Growth-related breast meat abnormalities in Broilers

Abstract
Artificial selection for fast-growing and high-breast-yield hybrids has considerably marked up the pressure on breast muscle development, leading to the appearance and expansion of myopathies (i.e. White Striping, Wooden Breast and Spaghetti Meat) affecting the pectoral muscle of heavy and fast-growing birds. Growth-related breast meat abnormalities negatively impact both visual aspect and technological properties of raw and processed meat, causing relevant economic damages for the poultry industry. The article aims to provide an overview on the current knowledge about their impact on meat quality, the possible causative mechanisms and forthcoming methods for mitigation.

Keywords
broiler, fast-growing, breast abnormalities, white striping, wooden breast, spaghetti meat, meat quality.

Evolution of the chicken meat market
Regardless different religions, cultures and traditions, poultry meat is one of the most widely eaten animal source food all over the world. In recent decades, the global consumption of chicken meat has rapidly and noticeably increased and recent FAO forecasts show that it’s expected to continue to rise (FAO, 2018). This trend has mainly been driven by human population growth and affordability of chicken meat, which is low in fat, rich in high-quality proteins and faces up to religious and cultural issues (Petracci et al., 2014). As a consequence, in order to meet the growing consumer demand, meat market has undergone an intense upsurge in poultry meat production, which since 1960 has increased fivefold and it’s expected to further grow by 3.6% per annum from today to 2030 (Steinfeld et al., 2006). Furthermore, global consumer aptitudes over years have been shifted from the consumption...
of whole carcass to ready-to-eat and processed products. While in the 1960s the commercialization of the whole carcass represented about 80% of the U.S. market, it was less than 10% in 2016, because nowadays consumers are willing to pay for the convenience of smaller portions already deprived of bone and skin. A similar trend has been observed in the EU, even though the Italian market is still focused on the commercialization of cut-ups (Figure 1). In this regard, poultry industry has been inevitably forced to apply intensive selection procedures aimed at accelerating the growth rate and enhancing the muscle mass of animals (Petracci and Berri, 2017).

Currently, chickens designed for meat production usually reach market weight (2.8 kg) within 47 days, namely about half the time compared to 40 years ago, while chickens average daily weight gain is doubled in the past 50 years (Figure 2) (NCC, 2019). The substantial genetic progress of the past few decades has resulted in an increased size and meat yield of the breast muscle, which currently exceeds one-fifth of the weight of the bird and certainly represents the most valuable portion in broiler industry (Table 1) (Petracci et al., 2015). Within this context, the improvement in broiler meat production has coincided with the development and expansion of muscular defects affecting the Pectoralis major muscle of fast-growing broiler chickens. Among these, White Striping, Wooden Breast and Spaghetti Meat are the main myopathies that, alone or combined, currently affect breast muscles and negatively influence both visual aspect and technological properties of raw and processed meat, causing relevant economic troubles for the poultry industry.

**Muscle growth-related abnormalities: an overview**

In recent years, a new group of muscular abnormalities has emerged, being a growing concern for the scientific community. Figure 3 shows the distinctive traits of White Striping (WS), Wooden Breast (WB) and Spaghetti Meat (SM) myopathies.

WS is macroscopically characterized by the presence of white striations of variable thickness and parallel to muscle fiber direction. White stripes usually cover the cranial part of the breast muscle and, depending on the severity grade, might extend until the caudal region of the fillet. The striations appear like “scars” and have been mainly identified as an accumulation of lipids (lipidosis) and connective tissue (fibrosis) (Kuttappan et al., 2013a). Micro-
Table 1: Progress in breast yield in a main commercial broiler hybrid (Ross 308 males) from 2001 to 2017.

<table>
<thead>
<tr>
<th>Year</th>
<th>Body weight (kg)</th>
<th>Age (d)</th>
<th>Breast yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>2.207</td>
<td>43</td>
<td>15.8</td>
</tr>
<tr>
<td>2007</td>
<td>2.200</td>
<td>36</td>
<td>18.6</td>
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<tr>
<td>2012</td>
<td>2.200</td>
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<td>21.1</td>
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<td>34</td>
<td>22.0</td>
</tr>
</tbody>
</table>

1 (Havenstein et al., 2003)
2 Ross 308 Broiler Performance Objectives.

Table 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td></td>
<td></td>
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<tr>
<td>Shear force</td>
<td></td>
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<tr>
<td>pHu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collagen</td>
<td></td>
<td></td>
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<tr>
<td>Ash</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to absorb water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to hold both added water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cook loss</td>
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</tr>
</tbody>
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Figure 3: Macroscopic appearance and main common traits of broiler Pectoralis major affected by growth-related meat abnormalities and U.S. (NCC, 2019).

White strips of variable thickness and parallel to the myofibers direction, covering the surface of P. major muscle.

Pale and out-bulging P. major muscle showing focally or diffusely hardened consistency. Presence of viscous exudate and hemorrhages.

Spongy P. major muscle showing an overall impaired integrity and tendency towards separation of the fiber bundles composing the muscle itself.

Impact of myopathies on meat quality and related costs

Meat affected by growth-related myopathies is usually considered harmless for human nutrition, since no specific biological or chemical hazards have been found to be related to its consumption. However, WS, WB and SM myopathies were found to negatively affect both quality traits and technological properties of raw and processed meat.
Table 1: Progress in breast yield in a main commercial broiler hybrid (Ross 308 males) from 2001 to 2017.

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Table 2 shows a summary of the main implications of myopathies on meat proximate composition and technological properties. Depending on the severity of the defect and the eventual co-existence within the same muscle, muscular abnormalities cause important modifications on meat chemical composition, since their occurrence is generally associated to an overall higher amount of moisture, fat and collagen to the detriment of proteins (Kuttappan et al., 2012a; Mudalal et al., 2015; Soglia et al., 2016b). However, the occurrence of WB abnormality seems to exert a more remarkable effect on meat quality than the mere presence of WS or SM (Baldi et al., 2019). The alterations in meat chemical composition are mainly due to the degenerative processes taking place in the muscle during the injury, as the replacement of fibers by both adipose tissue and collagen and the increase of extra-cellular water because of the inflammatory processes (i.e., edemas) (Clark and Velleman, 2017; Baldi et al., 2019). As a result of the increased fat content and the elevated collagen-to-total-protein ratio, abnormal meats are characterized by a significantly lower nutritional value (Petracchi and Berri, 2017).

In spite of the higher pHu, meat affected by myopathies also exhibit reduced technological properties (Bowker and Zhuang, 2016). In detail, several authors reported their poor ability to hold water (Mudalal et al., 2015; Tijare et al., 2016; Tasoniero et al., 2017). Among abnormal meats, WB fillets display a particularly remarkable impaired ability to hold both added (i.e. lower marinade uptake and higher cooking loss) and constitutional water (i.e. higher drip loss) (Bowker et al., 2017; Dalggaard et al., 2018), as a result of the severe degeneration of muscle tissue. It has been also speculated that the reduced water holding and binding capacities of abnormal meat could be due to an overall reduction in protein functionality, since myopathic muscles show a higher concentration of oxidized protein (Utrera and Estévez, 2012; Soglia et al., 2016a). The textural properties of raw meat were found to be altered by muscular abnormalities, with a special reference to WB meat that, if compared to unaffected samples, exhibits significantly higher shear and compression forces (Chatterjee et al., 2016; Soglia et al., 2017), while WS and SM conditions sparsely affect texture of both raw and cooked meat (Kuttappan et al., 2013b; Baldi et al., 2019). According to the analytical method, controversial results were found for cooked WB meat. While (Aguirre et al., 2018) detected significantly higher hardness of WB samples using texture profile analysis, (Soglia et al., 2017) and (Baldi et al., 2019) didn't find any difference in the compression forces between cooked fillets. The authors assumed that the solubilization of the thermally-labile collagen cross-links is the cause for the tenderization of WB meat during cooking.

Beyond the detrimental effect of muscular abnormalities on meat quality traits and technological properties, WS, WB and SM raise concerns over the consumer acceptance of meat, since their occurrence remarkably impairs the visual appearance of fillets and reduces the consumer’s willingness to buy (Kuttappan et al., 2012b; Huang and Ahn, 2018). Severely affected fillets are usually discarded or downgraded for the manufacture of further processed products (i.e., nuggets, sausages, hamburger), while moderate cases are marketed for fresh retailing (Petracci et al., 2014). Considering the high and unsustainable incidence of these worldwide-spread myopathies, it has been estimated that the defects result in $ 200 million loss per year in the US (Bunge, 2019). The economic damage is related not only to poultry processors (i.e. meat downgrading or discarding, lower processing yields, etc.) but also to retailers. Indeed, as reported by a recent article published in the Wall Street Journal, Wendy’s, a colossal fast-food chain in the US, after several customers complaints, decided to shift its chicken...
supply to smaller birds, despite the $30 million higher cost for the company (Bunge, 2019). Moreover, it was also mentioned that a US major chicken producer (Sanderson Farms) has begun slaughtering animals at younger ages in order to reduce the frequency of wooden breast myopathy, while Panera Bread and Whole Foods Market declared they would shift their chicken purchasing toward slower-growing genotypes (Bunge, 2019).

**Methods for mitigation**

Given the notable impact of WS, WB and SM on the quality of both raw and processed meat and the related economic damage, poultry industry and the scientific community take an interest in searching for solutions to avoid or at least mitigate the occurrence of muscular abnormalities. It is commonly recognized that the incidence of myopathies boosts with increasing growth rate, slaughter age and weight (Lorenzi et al., 2014; Radaelli et al., 2017; Kuttappan et al., 2017). Thus, attempts have been made in the field of animal nutrition to reduce the occurrence of abnormalities through the modulation of both feed formulation (i.e. dietary supplementation of antioxidants, organic minerals, vitamins and aminoacids) or dietary intake through feed restriction. However, the implementation of these strategies under commercial conditions might be challenging and does not result in any significant mitigation effect, because a reduction of the incidence of breast abnormalities has been attributed as an indirect consequence of decreased slaughter weight and breast size of the animals (Petracci et al., 2019). Despite it was recently assessed that an increased arginine:lysine ratio can have significant mitigation effect on breast meat abnormalities (Zampiga et al., 2018), further researches are needed to confirm these outcomes. Within this context, the most efficient solution seems the incorporation of downgraded meat into the formulation of processed products. Finally or coarsely minced WB meat could be included in the formulation of hamburger and meatballs without detrimental effects on finished product quality (Brambila et al., 2017; Xing et al., 2017). Since it has been proved that muscular abnormalities mainly affect the superficial section of breast muscles (Baldi et al., 2018, 2019), one possible approach could be to separately process superficial and deep layers of fillets to limit the effect of meat downgrading (Petracci et al., 2019). However, no really efficient solutions aimed at inhibiting the onset of myopathies or at least alleviating the symptoms and consequences on raw and processed meat quality have been found yet. Furthermore, it seems that genetic selection for broilers growth has reached a plateau and further improvements might be restrained by muscle biological potential and animal welfare concerns (Tallentire et al., 2018). In this scenario, it has been recently suggested that particular attention should be given on the modulation of embryonic formation of additional myofibers, instead of relying on post-hatch selection aimed at increasing muscle mass accretion (Velleman, 2019).

**References**


FAO. 2018. OECD-FAO Agricultural Outlook 2018-2027. OECD.


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NOTES