Revista Ciência Agronômica, v. 50, n. 1, p. 18-26, jan-mar, 2019
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Scientific Article
ISSN 1806-6690

Mortality prediction of laying hens due to heat waves[1]

Previsão de mortalidade de galinhas poedeiras em função de ondas de calor

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ABSTRACT - Mortality in the production of laying hens is a concern for producers and constitutes a considerable economic loss. Some climatic events, such as heat waves, are directly related to the mortality increasing. The aim of this study was to relate the occurrence of heat waves with laying hens mortality, considering the effect of two different kinds of shed used in egg production. Daily mortality data were obtained from two aviaries located in the city of Bastos-SP for the period of October 2014 to January 2016. The data about the climate were gotten from two meteorological stations located in the cities of Tupã-SP and Rancharia-SP, Brazil, from 2010 to 2015. The heat waves were classified in the climatic database using different definitions recommended in the literature (FRICH *et al*., 2002; INSTITUTO NACIONAL DE METEOROLOGIA, 2016; ROSSATO; SARTORI; MISSIO, 2003 TEBALDI *et al*., 2006). Mortality and climate data were related in a single database and were classified into normal and high mortality by data mining using the J48 algorithm. It was possible to associate the occurrences of heat wave and the increase of mortality of laying hens. The classification tree generated identified accurately 71% of occurrences of high mortality and 95% of all mortality data. The classification tree allowed to relate the increase in laying mortality in function of heat waves and allows a prediction of when there will be a bigger chance of high mortality.

Key words: Data mining. Poultry farming. Climate changes. Animal husbandry.

RESUMO - A mortalidade na produção de galinhas poedeiras é fato preocupante para produtores e constitui considerável perda econômica. Alguns eventos climáticos, como ondas de calor, estão diretamente relacionados ao aumento da mortalidade. O objetivo deste trabalho foi relacionar a ocorrência de ondas de calor com a mortalidade de poedeiras, considerando o efeito de duas diferentes tipologias de galpão utilizado na produção de ovos. Os dados de mortalidade diária foram obtidos em dois aviários localizados na cidade de Bastos-SP para o período de outubro de 2014 a janeiro de 2016. Os dados do clima foram obtidos de duas estações meteorológicas localizadas nos municípios Tupã-SP e Rancharia-SP para o período de 2010 a 2015. As ondas de calor foram classificadas na base de dados climática usando diferentes definições recomendadas na literatura (FRICH *et al*., 2002; INSTITUTO NACIONAL DE METEOROLOGIA, 2016; ROSSATO; SARTORI; MISSIO, 2003; TEBALDI *et al*., 2006). Os dados de mortalidade e clima foram relacionados em um mesmo banco de dados e foram classificados em mortalidade normal e alta por meio de mineração dos dados utilizando o algoritmo J48. Foi possível associar as ocorrências de onda de calor ao aumento da mortalidade de poedeiras. A árvore de classificação gerada identificou com precisão 71%, das ocorrências de mortalidade alta e 95% de todos os dados de mortalidade. A árvore de classificação permitiu relacionar o aumento da mortalidade de poedeiras em função de ondas de calor e permite que se faça uma previsão de quando haverá maior chance de ocorrer mortalidade alta.

Palavras-chave: Mineração de dados. Avicultura de postura. Mudanças climáticas. Zootecnia de precisão.

DOI: 10.5935/1806-6690.20190003
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Received for publication in 16/12/2015; approved in 22/02/2018
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INTRODUCTION

The production of laying hens on cages is currently the most widespread breeding system. The intensification of the poultry industry during the 1930s and 1940s resulted in egg production in cages in large-scale, becoming mechanized, because of the high production rates and relatively low costs due to labor shortages and declines of feed wastage; however, the mechanization of the aviaries allows greater use of the housing space, reducing the space offered to the animals and leading to the adoption of practices that have increased stocking density (CASTILHO *et al*., 2015; PEREIRA *et al*., 2013).

The temperature maintenance is essential for the welfare of laying hens. The thermal factors that can be represented by air temperature, humidity, thermal radiation and air movement cause several physiological changes in the birds, compromising the homeothermy. Outside the comfort zone, there is a decrease in productive, reproductive and immunity performance, and temperature extremes can be lethal (TINÔCO, 2001; ZHAO *et al*., 2013).

The increasing rates of carbon dioxide in the atmosphere have caused world-wide climate change, favoring the temperature rise on the planet and the increasing occurrence of heat waves, hitting successive records of intensities and resulting in losses in the agribusiness (FIRPO; SANSIGOLO; ASSIS, 2012; SILVEIRA; BONETTI; ROSSLER, 2015; ZUO *et al*., 2015).

The heat waves are extremely dangerous to living things and can be lethal. They have a combination of extremely damaging factors to the organism such as high air humidity, strong sun and absence of wind. Studies have shown that the events of heat waves will be increasingly severe. It is expected that by 2100, the overall effective temperature will increase by about 5.8 °C. At every 1 °C of increase in global temperature, the risk of mortality can be increased by 1.4% until the acceptable thermal limit is exceeded before the hyperthermia (NORTE *et al*., 2007; ZENG *et al*., 2014; ZUO *et al*., 2015).

According to Pereira *et al*. (2010), the heat waves are directly associated with laying hens mortality. The lineage management manuals indicate acceptable mortality rates between 0.2 to 0.5% when birds are in production peak from 22 to 24 weeks, rising gradually from 0.01 to 0.02% per week until reaching 10% of accumulated mortality at the 90th week. The mortality due to thermal stress, generally more intense during the heat waves, is a significant economic loss for egg producers (ABIDIN; KHATOON, 2013; INTERAVES, 2016).

The software resources and computational modeling have been increasingly used in the search for mitigating solutions for the poultry industry. Due to the problem complexity, the modeling studies together with analytical or semi-empirical methods are applied in the development of new procedures and methods for heat dissipation (HAN; NAM, 2016; LEE *et al*., 2012).

This study sought to associate the effects of heat waves on laying hens mortality, considering the effect of two different shed typologies used in egg production. Data mining techniques were used to generate a classification tree that can be used by producers to anticipate these losses and to provide mitigation measures.

MATERIAL AND METHODS

The research was carried out in two sheds of an egg-producing farm, located in the municipality of Bastos-SP, whose coordinates are 21º92’02” South latitude, 50º73’17” West longitude and 445 meters of altitude. According to the Köppen climatic classification, the climate is defined as Cwa, characterized by humid temperate climate, with dry winter and hot summer. The producer provided the production data of the aviaries using spreadsheets. The spreadsheets contained the production data, age and mortality of the lot studied. Both aviaries housed *Hisex White* broilers of the same lot and age between 18 and 70 weeks and received the same feed. These data served as a basis for statistical analyzes and for the construction of the model for predicting the mortality of laying hens. The description of the aviary characteristics is shown in Table 1.

To verify the occurrence frequency of heat waves, the maximum and minimum daily temperatures and average daily relative humidity were analyzed.

The available data of the neighboring municipalities of Tupã (distant 22km) and Rancharia (distant 38km) were analyzed, since the municipality of Bastos has no meteorological station. The meteorological data were obtained from the Integrated Center for Agrometeorological Information - CIIAGRO for a period of six years, from January 1st, 2010 to December 31st, 2015.The National Institute of Meteorology (INMET) database was also used for a period of four years, from January 1st, 2012 to December 31st, 2015.

The characterization of the heat wave has different criteria according to each agency or meteorological institute. This study adopted four different definitions for the search of the best one that associated the extreme climatic event with the mortality of the birds in the region of study. The definitions adopted are described in Table 2.

Table 1 - Constructive and occupational characteristics of aviaries

Characteristic	Aviary B1*	Aviary G2*
Width	4 m	3 m
Length	130 m	130 m
High Ceiling	3.5 m	2 m
Tile type	Ceramic clay of French type, painted with white thermal ink.	Clay ceramic of French type without painting.
Cage Type	Vertical system, with three floors of cages on both sides. Polyethylene sides and wire front.	Pyramidal system two-story pyramidal batteries and cages on both sides with a central hallway.
Direction	East-West	East-West
Ridge	Does not have	Does not have
Headliner	Does not have	Does not have
Curtain	Does not have	Does not have
Plastic covering	Both sides with 70% north-south faces.	Does not have
Raised Floor	Does not have	Does not have
Walls	Masonry on the East-West sides.	Does not have
Cage Dimensions	60 cm of wide, 63 cm of deep and 50 cm of height.	60 cm of wide, 53 cm of deep and 45 cm of height.
Birds per Cage	11 Birds	10 Birds
Cage Density	343.64cm²/bird/cage.	318 cm²/bird/cage.
Total birds housed	12,100	5,309

*The denomination of the aviary is the same one used by the farm

Table 2 - Criteria for determinant variables of heat wave

Reference	Description	Criterion
HWDI - (Heat Wave Duration Index)	5 consecutive days and maximum temperature> 5 °C than the average daily maximum value of the period.	C1
THI - (Temperature and Humidity Index)	THI> to 81 for at least 3 consecutive days.	C2
INMET - National classification	Maximum temperature ≥ 32 °C and 5 °C above the average in parts of that area for at least 2 days.	C3
Rossato, Sartori and Missio (2003)	Minimum temperature > 22° and maximum ≥ 32° for at least 3 consecutive days.	C4

The association of the periods indicated as heat waves occurred in each criterion was made with the number of birds killed in each day and the mortality was considered high when it remained higher than the expected for the lineage. The adherence of the rules to the production and mortality data was analyzed through the ROC curve (Receiver Operator Characteristic), using daily mortality as a predictor variable. In this analysis, each problem is divided into special classes whose values refer to the true or false classification of cases. The ROC charts were generated using the IBM SPSS Statistics Software (MARGOTTO, 2010).

To validate the effectiveness of each rule, the positive predictive values of heat waves associated with the increase in lot mortality were analyzed. For heat wave confirmation, a mortality from 0.2 to 0.5% was considered when birds were in peak production from 22 to 24 weeks, rising gradually from 0.01 to 0.02% per week until reaching 10% in the 90th week, which is the standard established by the lineage manual. The verification of the positive predictive value was obtained through the Equation 1(KAWAMURA, 2002).

$$PPV = TP / (TP + FP) \quad (1)$$

where: *PPV = Positive predictive value; TP = True Positives; FP = False Positives.*

The study analyzed the mortality data recorded during the period from October 2014 to January 2016. The technique used for data mining was proposed by CRISP-DM (Cross Industry Standard Process for Data Mining). According to this methodology, the analysis was divided in five distinct phases: 1) Understanding the domain of knowledge to which the study refers; 2) Knowledge and understanding the database for this domain; 3) Data preparation (cleaning, construction, selection, integration and formatting); 4) Modeling; 5) Evaluation of the results, allowing reconsiderations and cyclical re-evaluations (CHAPMAN *et al*., 2000).

The data set for analysis contained 22 attributes and was constituted by three attributes originating from the original data of the aviaries; 9 attributes of the original weather station data; 6 attributes derived from the original weather station data; one original that identifies the sheds; and one classifier attribute, separated into two categories: high mortality (HM) and normal mortality (NM). Table 3 shows all the attributes used in the data mining process.

The database was prepared in spreadsheets where each column contained an attribute; later they were exported to the Weka® program for classification task. The algorithm used to construct the classification tree was the J48 because it is the most used in agricultural data set (GIASSON *et al*., 2013; MOI *et al*., 2014).

The classification attribute was elaborated according to the daily mortality data recorded by the farm. From the calculation of daily mortality, this was categorized into two classes, HM or NM, which considered daily mortality as a percentage of the expected daily for the lineage according to the lineage management manual (INTERAVES, 2016).

In order to select the most significant attributes, the main component analysis techniques, linear combinations (main components) were used, forming a subset of the attributes, preserving the original information as much as possible through the MINITAB® program in its 17 version; and using the attribute selection algorithms available in the Weka® program, CorrelationAttributeEval, GainRatioAttributeEval.

RESULTS AND DISCUSSION

The results of the analysis of the meteorological station data according to the definition criteria of heat waves (C1, C2, C3 and C4) are shown in Figure 1.

In Figure 1, the criteria C3 and C2 were more sensitive for the identification of heat waves. Regardless of the criterion, the heat waves in the region occur between September and February. Comparing the mortality data with the occurrences of heat waves, it was possible to construct the ROC graphs for each criterion (Figure 2) and the results are summarized in Table 4.

For a confidence level of 95%, the criteria C1, C3 and C4 could associate the heat wave with the increase of the lot mortality, all with significance $p < 0.01$. Considering all cut-off points, the Criterion 3 has the highest PPV, as can be seen in Table 4.

The false positives can assume different values in the ROC curve according to the chosen cut-off point. The best cut-off point is the one that is able to represent the highest possible sensitivity and specificity. In Table 4, the false positives are represented by the value of 1 (one) minus the specificity and, according to the cut-off point, the Criterion 3 was the one that presented the lowest value of false positives.

Table 3 - List of attributes used to form the final database

Attribute	Type	Attribute	Type
Mortality Classifier	0	Maximum wind speed	3
Month of the experiment	1	Range of RH	3
Age, days	1	Temperature Range	3
Age, weeks	1	Average THI (SANTOS et al., 2014)	3
Average temperature	2	Maximum THI (SANTOS et al., 2014)	3
Maximum absolut temperature	2	Minimum THI (SANTOS et al., 2014)	3
Maximum relative humidity	2	Aviary type	4
Minimum relative humidity	2		
Minimum wind speed	2		

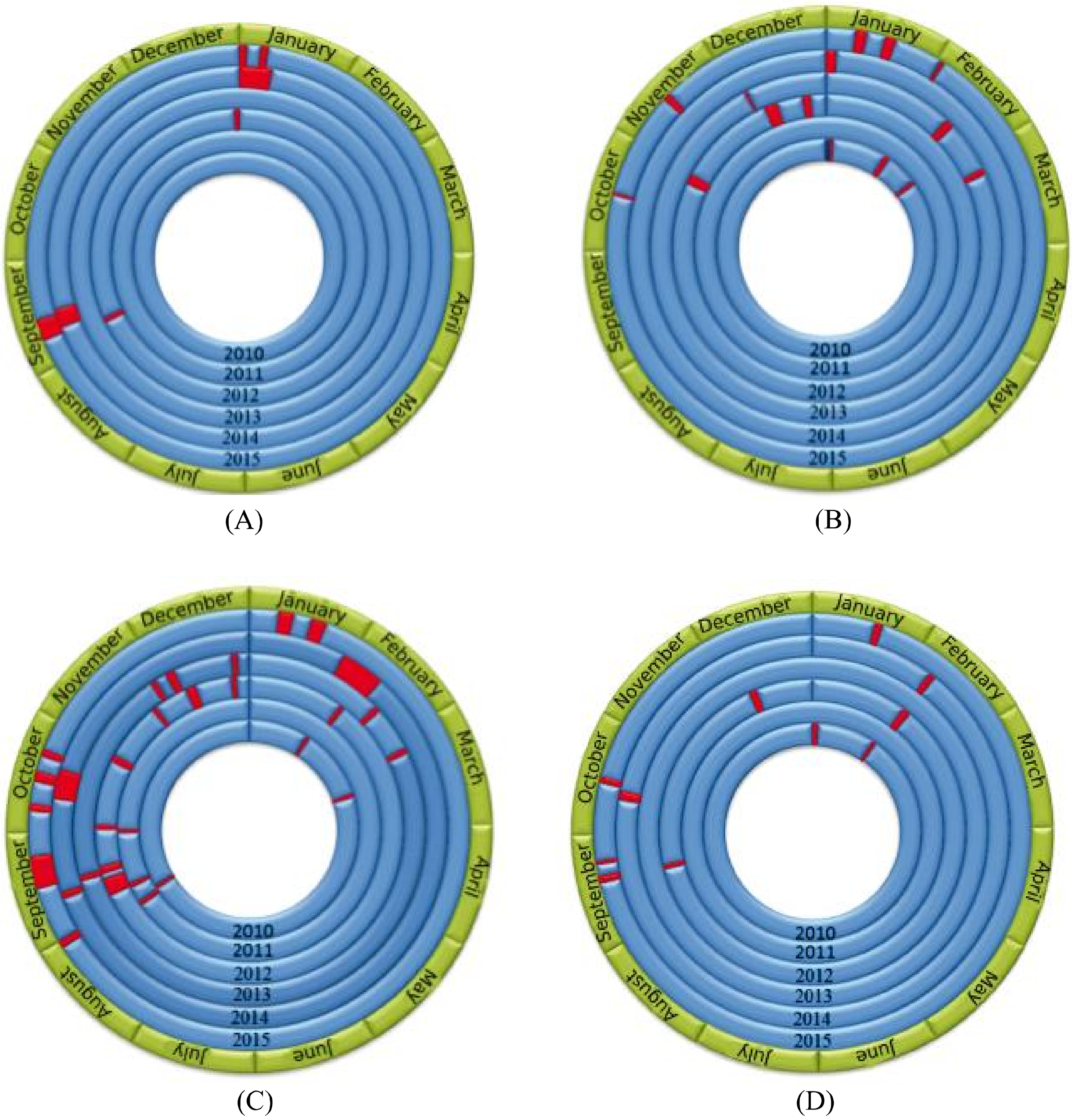
Where: 0 - Classifier attribute, formed by the calculation of mortality; 1 - Attributes obtained in the shed and with producer; 2 - Attributes of meteorological stations, data provided; 3 - attributes derived from the meteorological station, calculated; 4 - Original attributes of the sheds

Thus, it is possible to have different correspondences in the curve. A restricted criterion (positive patient when the evidence of disease is very strong) is one that translates a small fraction of false positives and also a small fraction of true positives (lower left corner of the ROC curve). The use of less restricted criteria leads to larger fractions of both types (points placed in the right corner of the curve).

The criterion stipulated by INMET (C3) for the detection of heat waves was the one that was most associated with the increase of the mortality of laying hens in this study, being the one chosen for the other analyzes.

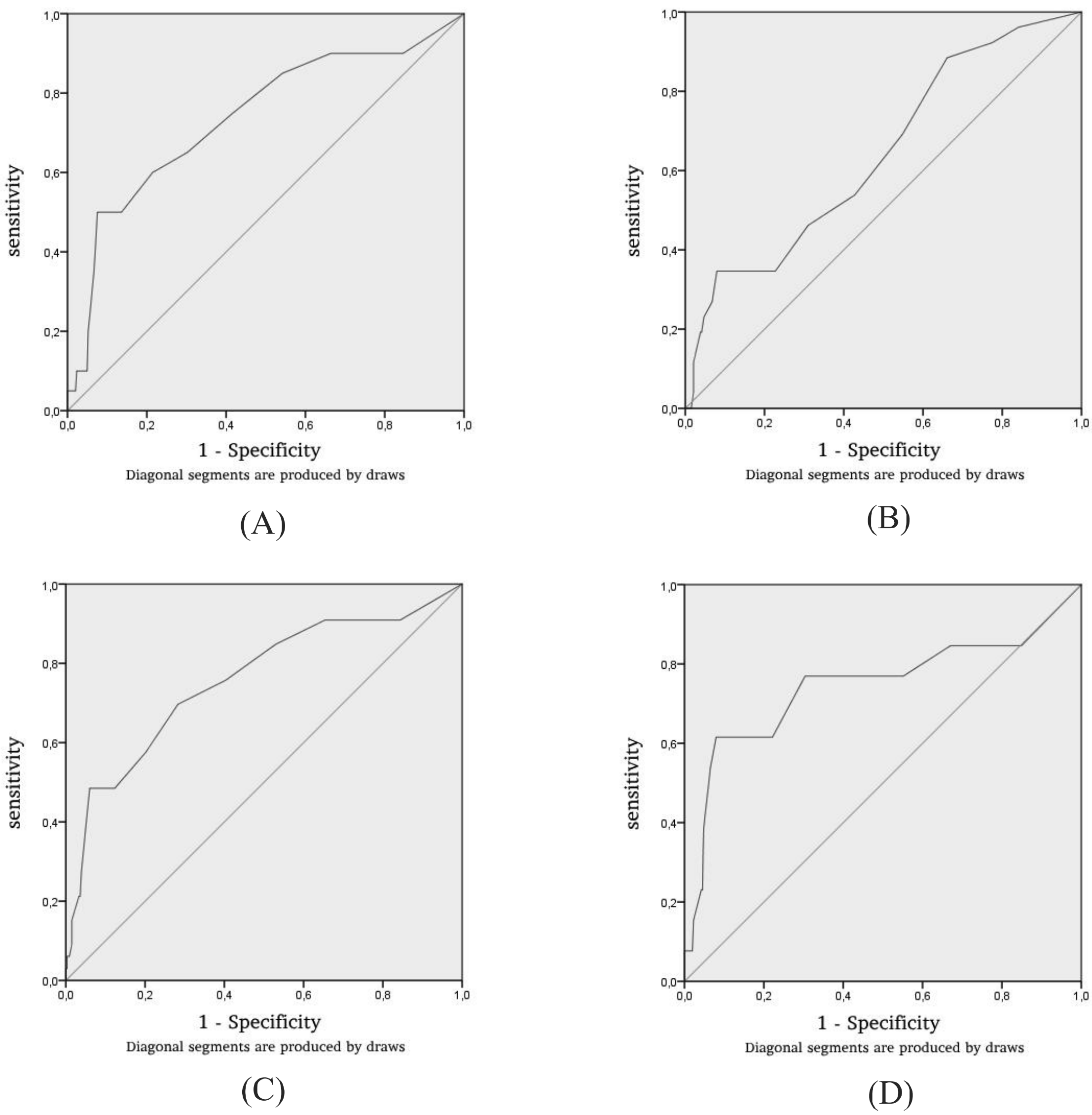
The daily mortality of laying hens in heat waves in shed B1 was on average 0.0398% per day. This mortality was lower when compared to the daily average of the

Figure 1 - Number and duration in days of the heat waves in each year studied, considering each of the determinant criteria of heat wave in Tupã



Where: (A) C1: HWDI - (Heat Wave Duration Index), (B) C2: THI - (Temperature and Humidity Index), (C) C3: INMET - National Classification, (D) C4: Rossato, Sartori and Missio 2003) - The periods of the year highlighted in red represent the occurrence of heat wave and the periods highlighted in blue represent the non-occurrence of heat wave

Figure 2 - Analysis of Receiver Operating Characteristic curves (ROC), considering each of the determinant criteria of heat wave in Tupã



Where: (A) C1: HWDI - (Heat Wave Duration Index), (B) C2: THI - (Temperature and Humidity Index), (C) C3: INMET - National Classification, (D) C4: Rossato, Sartori and Missio 2003). The diagonal segments are produced by draws

Table 4 - Results of the PPV test for each criterion and their respective values of sensitivity and specificity

Criterion	Area under the ROC curve	Positive Predictive (%)	Sensitivity	1 - Specificity
C1	0.737	79.850	0.750	0.417
C2	0.641	25.700	0.538	0.428
C3	0.757	87.620	0.758	0.404
C4	0.745	81.790	0.769	0.423

Where: (A) C1: HWDI - (Heat Wave Duration Index), (B) C2: THI - (Temperature and Humidity Index), (C) C3: INMET - National Classification, (D) C4: Rossato, Sartori and Missio (2003)

G2 shed, which was 0.0560%, according to the paired t-student test result (p = 0.004). This result evidences that the typology interferes in the thermal environment and, therefore, interferes in the mortality of the birds. There was an average daily mortality of 0.0161 percentage points higher than in the G2 aviary, adding up all the periods when there were heat waves. The comparative distribution of the mortality rate between the two aviaries is shown in Table 5, in which the five heat waves occurred in the period are demonstrated.

Table 5 - Percentage of mortality observed in each aviary in the occurrence of heat wave

Heat wave	Number of days of duration	Observed Mortality (%)	
		B1	G2
1	6	0.2767	1.2106
2	7	0.4039	3.1232
3	13	1.4531	1.9155
4	7	0.6896	0.5957
5	3	0.3132	0.7328
6	3	0.0025	0.0033
Average	6.5	0.0804	0.1943
Standard deviation	3.7	0.5064	1.1137

For the construction of the classification model, it was necessary to work on the dimensionality reduction of the database, removing the records where high mortality was observed on days that did not occur extremes of heat. For the elimination of these records, it was considered that the high mortality in days of normal thermal environment was due to other factors not monitored and, therefore, that could not be predicted in this model (ARCHANA; ELANGOVAN, 2014).

The mining of aviaries mortality data to predict the mortality of laying hens between 18 and 70 weeks generated a decision tree with total classification accuracy for the 95.51% model and the precision of the high mortality class was 71.40%. The percentage data with results from this model are shown in Table 6, and the classification tree is shown in Figure 3.

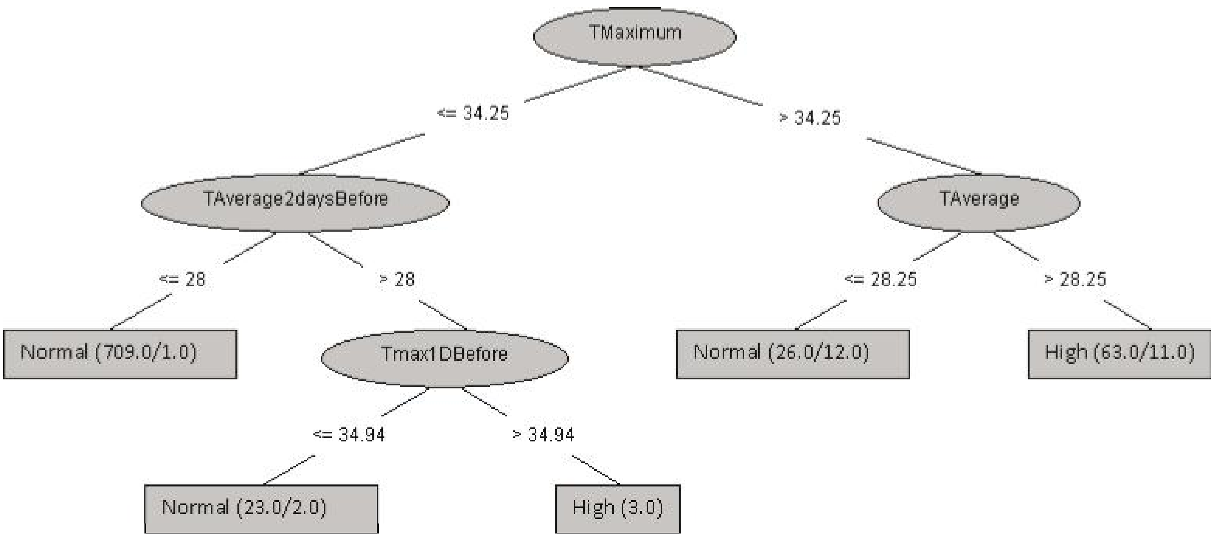
Table 6 - Precision percentage of the model

Model	Total Precision	NM Precision	HM Precision	Kappa
ModMASO	95.5%	98.0%	71.4%	0.7237

The criteria used for heat wave design were efficient for the determination of heat waves applied to laying hens. In the decisive attributes appeared the Maximum Temperature, Average Temperature, and the values measured in the two previous days of maximum and average temperature (average temperature of two days before and maximum temperature of the previous day).

As noted by Abidin and Khatoon (2013), the high temperature is the main cause of acute thermal stress in laying hens, the main consequences are the decrease in the concentration of adrenal ascorbic acid (vitamin C)

Figure 3 - Classification tree generated



that is responsible for the synthesis and production of hormones involved in stress resistance, unnecessary increase in antibody production, lower feed intake in order to reduce the thermogenic effect, decrease the nutrient absorption, increase the mortality, reduce the egg quality and production, and deficiencies in carcass formation.

Under the conditions of this study, the previous day's maximum temperature of 34.94 °C, average of 28.25 °C, daily maximum higher than 34.25 °C and average of two days ago greater than 28.00 °C were the thresholds triggering the high mortality.

The average temperature was decisive for periods when the maximum was higher and lower than 34.25 ºC. High average temperatures imply in days with minimum temperatures, usually nocturnal, very close to the maximum temperatures. The lack of mild nocturnal temperatures aggravates the problem of the birds, since it does not allow the mitigation of the effects of heat stress generated during the day, thus, end up aggravating the hyperthermic stage leading to high mortality (ABDELQADER; AL-FATAFTAH, 2014).

As with other animals, nocturnal cooling can help the laying hens on body heat balance and can be effective in improving the welfare of the birds (HONIG *et al*., 2012; SPIERS *et al*., 2001).

Considering that it is possible to obtain almost accurate weather forecasts up to a week in advance, this allows the producer to take mitigating and preventive actions that minimize mortality and consequent productive losses.

The generated model presents a high assertiveness for normal mortality, favoring the decision of the producer.

CONCLUSION

1. The occurrence of high mortality of laying hens was strongly associated with the occurrence of heat waves and classified from meteorological variables, being affected by the typology of the shed in identical external environment conditions;
2. The classification tree generated allows predicting the mortality of laying hens caused by heat waves, through the data from meteorological stations or meteorological forecasts;
3. The techniques of data mining adopted in zootechnical and meteorological databases indicated that it is possible to discover new knowledge, generating models of high comprehensiveness.

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