Vitagenes in poultry production: stresses and antioxidants

Abstract. Commercial poultry production is related to a range of various stresses. A growing body of evidence indicates that excess ROS/RNS production, disturbance of redox balance and oxidative stress are major molecular mechanisms of the most common commercial stresses in poultry production. During evolution, antioxidant defence systems were developed in birds to survive in an oxygenated atmosphere. It seems likely that all antioxidants in the body work cooperatively together as a team to maintain optimal redox balance in the cell/body. Nutritional modulation of vitagenes is considered as a new direction in nutritional research. Therefore, there is an opportunity to activate a range of vitagenes to maximise internal AO protection and maintain redox balance and improve stress resistance. Since ROS/RNS are considered to be important signalling molecules, their concentration is strictly regulated by the antioxidant defence network associated with various transcription factors and vitagenes.

Key words: poultry, stress, antioxidants, molecular mechanism, vitagenes

Introduction

It is well appreciated that commercial poultry production is associated with a range of environmental, technological, nutritional and internal/biological stresses, responsible for decreased productive and reproductive performance and compromised health (Surai and Fisinin, 2016a; 2016b). Generally speaking, many stress conditions could be avoided by technological improvements, but the main restriction is the cost of such improvements. Accumulating evidence indicates that at the molecular/cellular level most commercially relevant stresses in poultry production are associated with overproduction of free radicals, compromised antioxidant defences network and oxidative stress (Surai, 2018; Surai et al., 2018; 2019). It has been clearly shown that free radicals in the form of reactive oxygen species (ROS) and reactive nitrogen species (RNS) are damaging to all types of biological molecules including polyunsaturated fatty acids (PUFAs), proteins and DNA. Furthermore, signaling roles of ROS have recently received tremendous attention. Indeed, adaptation to various stresses relies on various signaling pathways and vitagenes were shown to play crucial roles in such an adaptation (Surai and Fisinin, 2016c; 2016d; Surai et al., 2019). Therefore, the main task of this review is to present an updated view on the commercially relevant stresses in relation to the antioxidant defence network in poultry.

1. Main stresses in Poultry Production

As mentioned above, commercial poultry production is associated with a range of various stresses (Table 1). Therefore, an important task for poultry nutritionist is to develop a nutritional program meeting poultry requirement in major nutrients.

However, it is very difficult to predict stresses in commercial poultry production and to develop an optimal program to deal with them. On one hand, in stress conditions requirements in various nutrients increase. On the other hand, feed consumption in stress conditions usually decreased. Therefore, at times when birds need more nutrients they actually
2. Antioxidant defence network

To address the aforementioned question, molecular mechanisms of stress development have been studied in details. The updated view on the antioxidant defence network is shown in Figure 1.

As can be seen from the Figure 1, there is a range of important options to maintain antioxidant defences in the cell/body. First of all, oxygen availability is a key regulator of free radical formation and a decreased oxygen availability could decrease ROS formation and less antioxidants would be needed to deal with a situation. Since, free iron and copper are major catalysts of ROS formation, their binding to proteins or chelating are important steps in AO defences. It is well known that mitochondria are a major source of ROS in the living cells and supporting mitochondria integrity by such nutrients as carnitine, taurine or silymarin are of major importance for the antioxidant defence network. There is also an important option to decrease ROS-producing enzyme activities to control antioxidant defences. Scavenging intermediate free radicals, for example, superoxide radical by SOD in mitochondria, is considered as the first level of the antioxidant defence network. Further detoxification of the such toxic products as H2O2 or lipid hydroperoxides by such enzymes as GPx and non-enzymatic antioxidants (vitamin E, GSH, coenzyme Q, etc.), plays a vital role in antioxidant defences. In particular, it is well accepted that vitamin E is the main chain-breaking antioxidant in biological membranes, but after catching a free radical alpha-tocopherol is oxidised and if not reduced back it is lost. Therefore, biological vitamin E recycling by ascorbic acid and further recycling with involvement of Se-dependent enzyme thioredoxin reductase, riboflavin-dependent glutathione reductase and other elements connecting to pentose phosphate cycle as a source of NADPH is a most important part of the antioxi-
dant defence strategy. Indeed, in the case of effective vita-
min E recycling even low dietary vitamin E doses can deal
with overproduction of ROS, while in the case of non-e-
fective vitamin E recycling even high vitamin E dietary sup-
plementation would not have adequate protective effect.
All the aforementioned mechanisms of the antioxidant
defence are still not able to prevent damages to biological
molecules and therefore repair of the damaged molecules
(e.g. HSP, methionine sulfoxide reductase, DNA-repair
enzymes, etc.) or their removal (phospholipases, etc.) are
deeply involved in the antioxidant defences. Interestingly,
if the stress is too high and the antioxidant defences are
not able to deal with it and there is an accumulation of
damaged molecules such processes as apoptosis and fer-
roposis would kill the damaged cell to prevent transfer-
ing damages to other cells. Furthermore, redox signaling
and activation of various transcription factors (HSF, Nrf2,
NF-kB, etc.) are key players in adaptation to stress and de-
creasing detrimental consequences of the oxidative stress.
In particular, antioxidant response element (ARE)-related
synthesis of antioxidant enzymes is considered to be the
main adaptive response mediated by transcription factor
Nrf2. Finally, activation of vitagenes via Nrf2, HSF and oth-
er transcription factors is a recent entrant into the antiox-
idant defence family.

3. Stress and adaptation

A modern view on stress adaptation is shown in Figure 2.
As mentioned above, overproduction of ROS and ox-
idative stress are major molecular mechanisms of various
stresses. Indeed, independently of the source of stress (e.g.
increased temperature, high amount of dust in air, myco-
toxins in the feed or vaccination stress, etc.) at the molec-
ular level ROS overproduction and damages to biological
molecules are driving forces of the detrimental consequenc-
es in terms of chicken health. Their productive and repro-
ductive performance. Therefore, when antioxidant defence
system can deal with those free radicals, the small amount
of ROS participates in cell signaling providing an important
mechanism of stress adaptation. In particular, they activate
such transcription factors as Nrf2 or HSFs, with following
vitagene activation and additional synthesis of protective
molecules (antioxidants) to maintain adaptive homeostasis.
However, when stress is too high and antioxidant defence
system cannot prevent damages to PUFAs, proteins and
DNA oxidative stress is responsible for activation of other
transcription factors, including NF-kB leading to synthesis
of pro-inflammatory cytokines and inflammation, com-
promised immunity and general health. This is associated
with decreased productive and reproductive performance of
growing chickens, rearing birds, layers and breeders.
Вітагени у птахівництві: стреси та антиоксиданти

Анотація. Промислове птахівництво пов’язане з низкою стресів. Дані останніх років переконливо свідчать про те, що надмірне утворення вільних радикалів, порушення редокс-балансу і окислювальний стрес є головними молекулярними механізмами більшості стресів у птахівництві. В процесі еволюції у птахів були вироблені спеціальні антиоксидантні механізми, що дозволяють їм вижити в атмосфері з високим вмістом кисню. Вважається, що всі антиоксиданти в організмі працюють спільно як одна команда, підтримуючи оптимальний редокс-баланс в клітинах/організмі.

Активізація вітагенів різними нутрієнтами вважається новим напрямом у дослідженнях в області питання. При цьому активізація вітагенів у стрес-условних умовах дозволяє усилити антиоксидантний захист, підтримати окислительно-відновний баланс у організмі та підвищити устойчивість до стресів. Таким чином, існує можливість активувати ряд вітагенів для максимального внутрішнього антиоксидантного захисту, подолання окислительно-восстановительного балансу в організмі.

Ключові слова: птахівництво, стрес, антиоксиданти, молекулярний механізм, вітагени

References