OPTIMIZATION OF THE ELECTRICAL PARAMETERS OF A NEW GENERATION MEDIUM VOLTAGE STIMULATOR IN A CHINESE ABATTOIR

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I. INTRODUCTION

Electrical stimulation (ES) has been applied commercially to avoid the cold shortening of meat since the 1970s, and is currently widely used in the meat industry in a number of countries [1]. Recently, a new generation medium voltage stimulation system was designed in Australia, using square pulse widths ensuring worker safety compared to high voltage systems. Such systems have been shown to give very effective results in lamb carcasses and are now widely used in Australia for lamb [1, 2]. Because a previous study found a high percentage of beef carcasses miss the Meat Standards Australia (MSA) ideal "pH-temperature" window in Chinese abattoirs [3], it was deemed that the new medium voltage system could have potential to address this issue on the basis that the technology can be retro fitted in many plants much cheaper than high voltage systems. Given the target is to ensure the pH drops to 6.0, when the temperature is between 12°C to 35°C [4], a study was undertaken to derive optimum parameters (current, pulse width, duration time) with a target of achieving a Temp@pH6.0 of 30°C.

II. MATERIALS AND METHODS

Chinese crossbred yellow cattle (n = 200, 24 months old, 472.6 ± 30.9kg) carcasses were randomly selected on the slaughter line in a local abattoir. The right sides of the carcasses were subjected to various combinations (n = 10 per combination) of stimulation before chiller entry, based on a quadratic general rotary design. All the left sides without stimulation were regarded as control (NSE). The pH and temperature of each half carcass were measured at 45min, 3, 6, 12 and 24h after death. Temp@pH6.0 of each carcass was estimated by an exponential model based on the pH and temperature data. A central composite design for three independent factors (current, pulse width and duration), with six axial points and six replicates at the center points, was employed to fit a second order polynomial model. The zero level of current, pulse width and duration was set as 1A, 1.5ms, 30s, respectively, based on a preliminary test. The level of the upper asterisk arm, upper level, lower level and lower asterisk arm are listed in Table 1. The quadratic regression model was developed using SAS software (2010), by setting Temp@pH6.0 as the objective function: $Y(\text{Temp.@pH6})=y_0+ax_1^2+bx_2^2+cx_3^2+dx_1x_2+ex_1x_3+fx_2x_3$; where x_1, x_2, x_3 means current, pulse width and duration, respectively. The complete design is shown in Table 1.

III. RESULTS AND DISCUSSION

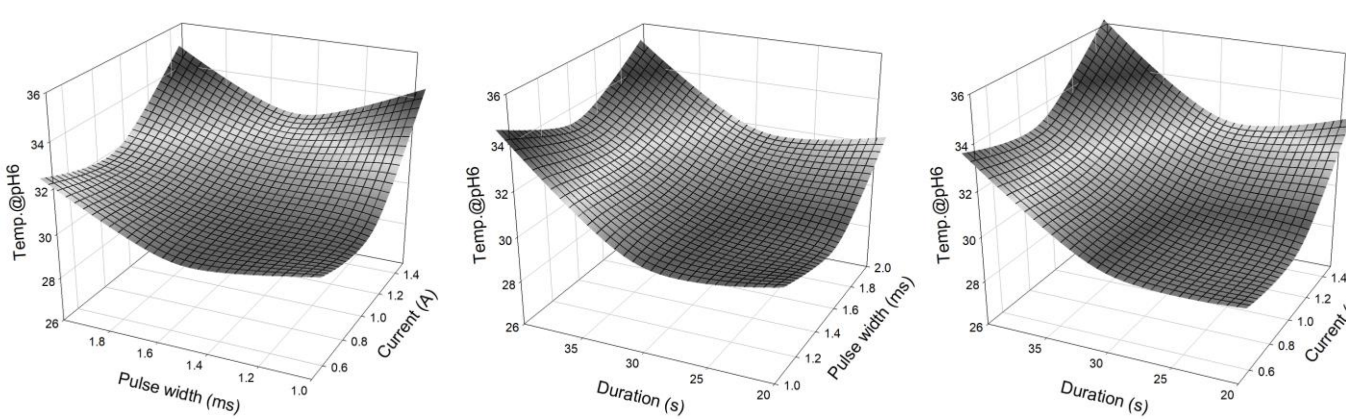

Fig.1 Response surface and contour plots

The results of analysis of variance of the response showed there was no significant lack of fit, indicating the regression model is valid. The *P* value of the total model was found to be below 0.05, meaning the final regression model is credible, and can be used to predict Temp@pH6.0. The equation was: Y(Temp.@pH6.0) = $26.258 + 1.671X_1 + 0.3945X_2 - 0.115X_3 + 2.06X_1^2 - 1.235X_2X_1 + 1.308X_2^2 - 0.0512X_3X_1 - 0.0587X_3X_2 + 0.0070X_3^2$. The results showed that, X_1(current) and X_3(duration) exhibited significant effects ($P < 0.05$) on Temp@pH6.0 X_2 (pulse width) was not significant ($P = 0.135$).

Table 1 The code and results of quadratic general rotary design

No.	X_1 (current)	X_2 (pulse width)	X_3 (duration)	Y (Temp@pH6.0)
1	1 (1.5A)	1 (2ms)	1 (40s)	35.56
2	1 (1.5A)	1 (2ms)	-1 (20s)	33.26
3	1 (1.5A)	-1 (1ms)	1 (40s)	35.60
4	1 (1.5A)	-1 (1ms)	-1 (20s)	32.25
5	-1 (0.5A)	1 (2ms)	1 (40s)	33.87
6	-1 (0.5A)	1 (2ms)	-1 (20s)	30.67
7	-1 (0.5A)	-1 (1ms)	1 (40s)	32.80
8	-1 (0.5A)	-1 (1ms)	-1 (20s)	28.25
9	1.628 (1.84A)	0 (1.5ms)	0 (30s)	32.08
10	-1.628 (0.16A)	0 (1.5ms)	0 (30s)	28.90
11	0 (1A)	1.682 (2.34ms)	0 (30s)	31.33
12	0 (1A)	-1.682 (0.66ms)	0 (30s)	28.59
13	0 (1A)	0 (1.5ms)	1.628 (47s)	33.78
14	0 (1A)	0 (1.5ms)	-1.628 (13s)	28.30
15	0 (1A)	0 (1.5ms)	0 (30s)	29.93
16	0 (1A)	0 (1.5ms)	0 (30s)	29.37
17	0 (1A)	0 (1.5ms)	0 (30s)	31.08
18	0 (1A)	0 (1.5ms)	0 (30s)	31.94
19	0 (1A)	0 (1.5ms)	0 (30s)	30.66
20	0 (1A)	0 (1.5ms)	0 (30s)	29.36

The pH-temperature decline rate during rigor onset is a very important factor influencing meat quality. Some have reported that the best tenderness was found when the Temp@pH6.0 was narrowed to 29°C to 30°C [5]. In the current study, the optimized indicator was defined as a Temp@pH6.0 of ~30°C. Without stimulation, the Temp@pH6.0 was 24.5°C. As shown in Table 1 and Fig. 1, the Temp@pH6.0 of ES treated carcasses increased as current, duration or/and pulse width increased. However, if those parameters are too large, the Temp@pH6.0 will reach 36°C, which is too high. Finally, three parameter combinations, which resulted in the value of Temp@pH6.0 approximate to 30°C, were identified as 1A, 1.55ms, 27s; 0.55A, 1ms, 34s and 0.55A, 2ms, 20s.

IV. CONCLUSION

Three ES parameter combinations were identified as optimal, with the current ranging from 0.55A to 1A, pulse width from 1ms to 1.55ms, and stimulation duration from 20s to 27s. For practical application, the effects of ES based on these combinations on traits such as the tenderness require evaluation.

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