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Identification of Critical Points of Thermal Environment in Broiler Production

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Broilers, hatchery, quality control.

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ABSTRACT

This paper describes an exploratory study carried out to determine critical control points and possible risks in hatcheries and broiler farms. The study was based in the identification of the potential hazards existing in broiler production, from the hatchery to the broiler farm, identifying critical control points and defining critical limits. The following rooms were analyzed in the hatchery: egg cold storage, pre-heating, incubator, and hatcher rooms. Two broiler houses were studied in two different farms. The following data were collected in the hatchery and broiler houses: temperature (°C) and relative humidity (%), air velocity (m s⁻¹), ammonia levels, and light intensity (lx). In the broiler house study, a questionnaire using information of the Broiler Production Good Practices (BPGP) manual was applied, and workers were interviewed. Risk analysis matrices were built to determine Critical Control Points (CCP). After data collection, Statistical Process Control (SPC) was applied through the analysis of the Process Capacity Index, using the software program Minitab15®. Environmental temperature and relative humidity were the critical points identified in the hatchery and in both farms. The classes determined as critical control points in the broiler houses were poultry litter, feeding, drinking water, workers' hygiene and health, management and biosecurity, norms and legislation, facilities, and activity planning. It was concluded that CCP analysis, associated with SPC control tools and guidelines of good production practices, may contribute to improve quality control in poultry production.

INTRODUCTION

Brazilian broiler meat production has grown and developed in the last few years, and has shown expressive results such as reduction of production cost, better product quality, increasing presence in the international market, increasing domestic consumption per capita, and good production performance as compared to other meat industries (Pinotti & Paulillo, 2006).

Cesari & Nascimento (1995) mentioned that critical points must be prevented, eliminated, or reduced to acceptable levels, which means they need to be controlled. The control of identified biological, chemical, and physical hazards is important from raw material supply up to product delivery to the consumers. The different links of the chain, such as raw materials, storage, transport, bird management, and pre-slaughter management, must be monitored and controlled for food quality and safety programs. Hazard analysis requires the assessment of two factors as to the identified risks: the probability of hazards and their severity.

Poultry production in Brazil is one of the animal production chains with the highest level of coordination, which allows it to be very competitive in the international market. As broiler meat consumption



has increased worldwide in the last few years, consumers have become more demanding as to the quality and safety of this product. In order to export, the Brazilian poultry industry must demonstrate through documents, records (traceability), and certifications that it has standardized systems of broiler production good practices (BPGP), of critical control points (CCP), and hazard analysis and critical control points (HACCP) in place, as required by the Brazilian legislation, as well as international certification programs relative to food safety (Almeida, 1998).

The present paper describes an exploratory study aimed at identifying critical points and possible hazards in hatcheries and broiler farms.

MATERIAL AND METHODS

The study was conducted in a multiple-stage hatchery and in two farms (A and B) located in the state of São Paulo, Brazil.

The following hatchery rooms were investigated: egg cold storage, egg pre-heating, incubator, and hatcher rooms.

Data loggers (HOBO®) to record environmental temperature (T) and relative humidity (RH) were placed in each room. Air velocity (AV) was measured using a hygro-thermometer anemometer (HTA4200 PACER®). In the broiler houses, ammonia was recorded using a suction pump and calorimetric tubes (DRAKER®) and light intensity was measured using a digital lux meter (HOMIS®) according to the methodology proposed by Jones *et al.* (2005) and Bessei (2006). The equipment was placed in the geometrical center of each hatchery room and broiler house. Egg and newly-hatched chick surface temperatures were collected using an infrared camera (TESTO® 880).

In the hatchery, CCP analysis was carried out considering internal environment parameters

(Nicholson, 2006; Mauldin, 2007); management and biosecurity were not evaluated.

In the broiler houses, the questionnaire of the manual Broiler Good Production Practices (Boas Práticas de Produção de Frango de Corte, Embrapa, 2007) was applied and employees/farmers were interviewed. The risk analysis matrix (Dillon & Griffith, 2001) was subsequently applied according to Equation 1, which determines if the indicated/classified risk can be controlled after its occurrence and severity are analyzed.

$$\text{Risk} = \text{probability of occurrence} \times \text{severity} \quad \text{Eq. 1}$$

The risk analysis matrix was applied to evaluate the frequency (probability of occurrence) and severity (how severe are the consequences if the incident occurs), using multiplication to obtain comparative scores (Table 1).

BPGP was evaluated according to seven classes (norms, legislation, and facilities; activity planning; management and biosecurity; poultry litter; feed; water; and workers' hygiene and health), which processes were assessed, and the set of questions corresponding to the analyzed step was presented.

After collection in the hatchery and broiler houses, data were submitted to statistical analysis using the software MINITAB 15® (Minitab, 2005), and mean comparison method. Process Statistical Control (PSC) was applied for the analysis of the Process Capacity Index to check if the process was within the specified limits (Tables 2 and 3). That index was also analyzed using Cp and Cpk (Equations 2 and 3).

$$C_p = \frac{LSE - LIE}{6\hat{\sigma}} \quad \text{Eq. 2}$$

Table 1 - Matrix for the assessment of biological, chemical, and physical risks and identification of possible vectors.

Probability of occurrence	Severity		
	Low (1)	Intermediate (2)	High (3)
Unlikely (1)	Irrelevant (1)	Tolerable (2)	Moderate (3)
Occasional (2)	Tolerable (2)	Moderate (4)	Considerable (6)
Likely (3)	Moderate (3)	Considerable (6)	Intolerable (9)
Irrelevant (1)	It does not require any action, only monitoring.		
Tolerable (2)	It requires monitoring and preventive measures.		
Moderate (3/4)	It requires actions/efforts to reduce risk. Control Plan.		
Considerable (6)	Work cannot be resumed until risk is reduced. If work is underway, urgent risk control measures should be taken, and risk must be reevaluated.		
Intolerable (9)	Work can only be resumed after correction actions. If work is underway, work after risk reduction can only be resumed after biosecurity and food safety measures are ensured.		

Source: Adapted from Dillon & Griffith (2001).



$$C_{pk} = \min \left(\frac{LSE - \bar{\bar{x}}}{3\hat{\sigma}}, \frac{\bar{\bar{x}} - LIE}{3\hat{\sigma}} \right) \quad \text{Eq. 3}$$

where: LSE = Higher Specification Limit, LIE = Lower Specification Limit, $\bar{\bar{x}}$ = process average, and $\hat{\sigma}$ = standard deviation.

RESULTS AND DISCUSSION

Hatchery

Table 4 shows a summary of the CCPs identified in the hatchery as a result of thermal environment analysis, comparing them with the specified maximum and minimum limit values, which must be controlled to obtain better productivity indexes.

Table 2 - Optimal value range to check critical limits (minimum and maximum) of the CCPs collected in the hatchery.

Parameter	Cold storage	Pré-heating room	Incubator	Hatcher and processing	References
T (°C)	19-22	25-27	37-38	35.7-37	Decuyper (1992); Gustin (2003); Boerjan (2006); Mauldin (2007).
RH (%)	70-80	≥70	50-60	65	Bruzual <i>et al.</i> (2000); Muraroli (2003).
sT chick	-	-	-	38.6	Nicholson (2006); Boerjan (2006).
sT egg	-	-	37.2-38.8	-	Boerjan (2006).
AV (m s ⁻¹)	-	-	-	0.5-3	Kaltofen (1969).

Table 3 - Lower and upper critical limits of tolerance adopted for broiler production.

Parameters	Limit		References
	Minimum	Maximum	
Internal environment			Albright (1990); Miragliotta <i>et al.</i> (2001); Moura (2001); Pereira (2005); (Owada <i>et al.</i> , 2007); Estevez (2007); Moraes <i>et al.</i> (2008)
Temperature	20°C	28°C	
Relative humidity	40%	80%	
Air velocity	1.0 m s ⁻¹	2.45 m s ⁻¹	
Light intensity	C.E.	-	
Density	C.E.	38 kg m ⁻²	
Air			
Ammonia	-	20 ppm	Miragliotta <i>et al.</i> (2001).
Feeding			
Feeding	C.E.	C.E.	Mendes <i>et al.</i> (1997); Macari (1996); Nääs <i>et al.</i> (2001); Brasil (CONAMA, 2005).
Drinking water	C.E.	C.E.	
Drinkability	2 ppm HCl	3 ppm HCl	
Distribution logistics	C.E.	C.E.	
Availability/consumption	280 L (10 ³ bird) ⁻¹	600 L (10 ³ bird) ⁻¹	
Worker			
PPEs	C.E.	C.E.	Nääs <i>et al.</i> (2001); Alencar <i>et al.</i> 2007; Pereira (2005); Salgado <i>et al.</i> (2007); Ohsas (1999) e Ohsas (1991); EMBRAPA (2007).
Hygiene	C.E.	C.E.	
Health risks: (physical, mechanical, chemical and mechanical contaminants, psychological stress, ergonomics)	Interview, observation e C.E.	Interview, observation e C.E.	
Facility (visual observation)			
Electricity and water supply	C.E.	C.E.	EMBRAPA (2007); Ohsa (1999), Nääs <i>et al.</i> (2001)
Inputs	C.E.	C.E.	
Surroundings	C.E.	C.E.	
Pest control	C.E.	C.E.	
Bird health control (weeks 4-7)	C.E.	C.E.	

Table 4 - Collected and recommended values, and CCPs identified in the hatchery.

Location Parameter	Cold storage		Pre-heating room		Incubator		Hatcher		CCP
	Collected	Optimal	Collected	Optimal	Collected value	Optimal	Collected	Optimal	
T (°C)	17.9	19-22	24.5	25-27	36.8	37-38	36.6	35.7-37	Sim
SD	0.920	0, 873	0.868	1, 58					
RH (%)	54.85	70-80	64	≥70	53.10	50-60	55.7	65	Sim
SD	18.68	6.189	10.2	6.034					
sT chick(°C)							34.1	38.6	Sim
SD			0.318						
sT egg (°C)	16.8	-	24.7	-	38.2	37.2-38.8-	38.4	-	Não
SD	0.2	0.12	0.38	0.34					
AV (m s ⁻¹)	0	0	0.54	-	1.32	-	0.73	-	Sim
SD	0.23	0.72	0.36						

- Indicates that there is no information. SD= standard deviation.



Average temperature recorded in the cold storage room was $17.9 \pm 0.9^{\circ}\text{C}$, which is much lower than the specified environmental temperature of 19 to 22°C (Decuypere, 1992; Gustin, 2003; Boleli, 2003; Boerjan, 2006; Mauldin, 2007). Environmental temperature Cp index (0.54) was < 1 , which means it was stable, but outside the specified tolerance limits. The Cpk value (-0.38) indicates that 87.03% of the data were below the specified lower tolerance limit (Figure 1). Average relative humidity was $54 \pm 18\%$ and the applied RH tolerance limits were 70 to 80%. Figure 2 shows that RH value was relatively stable in the analyzed environment; however, it was below the lower limit. The determined Cp value (0.09) indicates relative variability of the collected data. The Cpk value (-0.27) confirms that the process is not controlled, showing that only 19.88% of the collected data was within the specified range (70 to 80% RH), and therefore needs to be reviewed.

As to the egg pre-heating room temperature (Figure 3), the obtained Cp value used to analyze process capacity was 0.38, outside the tolerance limits of 25 to 27°C , and that the data were symmetrical, varying between 23.1 and 24.3°C , but below the lower tolerance limit. The obtained Cpk value (-0.32) indicates that the process is not centralized within the average tolerance levels, and that only 16.51% of the values were in the range of 25 to 27°C . Average RH of the egg pre-heating room was $64 \pm 6\%$, which is below the recommended limit (70 to 80%, Bruzual *et al.*, 2000) as shown in Figure 4. The process that controls this parameter was not able to keep RH within the recommended limits, and low RH may reduce chick weight and result in longer incubation time (Muraroli & Mendes, 2003), causing late embryo mortality (Decuypere *et al.*, 2003; Pedroso, 2006). The Cp value (0.27) used to analyze process capacity was constant and with low variability, but below the lower tolerance limit (70 to 80%). Cpk (-0.32) indicated that the process was not within the average or specified values - only 16.62 % of the data were within the RH range of 70 to 80% (Bruzual *et al.*, 2000).

Incubator average environmental temperature ($36.8 \pm 0.9^{\circ}\text{C}$) indicates that only part of the data comply with specified temperature range (37 to 38°C), which indicates this is a CCP (French, 1997; Decuypere *et al.*, 2003; Gustin, 2003; Hill, 2004; Boerjan, 2006; Gigli, 2007). The obtained Cp value to analyze process capacity was 0.19, indicating that temperature remained constant and presented low variability, despite being below the lower tolerance limit, as

presented in Figure 5. The obtained Cpk was -0.13, showing that the process is not centered within the specified temperature range of 37 to 38°C . According to Gustin (2003) temperature variations of $\pm 1^{\circ}\text{C}$ may have a strong impact in hatchability as it increases hatching time. The average RH value ($53.09 \pm 10\%$) was within the specified tolerance limits (50 to 60%, Figure 6). The calculated Cp value (0.17), with constant variation, showed that 62.40% of the collected data complied with the specifications. The Cpk value (0.10) indicates the need of better control of RH in the incubator; despite being closer to the center, it still has some points outside the specified limits. Although there was better control of incubator relative humidity, indexes show that 37.6% of the data was below the lower limit and approximately 13% were beyond the upper limit. This better control of the thermal environment of the incubator was obtained by a closer monitoring of the process to improve the rate of 85% hatchability of fertile eggs in 2008 in that hatchery. Decuypere *et al.* (2003) and French (1997) mentioned that hatchability is less affected by variations in relative humidity than variations in temperature, which must be maintained within an optimal range of 37 to 38°C to ensure good results, according to Wilson (1991).

In the hatcher room, average environmental temperature was $36.6 \pm 1.6^{\circ}\text{C}$, and 68.69% of the collected data were within the tolerance limits (35.7 to 37°C ; Decuypere, 1992; Boerjan, 2006; Mauldin, 2007). Cp (0.13) presented constant variation, indicating that 68.69% of the measured temperatures were according to the recommended specifications. The obtained Cpk value (0.07) showed that the process that controls temperature was more consistent, despite some points outside the specified limits (Figure 7). Figure 8 shows that the average RH value in the hatcher ($55.7 \pm 6\%$) was below the lower limit of 65%, which indicates considerable risk of lower efficiency, embryo weight reduction, and consequent chick mortality (Bruzual *et al.*, 2000).

Broiler houses

The identified critical points identified in the evaluated broiler houses were environmental temperature and relative humidity. Average environmental temperatures in farm A ($26.4 \pm 1.8^{\circ}\text{C}$, Figure 9) and farm B ($28.2 \pm 1.5^{\circ}\text{C}$, Figure 10) were within the threshold limits (20 to 28°C), as determined by Curtis (1983), Albright (1990), Moura (2001), Pereira (2005), and Owada *et al.* (2007).

The Cp value obtained in farm A (0.74) showed

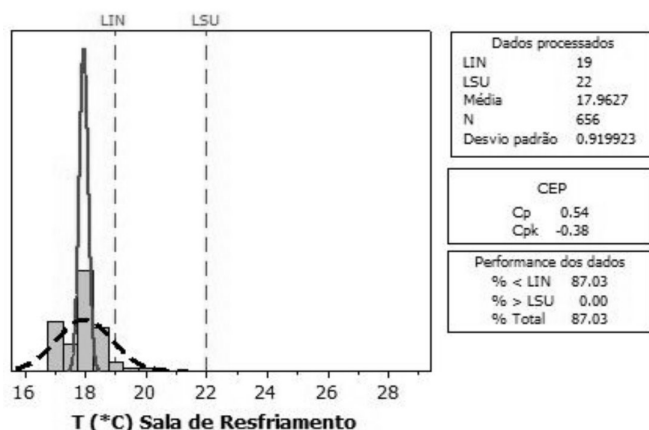


Figure 1 - Histogram of the environmental temperature in the egg cold storage room.

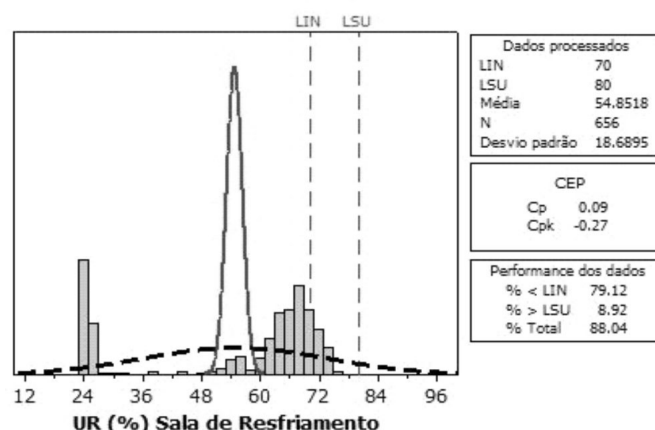


Figure 2 - Histogram of the relative humidity in the egg cold storage room.

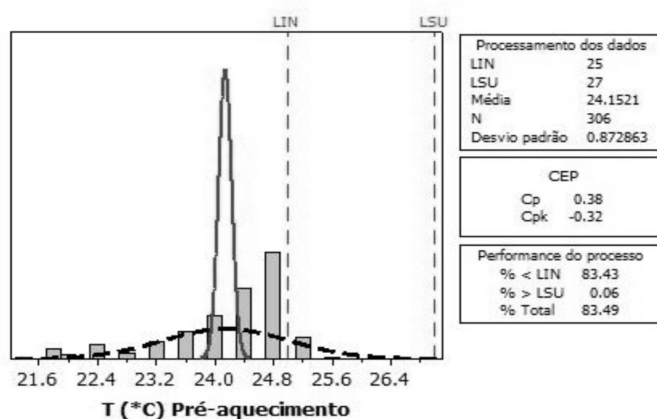


Figure 3 - Histogram of the environmental temperature in the egg pre-heating room.

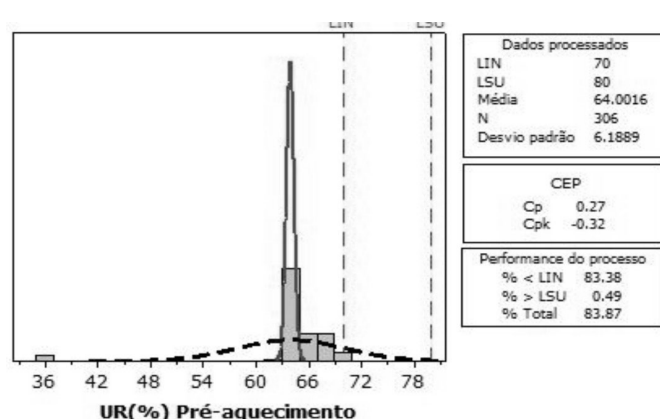


Figure 4 - Histogram of the relative humidity in the egg pre-heating room.

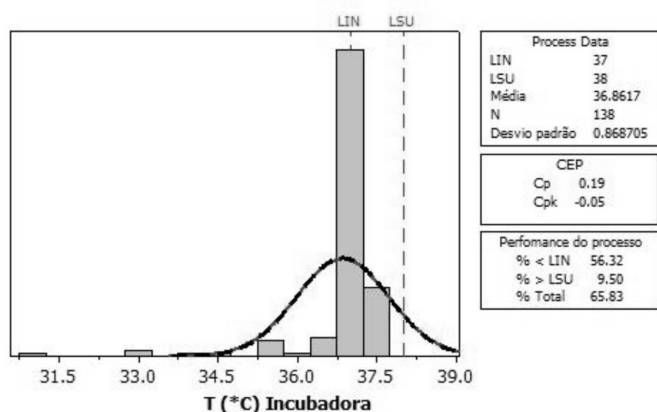


Figure 5 - Histogram of the temperature in the incubator.

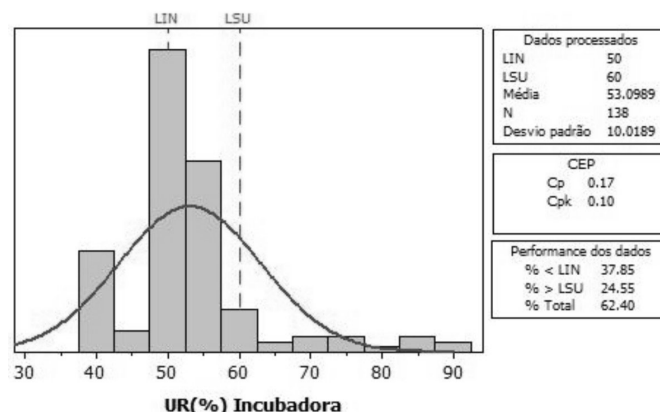


Figure 6 - Histogram of the relative humidity in the incubator.

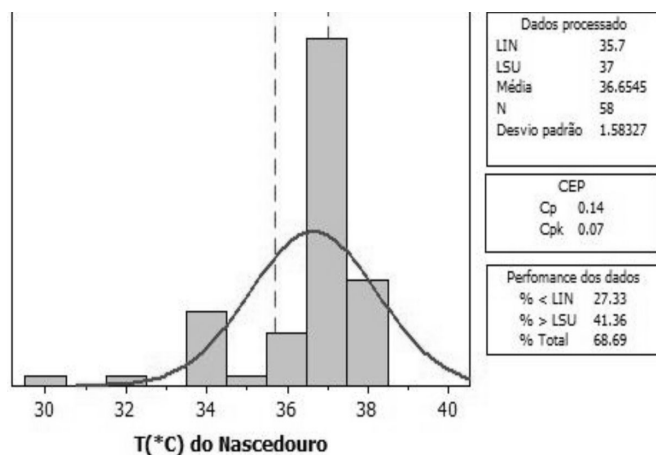


Figure 7 - Histogram of the temperature in hatcher room.

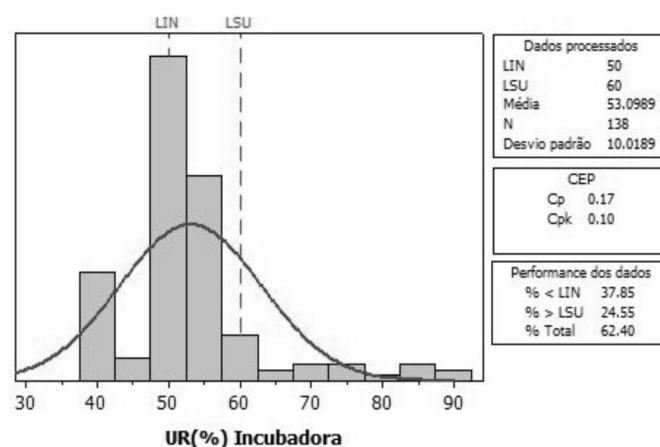


Figure 8 - Histogram of the relative humidity in the incubator.

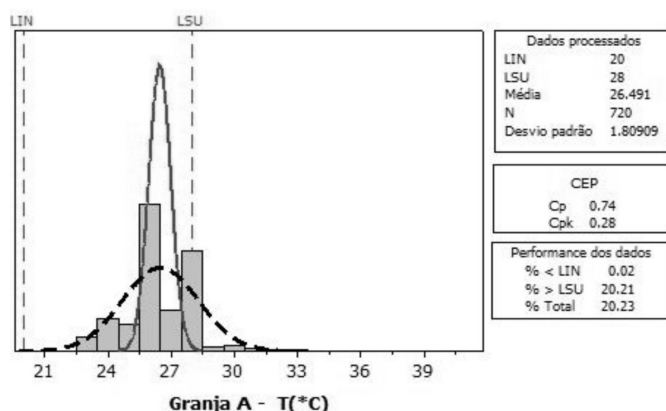


Figure 9 - Histogram of the temperature in the broiler house of farm A.

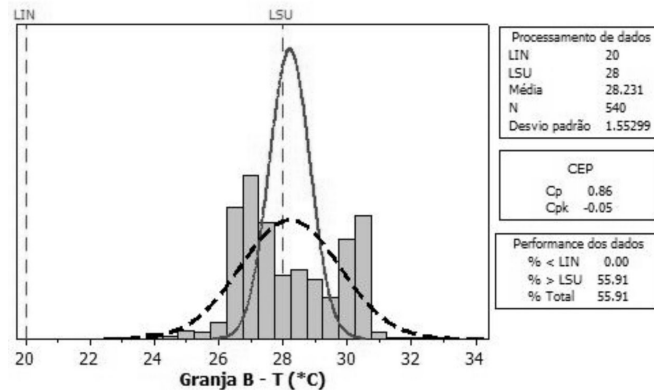


Figure 10 - Histogram of the temperature in the broiler house of farm B.

higher variation for the upper limit of 28°C, with 20% of the data being higher than the established upper limit. The Cpk value (0.28) revealed that the process for the control of average temperature should be 24 °C, but the obtained average value was 26.4, indicating that the process, despite complying with the tolerance limits, was asymmetrical to the left, and therefore needs to be reviewed. As the broiler house was not insulated, internal environmental conditions were very sensitive to daily variations in the external environment, resulting in wide daily temperature amplitude (Moura, 2001).

In farm B the obtained Cp value (0.86) presented constant and increasing variation relative to the upper limit, showing that 55.9% of the house temperature was beyond the specified upper limit of 28 °C. This

thermal environment is outside the zone considered as thermoneutral, causing heat stress and increasing mortality (Nääs, 1997; Silva, 2008). The data collected showed that the process was asymmetrical to the left, and was not able to comply with the Cpk index, with average expected values of 24°C. Therefore, better monitoring and process control are strongly recommended.

Average RH values obtained in farm A ($43.47 \pm 6\%$, Figure 11) and farm B ($53.01 \pm 8\%$, Figure 12) were within the specified threshold of 40 to 80% (Miragliotta *et al.* 2001; Moura 2001). In farm A, Cp (1.09) showed higher variation as to the lower specified limit, with 28.52% of relative humidity data below this limit, which indicates that the process is acceptable. Cpk (0.19) shows that the process is not centered in the average



value of 60%, and therefore corrective actions are required to obtain a more accurate control. The Cp value obtained for RH in farm B (0.78) indicates that data were concentrated and there was higher variation as to the lower limit, considering an optimal average value of 60%. About 6.29% of the collected data were outside the established lower limit of 40%. Cpk (0.51) indicated the need to review the process to obtain higher precision in the control of the internal environment, as the obtained average RH value was 53%, which is below the optimal value of 60%.

Air velocity value (m s^{-1}) in farm A was below the lower specified level of tolerance (1m s^{-1}), whereas in farm B, there was better control. The increase in temperature associated with lower air velocity is a critical control point, as it usually increases bird mortality (Owada *et al.*, 2007). The ammonia levels collected in farms A and B were below the limit of 20ppm, which is considered acceptable (CIGR, 1994; Sampaio *et al.*, 2005; Miragliotta, 2005; Owada *et al.*, 2007). Average light intensity values recorded in both farms were homogenous.

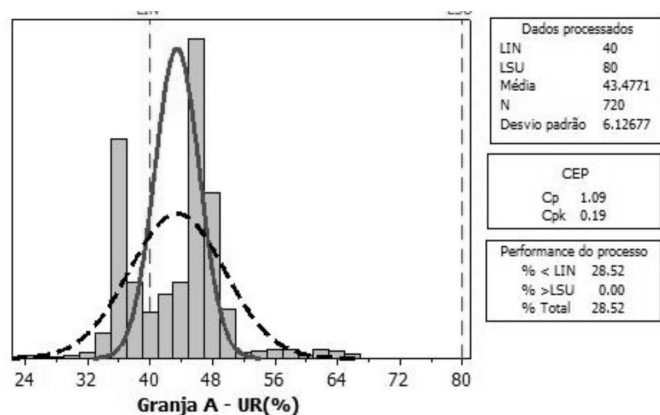


Figure 11 - Histogram of the relative humidity in the broiler house of farm A.

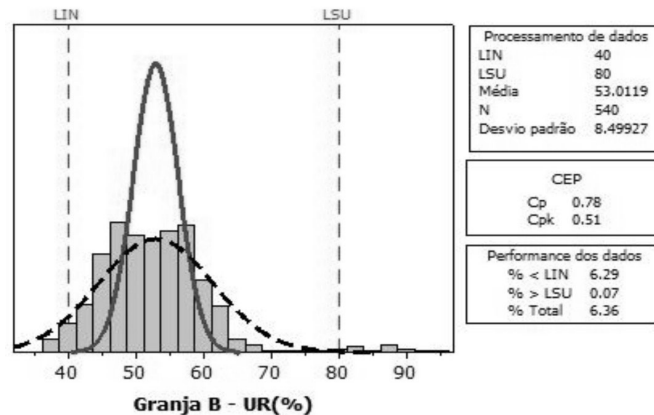


Figure 12 - Histogram of the relative humidity in the broiler house of farm B.

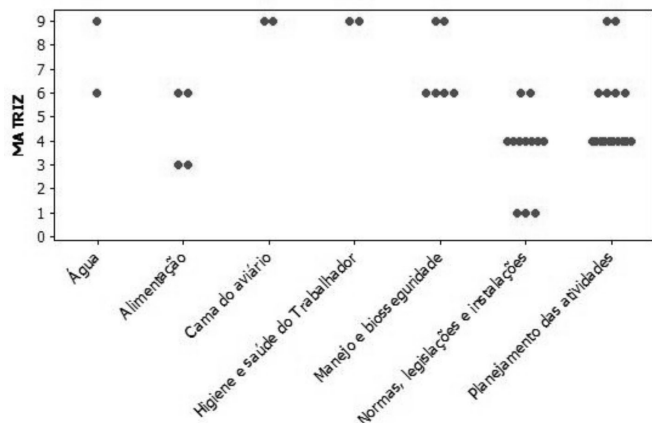


Figure 13 - Risk analysis matrix and classification of critical control points according to class.

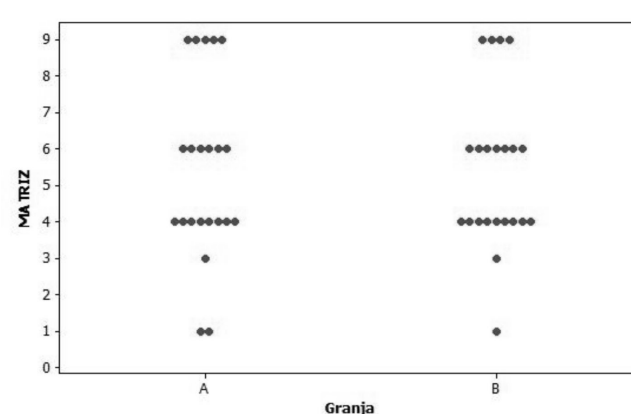


Figure 14 - Comparative classification of risk analysis matrices of farms A and B.



CONCLUSIONS

The critical control points evaluated in the different steps of the hatchery were ambient temperature and relative humidity, which severity can be minimized by implementing higher control. As to the broiler houses, environmental temperature and relative humidity were the identified critical points. When BPGPs were analyzed, the following critical control points were determined: poultry litter, feeding, drinking water, workers' hygiene and health, management and biosecurity, norms and legislation, facilities, and activity planning. The critical control points can have their severity minimized by the implementation of BPGPs and control of CCP, thereby providing better planning, monitoring, traceability, and safety for the broiler production chain, resulting in higher productivity and better animal welfare and worker wellbeing.

CCP analysis, associated with SPC control tools and good production practice guidelines, may contribute to quality assurance in industrial poultry production, bringing more reliability to the production chain.

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