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Research Article
Pale, Soft and Exudative (PSE) and Dark, Firm and Dry (DFD) Meat Determination in Broiler Chicken Raised Under Tropical Climate Management Conditions

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Abstract

Background and Objective: The Brazilian poultry industry has difficulties in maintaining meat quality standard as the country presents diverse climate conditions particularly having tropical and subtropical zones. Whilst the total gross production is located within the subtropical zones no much is currently known in the tropical zone particularly within the North Eastern (NE) region. This study was conducted to evaluate the broiler breast meat quality by quantifying the incidence of pale, soft and exudative (PSE) and dark, firm and dry (DFD) meat in a commercial processing plant during the dry and rainy seasons in the Brazilian NE region. **Materials and Methods:** A total of 2,800 breast samples were collected during the dry (n = 1,400) and rainy (n = 1,400) season. The animals were slaughtered and carcass processed according to the standard industry practices. The student's t-test with a 5% probability ($p<0.05$) was used to compare the differences among the averages of lightness (L*), redness (a*), yellowness (b*), ultimate pH (pHu) and Water Holding Capacity (WHC) in pectoralis major. **Results:** The incidence of PSE meat was 43.53 and 10.46% in dry and rainy season, respectively. Additionally, 3.3% of DFD meat was found as the result of wet weather conditions only observed in the rainy season. **Conclusion:** The high occurrence of PSE-meat suggested the need to control broiler pre and pos-slaughter handling conditions in order to maintain the meat quality. Despite of hot weather conditions either in the rainy or dry season, it is feasible to motivate the broiler growth activities within the Brazilian tropical zone.

Key words: Meat quality, heat stress, wet-cold weather, hyperthermia, accidental hypothermia, cut-off values determination

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The climate conditions under tropical zones present unique opportunity to study animal welfare and its consequences on meat quality in particular meat colour abnormalities such as pale, soft and exudative (PSE) and dark, firm and dry (DFD) meat. The PSE meat occurs when the animal frequently faces heat stress accelerating the muscle glycolysis thus under stress conditions the meat proteins denature and consequently lose their Water Holding Capacity (WHC). As a result, the meat becomes wet and pale at its surface and has a soft appearance[1]. Conversely, DFD meat is the consequence of depleted muscle glycogen and it is a post-rigor condition resulting in a relatively higher ultimate pH (pHu) thus the myofibril proteins present higher WHC and the meat surface is dry resulting in dark colour and a firm appearance[2,3].

Figure 1a shows that Brazil is located under equator line in the North and below the tropic Capricorn line in the South. Whilst, the Southern region contributes 62.83% of the total broiler meat production (Fig. 2), the North East (NE) presents its production equivalent to only 2.07% of the national production (Fig. 2). Moreover, Bahia (BA), Paraíba (PB), Pernambuco (PE) and Piauí (PI) among the 9 NE states are the only states with broiler chicken companies inspected by the Federal Inspection Service (FIS)[4] (Fig. 1b). An official estimation indicates that in 2015, the consumption of broiler meat was 43.25 kg capita^{-1} however, in the NE[4], it was only 5.12 kg capita^{-1}. This figure does not represent the actual consumption by the NE population as broiler meat is routinely distributed at the commercial level as "Hot chicken meat" as at the purchase location, the bird is slaughtered, plucked and deboned the carcass at real-time in front of the consumer without any food inspection thus affecting the food safety system. Consequently, there is no official estimation of the actual quantity of meat-consumed locally[5].

These facts indicated the need to motivate the implementation of commercial slaughterhouses in the North and NE regions resulting obviously in offering a safer food to the local population and also promoting the agro-technological area development leaving its broiler meat dependence on the importation from other productive states[5].

The present study was carried out in a semi-arid tropical region (Fig. 1a)[6] where there are only annually two seasons as dry in the summer season and rainy in the winter season and the cold weather is practically nonexistent. In addition, the interrelationship between poultry stress and its consequence on meat qualities has been previously evaluated in the subtropical region[1,2,7-9].

Appropriate management systems are thus necessary to promote poultry welfare preventing stressful conditions leading to this heat stress conditions and the development

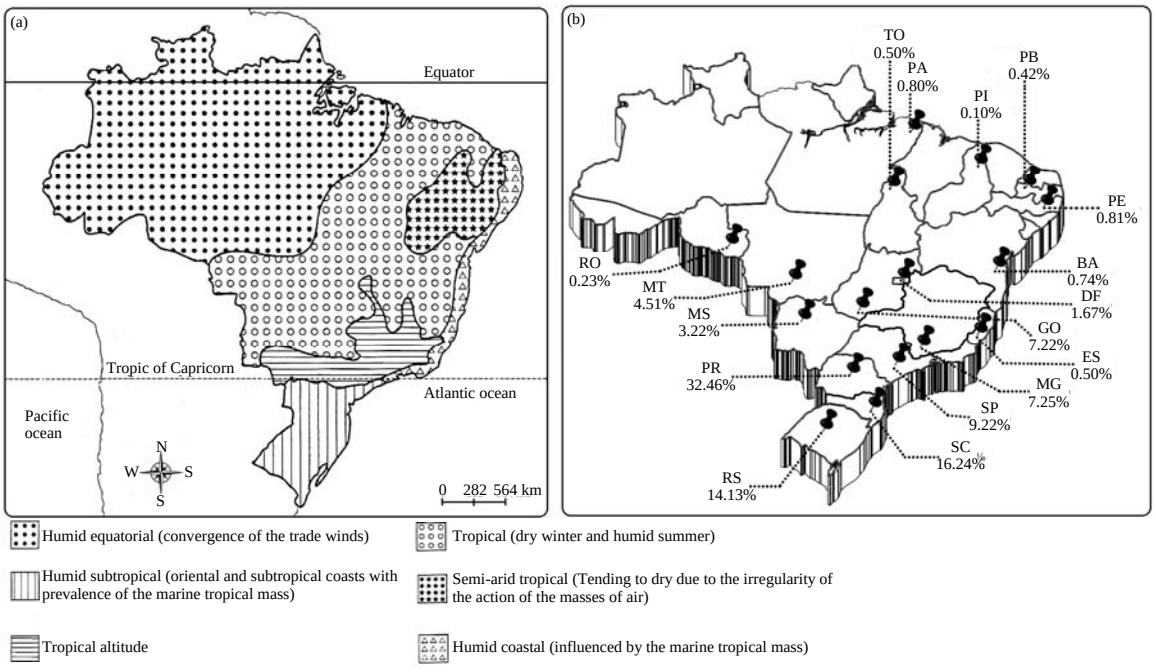

Fig. 1(a-b): (a) Brazil geographical localization under Equator line in the north and below the Tropic Capricorn line in the South and the respective climate zones and (b) Broiler chickens slaughtered (%) in every Brazilian state in 2015[4]. The birds slaughtering distribution is concentrated within the subtropical zone

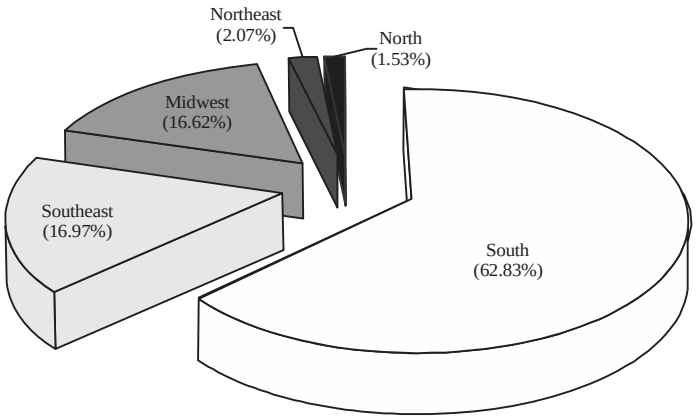

Fig. 2: Percentages of broiler chickens slaughtered among Brazilian 5 regions of North, Northeast, Midwest, Southeast and South, in 2015[4]

of meat colour abnormalities[1,7,8]. In a previous study, the in-transit handling of the animals and lairage conditions were thoroughly discussed[9] and unfortunately other technical reports are difficult to find in the literature therefore there is a need to study the birds behaviour and meat quality under hot and dry climate conditions.

Thus, the aim of this study was to examine the broiler chicken welfare by determining the incidence of broiler breast PSE and DFD-meat in a commercial slaughterhouse located in a tropical climate as Brazilian NE region.

MATERIALS AND METHODS

Commercial slaughterhouse location: This study was conducted during the rainy season (from May-July, 2015) and the dry season (from September-November, 2015) in Guarabira city area, Paraíba (PB), located within Brazil tropical climate region[9]. The experiment was performed in a commercial processing plant of a cooperative integrated system and the birds were collected originally from different broiler chicken farms. The animals were processed using the following sequence of standard industry practices: Suspension, electrical stunning, bleeding, scalding, evisceration, carcass cooling through chillers, deboning and the removal of breast samples (Pectoralis major m.). The breast meat samples were randomly collected and refrigerated at 4°C for 24 h for the subsequent colour, pH and WHC analyses.

Determination of pH and colour: A total of 2,800 breast samples were collected during the dry (n = 1,400) and rainy (n = 1,400) season. The ultimate pH (pHu) values were obtained by inserting electrodes into the ventral cranial part of the filet using a contact pH meter system (Testo 205, Lenzkirch, Germany). The analyses were performed in triplicate 24 h post mortem as previously described in Olivo *et al.*[10]. A Minolta CR400 colorimeter (Konica Minolta Sensing Inc., Osaka, Japan) was used to evaluate the colour L* (lightness), a* (redness) and b* (yellowness) (CIELAB colour system) at the dorsal surface of the intact skinless breast muscles. The L*, a* and b* values were measured at 3 sites in the same sample, the proximal extremity of the muscle, the distal extremity and the medial side halfway between the proximal and the distal extremity[11].

Water Holding Capacity (WHC) measurement: The WHC determination was based on the technique reported by Hamm[12] described by Wilhelm *et al.*[13]. At 24 h the post mortem samples were collected from the cranial side of the breast fillets and cut into cubes 2.0±0.10 g. A total of 524 samples were analyzed in duplicate. The samples were carefully placed between two pieces of filter paper (Whatman No. 2) in acrylic plates and then compressed under a 10 kg weight for 5 min. The samples were weighed and then the WHC was determined using the exuded water weight and the following equation:

$$100 - \frac{\text{Wi-Wf}}{\text{Wi}} \times 100$$

where, Wi and Wf are the initial and final weights of the sample[12], respectively.

Statistical analysis: The student t-test ($p<0.05$) was applied to compare the differences among the data (pH, L* and WHC) of the of the PSE, DFD and normal meat collected during the rainy and dry season. Data were presented as Mean±Standard Deviation (SD). The comparison t-test ($p<0.05$) was performed

using the Statistic 7.0 software program (StatSoft, Tulsa, OK, USA). The Pearson correlation coefficient was determined ($p<0.01$) to verify the correlations among obtained data (pH, color parameters and WHC) from all samples of dry and rainy seasons.

RESULTS

Determination of cut-off values of pH and L* for PSE and DFD-meat: The pHu and L* values were determined under commercial conditions of the slaughterhouse and the histogram of distribution was constructed to define the respective values of pHu and L* cuts for the chicken breasts PSE and DFD collected during the rainy (n = 1,400) and dry (n = 1,400) seasons. The L* values (Fig. 3a) ranged from 38.0 (dark) to 68.0 (pale) and the average value was 53.1. The pHu values (Fig. 3b) ranged from 5.5-6.5 and the average value was 5.9.

The Pearson correlation (Table 1) between L* and pHu values was significantly ($p<0.01$) negative (-0.58). Negative value indicates a lower pHu value which was associated with higher L*. As a result, less moisture is retained within the muscle and consequently a low WHC value was obtained. A negative Pearson correlation (-0.36) between the L* and WHC values was also observed. These results indicate a relationship of L*, pHu and WHC, as higher L* values, lower are the values of pHu and WHC of the samples collected.

From the histograms (Fig. 3a, b) and Pearson's correlations (Table 1), a cut-off value for L* and pHu was determined and they were suitable to classify breast samples into normal, PSE and DFD-meat specifically to the slaughterhouse conditions in relation to the birds managements. Therefore, the following cut-off values were applied:

- PSE = $L^* \geq 51.0$ and $pHu \leq 5.9$
- Normal = $5.9 < pHu < 6.2$ and $45.0 < L^* < 51.0$
- DFD = $L^* \leq 45.0$ and $pHu \geq 6.2$

Incidence of chicken breast meat colour abnormalities harvested during the dry and rainy season: Table 2 shows the mean values of L*, a*, b*, pH and WHC for the dry and rainy seasons. The broilers slaughtered during dry season had colour values that were significantly ($p<0.05$) higher pale (L*), lower red (a*) and higher yellow (b*) than the samples

Table 1: Correlation coefficients between the L*, a*, b*, pHu and WHC measurements of broiler breast samples harvested in both dry (n = 1,400) and rainy seasons (n = 1,400)

Parameters	L*	a*	b*	pHu	Means	SD
L*	-				53.14	5.18
a*	-0.52*	-			1.49	1.29
b*	0.61*	-0.45*	-		6.31	2.14
pHu	-0.58*	0.25*	-0.27*	-	5.97	0.24
WHC	-0.36*	0.08*	-0.16*	0.31*	70.75	1.71

*Values are significant at $p<0.01$

Table 2: Averages of L*, a*, b*, pHu and WHC in pectoralis major collected during dry and rainy seasons

	Season	
Parameters	Dry	Rainy
L*	57.31 ± 3.09^a	49.42 ± 2.93^b
a*	0.67 ± 0.86^b	2.14 ± 1.03^a
b*	7.54 ± 2.31^a	5.14 ± 1.51^b
pHu	5.88 ± 0.18^b	6.01 ± 0.19^a
WHC (%)	69.61 ± 1.48^b	71.86 ± 1.18^a

Different letters on the same row indicate significant differences (Student's t-test, $p<0.05$), the results are expressed as the Mean±SD (n = 2,800)

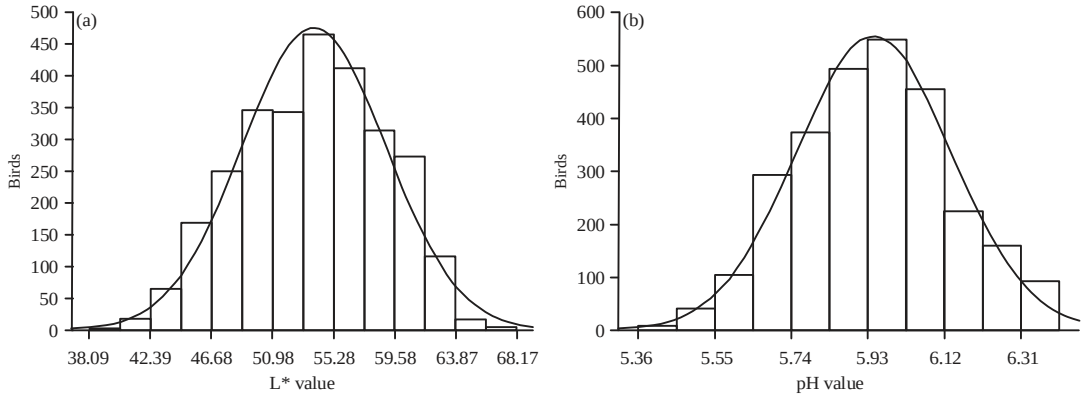

Fig. 3(a-b): Histograms of distribution of (a) L* and (b) pHu in chicken breast meat samples measured in both dry (n = 1,400) and rainy (n = 1,400) seasons

processed during the rainy season. Therefore, in the dry season, the breasts of chickens showed the higher value of L* (13.77%), lower value of a* (68.69%), higher value of b* (31.83%), lower value of pHu (2.16%) and WHC (2.25%) when compared with the breast samples harvested in the rainy season.

During the dry season, the incidence of PSE meat was 43.53% while in the rainy season this incidence was 10.46% (Fig. 4a, b, Table 1, 2). The occurrence of DFD meat was observed only in the rainy season.

DISCUSSION

Table 3 shows further comparative values of PSE and DFD-meat obtained by other researchers in different countries relative to results reported herein. The L* values described in this study were higher than the values reported in the USA[14], Italy[15] and Southern Brazil[16].

In Canada, Barbut[17] analysed the incidence of PSE broiler meat using parameters such as L*, a*, b*, pH and WHC. The researchers found L* values ranged from 38.0-57.0 and the average was 46.3. These findings suggested the cut-off value of L*>50 had acceptable correlations for L* and pH values (-0.79), in addition to pH and WHC (0.85). Present study also found a significant correlation between L* and pH (-0.58) and L* and WHC (-0.36). The experiments conducted in China[18] demonstrated L* values varied from 42.70-58.37 and had an average of 51.34, which is less than the cut-off value of L*>53. The evaluation of cut-off values for L* = 53.1 and pHu = 5.9 (Fig. 3a, b) allowed the determination of occurrence of PSE and DFD of 23.39 and 7.46%, respectively.

The occurrence of PSE meat found in the summer or dry season in this study was higher than the value reported by Soares *et al.*[16]. In their study, the researchers stated the incidence of PSE was 15.86% during summer season in the Southern of Brazil located down to tropic of Capricorn (Fig. 1a) far below from 43.53% found in this study (Fig. 4a). The researchers also found during the same season that the incidence of DFD meat was 5.86%, which was higher (3.34%) than the result of this study.

This result indicated that the birds were also under cold stress in NE climate conditions depleting the level of glycogen in order to keep the body temperature resulting in higher pHu influencing the normal post mortem muscle glycolysis rate[9]. In this case, however, the conditions were not the season itself but rather accidental and pre-slaughtering activities occurrences because of the association of rain during transport and nebulization during lairage. Similar conditions were observed in Africa during broiler rainy transportation by Minka and Ayo[19] and Mallia *et al.*[3] in Canada, under

Table 3: Comparative values of PSE and DFD chicken broiler breast meat obtained in different countries in relation to the results described in this study

Parameters	Allen *et al.*[14]	Petracci *et al.*[15]	Soares *et al.*[16]	Present study
Country	USA	Italy	Southern Brazil (subtropical zone)	Northeastern Brazil (tropical zone)
Sample number	760	6,997	353	2,800
L* range	43.0-51.0	40.0-66.0	38.57-58.50	38.0-68.0
PSE L* cut-off value	>50	>56	>53	>51
DFD L* cut-off value	<45	<50	<44	<45

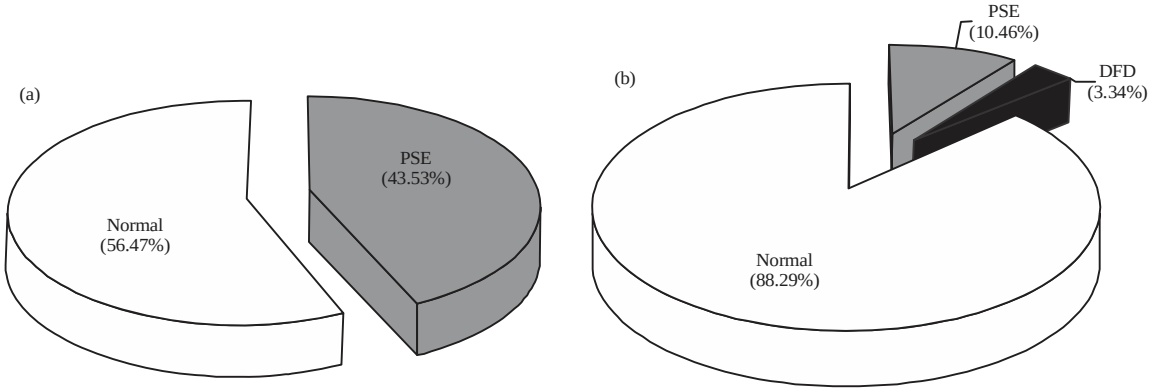

Fig. 4(a-b): (a) Occurrence of PSE meat in broiler breast meat during the dry season (n = 1,400) and (b) In the rainy season (n = 1,400) harvested in the tropical climate zone. The DFD meat samples occurrence was only observed in the rainy season

extreme cold weather, where the occurrence of DFD meat was higher during the winter season because the cold stress depleted muscle glycogen in order to maintain the normal bird's body temperature.

It is noteworthy that birds are sensitive to temperature being a homeothermic animals[20,21]. It is reasonable to state that during both seasons, dry and rainy, animals suffer corporal hyperthermia and hypothermia that lead to the development of PSE[22] and DFD[2] meat, respectively, as recently reported[9].

These results were in accordance with experiments reported by McCurdy *et al.*[21] and Barbut[17] with turkeys. The authors reported the incidence of PSE meat is higher in the summer in USA and Canada, respectively, corroborating the assumption that during the warm season there was higher level of paler meat because of the heat stress in birds regardless of bird's species.

Finally, this experiment revealed the feasibility of raising broiler chickens in hot weather provided that activities should be taken in order to avoid heat stress conditions as the PSE occurrence was over 40.0% (Fig. 4) in the dry season. That would bring about a social benefit to the local population when a more restricted contingency would be applied in order to have availability of broiler meat under food safety regulation.

CONCLUSION

The conditions of tropical climate under dry season affect broiler chicken welfare promoting heat stress consequently to a high incidence of PSE meat.

Under wet conditions, incidence of the DFD meat occurred demonstrating that the birds suffered a mild cold stress.

SIGNIFICANCE STATEMENTS

This study found out that tropical climate region is suitable to raise broilers and that will be beneficial for a further development of the hot climate agricultural activities areas.

This study shows the contradiction despite of being the major export country in the world, the local population is exposed to broiler meat without installation of a complete food safety programme.

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