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MODELLING THE TEMPERATURE AND pH DECLINE EARLY *POST-MORTEM* OF BEEF CARCASSES

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ABSTRACT

The objective of this work was to model the pH and temperature decline early *post-mortem* on beef carcasses and to study the effect of gender, genotype and weight class on the pH and temperature decline patterns. A total of 24 beef animals slaughtered in a local abattoir were sampled. pH and temperature were recorded using an OMEGA wireless receiver/host (UWTC-REC1). The decline of pH and temperature was modelled using one parameterisation of the exponential decay function, and its parameters were estimated using the software R. The fitted models were used to predict pH and temperature at 1.5 h, at 3.0 h and at 24 h; the time when pH reached 6.0, and the temperature at which pH reached 6.0. The rate parameters of the exponential decay function for pH (K_{pH}) and temperature (K_T) were found to be independent ($r=0.35$, $P>0.05$). The correlation between pH at 3 h and final pH (at 24 h) was very high ($r=0.930$, $P<0.01$). The K_T was influenced by the time elapsed from slaughter until the first recording, and by the carcass weight. In opposition, those variables did not affect the K_{pH} . The exponential decay function was able to model the early *post-mortem* decline of both pH and temperature, and the pH at 3 hours can be used as predictor of the final pH of beef meat.

INTRODUCTION

Temperature and pH control is extremely important since it affects meat tenderness, and varies with animal species, cooling rate and the stress level that the animal is subjected to before harvesting (Bianchini et al. 2007).

During the first 24 h *post-mortem*, the rate of temperature decline affects the biochemical and structural changes during the conversion of muscle to meat. High temperature accelerates the pH decline in muscle (Kahraman et al. 2012). During this period, the rate of decrease in pH and the final pH of meat are highly variable. When the process of glycolysis develops slowly, the initial pH (right after slaughter), which is about 7.0, goes down to 6.4-6.8 after 5 hours, and subsequently to 5.5-5.9 after 24 hours (Roça 2000).

If, due to a deficiency of glycogen, the final pH (after 24 hours) remains high, above 6.2, the muscle turns into DFD meat (dark, firm, dry or dark-cutting). Thus, the pH 6.0 is considered as the limit value for the emergence of DFD meat (Bianchini et al. 2007). In general, for optimal eating quality, beef should reach a pH of 6.0 while the carcass temperature is between 15°C and 35°C (Thompson 2002). In addition, the storage temperature of carcasses is another factor that can cause significant changes in the rate of chemical reactions *post-mortem*. One of the most significant effects of storage temperature is the phenomenon of cold shortening, which consists in accelerating muscle metabolism with low temperatures (0-10°C) (Roça 2000). Studies have shown that temperature and pH (initial, final and decline rates) are good predictors of meat quality (flavour, juiciness, tenderness and texture). Also, pH is a good predictor of the colour and drip loss of meat (Ibarburu et al. 2007). Therefore, given the importance of pH and temperature for the meat quality, it would be of great benefit for meat processors to know in advance how they are likely to behave. This would allow the introduction of rapid chilling systems, for example, to reduce evaporative weight losses without adversely affecting meat tenderness. Thus, the objective of this study was to model the decrease in pH and temperature during chilling of beef carcasses in order to assess their predictability from an earlier stage. A second objective was to verify whether sex, breed and weight class have any influence on the pH and temperature decline rates.

MATERIALS AND METHODS

Animals

In this study, a total of 24 beef animals (17 crossbred, undefined breed, and 7 Mirandesa), 18 males and 6 females, slaughtered in a local abattoir were sampled. The carcasses had an average hot carcass weight (hcw) of 203.4 ± 52.1 kg. Carcasses were assigned to a "light" category if weight was below 200 kg and to a "heavy" category if the weight was above this value.

The animals were transported by truck to the slaughterhouse when they were 9.7 ± 1.91 months old. At arrival, they were led to individual stalls, where they were kept until slaughtering. They were not fed at the slaughter plant, but they did receive water *ad libitum*.

Temperature and pH recording

Two hours after slaughter, the pH and temperature decline were recorded, at intervals of 10 min during 24 h of carcass chilling, in *longissimus thoracis* muscle at the level of the 4th rib. The pH and temperature measurements were made using an OMEGA wireless receiver/host (UWTC-REC1) equipped with a weather resistant wireless pH/temperature transmitter and temperature probe Pt100.

Temperature and pH decay modelling

The pH and temperature decline post-mortem (p.m.) were modelled as a function of time using the parameterisation of the exponential decay function proposed by Hwang and Thompson (2001), as follows:

$$Y_{(t)} = A_{(u)} + (A_{(i)} - A_{(u)})e^{-Kt}$$

where $Y_{(t)}$ is the pH or temperature at time t ; $A_{(u)}$ is the final pH or temperature; $A_{(i)}$ is the initial pH or temperature; K is the exponential constant of decay; and t is the time in hours after slaughtering.

The parameters ($A_{(u)}$, $A_{(i)}$ and K) were estimated using the non-linear least squares (nls) function implemented in the software R (R Core Team, 2014). The fitted models were used to predict the pH at 1.5 h ($pH_{1.5}$), at 3.0 h ($pH_{3.0}$) and at 24 h (pH_{24}), the time when pH reached 6 (t_{pH6}), the temperature at 1.5 h ($T_{1.5}$), at 3.0 h ($T_{3.0}$), and at 24 h (T_{24}) and the temperature at which pH reached 6 (T_{pH6}).

Data analysis

Data were analysed using correlation and analysis of variance models. One way analysis of variance was used to investigate the effects of gender (male and female), breed (Crossbred and Mirandesa breed), and carcass weight class (V - Veal and Z - Steer). Regression analysis was used to study the relationship between $pH_{3.0}$ and pH_{24} .

RESULTS AND DISCUSSION

Modelling the pH and temperature decline

Figure 1 presents the pH decline of three beef carcasses during cooling showing different patterns. The k_{pH} varied between 0.092 and 1.149, and the results clearly indicated that large differences in pH decline are likely to occur among carcasses. It can be observed that the pH decline rate was higher during the first few hours after slaughtering (approximately 5 hours). After 5.0 hours, the pH continues to decrease but at a slower rate, becoming relatively constant. A poor pH decline was observed in 68% of the carcasses, with a final pH higher than 5.8, which is a reason for concern considering the meat quality obtained from those carcasses (Pearce et al., 2010).

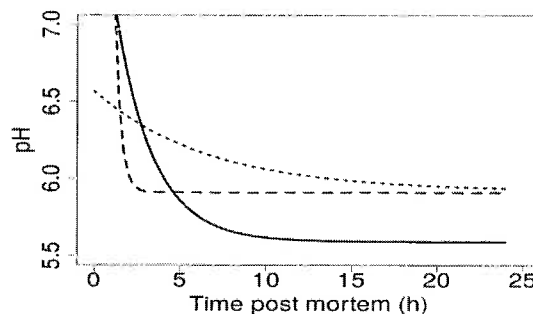


Figure 1: pH decline of three beef carcasses during cooling showing different patterns

In this study, the pH decline can be considered overall as suboptimal since a slow pH-temperature decline was observed. Thus, the slaughterhouse chilling regime needs to be improved so that carcasses attain the quality target of pH = 6 at 18 °C.

Figure 2 presents the temperature decline of three beef carcasses during cooling showing different patterns. The k_T varied between 0.074 and 0.235, showing that also the temperature decline was highly variable among carcasses, and this variability was associated with high (> 35 °C) and low (< 15 °C) temperatures when pH reached the critical value of 6. The mean temperature at pH 6 was 22.0 °C, however 26% of the carcasses presented a final pH higher than 6.

The prediction of the temperature decline curve can be used to adjust the cooling rate in order to force carcasses' temperature lay between 35 and 15 °C when pH reach the critical value of 6.

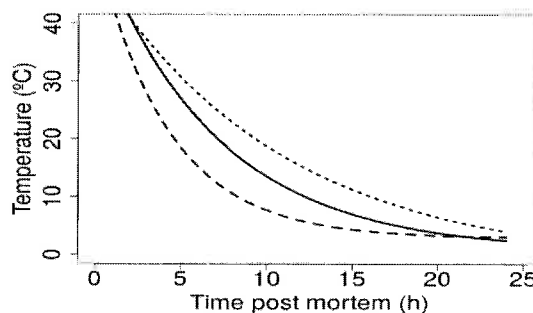


Figure 2: Temperature decline of three beef carcasses during cooling showing different patterns

Figure 3 shows the relationship between the K_{pH} and K_T parameters. These two parameters presented a low and non-significant correlation (0.35, $p < 0.05$), which corroborated previous results of Hwang et al. (2001) who stated that they are independent parameters. The small data set used in this study and occurrence of some influential points may bias this relationship. Hence, results should be interpreted with some caution. More data should be collected in order to clarify this relationship.

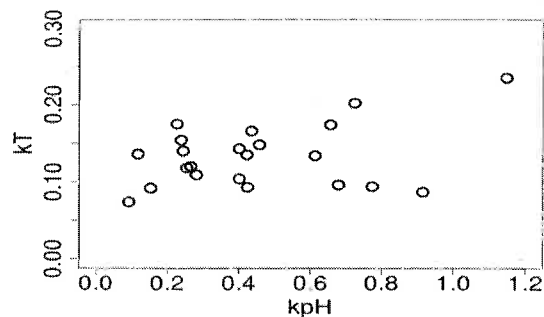


Figure 3: Relationship between the K_{pH} and K_T parameters

The simple linear correlations and the k-adjusted linear correlations among $pH_{1.5}$, $pH_{3.0}$ and pH_{24} are compiled in Table 1. The correlation between the $pH_{3.0}$ and pH_{24} was very high and highly significant (0.930, $P < 0.01$) as suggested in Figure 4. These results show that $pH_{3.0}$ can be used to predict the final pH (pH_{24}) of beef meat. It is an interesting finding, as using data obtained early post-mortem carcasses could be classified according to their final pH.

Table 1: Correlations among $pH_{1.5}$, $pH_{3.0}$ and pH_{24} : a) simple correlations below the ones-diagonal; and b) k-adjusted correlations above the ones-diagonal

	$pH_{1.5}$	$pH_{3.0}$	pH_{24}
$pH_{1.5}$	1	0.59	-0.15
$pH_{3.0}$	0.48*	1	0.62
pH_{24}	-0.07ns	0.62**	1

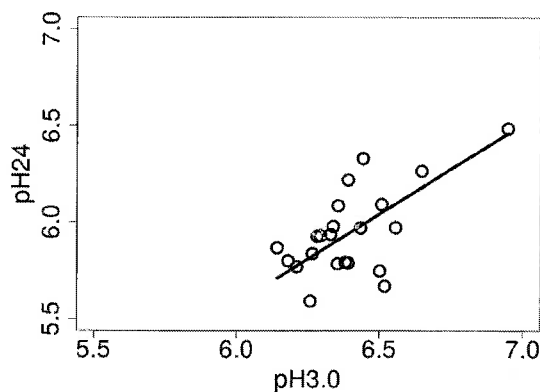


Figure 4: Relationship between $pH_{3.0}$ and pH_{24}

Effect of gender, genotype and class on temperature and pH decline

Table 2 shows the effect of gender on the K_{pH} , K_T , $pH_{1.5}$, $pH_{3.0}$, pH_{24} . No differences were found ($P > 0.05$) in these parameters between females and males. The last pH_{24} presented a wide range of values equally in males (5.59 to 6.09) and females (5.67 to 6.49). Similar patterns were

found for the effects of genotype presented in Table 3, and class presented in Table 4.

Table 2: Effect of gender on K_{pH} , K_T , $pH_{1.5}$, $pH_{3.0}$, pH_{24}

	Female (n=16)	Male (n=6)
K_{pH}	0.355 ± 0.1771^a	0.487 ± 0.2995^a
K_T	0.132 ± 0.1318^a	0.134 ± 0.0472^a
$pH_{1.5}$	6.68 ± 0.2351^a	6.98 ± 0.5872^a
$pH_{3.0}$	6.30 ± 0.1186^a	6.43 ± 0.1837^a
pH_{24}	5.83 ± 0.1688^a	5.99 ± 0.2285^a

CONCLUSIONS

Beef carcasses showed high variation in the pH and temperature decline patterns early post-mortem, which results in high variability observed in the final pH_{24} . The exponential decay model showed a good fit to the pH and temperature data, and parameters K_{pH} and K_T were found to be independent. This model can be used to predict the meat quality indicators $pH_{3.0}$, pH_{24} , T_{pH6} . The predicted pH at three hours after slaughtering ($pH_{3.0}$) seems to be a good predictor of the ultimate pH (pH_{24}) in beef meat. This study clearly shows that a quality control system should be implemented in the slaughter-house to ensure an optimal meat quality.

Table 3: Effect of genotype on K_{pH} , K_T , $pH_{1.5}$, $pH_{3.0}$, pH_{24}

	Crossbred (n=16)	Mirandesa (n=6)
K_{pH}	0.456 ± 0.3119^a	0.441 ± 0.1893^a
K_T	0.122 ± 0.0395^a	0.158 ± 0.0316^a
$pH_{1.5}$	6.96 ± 0.6204^a	6.76 ± 0.2156^a
$pH_{3.0}$	6.38 ± 0.1982^a	6.43 ± 0.1248^a
pH_{24}	5.91 ± 0.2238^a	6.03 ± 0.2122^a

Table 4: Effect of class on K_{pH} , K_T , $pH_{1.5}$, $pH_{3.0}$, pH_{24}

	Veal (n=16)	Steer (n=6)
K_{pH}	0.491 ± 0.2954^a	0.442 ± 0.2774^a
K_T	0.135 ± 0.0364^a	0.133 ± 0.0421^a
$pH_{1.5}$	6.80 ± 0.7561^a	6.84 ± 0.4755^a
$pH_{3.0}$	6.44 ± 0.1082^a	6.39 ± 0.1893^a
pH_{24}	5.87 ± 0.1217^a	5.97 ± 0.2389^a

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BIOGRAPHIES

CRISTINA XAVIER is a Portuguese national, graduated in Animal Science Engineering at the School of Agriculture of the Polytechnic Institute of Braganza, Portugal, in 2011. Currently, she is on her 3rd year of PhD in Animal Science, with an investigation whose general objective is to develop a novel monitoring system of pH and temperature decline post-mortem for beef meat carcasses.

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