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Genetic Perspective of Ascites Syndrome in Meat-Type Chickens

Review Article

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ABSTRACT

Pulmonary hypertension syndrome (ascites) is a metabolic disorder in fast-growing broilers. Inconsistency of oxygen requirement and the cardiovascular ability make the birds susceptible to ascites. Incidence of ascites was accompanied by right ventricular hypertrophy, fluid accumulation in the abdominal cavity and finally mortality. The objective of the current study was to review the genetic basis of ascites syndrome and investigation of indicator traits of ascites syndrome to use in selection indices for reducing ascites susceptibility in broilers. Developing a breeding objective to increase body weight and to reduce ascites susceptibility in broilers is of ongoing interest, because the ascites syndrome is still a major challenge for poultry breeders. The blood gas parameters, which measured early in life, make it possible to design alternative selection schemes to reach birds resistance to ascites. In this way, ascites susceptibility can be effectively reduced but it might be comes at a cost, including a reduction in selection response for growth rate, due to genetic correlations. Based on the best combination of traits considered, reduction in gain for growth rate might be decreased, although with limited efficiency. Also, marker-assisted selection can be used effectively to reduce ascites susceptibility with respect to benefit-costs analysis.

KEY WORDS ascites, genetic aspect, meat-type chickens, selection strategy.

INTRODUCTION

Genetic selection for increased growth rate (Decuypere *et al*. 2005), improved feed conversion (Decuypere *et al*. 2000; Pakdel *et al*. 2002), carcass yield and breast percentage (Hoving-Bolink *et al*. 2000) in modern broiler chickens have been made negative physiological impositions such as ascites syndrome (Havenstein *et al*. 2003; Moghadam *et al*. 2001). Ascites (pulmonary hypertension syndrome) is a metabolic disorder in fast-growing broilers (Siegel and Dunnington, 1997), resulting in serious economic losses for the broiler industry due to high mortality (Witzel *et al*. 1990). As pointed out by Siegel and Dunnington (1997), allomorphic discrepancies in heart and lung tissues and the size of the bird make it susceptible to ascites.

In such cases, oxygen demand is increased, causing inconsistency of oxygen requirement and the cardiovascular ability (Julian and Mirsalimi, 1992; Scheele *et al*. 1992; Decuypere *et al*. 2000), putting pressure on the pulmonary vascular system (Closter *et al*. 2009) and leading to oxygen imperfection in the tissues (Wideman *et al*. 2013). In this way, pulmonary arterials incur high blood pressure. Consequently, incidence of ascites is associated with right ventricular hypertrophy, fluid accumulation in the abdominal cavity and finally mortality (Decuypere *et al*. 2000; Havenstein *et al*. 2003). The syndrome is largely characterized by oedema, fluid accumulation in the pericardium, epicardial fibrosis, lung oedema, flaccid heart, hypertrophy and dilation of the heart, especially the right ventricle, variable liver changes, hypoxaemia, pale comb and higher blood

hematocrit (Decuypere *et al*. 2000; Olkowski *et al*. 2003; Balog *et al*. 2003; Luger *et al*. 2003; Tekeli, 2014). As described by Balog *et al*. (2003) and Pavlidis *et al*. (2007), mortality of ascites ranged from 5% to 8% in various populations, increasing up to 30% in heavier broiler flocks.

Information on blood gas parameters that are measured early in life and their associations with ascites is the best tool available to predict ascites susceptibility in juvenile broilers (Van As *et al*. 2010). Increased partial pressure of CO_2 in venous blood (called hypercapnia) of chickens which suffer from ascites, confirmed by Olkowski *et al*. (1999); Scheele *et al*. (2005); Hassanzadeh *et al*. (2010) and Hassanzadeh *et al*. (2014). By studying partial pressure of CO_2 in venous blood in 11 day old chicks, Olkowski *et al*. (1999) concluded that partial pressure of O_2 discrepancies in venous blood at 4 wk of age is associated with partial pressure of CO_2 in venous blood on day 11. However, Closter *et al*. (2009) proposed blood gas parameters as indicator traits in selection index to reduce ascites susceptibility in broilers. They estimated genetic and phenotypic relationships between blood gas parameters and ascites-related traits. Such an outcome was described by McMillan and Quinton (2002), who indicated that by the use of sib information and an indicator trait for ascites, the genetic level for ascites can be reduced. On the other hands, the results of Wideman and French (2000); Anthony *et al*. (2001) and Balog *et al*. (2001) showed that selection for increased body weight (BW) and resistance to ascites syndrome was possible in broilers. Therefore, the objective of the current study was to identify the genetic basis of ascites syndrome and good indicator traits to use in selection index for reducing ascites susceptibility in broilers.

The genetic basis of ascites syndrome

Broiler breeders have performed very successful selection on growth related traits of broilers. The methods have created problems since the production of robust flocks was of secondary importance (Pakdel, 2004). It has been shown that heavier broilers, likely to be male broiler lines, are more prone to develop ascites due to intensive selection on growth rate (Decuypere *et al*. 2000; Pakdel, 2004). Moreover, the broiler chickens selected for high growth rate have low partial pressure of O_2 and high partial pressure of CO_2 in venous blood (Decuypere *et al*. 2005). Ascites related traits have high heritabilities which show impressibility of genetic factors (Lubritz *et al*. 1995; Moghadam *et al*. 2001; Pakdel *et al*. 2002). There have been a relatively few published papers on the estimation of genetic parameters for ascites-related traits in broiler chickens. By the use of a sire model in three male lines of broiler population, Lubritz *et al*. (1995) estimated the heritability for the ratio of right to total ventricle weight (0.21, 0.21 and 0.27) and fluid accumulation in the abdominal cavity (0.36, 0.11 and 0.44). Also, Pakdel (2004) was extensively reviewed the genetic parameters of ascites related traits and their correlations with feed efficiency and carcass traits in broilers. For feed efficiency and ascites-related traits, low positive genetic relationship was reported in which more efficient broilers were slightly more susceptible to ascites.

Moghadam *et al*. (2001) reported moderate to high heritabilites (0.22 and 0.41) for ascites syndrome in two Cornish (female) and white rock (male) chicken populations. Closter *et al*. (2009) suggested that there is a moderate heritability for ratio of right to total ventricular weight, right ventricular weight and total ventricular weight. Ascites related traits are significantly influenced by maternal genetic effects (Pakdel *et al*. 2002; Navarro *et al*. 2006; Closter *et al*. 2009).

Therefore, ignoring maternal genetic effects in the model of analysis tended to overestimate direct additive genetic variances as well as their corresponding heritabilities for ascites-related traits.

Figure 1 shows, in part, the percentage of direct and maternal genetic variances for BW and ascites related traits (Pakdel *et al*. 2002; Closter *et al*. 2009).

Also, De Greef *et al*. (2001) and Zerehdaran *et al*. (2006) demonstrated that the estimates of genetic parameters for ascites related traits are considerably influenced by the severity, outcome and challenges of the ascites syndrome. According to a survey conducted by Zerehdaran *et al*. (2006), effect of ascitic bird frequency on overall genetic correlation among BW with hematocrit value and the ratio of right to total ventricular weight is presented in Figure 2.

In such cases, De Greef *et al*. (2001) and Zerehdaran *et al*. (2006) suggested mixture models to separate heterogeneous populations into homogeneous distributions. For ascites syndrome, observations are in scale divided as ascitic and non-ascitic, then the recognition and culling of birds could be based on the probability of presumed ascites, given ascites indicator traits, rather than on half-baked ascites traits.

Only few sets of genetic correlations among BW and ascites-related traits in both normal and cold conditions have been presented in the scientific literature (De Greef *et al*. 2001; Moghadam *et al*. 2001; Pakdel *et al*. 2005a). Moghadam *et al*. (2001) reported a positive genetic correlation between ascites and BW under normal condition. De Greef *et al*. (2001) and Pakdel *et al*. (2002) have shown a negative inferred genetic correlation among ascites-related traits and BW under cold condition.

However, a low but positive genetic correlation between traits related to ascites measured under cold conditions and BW measured under normal conditions was reported by Pakdel *et al*. (2005b).

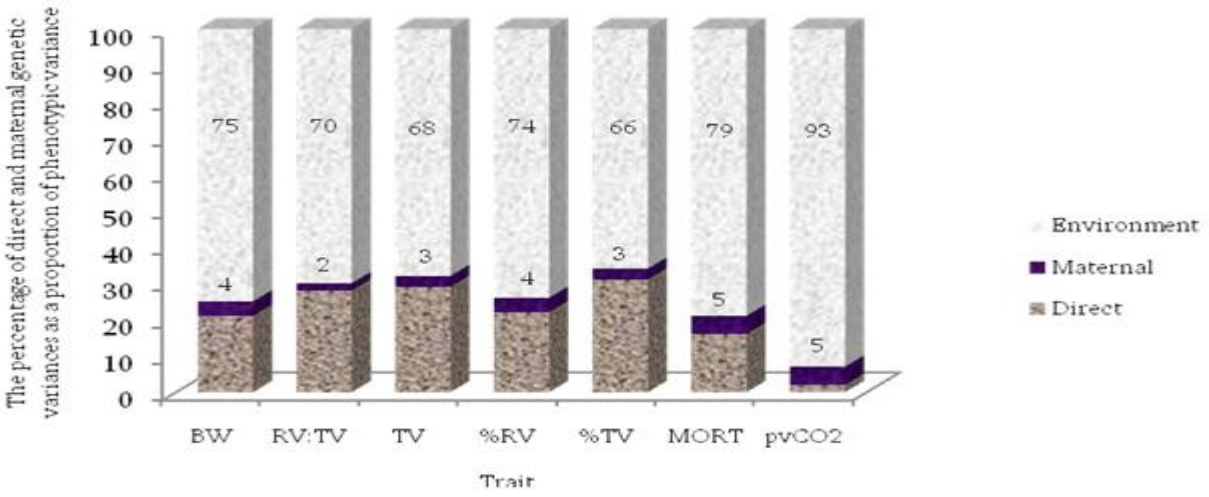

Figure 1 The percentage of direct and maternal genetic variances as a proportion of phenotypic variance for body weight at 5 wk, ratio of right to total ventricular weight (RV:TV); total ventricular weight (TV); right ventricular weight as percentage of BW (% RV); total ventricular weight as percentage of BW (% TV); total mortality (MORT) and partial pressure of CO_2 in venous blood ($pvCO_2$)

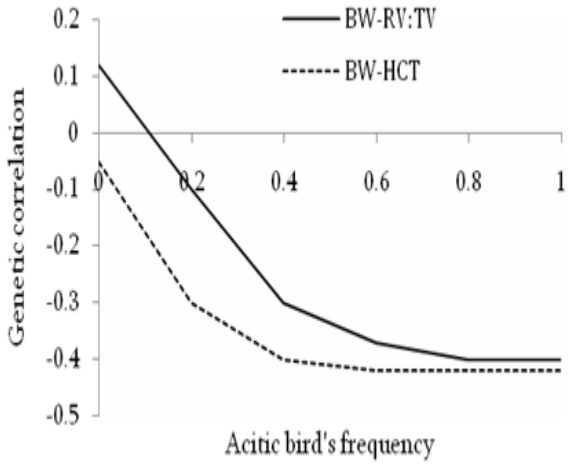

Figure 2 Effect of ascitic bird's frequency on overall genetic correlation among body weight (BW), ratio of right to total ventricular weight (RV:TV) and hematocrit value (HCT)

Ascites and indicator traits

As pointed out by Decuypere *et al.* (2000); Moghadam *et al.* (2001); Balog *et al.* (2003); Pakdel *et al.* (2005a); Zerehdaran *et al.* (2006) and Tekeli (2014), the most usual clinical indication of ascites are right ventricular hypertrophy and fluid accumulation in the abdominal cavity. Also, the ratio of right to total ventricular weight (RATIO) trait demonstrated as an indicator trait for ascites (Julian and Mirsalimi, 1992; Pakdel *et al.* 2005c; Hassanzadeh *et al.* 2014), fitting in selection index to reduce ascites susceptibility (Pakdel *et al.* 2005a). However, the traits mentioned can only be measured postmortem, reflecting complexity of selection strategies.

Because information on the relatives is the only tool available for selection (McMillan and Quinton, 2002; Pakdel *et al.* 2005a).

Therefore, Closter *et al.* (2009) suggested blood gas parameters as an alternative criterion. The results of Closter *et al.* (2009) were in agreement with the previous results obtained by Wideman *et al.* (2003); Navarro *et al.* (2006); Druyan *et al.* (2007); Hassanzadeh *et al.* (2010) and Tekeli (2014).

To use blood gas parameters as indicator traits, genetic correlations with ascites related traits are required. Genetic correlations among blood gas parameters and ascites related traits were reported by Pakdel *et al.* (2002); Navarro *et al.* (2006); Druyan *et al.* (2007) and Closter *et al.* (2009). According to genetic correlations among traits considered, hematocrit value (HCT), oxygen saturation in venous blood (sO_2), blood bicarbonate concentration in venous blood (HCO_3) and total carbon dioxide in venous blood (TCO_2) were suggested as indicator traits to use in selection index. The summary of genetic parameters reported by different authors is presented in Table 1.

However, the genetic correlations among blood gas parameters, measured early in life, with BW and ascites-related traits make it possible to design alternative selection schemes to reach birds resistance to ascites (Pakdel *et al.* 2002; Navarro *et al.* 2006; Closter *et al.* 2009).

Genetic selection strategies to reduce ascites susceptibility in broilers

The broiler growth rate has been found to have a distinct association with ascites susceptibility (Pakdel *et al.* 2002; Navarro *et al.* 2006).

Through selection to increase body weight, the ascitic birds frequency in the population is going to be elevated. Therefore, optimized selection strategy in which achieved selection response for BW is acceptable with respect to reduced ascites susceptibility is required, although with limited efficiency.

Table 1 Summary of genetic correlations among blood gas parameters with body weight and ascites-related traits in broiler populations under cold condition

Traits		r_g	r_p
HCT	BW	-0.23	-0.37
	ABDOMEN	0.66	0.29
	RV:TV	0.56	0.50
	RV	0.54	0.40
sO_2	BW	0.60	0.07
	ABDOMEN	-0.52	NA
	RV:TV	-0.18	-0.15
	RV	0.06	-0.03
HCO_3	BW	0.45	0.04
	ABDOMEN	NA	NA
	RV:TV	0.31	0.15
	RV	0.41	0.15
TCO_2	BW	0.53	0.10
	ABDOMEN	NA	NA
	RV:TV	0.31	0.15
	RV	0.42	0.18

HCT: hematocrit value; sO_2: oxygen saturation in venous blood; HCO_3: blood bicarbonate concentration in venous blood; TCO_2: total carbon dioxide in venous blood; BW: body weight; ABDOMEN: fluid in the abdomen; RV:TV: ratio of right ventricular weight to total ventricular weight; RV: right ventricular weight; r_g: genetic correlation and r_p: phenotypic correlation.
NA: not available.

The tested selection schemes can be divided as experimental and theoretical studies. A method to test a bird ability stand up to the intense stress of unilateral pulmonary artery occlusion (Wideman and French, 2000). They claimed improved resistance to ascites of progeny through selection. However, BW of non-ascitic birds showed no difference with the base population in only one of two experiments. Also, Balog *et al*. (2001) indicated that selection for ascites resistance is possible in which BW is not affected. In theoretical scale, alternative selection strategies were assumed to reduce ascites susceptibility while increasing BW (Pakdel *et al*. 2005a). The results further indicated that selection for increased BW only make the birds susceptible to ascites. The relatively high gain for BW can be achieved by considering the information of HCT and ratio of right to total ventricular weight (RV:TV) traits in selection index. On the other hands, using stochastic simulation, McMillan and Quinton (2002) indicated that the genetic level for the ascites syndrome can be reduced through selection based on sib information and an indicator trait.

Among the livestock species, chicken has the most extensive genomics toolbox available to detect quantitative trait loci (QTL) and to use marker-assisted selection (MAS). As described by Dekkers and Hospital (2002), MAS is useful for traits with low heritability or difficult to measure. Rabie (2004) accomplished a whole genome scan to find QTL for ascites-related traits, who reported three significant QTLs in which two QTLs reached the genome-wide inferred threshold.

To find chromosomal regions which display linkage disequilibrium with ascites susceptibility, Krishnamoorthy *et al*. (2014) fulfilled a genome-wide single nucleotide polymorphism (SNP) survey. A region on chromosome 9 was discovered in which ascites in the ascitic lines and in several commercial broiler breeder lines was associated with a significant sex effect.

Also, alternative selection strategies along with information on the underlying genes to reduce ascites susceptibility were tested by Pakdel *et al*. (2005a). The results showed that by considering information on the underlying genes in selection strategy in which QTL explains 5% of the genetic variance of ascites syndrome, the incidence of ascites can be reduced.

CONCLUSION

Developing a breeding objective to increase BW and to reduce ascites susceptibility in broilers is of ongoing interest, especially in developing countries, because the ascites syndrome is still a major challenge for poultry breeders. It has come to the conclusion that ascites susceptibility can be effectively reduced but it might be comes at a cost, including a reduction in selection response for growth rate, due to genetic correlations. There are, however, more efficient ways of minimizing the cost while increasing growth rate by using good indicators of ascites syndrome for designing selection strategies.

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