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Original Article

Factors Affecting Broiler Production: A Meta-Analysis

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Keywords

Poultry production; animal production; broiler genetic strain; rearing environment.

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ABSTRACT

The meta-analysis data were obtained from a survey of published articles over 15 years. The data were selected to classify the factors that impact broiler production and separated by influence aspects of animal production (thermal environment and other factors). The relevant data for each study were systematized, grouped and later tabulated and inserted into a database prepared in a spreadsheet. The variables used to analyze the thermal environment were temperature (comfort, high and low) and performance data (weight gain, feed intake, and feed conversion). The variables used for other features were ventilation (TER = tunnel + evaporative cooling, PP = positive pressure, NV = natural ventilation) and performance (feed conversion, live weight, mortality, and weight gain). The factors that may influence the production of broilers were tested by covariance analysis, Pearson correlation coefficient and divergence analysis, about the Cobb®, Ross® and Hubbard® strains. The results showed that the factors that most influenced the performance of broilers were temperature, ventilation rate, and genetic strain.

INTRODUCTION

Broiler meat is vastly consumed worldwide (FAO, 2008). In 2016 the world production was nearly 90 million metric tons (Statista, 2017). The genetic selection for fast growth and weight gain to which broiler chickens have been subjected in the last decades has led to birds more vulnerable to environmental factors. Therefore, tropical regions with intense solar radiation, high temperature, and high humidity, tend to lead to losses due to heat stress and consequently discomfort, and lack of welfare (Deaton *et al.*, 1997; Marchini *et al.*, 2016).

The production environment plays a fundamental role in the modern broiler industry, which seeks to achieve high productivity, in a relatively small space and time (Dawkins *et al.*, 2004; Amaral *et al.*, 2011). The facilities should ensure an environment of thermal comfort that allows the animal to express its full genetic potential (Nascimento *et al.*, 2014). The intensification of automation and innovative technologies has brought about the increased variability of the thermal environment of the facility, with consequent variability in the indexes of performance (Carvalho, 2012).

There has been a growing interest in the use of meta-analysis in areas related to animal production and veterinary sciences as an essential tool for synthesizing computed results from multiple studies, particularly in those in which the effect is not readily detectable and the sample is smaller (Cernicchiaro *et al.*, 2016). Also, studies have shown the successful application of the technique (Sanches *et al.*, 2007; Andretta *et al.*, 2011; Carvalho *et al.*, 2011; Pauly *et al.*, 2012). The use of meta-analysis in the broiler environment makes it possible to obtain a larger sample by combining several studies already performed, allowing a more accurate response than that obtained in individual studies (Andretta *et al.*, 2011). The present study aimed to identify from previous researches the variables that are most influential in the intensive production of broiler chicken using meta-analysis.

MATERIAL AND METHODS

Search strategy

The selected keywords were broiler, behavior, welfare, housing, rearing condition, stress, management, lighting, heat, production, acoustic environment, and thermal environment, both in English and Portuguese. The keywords were searched into three databases Google Scholar, Scopus, and Scielo.

The research started with an input of published scientific papers (*n* = 5,994) from the following databases Google Scholar, Scopus, and Scielo, within 2000 until 2015. A total of 5,960 articles were discharged in every step of the selection, adopting the criteria shown in Figure 1. The criterion for selection of parameters was a study that showed factors which most influenced broiler production. The relevant data for each work were systematized, grouped and later tabulated and inserted into a prepared spreadsheet. The data were separated by the factors that affect broiler production (rearing temperature, T; and other factors (weight gain, WG; feed conversion, FC, ventilation, V, flock mortality, M).

Data extraction and assessment

From each scientific paper, we checked performance data and the individual comparisons where the outcome was measured in a rearing temperature at a specified time and compared with the result in a control group. When the treatment group received more than one intervention, this was recorded. For each comparison and for each treatment and control group we registered data for number per group, mean outcome and its standard deviation. Data was only used when presented in tables, and when one group of birds was scored in more than one trial, data were combined with the genetic strain manual to estimate of effect size and standard error. The primary outcome assessment was the effect of the temperature in the rearing environment during broiler grow-out according to the genetic strain. The other variables which were extracted from the published data were those that affect broiler performance such as the type of ventilation used during the rearing period, and the performance data (feed conversion, live weight, mortality, and weight gain).

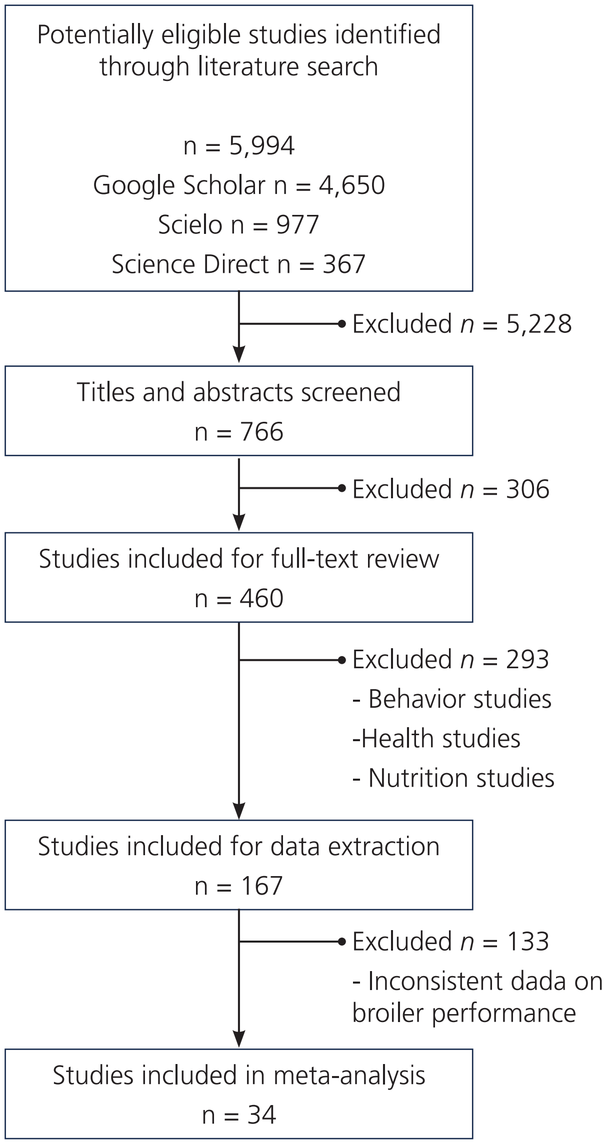


Figure 1 – Criteria and flowchart of the selection of studies considered in the meta-analysis.

Fonte: Adapted from Bawor *et al.* (2015).

The study focused the selection based on the following characteristics (1) publication in a peer-reviewed journal; (2) statement of broiler production data; (3) randomization to treatment or control; (4) sample size calculation; (5) statement of compliance with regulatory requirements; and (6) statement regarding possible conflicts of interest.

Data analysis

The variables used to analyze the thermal environment were temperature (comfort, high and low) and performance data (weight gain, feed intake, and feed conversion). The thermal environment variables (rearing temperature) and the influence factors in the animal production were submitted to Pearson correlation analysis (p<0.0001) and the results were of variance (ANOVA) with a probability of 95% of the confidence interval.

The factors that may influence the production of broiler chickens were tested using the VassarStats (Lowry, 2017) online software, by covariance analysis (ANCOVA), Pearson's correlation coefficient, and divergence analysis of the statistical compilation of the data in relation to broiler performance indicators of the Cobb, Ross and Hubbard genetic strains. The study of divergence was done by comparing the data of the compiled variables with the normalized indicator data of each lineage. Pearson correlation coefficients and divergencewere used as normalized standard reference values, the means of the performance variables were compiled from the production and nutrition manuals of broilers from the Cobb, Ross and Hubbard strains.

The statistical model for the analysis of covariance, with a factor and a covariate, is described in Equation 1:

$$yij = \mu + \alpha i + \beta(Xij - \overline{X}) + \varepsilon ij \qquad \text{Eq. 1}$$

where: μ = constant; αi = effect of the i_{th} treatment; X_{ij} = value observed of the covariable; $\overline{X}$ = mean of the covariable; β = coefficient of linear regression between the covariable (X) and the response variable (Y), with $\beta \neq 0$. In this model, it is assumed that the response variable and the covariate are linearly related, with a probability of 95% of the confidence interval. In this model, it is assumed that the response variable and the covariate are linearly related, with a probability of 95% of the confidence interval.

The correlation coefficient effect size (*r*) was calculated. The value of *r* is always between -1 and +1, and *r* = 0 corresponds to non-association. We use the term positive correlation when *r* > 0, and in this case, as *x* grows *y* increases, and negative correlation when *r* < 0, and in this case as *x* grows, *y* decreases (on average). The higher the value of *r* (positive or negative), the stronger the association. At the extreme, if *r* = n and/or *r* = -n then all the points in the scatter plot fall precisely in a straight line. At the other extreme, if *r* = 0 there is no linear association.

The effect size by correlation (CESr) was calculated from the factors considering ventilation *vs.* feed conversion, ventilation *vs.* mortality and conversion *vs.* mortality, the model described in Equation 2. The selection of the elements was due to the weight attributed to the factors within the temperature above the thermal neutral zone. The effect sizes for each study were grouped according to the lineage of the birds. The Practical Meta-Analysis Effect Size Calculator (Wilson, 2001) was used for calculating the size of effects dependent on meta-analysis.

$$CESr = \frac{(1 - r^2)^2}{n - 1} \qquad \text{Eq. 2}$$

where CESr = correlation coefficient effect size (Lipsey & Wilson, 2001), r^2= coefficient of determination, and *n* =the sample size.

RESULTS

Rearing temperature *vs.* performance

In most papers, the heat stress exposure was set when the broiler chicken was at a rearing temperature between 31 to 35 °C. The thermal comfort temperature was near 25 °C, and below 20°C was considered cold stress for broilers older than 30 days. The weight gain at 42days of age varied according to the genetic strain, being the studies with Cobb within the range of 1428 to 2500 g. The Ross broilers presented a variation of 1890 to 2400 g, and the Hubbard broiler showed a range of 1980 to 2100 g.

Table 1 presents the correlation amongst the rearing temperature and the following performance data weight gain (WG), feed consumption (FCO), feed conversion (FC), and flock mortality (M). Weight gain and feed consumption showed a strong positive correlation as expected (0.85). The remaining values varied; however, the rearing temperature presented a negative correlation to some performance variables (weight gain, feed consumption, feed conversion, and flock mortality).

Table 1 – Correlation between rearing temperature and the variables of performance.

	WG	FCO	FC	T
WG	1	-	-	-
FCO	0.85	1	-	-
FC	-0.48	0.00	1	-
T	-0.13	-0.60	-0.69	1

Wg=weight gain; FCO=feed consumption; FC=feed conversion; T=temperature

Table 2 presents the results of the ANOVA of temperature *vs.* weight gain (WG), temperature (T) *vs.* feed consumption (FCO), and temperature (T) *vs.* feed conversion (FC).

Considering the data on weight gain, feed consumption, and feed conversion the values of F were 8.32, 9.59, and 7.32 respectively ($p<0.05$) showing a difference between the treatments (thermal comfort, high and low temperature).

Table 2 – Analysisof the data on temperature (T)*vs.* weight gain (WG), temperature (T) *vs.* feed consumption (FCO), and temperature (T) *vs.* feed conversion (FC).

WG	DF	SQ	QM	F
Treatment	2	938732.10	469366.10	8.36*
Residue	8	449118.90	56139.90	
FCO	DF	SQ	MS	F
Treatment	2	1994671.55	997335.80	9.59*
Residue	8	83175.00	103969.60	
FC	GL	SQ	QM	F
Treatment	2	0.40	0.20	7.32*
Residue	8	0.21	0.027	

FCO = feed consumption; FC = feed conversion; DF =degree of freedom; SQ = sum of squares; MS = mean square.

Ventilation vs. performance

Pearson correlation for the three studied genetic strain, considering the interaction of the use of ventilation and performance (represented by the values of feed conversion- FC, and flock mortality-M) is presented in Table 3. Moderate correlation was found for ventilation *vs* mortality (r = 0.57) for Cobb data. Mortality *vs* feed conversion (r = 0.54) for the Ross and Hubbard strains ventilation *vs* feed conversion (r = 0.51) and ventilation *vs* mortality (0.55).

Using the Pearson correlation, the effect of the size (*r*) was calculated and the results are shown in Table 4, 5 and 6 for Cobb, Ross, and Hubbard genetic strains, respectively. The effect of ventilation *vs.* mortality was 0.57 (95% CI, 0.12: 0.82) for Cobb genetic strain with a positive correlation (Table 4).

The estimated effect size for mortality-related ventilation (V *vs.* M) of Ross genetic strain showed a negative correlation of -0.32 (95% CI, -0.74: 0.29) indicating that as ventilation improves (ventilation rate, m s^{-1}) mortality decreases (% per productive cycle). However, as feed conversion improves, regarding feed weight consumed as a function of the live weight of the bird, mortality increases in percentage per productive cycle, with an effect size estimate with a positive correlation of 0.54 (95% CI, -0.01: 0.84) (Table 5).

The results for the genetic strain Hubbard showed that the size of the effect of ventilation *vs.* mortality was 0.52 (95% CI, -0.22:-0.88) with a positive correlation (Table 6).

Table 3 – Pearson correlation of the use of ventilation and the results of feed conversion, and flock mortality of broiler from the genetic strains Cobb, Ross, and Hubbard.

Cobb				Ross			Hubbard		
	V (*x*)	FC	M	V (*x*)	FC	M	V (*x*)	FC	M
V	1	*	*	1	*	*	1	*	*
FC (*y*)	0.24	1	*	0.20	1	*	0.52	1	*
M (*y*)	0.57	0.13	1	-0.31	0.54	1	0.13	0.55	1

V= air velocity; FC=feed conversion; M=flock mortality.

Table 4 – Correlation coefficient to determine the effect size (*r*) for the genetic strain Cobb.

Correlation coefficient effect size (*r*) - Cobb									
				95% IC			95% IC		
Pearson Correlation	Factors	n	r	Lower	Upper	F Test Zr	Lower	Upper	V
0.24	V*vs* FC	17	0.25	-0.26	0.65	0.25	-0.27	0.78	0.07
0.57	V *vs* M	17	0.57	0.12	0.82	0.65	0.12	1.17	0.07
0.13	FC *vs* M	17	0.13	-0.37	0.57	0.13	-0.39	0.65	0.07
	Cobb	17	0.32	-0.17	0.68	0.34	-0.18	0.87	0.07

V= ventilation; FC=feed conversion; M=flock mortality; CI=confidence interval.

Table 5 – Correlation coefficient to determine the effect size (*r*) for the genetic strain Ross.

Correlation coefficient of the effect size (*r*) for the genetic strain Ross									
				95% CI			95% CI		
Pearson	Fator	n	*r*	Lower	Upper	F Test Zr	Lower	Upper	V
0.20	V *vs* FC	13	0.20	-0.39	0.68	0.21	-0.41	0.83	0.1
-0.31	V *vs* M	13	-0.32	-0.74	0.29	-0.33	-0.94	0.29	0.1
0.54	FC *vs* M	13	0.54	-0.01	0.84	0.61	-0.01	1.23	0.1
	Ross	13	0.14	-0.38	0.60	0.16	-0.46	0.78	0.1

V= ventilation; FC=feed conversion; M=flock mortality; CI=confidence interval.

Table 6 – Correlation coefficient to determine the effect size (*r*) for the genetic strain Hubbard.

Correlation coefficient of the effect size (*r*) for the genetic strain									
				95% CI			95% CI		
Pearson	Factors	n	*r*	lower	upper	F Test Zr	lower	upper	V
0.52	V *vs* FC	9	0.52	-0.22	0.88	0.57	-0.23	1.37	0.17
0.13	V *vs* M	9	0.13	-0.58	0.73	0.13	-0.67	0.93	0.17
0.55	FC *vs* M	9	0.55	-0.18	0.89	0.62	-0.18	1.41	0.17
	Hubbard	9	0.40	-0.33	0.83	0.44	-0.36	1.24	0.17

V= ventilation; FC=feed conversion; M=flock mortality; CI=confidence interval.

Since the data significantly varied amongst the studies the reference from the manual of each genetic strain was used to normalize and adjust the data. Table 7 presents the meta-analysis results showing a correlation between the studied variables (weight gain, weight, feed conversion, and flock mortality).

Table 7 – Performance responses obtained by meta-analysis.

	Treatment			
		n		Total
	17	19	3	39
Variable	TER	PP	NV	
Weightgain (WG, g)	71.16	75.91	53.93	72.15
Adjusted WG (g)	71.10	74.84	61.06	72.15
Aggregated correlation within the samples				
r		0.67		
r^2		0.46		
p-value		0.18		
Live weightW, kg)	2.54	2.58	1.81	2.50
Adjusted W (kg)	2.51	2.57	1.99	2.50
Aggregated correlation within the samples				
r		0.47		
r^2		0.22		
p-value		0.09		
Feed conversion (FC)	1.95	1.96	1.96	1.94
Adjusted FC	1.88	2.00	1.89	1.94
Aggregated correlation within the samples				
r		0.54		
r^2		0.30		
p-value		0.51		
Flockmortality (M, %)	2.82	3.04	1.77	2.85
Adjusted M (%)	2.70	2.98	2.84	2.85
Aggregated correlation within the samples				
r		0.79		
r^2		0.62		
p-value		0.58		

F Test: α = 95% of probability. TER = use of tunnel ventilation plus adiabatic cooling; PP = positive pressure fans plus fogging; NV = natural ventilation.

The feed conversion showed variations between 1.52 and 2.11 about the rearing environment ventilation (0.06. 0.18 and 0.24 m s^{-1}) and the feed conversion normalized to Cobb genetic strain. Broiler mortality presented results from 0.15 to 3.00% compared to 1.77% of normalized mean mortality. The feed conversion showed variation between 1.68 and 2.05 about the ventilation (0.18 and 0.24 m s^{-1}) and the feed conversion normalized to Ross strain. Flock mortality results were from 2.18 to 4.67% compared to 2.73% (normalized mean mortality). The feed conversion showed variation between 1.93 and 2.12 about the ventilation (0.18 and 0.24 m s^{-1}) and feed conversion normalized to Hubbard strain. Mortality found presented results of 3.00 to 7.69% compared to 5.05% of normalized mean flock mortality for the same genetic strain.

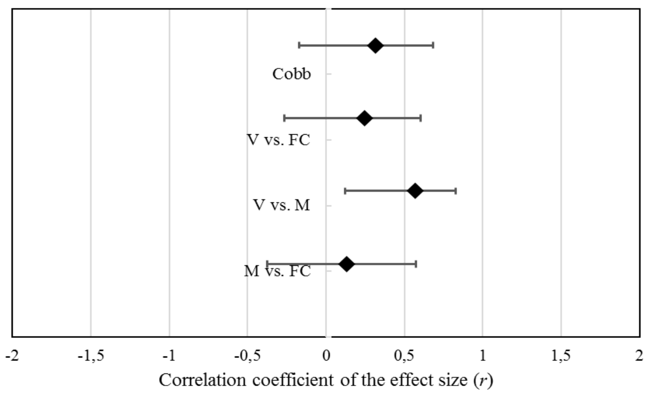
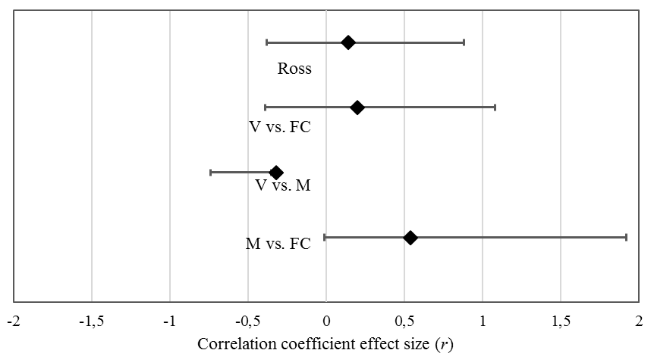
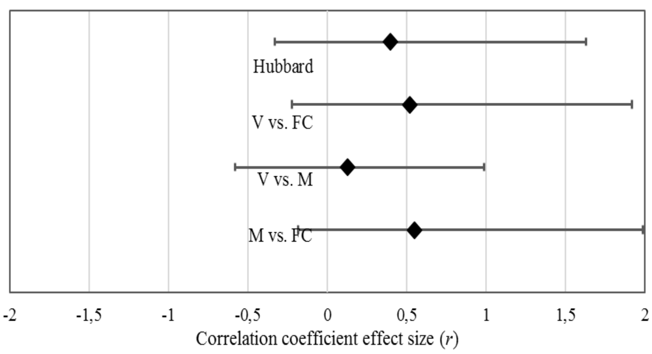
Data on authors, number of samples in each study (n), feed conversion rate (FC), broiler mortality (M), air velocity (V ms^{-1}bird), and Forest graph of the correlation coefficient of the effect size (*r*) are shown in Table 8.

DISCUSSION

The current manuscript presents the revised recommendations on the factors that affect broiler production on the point of view of rearing environment and relating to some performance variables. It is observed that the average heat stress occur when rearing temperature is around 32.5 °C. The effect of this temperature on the birds influences productivity, by altering their heat exchange with the environment, modifying food consumption, body weight gain and, consequently, metabolizable nutrients (Carvalho *et al.*, 2011), and thermal comfort (Vigoderis *et al.*, 2010). According to (Marchini *et al.*, 2016) different factors contribute to this situation: rapid growth, physiological changes and changes in the mucosa of the small intestine.

The influence of the thermal environment on birds varies with species, age, body weight, sex, physical activity and food consumption (Amaral *et al.*, 2011). Already, Dawkins *et al.* (2004) indicate that the importance of the indoor housing environment is more critical to meet animal welfare issues than flock density. Such statement means that the productivity of broiler chickens would probably be better in a most

Table 8 – Data on authors,number of samples in each study (n),feed conversion rate (FC),broiler mortality (M),air velocity (V m s^{-1}bird),and Forest graph of the correlation coefficient of the effect size (*r*).

Author	GeneticStrain	n	FC	M	V	Forest plot of the interactions between FC, M, and V, and the effect size (*r*)
Stringhini *et al.* (2003)		2016	1.64	1.77	0.18	
Furtado *et al.* (2006)		2016	1.93	3.00	0.24	
		4400	1.94	2.75	0.24	
		4400	1.92	2.61	0.24	
Menegalli *et al.* (2010)		4400	1.95	0.21	0.06	
		2400	1.78	0.15	0.18	
Moraes *et al.* (2008)		2400	1.66	1.77	0.18	
		2400	1.66	1.77	0.18	
		840	1.67	1.77	0.18	
		840	1.69	1.77	0.06	
		840	1.63	1.25	0.18	
Vigodeis *et al.* (2010)		9500	1.59	1.50	0.06	
		9500	1.68	2.24	0.24	
Souza *et al.* (2010)		24000	1.69	2.31	0.24	
		17000	1.52	1.69	0.24	
Barbosa *et al.* (2012)	Cobb	960	2.11	1.77	0.24	
		960	1.92	1.77	0.24	
Stringhini *et al.* (2003)		2016	1.68	2.73	0.18	
Bueno & Rossi (2006)		2016	1.92	2.58	0.18	
		2016	1.92	2.73	0.24	
		2016	1.85	2.23	0.18	
		2016	1.95	2.71	0.24	
		17940	2.05	4.67	0.18	
		24840	1.93	2.44	0.24	
		17940	1.68	2.46	0.18	
		24840	1.76	2.39	0.24	
		17940	1.91	2.88	0.18	
		24840	1.76	2.18	0.24	
Abreu *et al.* (2007)	Ross	800	1.70	2.73	0.18	
		800	1.71	2.73	0.18	
Oliveira *et al.* (2000)		1664	2.02	3.00	0.24	
		1664	1.96	4.66	0.18	
		1664	2.03	5.14	0.18	
		1664	1.99	7.52	0.18	
		1664	1.95	3.00	0.18	
Sartor (2001)	Hubbard	13000	1.93	3.99	0.18	
		13000	2.00	4.69	0.24	
		13000	2.12	7.69	0.24	

appropriateenvironment (temperature and relative humidity close to the thermal neutral zone). According to Salgado *et al.* (2007), the excess of cold (in the early stage of the grow-out period) and mainly the excess of heat (after the 5th week of growth) in the broiler rearing environment decrease productivity. Such a scenario also affects their growth and health. which can lead to an extreme situation, such as the increase in flock mortality.

Several authors found out that the bird development is affected by the internal and external conditions in which they are reared (Garcia Neto & Campos, 2004; Amaral *et al.*, 2011; Carvalho, 2012; Baracho *et al.*, 2013). In the present analysis, the effect of ventilation

(TER = tunnel plus evaporative cooling, PP = positive pressure plus fogging, VN = natural ventilation) on broiler production were compared. Considering the Cobb strain, there was a positive effect of the ventilation on the flock mortality (Table 8). Flock mortality had a negative effect size on Ross genetic strain, while no effect of ventilation was found in the Hubbard strain (Table 8). No impact of ventilation on the feed conversion was observed amongst the genetic strains. Although authors recommend roof insulation (Oliveira *et al.*, 2000; Abreu *et al.*, 2007) to decrease the solar heat transfer to the house, the meta-analysis could not detect the size of the effect.

The best feed conversion was the Cobb strain, followed by Ross and Hubbard strains. Stringuini *et al.* (2003) reported that the Ross strain presented better feed conversion (1.67) than Holsheimer & Veerkamp (1992), and Souza *et al.* (1994) who found better feed conversion of Ross broilers when compared with Cobb broilers. Other authors reported that feed conversion was significantly affected by the strain,and the best results were obtained in birds of the Ross strain, when compared to the Cobb and Hubbard lineage (Garcia Neto & Campos, 2004). Such a parameter is critical when evaluating the performance of breeding chicken lots (Mendes *et al.*, 2004) and may impact the cost of production (Lupatini, 2015).

The highest feed conversion was found for the Hubbard strain. The causes of high feed conversion are multifactorial, such as feed quality, including quality of ingredients; failures in the production process; health of birds including vaccination program, sanitary challenge, and lastly, the management which involves issues with equipment, installations, ambient, and workers (Aviagem, 2011). It is necessary to intensify the management techniques at the environment so that the feed conversion does not increase beyond what is expected for the genetic strain (Lupatini, 2015). Small changes in the conversion rate whatever the price of the ration will have a substantial impact on financial margins (Mendes *et al.*, 2004; Aviagem, 2011).

The literature on alternative mitigation strategies of broiler heat stress exposure is scarce during production, although there are studies in alleviating the effect of heat stress during transportation (Drain *et al.*, 2007; Warriss *et al.*, 2005). Most scientific articles refer to intervention strategies to deal with heat stress conditions with the focus on different approaches, including environmental management, housing design, ventilation, sprinkling, and shading, amongst others (Yahav & Hurwitz, 1996; Yahav *et al*, 2004; Mengali *et al.*, 2010; Abreu & Abreu, 2011). Furtado *et al.* (2006) observed that the performance was maintained within the threshold values when ventilation and fogging systems were on during hot weather. The decrease in mortality rate and increase in performance parameters were found in houses when the ventilation rate was high and continuous, and associated with adiabatic cooling, mainly during the last weeks of grow-out (Damasceno *et al.*, 2010; Menegali *et al.*, 2010; Abreu & Abreu, 2011; Barbosa *et al.*, 2012).

The Hubbard strain presented the highest mortality values. According to Figueiredo (2003), mortality above 3% must be out of acceptable standards. To reduce mortality on the farm requires the use of proper technologies, management, health control, nutrition, and genetics to improve efficiency and reduce waste (Lupatini, 2015).

CONCLUSION

After analyzing the published data using the meta-analysis tools, we could conclude that the factors that most influenced the performance of broiler chicken were temperature, ventilation,and genetic strain. The factors affect each studied broiler genetic strain differently, causing distinct impact in intensive production. Considering the different ways the published studies were designed it is challenging to make specific propositions for a suitable rearing environmental design. One important issue when suggesting recommendations is to assess to what extent the factors might be used by engineers to design a more favorable rearing environment for broiler production.

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REFERENCES

Abreu PG, Abreu VMN, Coldebella A, Jaenisch FRF, Paiva DP. Condições térmicas ambientais e desempenho de aves criadas em aviários com e sem o uso de forro. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 2007;59:1014-1020.

Abreu VMN, Abreu PG. Os desafios da ambiência sobre os sistemas de aves no Brasil. Revista Brasileira de Zootecnia 2011;40:1-14.

Andretta I, Kipper M, Lehnen CR, Hauschild L, Vale MM, Lovatto PA. Meta-analytical study of productive and nutritional interactions of mycotoxins in broilers. Poultry Science 2011;90:1934-1940.

Amaral AG, Yanagi Junior T, Lima RR, Teixeira VH, SchiassiL. Efeito do ambiente de produção sobrefrangos de cortesexadoscriados em galpão comercial. Arquivo Brasileiro Medicina de Veterinaria Zootecnia 2011;63:649-658.

Aviagen. Aviagen brief: otimizando a taxa de conversão alimentar do frango de corte [cited 2017 Dec 14]. Aviagen; 2011. Available from: http://en.aviagen.com/assets/Tech_Center/BB_Foreign_Language_Docs/Portuguese/Otim izando-a-Taxa-de-Converso-Alimentar-do-Frango-de-Corte.pdf.

Baracho MS, Cassiano JA, Naas IA, Tonon GS, Garcia RG, Royer AFB, *et al.* Ambiente interno em galpões de frango de corte com cama nova e reutilizada Revista Agrarian 2013;6:473-478.

Barbosa OR, de Lima M, Klosowski ES, Carneiro de Paula Leite M, Dalazen Castagnara D, Capossi C. Eficiência de sistemasevaporativos e dos níveis de energiana ração no desempenho de frangos de corte em crescimento. Semina: CiênciasAgrárias 2012;33:1589-1598.

Bawor M, Dennis BB, Bhalerao A, Plater C, Worster A, Varenbut M, *et al.* Sex differences in outcomes of methadone maintenance treatment for opioid use disorder: a systematic review and meta-analysis. CMAJ Open 2015;3:E344-E351

Bueno LG, Rossi LA. Comparação entre tecnologias de climatização para criação de frangos quanto a energia, ambiência e produtividade. Revista Brasileira de Engenharia Agrícola e Ambiental 2006;10:497-504.

Carvalho FB, Sartori JR, Stringhini JH, Fascina VB, Pereira LA, Pelícia VC. Efeito da temperatura ambiente e da idade do frango sobre o valor energético do farelo de soja. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 2011;63:1437-1445.

Carvalho RH. Influência de diferentes modelos de instalações de frango de corte e ambiência de luz pré-abate sobre o bem-estar animal e qualidade de carne [dissertação]. Londrina (PR): Universidade Tecnológica Federal do Paraná; 2012.

Cernicchiaro N, Corbin M, Quinn M, Prouty F, Branine M, Renter DG. Meta-analysis of the effects of laidlomycin propionate, fed alone or in combination with chlortetracycline, compared with monensin sodium, fed alone or in combination with tylosin, on growth performance, health, and carcass outcomes in finishing steers in North America. Journal of Animal Science - Animal Production 2016;94:1662-1676.

Cobb. Cobb 500 manual. Suplemento de crescimento e nutrição para frangos de corte [cited 2018 Dec 12]. Available from: http://www.cobb-vantress.com/.../7df1f9a1-c867-4290-bd36-3aeb0ba48d25_pt.html.

Damasceno FA, Yanagi Júnior T, Lima RR, Gomes RCC, Moraes SRP. Avaliação dobem-estar de frangos de corte em dois galpões comerciaisclimatizados. Ciência e Agrotecnologia 2010;34:1031-1038.

Dawkins MS, Christla D, Tracey J. Chicken welfare is influenced more by housing conditions than by stocking density. Nature 2004;427:342-344.

Deaton JW, Reece FN, McNaughton N. The effect of temperature during the growing period on broiler performance. Poultry Science 1997;57:1070-1074.

Drain ME, Whiting, TL, Rasali DP, D'Angiolo VA. Warm weather transport of broiler chickens in Manitoba. I. Farm management factors associated with death loss in transit to slaughter. Canadian Veterinary Journal 2007;48:76–80.

FAO. World Agriculture: Towards 2015/2030 - An FAO perspective [cited 2018 Nov 28]. Rome; 2008. Available from: http://www.fao.org/docrep/005/y4252e/y4252e05b.htm.

Figueiredo EAP. Sistema de produção de frango de corte: material genético [technical bulletin, 2003] [cited 2018 Jul 29]. Concórdia; 2003. Disponível em: http://sistemasdeproducao.cnptia.embrapa.br/FontesHTML/Ave/ProducaodeFrangodeCor te/Material-g.html.

Furtado DA, Dantas RT, Nascimento JWB, Santos JT, Costa FGP. Efeitos de diferentes sistemas de acondicionamento ambiente sobre o desempenho produtivo de frangos de corte. Revista Brasileira de Engenharia Agrícola e Ambiental 2006;10:484-489.

Ross. Ross 308 manual. Objetivos de desempenho [2018 Jul 12]. 2012. Available from: http://www.en.aviagen.com/assets/Tech.../Ross308FrangosObjetivosDesempenho12PT.pdf

Garcia Neto M, Campos EJ. Suscetibilidade de linhagens de frangos de corte à síndrome ascítica. Pesquisa Agropecuária Brasileira 2004;39:803-808.

Holsheimer JP, Veerkamp CM. Effect of dietary energy, protein level and lysine content of on performance and yield of two strains of male broiler chicks. Poultry Science 1992;66:872-879.

Hubbard. Hubbard manual [cited 2018 Dec 14]. 2006. Available from: http://www.hubbardbreeders.com/media/hubbard_broiler_management_guide__078897700_0945_07012015.pdf.

Lipsey MW, Wilson DB. Practical meta-analysis. Thousand Oaks: Sage Publications; 2001.

Lowry. R. Vassar stats: website for statistical computation [cited 2018 Sep 14]. 2017. Available from: http://www.vassarstats.net.

Lupatini F. Avaliação doefeito de variáveis produtivas na conversão alimentar de frangos de corte [thesis]. Goiânia (GO): Universidade Federal de Goiás; 2015.

Marchini CFP, Café MB, Araújo EG, Nascimento MRBM. Physiology, cell dynamics of small intestinal mucosa, and performance of broiler chickens under heat stress: a review. Revista Colombiana de Ciencias Pecuarias 2016;29:159-168.

Mendes AA, Nääs IA, Macari M. Produção de frangos de corte. Campinas: FACTA; 2004. 356 p.

Menegali I, Baêta FC, Tinôco IFF, Cordeiro MB, Guimarães MCC. Desempenho produtivo de frangos de corte em diferentes sistemas de instalações semiclimatizadas no sul do Brasil. Engenharia na Agricultura2010;18:461-471.

Nascimento GR, Nääs IA, Baracho MS, Pereira DF, Neves DF. Termografia infravermelho na estimativa de conforto térmico de frangos de corte. Revista Brasileira de Engenharia Agrícola e Ambiental 2014;18:658-663.

Oliveira JE, Sakomura NK, Figueiredo AN, Lucas Júnior J, Santos TMB. Efeito do isolamento térmico de telhado sobre o desempenho de frangos de corte alojados em diferentes densidades. Revista Brasileira de Zootecnia 2000;2:1427-1434.

Pauly C, Luginbühl W, Ampuero S, Bee G. Expected effects on carcass and pork quality when surgical castration is omitted- Results of a meta-analysis study. Meat Science 2012;92:858–862.

Salgado DD, Nääs IA, Pereira DF, Moura DJ. Modelos estatísticos indicadores de comportamentos associados a bem-estar térmico para matrizes pesadas Engenharia Agrícola 2007;27:619-629.

Sartor V, Baêta F da C, Luz ML, Orlando RC. Sistemas de resfriamento evaporativo e o desempenho de frangos de corte. Scientia Agricola 2001;58:17-20.

Souza PA, Souza HBA, Campos FP, Brognoni F. Desempenho e características de carcaça de diferentes linhagens comerciais de frango de corte. Revista Brasileira de Zootecnia 1994;23:782-790.

Souza VLF, Buranelo GS, Gasparino E, Cardozo RM, Barbosa MJB. Efeito da automatização nas diferentes estações do ano sobre os parâmetros de desempenho, rendimento e qualidade da carne de frangos de corte. Acta Scientiarum- Animal Sciences 2010;32:175-181.

Statista. Global broiler meat production 2012-2019 [cited 2018 Dec 14]. 2017. Available from: https://www.statista.com/statistics/237637/production-of-poultry-meat-worldwide-since-1990/.

Stringhini JH, Laboissiére M, Muramatsu K, Leandro NSM, Café MB. Avaliação do desempenho e rendimento de carcaça de quatrolinhagens de frangos de corte criadas em Goiás. Revista Brasileira de Zootecnia 2003;32:183-190.

Vigoderis RB, Cordeiro MB, Tinôco IFF, Menegali I, Souza Júnior JPS, Holanda MCR. Avaliação do uso de ventilação mínima em galpões avícolas e de sua influência no desempenho de aves de corte no período de inverno. Revista Brasileira de Zootecnia 2010;39:1381- 1386.

Yahav S, Hurwitz S. Induction of thermotolerance in male broiler chickens by temperature conditioning at an early age. Poultry Science 1996;5:402–406.

Yahav S, Straschnow A, Luger D, Shinder D, Tanny J, Cohen S. Ventilation, sensible heat loss, broiler energy, and water balance under harsh environmental conditions. Poultry Science 2004;83:253–258.

Warriss PD, Pagazaurtundua A, Brown SN. Relationship between maximum daily temperature and mortality of broiler chickens during transport and lairage. British Poultry Science 2005;46:647–651.

Wilson DB. Practical meta-analysis effect size calculator [cited 2018 Nov 11]. 2001. Available from: https://www.campbellcollaboration.org/escalc/html/EffectSizeCalculator-Home.php.