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Turkey Meat. Seasonal Effect on Meat Quality and on Dead on Arrival Index in a Commercial Plant

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ABSTRACT

The objective of this study was to determine the incidence of Pale, Soft, Exudative (PSE) meat and to characterize the Dark, Fim, Dry (DFD) meat as well as the Dead on Arrival (DOA) index in a commercial turkey slaughterhouse in southern Brazil during the summer and winter seasons. The journeys (n=64) were over a distance of 36 ± 20 km and took approximately 95 ± 20 min. Color (L) and pH distribution of turkey breast meat (n=5,352) were evaluated from different farms (n=64) during the 2015-2016 years. The pH, water-holding capacity, color (L*, a*, b*) were used to establish cutoff values for DFD meat (L* < 44.0 and pH > 5.90) and presented correlation among them. The L* value was the highest during the summer (P<0.01), indicating the highest incidence of PSE meat (28.35 %), and lowest during winter, observing the highest incidence of DFD meat (10.3 %). Finally, the obtained summer DOA index was 0.23 % higher in relation to winter.*

Keywords: Animal Welfare, Color Meat, DFD meat, PSE meat, Slaughterhouse.

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INTRODUCTION

The production and consumption of turkey meat have increased rapidly around the world. This production raised around 6% from 5,610 million pounds (2015) to 5,981 million pounds (2016) and Brazil produced over 330 mil pounds (2015) according to USDA [1]. The Brazilian poultry industry has various critical factors to keep the meat qualities throughout the year because Brazil having a continental size is located within tropical and subtropical zones and the birds are frequently exposed to different weather conditions [2]. Problems with the quality of meat are generally caused by biochemical and morphological changes of muscles (*antemortem*) and by processing (*postmortem*)[3-4]. Two conditions are known under stress pre-slaughter: pale, soft and exudative (PSE), and dark, firm and dry (DFD) that are developed as the result of stress in the short and long-term, respectively [5].
In summer, the climatic effect can induce PSE problem in birds [6], as well as processing after slaughtering [7]. Owens et al. [8] and Barbut et al. [9] suggested that PSE poultry breasts can be classified by color in the processing plant due to its high correlation with the functional properties [2,10].
Long stress conditions before slaughter influences the level of glycogen and final pH of breast muscle [5] resulting in a high water holding capacity (WHC) and reduced shear force (SF) [11], characteristics which are typical of DFD meat. Another interesting aspect is that the birds are sensitive to seasons by being homoeothermic animals [12-13]. The objective of this work was to evaluate the incidence of PSE meat and characterize the DFD meat in turkey breast meat in a Brazilian commercial processing plant during summer and winter seasons.

MATERIAL AND METHODS

Animals

This study was conducted during the summer and winter seasons from December 2015 to September 2016 in a commercial plant in the Chapecó city region (Latitude: 27º 05' 47" S; Longitude: 52º 37' 06" W; Altitude: 674m) Santa Catarina State, Brazil. The transportation activity conditions from the farm to the turkey commercial processing plant were described in details in [2]. The weather conditions in this region were characterized by the minimum and maximum temperatures, and the relative humidity as measured using a Kestrel 4000 instrument (Nielsen-Kellerman, Boothwyn, PA, USA) as seen in Table 1. The feed was removed 9 to 12 h before slaughter, and water was provided *ad libitum*. The animals were manually placed into crates at a density of 8 birds each and installed within the truck open container. The average catching and loading time was 24 min. Turkeys were handled in accordance with the principles and procedures outlined by the Londrina State University Animal Care and Use Ethical Committee (Process #167/2015).

Table 1. Samples, period, animals and climatic characteristics of the region.

	Summer (2015/2016)	Winter (2016)
Lineage and gender	Nicholas-700, male	Nicholas-700, male
Weight	18 ± 2 kg	18 ± 2 kg
Number of fillets analyzed	2674	2678
Days of sampling	56	73
Temperature range	24 to 36 °C	-2 to 24°C
Relative humidity range	43 to 67%	42 to 65%

The animals were reared on 64 turkey farms under a cooperative system and subsequently transported over a distance of 36 ± 20 km for a journey that took approximately 95 ± 20 min. Upon arrival at the slaughterhouse facilities, the birds were placed in a holding area under water mist and ventilation for 70 min before slaughtering. The animals were sacrificed according to standard industry practices, which consisted of hanging, electrically stunning, bleeding, scalding, defeathering, evisceration, cooling the carcass through a tunnel of cold air (-6 °C for 6 h) and deboning [14]. Subsequently, the breast meat samples (*Pectoralis major*) were collected and refrigerated at 4 °C until completing 24 h to measure the color (L*, a* and b* values), pH and water holding capacity (WHC) and thus evaluating the occurrence of PSE [2] and DFD meat.

Transport of Truck Container Microenvironment Assessment

Six portable weather meter devices with bidirectional Kestrel anemometers and data logging capability were set to take measurements at an interval of 30 seconds during the journeys [15]. The transport temperature (TT), transport relative humidity (TRH), air ventilation (AV), ambient temperature (AT), ambient relative humidity (ARH), heat index (HI) and wind chill (WC) values were simultaneously measured as in Spurio et al. [6], allowing for a representative analysis of the heterogeneous distribution of the thermal microenvironment within the loaded vehicle. The weather conditions in moment of transport were characterized by temperatures (AT), and the relative humidity (ARH). HI or apparent temperature is an index that combines temperature and RH to measure the observed equivalent temperature [15]. HI is usually higher than the temperature evaluated by the dry bulb temperature [16]. WC or apparent temperature is an index that combines air temperature and air ventilation to measure the perceived equivalent temperature [17].

Color and pH Measurements in Fresh Breast Meat

This evaluation was performed using a Minolta CR-400 colorimeter, taking five different reading points per sample for color determination (L*, a* and b*), as described by Carvalho et al. [2] . The pH was measured (in duplicate) by inserting electrodes into the *pectoralis major* m. as described in Carvalho et al. [14]. The meat samples (n = 5,352; summer = 2,674; winter = 2,678) were classified as PSE according to their L* values, with L* > 53 and pH < 5.60, considered typical of PSE turkey meat, as thoroughly discussed in Carvalho et al. [2].

Water Holding Capacity (WHC)

This measurement was carried out based on the technique of Hamm [18], as described in Carvalho et al. [19]. After 24 h *postmortem*, samples were collected from the cranial side of the breast fillets and cut into cubes 2.0 ± 0.10 g. They were first carefully placed between 2 pieces of filter paper on acrylic plates and then left under a 10-kg weight for 5 min. The samples were weighed and WHC was determined using the weight of exudate water and the following equation: 100 - [(Wi - Wf / Wi) X 100], where Wi and Wf are the initial and final sample weights, respectively. A total of 104 samples was analyzed in triplicate.

Mortality Evaluated by Dead on Arrival (DOA)

A total 30,720 turkeys were transported from 64 different farms. The percentage of DOA per loaded truck was calculated by counting each dead bird during the hanging step at the slaughtering plant, taking care to observe the truck region from which the birds were collected [6].
DOA = Number of birds dead / Number of birds transported

Statistical Analysis

The Statistica software for Windows 13.0 (StatSoft, Tulsa, USA) was used. Student's t-test at 1% probability ($P<0.01$) was used for comparing the differences between the two treatments of summer and winter, and Pearson's correlation ($P < 0.01$ and $P <0.05$) coefficient to assess the correlation among pH, a*, b*, L* values and WHC.

RESULTS AND DISCUSSION

Summer and Winter Weather Conditions in the Farm Region

Table 2 shows the AT, TT, ARH, TRH, AV, HI and WC during summer and winter seasons. The AT in the summer season showed approximately 5.5 times higher ($P<0.01$) compared to the winter. TT values in the summer season showed 3.1 times higher ($P<0.01$) compared to winter. The relative humidity (TRH and ARH) was not significantly different ($P\geq0.01$) as well as the air ventilation (AV) values. HI in the summer season showed a high value of 30.04 °C and obviously, the WC in winter showed a lower value (10.6 °C). WC in summer was not measured because the temperatures need to be between -50°C and 10 °C [17].

Table 2. Mean values of ambient temperature (AT), transport temperature (TT), ambient relative humidity (ARH), transport relative humidity (TRH), air ventilation (AV), heat index (HI) and wind chill (WC) performed under two treatments: summer and winter during turkey transportation.

	Summer	Winter	P-value
AT (ºC)	$33.02^{a} \pm 0.51$	$5.97^{b} \pm 0.87$	< 0.001
#TT (ºC)	$33.87^{a} \pm 2.84$	$10.89^{b} \pm 4.47$	< 0.001
ARH (%)	$48.99^{a} \pm 4.57$	$44.92^{a} \pm 5.67$	0.948
#TRH (%)	$59.84^{a} \pm 11.90$	$59.42^{a} \pm 12.93$	0.976
#AV (m/s)	$1.31^{a} \pm 1.16$	$1.10^{a} \pm 1.12$	0.626
#HI (ºC)	41.0 ± 4.32	-	
#WC (ºC)	-	10.6 ± 3.65	

$^{a-b}$ Means ± standard deviation in the same line with no common superscripts are significantly different by Student t-test ($P<0.01$). #Parameters analyzed during the transport of turkeys.

Meat Characteristics in the Summer Season

Color variation of fresh turkey breast meat in summer is shown in Figure 1A. The L* values varied from 40.28 (dark) to 63.73 (pale), and the average value was 50.88, the variance (8.51), skewness (-0.12), and kurtosis (-0.10) were calculated ($P\geq0.05$). The pH variation is shown in Figure 1B, and their values varied from 5.49 to 6.03, and the average value was 5.72, the variance (0.007), skewness (-0.08), and kurtosis (-0.19) were calculated ($P\geq0.05$).

There was significant (P<0.01) negative Pearson correlation (Figure 2) between the pH and L* values, with a value of the coefficient of −0.55. During the summer season, poultry breast meat showed high L* and low pH values. In Brazilian summer high L* values were found in poultry [6,20-22], and this phenomenon obviously is related to the season climate (Table 1) being the heat located outside the comfort zone (18 to 30 °C) [6,22-23]. During the pre-slaughter phases, the microclimate of transport truck container is also an important factor that influences the meat quality (Table 2). During the summer season as observed previously unfavorable transport microclimate related in particular to temperature, relative humidity and ventilation resulted in breast meat with high L* and low pH values [6,21].

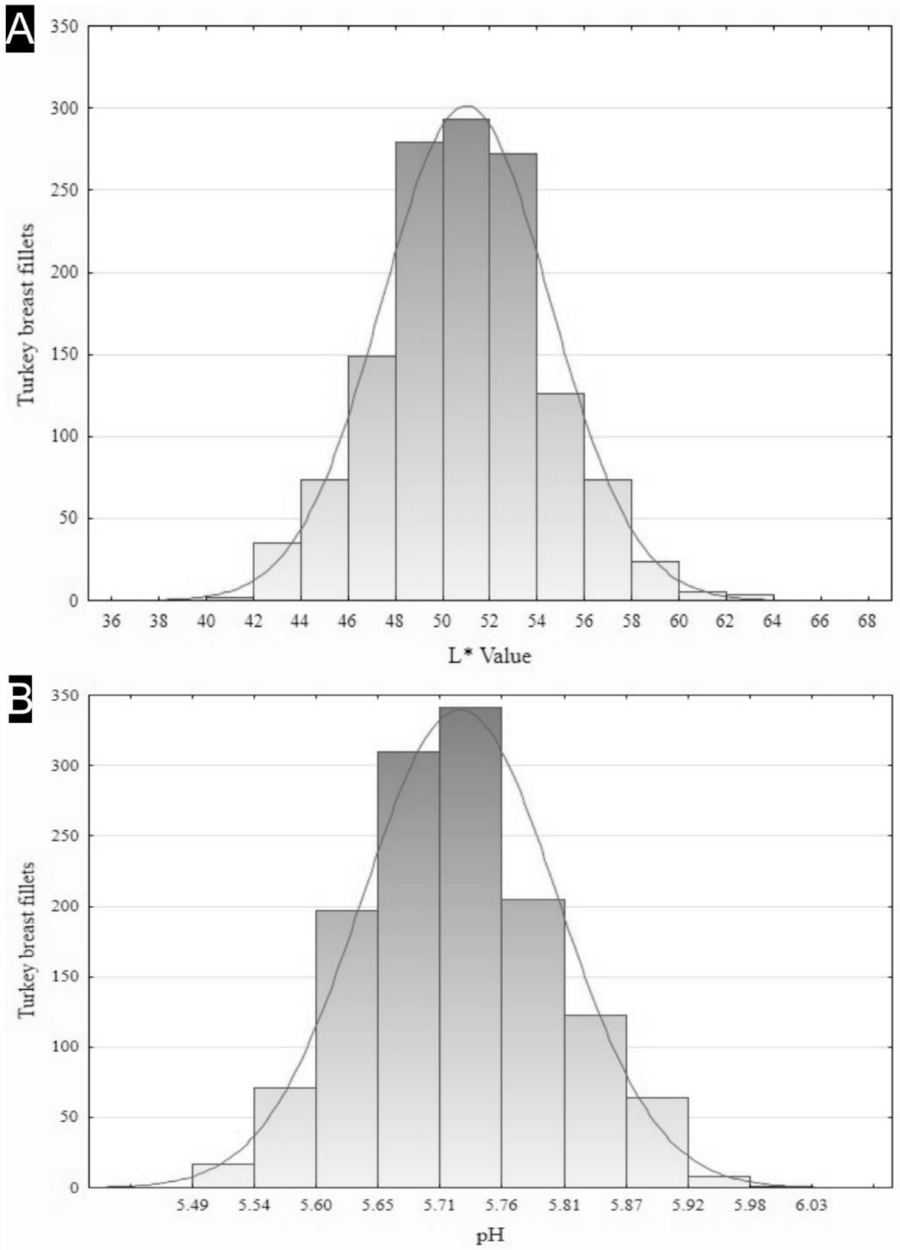

Figure 1. Histograms of turkey breast fillets harvested during summer season. **A)** showing the distribution of L* values. **B)** showing the distribution of pH values (*n* = 2,674).

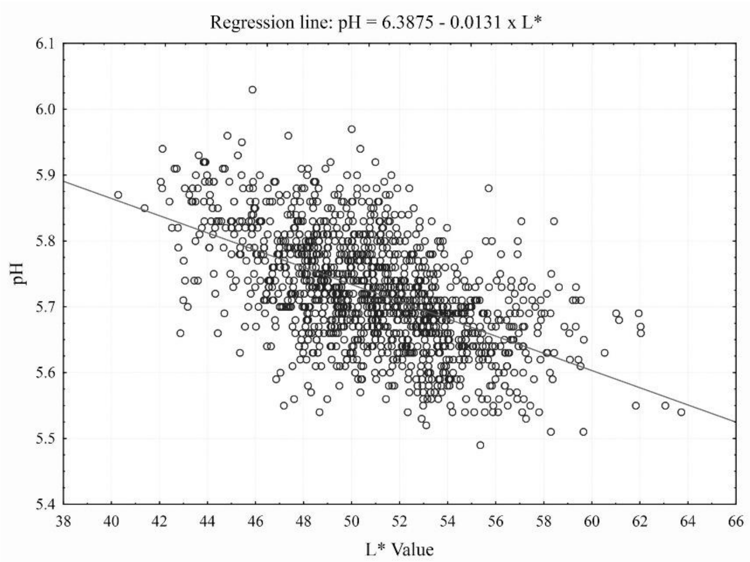

Figure 2. The relationship between L* and pH values in turkey breast fillets harvested in summer season (*n* = 2,674). Correlation coefficient of - 0.55 (P<0.01).

Meat Characteristics in the Winter Season and DFD Characterization

Color variation of fresh turkey breast meat during winter season is shown in Figure 3A. The L* values varied from 36.38 (dark) to 60.69 (pale), and the average value was 47.69 units, the variance (8.81), skewness (-0.11), and kurtosis (-0.25) were calculated (P≥0.05). The pH variation is shown in Figure 3B from 5.59 to 6.20, and the average value was 5.84 units, the variance (0.009), skewness (-0.16), and kurtosis (-0.26) were calculated (P≥0.05). There was significant (P<0.01) negative Pearson correlation (Figure 4) between the pH and L* values, with a value of the coefficient of -0.61. Table 3 shows a significant negative Pearson correlation is observed between L* and pH (-0.62, P<0.01) and between L* and WHC (-0.47, P<0.01). pH values showed correlations between WHC (0.31, P <0.05), a* (-0.43, P<0.01), b* (-0.31, P<0.05).

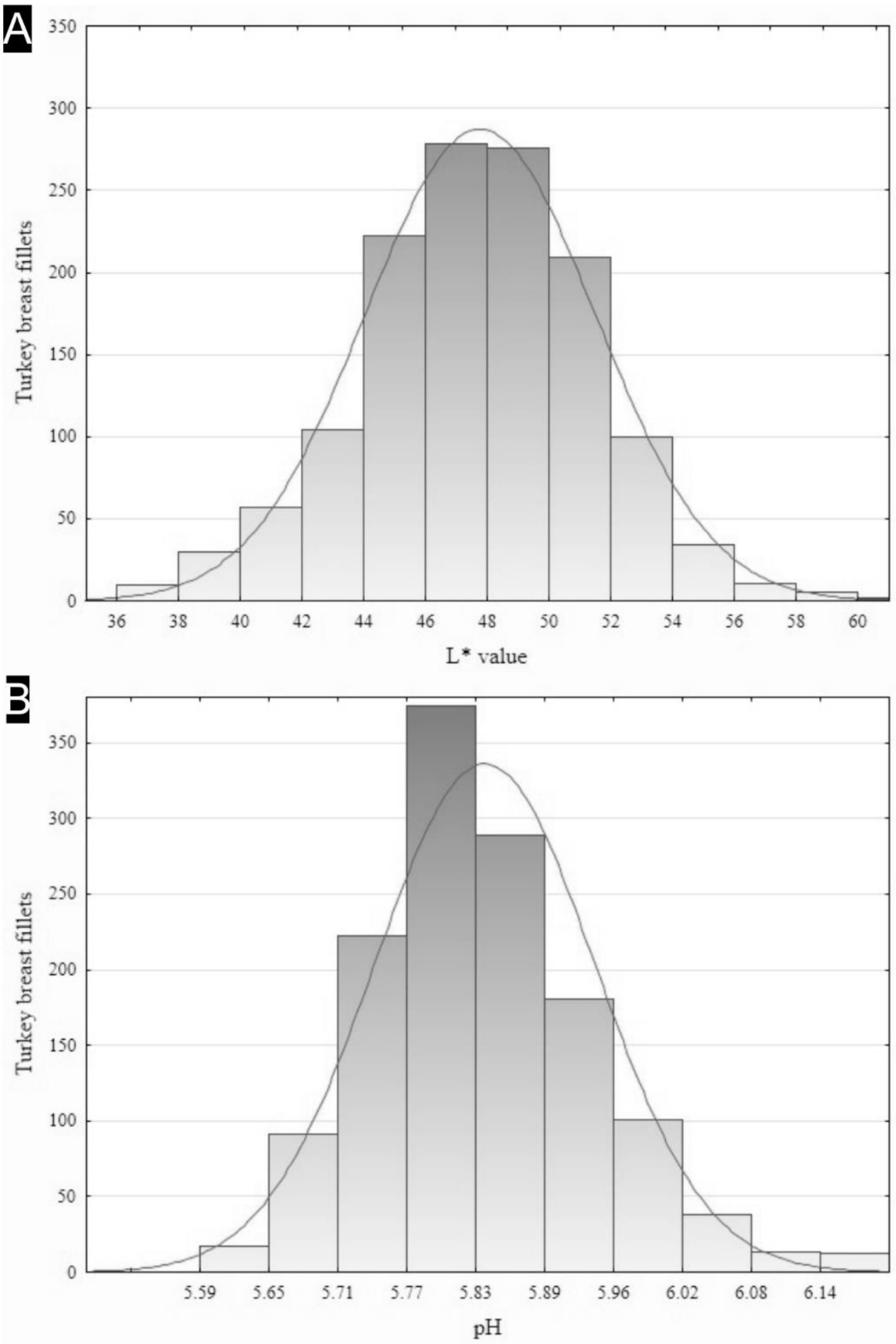

Figure 3. A) Histograms of turkey breast fillets harvested during winter season. **A)** showing the distribution of L* values. **B)** showing the distribution of pH values (n = 2,678).

Table 3. Pearson correlation coefficients among physical measurements of turkey breast meat samples.

Parameter	L*	a*	b*	pH	WHC %	Means	Standard deviation
L*	1	-	-	-	-	48.90	2.72
a*	0.37**	1	-	-	-	3.86	0.95
b*	0.58**	0.60**	1	-	-	3.56	1.27
pH	-0.62**	-0.53**	-0.71**	1	-	5.97	0.10
WHC %	-0.47**	-0.43**	-0.31*	0.31*	1	77.16	1.88

*Values significantly at P<0.05 unless otherwise stated. n = 104. **Values significantly at P<0.01 unless otherwise stated. n = 104.

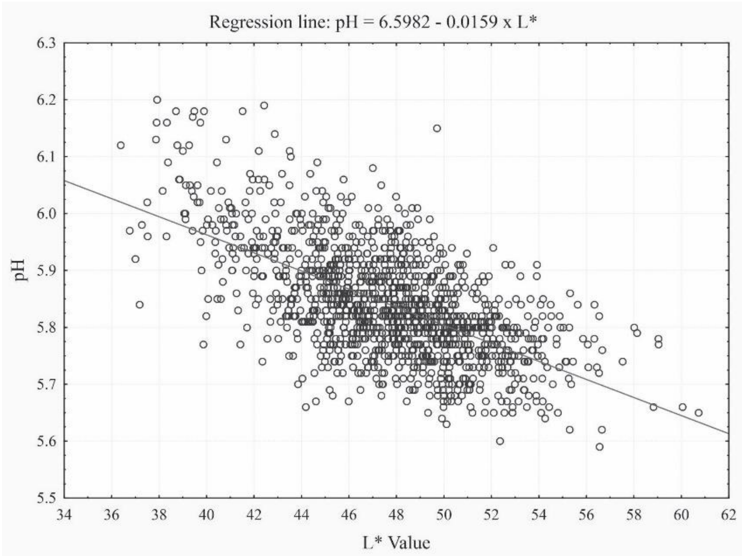

Figure 4. The relationship between L* and pH values in turkey breast fillets in winter season (*n* = 2,678). Correlation coefficient of -0.61 (P<0.01).

The methodology for detection or prediction of color abnormalities has recently been a matter of debate because of a single measurement of color is not sufficient for accurate characterization of either PSE and DFD-meat [25]. On the other hand, several authors reported evidence that a color measuring system is an important meat quality tool and is often used as an indicator of PSE meat [2,26–29].

Owens et al. [8] reported the incidence of PSE meat in turkeys using parameters such as L*, a*, b*, pH and WHC and found L * values ranged from 41 to 63. In addition, the values of L* were the best predictor of PSE meat condition. According to Barbut [29], the L* values were the best predictor of PSE meat condition. According to Barbut [29], the L* value of 50/51 correctly identifies turkey meat PSE because this classification presented a significant correlation with WHC. Several works indicated that the L* parameter can be used for identification of poultry meat abnormalities since that correlated with other attributes such as pH, WHC and drip loss [2,8,19,26]. McCurdy et al. [12] obtained correlations between pH and L* (-0.62), and they suggested an L* cut off > 50/51 for detection PSE meat.

The color (L*) and pH data from commercial plant were used to show the typical bell-shape distribution obtained (Figure 1 and 3). To characterize the distribution of the L* and pH values for each season, the variance, skewness, and kurtosis were calculated. The skewness (indicating a tendency to form a tail towards a certain side of the curve [30]) was negative for the summer and winter data, showing a tendency that the skew of the distribution is to the left to form a tail towards the low L* and pH values[30]. The kurtosis values also were negative between the seasons. In addition, all parameters were significantly correlated (P<0.01; P<0.05). As expected, the PSE turkey fillets had higher L* values, lower muscle pH, and lower WHC compared with the normal and DFD fillets. The DFD turkey fillets had lower L* values, higher muscle pH, and higher WHC compared with the normal and PSE fillets.

Therefore, using Figures 3A, 3B, 4 and Table 3 we proposed a convenient cutoff value for detection of DFD meat in turkey breast fillets under the conditions of our experiment: DFD meat = L* < 44 and pH > 5.90. Thus, the results of this experiment associated with our previous one by Carvalho et al. [2] encouraged us to assume the following meat color abnormalities classification:

i. L* > 53.00 and pH < 5.60 = PSE meat [2].
ii. Normal: 53.00 ≤ L* ≥ 44.00; and 5.60 ≤ pH ≤ 5.90.
iii. L* < 44.00 and pH > 5.90 = DFD meat.

Comparison of Summer *versus*. Winter Seasons

In Table 4 is shown the pH, L*, a*, b* values and the incidence of PSE and DFD meat and DOA index. The breast meat in the summer showed average pH value 0.13 lower units, L* value 3.19 units higher, a* value lower 0.63 units and b* value lower 0.21 units compared to winter season samples (P<0.01). In relation to the classification of turkey breast meat in summer, there was 28.35% incidence of PSE meat and 1.2 % of DFD meat. Conversely, during the winter season the incidence of PSE and DFD meat were 6.7% and 10.3%, respectively. The DOA index in summer was relatively higher by 0.23% while in the winter season it was extremely low.

Table 4. Mean values of pH, L*, a*, b*, PSE and DFD meat in turkey breast meat performed under two treatments: summer and winter.

	Summer	Winter	P-Value
pH	$5.71^b \pm 0.05$	$5.84^a \pm 0.06$	< 0.001
L*	$50.88^a \pm 1.68$	$47.69^b \pm 2.40$	< 0.001
a*	$4.45^b \pm 0.50$	$5.08^a \pm 0.67$	< 0.001
b*	$3.69^b \pm 0.65$	$3.90^a \pm 0.71$	< 0.002
PSE (%)	28.35	6.7	
DFD (%)	1.2	10.3	
DOA (%)	0.23^a	0.001^b	< 0.001

$^{a\text{-}b}$ Mean ± standard deviation in the same row with no common superscripts are significantly different by Student t-test (P<0.01).

According to the results reported herein, L * values in the winter were lower than those found in the summer season. Corroborating with these results, McCurdy et al. [12] in Canada also showed lower L* in winter and high values in summer. These authors reported a higher incidence of PSE meat in summer (15%) and similar to the results obtained where the incidence of PSE was 21.7% higher (Table 4) compared to winter season. Stress before slaughter such as heat stress and weather climate accelerate *antemortem* muscle metabolism and influence on meat quality. The physiology impact about the stress in animals has been the subject of several studies [2, 6, 8, 21, 23]. In the development of the PSE meat the glycogen reserves are rapidly consumed due to metabolism changes caused by stress before slaughter, this event leading to rapid *postmortem* glycolysis that lowers the pH while the carcass is still warm. Hence, the sharp drop in pH and the high temperature of the carcass cause the denaturation of myofibrillar and sarcoplasmic proteins [4, 7, 8, 14].

The high incidence of DFD meat (10.3 %) in the winter months is probably the result of the combined effects of low ambient temperature and transport temperature, as shown in Table 2. These conditions are common in the winter season in southern Brazil. Exposure to extreme environmental temperatures during transportation could affect the body temperature of birds, which physiologically is normally between 40.5 and 42.5°C [5]. It is suggested that cold temperature exposure during transport causes glycogen depletion in the muscle of the birds due to increased energy consumption to maintain normal body temperature under these conditions. As a result, these birds have less muscle glycogen stores at the time of slaughter to convert to lactic acid and lower the pH of the meat [5, 7, 8, 21].

The DOA values were different between treatments (Table 4), suggesting that those values were related to thermal stress during the summer months, as the PSE meat incidence indicated. The commercial company where this study was conducted has a relatively effective practice regarding animal welfare compared to Petracci et al. [31] that reported an average of 0.48 % DOA (turkey) in Italy. The season conditions influenced the pre-slaughter mortality rate in turkeys also seen in other reports. DOA prevalence was higher in turkeys in the summer (0.52%) compared to autumn (0.29 %), winter (0.29%), and spring (0.32%) (29) in Italy. Vieira et al.[32] reported that the mortality incidence in the summer was 0.42%, followed by spring (0.39%), winter (0.28%), and autumn (0.23%) in Brazil. The thermal sensation of the seasons calculated by heat (HI) and cold (WC) (Table 2) affects the turkey meat characteristics such as pH, L*, a*, b* and occurrence of PSE and DFD meat, as well as animal welfare.

CONCLUSION

The incidence of DFD turkey meat is higher in winter and PSE turkey meat in summer, as well as DOA index in summer season in a southern region of Brazil. These results suggest, as the first priority to introduce management tools to maintain animal welfare and thus preventing stressful conditions for the birds consequently keeping the quality of the breast fillet meat.

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