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INNOVATION IN LIVESTOCK PRODUCTION: FROM IDEAS TO PRACTICE

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Antioxidant nutrition in dairy ruminants

A. Baldi & L. Pinotti

[luciano.pinotti@unimi.it]
Department of Health, Animal Science and Food Safety,
Università degli Studi di Milano, 20133, Milano, Italy

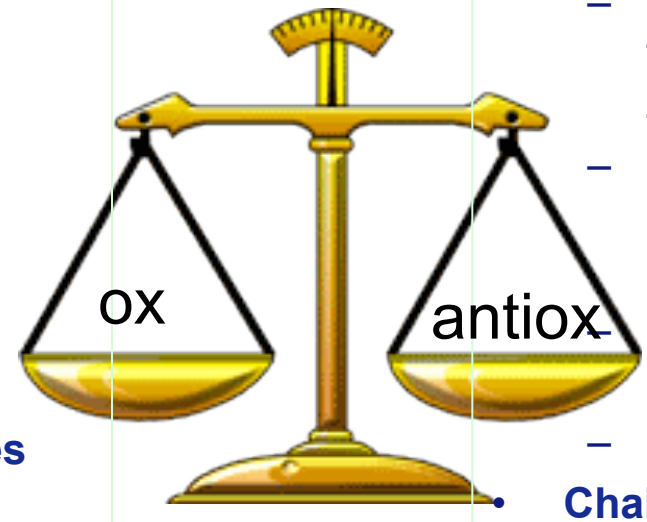
FOOD&FEED FOR WELLBEING

UNIVERSITÀ DEGLI STUDI DI MILANO
FACOLTÀ DI MEDICINA VETERINARIA

Dipartimento di Scienze veterinarie per la Salute la Produzione animale e la Sicurezza alimentare

PRO-OXIDANT AND ANTIOXIDANT BALANCE

- **Reactive oxygen species** (ROS)
  - –Radicals
    - •Superoxide, • O^-_2,
    - •Hydroxyl, •OH
    - •Hydroperoxyl, $H_2O•_2$
    - •Alkoxyl, $RO•_2$
- **Reactive nitrogen species** (RNS)
  - –Radicals
    - •Nitric oxide, NO
    - •Nitrogen dioxide, NO_2
- **Reactive chlorine species**



- **Preventive and scavenging**
  - – Metalloproteins Fe: Ferritin, transferrin; Cu: Caeruloplasmin; Zn: Metallothionein
  - – Superoxide dismutase, Glutathione peroxidase, Glutathione reductase, Catalase
  - – Vitamin E, vitamin C, vitamin A, uric acid
  - – carotenoids, flavonoids
- **Chain breaking**
  - – Vit. C, vit. E, carotenoids, flavonoids, ubiquinol, albumin, bilirubin, uric acid
  - – Superoxide dismutase
  - – Glutathione peroxidase
  - – Glutathione reductase

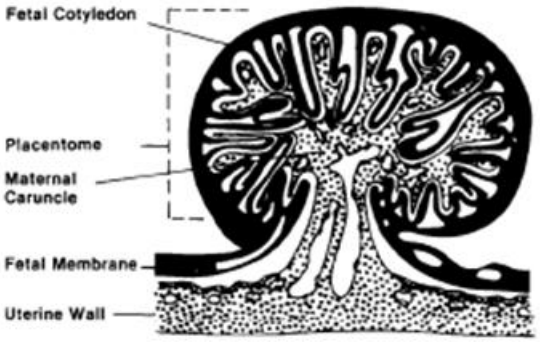
Antioxidant 3 major groups

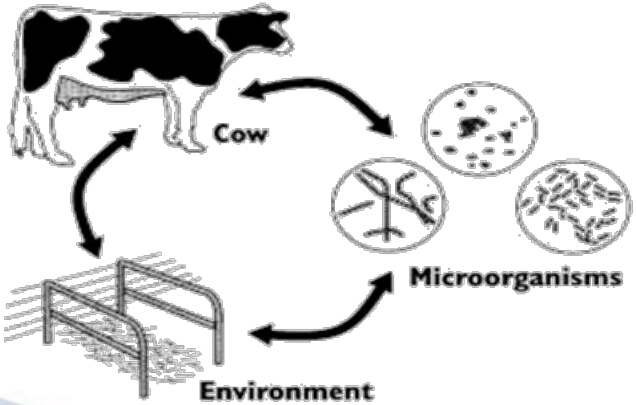
- 1° group comprises enzymatic antioxidants (mainly intracellular) > glutathione peroxidase , SOD
- 2° group includes non-enzymatic protein antioxidants that are primarily found in plasma > SH-albumin
- 3° group includes low-molecular weight antioxidants, and it is found mainly in plasma but also in other extracellular and intracellular fluids > glutathione, α-tocopherol, β-carotene…..

Chauhan *et al*., 2014

Oxidative stress (OS) & related disorders in dairy ruminants

Retained foetal membrane (RFM)

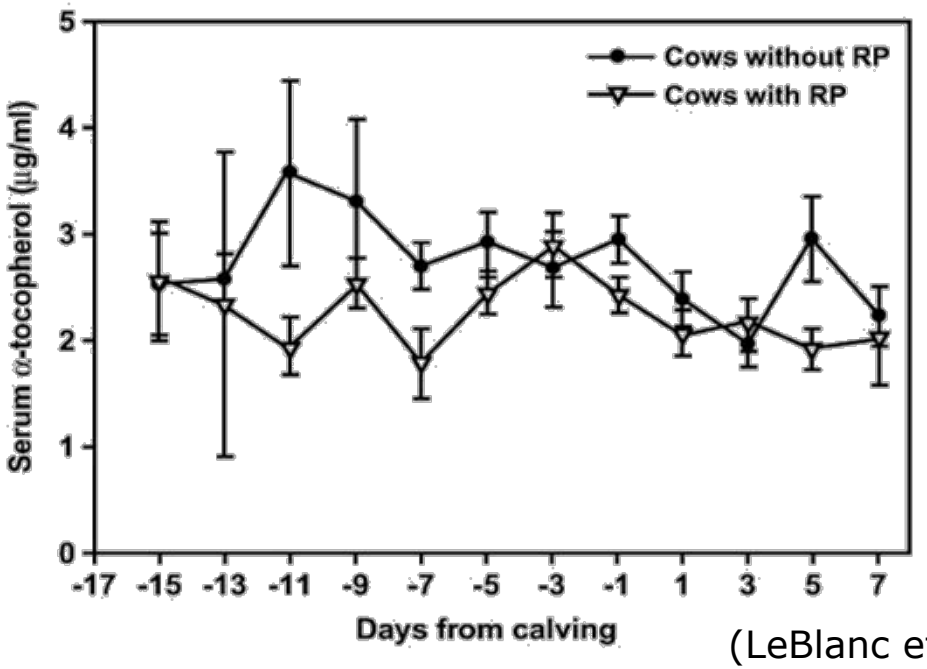


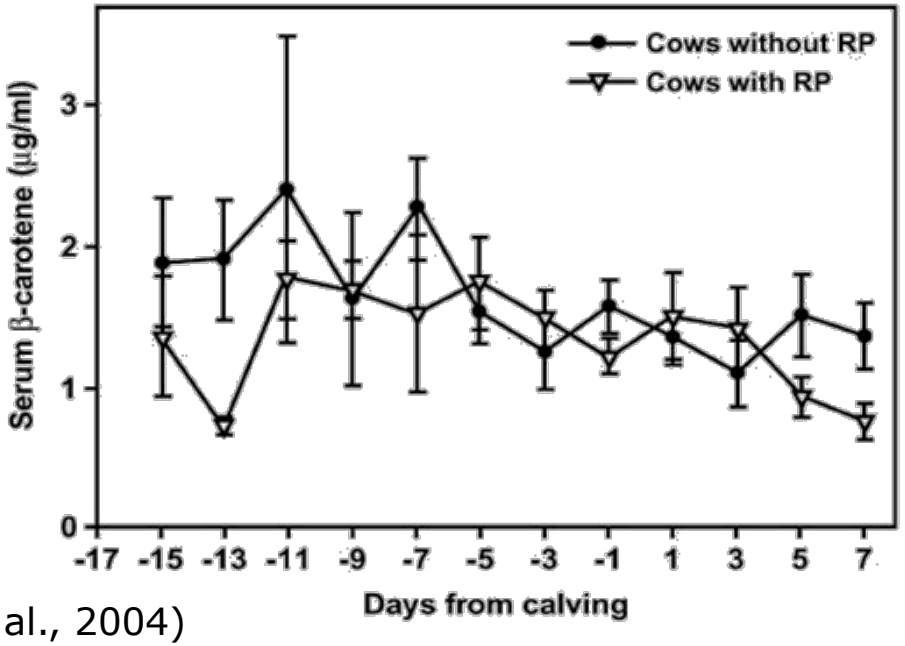


IMI and mastitis

(Baldi & Pinotti, 2007, Politis 2012)

Peripartum serum vitamin concentrations in cows with and without RFM

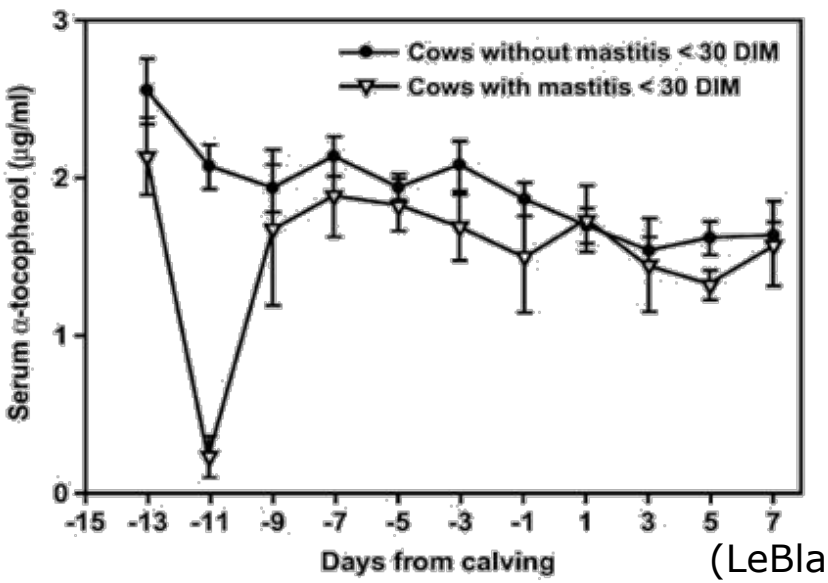


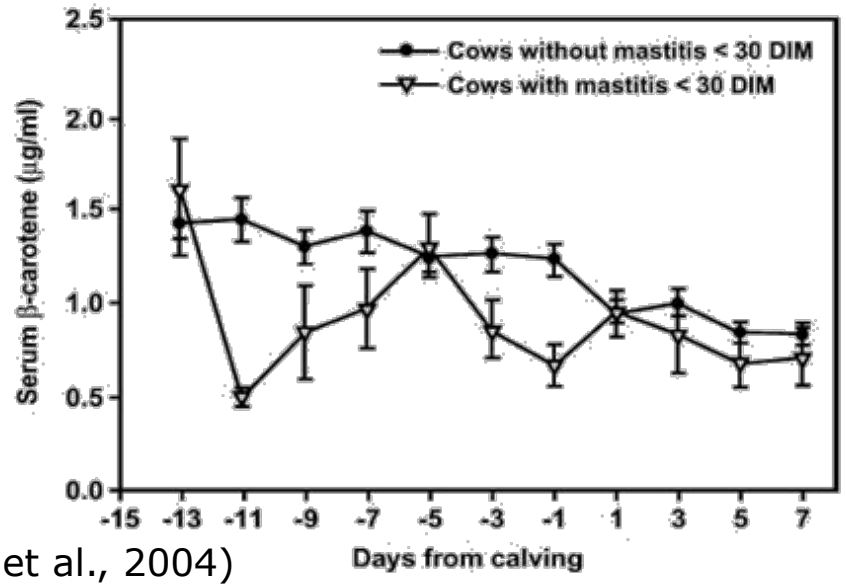


(LeBlanc et al., 2004)

- A survey of 44 studies reports that vitamin E supplementation (up to 3000 IU) reduce the risk of RFM >fertility (Bourne et al., 2007)
- For every 1mg/l increase of vitamin E, the risk of RFM decreases by 21% (LeBlanc et al., 2004)

Peripartum serum antioxidants concentrations in cows with and without mastitis before 30 DIM





(LeBlanc et al., 2004)

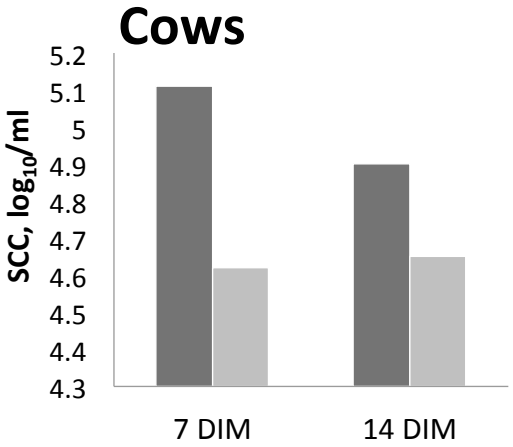
Antioxidants supplementaion (i.e. vitmin E) is generally associated with a decreased risk of mastitis (Politis 2012).

There is a significant correlation between antioxidant supplementation and decreased incidence of mastitis (Sordillo & Aitken, 2008)

Antioxidants and mammary gland health & SCC:

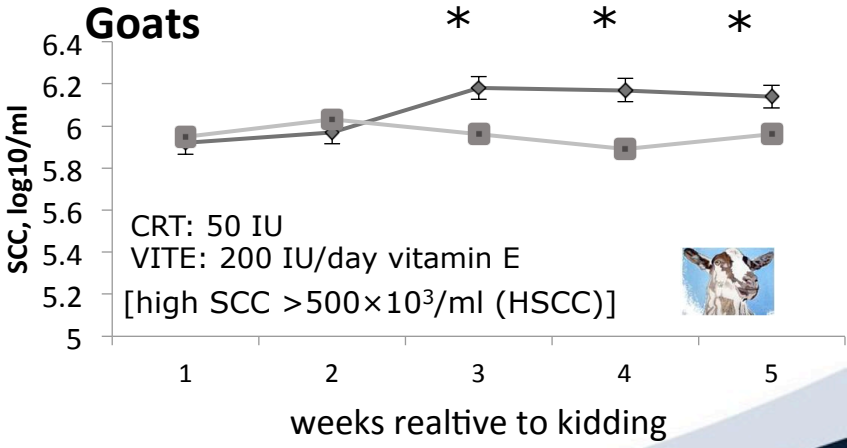
α-tocopherol serum content	DIM		
dry off	**30**	**60**	**90**
>3 µg/mL	1.125	0.923	1.669
<3 µg/mL	1.719	1.723	1.484
***P*-value**	0.18	**0.07**	0.68

(Savoini et al., 2015)



(Baldi et al., 2000)

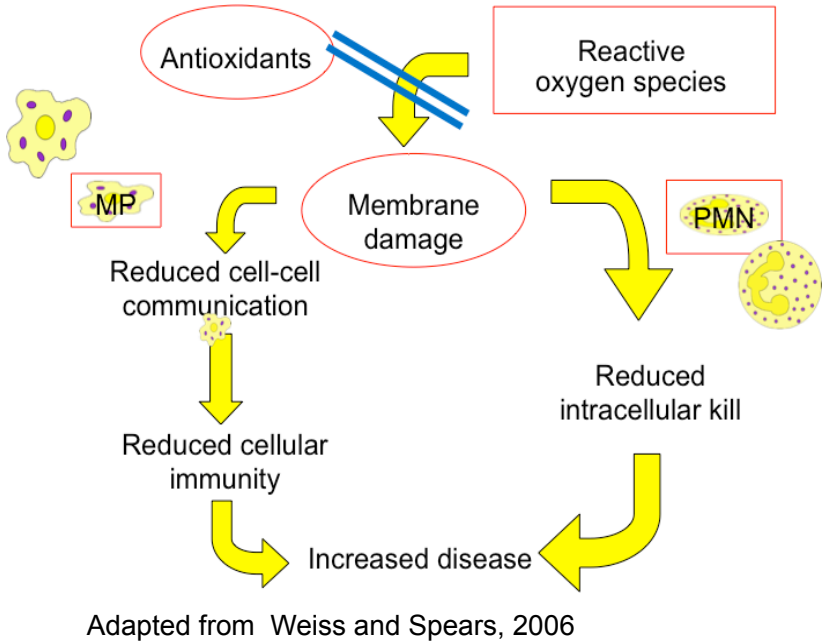
- Vitamin E supplementation can reduce SCC, if Se is adequate
- Vitamin E status at dry off is correlated with SCC in fresh cows
- Results are equivocal



(Pinotti & Baldi, 2009)

Vitamin E (& Se): mechanisms of action

- Vit.- E plays a central role as antioxidant by scavenging ROS with consequent reduction of cellular damage.
- In addition Vit.-E exerts also non-antioxidant cellular activities suggesting alternative molecular pathways for disease prevention.

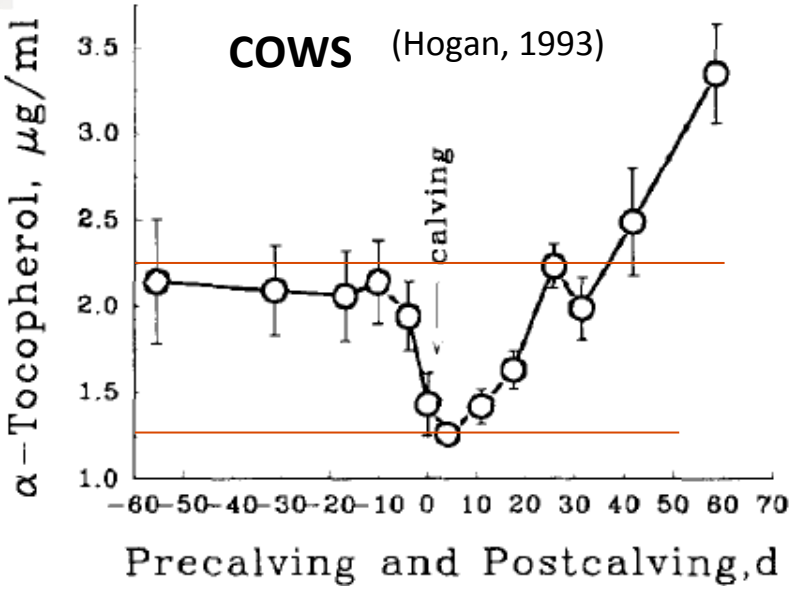


Adapted from Weiss and Spears, 2006

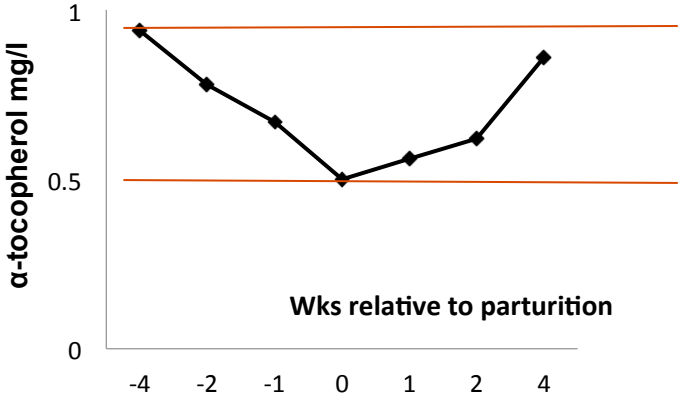
- "Ref. Values": Based on health and immune function in cows, plasma α-TC should be above 3 μg/ml in plasma [Adequate Selenium status: Whole blood >0.20 μg/ml]

In all dairy ruminats Transition period is risky

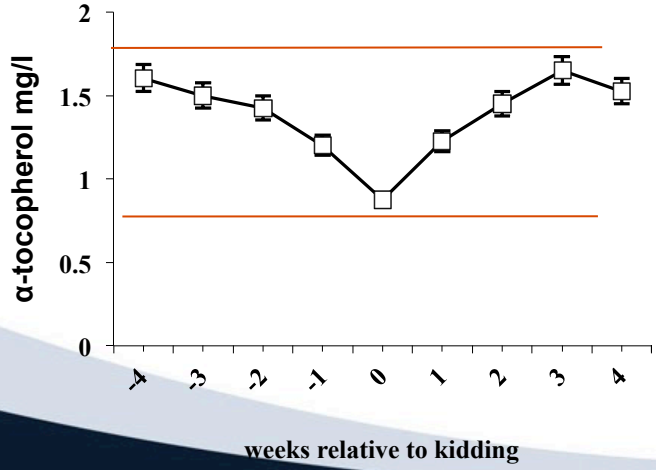
COWS (Hogan, 1993)



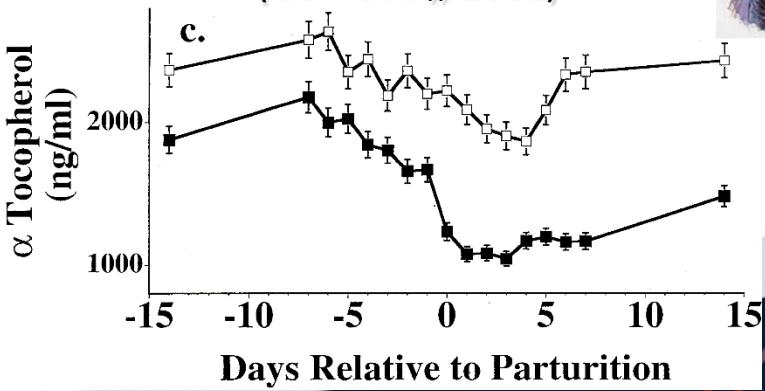
BUFFALOES (Panda et al., 2005)



GOATS (Pinotti & Baldi, 2009)

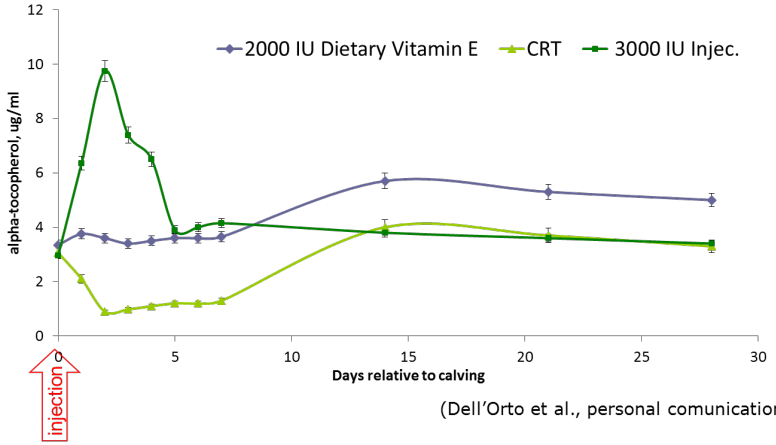


Effect of mastectomy on plasma α-TC in (Goff et al,, 2002)



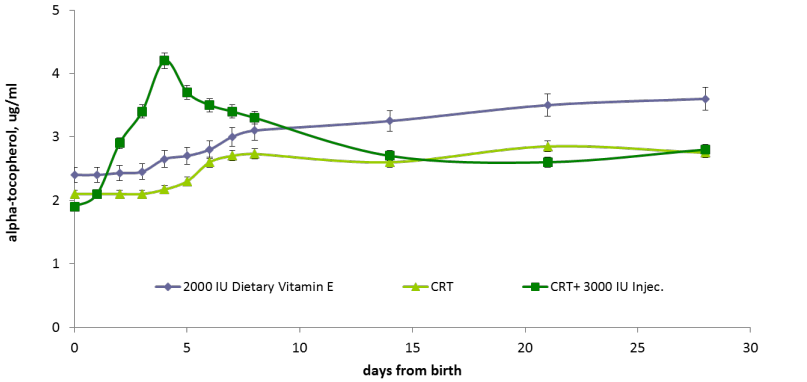
Route of administration: Injection vs feed

Plasma α-TC in beef cows



(Dell'Orto et al., personal comunication)

Plasma α-TC in calves according to cows treatments



(Dell'Orto et al., personal comunication)

Feed supplemention long term effect

Injection can be used for an immediated response

Forms and formulations

Vitamin E	Notes	References
Feed technology	↑ Microincapsulation	Baldi et al., 1997; Bontempo et al., , 1998
Forms-bioavalability	↑ Natural (RRR- form) ↓ Syntetic	Weisset al., 2009; Meglia et al., 2006; Baldiet al., 2011; Politis, 2012
Interactions with other nutrients (fats)	↑ Plasma α-TC increased by 1.9 times when fats were fed; Of note: 160 DIM, ➲ Limited effect in transition	Weiss et al., 2003 Baldi et al., 2000, 2011
Route of administration	➲ Feed suppl. Long term effects ➲ Injection immediate effects	Dell'Orto, pers. Com. Politis, 2012.

Vitamin E: summary

- Bioavalability, biopontecy, feed tecnology & nutrients inteactions need further investigations in **all dairy ruminants**
- **Minimum response around parturition**
  - Irrespective of vitamin E intake, plasma α-TC drops at parturition (over 30%), suggesting that an extra dose of the vitamin is useful at this time
- **Vitamin E supplementation** (in transition period)
  - Cows/buffaloes: 1000-2000 IU/day of vitamin E
  - Higher amounts for specific purpose (3000 IU/day for SOF in milk, herds with high inc. mastitis)
  - Ewes/goats: 100-200 IU/day vitamin E

(Baldi 2005; Baldi et al., 2000; 2007; Pinotti et al., 2008; Politis, 2012)

Selenium: in brief

Selenium effect

- Se can ameliorate OS and reduce the severity of several economically important diseases in dairy cattle including mastitis and metritis
- Many of the health benefits of Se can be attributed to the antioxidant functions of selenoproteins

Selenium forms

- Se yeast results in up to 20% higher GSH-Px activity, and Se blood concentrations compared with similar amounts of Se-selenite
  - i.e. bioavailability of organic Seis higher than inorganic Se
  - No differences in neutrophils function and health/productive traits
- **Selenium supplementation**:
  - Cows 0.30 mg/kg DM
  - Small ruminants 1-1.2 mg/kg DM

Weiss,2003; baldi et al., 2007; Phipps,2008 and Caballos,2008; Sordillo & Aitken, 2008;

Vitamin E & Se are the antioxidants commonly investigated

- Traditionally, vitamin E & Se have been the antioxidants most commonly investigated in dairy ruminants
- **Both** act synergistically to prevent OS, and **supplementation** of one appears to be less effective when the other is limiting
- Vit.-E & Se can mitigate OS and reduce the severity of several economically important diseases in dairy cattle including mastitis, RFM and metritis (other dairy rum??)
- Many of the health benefits of Vitamin E & Se can be attributed to their antioxidant functions (other under invst.)

Chauhan *et al*., 2014; Sordillo, 2013

Production:
High-producing dairy cows and OS

Group	No.	Milk yield (Kg/d)	Milk energy (MJ/d)	Lipohydroperoxide (μM)
I	5	34.2	122.2	3.6
II	6	51.7	164.8	6.5
P		0.001	0.021	0.015

High milk yield can be associated with OS indicated by oxidative modifications of circulating lipids

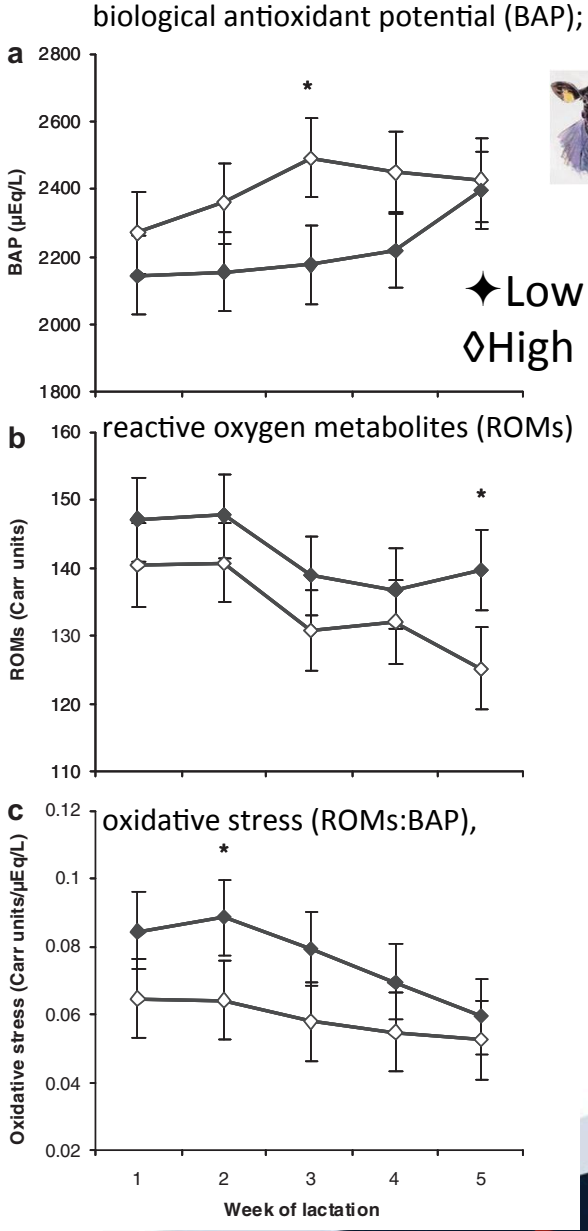
Marked increase in superoxide formation

(Lohrke et al., 2005)

Feeding regime

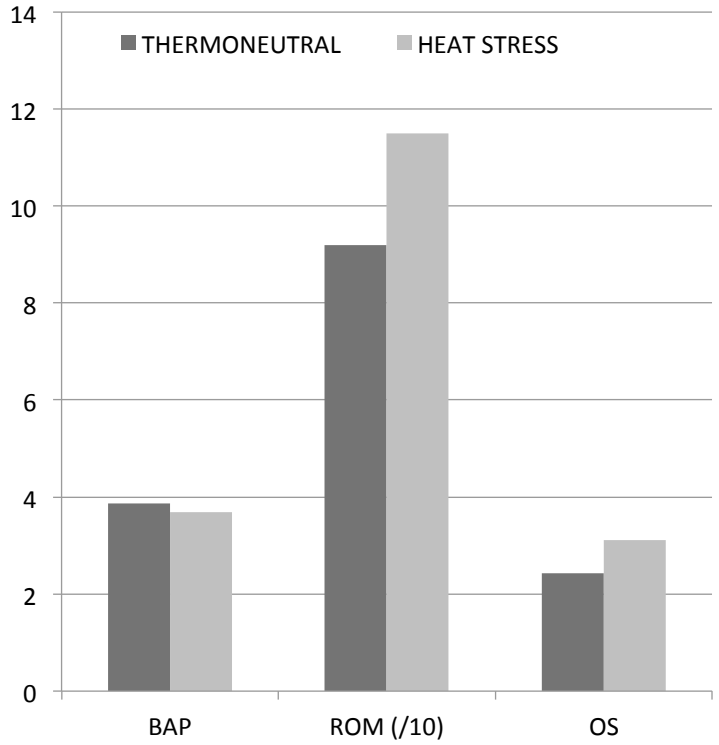
- Feeding regime has an indirect effect on the level of OS in lactating dairy cows particularly 2 weeks post-partum.
- Cows in severe NEB during early lactation had increased OS,
  - possibly due to the reduced availability of antioxidants rather than to changes in ROMs production.

(Pedernera et al., 2010; Chauhan et al., 2014)



Environmental hyperthermia

- Sheep study:
- Heat stress has been implicated in promoting OS either through:
  - excessive reactive oxygen species (**ROS**) production or
  - decreased antioxidant defenses



Chauhan *et al*., 2014

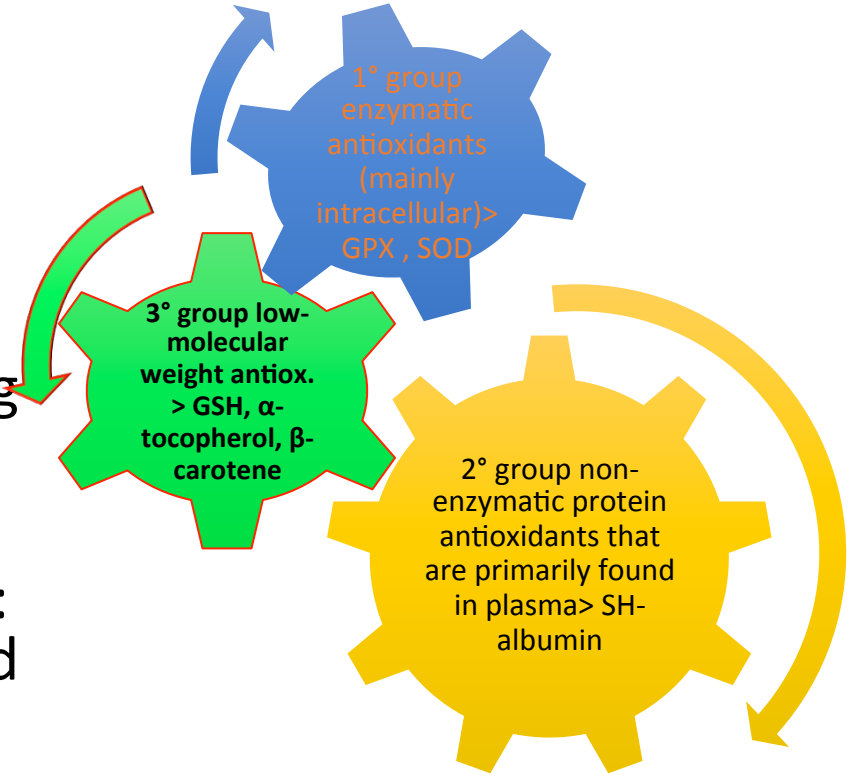
Conclusions

- A robust antioxidant network is raccomended for improving the health and performance of dairy ruminants in several crucial phases & circumstances (transition, NEB, high dietary fat and heat stress)
- Nutrition can have a major influence on OS occurrence, since several antioxidant system components are micronutrients or are dependent on dietary micronutrients.
- Vitamin E & Se are known to be effective dietary antioxidants in ruminants, while several others are under investigation and cannot yet be recommended as routine dietary supplements

Baldi et al., 2007; Chauhan *et al*., 2014; Pinotti & Baldi 2015

Future directions in all dairy ruminants

- Ideal OS biomarker does not exist
- Lack of reference values for exising markers (e.g. ROMs, ROS, BAP)
- No single biomarker can adequately characterize OS status: «panel of measurements» the gold standard in ruminants



- 2° group non-enzymatic protein antioxidants: i.e. sulfhydryl groups (SH) of albumin and are considered a significant element of extra-cellular antioxidant defense system> liver function> methyl group metabolism

Celi, 2010; Loor et al., 2015; Pinotti 2015

COST ACTION FA1308