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MARTA DOS SANTOS BARACHO

FACTORS THAT INFLUENCES IN THE PRODUCTION OF BROILER CHICKEN: SYSTEMATIC REVIEW AND META-ANALYIS

FATORES DE INFLUÊNCIA NA PRODUÇÃO DE FRANGO DE CORTE: REVISÃO SISTEMÁTICA E META-ANÁLISE

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Thesis presented to the School of Agricultural Engineering of the University of Campinas in partial fulfillment of the requirements for the degree of Doctor in Agricultural Engineering, in Rural Constructions and Ambience.

Tese apresentada à Faculdade de Engenharia Agrícola da Universidade Estadual de Campinas como parte dos requisitos exigidos para obtenção do título de Doutora em Engenharia Agrícola na Área de Construções Rurais e Ambiência.

Orientadora: Profa. Dra. Irenilza de Alencar Nääs

ESTE EXEMPLAR CORRESPONDE À VERSÃO FINAL DA TESE DEFENDIDA PELA ALUNA MARTA DOS SANTOS BARACHO E ORIENTADA PELA PROFa. DRA. IRENILZA DE ALENCAR NÄÄS

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Profa. Dra. Daniella Jorge de Moura – Membro Titular

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A Ata da defesa com as respectivas assinaturas dos membros encontra-se no processo de vida acadêmica do discente.

Aos meus pais Ivanhoé Baracho e Conceição Baracho e ao Danilo O. Prado meu parceiro e companheiro

DEDICO

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Velho Sobrado

Não descubro por que êste sobrado,
Sujo, sombrio, carcomido e triste,
Tem uma força a que não mais resiste
Meu coração vencido e torturado.

Por que atormenta, a mim, o desgraçado?
Em que segredo mágico consiste
Êste poder fatal e que persiste
Martirizando o meu viver fanado?

Por ventura chegou a perceber
Que, igual a ele, fui também vencido,
Perdi na vida o gôsto de viver?

Porém êle, apesar de o ter perdido,
Tu pretendes fazê-lo reviver.
E eu? Jamais serei reconstruído.

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Rodrigues

Um dos sonetos de José Rodrigues, escrito a mão, e que foi guardado pelo sobrinho Ivanhoé Baracho. O poeta nasceu na cidade de Areia-Pb, cidade onde nasceu o pintor Pedro Américo.

RESUMO

O Brasil é hoje o maior exportador mundial de aves. No atual nível de desenvolvimento da avicultura brasileira, principalmente nas criações com alta densidade, faz-se necessário o manejo adequado objetivando o conforto das aves a fim de garantir um produto de melhor qualidade ao consumidor. O objetivo deste trabalho foi identificar os fatores mais influentes na produção de frango de corte, tendo como objetivos específicos qualificar as categorias e/ou grupos de fatores prevalentes, determinar o efeito dos fatores na produtividade, identificar as condições que produzem efeitos benéficos e de risco. As informações e dados foram provenientes de ampla revisão sistemática da literatura de dados disponíveis. A organização do banco de dados de artigos publicados utilizou resultados de estudos prévios, através de busca eletrônicas nas bases de dados, *Scielo*, Scopus e Google Acadêmico, para o período de 2010 a 2015. As buscas foram restringidas através das opções título, resumo e palavras-chaves. Os dados foram analisados estatisticamente através de correlação de Pearson, ANOVA e ANCOVA. Nesta tese, os resultados são apresentados na forma de artigos e discutidos no texto em três capítulos. O uso da revisão sistemática de literatura permitiu identificar as principais variáveis que influenciam o desempenho do frango de corte. Os resultados mostram que os fatores que influenciaram no desempenho de frango de corte foram: temperatura, ventilação e linhagem genética.

Palavras-chaves: condições ideais de alojamento, avicultura, produção intensiva.

ABSTRACT

Brazil is the world's largest exporter of poultry. At the current level of development of the Brazilian poultry industry, especially in farms having high density, it is necessary to the proper management aiming at the bird comfort to ensure a better quality product to the consumer. The objective of this work is to identify the most influential factors in the production of broilers, with the specific objectives qualifying categories and/or groups of factors prevalent, determine the effect of factors on productivity, and identify conditions that produce beneficial effects and risk . The information and data will from extensive systematic literature review of available data and /or unpublished. The organization of the database of published articles utilizes results of previous studies by searching the electronic databases *Scielo,* Scopus, and Google Scholar for the period 2010-2015. The search will be restricted the options title, abstract and keywords. The data will be statistically analyzed using Pearson correlation coefficient, analysis variance (ANOVA) and covariance analysis (ANCOVA). The use of the systematic review of the literature allowed identifying the main variables that positively influence the broiler performance. The prediction of influencing factors in the production of broiler chicken was possible using the data mining technique.

Key-words: ideal conditions of house, broilers, intensive production.

SUMÁRIO

1 INTRODUÇÃO GERAL

A avicultura brasileira ocupa um lugar privilegiado na economia mundial e em 2013 foram produzidas 12,3 milhões de toneladas de carnes das quais 3,9 milhões forma exportadas (ABPA, 2014).

Diante dos mercados globalizados e das exigências crescentes nos aspectos de qualidade e segurança do produto, a indústria avícola brasileira tem se destacado essencialmente pelos altos níveis tecnológicos e por sua competitividade (GODOY, 2007).

Na moderna avicultura tecnificada, as aves são o produto da genética, nutrição e ambiente onde é de fundamental importância conhecer a relação aves/alojamento/bem estar animal. No atual nível de desenvolvimento da avicultura brasileira, principalmente nas criações com alta densidade, faz-se necessário o manejo adequado objetivando o conforto das aves a fim de garantir um produto de melhor qualidade ao consumidor.

Existem muitos fatores durante o manejo que têm o potencial de afetar a qualidade do produto final. O conhecimento destes fatores proporciona a base para estabelecer práticas de manejo e bem estar animal, visando obter uma ótima qualidade e rentabilidade do lote.

Diversos estudos mostram a influência negativa do estresse térmico sobre o desempenho de frangos de corte, sendo que o calor é apontado como maior colaborador para tal queda (LAURENTZ, 2005; OBA et al., 2012)

De acordo com Curtis (1983) e Esmay e Dixon (1986), quando as condições ambientais no interior da instalação não estão dentro de limites adequados, o ambiente térmico torna-se desconfortável, porém, o organismo o animal ajusta-se fisiologicamente para manter sua homeotermia, seja para conservar ou dissipar calor. Para isso, ocorre dispêndio de energia, resultando na redução da sua eficiência produtiva.

No domínio agrícola, em especial na área animal, o número de meta-análises publicado tem aumentado nos últimos anos (LOVATTO e SAUVANT, 2002; MARTIN e SAUVANT, 2002; OFFNER et al., 2003; EUGÊNE et al., 2004; HAUPTLI et al., 2007), sinalizando que esse procedimento possa se tornar rotina nesse campo da ciência.

A meta-análise é um recurso à disposição dos pesquisadores, que lhes permite tratar, quantitativamente e de forma simultânea, conjuntos de dados, alheios ou não, obtidos independentemente (LUIZ, 2002). Esses procedimentos podem melhorar o nível de compreensão dos artigos publicados e orientar a execução de experimentos de campo já que é uma importante ferramenta de investigação científica para a tomada de decisão, promissora, nas áreas de nutrição e produção animal, motivada pelo grande número de estudos similares em determinados assuntos.

O sistema produtivo avícola tem investido cada vez mais em ferramentas que possam otimizar a produtividade de frangos de corte. Frente às atuais demandas existentes, há uma busca incansável por conhecimento dos parâmetros que afetam essa atividade para que se obtenha a máxima produtividade de carne com o menor custo (POCIANO et al., 2011).

1.1 JUSTIFICATIVA

A hipótese deste trabalho é que, o conhecimento dos fatores e das relações com as variáveis de produção intensiva, permitirá estabelecer condições de melhoria à produção de frango de corte.

2 OBJETIVOS

2.1 Geral

Identificar as condições que produzem maior relevância quanto aos efeitos benéficos e prejudiciais na produção de frango de corte.

2.2 Específicos

- Qualificar as categorias e/ou grupos de fatores prevalentes
- Determinar o efeito dos fatores na produtividade

3 METODOLOGIA

A pesquisa bibliográfica foi realizada no Laboratório de Conforto Térmico da FEAGRI- UNICAMP na cidade de Campinas, estado de São Paulo.

3.1 Formação e organização do banco de dados

Informações e dados foram provenientes de ampla revisão sistemática da literatura de dados disponíveis no período de 2000 a 2015.

Foram selecionadas publicações indexadas com resultados de experimentos em frangos de corte. A estratégia de pesquisa dos trabalhos foi a consulta de diferentes bancos de dados digitais como, *Scielo, Scopus* e Google Acadêmico.

As buscas foram restringidas através das opções título, resumo e palavras-chaves e os dados contidos nos artigos foram utilizados para montagem de uma base de dados utilizando planilha eletrônica.

Foram identificadas e avaliadas as metodologias que descrevem características experimentais e dos animais. Os principais critérios para a seleção das publicações foram: frangos de corte de linhagens comerciais, produção intensiva, período experimental, condições de alojamento, idade, ambiência térmica, ambiência aérea, ambiência acústica, luminosidade, manejo, estresse térmico.

Durante a fase de seleção e de análise dos resultados, todos os estudos foram avaliados em sua qualidade metodológica.

Após a seleção dos trabalhos e posterior análise exploratória, foram tabuladas as informações para permitir a análise descritiva dos estudos inseridos na base. Estas informações foram selecionadas nas seções do material e métodos e dos resultados dos artigos e tabuladas em uma base elaborada em planilha de dados.

3.2 Análise dos dados

Foram utilizadas as seguintes análises sequenciais para análise dos dados:

3.2.1 Análise gráfica

Foi realizada a análise gráfica de dados para monitorar a qualidade da base e observar a coerência dos dados que representa uma fase essencial de uma meta-análise, permitindo uma visualização das representações gráficas, identificando rapidamente as informações e relações importantes.

3.2.2 Correlação

Entre as diversas variáveis, para identificar os fatores relacionados.

3.2.3 Análise estatística

Os dados do Capitulo III foram testados por analise de variância (ANOVA), por análise de covariância (ANCOVA), coeficiente de correlação de Pearson e análise de divergência.

4 RESULTADOS E DISCUSSÕES

Nesta tese, os resultados são apresentados na forma de artigos e discutidos no texto.

O Capítulo I, intitulado FATORES QUE IMPACTAM NA PRODUÇÃO INTENSIVA DE FRANGO DE CORTE-UMA REVISÃO foi escrito nas normas da Revista Brasileira de Engenharia de Biossistemas e discute os fatores que impactam na produção intensiva de frango de corte.

O Capítulo II, intitulado FATORES DE INFLUÊNCIA NA PRODUÇÃO, ÂMBIENCIA E BEM ESTAR DE FRANGO DE CORTE: REVISÃO SISTEMÁTICA foi escrito nas normas da Revista Brasileira de Ciência Avícola e descreve os principais fatores que influenciam a produção de frango de corte.

O Capítulo III, intitulado FATORES DE INFLUÊNCIA NA PRODUÇÃO DE FRANGO DE CORTE: APLICAÇÃO DE META-ANÁLISE foi escrito nas normas do Periódico Tropical Animal Health and Production e discute os tipos de aviário, manejo e instalações nas variáveis que incidem na performance dos frangos de corte.

CAPÍTULO I

FACTORS THAT AFFECT BROILER PRODUCTION

Artigo de revisão escrito nas normas da Revista Brasileira de Engenharia de Biossistemas

ABSTRACT

Brazil occupies a privileged position worldwide in poultry farming. The economic activity is recognized as necessary for the country's GDP and also has a significant climatic diversity. Because of this, different types of aviaries were and still are built in the national territory. The objective of this study was to present a systematic review of the factors that have an impact on the intensive production of broiler chicken based on the scientific publications since the year 2000. The literature review showed a constant evolution and the knowledge about the form of housing that best expresses the genetics of birds. It was found that the thermal environment, air quality and other factors related to the housing of broiler chickens significantly imply in their performance.

Keywords: thermal comfort, ambient cooling, flock density, broiler genetic strains.

FATORES QUE AFETAM A PRODUÇÃO DE FRANGOS DE CORTE

O Brasil ocupa uma posição privilegiada em todo o mundo na produção de frangos de corte. A atividade econômica é reconhecida como necessária para o PIB do país, que também possui uma expressiva diversidade climática. Por isso, diferentes tipos de aviários foram e ainda são construídos no território nacional. O objetivo deste estudo foi apresentar uma revisão sistemática dos fatores que têm impacto na produção intensiva de frangos de corte com base nas publicações científicas desde o ano 2000. A revisão da literatura mostrou evolução constante e conhecimento sobre a forma de alojamento que melhor expressa a genética dos frangos. Verificou-se que o ambiente térmico, a qualidade do ar e outros fatores relacionados ao alojamento de frangos de corte impactam expressivamente no desempenho.

Palavras chaves: conforto térmico, refriamento de ambiente, linhagens genéticas de frangos.

INTRODUCTION

The Brazilian production of broilers has grown in remarkable numbers in the last 50 years, and this was only possible because there was an increase in domestic meat consumption and exports (MENDES, 2014). Brazil occupies a privileged position of the 2 nd largest producer in the world´s poultry production, an essential activity for the country's economy. Brazil is standing out as the leader in exports (581,558 tons in 2013) and the third largest producer of chicken meat (12,645,1 thousand tons in 2012) (UBA, 2013; UBABEF, 2014). Today, large numbers of female breeders are housed in the country's farms, founding a dynamic, highly competitive segment in which the product of the best yield influences the systemic chain that includes everything from inputs to production on the farms, and processing in the industry. The high technological level achieved by the national poultry industry placed this economic activity in an advantaged position about other livestock activities developed in Brazil, with na international productivity level, compared to the most updated countries in the world (LIMA et al., 1995). Broiler production is a business that requires reasonable investment whose return is proportional to the producer's ability to maximize sources of loss (RIZZI, 1993). The food and management, and health are also important issues during the production. As the animal production systems are modified, efforts were made to develop techniques and tools to assist in animal production monitoring (ABREU, 2010; ABREU & ABREU, 2011). The intensification of automation and state-of-the-art technologies brought the increase in the variability of the thermal environment of the houses, with consequent variability in the performance indexes (CARVALHO, 2012). All these innovations introduced in studies of broiler production have allowed researchers to deepen knowledge of the factors that interfere in the rearing environment, leading to higher precision in the corrections and adjustments of these systems (ABREU & ABREU, 2011).

SYSTEMS FOR BROILER PRODUCTION

Brazil has significant climatic diversity and, therefore, different types of aviaries were and still are built in the national territory (NÄÄS et al., 2014). The facilities must ensure an environment of thermal comfort that allows the animal to express its full genetic potential (NASCIMENTO et al., 2014). Animal facilities are the result of all the external and internal conditions that affect the development, responses, and growth of the animals housed in them. As per ESTRADA-PAREJA et al. (2007), the factors affecting the animal environment can be physical (light, noise, construction, and equipment), social (density), and technical factors (Temperature, relative humidity, air movement, thermal radiation, among others). In poultry farming, it is known that substantial losses in production occur mainly in the final stages of rearing. Those failures are due to thermal stress that reduces performance indexes and increases bird mortality (ABU-DIEYEH, 2006). MORROW (2001) raised the ambient temperature and found that this action leads to a decrease in the bird's ability to dissipate heat resulting in a circular and respiratory imbalance. Thus, the ideal bird productivity depends on the effective temperature, which reflects the combination of the effects of dry bulb temperature, relative humidity, solar radiation and wind speed (MOURA, 2001). One of the ways to predict if the environment causes stress due to heat is through the ITU - temperature and humidity index, and the same was adapted for chickens by CHEPETE et al. (2005) and through the ITGU - black globe temperature index and humidity. Light intensity, distribution, color and duration of light affect the performance and well-being of the batch. Light management is an advantageous and low-cost technique in the production of broiler chicken and is a tool to be used within a management program (RUTZ et al., 2014). Modern aviaries are carefully lit to reduce cannibalism, bird movement, and energy costs (ARAÚJO et al., 2013). Furthermore, proper positioning of light sources and their distribution in the shed encourages birds to seek food, water, and heat during the rearing phase. For Santana et al. (2014) the use of LEDs has been highlighted in aviculture because it presents energy savings and provides viability of the breeding process. Studies on the welfare of broilers (MOURA et al., 2006; BESSEI, 2006) indicate that the themes related to the thermal and aerial environment, as well as the quantity and intensity of light of the sheds, are more influential in the response of birds. Among the most important strategies to prevent loss of productivity due to caloric stress is the control of luminosity in aviaries (LINET et al., 2006; BLATCHFORD et al., 2009). Alvino et al. (2009) suggest exposing the birds to higher luminous intensities to increase their wellbeing, as light increases the behavioral rhythms and the comfort behaviors of birds.

ENVIRONMENT IMPACT IN POULTRY PRODUCTION

The production environment plays a fundamental role in modern poultry farming, which seeks to achieve high productivity, in physical space and relatively short time (AMARAL et al., 2011). Chicken is a homeothermic animal, that is, it maintains the body temperature constant. To keep homeothermic, the rate of heat transfer to the environment should be equal to the rate of heat production (BRUCE & CLARK, 1979). Birds, as well as pigs, do not sweat in response to a temperature rise (INGRAM, 1974; HARRISON, 1995), and both growing pigs and chicks have relatively little plumage and thus little thermal insulation. Therefore, birds tend to respond more to changes in the thermal environment than other species of domestic animals, which can be offset by behavioral responses such as grouping of chicks. For Damasceno et al. (2010) and Amaral et al. (2011) thermal factors, mainly represented by air temperature relative humidity, thermal radiation, and air velocity, are those that affect birds more directly, as they can compromise their homeothermic. The facilities must ensure the maintenance of homeothermic, to maintain animal thermal comfort and ensure the well-being in the production (NASCIMENTO, 2011). Birds are also endothermic animals, which means that they can increase the amount of body temperature by generating considerable amounts of heat inside their tissues rather than relying solely on heat gained directly from their surroundings (Bligh & Johnson, 1973). According to these authors, thermoregulation characteristics are similar in birds and other large groups of homeothermic animals and mammals. The mechanisms of thermal regulation seek to maintain the temperature inside the stable body (BRUCE & 4, 1979). To achieve this, however, the temperature of the peripheral tissue can vary considerably, causing fluctuations in the average temperature of the body. The thermoneutral zone is related to an ideal thermal environment, where birds find perfect conditions to express their best productive characteristics (FURTADO et al., 2003). The zone of thermal comfort or thermoneutral varies according to the species and within the same species. In the birds, the thermoneutral zone changes with its genetic constitution, age, sex, body size, weight, diet, physiological state, previous exposure to heat, a variation of ambient temperature, radiation, humidity and air velocity (CASSUCE, 2011). Inadequate rearing conditions affect the production of broiler chickens, and it is necessary to improve the houses and balance the management to overcome the harmful effects arising from some critical environmental factors (FURTADO et al., 2003). The constructive typology of the houses, associated with the local macroclimate, the topography, and the surrounding vegetation, influences the internal microclimate conditions. Associate to these factors, internal temperatures, ventilation and flow, speed and relative humidity of the air, can alter the emission of greenhouse gases, becoming an additional concern with the broader environmental aspect (MIRAGLIOTTA, 2005). In environments considered comfortable, the birds present higher productivity and better performance parameters (MEDEIROS et al., 2005). Therefore, excess heat in the housing environment can be detrimental to bird performance. Wherefore, there is a high influence of the typology on the environmental conditions inside the houses, and the technical norms must be observed to obtain good thermal conditioning (FURTADO et al., 2003). According to Yahav et al. (2004), the more precise quantification of the surface temperature of the birds the more accurate is the estimation of the heat exchanges of broilers. The proportion of the animal body that is at the same temperature as the interior of the body may vary, depending on environmental conditions. As a consequence, of the vasoconstriction, the temperature of the extremities, and skin of the animal are more influenced by the external heat in a cold environment. If the ambient temperature is high, vasodilation increases peripheral blood flow, making the body's distribution of temperature more uniform (INGRAM & MOUNT, 1975). The thermal comfort of an animal cannot be determined solely by heat unless all other conditions are standardized (INGRAM & MOUNT, 1975). Many factors influence the air temperature range perceived by animals as comfortable. The thermal environment is composed of the various environmental factors that affect the heat transfer between the animal and its surroundings. It is not fixed, in the sense that the perception of the environment varies from animal to animal. An increase in air movement will increase heat losses by conduction and make the animal feel cold; while the presence of a radiant heater will result in a net gain of heat by radiation and make the bird feel warm. Thermal insulation of the floor also affects the rate of heat loss by conduction. Thus, at a given temperature, the same animal may be hot, if it is exposed to solar radiation, or cold if it is wet, in the wind and the shade. Also, the number of animals in pen or the house affects the contact area when the animals are grouped, making them more resistant to cold in a larger group. The level of food intake influences the production of metabolic heat so that the same animal can respond differently to the same environment, depending on the feeding program used (INGRAM & MOUNT, 1975). To accurately assess the effect of the environment on broilers, one must consider all environmental factors as well as the animal's characteristics and peculiarities of the production system. The thermal environment can be characterized by air temperature, radiant temperature, air velocity, air humidity. For broilers, temperature values between 32 and 34 °C are considered comfortable for the first week (CONY & ZOCHE, 2004; OLIVEIRA et al., 2006; PAULI et al., 2008). According to Bridi (2011) at least three primary conditions must be observed for optimal thermal comfort from a physiological point of view: 1. Consider that there is a caloric balance between the animals and the environment; Establishment of an essential relationship between the average temperature of the skin and the activity of the animal in the comfort zone; and, 3. Establishment of water loss through evaporation and the activity of the animal in the comfort zone. The evolution of the studies on the rearing environment in broilers has reached remarkable levels concerning information on air quality, the thermal, acoustic and luminous environment in the different stages of broiler breeding (SILVA & VIEIRA, 2010). These factors directly influence the comfort and welfare condition of the birds, affecting their productivity (PONCIANO et al., 2011). According to Moura et al. (2006) and Santos et al. (2009), thermal comfort inside poultry farms is a highly significant factor, since poor conditions considerably affect the production of broiler chickens. Estimating comfort conditions is a desirable feature in models that determine the thermal wellbeing of broiler chickens. Situations classified as hazardous actions may result in the expenditure of economic resources avoiding productive losses (NASCIMENTO et al., 2011). Welfare issues in poultry production are related to the thermal and aerial environment, as well as the quantity and intensity of light of the houses. These subjects are addressed, for instance, in the studies in roof insulation, being, however, more influential in the response of the birds when extremes of temperatures occur inside the rearing environment (LIMA et al., 2003)

FINAL REMARKS

The evolution of the scientific publications on broiler housing has generated crucial scientific information about air quality, the thermal, acoustic and luminous environment in the different stages of breeding. Also, knowledge about the behavior and performance of the lineages in various forms of rearing systems has also been generated by the international and Brazilian research groups, helping the development of the sector.

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CAPÍTULO II

FATORES DE INFLUÊNCIA NA PRODUÇÃO, AMBIÊNCIA E BEM-ESTAR DE FRANGO DECORTE: REVISÃO SISTEMÁTICA

FACTORS THAT INFLUENCES IN THE PRODUCTION, ENVIRONMENT, AND WELFARE OF BROILER CHICKEN: A SYSTEMATIC REVIEW

Este Capítulo foi escrito nas normas da Revista Brasileira de Ciência Avícola

Factors that Influence the Production, Environment, and Welfare of Broiler Chicken: A Systematic Review

ABSTRACT: The objective of the present study was to characterize the scientific production regarding the factors that influence broiler chicken production, and that were published from 2000 to 2015 in journals indexed in the database of Google Scholar, Scielo, and ScienceDirect. The research was done in the Thermal Comfort Laboratory at FEAGRI-UNICAMP, and the concept of the systematic review was applied. The research criterion was initially defined (the keywords) aiming to identify and evaluate the variables that describe the experimental characteristics and the animals. The primary keywords identified were: broiler chicken from commercial strains, broiler production, rearing conditions, thermal environment, air quality, acoustic environment, light intensity, management, and heat stress. Those were the key words searched the database of the online libraries. The selected articles were registered into an electronic spreadsheet with the title, the name of the authors, year of publication, language, the journal where it was published, the keyword, the period when the research was done, source/ database, and the abstract. A total of 167 articles were selected, and only 34 were added to the review. The use of the systematic review of the literature allowed identifying the main variables that positively influence the broiler performance, such as the temperature near the thermal comfort, the use of roof lining, besides the use of adiabatic cooling and cast bricks in the laterals. The presence of positive ventilation, as well as the use of yellow curtains and constant lighting, has also influenced a better performance to broilers.

Keywords: broiler production, intensive rearing, poultry housing.

INTRODUCTION

Brazilian poultry industry is highly relevant to the country economy. In 2016 a total of 13 million tons of broiler meat was produced, and nearly 35% was exported. (ABPA, 2017). Broiler production is carried out in several variations of house design. However, most of the production in the integrated system is done in open-sided houses with lateral polypropylene curtains, and with solar orientation East-West. The inside cooling is a combination of natural and forced ventilation (axial fans) associated with the fogging system. Modern houses adopt the closed sides using a more resistant curtain, and the inside ventilation may be done with positive pressure by using axial fans or exhausting fans associated with adiabatic cooling.

The systematic review (SR) of literature is the scientific technique that aims to review and evaluate the published literature using methods to identify and select the studies that are relevant. This method has been used by authors in various circumstances. Kerr et al. (2013) used the systematic review to identify the effectiveness of competitive exclusion and its effect on the prevalence of salmonella in broiler breeding. Rodrigues Filho & Gonçalves (2015) applied the systematic review to identify the contribution of legal metrology to control processes, in addition to identifying the research needs of the sector. Offedo et al. (2016) reviewed the impact of interventions in the poultry market, aiming to reduce the contamination of humans by Avian Influenza, based on published scientific evidence. Średnicka-Tober et al. (2016) used the systematic review and meta-analysis from sixty-seven published papers to compare the nutrient content in organically produced beef compared to meat produced traditionally. Clarck et al. (2016) conducted a systematic review of scientific studies focusing on the reaction of consumers when informed about diseases in animal production in intensive systems. Clune et al. (2017) presented the results of a systematic review of the literature on greenhouse gas emissions for different food types, which offered the life cycle computation, aiming at recommending a sustainable food type.

The present study aimed to characterize the scientific publications on the topics of the factor that influences broiler production published between 2000 and 2015 in journals indexed in the databases of Google Scholar, Scielo, and Science Direct.

MATERIALS AND METHODS

The literature review was carried out at the Thermal Comfort Laboratory of FEAGRI-UNICAMP, using the concept and method of the systematic review. Figure 1 shows the flow of information from the systematic review used.

The research criteria and the keywords were initially defined with the purpose of identifying and evaluating the variables that describe the experimental and animal characteristics. The main keywords identified were: commercial broilers, production, lodging conditions, thermal environment, air environment, acoustic environment, luminosity, handling, thermal stress) in databases (Google Scholar, ScienceDirect, and SciELO).

Insert Figure 1

Table 1 shows the keywords used to search in the literature databases. The articles selected using the criteria were organized by the association of a database using a spreadsheet. The list contained the title, author, year of publication, language, and journal in which the title was published (inserted in the database), a period in which the research was carried out, the source/database, and the summary of the article (Andretta, 2011; Offeddu et al., 2016).

Insert Table 1

The research criteria and the keywords were initially defined with the purpose of identifying and evaluating the variables that describe the experimental and broiler characteristics. The main ones were the commercial broilers, production, housing conditions, thermal environment, air quality and conditions, acoustic environment, luminosity, handling, and thermal stress) in the studied databases (Google Scholar, ScienceDirect, and SciELO).

The second step was to check the titles and summaries of the articles to identify the articles that were related to influence factors in the production of broiler chicken, as suggested by Średnicka-Tober et al. (2016). The third step was to analyze each article to decide inclusion and exclusion criteria (Table 2).

Insert Table 2

RESULTS

A total of 167 scientific articles were identified (Figure 2) using a critical analysis as recommended by Riera et al. (2006). From the total scientific papers selected, 22 articles were found in the Google Scholar database, 92 on ScienceDirect, 53 on SciELO. A total of 99 articles were in English and 68 in Portuguese. The year that presented the highest number of publications was during 2010 (24 articles), followed by 2014 (21 articles), as shown in Figure 3.

Insert Figure 2

Insert Figure 3

The year 2014 was the one that presented the most significant number of articles published in English, and Portuguese was in the year of 2010 (Figure 3). The higher number of papers published may not reflect qualitative advances. Therefore, systematic reviews have become essential tools for tracking evidence that accumulates in a particular field of interest (Andreta, 2011).

Amongst the most various journals that publish articles on broiler production, the following may be highlighted: Applied Behavior (15%), Engenharia Agrícola/Agricultural Engineering (12%) and Revista Brasileira de Zootecnia/Brazilian Journal of Animal Science (12%). From the 167 articles selected, after applying the critical review (Figure 1) only 34 were considered in the review (Table 3).

Insert Table 3

DISCUSSION

The discussion is presented relating the effects identified in the systematic review. No paper was found describing noxious gasses production and the aspects of broiler performance. Therefore, no comments can be drawn from the review regarding the effect of air quality.

Effect of the thermal rearing environment in broiler production

Oliveira Neto et al. (2000) reported that the ambient temperature influenced the weight gain, which was 16% lower in birds kept under heat stress (32.3 ± 0.31 ^{o}C) than those maintained in thermal comfort (23.3 ± 0.58 ^{o}C). Similar to the weight gain, it was verified that the high temperature (32 ^{o}C) determined a 19% increase in the feed conversion rate of the birds.

For Sartori et al. (2001) the weight and the weight gain of the birds reared in the warm environment were lower than those of the birds kept in the thermoneutral and cold environment. These results probably occurred due to the lower feed intake of the birds in the heated chamber when compared to the birds raised in the thermoneutral and cold climatic chambers. Among the birds housed in the thermoneutral and cold environmental chambers, feed intake was lower for birds housed in the thermoneutral room, indicating that the cold temperature caused an increase in the voluntary consumption of food. The ambient temperature affected the broiler performance.

Oliveira et al. (2006) indicate that, in all the analyzed periods, birds kept in the thermal comfort environment presented the highest values of feed intake and weight gain and the worst feed conversion. According to the authors (Oliveira et al., 2006), the best results of weight gain and absolute weights of the breast, thigh, and carcass of male broilers of the Avian Farms strain were obtained in the birds reared at inside temperature from 24 to 26, 3 °C. Ambient temperatures below 24ºC and above 26.3ºC negatively influenced the weight gain and the absolute weights of chest, thigh, and carcass.

Heaters provide a reliable, low-maintenance source of heat for young birds. Cordeiro et al. (2010) showed that the heating system conjugating several radiant heaters is more efficient because it maintains the house in better thermal conditions on condition that offers welfare for the birds in the first and second weeks of grow-out, which provides improved productive performance. The system with minimal ventilation significantly reduces the temperature inside the house, compromising thermal comfort and damaging animal performance, evaluated through feed conversion, slaughter weight and productive efficiency (Vigoderis et al., 2010).

Broilers reared close to the ventilation system presented better performance in a hot environment (Bilal et al., 2014).

Effect of the housing, flock density, and the use of adiabatic cooling

Houses with evaporative cooling systems associated with ventilation provided higher values of broiler weight gain and lower values of feed conversion and mortality (Sartor et al., 2001).

Bueno & Rossi (2006) observed in both housing systems (conventional and high density) that the daily weight gain was below, while the feed conversion was above the Ross lineage standard (Ross, 2012). The analysis of the primary variables the high-density housing showed, on average, better results when compared to those of the conventional shed.

Furtado et al. (2006) in an experiment evaluating three systems (sprinkler system, ventilation system, misting system) reported that the values observed that the productive indexes remained within the ideal ranges for the chicken industry. In the positive pressure system, the best results were obtained for the performance indexes of the birds, for the parameters live weight and feed conversion (Menegali et al., 2010). On the other hand, according to Vigoderis et al. (2010) in non-ventilation sheds, birds presented better performance.

Results from two different cooling systems wetted porous plates of cellulose associated with fogging and moistened plates of plastic shade related to fogging, did not differ from the values of feed intake, weight gain and feed conversion (Damasceno et al., 2010).

Different ventilation systems used by Abreu et al. (2011), did not show significant differences in poultry performance, mortality rate and the presence of foot injuries. Barbosa et al. (2012) detected that the use of the evaporative adiabatic cooling system was more efficient when associated with the evaporative system of wet hollow bricks, providing a more comfortable and homogeneous environment showing the effect on the performance parameters, and favoring feed conversion.

The semi-intensive breeding system provided conditions that increased bird welfare, positively influencing performance, even under conditions of thermal stress (Silva et al., 2003). In studies conducted by Lima & Naas (2005) comparing two systems of broiler breeding (conventional-A and semi-extensive-B), feed conversion was 1.97 and 2.98 in A and B, respectively. Conventionally bred broiler chickens had better feed conversion than broiler chickens in the semi-extensive system. Zhao et al. (2015) reported that data on weight gain, feed intake, feed conversion, and mortality were not affected by the breeding system (confinement and semi-confinement).

In studies by Souza et al. (2010) non-automated sheds and during winter and spring, birds presented better performance. Furtado et al. (2010), analyzing two sheds (ceramic tile and another with fiber cement tile) did not observe a significant difference between the mean values of the variables live weight, daily weight gain, feed conversion and mortality rate in the two systems analyzed.

Other identified effects

Roof insulation

Oliveira et al. (2000) observed that the use of roof thermal insulation gave birds greater feed intake, higher weight gain and better feed conversion than the environment without thermal insulation. There was a decrease of 4.06% in poultry mortality in the housing with thermal insulation compared to the house without thermal insulation. Abreu et al. (2007) reported that the use of the polyethylene on roof insulation of the house, results in better conditions of thermal comfort for the birds and better results of live weight, weight gain and feed consumption and feed conversion not was influenced by the use of the roof insulation.

Genetic strains and sex

In the study presented by Stringhini et al. (Ross, Cobb, Arbor Acres and Avian Farms) showed a proper performance and the Ross strain had the weight gain and slaughter weight superior to the other strains at 44 days of age; however, the result was not the same in the different phases. The Avian Farms and Arbor Acres strains showed higher cumulative feed intake at 48 days of age. At this stage, Arbor Acres and Avian Farms chickens had a cumulative feed intake statistically superior to the Cobb strain at 168.65

and 148.49 g, respectively. The Ross strain showed better feed conversion (1.7) about Avian Farms (1.8) and Arbor Acres (1.8) from 1 to 44 days of age. Males had superior performance and carcass weight than the females, but carcass yield characteristics were similar. According to Amaral et al. (2011), higher body mass was found in males when compared to females.

Semi-intensive and extensive way of rearing

Data from broilers reared in a semi-intensive mode, data of weight gain of the birds was influenced by the genetic strain and birds of the Ross strain presented more significant weight gain when compared to the Master Griss and Vermelhão Pesado strains, which did not differ from each other. Label Rouge birds had lower weight gain, according to Madeira et al. (2010). Zhao et al. (2014) showed that the mortality rate of broiler breeder raised outdoors was significantly higher than for those reared inside the housing.

Flock density and season of the year

Silva et al. (2005) researched broilers with flock densities from 10 to 14 birds m^{-2} and observed that the flock density did not affect the feed conversion in any of the grow-out phases. However, the increase in flock density reduced the weight gain in 19-38 days of grow-out and the total time of growth, and in the fall feed conversion was high, on average, 3.27. Gopinger et al. (2015) increased density from 11.08 to 13.20 m^{-2} birds and observed that the flock density did not affect broiler performance in the tested range.

Lighting

The live weight of the birds was higher in the treatment with increasing light, and the feed consumption was lower, according to Moraes et al. (2008). Abreu et al. (2011) a program of almost continuous lighting and yellow curtains provide better performance of broilers. However, this program causes increases in the mortality rate and the consumption of electricity. Santana et al. (2014) showed that the use of LEDs of different colors had the same effect of fluorescent lamps on the performance and carcass yield of broilers.

Floor

The work presented by Abreu et al. (2011), showed that there is no difference in the performance parameters in broilers raised on two types of floors (concrete and dry land).

Wang et al. (2015) reported that chickens reared in three types of poultry facilities using multiple layers of cages, compared to broiler chickens raised on slatted plastic, were not affected by the housing or floor condition.

Table 4 shows the summary of the primary variables that positively influenced broiler performance.

Insert Table 4

CONCLUSIONS

The use of systematic review of the literature allowed to identify the primary variables that influence the performance of the broiler chicken. These are related to the maintenance of temperatures close to the thermal comfort of the birds, which can be achieved with the use of roof thermal insulation, as lining, besides the use of adiabatic cooling and the use of brick cast on the sides. The presence of positive ventilation, as well as the use of yellow curtains and the continuous lighting, also positively influences the performance of the broiler chickens. The sex of the chicken seems to matter the performance.

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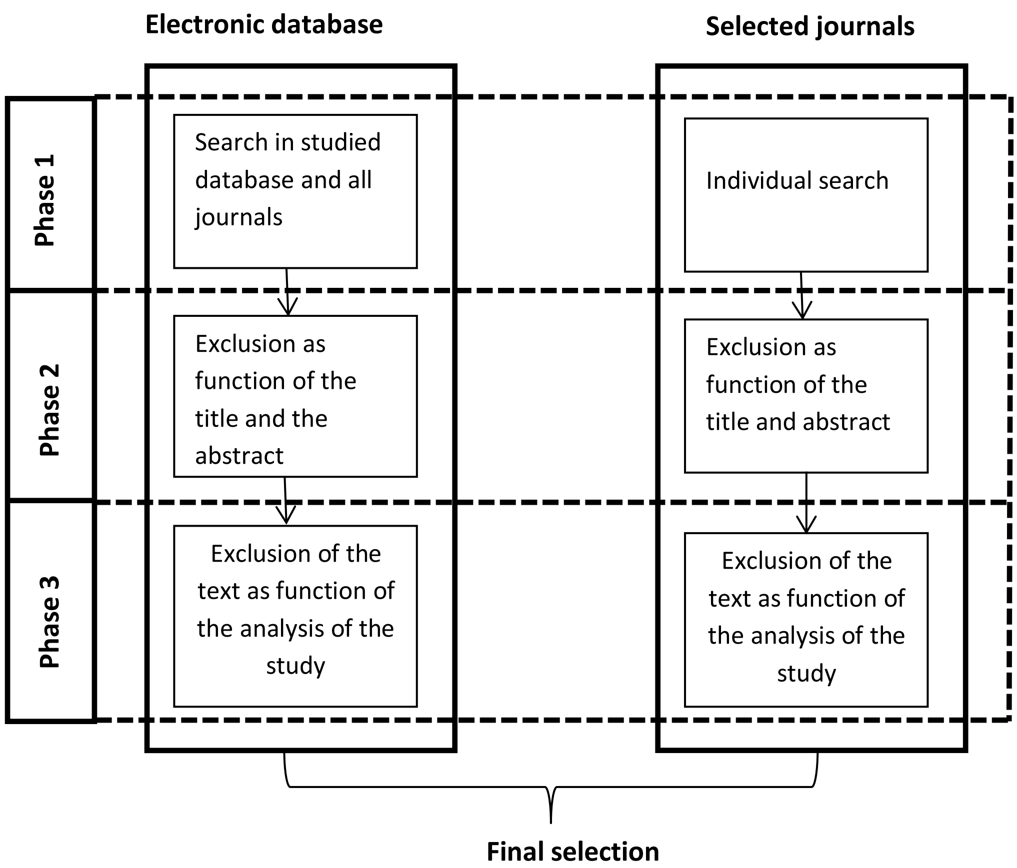

Figure 1. Scheme of the systematic review process of scientific articles considered in the current study.

(Adapted from Rodrigues Filho & Gonçalves, 2015).

Table 1. Keywords used in the systematic review.

Keywords	
Portuguese	English
Frango de Corte	Broiler
Frango de Corte e Conforto Térmico	Broiler and Behaviour
Frango de Corte e Ambiência	Broiler and Welfare
Frango de Corte e Alojamento	Broiler and Housing
Frango de Corte e Produção	Broiler and Conditions
Frango de Corte e Bem-Estar	Broiler and Stress
Frango de Corte e Luminosidade	Broiler and Management
Frango de Corte e Ambiência Aérea	Broiler and Lighting
Frango de Corte e Temperatura	Broiler and Heat Stress
Frango de Corte e Estresse Térmico	Broiler and Production
Frango de Corte e Ambiência Acústica	Broiler and acoustic environment
Frango de Corte e Ambiência Térmica	Broiler and thermal environment

Table 2. Adopted criteria for inclusion and exclusion of the keywords

Criteria	**Definition**
Inclusion	Study with broilers and available production and performance data
Exclusion	Study with broilers and unavailable production and performance data

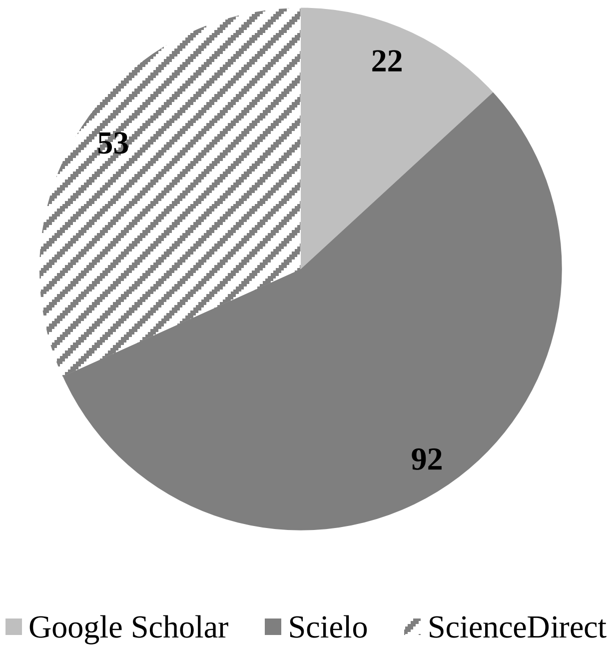

Figure 2. The total of scientific articles identified in the studied databases.

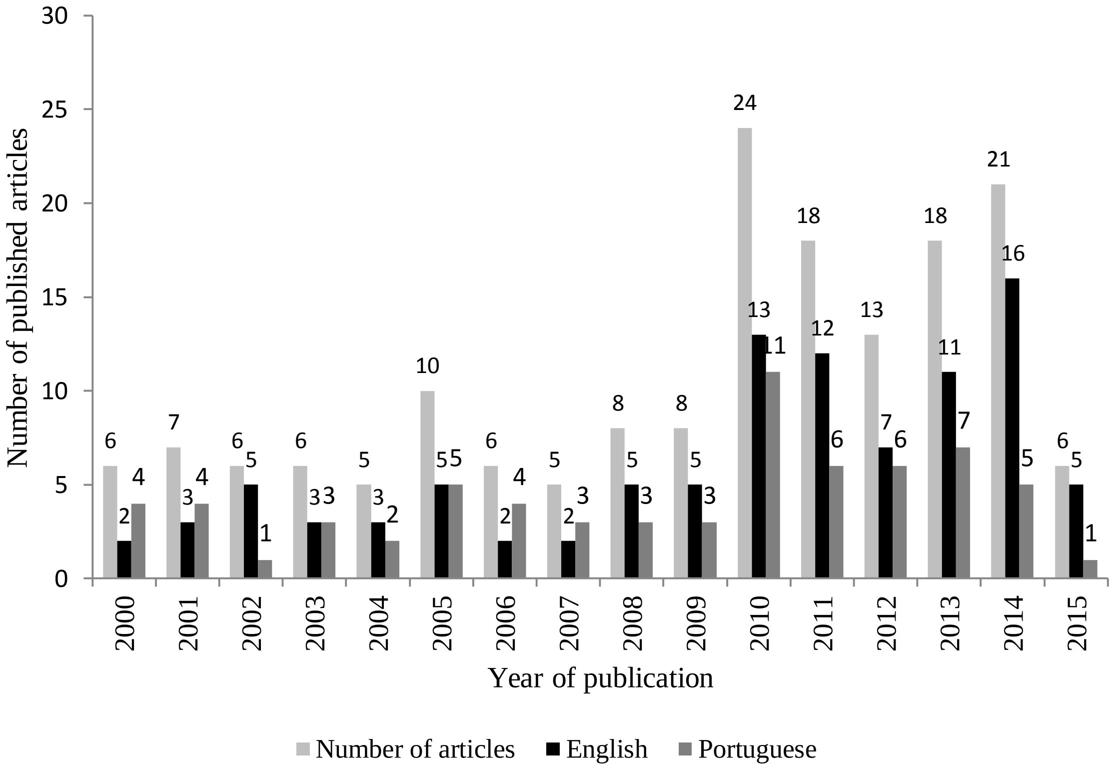

Figure 3. Total of scientific publications by the year and the language

Table 3. Scientific articles selected for the systematic review, following the established criteria.

Title	Author	Year of publication	Language	Journal, Volume, and Local of Publication
Desempenho produtivo e bioeconômico de frangos de corte criados em diferentes sistemas de aquecimento	Abreu et al.	2000	Portuguese	Rev. Bras. Zootec. v.29 n.1 Viçosa
Efeito da temperatura ambiente e da restrição alimentar sobre o desempenho e a composição da carcaça de frangos de corte	Lana et al.	2000	Portuguese	Rev. Bras. Zootec. v.29 n.4 Viçosa
Efeito da temperatura ambiente sobre o desempenho e características de carcaça de frangos de corte alimentados com dieta controlada e dois níveis de energia metabolizável	Neto et al.	2000	Portuguese	R. Bras. Zootec. vol.29 no.1 Viçosa
Efeito do isolamento térmico de telhado sobre o desempenho de frangos de corte alojados em diferentes densidades	Oliveira et al	2000	Portuguese	Rev. Bras. Zootec. vol.29 no.5 Viçosa
Efeito da temperatura ambiente e da restrição alimentar sobre o desempenho e a composição de fibras musculares esqueléticas de frangos de corte	Sartori et al.	2001	Portuguese	Rev. Bras. Zootec. vol.30 no.6 Viçosa
Sistemas de resfriamento evaporativo e o desempenho de frangos de corte	Sartor et al.	2001	Portuguese	Sci. Agric. vol.58 n.1 Piracicaba
Avaliação do desempenho e rendimento de carcaça de quatro linhagens de frangos de corte criadas em Goiás	Stringhini et al.	2003	Portuguese	Rev. Bras. Zootec. vol.32 no.1 Viçosa

Influência do sistema de criação sobre o desempenho, a condição fisiológica e o comportamento de linhagens de frangos para corte	Silva et al.	2003	Portuguese	Rev. Bras. Zootec. vol.32 no.1 Viçosa
Evaluating two systems of poultry production: conventional and free-range	Lima & Nääs	2005	English	Rev. Bras. Cienc. Avic. vol.7 no.4 Campinas
Efeito do bebedouro e da densidade no desempenho de frangos alojados em alta temperatura	Silva et al.	2005	Portuguese	Rev. Bras. Eng. Agríc. Ambient. vol.9 no.4 Campina Grande
Índice térmico ambiental de produtividade para frangos de corte	Medeiros et al.	2005	Portuguese	Rev. Bras. Eng. Agríc. Ambient. vol.9 no.4 Campina Grande
Comparação entre tecnologias de climatização para criação de frangos quanto a energia, ambiência e produtividade	Bueno & Rossi	2006	Portuguese	Rev. Bras. Eng. Agríc. Ambient. vol.10 no.2 Campina Grande
Efeito da temperatura ambiente sobre o desempenho e as características de carcaça de frangos de corte dos 22 aos 42 dias	Oliveira et al.	2006	Portuguese	Rev. Bras. Zootec. vol.35 no.4 Viçosa
Efeitos da temperatura e da umidade relativa sobre o desempenho e o rendimento de cortes nobres de frangos de corte de 1 a 49 dias de idade	Oliveira et al.	2006	Portuguese	Rev. Bras. Zootec. vol.35 no.3 Viçosa
Efeitos de diferentes sistemas de acondicionamento ambiente sobre o desempenho produtivo de frangos de corte	Furtado et al.	2006	Portuguese	Rev. Bras. Eng. Agríc. Ambient. vol.10 no.2 Campina Grande

Condições térmicas ambientais e desempenho de aves criadas em aviários com e sem o uso de forro	Abreu et al.	2007	Portuguese	Arq. Bras. Med. Vet. Zootec. vol.59 no.4 Belo Horizonte
Efeitos dos programas de luz sobre desempenho, rendimento de carcaça e resposta imunológica em frangos de corte	Moraes et al.	2008	Portuguese	Arq. Bras. Med. Vet. Zootec. vol.60 no.1 Belo Horizonte
Behavioural time budgets of broiler chickens reared in varying light intensities	Alvino et al.	2009	English	Applied Animal Behaviour Science 118 54–61
Índíces de conforto térmico e concentração de gases em galpões avícolas no semiárido paraibano	Furtado et al.	2010	Portuguese	Eng. Agríc., Jaboticabal, v.30, n.6, p.993-1002,
Conforto térmico e desempenho de pintos de corte submetidos a diferentes sistemas de aquecimento no período de inverno	Cordeiro et al.	2010	Portuguese	Rev. Bras. Zootec., v.39, n.1, p.217-224
Avaliação do desempenho e do rendimento de carcaça de quatro linhagens de frangos de corte em dois sistemas de criação	Madeira et al.	2010	Portuguese	Rev. Bras. Zootec., v.39, n.10, p.2214-2221
Efeito da automatização nas diferentes estações do ano sobre os parâmetros de desempenho, rendimento e qualidade da carne de frangos de corte	Souza et al.	2010	Portuguese	Acta Scientiarum. Animal Sciences. Maringá, v. 32, n. 2, p. 175-181.
Desempenho produtivo de frangos de corte em diferentes sistemas de instalações semiclimatizadas no sul do brasil	Menegali et al.	2010	Portuguese	Engenharia na Agricultura, viçosa - mg, V.18 N.6,
Characterization of heat waves affecting mortality rates of broilers between 29 days and market age	Vale et al.	2010	English	Brazilian Journal of Poultry Science v.12 / n.4 / 279 - 285

Avaliação do uso de ventilação mínima em galpões avícolas e de sua influência no desempenho de aves de corte no período de inverno	Vigoderis et al.	2010	Portuguese	Rev. Bras. Zootec., v.39, n.6, p.1381-1386
Avaliação do bem-estar de frangos de corte em dois galpões comerciais climatizados	Damasceno et al.	2010	Portuguese	Ciênc. Agrotec., Lavras, v. 34, n. 4, p. 1031-1038,
Efeito do ambiente de produção sobre frangos de corte sexados criados em galpão comercial	Amaral et al.	2011	Portuguese	Arq. Bras. Med. Vet. Zootec. vol.63 no.3 Belo Horizonte
Evaluation of litter material and ventilation systems in poultry production: I. Overall performance	Abreu et al.	2011	English	Rev. Bras. Zootec. vol.40 no.6 Viçosa
Curtain color and lighting program in broiler production: I – general performance	Abreu et al.	2011	English	Rev. Bras. Zootec., v.40, n.9, p.2026-2034
Evaluation of litter material and ventilation systems in poultry production: I. Overall performance	Abreu et al.	2011	English	Rev. Bras. Zootec. vol.40 no.6 Viçosa
Effect of floor type (dirt or concrete) on litter quality, house environmental conditions, and performance of broilers	Abreu et al.	2011	English	Brazilian Journal of Poultry Science - / v.13 / n.2 / 127-137
Eficiência de sistemas evaporativos e dos níveis de energia na ração no desempenho de frangos de corte em crescimento	Barbosa et al.	2012	Portuguese	Semina: Ciências Agrárias, Londrina, 33 (4): 1589-1598
Behavior of Broiler Chickens in Four Different Substrates: a Choice Test	Villagrà et al.	2014	Inglês	Brazilian Journal of Poultry Science v.16 / n.1 / 67-76
Effects of Housing Systems on Behaviour, Performance and	Zhao et al	2014	Inglês	Asian Australas. J. Anim. Sci. vol. 27. No. 1 : 140-146

Welfare of Fast-growing Broilers

Table 4. Main variables that positively influenced broiler chicken performance

Variables
Thermal comfort
Environmental temperature of 24 to 26.3ºC
Roof thermal insulation
Increased lighting
Brooding heating system
Non-automatic ventilation system – cold season
Positive ventilation system
Low ventilation during the winter
Male broiler
Yellow curtains and continuous lighting
Adiabatic evaporative cooling +hollow clay bricks walls

CAPÍTULO III

FATORES DE INFLUÊNCIA NA PRODUÇÃO DE FRANGO DE CORTE: META-ANÁLISE

FACTORS AFFECTING BROILER PRODUCTION: A META-ANALYSIS

Artigo redigido de acordo com as normas da Tropical Animal Health and Production

Factors Affecting Broiler Production: A Meta-Analysis

Abstract: The meta-analysis data were obtained from a survey of 34 published articles over a 15-year period (2000 to 2015). The data were selected to classify the factors that influence poultry production, and separated by influence aspects of the 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 an Excel 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 (ANCOVA), Pearson correlation coefficient and divergence analysis, about the Cobb, Ross and Hubbard lineages. The results showed that the factors that most influenced the performance of broilers were temperature, ventilation, and genetic strain.

Keywords: poultry production, animal production, broiler genetic strain, rearing environment

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 rendered the 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 smaller (Duffield et al. 2012; Cernicchiaro et al., 2016). In addition, a large number of studies have shown the application of this technique (Sanches et al., 2007, Averos et al., 2010; Lehnen et al., 2011; Carvalho et al., 2011; Andreatta et al., 2012, Pauly et al., 2012; Andreatta et al., 2016). The use of meta-analysis in the animal 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 (Giannoti 2004). The current study aimed to identify the factors which might impact intensive broiler production using meta-analysis. The present study aimed to identify from previous research 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. 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 papers 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 mostly influenced animal 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).

Insert Figure 1

Data extraction and assessment

From each scientific paper, we checked performance data and the individual comparisons where the outcome was measured in a particular rearing temperature at a specified time and compared with outcome 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).

The study was select 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 analysis of divergence is done by comparing the data of the compiled variables with the normalized indicator data of each lineage. Pearson correlation coefficients and divergence were 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:

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

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

and 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 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 old 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).

Insert Table 1

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).

Insert Table 2

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

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).

Insert Table 3

Using the Pearson correlation data 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).

Insert 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).

Insert 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).

Insert Table 6

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).

Insert Table 7

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. Mortality found 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. m/s/bird), and Forest graph of the correlation coefficient of the effect size (*r*) are shown in Table 8.

Insert 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. This means that the productivity of broiler chickens would probably be better in a better environment (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 5^{th} week of growth) in the broiler rearing environment decrease productivity. Such scenario also affects their growth and health. which can lead to the extreme situation, such as the increase in lot mortality.

Several authors found out that the bird development is affected by the internal and external conditions in which they are reared (Garcia Neto and 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 effect 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 and 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 and Campos, 2004). This 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 and Hurwitz,. 1996; Yahav et al, 2004; Mengali et al., 2010; Abreu et al., 2011). Furtado et al. (2006) observed that performance index was maintained within the threshold values when ventilation and dogging 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 continous, and associated with adiabatic cooling, mainly during the last weeks of grow-out (Damasceno et al., 2010; Menegali et al., 2010 Abreu et al., 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 the 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.

Notes

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Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflict of interest.

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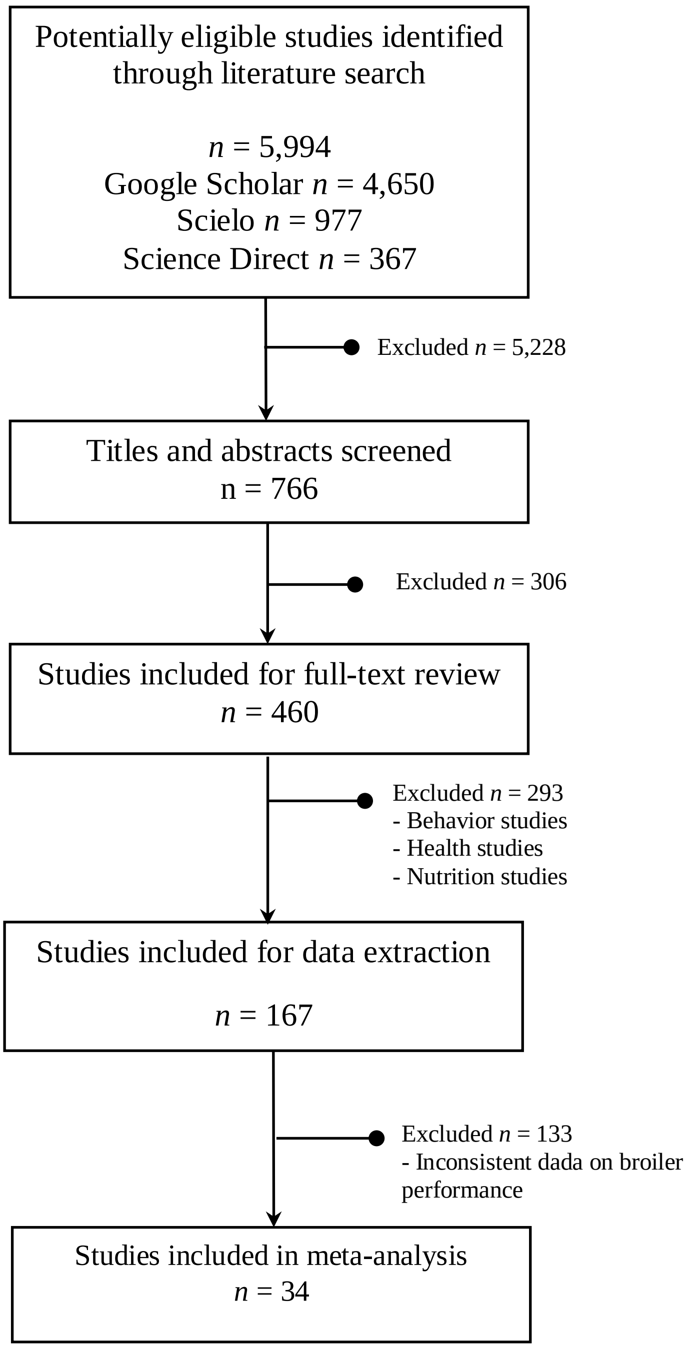


Figure 1. Selection strategy for the studies which were included in the meta-analysis. Adapted from Bawor at al. (2015).

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. Analysis of 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.

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

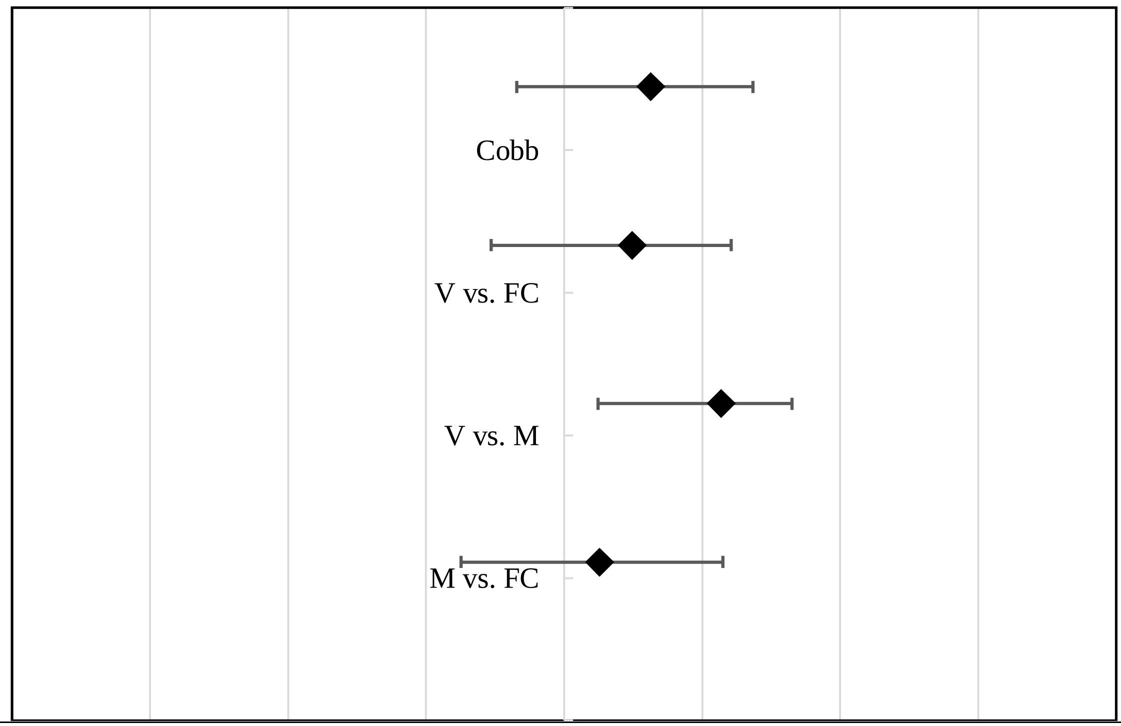
V= ventilation; FC=feed conversion; M=flock mortality; CI=confidence interval

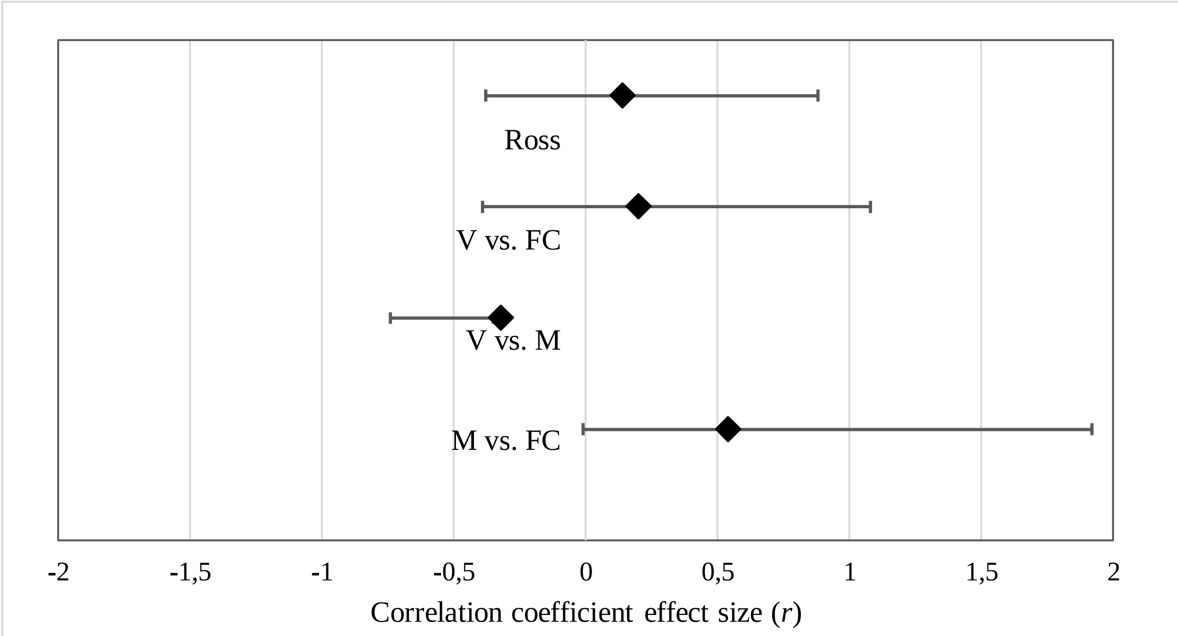
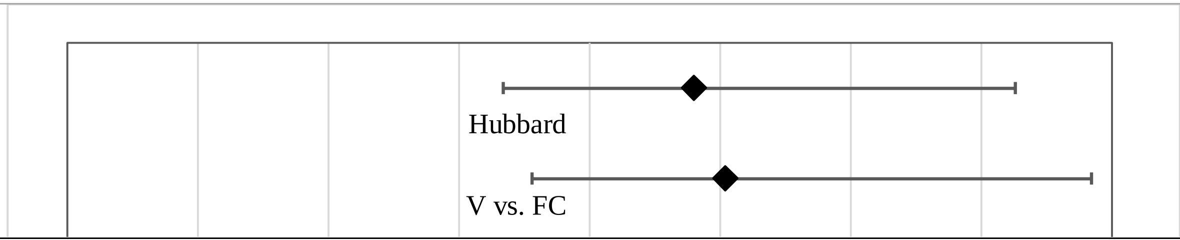
Table 7. Performance responses obtained by meta-analysis.

Variable	Treatment			
	n			Total
	17	19	3	39
	TER	PP	NV	
Weight gain (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 weight W, 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			
Flock mortality (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.

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

Author	Genetic Strain	n	FC	M	V	Forest plot of the interactions between FC, M, and V, and the effect size (*r*)
Stringhini et al. (2003)	Cobb	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	
Vigoderis et al. (2010)		9500	1.59	1.50	0.06	
Souza et		9500	1.68	2.24	0.24	

al. (2010)		24000	1.69	2.31	0.24	
		17000	1.52	1.69	0.24	
Barbosa et al. (2012)		960	2.11	1.77	0.24	
		960	1.92	1.77	0.24	
Stringhini et al. (2003)	Ross	2016	1.68	2.73	0.18	
		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	
Bueno & Rossi (2006)		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)		800	1.70	2.73	0.18	
		800	1.71	2.73	0.18	
Oliveira et al. (2000)	Hubbard	1664	1.97	5.78	0.24	
		1664	2.02	3.00	0.24	
		1664	1.96	4.66	0.18	
Sartor (2001)		1664	2.03	5.14	0.18	
		1664	1.99	7.52	0.18	

1664	1.95	3.00	0.18
13000	1.93	3.99	0.18
13000	2.00	4.69	0.24
13000	2.12	7.69	0.24

5. CONCLUSÕES

O levantamento bibliográfico mostrou uma constante evolução no conhecimento sobre a forma de alojamento que melhor expressa a genética das aves e indicou que o ambiente térmico, a qualidade do ar e outros fatores ligados ao alojamento dos frangos implicam em seu desempenho.

O uso da revisão sistemática de literatura permitiu identificar as principais variáveis que influenciam o desempenho do frango de corte, como temperaturas próximas ao conforto térmico das aves, o uso de forro, além do uso de resfriamento adiabático e uso de tijolo vazado nas laterais. A presença de ventilação positiva, bem como o uso de cortinas amarelas e a luminosidade contínua, também influenciam positivamente o desempenho do frango de corte.

Os resultados indicam que os fatores que influenciaram no desempenho de frango de corte foram temperatura, ventilação e linhagem genética.

A predição de fatores influentes na produção de frango de corte foi possível usando a técnica de mineração de dados. A linhagem, temperatura e a ventilação influenciam no desempenho do frango de corte.

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7 ANEXOS

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REVISTA BRASILEIRA DE ENGENHARIA DE BIOSSISTEMAS - BIOENG

UNESP – Universidade Estadual Paulista – Câmpus de Tupã
Faculdade de Ciências e Engenharia

Av. Domingos da Costa Lopes, 780 – Jardim Itaipu – CEP 17.602-496 - Tupã - SP
Fone (14) 3404-4200 – Fax (14) 3404-4201

bioeng@tupa.unesp.br

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