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TECHNICAL FEASIBILITY OF THE ACCLIMATIZATION SYSTEM IN AVIARY OF POSTURE: A CASE STUDY

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ABSTRACT: The objective of this study was to compare the performance of laying hens between automated aviaries, one with and another without acclimatized system. On a daily basis it was registered in each aviary the mortality, the egg production, and the feed consumption. The variables of the dry bulb temperature, relative humidity and black globe temperature were registered every 30 minutes using the thermos hygrometer. Every 28 days ninety eggs from each aviary were collected randomly and the variables egg weight, shell weight, shell thickness and Haugh Unit were registered. The consumption and quality of the electrical energy supply were monitored every 30 minutes using registers of electrical magnitude. The results showed that the acclimatization system consumes more electrical energy; however it provides thermal environment more suitable for bird raising, resulting in better production and quality of the eggs. The quality of the electrical energy supply was not maintained, since several interruptions occurred which resulted in higher mortality in the acclimatized aviary. It was concluded that the acclimatization system is technically feasible, since the electrical energy supply is guaranteed.

KEYWORDS: ambience, electrical energy, mortality, egg production, precision animal science.

INTRODUCTION

Brazil has the largest egg production industry in Latin America and the seventh largest in the world, according to the USDA - United States Department of Agriculture (USDA, 2011). In 2014, the national production was 37,245 billion eggs, with gross revenues of R$ 7,784 billion, representing 1.7% of the total gross revenues on Brazilian Agribusiness of R$ 452.5 billion (MAPA, 2015). The per capita consumption in 2014 was 182 eggs inhabitant^{-1} (ABPA, 2015). Eggs exports in 2014 amounted US $ 89,355 million and the obtained revenue from the exports was US $ 63,518 million (MDIC, 2015).

The increasing on egg production in Brazil has promoted in recent years the mechanization of the aviaries and a high density in the cages on commercial creation of laying hens. There is greater heat generation in the environment which needs to be removed from the aviary, since the stress generated by high temperatures in poultry can lead to a decrease in food intake and physical activities, as well as losses in production, such as a decrease in the number of produced eggs, worsens egg size and quality, and birds mortality (Renaudeau et al., 2012; Lara & Rostagno, 2013; Mack et al., 2013; Silva et al., 2013, Abdelqader & Al-Fataftah, 2014).

To minimize these losses, egg companies have installed acclimatization system in their aviaries using exhaust fans and evaporative panels. In acclimatization system there is an increase in the consumption of electric energy, since, in order to avoid heat stress, electrical equipment is used and operates more frequently (Khokhar et al., 2015). However, these companies mostly, do not record the electricity consumption of their equipment which according to Mosko et al. (2010) constitutes a significant part of the production cost of an industry making necessary to study the quality of supply and the consumption (Turco et al., 2002). The scaling of energy transformers and motors in relation to the equipment must be considered in the production sectors, since when

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inadequate, it leads to power supply failures and variation in the internal environment in a same shed with acclimatization system (Bueno & Rossi, 2006; Silva et al., 2013).

Considering the hypothesis that the acclimatization system is effective in providing a better thermal environment for the poultry and that they present better productive performance, the aim of this research was to verify the consumption and the quality of the electric power supply for the used equipment in the acclimatization system and the productive performance of it, comparing with the results of an automated aviary without acclimatization system in a laying hen aviary located in the municipality of Bastos-SP.

MATERIAL AND METHODS

The research was carried out under field conditions at an egg-producing farm located in Bastos, municipality of the state of São Paulo, Brazil at coordinates 21º55'19" south latitude and 50 º 44' 02" west longitude and altitude of 445 meters. According to the climatic classification of Köppen, the climate is Cwa, characterized by humid temperate climate with hot summer and dry winter.

In the acclimatized aviary (C) were housed 61,060 birds of the Dekalb White lineage. The shed was 110.00 m long and 11.25 m wide. Its structure consisted of brickwork walls on the east-west sides, blue-colored curtains on the north-south face and a roof with no zinc ridge vent. The aviary had 14 exhaust fans on one end, *pad cooling* on the opposite end and vertical cage system with 3 batteries of 6 storeys and cages on both sides. In each cage which the dimensions were 72 cm wide and 55 cm deep were placed 12 hens.

In the not acclimatized aviary (NC) where the dimensions were 110.00 m in length and 9.00 m in width, were housed 37,585 hens of the same lineage and age than those from acclimatized aviary. The structure consisted of brickwork walls and zinc on the east-west sides with curtains on the north-south faces and zinc roof, without ridge vent. It had 2 batteries of 6 storeys and cages on both sides. One battery consisted of polyethylene cages with dimension of 60 cm wide and 53 cm deep and where housed 10 hens. The other battery consisted of wire cages, 60 cm wide and 60 cm deep, with 10 hens.

The values of the dry bulb temperature (DBT), relative humidity (RH) and black globe temperature (BGT) were collected by means of 12 thermo hygrometers HOBO® (Onset, Bourne, Massachusetts, USA) installed inside the aviaries in equidistant points in all corridors of the sheds.

The Black Globe Temperature and Humidity Index (BGHI) were calculated from collected data by [eq. (1)] (Buffington et al., 1981):

$$BGHI = BGT + 0{,}36 * DPT - 330{,}08 \tag{1}$$

On what,

BGT - Black globe temperature, K, and

DPT - Dew point temperature, K, calculated by dry bulb temperature and relative humidity using psychrometric equations.

The data from 04/02/2013 to 04/30/2014 were used and compared by the non-parametric Mann-Whitney test at 5% significance level.

Egg collection in both sheds was performed daily and the total amount of eggs from each shed was recorded to determine the total egg production. The number of dead hens from each shed was recorded daily to determine the total viability of the lots.

The index of eggs per housed hen is the number of produced eggs by each hen during its productive life and, in the case of this study, was determined from the accumulated number of produced eggs from 18 to 74 weeks, and the number of housed hen in the aviary (Equation 2):

$$\mathbf{EHH} = \frac{\mathbf{EH}}{\mathbf{HH}} \quad (2)$$

On what,

EHH - index of eggs per housed hen;

EH - The cumulative number of eggs produced in the week, and

HH - The number of hens initially housed in the shed.

The feed silo supplies of each aviary were recorded for the calculation of feed intake per housed hen (Equation 3):

$$\mathbf{FC_t} = \frac{\sum(\mathbf{DC_d} * 7)}{1000} \quad (3)$$

On what,

FC_t - The total feed consumption of each housed hen, kg housed hen^{-1}, and

DC_d - Daily consumption of each hen, g hen $^{-1}$.

Daily feed intake was calculated using [eq. (4)]:

$$DC_d = \left\{\left(\frac{\mathbf{FC_s}}{7 * \mathbf{H}}\right)\right\} * 1000 \quad (4)$$

On what,

FC_s - The amount of feed supplied in the silo, kg, and

H - The number of totaled hens in the week.

The quality of the eggs was evaluated from ninety collected eggs at random points throughout the shed, every 28 days, in each of the sheds. Analyzes were performed by the machine DET 6000 model (NABEL Co. Ltd., Kyoto, Japan) which provided precise values of the parameters of weight, shell strength, shell thickness and Haugh Unit.

All data were collected from April 2nd, 2013 to April 30th, 2014.

SmartMeter® meters (IMS, Porto Alegre, Rio Grande do Sul, Brazil) were installed in the aviaries, two of them in the acclimatized aviary (in the circuits connected to the exhaust fans and lighting) and one in the no acclimatized aviary (in the lighting circuit) so that the electricity consumption was monitored in each shed. These measures were taken every 30 minutes during the period from June 1st, 2013 to April 30th, 2014.

At the end of the measurements period of the electric quantities on the lighting and acclimatization systems in the aviaries was estimated the daily and monthly electric consumption of the analyzed aviaries.

RESULTS AND DISCUSSION

The acclimatized shed had a smaller variation on the thermal environment for the monitored variables (Figure 1).

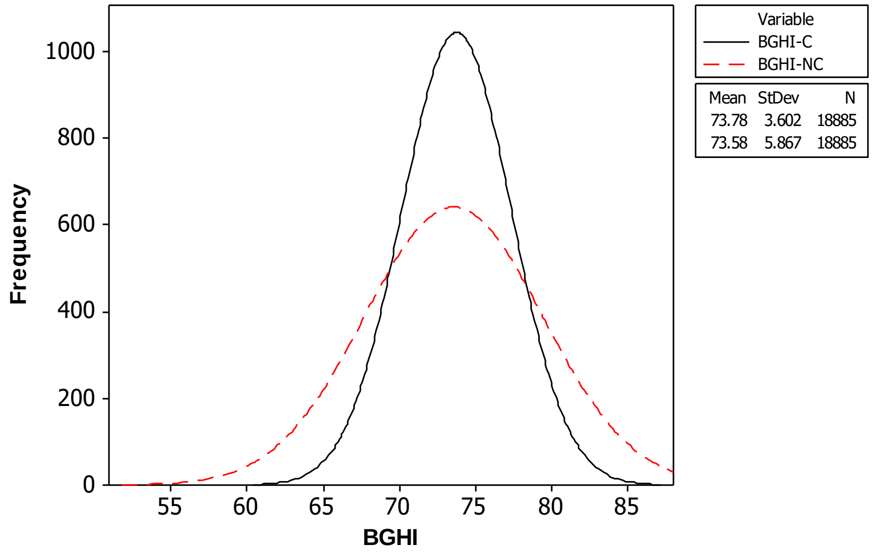

FIGURE 1. Histogram of values of black globe temperature and humidity index (BGHI) in acclimatized (C) and no acclimatized (NC) sheds.

Despite the difference in the data distribution there was no difference in the BGHI ($p> 0.05$) between the sheds when accumulated data were analyzed during the year. Thus, the statistical test to subsets of data grouped by seasons was applied (Table 1).

TABLE 1. Differences between the variables on the thermal environment in the acclimatized, and no acclimatized sheds.

Seasons	Variable	Shed	
		Acclimatized	No Acclimatized
Total	Air temperature (°C)	24.929 [b]	25.423 [a]
	Relative humidity (%)	74.373 [a]	67.891 [b]
	Black globe Temperature (°C)	25.168 [b]	25.454 [a]
	BGHI	73.887	73.806
Autumn	Air temperature (°C)	24.533	24.468
	Relative humidity	75.358 [a]	72.314 [b]
	Black globe Temperature (°C)	24.869 [a]	24.526 [b]
	BGHI	73.520 [a]	73.022 [b]
Winter	Air temperature (°C)	24.561 [a]	22.803 [b]
	Relative humidity (%)	67.649 [a]	61.058 [b]
	Black globe Temperature (°C)	24.821 [a]	22.813 [b]
	BGHI	72.534 [a]	69.726 [b]
Spring	Air temperature (°C)	24.700 [b]	25.939 [a]
	Relative humidity (%)	76.306 [a]	66.691 [b]
	Black globe Temperature (°C)	24.690 [b]	26.032 [a]
	BGHI	73.492 [b]	74.514 [a]
Summer	Air temperature (°C)	26.054 [b]	27.469 [a]
	Relative humidity (%)	76.491 [a]	68.442 [b]
	Black globe Temperature (°C)	26.601 [b]	27.430 [a]
	BGHI	75.952 [b]	76.547 [a]

Different letters on the same line indicate a significant difference (5%) in the Mann-Whitney test.
BGHI = Black Globe Temperature and Humidity Index.

The variables of air temperature and black globe temperature were lower ($p \leqslant 0.05$) in acclimatized shed when compared to no acclimatized shed, confirming the efficiency of the system in reducing temperature. The results corroborate with those by Al-Fataftah & Abdelqader (2013) who comparing acclimatized aviary with one without acclimatization in the spring and summer verified that the air temperature was significantly lower. However, as expected, the relative humidity in acclimatized shed was higher ($p \leqslant 0.05$) than in the no acclimatized shed. The results corroborate with those observed by Silva et al. (2013).

The results show the importance of controlling environmental variables, because understanding and controlling the bioclimatic environment is crucial for the success of the production and welfare of the hens. Heat is one of the most important environmental stressors that challenge world poultry production. The negative effects of thermal stress on laying hens vary from reduced growth to decreased production and egg quality. In addition, the negative impact of heat stress on hen welfare has recently attracted increasing population awareness (Lara & Rostagno, 2013).

Another positive factor of the lower BGHI inside the acclimatized shed can be described by Mack et al. (2013), in relation to the heat stressed hens. The authors report that in high temperature conditions, hens alter their behavior and physiological homeostasis seeking thermoregulation and thus decrease body temperature. In general, different types of birds react similarly to heat stress, expressing some individual variation in the intensity and duration of their responses. Hens under heat stress conditions spend less time feeding, more time drinking and gasping, as well as more time with raised wings, less time moving or walking, and more time in idleness.

In addition to these behavioral changes, Felver-Gant et al. (2012) observed reduced liver weights in laying hens subjected to chronic thermal stress conditions. Recent studies have also shown that heat stress can alter blood cell levels. Together with this fact, Kodaira et al. (2015) demonstrated that thermal stress causes an increase in the heterophil: lymphocyte ratio.

For the BGHI, when analyzed by seasons (autumn, winter, spring and summer), presented differences ($p \leqslant 0.05$) in all seasons. In the spring and summer, the BGHI in the acclimatized shed was lower ($p \leqslant 0.05$) than the no acclimatized aviary, and in the fall and winter, it was higher ($p \leqslant 0.05$), corroborating with the frequency distribution graphs showing lower variation in the internal environmental conditions when compared to no acclimatized shed. Silva et al. (2013) observed that birds in an environment where the BGHI was between 72 and 79 had higher productivity and better animal husbandry technical parameters.

At the end of the research, comparing the number of eggs per housed hen between the sheds, the hens in acclimatized shed produced 5.24 eggs more than no acclimatized shed. The number of eggs per housed hen in the acclimatized shed was 299.06 and in no acclimatized the rate was 293.82 eggs per hen.

The no acclimatized hen consumed less feed than the ones on the acclimatized shed at all seasons, and this difference reached 12% in spring and decreased in the winter to 2% (Figure 2).

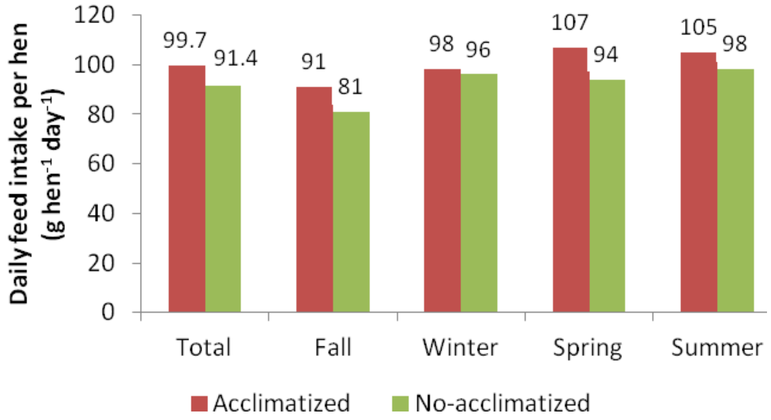

FIGURE 2. Average daily feed intake per hen (g hen^{-1} day^{-1}) in different sheds.

The results agree with Felver-Gant et al. (2014) and Al-Fataftah & Abdelqader (2013), who observed reduction in feed intake under thermal stress birds. Kilic & Simsek (2013) found a decrease of 16% in feed intake in birds with mean temperature at 31.15ºC. Feed intake was also lower in birds exposed at 31ºC compared to those exposed at 23 and 27ºC, but there were no differences between the yields in the study conducted by Yoshida et al. (2011).

For egg quality variables, Table 2 presents the values of egg weight, Haugh unit, shell resistance and shell thickness.

TABLE 2. Comparison of averages on egg quality variables between the acclimatization and no acclimatized sheds.

Season	Variable	Shed	
		Acclimatized	No Acclimatized
Total	Egg weight (g)	60.445 ± 5.005 [a]	58.962 ± 4.776 [b]
	Haugh Unit	82.300 ± 9.900 [b]	84.050 ± 9.750 [a]
	Shell Strength (kgf)	4.212 ± 0.918	4.205 ± 1.030
	Shell thickness (mm)	0.380 ± 0.052	0.378 ± 0.059
Autumn	Egg weight (g)	58.407 ± 5.152 [a]	56.380 ± 5.618 [b]
	Haugh Unit	85.268 ± 8.409 [b]	87.551 ± 10.550 [a]
	Shell Strength (kgf)	4.126 ± 0.872	4.021 ± 1.054
	Shell thickness (mm)	0.380 ± 0.064	0.374 ± 0.065
Winter	Egg weight (g)	59.307 ± 4.137	59.150 ± 4.263
	Haugh Unit	84.690 ± 9.673	85.691 ± 9.208
	Shell Strength (kgf)	4.685 ± 0.831 [b]	4.933 ± 0.726 [a]
	Shell thickness (mm)	0.428 ± 0.033 [b]	0.449 ± 0.035 [a]
Spring	Egg weight (g)	60.920 ± 4.711 [a]	59.427 ± 4.389 [b]
	Haugh Unit	79.290 ± 9.950	80.430 ± 9.070
	Shell Strength (kgf)	4.198 ± 0.841	4.207 ± 0.959
	Shell thickness (mm)	0.384 ± 0.029	0.381 ± 0.032
Summer	Egg weight (g)	62.325 ± 5.288 [a]	59.716 ± 4.439 [b]
	Haugh Unit	81.932 ± 9.815	83.460 ± 8.386
	Shell Strength (kgf)	3.826 ± 0.929 [a]	3.603 ± 0.980 [b]
	Shell thickness (mm)	0.360 ± 0.054 [a]	0.350 ± 0.061 [b]

Different letters on the same line indicate significant difference by the Tukey test at 5% significance.

It was observed a lower weight of the eggs in the no acclimatized sheds ($p \leqslant 0.05$) in comparison to the acclimatized one for the whole period of the research, except for winter, where there was no difference ($p > 0.05$) corroborating with the results obtained by Tůmová & Gous (2012) who observed temperature effects (20 and 28ºC) on feed intake, egg production and egg quality parameters. The weight of the egg was significantly lower in hens maintained at room temperature at 28ºC compared to those kept at 20ºC. According to the authors, the fact is due to the negative effect of high temperature on feed consumption which decreases in birds under thermal stress. Mack et al. (2013) and Ebeid et al. (2012) observed reduction on egg weight in laying hens exposed to thermal stress.

Haugh unit values for no acclimatized sheds ($p \leqslant 0.05$) were observed for the total period of the study, corroborating with Mashaly et al. (2004) who observed increase on Haugh unit in produced eggs by housed hens under high temperature conditions. The authors' explanation is that hens can produce eggs with better internal quality due to the reduction in the number of produced eggs.

Acclimatized provided better external quality of the egg compared to the no-acclimatized aviary in the summer, since the shell strength and shell thickness were higher ($p \leqslant 0.05$) during this period. These findings corroborate with Mack et al. (2013) and Ebeid et al. (2012), who observed a significant decrease in the shell thickness under caloric stress condition.

The acclimatized shed consumed more electricity than the no acclimatized one. The total electric energy consumed in the acclimatized system shed was 104,912 MW, while in the no-acclimatized shed was 2,792 MW during the analyzed period.

In the no-acclimatized shed there are two peaks of use electricity during the activation of the artificial lighting system to complete the photoperiod for hens. In the acclimatized shed the peak of the electric use energy is between 3:00 pm and 5:00 p.m., as the hottest time of the day and, therefore, demands a longer activation time of the acclimatization system (Figures 3 and 4).

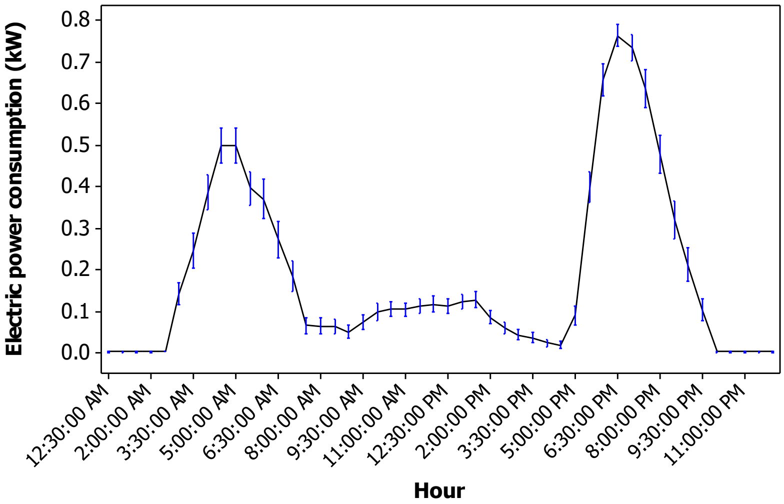

FIGURE 3. Average power consumption in no-acclimatized shed (kW).

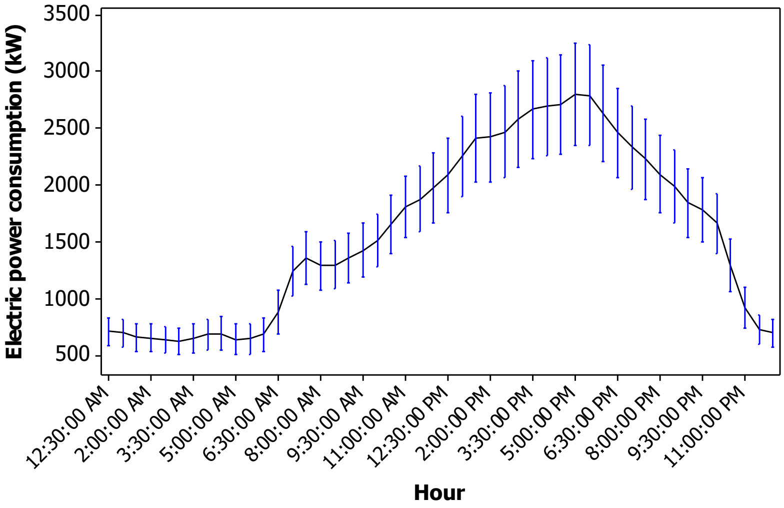

FIGURE 4 - Average consumption of electricity in the acclimatized shed (kW).

The reading voltage measured by the equipment was compared with the nominal mains voltage. According to ANEEL (National Electric Energy Agency) Resolution 505, the voltage supply can be classified as "Adequate", "Precarious" and "Critical" (Picture 1). Table 3 shows the percentage of records made in each of these categories, as well as the range of values which each category belongs, according to ANEEL (National Electric Energy Agency) Resolution 505/2001 (ANEEL, 2001).

CHART 1. Reference values for classification of voltage supply according to ANEEL Resolution 505/2001.

Category	Range of values
Suitable	0.98*NV ≤ RV ≤ 1.03*NV
Precarious	0.95*NV ≤ RV < 0.98*NV or 1.03*NV < RV ≤ 1.05*NV
Critical	RV < 0.95*NV or RV > 1.05*NV

NV = nominal mains voltage; RV = reading voltage measured by calibrated equipment.

TABLE 3. Percentage of voltage records classified in the categories defined by ANEEL Resolution 505/2001.

Shed / circuit	Category		
	Suitable	Precarious	Critical
Acclimatized / Lighting	95.62%	3.73%	0.65%
Acclimatized / Exhaust	74.42%	22.05%	3.54%
No Acclimatized	99.97%	0.03%	0.62%

There were in the acclimatized exhaust fans 3.54% of registers as critical and 22.5% as precarious. Voltage values classified as "Critical" are due to interruption in the power supply and, "Precarious", result from oscillations in the electric power supply.

Failures in power supply occurred more frequently during the hottest times of the day, harming the operation of the installed acclimatized (Figure 5).

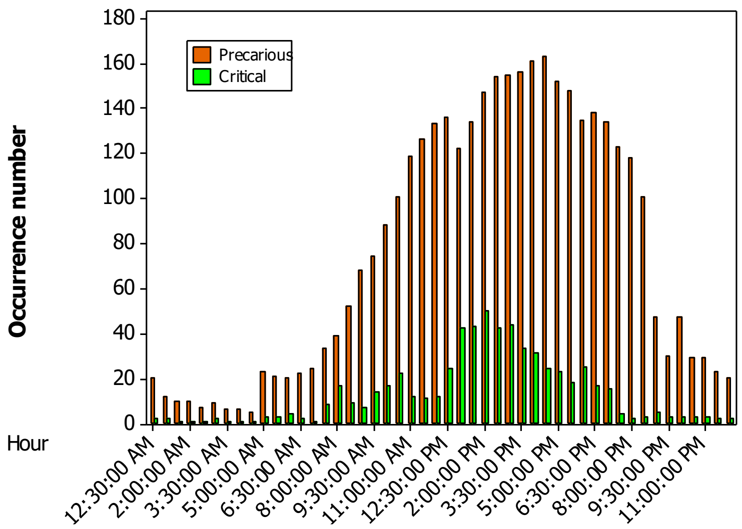

FIGURE 5. Frequency of failures in electricity supply by daylight hours.

The number of occurrences on power supply failures is observed during the entire period of the survey (Figure 6).

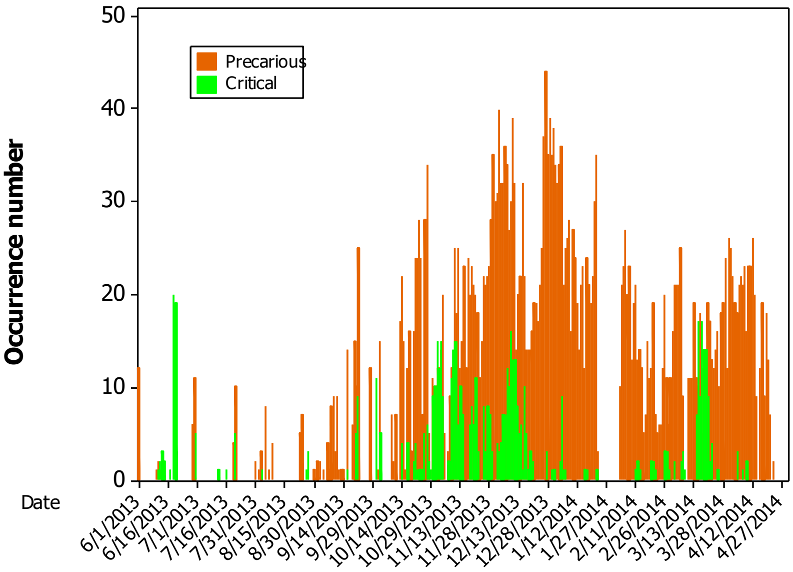

FIGURE 6. Number of failures in electricity supply in the acclimatized shed, measured on the exhaust fans, per day of experiment.

In the comparative analysis of mortality between the acclimatized and no acclimatized sheds, there was no difference in the *Student-t* test at 5% significance where the average mortality of the acclimatized shed was 0.21% and the no acclimatized shed remained at 0.20% per week.

However, in the *boxplot* graphic, Figure 7 the total weekly mortality shows two occurrences (weeks) in the acclimatized shed where mortality was well above average. These weeks correspond to the week of April 3rd to 9th, 2013 and to the week of November 6th to 12th, 2013 where were observed 605 and 700 dead hens, respectively, when the expected would be 60 hens (0.1% mortality week^{-1}). Figure 8 shows the hens mortality in each shed throughout the survey period.

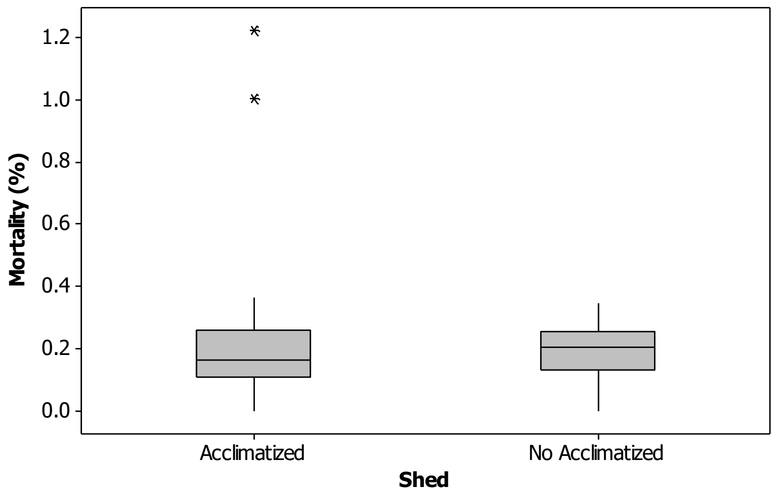

FIGURE 7. *Boxplot* graphic of total weekly mortality (%) in the different sheds.

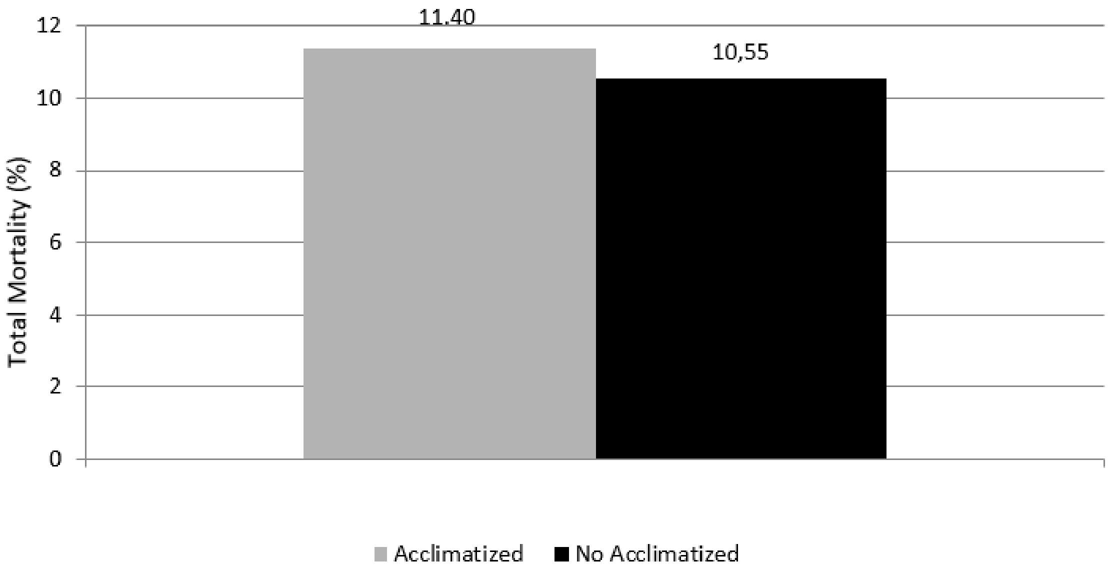

FIGURE 8. Cumulative mortality (%) in different sheds.

The results were different from those observed by Silva et al. (2013) and Al-Fataftah & Abdelqader (2013) who verified that total mortality of the acclimatized shed was significantly lower than in the no acclimatized shed in their respective surveys.

In this study, the maximum BGHI recorded in the week of April, 2013 was 81.00 and the recorded mortality in one day was 590 hens in the acclimatized shed. In November were registered several interruptions of electricity, and on November 11th was recorded mortality of 600 hens in the acclimatized shed. The previous day when there were several interruptions in the electricity supply was recorded in the shed maximum BGHI of 86.31. The ability to acclimatization laying hens at high temperatures is obtained after 7 days of exposure to heat (Sylkes & Fataftah, 1986; Yahav, 2009), a fact observed by Pereira et al. (2010) which verified a higher mortality rate in aviaries in Bastos-SP from September to October, months in which occur the first heat waves in relation to December and January, when is recorded the highest temperatures. The hens in the acclimatized shed were not acclimatized to high temperatures when power supply failures occurred, so mortality was well above the lineage standard.

CONCLUSIONS

The acclimatization system was effective, providing the reduction of temperature and a thermal environment more suitable for raising hens.

The electricity supply at times of higher temperature was not guaranteed and the acclimatization was not efficient on mortality control. However, even with the interruptions, the production and quality of the eggs in the acclimatized shed were better, ensuring the technical feasibility of the system. .

It is necessary that the system of electricity supply is best sized for the aviary.

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