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Strategies to Alleviate the Incidence of Ascites in Broilers: a Review

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ABSTRACT

Ascites is a complex problem caused by many interacting factors such as genetics, environment and management. Many nutritional, medicinal and management strategies have been proposed to alleviate the problem. Higher levels of dietary vitamin C and E along with selenium yeast might be beneficial, presumably because of their role in improving cellular integrity. Oils rich in n-3 fatty acids have been shown to reduce pulmonary hypertension and, consequently, ascites incidence. The potential use of flax oil has already been demonstrated, whereas the effects of other oils rich in n-3 fatty acids (fish, linseed and canola oils) remain to be investigated. The assessment of the effects of dietary electrolyte balance on ascites incidence seems to be a promising field of research in broiler nutrition. In general, reducing the dietary level of salt (NaCl) and adding bicarbonates to the diet and drinking water have been proposed as potential "cost-effective" methods to reduce ascites incidence. The use of nutrients/drug agents that increase the vascular capacity of the lungs or decrease the pulmonary vascular resistance may help to alleviate the problem, but economic and local feed regulations might restrict such use. Diuretics have also shown positive effects, presumably because there is a reduction of sodium and fluid retention in the body; litter humidity however must be closely monitored if diuretics are continuously administered. As the high metabolic rate (fast growth) is a major factor contributing to the susceptibility of broilers to ascites, early-age feed or nutrient restriction (qualitative or quantitative) or light restriction in order to slow down the growth rate seem practically viable methods, since final body weight is not compromised. Optimization of the house temperature and ventilation in cold weather seem helpful practices to decrease ascites incidence. Under practical conditions, it might be interesting to test the additive effects of different approaches when used in combination.

INTRODUCTION

Pulmonary Hypertension Syndrome (PHS or ascites) is one of the major causes of mortality and morbidity in modern broiler production. Genetics, environment, and management all seem to interact to produce a cascade of events that culminate in ascites syndrome. It is generally proposed that the high metabolic rate of current broiler lines causes an increased demand for oxygen, especially in cold environments or when birds are fed high nutrient density diets. In such situations, the proportionately underdeveloped cardio-respiratory system of modern broilers fails to fulfill the required oxygen demand, resulting in hypoxemia. High hematocrit levels and vasoconstriction are consequences of hypoxemia that lead to elevated viscosity/pressure and low oxygen saturation of blood. Therefore, the heart (right ventricle) must respond

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with more vigorous contractions in order to overcome the oxygen insufficiency and to cope with the high venous return, resulting in the development of pulmonary hypertension and congestive heart failure.

Based on the published literature, this revision aims to present some specific and general recommendations that have been shown to alleviate the incidence of ascites in broilers. The information presented herein may hopefully provide some practical guidelines to veterinarians and anyone involved in poultry production that face this challenge in field conditions.

NUTRITIONAL CONTROL

Manipulation of the levels of different nutrients in the diets has been and still is an important research area in broiler nutrition, since it affects the incidence of ascites. Based on the proposition that lipid peroxidation may be involved in the degeneration of cardiac tissue and lead to the development of pulmonary hypertension syndrome, the possible role of nutrients with "antioxidant" properties has been investigated in many studies. The combined use of higher dietary levels of vitamin E and organic selenium (250 IU vitamin E and 0.3 ppm selenium yeast) significantly reduced the mortality caused by PHS and improved gain: feed in cold-stressed broilers (Roch *et al.*, 2000). Such better results have been attributed to improved cellular integrity provided by the antioxidant effects of vitamin E and selenium. Selenium yeast added to diets (0.1%) has also been shown to reduce ascites mortality from 11% (no selenium yeast) to 2.3% (with selenium yeast) with a concurrent increase in body weight gain (14%) in supplemented broilers compared to the non-supplemented birds (Stanley *et al.*, 1998). Supplementation of 500 mg Vitamin C per kg diet has reduced the number of thick-walled peripheral vessels in the lungs and ascites incidence (Xiang *et al.*, 2002). Nevertheless, Packed Cell Volume, weight gain and feed efficiency were not affected by the treatment (Table 1). In addition to the suggestions that vitamin C may exert positive effects on alleviating ascites because it depresses the oxygen-derived free radical status (Ladmakhi *et al.*, 1997), the results presented in Table 1 show that vitamin C markedly reduced the muscularization of the pulmonary arterioles as indicated by the lower number of thick-walled peripheral vessels (TWPV). Thus, it may reduce the resistance to blood flow that is seen in pulmonary vessels of broilers.

The administration of flax oil (50 g per kg diet) to broilers under hypobaric conditions reduced right ventricular hypertrophy, hematocrit and hemoglobin content; erythrocyte deformability was increased and whole blood viscosity was reduced (Walton *et al.* 1999) (Table 2). Diets containing flax oil (50 g oil per kg) increased the content of unsaturated fatty acids in erythrocyte membranes, thereby increasing the fluidity of the membranes and the deformability of erythrocytes (lower filtration index; Table 2). Flax oil is rich in alpha-linolenic acid, which is a precursor of eicosapentaenoic acid (EPA, 20:5 n-3) and docosahexaenoic acid (DHA, 22:6 n-3). As EPA and DHA might be further metabolized to prostacyclins, PGI_3 and PGI_2, which function as coronary relaxants, it was suggested that the higher dietary ratio of n3/n6 fatty acids increase the production of compounds that reduce the resistance to blood flow (Walton *et al.*, 1999). A later study evaluated the effect of dietary flax oil and antioxidants on the incidence of ascites in broilers reared under low temperatures. Although the results were statistically non-significant, the group supplemented with flax oil at 50 g per kg of diet tended to show lower incidence of ascites and decreased right ventricle to total ventricle ratio compared to broilers given control diets (Walton *et al.*, 2001).

Table 1 - Effect of vitamin C on performance and incidence of ascites in broilers at 49 days of age[A]

Treatment	Gain, g	Feed conversion, g/g	Incidence of ascites, %	RV/TV[B]	TWPV[C], %
Normal Control	423[a]	3.06[a]	2.0[a]	0.34	11.57[a]
Cold Control	372[b]	3.64[b]	11.43[b]	0.33	18.36[c]
Cold + 500 mg Vit. C per kg feed	386[b]	3.42[b]	1.42[a]	0.31	13.79[b]

[a-b] Means followed by different superscripts within a column differ significantly ($p<0.05$). [A] Xiang *et al.* (2002). [B]Right Ventricle to Total Ventricle ratio (RV/TV). [C]Thick-Walled Peripheral Vessels (TWPV).

Table 2 - Effect of flax oil and animal/vegetal blend (A/V blend) on the performance and ascites parameters of broilers, 28 d [A]

Treatment	Gain, g	RV/TV	Hemoglobin, g/l	Blood viscosity,Cps	Filtration Index, s
A/V blend 50 g per kg feed	558	0.331[a]	110[a]	3.1[a]	23.5[a]
Flax oil 50 g perkg feed	542	0.305[b]	94.3[b]	2.8[b]	16.3[b]

[a-b] Means followed by different superscripts within a column differ significantly ($p<0.05$). [A] Walton *et al.* (1999)

There are evidences that the inclusion of 1000 mg potassium carbonate per liter of drinking water may be a practical method to increase blood oxygenation (PaO_2) of broilers and perhaps to act as a prophylactic to reduce losses due to ascites (Shlosberg *et al.*, 1998). Similarly, birds fed on high-bicarbonate, low-chloride diets have shown significantly lower pulmonary hypertension and lower heart weights, and this technique has been suggested as a potential means to reduce pulmonary hypertension and ascites in broilers (Squires & Julian, 2001). The addition of 1% sodium bicarbonate to the diets of broilers has decreased mortality due to ascites. The decrease was ascribed to the alkaline nature of sodium bicarbonate and a possible induction of alkalosis (Owen *et al.* 1994). It is generally proposed that treatments that potentially induce alkalosis may reduce the incidence of ascites, whereas treatments with acid-inducing effects may exacerbate it.

It has been shown that 1% L-arginine supplemented to the diet significantly reduced the right ventricle: total ventricle ratio and total ascites mortality (Wideman *et al.*, 1995). It was proposed that L-arginine is required as a substrate for nitric oxide, a potent endogenous pulmonary vasodilator, when added at levels higher than the requirements for maximal growth.

MEDICINAL CONTROL

Pulmonary vasoconstriction and increased blood viscosity are the major effectors that ultimately lead to pulmonary hypertension and ascites. In this context, factors that tend to increase the vascular capacity of the lungs or decrease the pulmonary vascular resistance would theoretically reduce the incidence of ascites. To test this hypothesis, a number of drug agents have been studied. Researchers of the University of Guelph studied the effects of Diaoxinxuekang (a Chinese medicine) on ascites in broilers (Wang & Hacker, 1993). Diaoxinxuekang has been reported to improve blood circulation. Besides, it is claimed to decrease oxygen consumption by cardiac myofibrils and improve the hydraulic pressure of blood in the heart. Diaoxinxuekang was added to experimental diets at 0, 500, 1500, and 3500 mg per kg and it was concluded that 3500 mg Diaoxinxuekang per kg of diet reduced the incidence of ascites in broilers, with no negative effects on the gain or feed efficiency.

Similarly, the addition of 0.2% of Aspirin to the diet has reduced the incidence of ascites (Balog *et al.*, 2000a). Aspirin addition, however, has also resulted in significant reduction in the final body weight of broilers when compared to the control group (no aspirin in the diet). Since it is suggested that the lower body weight also reduces the intensity of ascites in broilers, it was not clear whether the reduction in ascites incidence was a direct effect of aspirin, or an indirect effect of the lower body weight (Acar *et al.*, 1995; Balog *et al.*, 2000b).

Researchers of the University of Arkansas have studied the effect of a diuretic named Furosemide on the incidence of ascites. The addition of 0.015% Furosemide to the diet has reduced both the right: total ventricle ratio and the cumulative ascites mortality. Body weight, however, has been significantly reduced as a result of this treatment in one of the two experiments reported (Wideman *et al.*, 1995). Lower levels of Furosemide (0.01% of diet) have significantly reduced ascites mortality but had no effect on body weight. It was later suggested that dietary furosemide added at levels of 0.015% does not seem to influence pulmonary vessels in broilers but it may extend the survival time of broilers during the pathophysiological progression of PHS (Forman & Wideman, 2001).

The supplementation of feed with 0.25 ppm Clenbuterol, a beta-adrenergic agonist, has been shown to reduce ascites mortality in broilers (Ocampo *et al.*, 1998). Dietary supplementation with Atenolol, a beta-adrenergic blocker, has also been shown to numerically reduce ascites incidence in broilers (7%) when compared with the non-supplemented diet (15%) (Hassanzadeh *et al.*, 2002). Further studies, however, are required to elucidate the precise mechanism by which these drugs reduce the incidence of pulmonary hypertension and ascites.

Chinese researchers studied the effect of dietary supplementation with Coenzyme Q10 (CoQ10) on the performance and ascites parameters of broilers (Geng *et al.*, 2004). CoQ10 supplemented at 20 or 40 mg per kg of diet resulted in significant reduction ($p<0.05$) in ascites mortality compared to the negative control. Supplementation at 40 mg per kg of diet also reduced ($p<0.05$) the right ventricle to total ventricle ratio, Erythrocyte Osmotic Fragility and Pulmonary Arterial Diastolic Pressure when compared to the negative control. Besides, gain and feed efficiency tended to improve with increasing dietary levels of CoQ10 (Table 3). It was proposed that CoQ10 alleviate ascites by protecting the cell membrane and cell structure against peroxidants.

Table 3 - Effect of different dietary Coenzyme Q10 levels (CoQ10) on the performance and ascites parameters of broilers [A]

CoQ10, mg/kg	Gain, g	FCR, g/g	AscitesMortality, %	EOF, % [B]	PADP, (kPa) [C]	RV/TV
0	2.07	1.94	26.7[a]	30.1[a]	3.11[a]	0.39[a]
20	2.13	1.85	5.0[b]	27.2[b]	1.27[b]	0.32[b]
40	2.29	1.82	5.0[b]	25.4[b]	1.13[b]	0.31[b]

[a-b] Means followed by different superscripts within a column differ significantly (p<0.05). [A] Geng *et al.* 2004. [B] Erythrocyte Osmotic Fragility. [C] Pulmonary Arterial Diastolic Pressure.

FEED RESTRICTION PROGRAMS

The growth rate or body weight gain in broilers has been shown to positively correlate with incidence of ascites. Broilers genetically selected for fast muscle growth seem more susceptible to ascites compared with slow-growing strains. Manipulation of the early growth cycle of broilers, with a subsequent compensatory gain, seems a practical and viable method to minimize losses caused by ascites. In this context, various feed restriction programs have been tested. Acar *et al.* (1995) studied the effect of early-age feed restriction on the subsequent growth and the incidence of ascites in broilers. A feed restriction regimen was used from either 4-11 (FR1) or 7-14 (FR2) days of age, consisting of limiting daily intake of the birds to 75% of the ME required for normal growth. It was concluded that although ascites mortality could be significantly reduced in early feed-restricted birds, there was a decrease in body weight and breast meat yield in restricted vs. full-fed birds (Table 4). Balog *et al.* (2000b) studied the effect of different feed restriction regimens on the growth and ascites mortality in broilers. The following treatments were used: 1) full-fed control; 2) feed available for 8 h/d for 6 weeks; 3) feed available for 8 h/d for the first 3 weeks and then full-fed; 4) full-fed in the 1st week, 8 h/d for 3 weeks and full-fed for the remaining 2 weeks. Mortality due to ascites was significantly lower in all restricted groups, while weight gain at 42 days was significantly smaller only in group 2 in comparison to the full-fed group (control). Breast meat yield, however, was significantly low in all feed-restricted groups compared with the control. More recently, Camacho-Fernandez *et al.* (2002) studied the effect of different feeding programs on the incidence of ascites and the production parameter of male and female broilers. They concluded that the birds fed on an *ad libitum* low-nutrient density regimen (2900 kcal, 21% CP for 0-21 d; 3000 kcal, 19% CP for 22-35 d; and 3160 kcal, 17.5% CP for 36-52 d) showed significantly reduced (p<0.0001) ascites mortality compared with the birds fed *ad libitum* with a high-nutrient density regimen (3000 kcal, 23.5% CP for 0-21 d; 3200 kcal, 20.5% CP for 22-35 d; and 3300 kcal, 18.5% CP for 36-52 d). In the study, body weight gain, feed efficiency, breast yield and abdominal fat yield were similar among treatments (Table 4). These results indicate that feed restriction programs might be potentially used to reduce the incidence of ascites; however, such programs must be carefully evaluated under different production systems.

HUSBANDRY/MANAGEMENT

Lower ambient temperatures trigger the incidence of ascites in broilers. The control of house temperature (particularly during brooding) could be extremely helpful in reducing ascites incidence. Lower brooding temperatures (26.7C, 24.4C and 21.1C in the 1st, 2nd and 3rd weeks, respectively) have been shown to significantly increase ascites mortality at 6 weeks of age, when compared with higher brooding temperatures (Deaton *et al.*, 1996). Therefore, minimum temperatures of 29.4C, 26.7C and 24.4C in

Table 4 - Effect of different feed restriction regimens on the performance and incidence of ascites in broilers.

Treatment	Gain, g	Feed conversion, g/g	Breast yield[B], %	Ascites, %	Pre-ascites, %
Acar *et al.* (1995)					
Ad-lib Control	822[a]	1.82	11.1[a]	12.92[a]	45.83
FR 1 [A]	725[b]	1.77	10.57[ab]	0.98[b]	34.51
FR 2 [A]	721[b]	1.68	10.18[b]	5.55[ab]	27.96
Camacho-Fernandez *et al.* (2002)					
Control	2616	2.30	32.95	3.82[a]	-
Ad-lib low-density Diet [A]	2607	2.34	32.25	1.36[b]	-

[a,b] For each experiment, means within a column followed by different superscripts differ significantly (p<0.05). [A] See text for the description. [B] *Pectoralis major* as a percentage of live weight (Acar *et al.* 1995); Breast weight as a percentage of carcass weight (Camacho-Fernandez *et al.* 2002)

the first, second and third week, respectively, have been suggested to optimize the energetic efficiency of the ingested fuel while reducing ascites-related mortality to a minimum (Deaton *et al.*, 1996). The general pathophysiology of the syndrome indicates that proper ventilation/air quality (provision of fresh-air with O_2 and reduction in the levels of CO_2 and NH_3 in the poultry house) may be beneficial to attenuate the problem. Poor air quality in the house (such as high levels of dust and ammonia) has been shown to exert an oxidative stress on the antioxidants of the lining fluid in the lung of broilers and this was found to be positively correlated with the right ventricle to total ventricle ratio. Therefore, oxidative stress in the lung lining fluid may be related to subsequent development of ascites (Bottje *et al.*, 1998). However, the economics of such inputs, i.e., brooding temperatures and ventilation rates, must be evaluated under different production systems to assess the commercial feasibility of using these as a tool to reduce ascites.

The effects of different lighting schedules on ascites have also been investigated. Broilers were kept on different lighting schedules, i.e., group 1 (23L:1D); group 2 (1L:3D, repeated six times a day); and group 3 (6L:18D for 14 days; 10L:14D between 15-21 days of age; 14L:10D between 22-28 d; 18L:6D between 29-35 d; and 23L:1D between 36-42 d). Birds kept on restricted lighting program (group 2 and 3) showed lower hematocrit and plasma T3 levels, and a numerically lower mortality due to ascites compared to the non-restricted group (Hassanzadeh *et al.*, 2003).

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