Effect of electrical stimulation and higher temperature conditioning on tenderness of bovine semitendinosus muscle

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SUMMARY: This study was designed to determine the effect of low voltage electrical stimulation (60 V, 2 min) and conditioning in water bath at different temperatures (30-60 °C) on tenderness of the cattle semitendinosus muscle. Four conditioning treatments were applied: 30 °C - 4 hours (II), 40 °C - 4 hours (III), 50 °C - 2 hours (IV), and 60 °C - 2 hours (V). Chilled muscles were used as control samples. Meat was evaluated after 2 and 7 days storage in chilling room. The combined treatment of electrical stimulation and conditioning in water bath caused an improvement of meat tenderness measured instrumentally. The highest conditioning temperatures i.e. 50 °C and 60 °C, had a particularly strong influence.

INTRODUCTION: The process of large scale meat tenderisation is usually connected with the application of conditioning treatments and for electrical stimulation. Temperatures most commonly used in the high temperature conditioning (HTC) are from 15 °C to 42 °C (BABIKER, 1985; PETÄJÄ et al., 1985; STABURSVIK et al., 1980), while the time of carcass or muscle exposure to these temperatures varies from several hours to a few days. The highest temperature which have been applied for conditioning is 60 °C - 65 °C (DAVEY et al., 1976). The effect of conditioning on tederisation markedly decreases at the temperature above 70 °C. Electrical stimulation improves tenderness by damaging muscle structure and accelerates liberation of some enzymes (mainly β-glucosonidase). With higher activity under conditions of increased temperature and pH value (BABIKER, 1985; PEARSON et al., 1985; RUDERUS et al., 1980). The aim of this research was to evaluate tenderness of the bovine semitendinosus muscle subjected to electrical stimulation and higher temperature conditioning. The results of these treatments were compared to samples stored two and seven days after slaughter.

MATERIALS AND METHODS: The bovine semitendinosus muscle was obtained directly after the slaughter of cattle with age from 18 to 24 months and pre-slaughter weight of about 500 kg. After stunning and bleeding the carcasses were electrically stimulated by low voltage current routinely used in slaughter houses (RUDERUS et al., 1980). The applied current was 60 V and its duration 2 minutes. Muscles excised from carcasses were weighed and placed in polyethylene bags from which air was removed. Experiments were conducted in five treatment groups. Muscles from the control treatment (I) were electrically stimulated and chilled in a cold store (+4 °C). Muscles from the remaining treatment groups were subjected to conditioning by immersing them in a water bath with different temperatures. Incubation conditions were as follows: treatment group II: 30 °C - 4 hours; treatment group III: 40 °C - 4 hours; treatment group IV: 50 °C - 2 hours, and treatment group V: 60 °C - 2 hours. After conditioning, muscles were chilled at +4 °C and stored at the same temperature for a period of 2 and 7 days. The following assessment were accomplished on the meat samples: pH values were measured using an Orion research 221 type pH-meter equipped with a combined electrode. Measurements were taken after cutting muscles from carcass, after conditioning, and after 24, 48 and 168 hours of storing from slaughtering. Temperature was measured after cutting muscles from carcasses and after conditioning. The thermometer was a thermistor type. Weight losses were assessed in percentage, in relation to the muscle weight before

conditioning, after 2 and 7 days storage at +4 °C. Muscle sections were subjected to differential scanning calorimetry with the use of Perkin Elmer DSC II apparatus. Samples were heated from 2 °C to 100 °C at the rate of 10 °C/min. The value of enthalpy was expressed in mcal/g muscle tissue. Heating was carried out in the large aluminium capsules, - the weight of a sample was approximately 40 mg. Measurements of muscle tenderness were carried out using the Instron apparatus, type TM-SM. Measurements were taken for extension forces acting along and across the muscle fibre axis. Tenderness was measured on slices from muscles previously subjected to thermal treatment (85 °C, 1 hour). Slices were cut by means of a special die with a thickness of 3 mm. Sensory evaluation of tenderness and juiciness were carried out by a team of specialized panelists, using a scale of 9 scores. Tenderness was estimated on the basis of susceptibility of slices to split along muscle fibres, slice resistance to compression, force needed for chewing, and force required to bite through slices. The data was analyzed by the Statistical Analysis System (SAS Institute Inc., Corry NC, 1985). The Duncan's multiple range test was applied to determine differences between means.

RESULTS AND DISCUSSIONS: Fig. 1 shows the changes in muscle pH from slaughtering till the 7th day of storage. The biggest changes in the pH values were recorded during the conditioning process itself and during the first 24 hours after slaughter. The lowest pH values were observed in muscles conditioned at temperatures from 40 °C to 60 °C. Differences between the curves for the control sample and the sample conditioned in 30 °C were small, but were clearly different from those of the remaining three treatments. After 48 hours, with the exception of the sample which underwent conditioning at 60 °C, small differences in pH were recorded between the samples. Muscle temperature after electrical stimulation ranged from 34.0 °C to 40.2 °C, depending on the animal carcass from which it was taken. After conditioning, depending on the treatment, the average temperatures were the following: for the control sample - 35.9 °C, for the samples kept at the thermostat at 30 °C-30 °C, at 40 °C - 39.6 °C, at 50-45,7 °C, and at 60 °C - 54.3 °C. It is evident from Table 1 that the force needed to disrupt the muscle along the fibre axis, i.e. when the action of myofibrillar proteins is dominant, was decreasing with the increase of the conditioning temperature. These measurements were recorded after 7 days of storage. For the first three treatment groups the mean values of differences ranged from about 11% to 15%, while for treatments IV and V these values were 46.13% and 61.04%, respectively. When the measurement were taken perpendicularly on the muscle fibres (primarily forces of connective tissue) forces necessary to disrupt the muscle were insignificant and did not seem to depend on the conditioning treatment (Tab 1). Sensory evaluation of meat tenderness after 2 and 7 days storage, showed the positive effect of conditioning on meat tenderness at higher temperature (Tab 2). Differences between control treatment and experimental treatments (conditioned meat) were statistically significant, but the panelists did not find any differences between experimental treatments. The mean values of juiciness scores presented in Table 2 showed that muscle conditioned at higher temperatures, in particular at 60 °C, obtained lower scores for this attribute. However, an analysis of variance did not reveal any significant influence of conditioning on juiciness. Higher temperatures during the conditioning process resulted in bigger muscle weight loss during storage (Fig. 2). Differences in weight loss between the first two treatments were significant. The highest loss of meat juice were found in samples conditioned at temperatures 50 °C and 60 °C. These changes were caused by denaturation processes confirmed by differential scanning calorimetry (Tab 3). The obtained thermogram showed the disappearance of the first peak corresponding primary to myosin (STABURSVIK et al. 1980; WRIGHT et al. 1977) in muscles conditioned at temperatures above 40 °C. With the increase

of the conditioning temperature, the size of the remaining peaks indicating the degrees of denaturating changes of actin (third peak) as well as sarcoplasm and collagen (second peak) also decreased. It is interesting that denaturation process which occurs in bovine meat at high temperatures and low pH values are not followed by weight loss as observed in porcine muscles, particularly in muscles with PSE defects (Fisher et al. 1978, George et al. 1980). It is even more interesting in view of the fact that muscles conditioned at 60 °C had approximately 1 cm layer of tissue of a slightly changed light pink colour. The tenderising effect of higher temperatures during conditioning could be explained not only by the higher activity of proteolytic enzymes, but also by the denaturation of proteins. Denaturated proteins are more susceptible to enzymatic degradation which will promote the tenderisation of the muscle.

CONCLUSION: This experiment showed that the combined treatment of electrical stimulation and conditioning using temperatures up to 60 °C contributes to the improvement of muscle tenderness. Muscle toughness was reduced significantly by the combination; ES, conditioning at 60 °C for 2 hours (V), 2 days storage at +4 °C, - ES, conditioning at 50 °C for 2 hours, 7 days storage at +4 °C. Although the use of high temperatures for 2 hours did cause considerable protein denaturation, and consequently some muscle juice loss, these effects were not so strong as in PSEs muscles from pork. Hot deboning of meat offers opportunities of treating the cuts in different ways. This method of conditioning of meat at higher temperatures in combination with electrical stimulation offers possibilities of rationalize and optimalize the aging, with respect to the different cuts of the carcass.

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Table 1. Extension test value of conditioned muscle

Treatment group	DIRECTION OF MUSCLE EXTENSION			
	Along	Perpendicular	Along	Perpendicular
	After 2 days storage		After 7 days storage	
Control	4.13 [a]	0.12	3.55 [a]	0.12
30 °C, 4 hours	3.73 [a]	0.17	3.38 [a]	0.09
40 °C, 4 hours	3.57 [a]	0.12	3.17 [a]	0.11
50 °C, 2 hours	3.23 [a]	0.08	1.49 [b]	0.09
60 °C, 2 hours	2.31 [b]	0.12	1.41 [b]	0.11

Table 2. Sensory evaluation of conditioned muscles (scores)

Treatment group	After 2 days storage		After 7 days storage	
	Tenderness	Juiciness	Tenderness	Juiciness
Control	2.82 [a]	5.61	3.63 [a]	5.80
30 °C, 4 hours	6.34 [b]	5.48	6.42 [a]	5.63
40 °C, 4 hours	4.48 [b]	5.44	4.50 [b]	5.61
50 °C, 2 hours	4.50 [b]	5.49	5.15 [b]	5.49
60 °C, 2 hours	5.5 [b]	5.02	6.01 [b]	5.02

Table 3. Changes of denaturation enthalpy of muscle (mcal/g)

Treatment group	After 2 days storage	After 7 days storage
Control	1065 [a]	953 [a]
30 °C, 4 hours	948 [a]	1066 [a]
40 °C, 4 hours	737 [b]	817 [b]
50 °C, 2 hours	649 [b]	667 [b]
60 °C, 2 hours	492 [c]	444 [c]

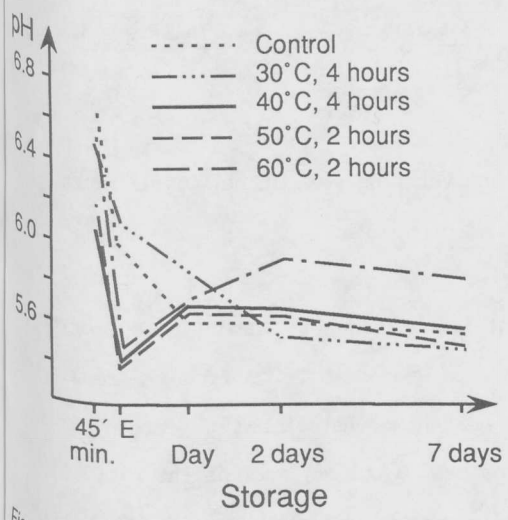

Fig. 1. *Changes of muscle pH during conditioning and storage*

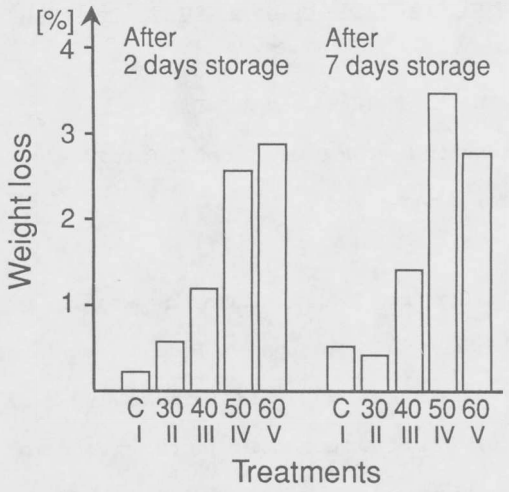

Fig. 2. Weight loss of muscle (%) during storage in cilling room. Treatments: I - control, II - 30 °C, 4 hours, III - 40 °C - 4 hours, IV - 50 °C, 2 hours, V - 60 °C, 2 hours