IS ELECTRICAL STIMULATION EFFICIENCY MUSCLE DEPENDENT ?

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The electrical stimulation of hot carcasses is a treatment used in order to hasten the rigor mortis process which prevents any risk of meat toughening during the chilling of the carcasses. For this purpose, the faster the fall of pH is in the meat during and after electrical stimulation, the more efficient the electrical stimulation is.

Requirements for an efficient electrical stimulation have been studied by many authors and particularly by DAVEY et al. (1976), CHRYSTALL and HAGYARD (1976), BENDALL et al. (1976), CHRYSTALL and DEVINE (1978), SAVELL et al. (1978) There appears to be a concurrence of view among New Zealand, American and British workers that high voltages give the best results particularly in the case of beef carcasses, but Australian workers reported that low voltage stimulation could also be efficient (BOUTON et al., 1978).

Whatever the conditions of stimulation, all the workers have observed a large variability in electrical stimulation efficiency among muscles from the same carcass. BENDALL et al. observed that the lower the stimulation voltage used was, the large the variability is, and SWATLAND (1975, 1977) related the high scatter in the post electrical stimulation pH values to the metabolic and contractile characteristics of the muscle fibers.

In order to check the hypothesis of SWATLAND we investigated the respective effects of the real electric field applied to the muscles and of the duration of stimulation on the pH drop during stimulation in three lamb muscles predominantly composed of βR, αR and αW (according to the classification of ASHMORE and DOERR, 1971) fibers (TALMANT,1979).

EXPERIMENTAL

Sixteen male Limousin lambs whose carcasses were weighing between 15 and 17 kg, have been used.

Samples were taken, 15 minutes post mortem, from the left Supraspinatus (SS), Longissimus dorsi (LD) at the level of the 13th rib and Tensor fasciae latae (TFL), and immediately frozen in liquid nitrogen, in order to furtherly determine the pH.

The three same muscles of the right side have been successively stimulated in situ. After stimulation, the part of muscle located between the electrodes was cut off and frozen in liquid nitrogen for subsequent pH determination. The conditions of stimulation were the following :

- electric field : 0.5 ; 1.0 ; 2.0 ; 4.0 Volts/cm
- duration of stimulation : 30 ; 60 ; 120 and 240 seconds
- frequency of the current : 12.5 Hz

Each coupled condition (electric field - duration of stimulation) was tested using one lamb.

The stimulating current was applied by a system of electrodes spaced by 3 cm or 5 cm ; 2 additional electrodes being located between the 2 sets of stimulating electrodes, allowing the measurement and thus the setting of the electric field applied to the stimulated portion of muscle.

The measurement of pH, before and after stimulation was made after grinding in liquid nitrogen the frozen samples, then homogenizing in cold 5 mM iodoacetate.

The activity of the lactic deshydrogenase and the pigment iron content of the tested muscles have been determined on 12 lambs, according to the methods used respectively by ANSAY (1974) and HORNSEY (1956).

RESULTS AND DISCUSSION

Table 1 relates for 12 lambs, the pigment iron content and the activity of the lactic deshydrogenase measured for a high concentration of pyruvate. This activity is closely correlated to the myofibrillar ATPase activity which characterizes the contractile type (TALMANT, 1979).

Table 1 : METABOLIC AND CONTRACTILE CHARACTERISTICS OF THE TESTED MUSCLES

Muscles	Heminic iron µg Fe/g of muscle	Activity of LDH in µmoles of pyruvate transformed/min/ g of protein (a)
Tensor fasciae latae (αW)	5.57 ± 0.29	2112 ± 177
Longissimus dorsi (αR)	11.02 ± 0.35	2903 ± 127
Supraspinatus (βR)	10.36 ± 0.25	675 ± 74

(a) protein measured in the whole muscle homogenate by the biuret method

These results lead us to consider :

SS muscle as predominantly composed of βR type fibers
LD muscle as predominantly composed of αR type fibers
TFL muscle as predominantly composed of αW type fibers

Figure 1 shows the relationship between the extent of the pH fall during stimulation in the muscles TFL, LD or SS and the electric field and the duration of stimulation.

Before stimulation the average pH of the 3 muscles studied were the following :

TFL : 6.83 ± 0.12
LD : 6.87 ± 0.04
SS : 6.98 ± 0.06

For these 3 muscles, one can see on figure 1 that the efficiency of the stimulation, shown by the pH fall during stimulation, increases with the value of the electric field, then it reaches a plateau depending on the duration of stimulation, for electric fields larger than 2 Volts/cm.

On this figure, one can see the smaller the electric field, the more important the influence of the metabolic and contractile type on the fall of pH, particularly for values lower than 2 Volts/cm.

The muscles that react the least to the weak stimulations are predominantly of the slow red type.

Thus for an electric field of 1 Volt/cm the following ΔpH values were registered :

Duration of stimulation	SS	LD	TFL
1 mn	0.16	0.25	0.40
2 mn	0.20	0.40	0.55

As the pH before stimulation of the Supraspinatus is very high, it is difficult to lower the pH of these muscles under 6.50 by electrical stimulation ; which explains that these muscles remain very sensitive to cold-shortening after electrical stimulation of the carcasses.

As one can see on the figures, electrical stimulation is particularly efficient for white fast-twitch muscles and slightly less for red fast-twitch muscles. These results confirm and extend those of SWATLAND (1975, 1977).

CONCLUSION

In industrial practice, stimulation of large bovine carcasses under 600 Volts during 90 seconds or 2 minutes, the conditions are near those of our stimulations by an electric field inferior or equal to 2 Volts/cm. The results reported here allow to understand why apart from any other cause of variability, the pH falls during stimulation are very different among muscles from the same carcass. Confirming SWATLAND's results we observe that the variability of the metabolic and contractile types can be a real limiting factor to the efficiency of the electrical stimulation.

However the results that we report also show that progresses are possible. Indeed it appears that an increase in the efficiency of the stimulation for red fast-twitch muscles and mostly for red slow-twitch muscles is possible by an increase in the electric field applied to these muscles as well as in the duration of the stimulation.

As far as the latter factor is concerned, it is likely that in industrial practice one cannot much increase the duration of stimulation beyond 2 minutes without slowing down the slaughtering rate.

The solution of our problem lies probably more in the search of the conditions of an increase of the electric field applied to the different muscles of the carcass and mostly to red muscles, as well as in the search of a better distribution of the electric field through the carcass.

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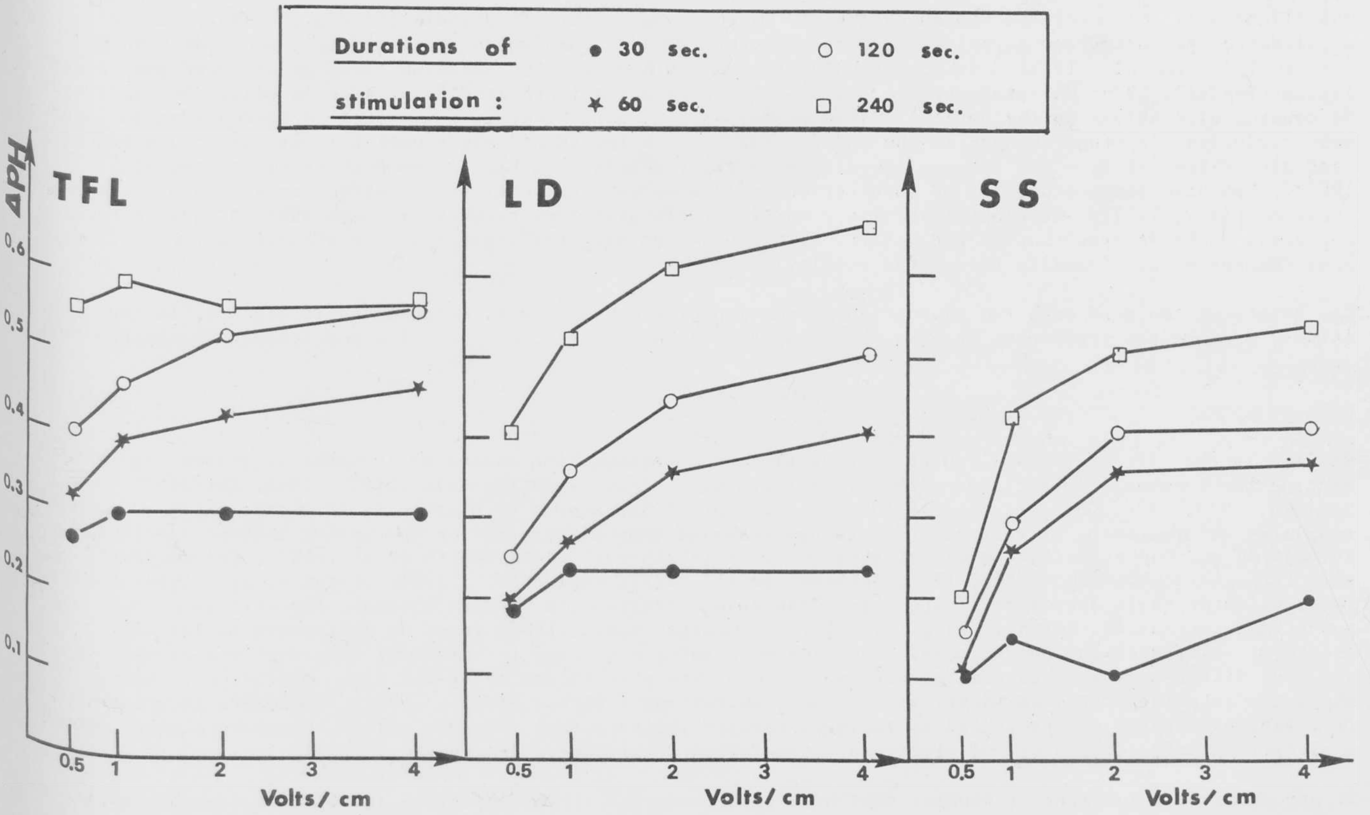

Figure 1. Effect of electric field and duration of stimulation on the pH fall in lamb TFL, LD, and SS muscles.