Antioxidants and phytomolecules mitigate quality degradation in broiler breasts

By Inge Heinzl and Ajay Bhoyar, EW Nutrition

Genetic selection for faster growth of breast muscle in broilers may lead to increased incidences of different types of muscle degeneration. Downgrading the affected breast fillets results in high economic losses for the poultry meat industry.

The article discusses the three important myopathies impairing the breast muscles, their impact on the meat industry, influencing factors, and how to cope with these challenges.

Muscle degeneration heaps up with faster broiler growth

According to Sirri and co-workers (2016), breast fillets from broilers with 3.9 kg live weight carry a higher risk for myopathic lesions. Studies in different countries revealed that myopathies in broilers are not neglectable:

Country	Myopathy	Number of breasts examined	Conditions	Occurrence	Reference

Italy	WS	28,000 broilers	commercial	12 %	Petracci et al., 2013
Italy	WS	70 flocks; always 500 of 35,000 breasts randomly examined	commercial	43%, with 6.2% considered severe	Lorenzi et al., 2014
Italy	WS	57 flocks	commercial	70.2 % (medium)-82.5 % (heavy-weight)	Russo et al., 2015
Italy	WS	16,000 samples	commercial	9 % moderate22 % severe	Petracci in Baldi et al., 2020
Brazil	WS	25,520	commercial	10 %	Ferreira et al., 2014
USA	WS	960 (week 6)+ 960 (week 9)	experimental	Score 1: 78.4 % (wk 6) 29.9 % (wk 9) Score 2: 14.0 % (wk 6) 53.9 % (wk 9) Score 3:0 % (wk 6) 15.1 % (wk 9)	Kuttapan et al., 2017
Brazil	WB		commercial	10-20 %	Carvalho, in Petracci et al., 2019
Italy	WB	16,000 samples	commercial	42 % moderate 18 % severe	Petracci, in Baldi et al., 2020
China	WB	1,135 breast fillets	commercial	61.9%	Xing et al., 2020
USA	WB	960 (week 6)+ 960 (week 9)	experimental	Score 1: 32.5 % (wk 6) 33.2 % (wk 9) Score 2: 7.9 % (wk 6) 36 % (wk 9) Score 3: 1.96 % (wk 6) 15.6 % (wk 9)	Kuttapan et al., 2017
Italy	SM	16,000 samples	commercial	4 % moderate 17 % severe	Petracci in Baldi et al., 2020
Brazil	SM	5,580 samples	commercial	10 %	Montagna et al., 2019

Figure 1: Different myopathies in broilers (R. Baileys)

As the appearance of products is one of the most important arguments for the purchase decision, these myopathies are serious issues; the downgrading of the breast quality results in a lower reward for the producer. Kuttapan et al. (2016) estimated that 90 % of the broilers are affected by wooden breast and white striping (see below), causing about $200 million to $1 billion of economic losses to the U.S. poultry industry per year.

Wooden Breast (WB), a result of the proliferation of connective tissues

The muscle affected by the wooden breast is bulging and hard, is covered with clear, viscous fluid, and shows petechiae (see figure 2). The myopathy of the pectoralis major is “pale expansive areas of substantial hardness accompanied by white striation” (Kuttapan, 2016; Huang and Ahn, 2018; Sihvo et al., 2013). It is characterized by microscopically visible polyphasic myodegenerations with fibrosis in the chronic phase. At approximately two weeks of age, it appears as a focal lesion but then develops as a widespread fibrotic injury (Papah et al., 2017). WB can be detected by palpating the breast of the live bird.

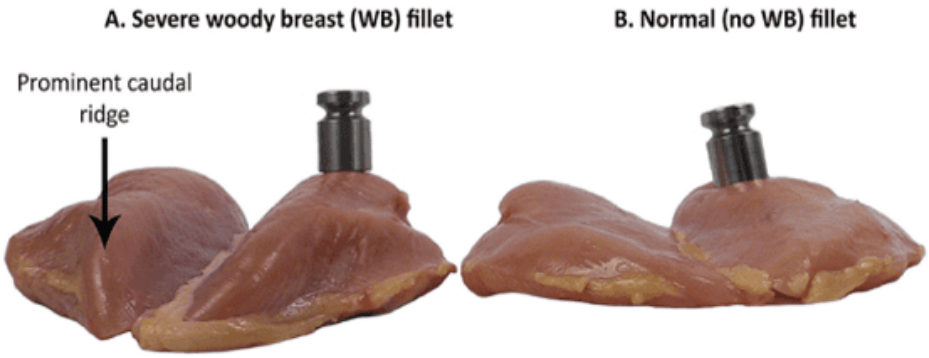


Figure 2: Comparison of a severe wooden breast (on the left) and a healthy breast fillet (on the right)

Source: Kuttapan et al., 2016

According to Kuttapan et al. (2016), the anomaly is caused by circulatory insufficiency and increased oxidative stress resulting in damage and degeneration. Its occurrence rose with increasing growth and slaughter weights of the birds. Wooden breast is more common in male than female broilers as they show an increased expression of genes related to the proliferation of connective tissues (Baldi et al., 2021).

The hardness of the meat, a 1.2 – 1.3 % higher fat content (Soglia et al., 2016, Tasoniero et al., 2016), and the worse appearance lead to a degradation of the fillet quality (Kuttappan et al., 2012). The reduction in the water holding capacity of muscle results in toughness before and after cooking.

White Striping (WS), a result of fiber degeneration

The characteristics of WS are white striations parallel to the muscle fibers. A microscopic examination of these white stripes reveals an accumulation of lipids and a proliferation of connective tissue occurring in breast fillets and thighs (Kuttappan et al., 2013a; Huang and Ahn, 2018). Kuttapan et al. (2016) adapted a scoring system for the evaluation of the severity of WS, which he had established earlier (Kuttapan et al., 2012)(see picture 1). It was concluded that broilers fed a diet with high energy content led to higher and more efficient growth (improved feed conversion, higher live and fillet weights) but also to a higher percentage of fillets showing a severe degree of white striping.

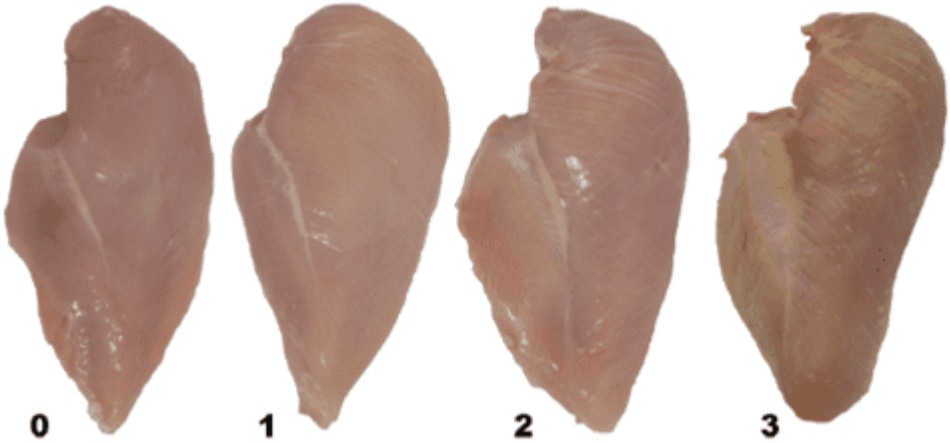


Figure 3: Different degrees of white striping

0 = normal (no distinct white lines)
1 = moderate (small white lines, generally < 1 mm thick)
2 = severe (large white lines, 1-2 mm thick, very visible on the fillet surface)
3 = extreme (thick white bands, > 2 mm thickness, covering almost the entire surface of the fillet
(scoring and image source: Kuttapan, 2016)

Moreover, the WB and WS can simultaneously occur in the same muscle (Cruz et al., 2016; Kuttappan, Hargis, & Owens, 2016; Livingston, Landon, Barnes, & Brake, 2018).

Spaghetti Meat (SM), a result of decreased collagen linking

The condition of Spaghetti Meat was first mentioned by Bilgili (2015) under “Stringy-spongy”. SM is characterized by an insufficient bonding of the muscles due to an immature intramuscular connective tissue in the pectoralis major. The fiber bundles composing the breast muscle detach, and the muscle gets soft and mushy and resembles spaghetti pasta (Baldi et al., 2021). Probably due to the reduced collagen-linking degree, the texture of SM fillets is smoother after cooking (Baldi et al., 2019). In contrast to wooden breast, SM cannot be noticed in the living animal. Meat severely impacted by SM is downgraded and can only be used in further processed products, whereas slightly affected meat can be sold in fresh retailing (Petracci et al., 2019).

Another possible explanation for this myopathy may be the enormous development of the breast muscle. The thickness of its upper section might reduce muscular oxygenation by compressing the pectoral artery (Soglia et al., 2021). The spaghetti structure generally appears mainly in the superficial layer and less in the deep ones.

Oxidative stress – one link in the chain of causes for myopathies

Oxidative stress is a result of impaired blood

supply

Oxidative stress is one key factor of myopathies in breast muscle. Selection for faster growth, especially for more breast meat yield, during the last 10-20 years led to increased muscle fiber diameter. The higher pressure of the surrounding fascia on the muscle tissue compresses the blood vessels, leading to a decreased blood flow, resulting in insufficient oxygen supply (hypoxia) and limited removal of metabolic by-products (Lilburn et al., 2019) from the muscle tissue. Hypoxia as – well as hyperoxia – plus the deficient removal of metabolic waste, promote the generation of free radicals (Kähler et al., 2016; Strapazzon et al., 2016; Petrazzi et al., 2019). If the endogenous antioxidant system cannot efficiently eliminate these ROS by using endogenous and exogenous antioxidants, the ultimate effect is increased oxidative stress.

Soglia and co-workers (2016) reported higher TBARS (Thiobarbituric acid reactive substances) and protein carbonyl levels, signs of oxidative stress, in severe wooden breast muscle tissue. The oxidative stress hypothesis was also supported by gene transcription analysis conducted by Mutryn et al. (2015) and Zambonelli et al. (2017).

Oxidative stress causes damage

ROS (reactive oxygen species) or free radicals are highly reactive. They can cause damage to the DNA, RNA, proteins, and lipids in the muscle cells (Surai et al., 2015), leading to inflammation and metabolic disturbances, and, in the end, the degeneration of muscle fibers (Kuttapan et al., 2021). If the regenerative capacity of the muscle cells does not countervail against the damages caused by oxidative stress, fibrous tissue and fat accumulate and lead to myopathies such as wooden breast (Petracci et al., 2019)

Oxidative stress can be managed

To support the animals in coping with oxidative stress, combining two approaches, an external and an internal, makes sense. This entails protecting feed at the same time as protecting the animal.

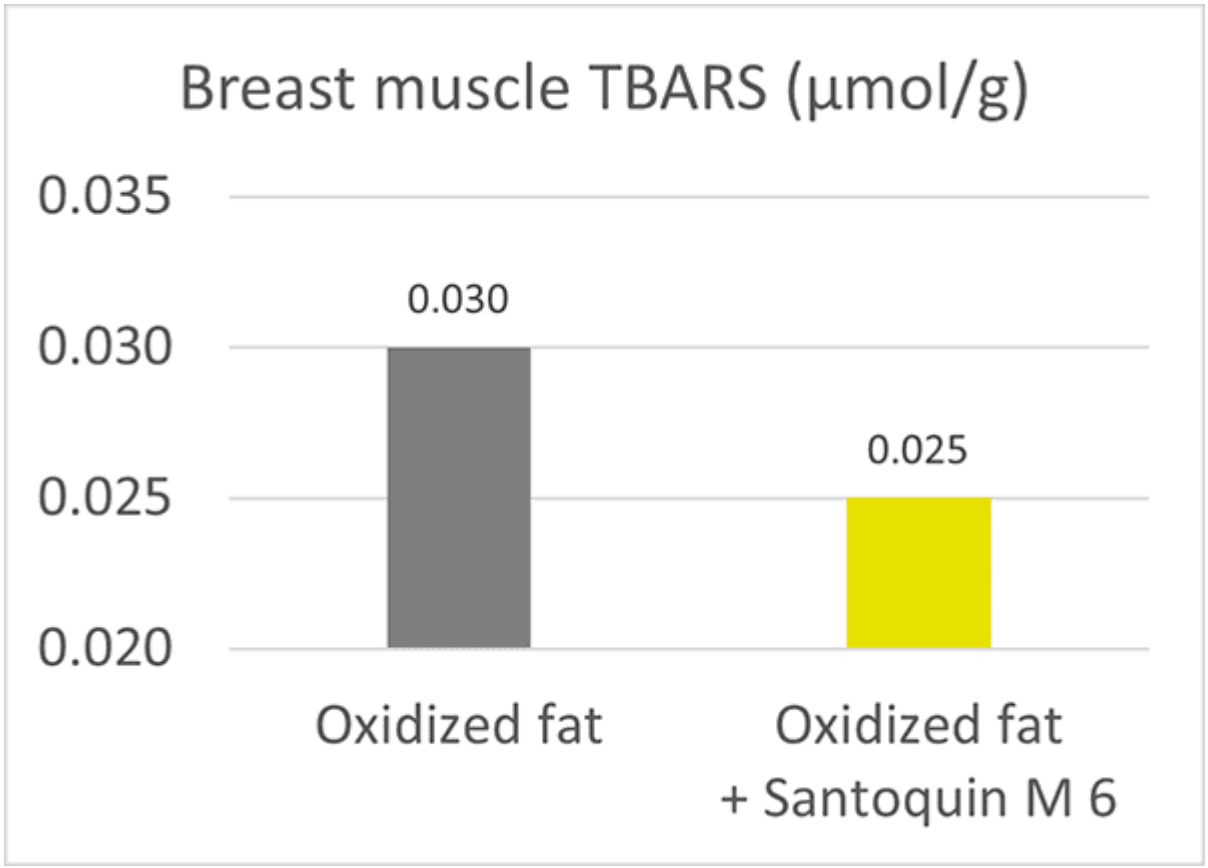
Chemical antioxidants preserve feed quality and prevent oxidation

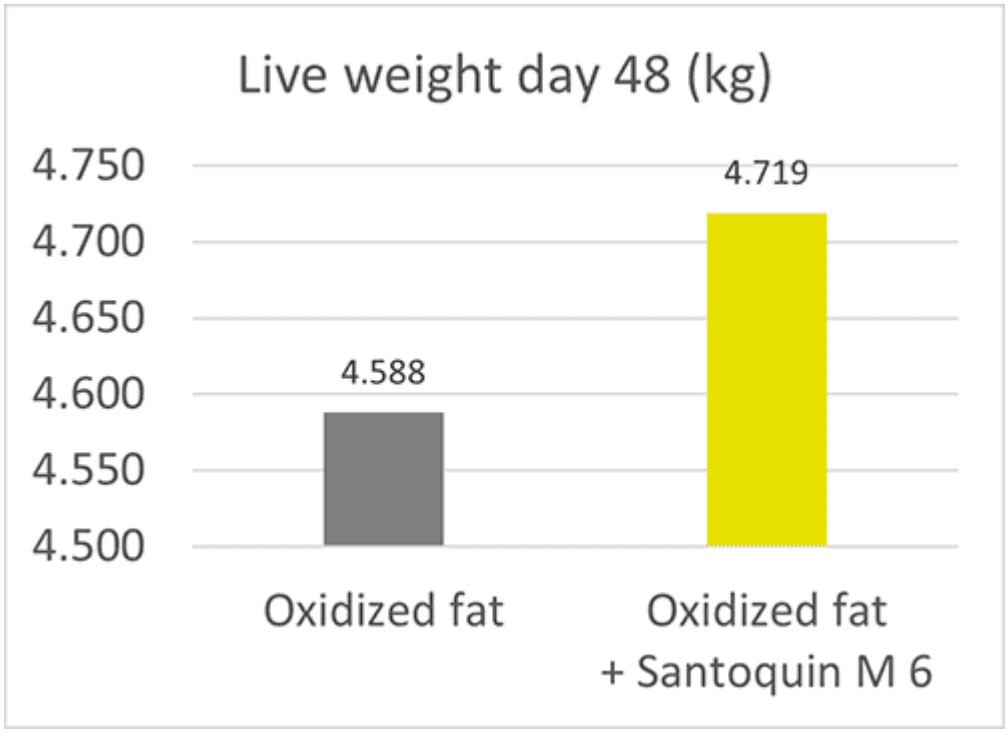
Chemical antioxidants such as ethoxyquin, BHA, and BHT efficiently prevent feed oxidation. These antioxidants prevent the oxidation of unsaturated fats/oils and maintain their energy value. They are scavengers for free radicals, protect trace minerals like Zn, Cu, Mg, Se, and Vit E from oxidation and spare them to be used in the body for different metabolic processes as well as for the endogenous antioxidant system.

Antioxidant capacity of Santoquin M 6 in feed confirmed in a trial

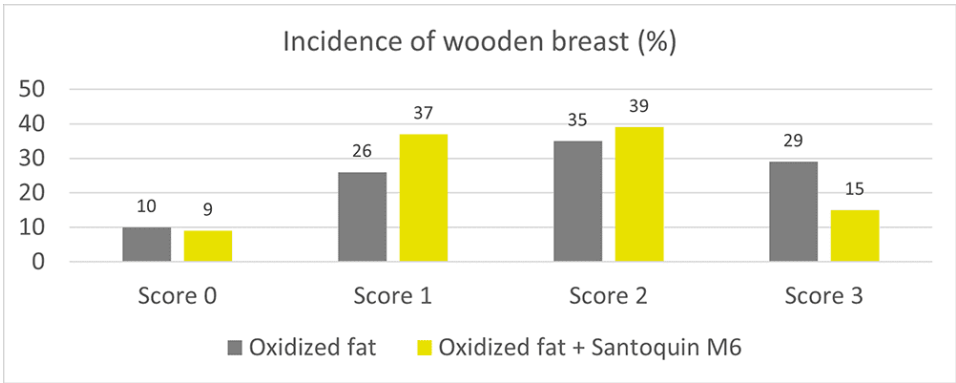
In a trial conducted by Kuttapan et al. (2021), Santoquin M 6, a product based on ethoxyquin, was tested concerning its ability to minimize the oxidative damage caused due to the feeding of oxidized fat. A control group receiving oxidized fat in feed was compared to a group receiving oxidized fat plus 188 ppm Santoquin M6 (≙125 ppm ethoxyquin). The main parameters for this study were TBARS in the breast muscle, the incidence of wooden breast, and the live weight on day 48.

Results indicated that the inclusion of Santoquin M 6 reduced the level of TBARS in the breast muscles, demonstrating a lower level of oxidative stress in the breast muscles. Additionally, it improved the 48-day live weight by 131 g.





The results also indicated that the inclusion of Santoquin M 6 reduced the incidence of severe woody breasts (Score 3) by almost half. It can be concluded that the inclusion of Santoquin in the broiler feed not only improves the production performance but also help mitigate the impact of breast muscle degradation due to increased oxidative stress.

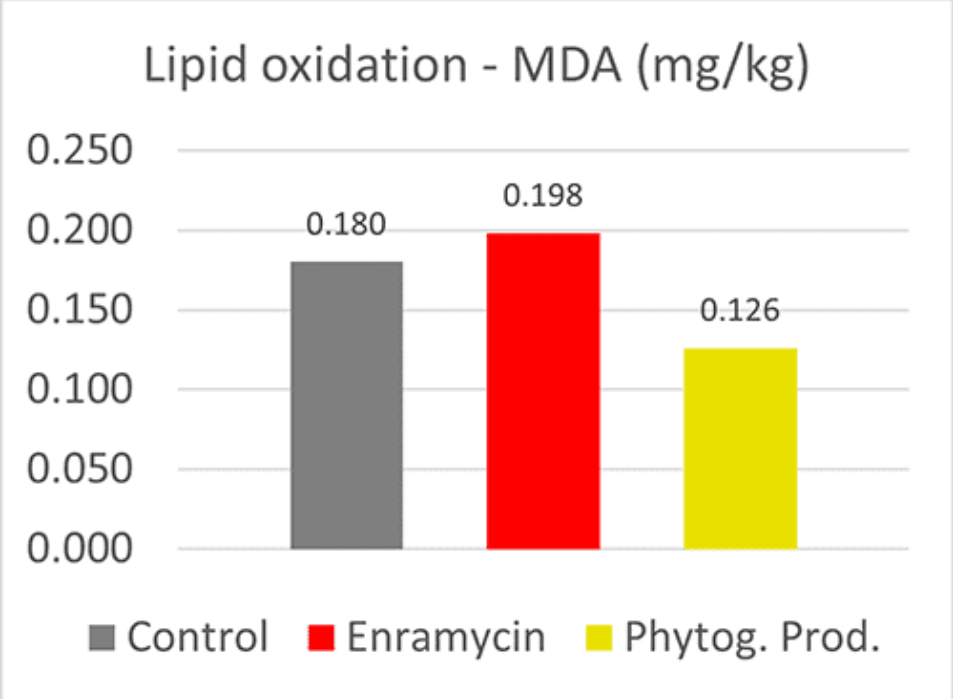


Phytomolecules act as natural antioxidants and reduce lipid oxidation in breast muscles

Inside the body, phytomolecules help to mitigate oxidative stress by the direct scavenging of ROS and the activation of antioxidant enzymes. Phytogenic compounds like Carvacrol and thymol possess phenolic OH-groups that act as hydrogen donors (Yanishlieva et al., 1999). These hydrogens can “neutralize” the peroxy radicals produced during the first step of lipid oxidation and, therefore, retard the hydroxyl peroxide formation. The increase in serum antioxidant enzyme activities and a resulting lower level of malondialdehyde (MDA) can be caused by cinnamaldehyde (Lin et al., 2003). MDA is a highly reactive dialdehyde generated as a metabolite in the degradation process of polyunsaturated fatty acids.

Antioxidant capacity of phytomolecules demonstrated in broilers

A trial with 480 Cobb male chicks (3 treatments, 8 replicates) was conducted at the University of Viçosa (Brazil). The breast muscles of the birds fed a blend of phytomolecules showed lower MDA levels and thus reduced lipid oxidation compared to the negative control, but also to the birds fed an antibiotic.



The impact of breast muscle degradation in broilers can be mitigated

The downgrading of broiler meat due to increased incidence of breast muscle myopathies is a common issue, resulting in the significant economic losses to the broiler meat producers. Oxidative stress caused due to due faster growth rate and various other stressors, including the oxidation of feed and feed ingredients, can contribute to increased incidence of woody breast and white striping. Different nutritional and management strategies are employed to reduce WB and WS in broiler production. The inclusion of synthetic antioxidants to control the oxidation in feed as well as phytomolecules to support the endogenous antioxidant system can be a part of promising tools to mitigate the impact of breast myopathies and reduce economic losses in broiler production.

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