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Wooden breast – a novel myopathy recognized in broiler chickens

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Abstract. Abnormally hard breast fillet consistency began to emerge in commercial broiler chickens around 2010. Due to the remarkable muscle hardness, the condition acquired the vernacular name 'wooden breast myopathy'. This myopathy starts to develop after two weeks of age at the earliest and typically proceeds into chronic myodegeneration in three to four weeks of age. The lesion begins focally and typically develops into a diffuse lesion that involves the entire major pectoral muscle. The restricted location of wooden breast lesion in the *m. pectoralis major* distinguishes it from several other myodegenerative diseases that widely affect the skeletal muscle system and often the cardiac and smooth muscle systems too. Although industry-wide incidence rates are difficult to assess, it has been estimated that approximately 5-10% of commercially produced breast fillets exhibit severe WB. Even at low incidence rates, the costs to industry are substantial, as breast fillets with the wooden breast condition are often downgraded and sold at a discount, used for further processing, or in extreme cases, discarded. Because the etiology of wooden breast is still unclear, in the future, study of the early lesions, pathogenesis and the possible reduction of animal welfare are likely to gain more attention.

1. Introduction

Agricultural production in both crop and animal sectors provides food for people and contributes to food security. Food security is defined as a condition when all people, at any time, can physically and economically access safe and nutritious food that fulfills their needs, is acceptable, enables them to engage in normal life activities, and provides them with a healthy life. Food security depends on many factors, and among the most significant are the increase in the world's population (seven billion in 2012, eight billion according to projections in 2028), climate change (global warming), environmental pollution, fewer drinking water resources, wars, and population migration. Under such conditions, as we face a population explosion, livestock production should provide sufficient quantities of macronutrients, primarily proteins, and micronutrients (minerals, vitamins). In spite of all the difficulties and while respecting animal welfare, it is considered that production of food of animal origin will continue to increase due to constant improvements in genetic selection, animal diet (feed that can make the most of the genetic potential of animals), health care, farming and care of animals.

In recent years, increasing importance is attached to the poultry industry, primarily broiler chicken production, which has higher annual increases than production of other domestic animals. Nowadays, poultry meat production is equal to pork production worldwide, and there is no doubt that in the years ahead, poultry meat will be the most common type of meat. Today, of the total animal origin protein, the most valuable protein in human nutrition, 45% comes from large ruminants (meat and milk), 31% from poultry (meat and eggs), 20% from pigs, and 4% from small ruminants (milk). The advantage of poultry production is the fact that this animal species has excellent feed conversion efficiency, short generation period (the average is 42 days), and the final product is acceptable in all countries and religions around the world. For one kg of poultry protein, between 18 and 28 kg of dry material is needed, and for one kg of protein derived from ruminants, 133 kg of dry material is needed.

The beginnings of intensive poultry production date back to 100 years ago (the time after World War I), when two lines of chicken hybrids were selected, one of which was directed to eggs (layer strain) and

the other meat (broiler strain). Multi-year selection efforts with heavy hybrid strains focused primarily on increasing the meat yield, especially breast meat with low fat. With modern broiler hybrids, up to 40% of the carcass (hull prepared for barbecue) is breast, and this contains about 1% fat.

Despite all the efforts of producers, conditions related to feed formulation, farming conditions, health care, and biosecurity measures, the safety of poultry meat is not absolute. Today, there are enormous efforts to reduce the frequency of the most common bacterial pathogens in poultry meat (*Salmonella* spp., *Campylobacter* spp., *Staphylococcus* spp.). In Europe, the previously common findings of antibiotics in foods of animal origin are now largely excluded by the prohibition of antibiotics used as growth promoters. Numerous *ante-mortem* and *post-mortem* factors can affect the quality of carcasses (skin changes, joint bleeding, bone fracture, hemorrhages) or meat (PSE and DFD meat, petechiae, wooden breast). In recent years, significant research has been conducted on these meat defects.

2. Myopathies in modern poultry

The increase in consumer demand for poultry meat has put pressure on producers to increase production while reducing the cost and duration of production. As a result, broilers are continuously selected to attain greater body weight at younger ages. This is evidenced by the modern broiler chicken gaining on average 20-40 g daily for the first two weeks of life, then approximately 100 g daily until slaughter age (about 42 days), when the broiler is approximately 3 kg liveweight [1,2]. On the other hand, parallel with the development of the body, undesirable traits have emerged such as poor reproduction, ascites syndrome, skeletal abnormalities and impairments of the immune system [3,4,5,6,7,8].

Muscle-related changes are called myopathies and pose a serious problem in the poultry industry. One of these myopathies is “wooden breast” (WB). The name “wooden breast” is related to the characteristic morphological change, i.e., the stiff, hard consistency, observed only on the pectoral musculature (*m. pectoralis major*) [9]. Although histological and morphological analyses indicate there is some similarity of WB to other known myopathies (such as hereditary muscular dystrophy, nutritional and toxic myopathies, deep pectoral myopathy, PSE, and DFD), more detailed studies nevertheless show these are different diseases [10]. WB myopathy most commonly occurs in combination with another previously detected myopathy, the so-called “white striping”, which is the presence of white stripes parallel to the muscle fibers [11,12,13,14,15]. Histologically, it is difficult to distinguish between these two myopathies, but it has been concluded that they are two different diseases, since their individual occurrence is possible [16,17].

The characteristic feature of WB is the hard consistency of the *m. pectoralis major*, without the involvement of other skeletal muscles, smooth muscle, or cardiac muscle, while these other muscle types are involved in other myopathies [18]. The macroscopic hallmarks of WB include the abnormally hardened consistency and pale color of the major pectoral muscle. Additional features include an outbulging appearance of the affected area and sometimes hemorrhage and a layer of clear, slightly gelatinous material covering the muscle. The hardened muscle consistency in WB could be explained by the prominent fibrosis often observed in the chronic phase of WB, although there are findings in which fibrosis has not been confirmed as an independent factor for WB formation. Moreover, some authors suggest myofiber degeneration and swelling together with fibrosis to be responsible for the hardened consistency of WB muscles [18].

3. Histological changes in *m. pectoralis major* in WB myopathy

After detecting the characteristic macroscopic changes, confirmed diagnosis of WB requires histological confirmation. The macroscopic WB lesions are strongly associated with polyphasic myodegeneration. The polyphasic lesion type denotes the occurrence of both degenerative and regenerative changes simultaneously within the lesion area. This indicates repeated or progressing damage to the muscle cells and rules out a single pathologic insult as the etiopathogenesis for WB. Histological examination of the lesions in *m. pectoralis major* revealed characteristic features such as an increase in degenerative and atrophic fibers associated with loss of cross striations, variability in fiber size, floccular/vacuolar degeneration and lysis of fibers, mild mineralization, occasional regeneration (nuclear rowing and multinucleated cells), mononuclear cell infiltration, lipidosis, interstitial inflammation, and fibrosis [9,12]. WB starts to develop after two weeks of age at the earliest and typically proceeds into a chronic myodegeneration at three to four weeks of age, but muscle degeneration is most pronounced from 5-6

weeks of age (slaughter period). The early macroscopic lesions are usually focal and exhibit mild muscle firmness compared to the more severe and typically diffuse lesions in the older birds. A gradual decrease in the histopathological lesions was detected moving from the surface towards the deep portion of the muscle, with the first exhibiting profound degenerative myopathic lesions accompanied by the replacement of chronically damaged muscle with adipocytes and fibrosis [19].

4. Etiology of the formation of wooden breasts and consequences

Although numerous studies have speculated about the etiology of this myopathy, it is still unclear. Some of the possible factors that could initiate the myopathic changes are reduced ability to store/utilize carbohydrate as an energy source [20,21,22], accumulation of calcium ions [23,24], hypoxia and oxidative stress [25], and circulatory insufficiency in these fast-growing birds [26]. A single factor that has been consistently associated with the incidence of these myopathies is heavier body weight and thicker fillets in broilers [27,28,29].

One of the most important factors for the development of WB myopathy in rapidly growing broiler chickens is metabolic distress resulting from hypertrophic muscle fibers that increases the diffusion distance between blood vessels and muscle fibers [30]. It has also been hypothesized that in poultry selected for meat production, the growth of the connective tissue in muscle does not keep pace with muscle fiber radial growth, and the fibers outgrow the supporting connective tissue, leading to muscle damage [31,32].

The degree of myodegeneration also affects changes in the muscle's chemical components, and the ability to process the meat. Meat quality is the direct result of muscle morphologic structure and cellular biologic processes regulating muscle development and growth. The poultry industry has made substantial genetic improvements in growth rate and breast meat yield. However, these increases have changed both the morphometry and cell biology of the *m. pectoralis major*. In general, growth selection has resulted in increased degeneration of muscle fibers [33], larger diameter muscle fibers (fast-growing male meat chickens have *m. pectoralis major* muscle fibers three to five times wider than slower growing birds) [34], decreased capillary blood supply to the muscle [35], reduced connective tissue spacing between muscle fiber bundles and muscle fibers [34,35], and increased myofiber degeneration [36].

WB occurs most frequently in fast-growing, high breast-yielding broiler strains. The incidence of WB also seems to be higher in broilers that are male, on high nutrient diets, or slaughtered at older ages and heavier weights [28,35,37,38]. Gait score is a good predictor for broiler mobility [39], and walking ability is usually weaker in heavier [40,41] and faster growing broilers [41]. In some studies, reduced wing mobility was linked to the myodegenerative WB lesions [42,43]. This arouses the suspicion that pain or discomfort occurs as a result of heightened sensitivity of the breast area in WB. Although the amount of pain associated with WB is difficult to demonstrate from the various studies, severe myodegenerative lesions in humans have been reported to cause substantial pain [44].

5. The influence of WB on the quality of broiler meat

WB, together with other myopathies (WS, PSE, vitamin E and Se deficiency, etc.) reflects primarily on meat quality [27]. Although these quality issues do not impose microbiological or other food safety risks, they render the products less attractive to the consumer [12]. The duration of broilers' lives affects the concentration of chemical components in the breast and leg muscles, resulting in more attractive sensory flavor properties in longer-lived birds.

M. pectoralis major is the most valuable part of the broiler carcass and constitutes approximately one fifth of the total body weight [45,46]. Structural changes in WB fillets have an overall negative effect on the meat quality. Consumers perceive increased fat deposits in breast fillet as unfavorable, as they give the impression the meat is "unhealthy" [12]. Moreover, increasing fat (which is hydrophobic) can further reduce the ability of the flesh to bind water. WB is known to impair the water-holding capacity of the breast meat. Fresh WB fillets exhibit more drip loss during refrigerated storage and greater cooking loss [47]. The pale color, soft consistency and poor water-holding capacity are caused by the denaturation of myofibrillar proteins due to rapid *post-mortem* decline of pH [48] when meat is still warm, before the temperature lowers during processing.

Texture analyses show fresh WB fillets have a high compression force. After thermal cooking treatment, WB fillets are harder, more rubbery, more elastic, and have greater resistance to chewing than

normal fillets. Generally, the change in the texture profile is a feature of complex chemical changes in the muscle fibers and connective tissue that accompany WB [49].

6. Conclusion

WB myopathy is a newly discovered meat quality defect in fast-growing meat chickens that is only observed *post-mortem*. One of the major challenges in research on WB is the lack of an effective biomarker to identify the condition in live birds. Although there was an attempt to assess the presence of WB by palatalizing the pectoral musculature, this was not effective. The second challenge is the lack of an effective, standardized scoring scale, as the WB scoring systems currently used are subjective. To date, the majority of published studies on WB have focused on the chronic and *post-mortem* changes, and the meat quality issues. In the future, study of the early lesions, pathogenesis and the possible reduction of animal welfare associated with WB are likely to gain more attention.

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