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Influence of organic trace minerals on broiler carcass quality

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During the last two decades a number of studies have been published on the effect of organic trace minerals related to improving carcass characteristics in poultry (15, 11, 6, 21, 12, 19, 23, 14, 7). As previously documented, many factors interact to improve or reduce poultry yields in processing plants (1, 2, 26). The major ones are controlled by improving management and operating procedures during pre-slaughter, sacrifice and processing phases.

Others depend on environmental control or come from situations occurring early in the growth of the birds (1, 26), creating uneven flocks and fragile tissues. The contribution of trace mineral nutrition to effect an improvement on carcass quality is mostly related to their influence on the way animals cope with different stressors and the strength and consistency conferred to their tissues.

Zinc is an important factor of many enzyme systems and is necessary for maintenance of growth, metabolism, normal reproduction and hormonal regulation. It is essential for keratinisation and immune function (13). Improving zinc nutrition has shown benefits in the integrity of skin, feathers, footpads, muscles, bones and reduction in bruises (6, 11, 21). These can be translated into increases in the output of poultry products that meet today's demanding market specifications.

Connective tissue proteins like collagen, elastin and keratin require trace minerals for their synthesis, cross-linkage and stability of their structural components (13). Also, metabolism requires trace minerals as cofactors of enzymes and as part of regulatory molecules and receptors (27). The role that trace minerals play in inflammatory response and immunity influences the maintaining of health status, tissue integrity and how the body of the bird reduces potential food contaminants (9, 13, 10).

Carcass quality and yield

Mineral sources are important since different sources have differing bio-availabilities. Attempts to show the effect on carcass quality and performance using incremental levels of inorganic sources of Zn and Mn have been trialled. Supplementation with zinc has shown to improve carcass weight and antioxidant status in quail kept under heat stress conditions (34°C, 8h/d) (21). In a study with Ross broilers grown to 42d, carcass and breast meat percentages were increased ($P \leq 0,05$) from 67,13% and 19,01% to 67,94% and 20,2% respectively, when using a Zn methionine complex compared to an inorganic source ($ZnSO_4$) (12).

In contrast, an early study performed by Collins and Moran (4) at the University of Auburn (Alabama, USA) NRC levels; 60/50 and high levels; 120/100, 180/150 were supplemented. No response was found on live performance, carcass quality or skeletal integrity. A study by Liu *et al* (14) showed positive effects ($P < 0,05$) of different sources of zinc on eviscerated carcass yield (69,5 vs. 70,1), decreased drip loss in breast muscle and lower shear force in thigh muscle with high supplemental levels of 120 and 180ppm.

However, no differences were found between the sources used. These contrasting responses on carcass quality even using organic sources of zinc are mostly explained by the type of organic Zn used, but a number of other factors might be interacting. Zinc and manganese in the form of monomeric (1:1) metal non-specific amino acid complexes has shown the most consistent effects.

Important causes of losses in carcass quality and plant yield are those produced by pre-slaughter fasting and carcass contamination. During feed withdrawal, body weight loss is usually referred to as "shrinkage", since it represents a decrease in live weight that had already been achieved. Losses can reach 0,40% of live weight per hour (26) after the first four hours. This is completely independent of the weight loss by the excreta, which is eliminated during the first four hours, and is caused by utilisation of body reserves.

Any nutritional help that reduces stress and increases body reserves is believed to help in reducing shrinkage. Contamination of carcasses is a potential problem for the processing plant as a downstream risk for the consumers. The improvement in immune function obtained when trace minerals like Zn and Mn are supplemented (9, 13), and the increase of some vitamins (vitamin A, C, E) to help the bird to get rid of bacterial infections, represents an opportunity to help through the use of nutritional programmes.

Carcass defects

Recent poultry literature suggests that suboptimal zinc status is associated with footpad lesions and poor carcass quality due to scratches and skin damage (1, 2). Even when management and other stresses and trauma are the main causes of carcass defects, nutrition plays an important role in reducing or increasing their severity (26, 1).

Having birds with weaker skin increases the prevalence and severity of the lesions. This makes poultry producers and nutritionists realise that adequate dietary zinc supplementation is critical in poultry production. Nutritional approaches have been studied to help reduce processing plant losses (6). Processing plant yield is affected by the reduction in the numbers of valuable products caused by different defects. Major causes of losses are related to skin and footpad conditions, bruises, hemorrhages and fractures (1, 26).

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Scratches, scabs and sores

These defects are created either days before or during loading and unloading of the birds (1). Scratches are line-shaped scars located mainly on the posterior back and upper thigh areas of skin on the bird with varying degrees of severity. The areas without feathers (apterium, lateral pelvic, lateral caudal and crural) are more prone to these types of damage. Birds climb on each other trying to flee away from the loading crew, or during late growth competing for access to the feeders.

"In recent years, pododermatitis has become more relevant because it has animal welfare implications and chicken feet are of high value for Asian markets."

Good management practices and well-trained crews are required to reduce the incidence and severity of this problem. Bilgili and Hess (2) studied the effect of stocking density on carcass quality defects and reported deterioration of feed conversion, increased skin defects and bruises in broilers at 42d, reducing grade A carcasses. Hess et al (11) found that Zn supplementation (40mg/kg, as forms of Zn-Met or Zn-Lys) could reduce skin tearing of the carcass in broilers when scars on the skin were reduced.

Scabs and sores can happen days before or during loading, and can be seen in different stages of healing (26). They are usually more superficial, or could have been created some time earlier and become infected, taking longer to heal (6, 26). The main factors that have been related to the prevalence of these defects are stocking density, lighting, feeding, water supply, unexpected noises and people making sudden movements inside the house (2, 26).

Even when the direct cause of these lesions is mainly mechanical, the strength of the skin and the feather covering plays an important role. Supplementing Zn in complexed organic form has also shown to significantly ($P < 0,05$) reduce the proportion of birds with skin lesions from 42,7% to 9,6% in contrast with inorganic (19). These findings could come from a mixed effect on improved skin strength and elasticity, as well as feather growth/covering where Zn and Mn play an important role (9).

Heat stress has also been identified as having a negative influence on skin condition. The incidence of skin scratches is deceased when temperatures are comfortable (26). Evidence exists regarding the effect of Zn supplementation in alleviating heat stress (22). This is mostly supported by the role of zinc in the antioxidant defence system through the synthesis and activity of superoxide dismutase enzymes (Zn-SOD). Sahin (22) also mentions the importance of vitamins E, A and C on antioxidant systems, and coping with heat stress.

IP: Infectious process

Infectious process is considered as the major cause of condemnation in the United States and many other countries (8). In general, all conditions that increase the frequency of scratches also increase the occurrence of cellulitis (26). Thus, from a management and nutritional standpoint, the reduction of both demand similar preventive measures. It is important to give adequate space, distribute feeding and drinking equipment evenly in the poultry house, and employ equipment to maintain a comfortable environmental temperature. Minimising the stress for space, reducing thermal stress and good management of birds will help to reduce cellulitis.

Cellulitis (IP) develops as a consequence of scars through which bacteria penetrate. Systemic bacterial infections that entered either by the respiratory or digestive tract may also result in cellulitis. Hess *et al* (11) showed a reduction in both scratches and the frequency of cellulitis in birds fed complex Zn and Mn when compared with birds fed diets with the same levels of Zn from inorganic sources (sulphates). Downs *et al* (6) had previously proved that using complex zinc alone, or in combination with vitamin E, reduced the severity of cellulitis in broilers.

Contact dermatitis or foot pad dermatitis (FPD)

Contact dermatitis can affect paws, hocks and breast skin. In recent years, pododermatitis has become more relevant because it has animal welfare implications and chicken feet are of high value for Asian markets. It has been related to wet litter, when it produces irritating substances like ammonia (NH3) (28, 3). Coarse litter materials, watery droppings, high stocking density, high viscosity of droppings and concurrent digestive problems can predispose more severe FPD.

On the other hand, birds can also be predisposed when they are weak and their skin becomes brittle, fragile and the normal regeneration process slows down. This situation is created when concomitant infections or immunosuppressive agents are present (5), mimicking a deficient stage for Zn and other nutrients. Haslam *et al* (10) found the mean flock percentage of moderate plus severe FPD lesions was 11,0%, ranging from 0 to 71,5%. FPD can cause varying economic impacts including performance, processing plant losses and animal welfare penalties.

The use of nutritional interventions to reduce FPD has been successful with the use of Zn supplements. El-Wahab *et al* (7) studied the influence of supplementing Zn from Zn oxide and Zn methionine complex together with biotin. Reductions from 25% to 50% in the number of cases, and a 24% reduction in severe scores, were obtained for the group combining high levels of biotin and zinc-methionine. Absence of the highest scores in the groups containing Zn-methionine complex were obtained. The incidence and severity of foot pad dermatitis was significantly reduced ($P < 0,05$) with treatments including zinc amino acid complexes at 40ppm in substitution and on top of a zinc sulphate control at 80ppm (19). Foot pad lesions and feed conversion were reduced ($P < 005$) in broilers fed Zn- amino acid complexes (11).

The effect of zinc on reducing prevalence and severity of FPD is explained by the evidence that zinc is known to encourage the production of collagen and elastin fibres as well as keratin synthesis (13). These proteins help to support the underlying structure of the skin and can create a stronger barrier against chemical

and physical agents. On the other side, once the lesion is developed, zinc works on improving the healing process of the epidermis, dermis and hypodermis, depending on the severity of the lesion. Skin zinc accounts for about 20% of the total zinc in the body (13). This means that when a challenge in the tissues occurs, large amounts of Zn will be needed.

Breast meat yield

Muscle is one of the tissues where a high proportion of body zinc is present (about 50-60%) (29). Intense metabolic activity is taking place in these and many other tissues in growing broilers. Rapid multiplication and growth of muscle fibres produce skeletal muscle enlargement (29). This demands many nutrients such as proteins, energy, calcium, phosphorous, Zn, Cu, Fe and other essential elements. Breast meat muscle normally accounts for 19-21% of the total carcass weight.

Jahaninan *et al* (12) in 2008 obtained 1% more breast meat yield (19,03 vs. 20,07%) with the use of Zn-methionine complex (40, 80, 120ppm) in Ross x Ross broilers at 42 days of age. McNaughton and Shugel (15) reported that feeding Zn-methionine and Mn-methionine increased breast meat yield in broilers. Saenmahayak *et al* (19) found incremental differences ($P < 0,05$) in total breast and fillets yield with the use of zinc amino acid complexes.

Once an optimal feed formulation for breast meat yield has been achieved, it will still be sensitive to different management and nutrient intake variations. Care must be taken to ensure uniform conditions in terms of poultry husbandry and feed manufacturing. For example, breast meat yield can be reduced where placement densities are high (2).

Bone strength

Defects produced by the fracture or exposure of bones during processing are a frequent cause of downgrading. The main causes are related to poor uniformity and consequential difficulty in the adjustment of processing equipment (mainly for stunning and plucking) (26). Rough handling of birds can increase the severity of this problem. Bone strength also accounts for causing joint dislocations and bone fractures.

Few studies have been published evaluating nutritional interventions for fractures in a processing plant. Nevertheless, different studies support the effect of improved nutrition on bone strength and mineralisation. Zinc and manganese supplementation have increased bone strength, density and mineralisation. In one study performed with inorganic sources of Zn and Mn (4) maximum load resistance of femurs and tibia was increased statistically ($P \leq 0,05$) from 31,2 to 33,5kg when increasing Zn/Mn supplementation levels from 60/50 to 120/100.

Štofaníková *et al* (20) found 100ppm to be the optimal level of total Zn inclusion in the diet of broilers (Ross 308) to achieve maximum bone strength at 35 days of age. There were significantly ($P < 0,05$ to $P < 0,01$) higher values for limits of elasticity (Re), bending strength (Rm) and fracture stress (RI), improving Re with 23,6%, Rm with 26,4% and RI with 41,0%. They conclude that Zn content in feed has a direct, statistically significant effect on bone strength in broiler chickens.

Carcass bruises and haemorrhages

Bruises and haemorrhages are an important cause of downgrading and partial condemnation following skin problems. Hess *et al* (11) found a reduction ($P <0,05$) in bruising of carcasses in wings and on the back when birds were fed Zn amino acid complexes. Zinc effects on blood vessel strength and regeneration may account for this effect, either preventing severe damage or healing it (13).

Other defects

A number of other defects are variable in their incidence and usually represent a lower percentage of the downgrades. Under specific circumstances they can become major concerns and cause significant losses from problems such as deep pectoral myopathy, green legs, cachexia, red tips, white stripping (of breasts and thighs), and dorsal myopathy. These conditions are present in most processing plants at low percentages. They can have varied causal factors associated and related to on-farm, pre-processing and processing plant management (1, 26).

There have been difficulties developing research models to assess the impact of nutrition on their appearance. This is mostly because their frequency is variable and sometimes the main causes are not well established or are difficult to standardise. Others may not have economic significance, and hence there is limited interest in pursuing a solution. Efforts will continue towards finding combined strategies to reduce their appearance and economic impact with improvements in trace mineral nutrition, and through other combined nutritional approaches.

Organic sources of zinc

Zinc is an important trace mineral in animal nutrition which is involved in many metabolic processes including growth, bone development, skin quality and wound healing (9). Greater bio-availability and efficacy of organic Zn sources in contrast with its inorganic counterparts has been reported (25). Within organic sources metal non-specific amino acid complexes (1:1 metal: amino acid) have shown consistent, and the greatest spectrum of responses compared to other forms of organic trace minerals (11, 6, 12, 19). Other organic sources such as Zn proteinates and Zn chelates (1:2 or 1:3, metal: amino acids – 17, 18, 14, 23, 24) have not been able to show consistent responses on carcass yield or carcass quality, nor consistent performance when compared with inorganic sources or increasing inclusions.

The use of these relatively highly available sources of zinc and manganese has made a difference in animal performance, as it has been evident that the trace mineral levels we had been feeding to animals did not meet their actual requirements. Most of this is due to the inherent presence of antagonists in diets (calcium, phosphorous, phytate and other trace minerals) and in the water (sulphates, carbonates).

Big changes in genetics and feed technology have also put more pressure on the growth of the birds. Producing a heavy broiler at a younger age implies higher metabolic stress and softer tissues. Tissues can become even weaker if their nutrient requirements are not fully covered, or if diseases or other stresses increase these requirements. ❖