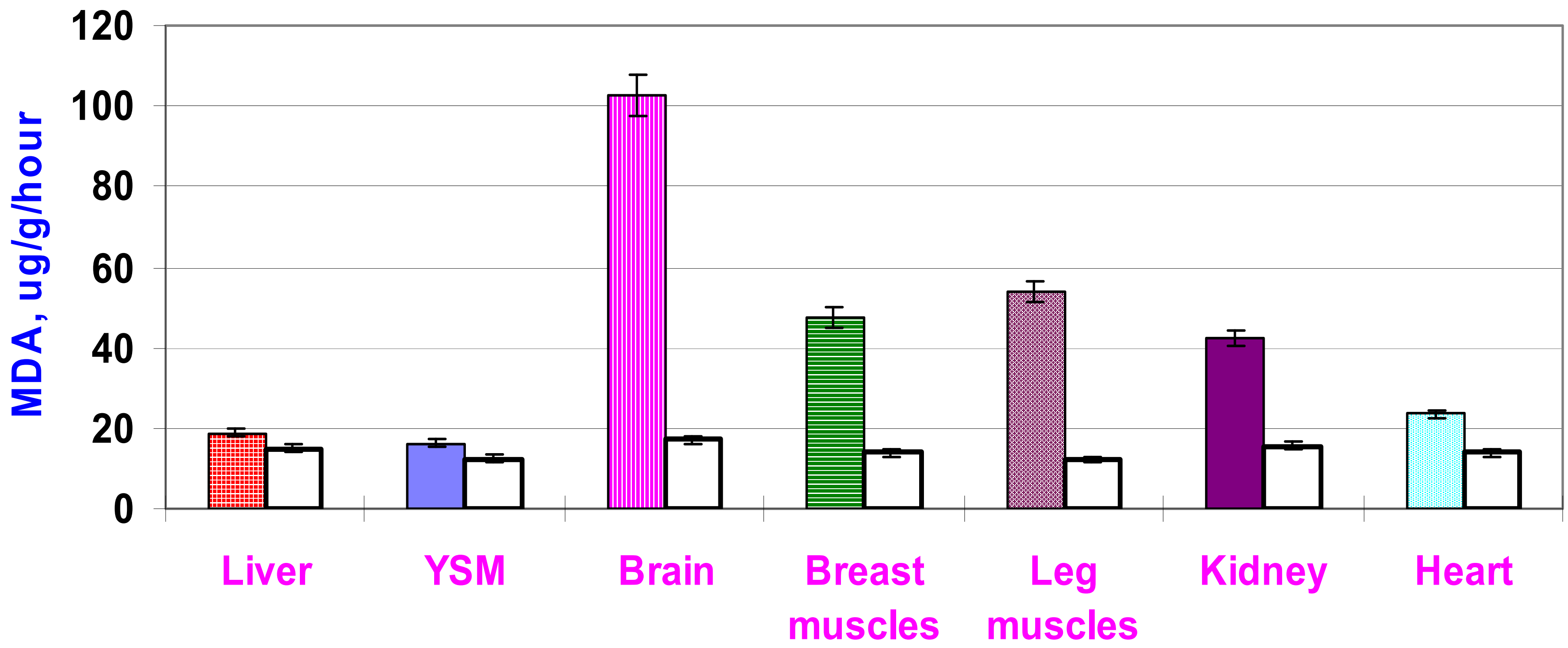
Surai, 2002

Relationship Between Vitamin E in the Egg Yolk and Liver



Surai, 2002

Effect of vitamin E in laying hen diet on lipid peroxidation in chick embryo tissues

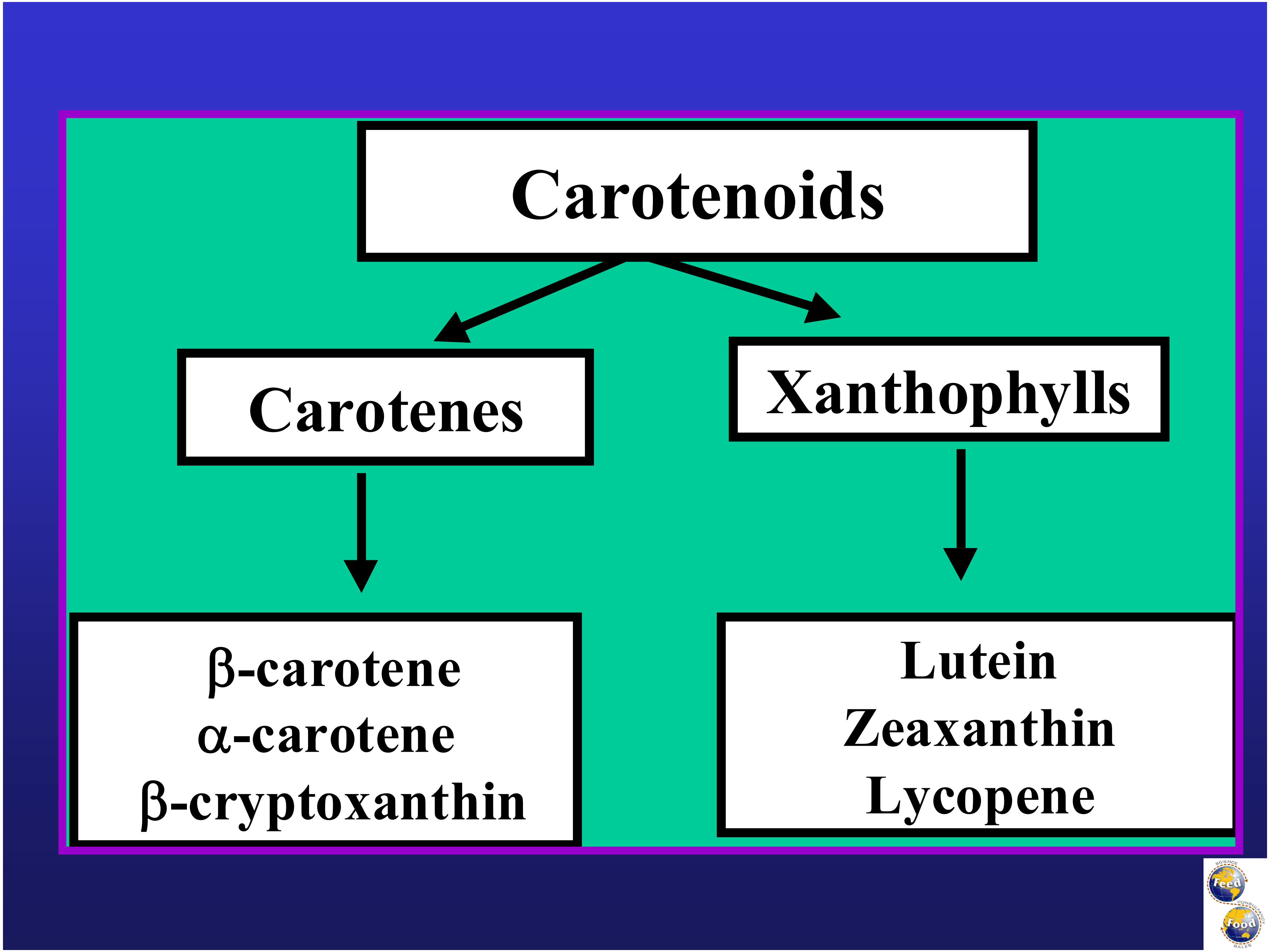


Surai et al., 2000

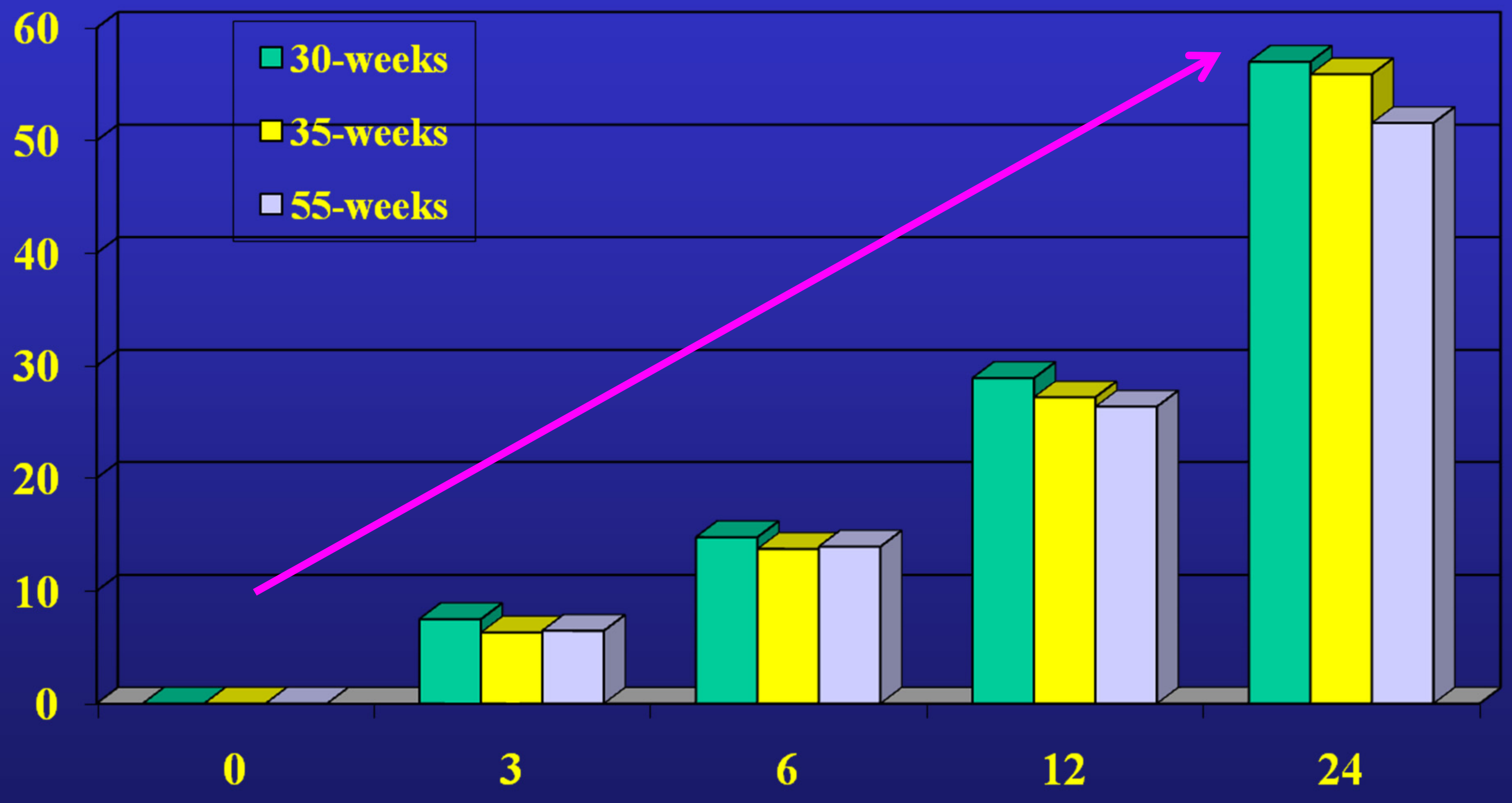
Some target genes regulated at transcriptional level by vitamin E

Gene Class	Function	Effect of vitamin E
Inflammatory cytokines	Inflammation	Inhibition
Apoptosis	Induction of apoptosis	Inhibition
Regulation of transcription	Induction of inflammatory genes	Inhibition
Regulation of transcription	Induction of immune response	Induction
Antioxidant defence	GSH biosynthesis	Induction
Detoxification	Detoxification of endogenous and exogenous compounds	Induction
Lipid metabolism	Lipid uptake, delivery transport	Inhibition

Mocchegiani et al., 2014

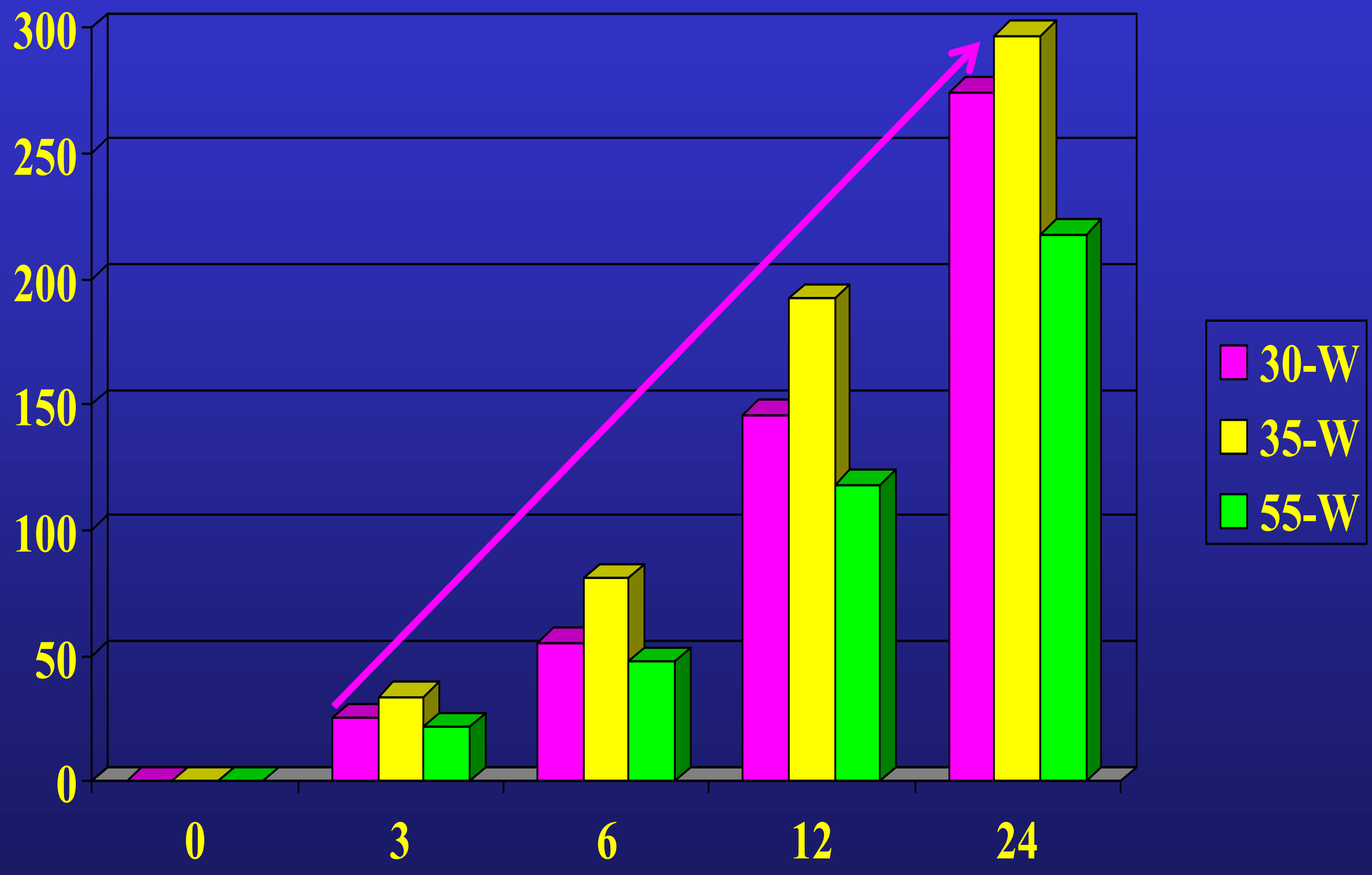

Carotenoids
Carotenes
Xanthophylls
β-carotene
α-carotene
β-cryptoxanthin
Lutein
Zeaxanthin
Lycopene

Canthaxanthin in egg yolk



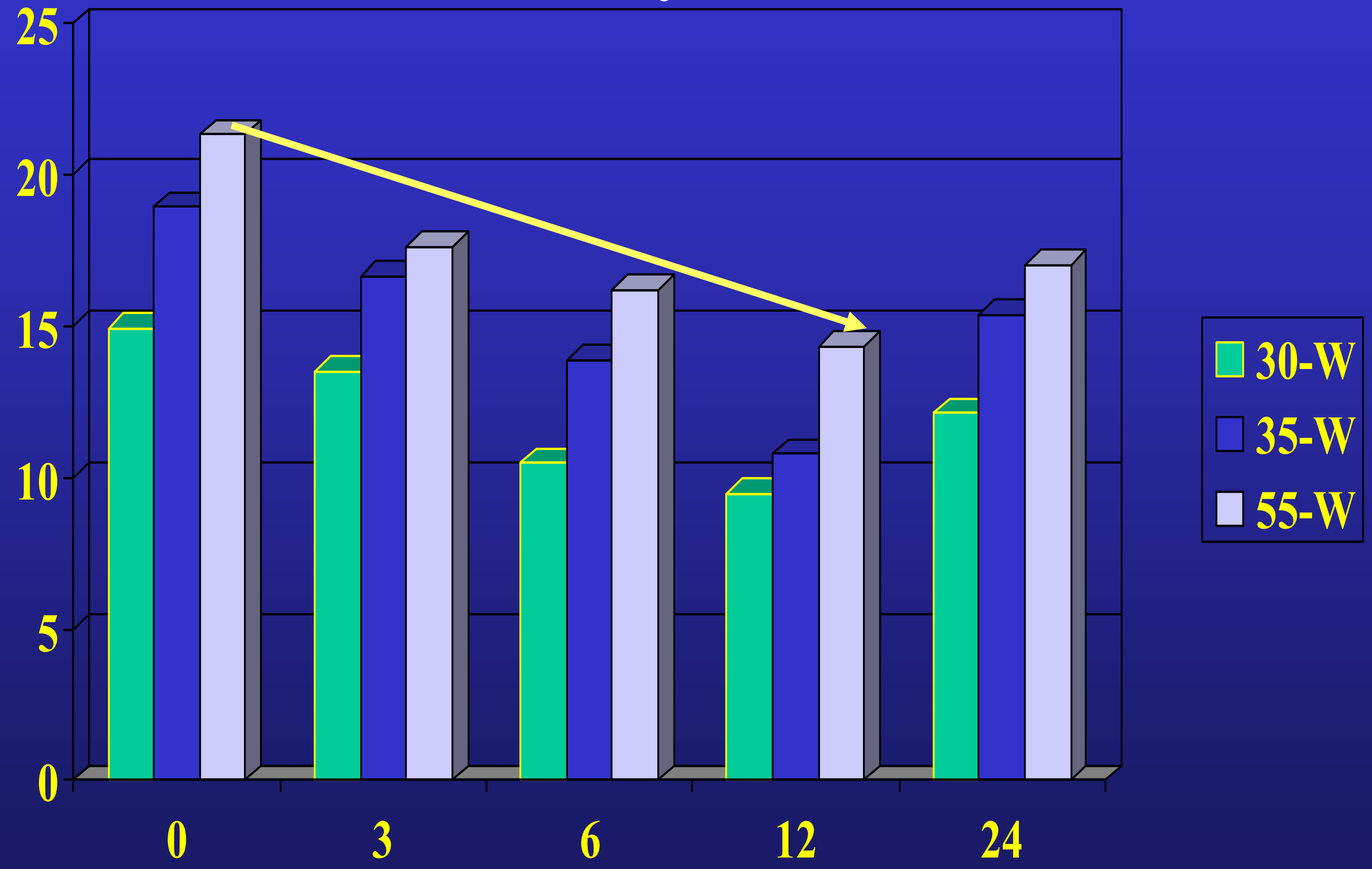
Surai et al., 2003

Canthaxanthin in the liver of day old chick



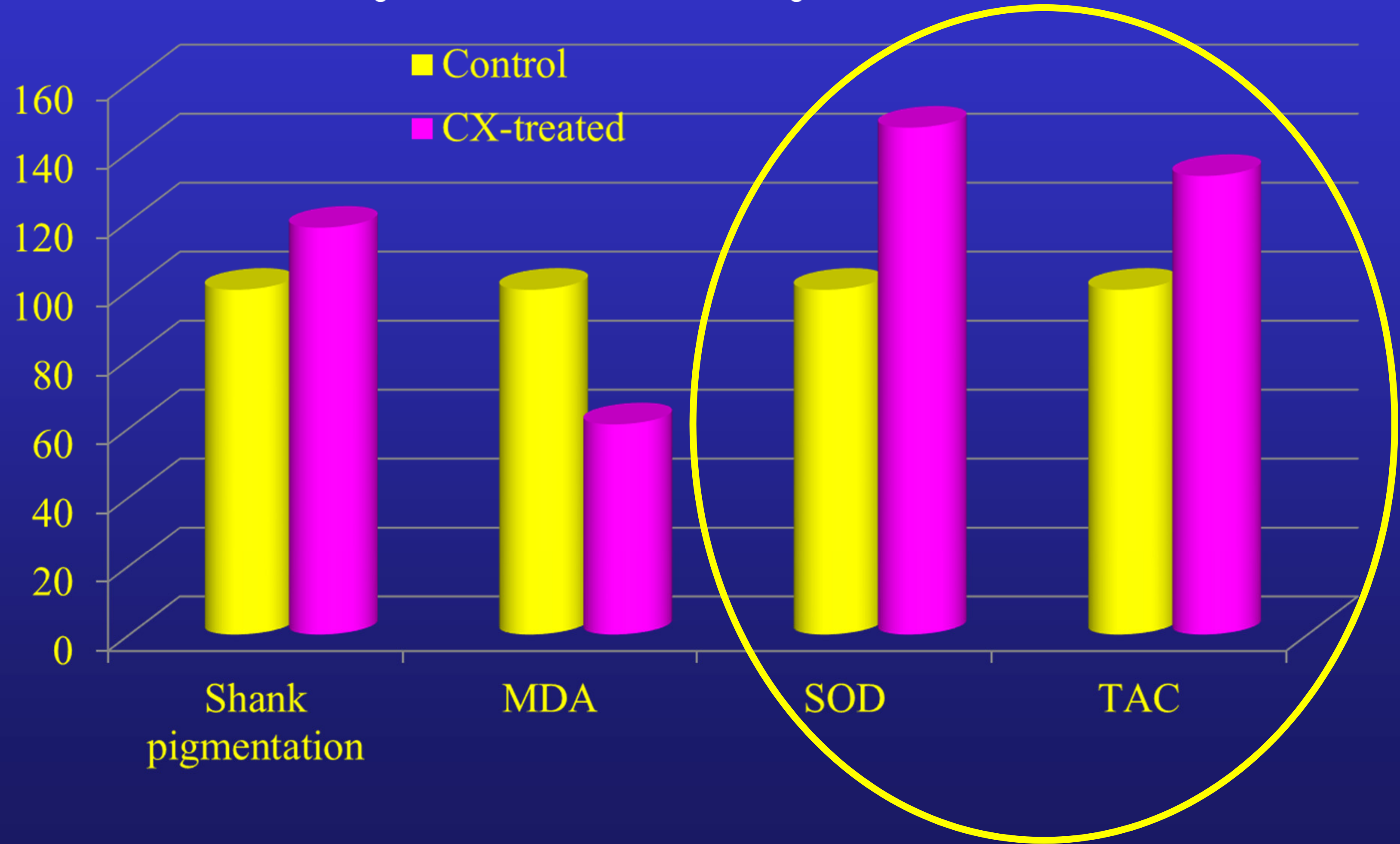
Surai et al., 2003

Effect of canthaxanthin on lipid peroxidation in the liver of newly hatched chicks



Surai et al., 2003

Effect of canthaxanthin in the breeder's diet on the AO system of the day-old chicken, %



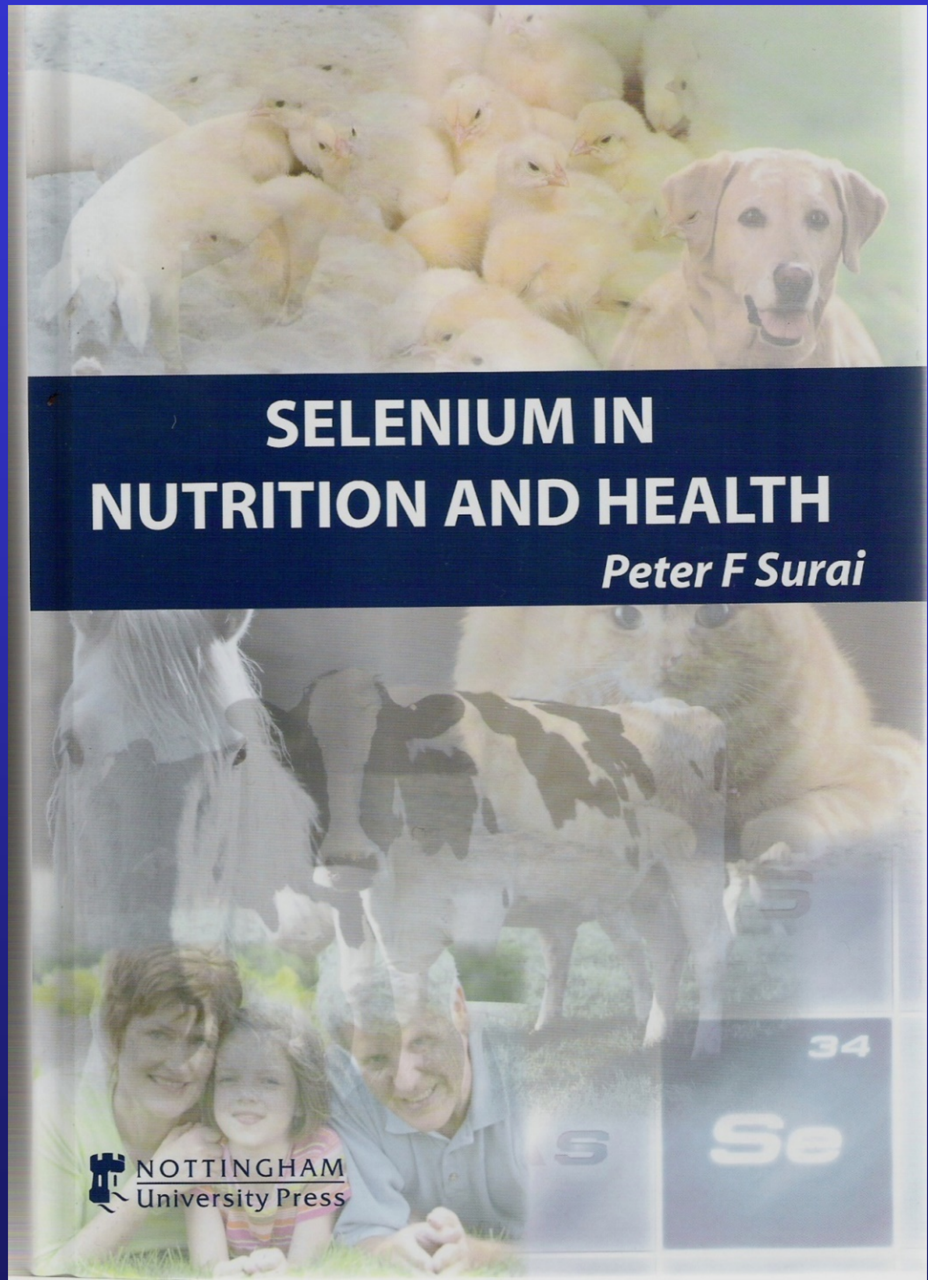
Zhang et al., 2011

Alterations in gene expression in mouse liver after treatment with lutein

Positive regulation	+ fold change	Negative regulation	- fold change
GSH-Px1	2.12	Glutathione reductase	2.27
Peroxiredoxin-4	2.26	TR1	5.39
SOD1	2.37	TR2	2.09
Uncoupling protein	3.53	SOD2 (mitochondria)	4.77
Nucleoredoxin	2.94	Isocitrate dehydrogenase	3.31
Copper chaperon for SOD	5.02	NADPH-oxidase	1.63

Sarpeloni et al., 2014

15 **P** 39.974	16 **S** 32.06	17 **Cl** 35.453
33 **As** 74.922	**34 Se 78.96**	35 **Br** 79.904
51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.91



Comparative Biochemistry and Physiology, Part B 151 (2008) 361–372

Contents lists available at ScienceDirect

Comparative Biochemistry and Physiology, Part B

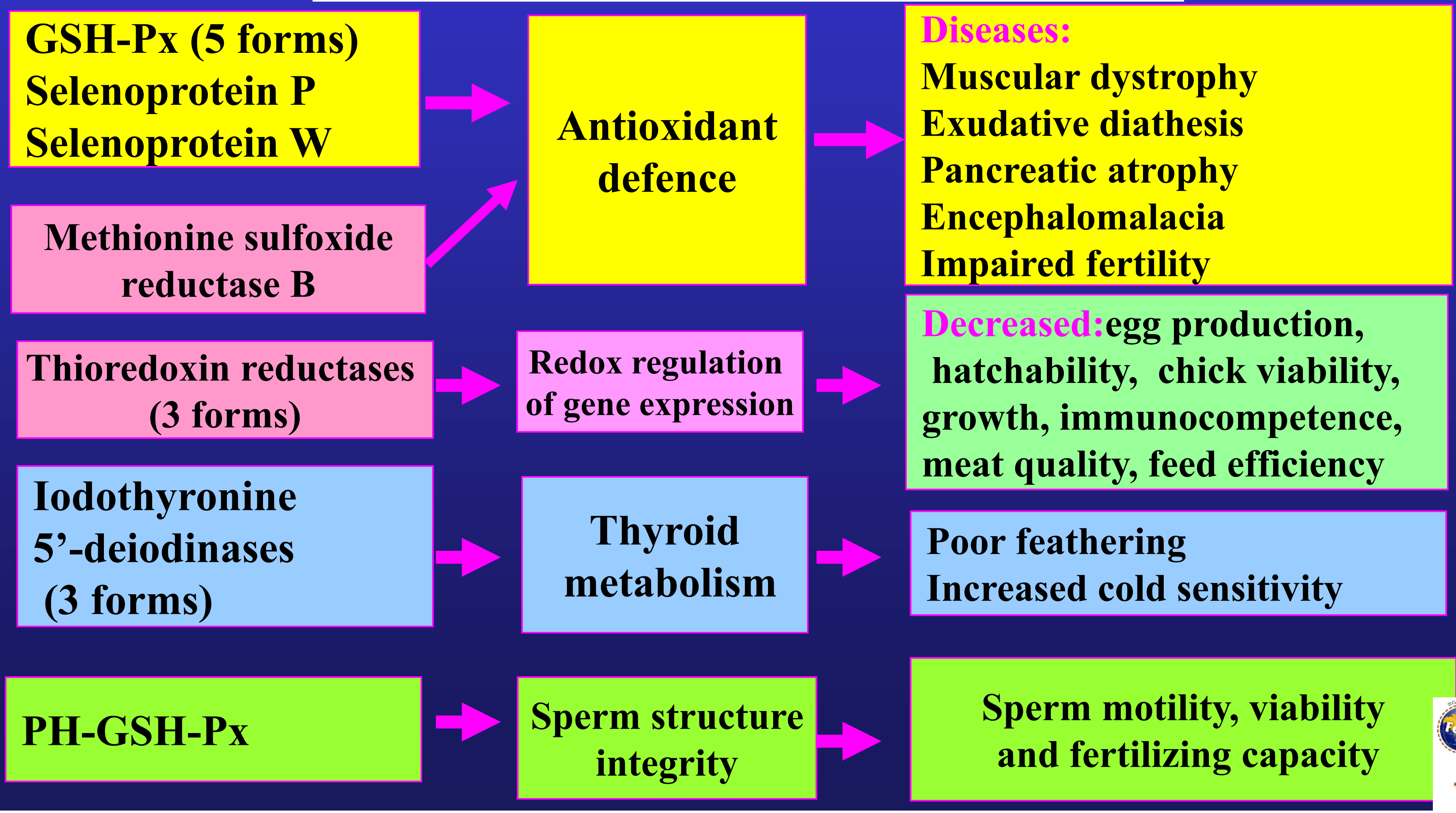
journal homepage: www.elsevier.com/locate/cbpb

Review

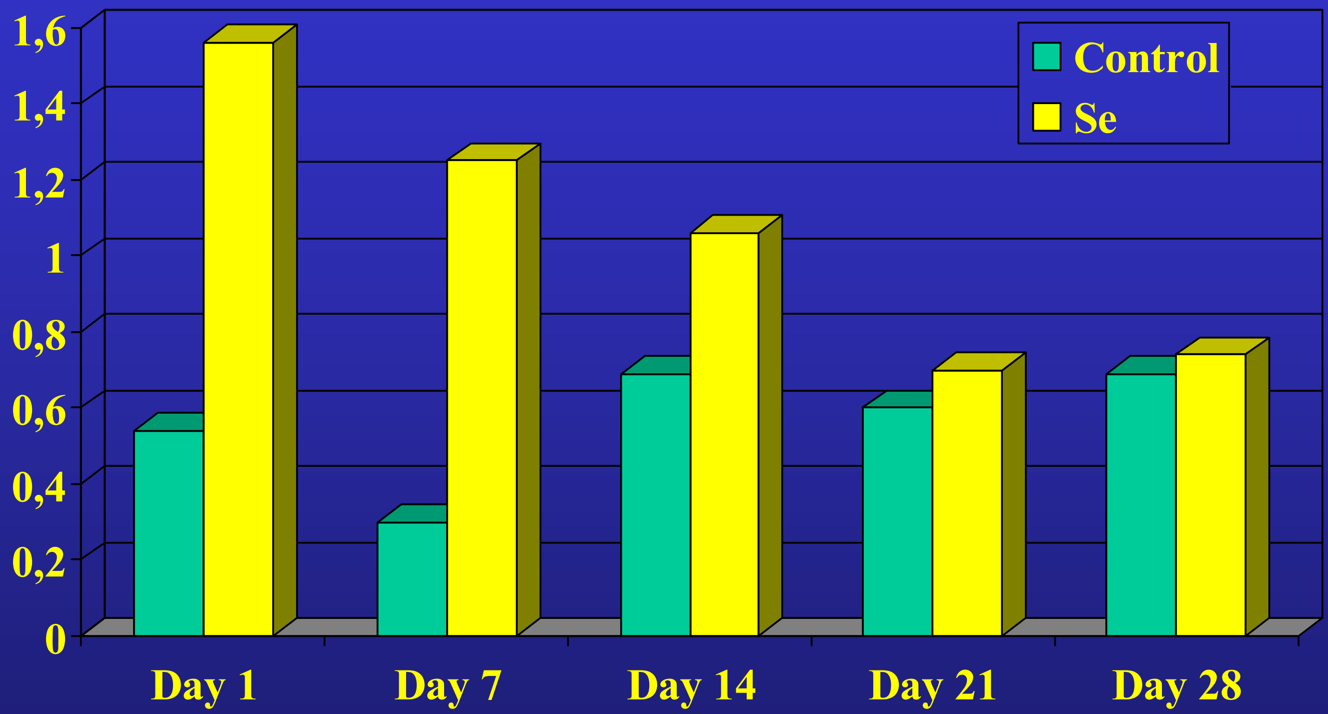
Selenoproteins and maternal nutrition

A.C. Pappas [a,*], E. Zoidis [a], P.F. Surai [b], G. Zervas [a]

[a] Department of Nutritional Physiology and Feeding, Faculty of Animal Science and Aquaculture, Agricultural University of Athens, 75 Iera Odos, 11855, Athens, Greece
[b] Division of Environmental and Evolutionary Biology, University of Glasgow, Glasgow, G12 8QQ, Scotland, UK



Effect of Se in maternal diet on GSH-Px activity in the progeny chicken liver, U/g



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Comparative Biochemistry and Physiology, Part B 142 (2005) 465 – 474

CBP

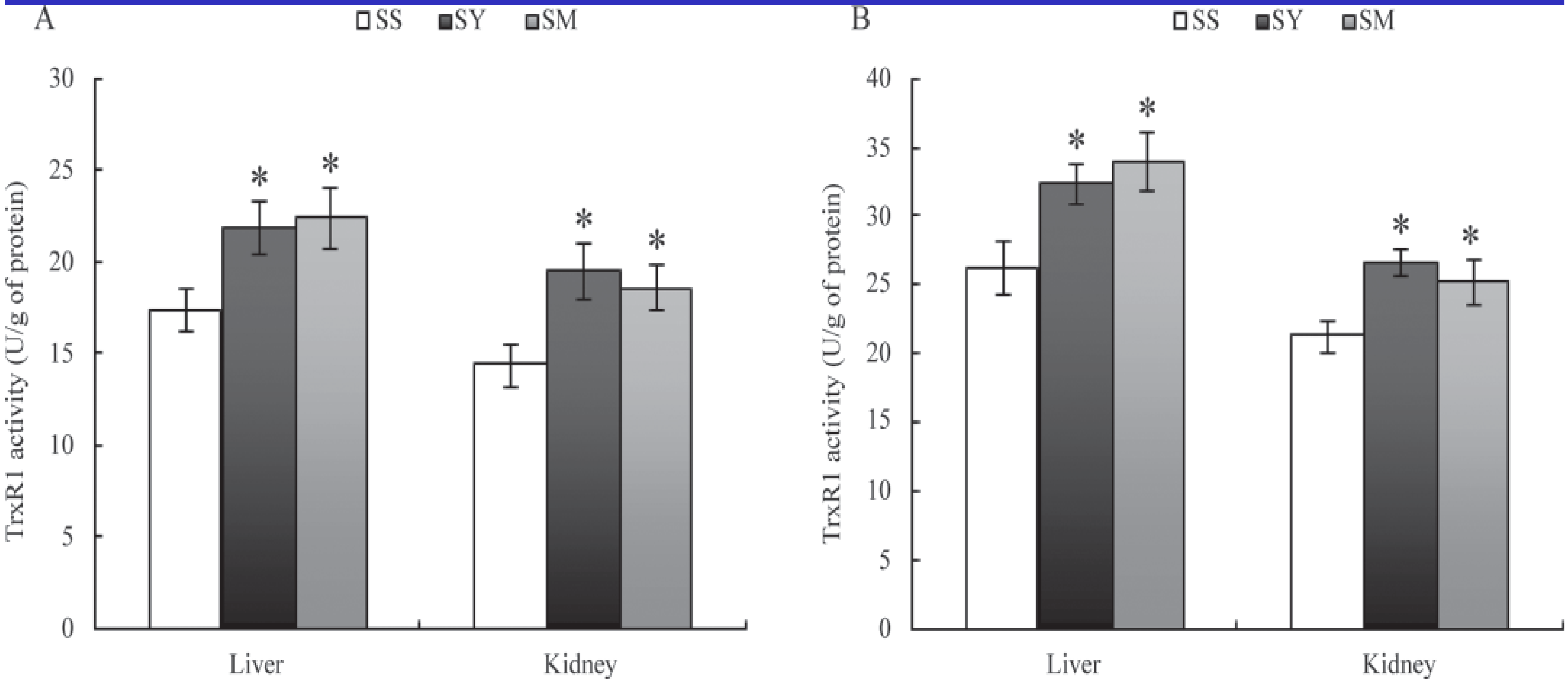
www.elsevier.com/locate/cbpb

The selenium intake of the female chicken influences the selenium status of her progeny

Athanasios C. Pappas [a], Filiz Karadas [b], Peter F. Surai [c], Brian K. Speake [a,*]

Pappas et al., 2005

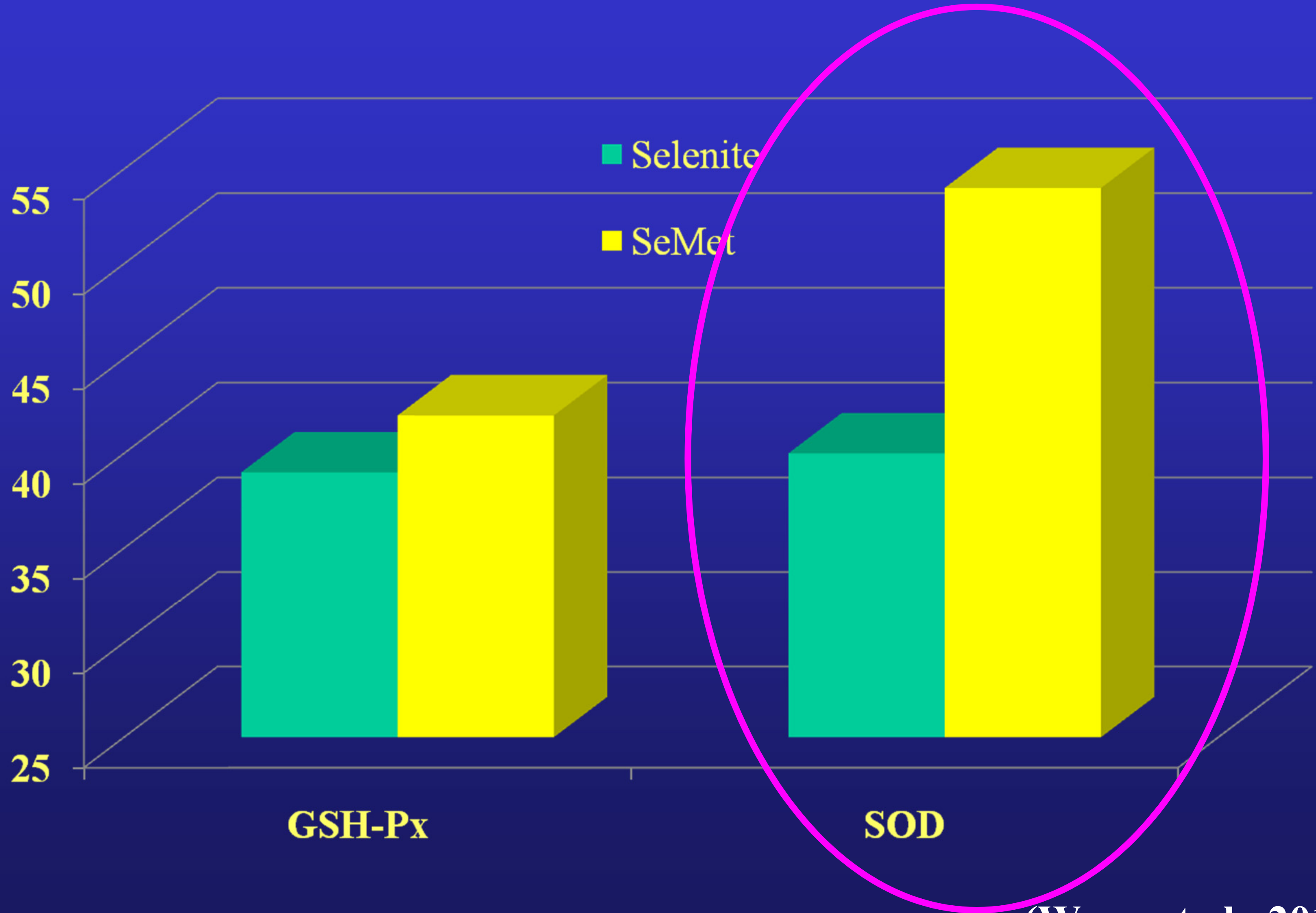
Effects of different sources of selenium (0.15 ppm) on TrxR1 activity of liver and kidney in broiler breeders (A) and their offspring (B).



Lingnan Yellow broiler breeders, SS-sodium selenite, SM- selenomethionine, SeY- Se-Yeast

(Yuan et al., 2012)

Effect of dietary Se (0.3 ppm) in maternal diet on AO enzymes in muscles of newly-hatched chicks, U/mg protein



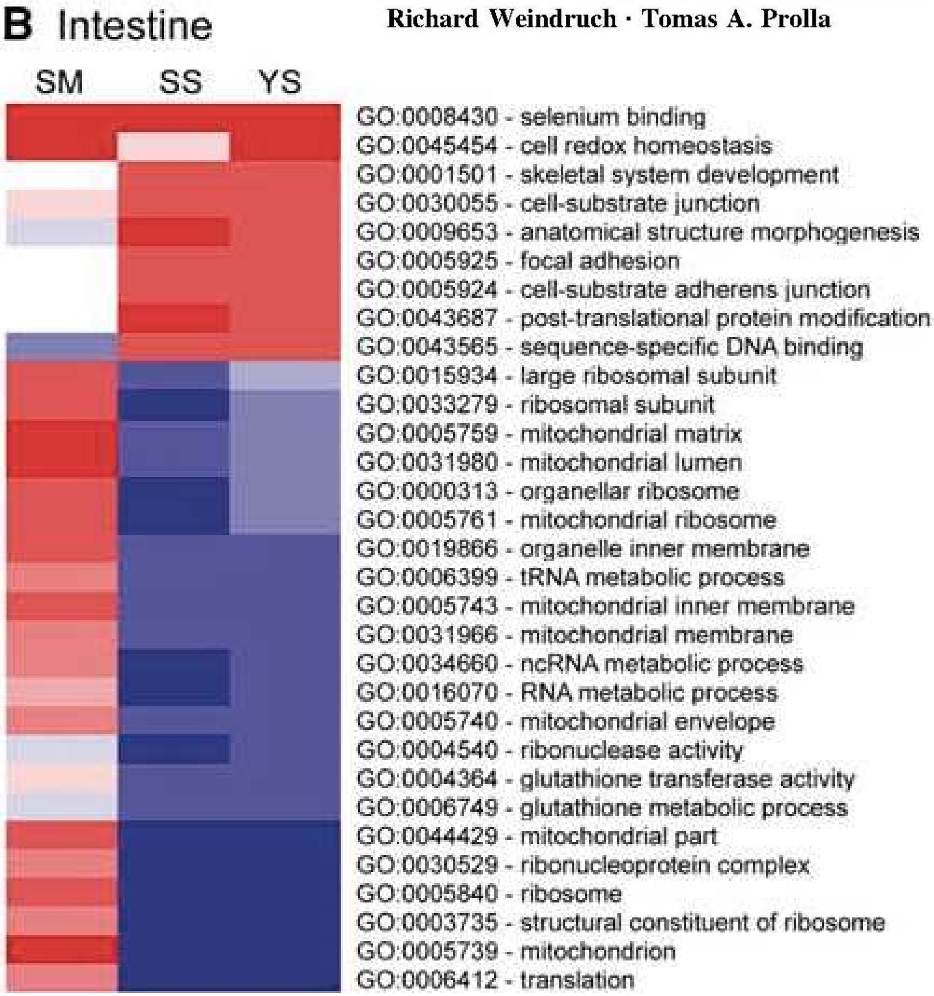
(Wang et al., 2011)

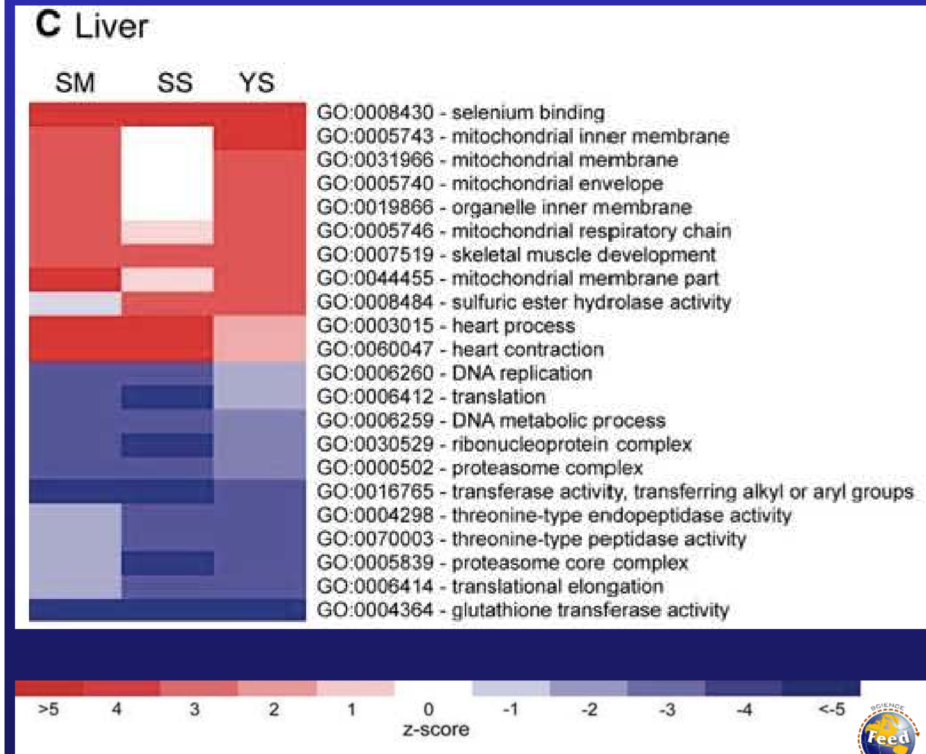
Genes Nutr (2012) 7:155–165
DOI 10.1007/s12263-011-0243-9

RESEARCH PAPER

Gene expression profiling reveals differential effects of sodium selenite, selenomethionine, and yeast-derived selenium in the mouse

Jamie L. Barger · Tsuyoshi Kayo · Thomas D. Pugh · James A. Vann · Ronan Power · Karl Dawson · Richard Weindruch · Tomas A. Prolla





Transcriptional changes in the oviduct in Cobb breeders

Pathway/function	Sodium selenite	Se- Yeast
Selenoproteins	⟷	↑
Protein synthesis	Translation of RNA↓ Protein synthesis and metabolism ↓	Protein synthesis and metabolism ↑
Oxidative phosphorylation	Down	Up
Ubiquinone	⟷	Ubiquinone biosynthesis ↑

Se concentration in oviduct was 0.086; 0.251 and 0.286 mg/kg respectively

(Brennan et al., 2011)

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Comparative Biochemistry and Physiology, Part A 145 (2006) 502 – 508
CBP
www.elsevier.com/locate/cbpa

Maternal diet influences gene expression in intestine of offspring in chicken (*Gallus gallus*)

Johanna M.J. Rebel *, Saskia Van Hemert, Arjan J.W. Hoekman, Francis R.M. Balk, Norbert Stockhofe-Zurwieden, Dirk Bakker, Mari A. Smits

Animal Sciences Group, PO Box 65, 8200 AB Lelystad ,The Netherlands

Received 15 December 2005; received in revised form 10 August 2006; accepted 18 August 2006
Available online 1 September 2006

- **The mother diet influenced expression of at least 11 gens in the intestine in the offspring at day 3 and day 14**
- **Genes that are higher expressed at day 3 and day 14 of age in the chicks of which the mothers received the higher mix are involved in epithelial turnover/ proliferation and maturation of intestinal cells**

Animal Feed Science and Technology 191 (2014) 1–15

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Animal Feed Science and Technology

journal homepage: www.elsevier.com/locate/anifeedsci

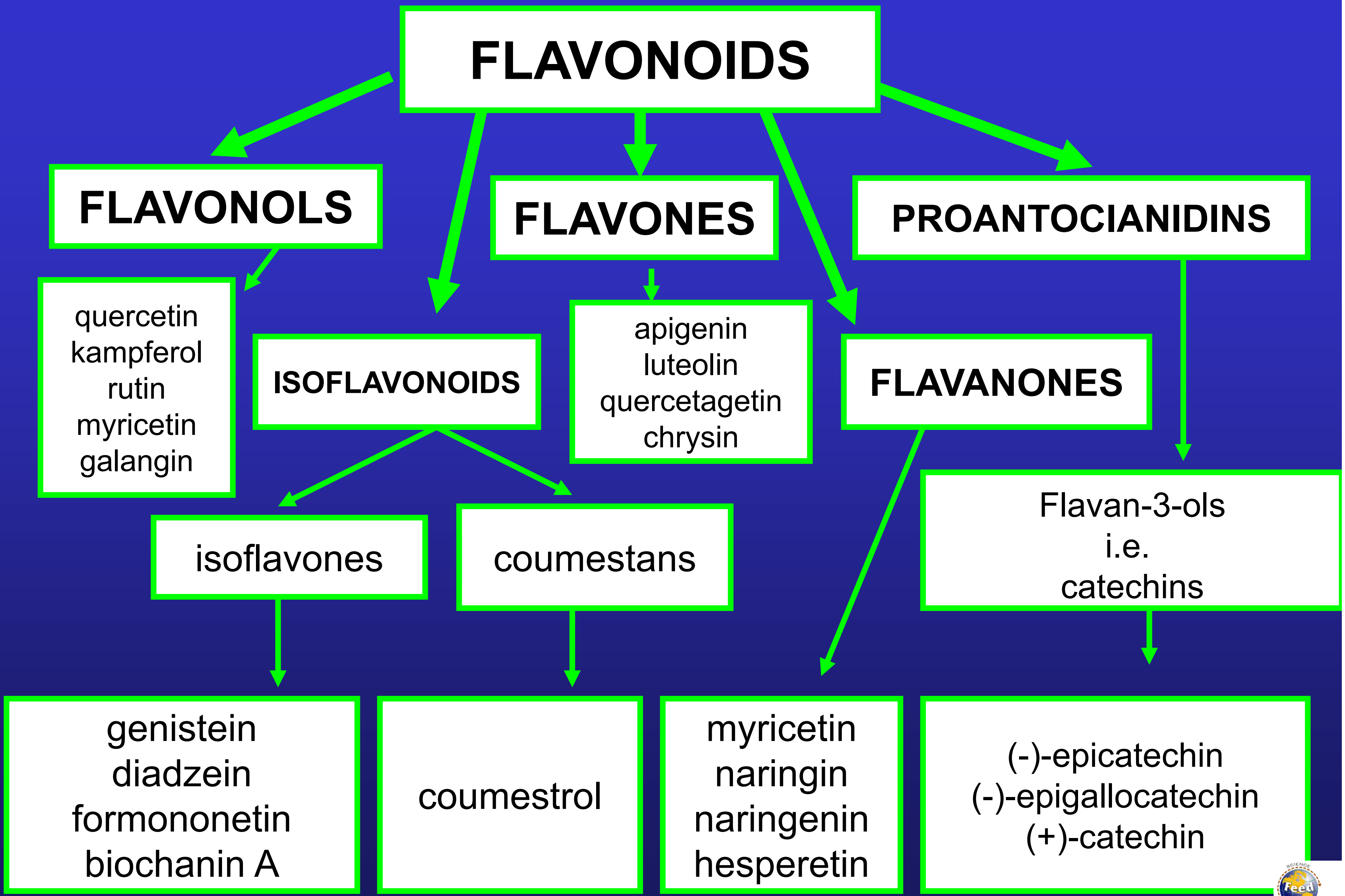
Review

Selenium in poultry breeder nutrition: An update

CrossMark

P.F. Surai[a,b,c,d,e,*], V.I. Fisinin[f]

- **Selenium is an effective regulator of antioxidant system via participation in the synthesis of various selenoproteins**
- **Effects of Se on gene expression and maintenance of the redox status of the cell need further investigation**
- **Se efficacy depends on the form of the element in the diet with organic Se (SeMet) being more effective than traditional sodium selenite**


FLAVONOIDS
FLAVONOLS
FLAVONES
PROANTOCIANIDINS
quercetin
kampferol
rutin
myricetin
galangin
ISOFLAVONOIDS
apigenin
luteolin
quercetagetin
chrysin
FLAVANONES
isoflavones
coumestans
Flavan-3-ols
i.e.
catechins
genistein
diadzein
formononetin
biochanin A
coumestrol
myricetin
naringin
naringenin
hesperetin
(-)-epicatechin
(-)-epigallocatechin
(+)-catechin

DOI: 10.1111/jpn.12070

REVIEW ARTICLE

Polyphenol compounds in the chicken/animal diet: from the past to the future

P. F. Surai[1,2,3]

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2 Scottish Agricultural College Ayr, UK, and
3 Sumy National Agrarian University Sumy, Ukraine

Summary

Animal feed provides a range of antioxidants that help the body building an integrated antioxidant system responsible for a prevention of damaging effects of free radicals and products of their metabolism. Vitamin E is considered to be the main chain-breaking antioxidant located in the membranes and effectively protecting them against lipid peroxidation. Recently, various polyphenol compounds, especially flavonoids, have received substantial attention because of their antioxidant activities in various *in vitro* systems. However, it was shown that flavonoid compounds are poorly absorbed in the gut and their concentrations in target tissues are too low to perform an effective antioxidant defences. The aim of the present paper is to review existing evidence about possible roles of various plant extracts provided with the diet in animal/poultry nutrition with a specific emphasis to their antioxidant activities.

Keywords polyphenolics, flavonoids, antioxidants, poultry, diet

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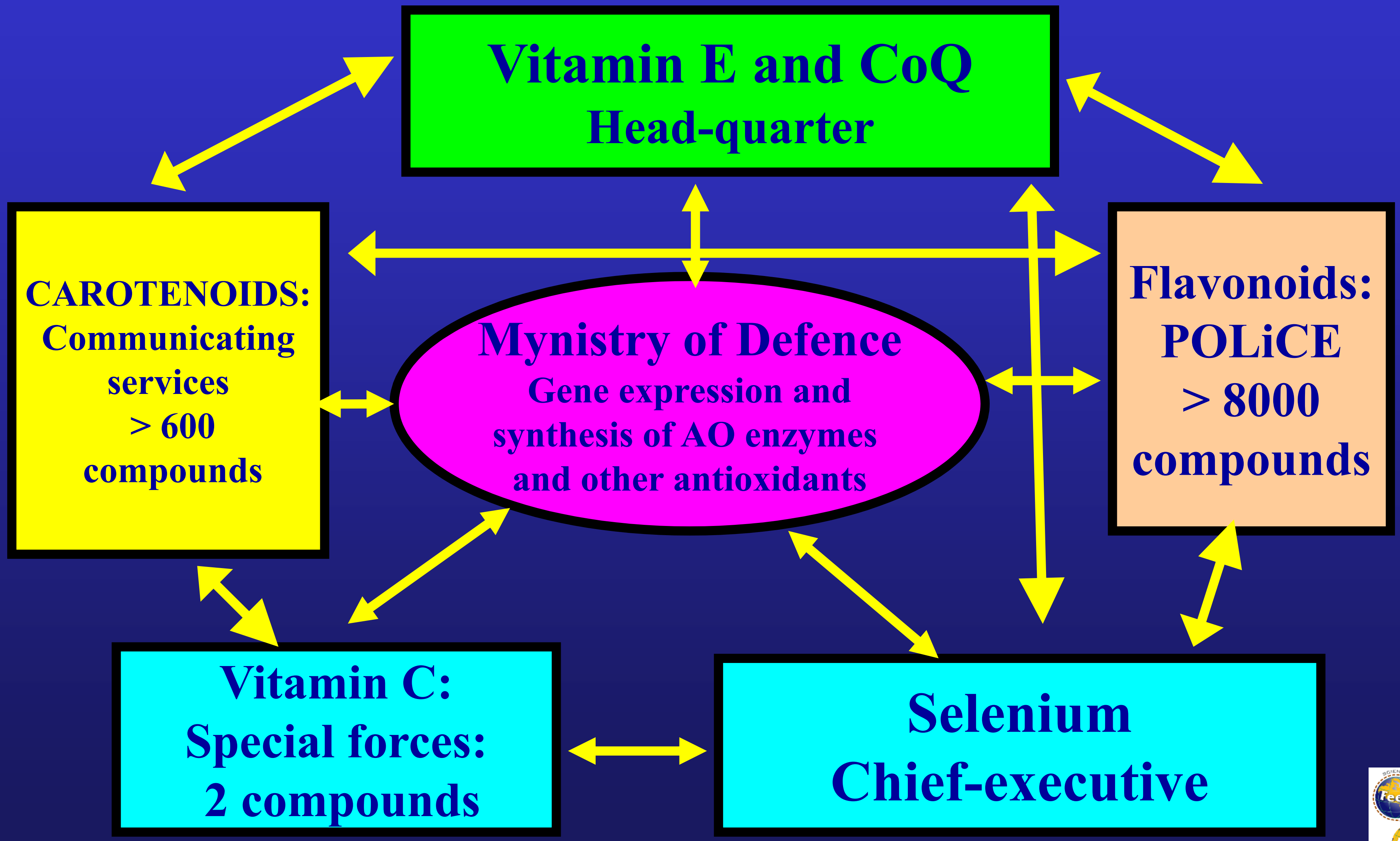
Introduction

Polyphenols constitute one of the most extensive groups of chemicals in the plant kingdom and more than 8000 such compounds have been isolated and described. They can be divided into three main subclasses: the flavonoids, phenolic acids and the stilbenoids. All these polyphenols are found in plants, esterified with glucose and other carbohydrates (glycosides), or as free aglycones. Polyphenols isolated from fruits, vegetables, green and black teas, herbs, roots, spices, propolis, beer and red wine are extensively researched for health-promoting potential (Szliszka and Krol, 2011). Numerous studies have demonstrated the beneficial effects of flavonoid-rich foods, including anticancer, antiinflammatory and cardiovascular protective effects, as well as a protective role in degenerative diseases (Egert and Rimbach, 2011; McCullough et al., 2012). However, positive associations between flavonoids intake and antioxidant defences *in vivo* (Duthie and Morrice, 2012) and human health (Jin et al., 2012) are not always the case.

There are two main basic questions related to polyphenols which urgently require answers. Firstly, it is necessary to understand processes of polyphenol absorption and metabolism in the body, including assessment of their availability and metabolism by gut microbiota. Generally speaking, most of polyphenolic compounds are poorly absorbed in the gut and their concentration in the target tissues is comparatively low. Secondly, more research should be conducted to understand molecular mechanisms of polyphenol action in the biological system. Initially, antioxidant properties of flavonoids attracted a substantial attention and generated a range of publications. However, recent, more comprehensive, studies indicate that antioxidant properties of polyphenol compounds are not major players in their mode of action. Nevertheless, a range of flavonoid-based products have been developed and marketed for human and some feed additives were designed for animal and poultry production. Even there were attempts in animal production to claim a possible replacement of traditional vitamin E supplementation with various plant extracts possessing antioxidant activities *in vitro*.

The aim of the present review is a critical analysis of achievements and misconceptions related to polyphenol physiological actions in poultry/animals with a specific emphasis to their antioxidant-related properties *in vivo*.

Antioxidant system



Antioxidant system maturation in piglets

(adapted from Yin et al., 2013)

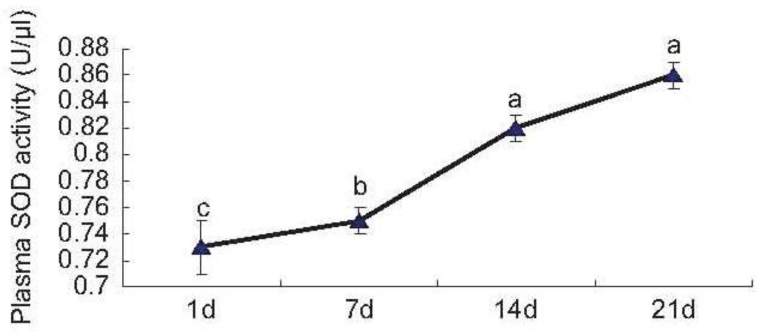


Figure 4. The fluctuation of plasma SOD activity in newborn piglets during 21 days. 1d, 7d, 14d, and 21d mean newborn piglets are slaughtered on Day 1, 7, 14, and 21 after birth ($n = 8$).

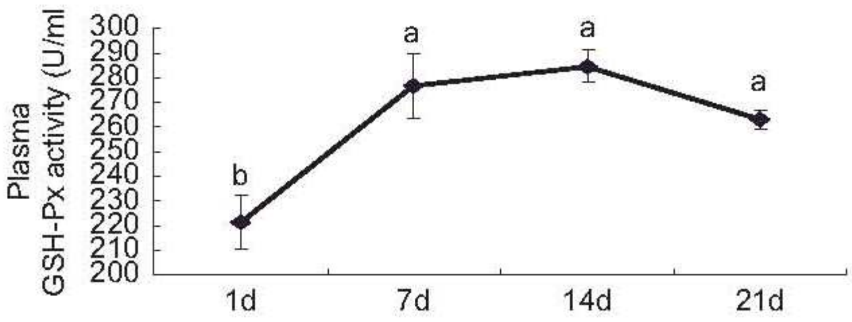


Figure 6. The fluctuation of plasma GSH-Px activity in newborn piglets during 21 days. 1d, 7d, 14d, and 21d mean newborn piglets are slaughtered on Day 1, 7, 14, and 21 after birth ($n = 8$).

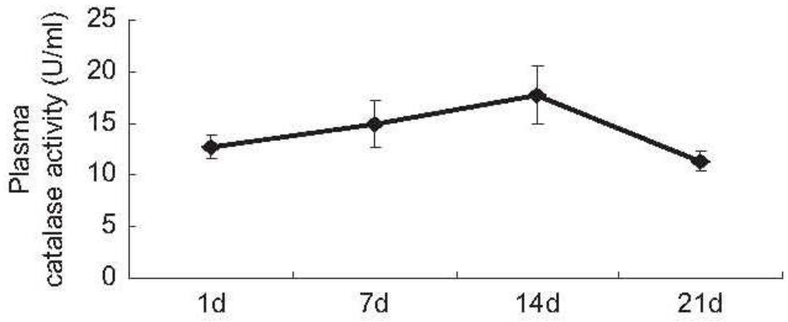


Figure 5. The fluctuation of plasma catalase activity in newborn piglets during 21 days. 1d, 7d, 14d, and 21d mean newborn piglets are slaughtered on Day 1, 7, 14, and 21 after birth ($n = 8$).

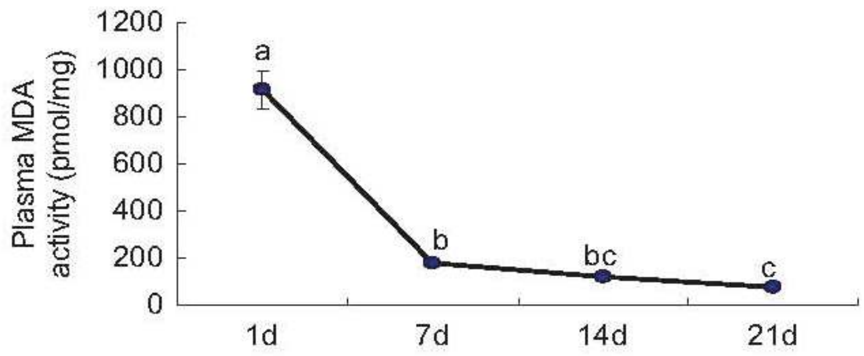
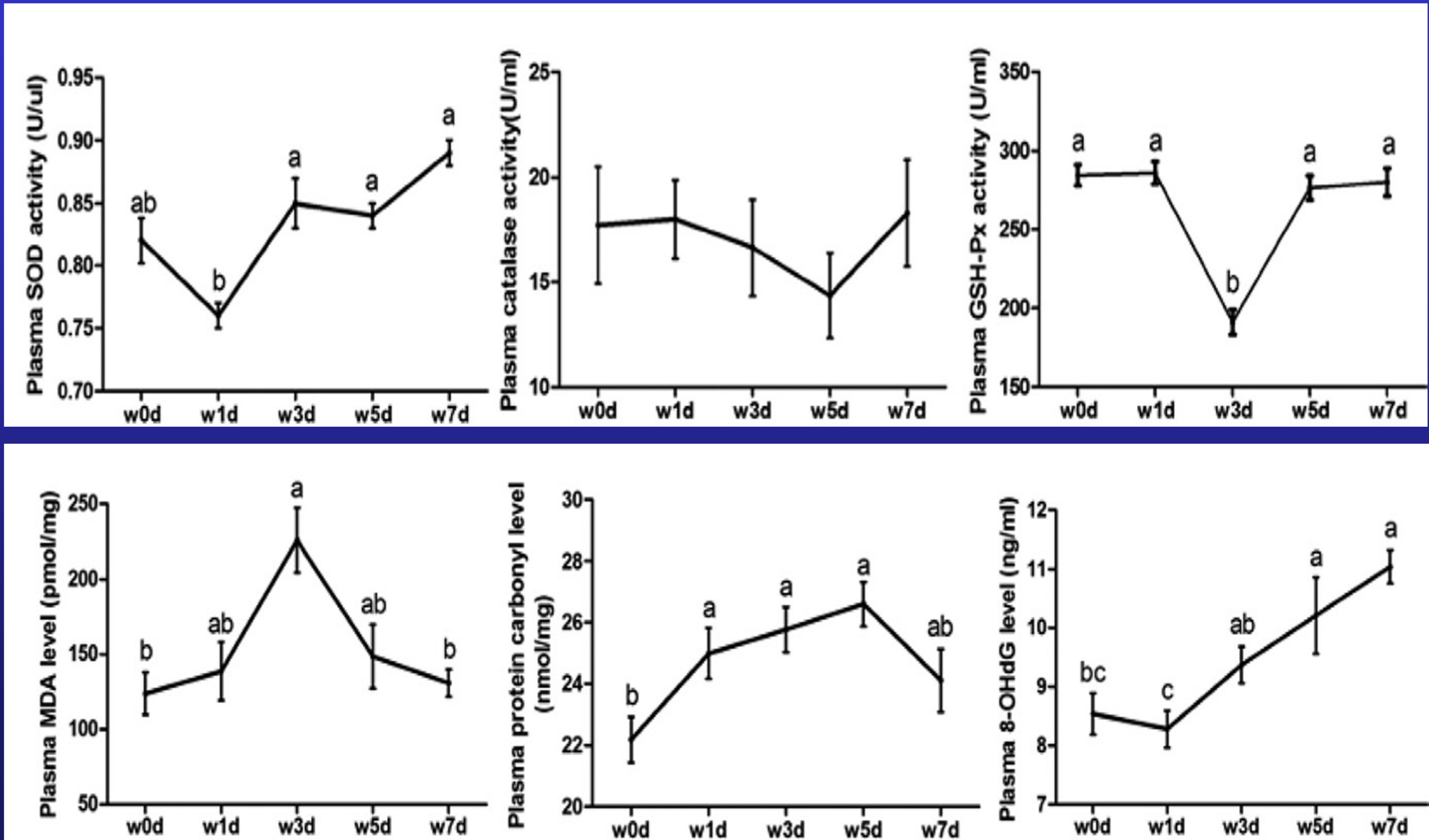


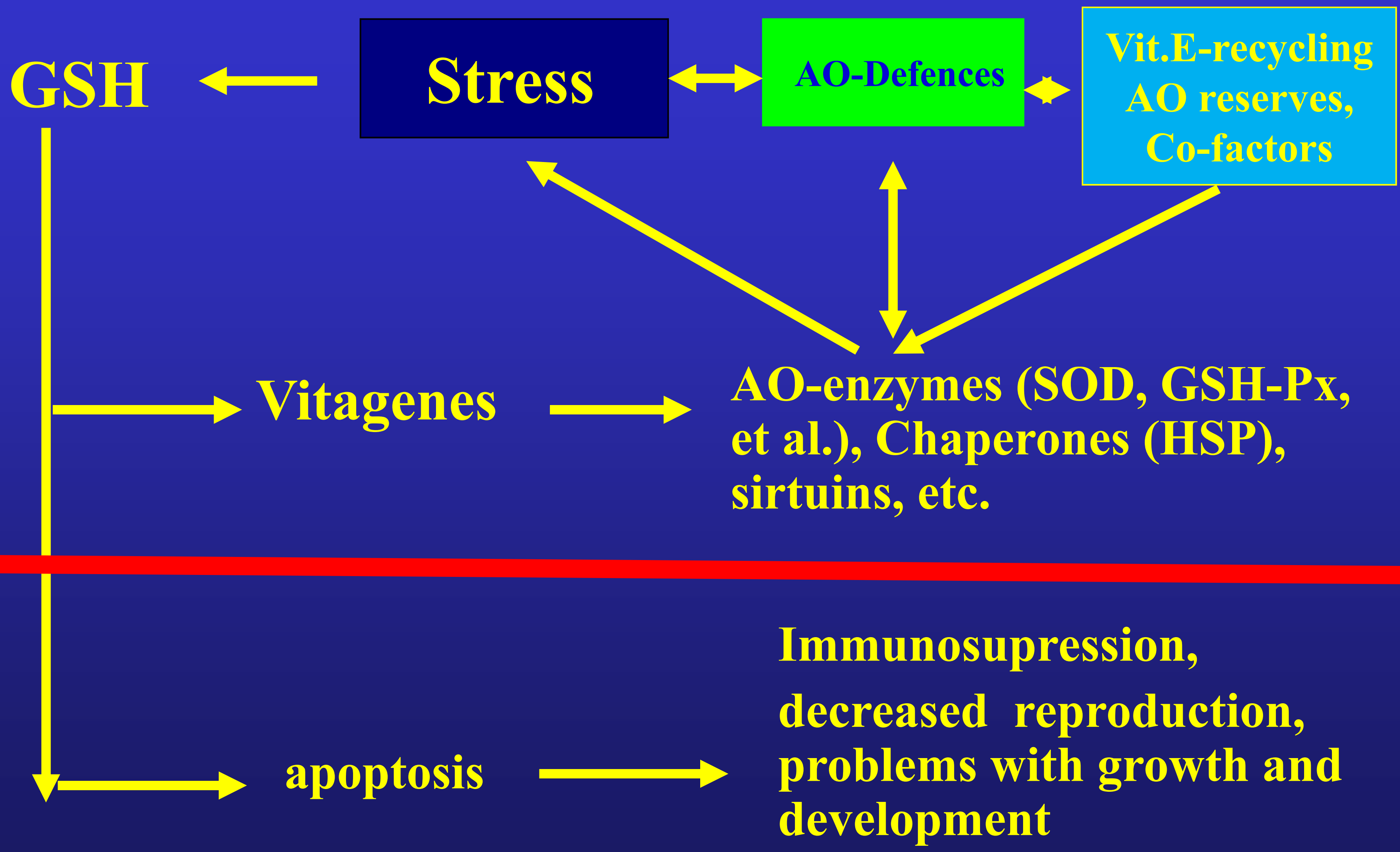
Figure 1. The fluctuation of plasma MDA in newborn piglets during 21 days. 1d, 7d, 14d, and 21d mean newborn piglets are slaughtered on Day 1, 7, 14, and 21 after birth ($n = 8$). Values are means ± SE.

Antioxidant system in early (14d) weaned piglets

(adapted from Yin et al., 2014)



Stress and Adaptation



Thank you very much for your attention

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