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# Nutritional and feeding strategies for controlling breast muscle myopathy occurrence in broiler chickens: a survey of the published literature

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ABSTRACT

Myopathies of the breast muscle in broiler chickens are a great concern of modern poultry production because of the economic losses associated with the waste of unfit meat, the effects on meat nutritional quality for food and on meat technological quality for processing, and last, but not less important, the effects on animal welfare and health. Largely spread in fast-growing genotypes, these muscle defects have a low hereditability for which genetic selection for their control seems to be a weak strategy or, at least, a weak long-term strategy. On the other hand, several investigations have been performed on the physiological mechanisms triggering the onset and the evolution of myopathies, and different non-genetic strategies have been proposed to control their *in vivo* occurrence. Thus, the present paper aimed to analyse the scientific literature investigating the effects of feeding and nutritional strategies on the occurrence of myopathies to find out the most tested strategies, the most promising ones and, in perspective, strengths and weakness of the same strategies.

## 1. Introduction

In the last decade, emerging myopathies, such as white striping (WS), wooden breast (WB), and more recently spaghetti meat (SM), have raised great concerns in poultry production because they can affect a high proportion of chicken breasts at slaughtering time (*Che et al.,* 2022; *Bordignon et al.,* 2022) which implies high economic losses; they importantly modify meat's nutritional quality and technological properties (*Petracci et al.,* 2019; *Bošković Cabrol et al.,* 2023), besides raising concerns for animal health and welfare (*Kawasaki et al.,* 2016; *Kieronczyk et al.,* 2017; *Norring et al.,* 2019). The occurrence of breast myopathies has been primary linked to the great hypertrophy of muscle fibres resulting from genetic selection in the fast-growing and high-breast yield commercial genotypes currently used (*Petracci et al.,* 2019; *Soglia et al.,* 2021). On the other hand, based on the review of several studies on the physiological and structural changes combined with the omic insights related to the muscle response, *Soglia et al.* (2021) have identified a sarcoplasmic reticulum stress as the most

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likely responsible of myopathies' onset, and hypoxic conditions as a cause of the conditions activating the muscle response, as for energetic metabolism, inflammation, degeneration, and regeneration. Nevertheless, despite being a condition common to selected commercial genotypes, the hereditability of myopathy occurrence is low to moderate, and the environmental and/or management factors contribute greater than 65% and 95% of the variance in the incidence of WS and WB, respectively (*Bailey et al.*, 2015; *Bailey,* 2023). Accordingly, to reduce myopathy occurrence and degree, several studies have been conducted to date on the non-genetic strategies that can mitigate the onset and development of these defects. Several of these studies focused on different nutritional and feeding strategies, especially intended to manipulate growth trajectory and/or modulate muscle response to oxidative stress and oxygen lack, besides inflammation, and, more widely, to regulate muscle metabolism. Thus, the present paper aimed at analysing the scientific literature investigating the effects of feeding and nutritional strategies on the occurrence of myopathies, to detect the most tested and promising strategies and, when possible, highlight their strengths and weakness.

## 2. Materials and methods

Bibliographical information and abstracts related to the scientific publications to be used in this paper were obtained by using Scopus (Elsevier B.V., Amsterdam, The Netherlands) on July 17, 2023. Four different searches were set and corresponding databases downloaded, i.e., 1) myopath* AND diet* AND chicken OR broiler*; 2) myopath* AND additive* AND chicken OR broiler*; 3) myopath* AND feed* AND chicken OR broiler*; 4) myopath* AND nutrition* AND chicken OR broiler*. Then, the four data sets were individually checked to exclude reviews, duplicates, and articles out of scope. Articles out of scope included all those articles describing studies not specifically testing the effect of nutritional/feeding strategies on the occurrence of myopathies; not reporting data on myopathy occurrence at a macroscopic examination; investigating nutritional myopathies other than WS, WB, and SM (Table 1). Then, the four data sets were joined and checked for duplicates. A total of 60 articles were finally obtained.

The full articles included in the final data set were retrieved as pdf files from the corresponding collections, and the following items were added to the data set spreadsheet in further columns based on abstracts and full text: effects tested in the study, distinguishing between detailed effects and the nutritional/feeding strategy adopted; and effects (decrease, increase, no effect) on myopathy occurrence, on growth traits of animals, and on breast weight and/or yield.

The PROC FREQ of SAS (SAS, 2013) was used to obtain the distribution of publications according to the publishing year, the investigated myopathies (WS, WB, and SM), the tested nutritional/feeding strategy, and the effects on myopathy occurrence. Finally, the correlation between the effects on myopathy occurrence, animal growth (final live weight and/or daily weight gain), and breast weight and/or yield were studied by the PROC CORR of SAS.

**Table 1.** Results of the analysis of the publications obtained by the literature search from the data available in Scopus on July 17, 2023

| | Search words | All retrieved articles and reviews | Duplicates | Reviews | Out of scope | Final set of selected articles |
|---|---|---|---|---|---|---|
| Set 1 | myopath* AND diet* AND chicken OR broiler* | 95 | 0 | 9 | 30 | 56 |
| Set 2 | myopath* AND additive* AND chicken OR broiler* | 7 | 0 | 1 | 4 | 2 |
| Set 3 | myopath* AND feed* AND chicken OR broiler* | 113 | 3 | 14 | 42 | 54 |
| Set 4 | myopath* AND nutrition* AND chicken OR broiler* | 75 | 0 | 26 | 25 | 24 |
| TOTAL | | 290 | 3 | 50 | 101 | 136 |

## 3. Results and discussion

The first scientific article about the effect of nutritional/feeding strategies to control myopathy occurrence was published in 2012 (Figure 1a), while the first paper on the occurrence of WS myopathy appeared in Scopus in 2009 (*Soglia et al*., 2021). After 9 years and 4 articles (published between 2012 and 2017), results of the studies investigating strategies to control myopathy increased from 2018 onwards, with the number of published articles ranging 6 to 15 per year. Consistently, with the evolution of studies about the occurrence of the different myopathies (*Soglia et al.,* 2021), the first articles focused on WS only, followed by articles including results about WS and WB at the same time (Figure 1b). Then, by 2021, the number of studies addressing WB alone increased, which could be attributed to its higher impact on consumers' acceptance and on technological properties for processing compared to WS (*Petracci et al.*, 2019), and, consequently, the higher economic losses for the industry. Research on nutritional/feeding strategies focusing on SM started to appear in 2018 (Figure 1b), while the first article about the occurrence of SM was published in 2016 *(Soglia et al.,* 2021). Nevertheless, the most recently discovered SM remains the least investigated myopathy (9 papers in the present review; 21 papers in *Soglia et al.,* 2021) compared to WS and WB.

The main nutritional/feeding strategies tested in the articles were identified and papers consistently assigned, as summarized in Table 2. Numerically, most studies investigated the effects of reducing the supply of dietary amino acids (13), and those addressed manipulation of the growth trajectory by nutrient allocation (13 in total), both with a qualitative approach (feeding plans based on decreasing dietary energy and/or protein content) (7 papers) and a quantitative approach (feeding plans based on different feed restriction levels, and different restriction and re-feeding periods) (6 papers). A total of 11 studies used different dietary supplementations, with additives acting as antioxidant or playing a role in inflammation, whereas another 4 studies addressed muscle oxygen homeostasis, using phytase and inositol. Finally, 5 studies were aggregated under the antibiotic/feed additive strategy, and another 5 specifically addressed supplementation with guanidine acetic acid (GAA). Due to the specific action mode of GAA (*Oviedo-Rondón et al.*, 2020), a specific set of articles was defined even if GAA supplementation finally contributed to improve the oxidative status of the muscle. The remaining 9 studies included a variety of approaches not ascribable to the previous ones.

Regardless of the specific myopathies, the data set was analysed to evaluate the most successful within the different nutritional/feeding strategies adopted to reduce the occurrence of defects (Figure 2). The highest success rates (100% and 80%, respectively) were obtained for the studies adopting strategies for controlling oxygen homeostasis and those using GAA, which however, were few in absolute number compared to the other strategies (3 and 5 articles, respectively) and require confirmation. On the other hand, the reduction of die-

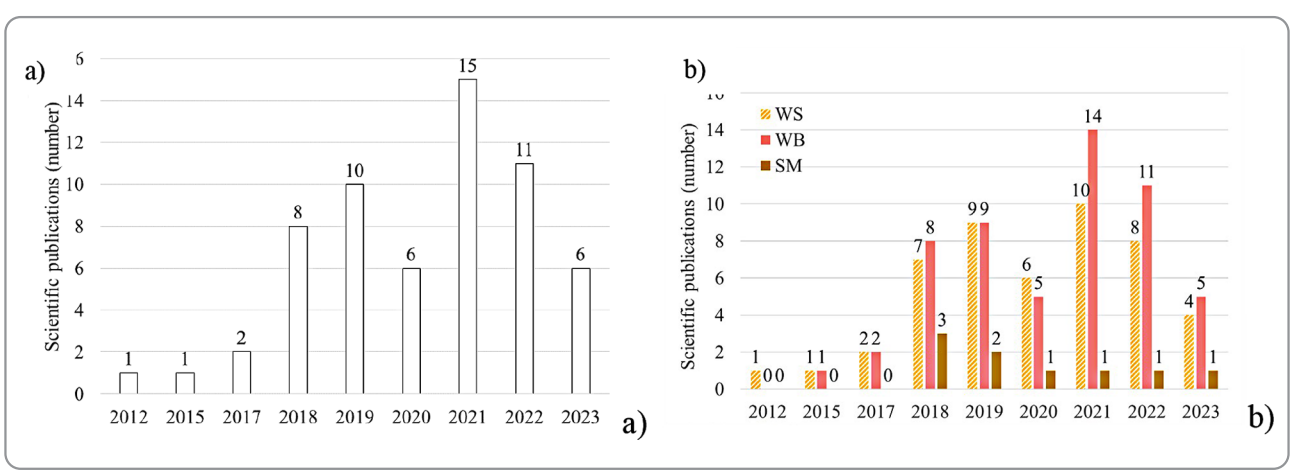


**Figure 1.** Number of publications testing the effects of nutritional/feeding strategies on the occurrence of myopathies retrieved from Scopus (data available on July 17, 2023) according to the publishing year (a); and number of the publications (same set) per publishing year reporting results about the occurrence of white striping (WS), wooden breast (WB), and spaghetti meat (SM) myopathies. The same article can report results about more than one myopathy.

**Table 2.** Results of the analysis about the main nutritional and feeding strategies identified based on the final data set of selected articles obtained by the literature search from the data available in Scopus on July 17, 2023

| Main nutritional and feeding strategies | Tested strategies | Total number of articles |
|---|---|---|
| Reducing dietary amino acids (AA) | Lysine, methionine, glutamine, arginine, valine, leucine, histidine, total sulphur AA, threonine, total amino acids | 13 |
| Nutrient allocation (qualitative) | Feeding plans based on diets with different energy and protein contents | 7 |
| Nutrient allocation (restriction) | Feeding plans based on different feed restriction levels, and different restriction and refeeding periods | 6 |
| Supplementation for controlling oxidation/inflammation | Se, Mg, Zn, Cu, Mn, antioxidants (including vegetal extracts), Vitamin E, alpha lipoic acid, n3 fatty acids (including algae inclusion) | 11 |
| Supplementation for improving oxygen homeostasis | Inositol, phytase (one study including a blend with vitamins) | 4 |
| Use of antibiotic/feed additives | Antibiotics and feed additives (probiotic, vegetal functional compounds, organic acids) | 5 |
| Supplementation with guanidine acetic acid | Guanidino acetic acid (plus nucleotides in one paper) | 5 |
| Miscellaneous | Fat source, choline chloride, Ca, P, K, vitamins, inorganic (sulphates) and carbo-aminophospho-chelate, methionine (synthetic vs. natural), *in-ovo* vitamin D, hatching system | 9 |

**Table 3.** Correlation coefficient and p-value (in italics between parenthesis) between effects on myopathy occurrence (YES, NO), growth performance (YES, NO), and breast weight/yield within the selected articles of the final data set (data available in Scopus on July 17, 2023)

| | Effects on myopathy occurrence | Effects on growth | Effects on breast weight/yield |
|---|---|---|---|
| Effects on myopathy occurrence | - | 0.283 *(0.034)* | 0.143 *(0.325)* |
| Effects on growth | - | - | 0.517 *(<0.001)* |
| Effects on breast weight/yield | - | - | - |

tary amino acids resulted in a reduction of myopathy occurrence in 58% of studies, while contrasting results were reported in a further study within the same strategy. As for nutrient allocation, the modulation of dietary energy and protein was successful in 26.8% of the studies, whereas strategies based on feed restriction were successful in the 50% of cases. The different strategies behind the studies included in the miscellaneous category justify the different results obtained with reference to the effects on myopathy occurrence (22.2% decrease, 44.4% no effect, 33.3% increase).

Based on the results of the selected articles, a significant correlation between the effects on growth (as for final body weight and daily weight gain) and myopathy occurrence (across the three myopathies)

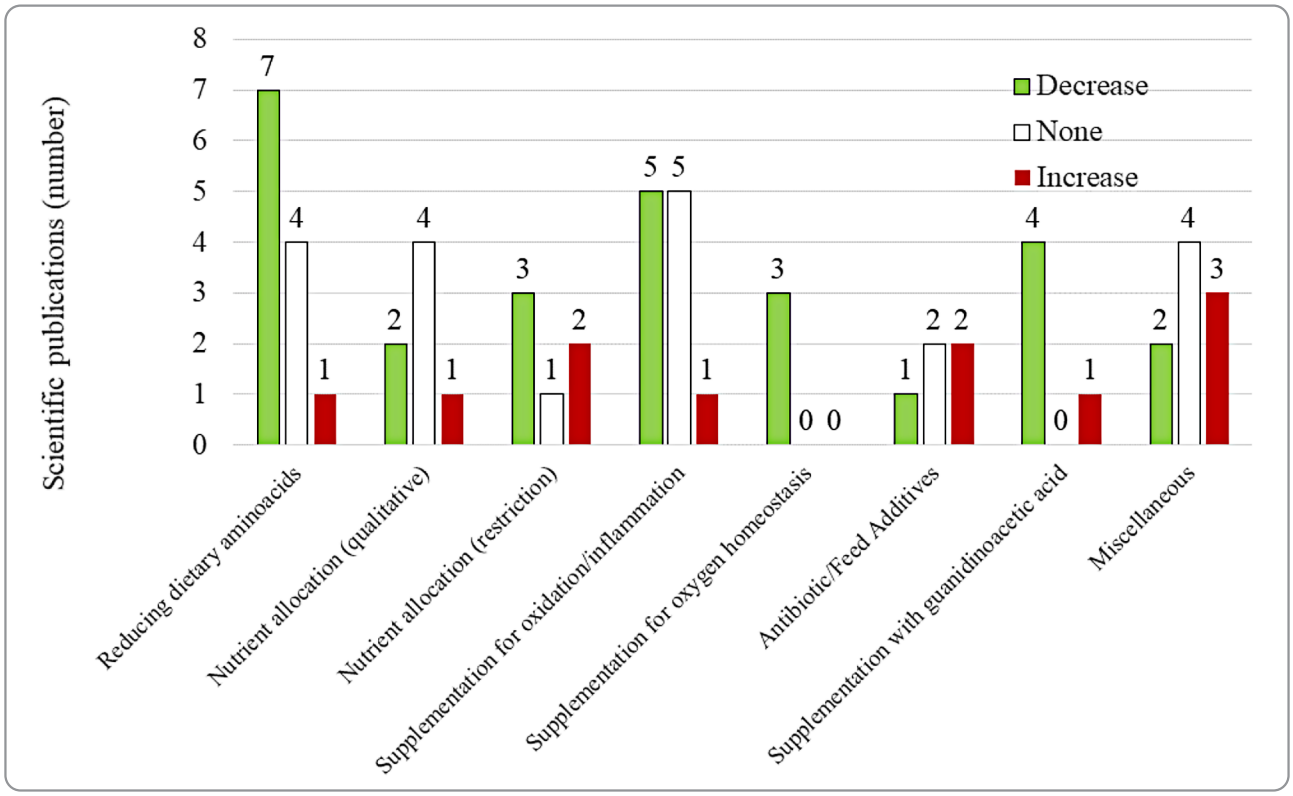


**Figure 2.** Number of selected articles of the final data set reporting a reduction (green bars, decrease), no change (white bars, none), and an increase of myopathy occurrence (red bars, increase) within nutritional/feeding strategy. Two articles (out of 60 selected ones) with contrasting results on myopathy occurrence were not included.

was recorded ($P<0.05$) (Table 3). Differently, no significant correlation was found between the effects on breast (weight and/or yield) and myopathy occurrence, whereas effects on growth and breast weight/yield were significantly correlated with myopathy occurrence ($P<0.001$) (Table 3).

## 4. Conclusion

Among nutritional and feeding strategies tested to reduce myopathy occurrence, most studies addressed nutrient manipulation and allocation both qualitatively (as macronutrients, i.e., protein and energy as well as amino acids) and quantitatively (using feed restriction), which firstly impacted on the growth trajectory of chickens. Nevertheless, despite the significant correlation found in the articles in the data set between myopathy occurrence and growth, the success of the strategies was also affected by the stage of growth at which nutrient allocation was applied as well as the duration of the manipulation period, i.e., compensatory growth has a key role. On the other hand, despite being studied less often compared to the other strategies, feeding strategies based on manipulation of nutrients that can play a role on the oxygen homeostasis (i.e. inositol, phytase, GAA) proved to be almost always successful compared to the use of feed additives acting directly as antioxidants or compared to feed additives with other metabolic roles. Further analysis of available data should distinguish between the most effective strategies for the different myopathies and their effects on growth and muscle development.

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