4:10 Influence of electrical stimulation and slow chilling on the texture of turkey breast muscle

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Introduction

One of the major problems in the poultry industry is the wide variation in tenderness of meat between birds (Khan and Nakamura, 1970; Ngoka, et al, 1982). Most research on toughness has shown the importance of cold-shortening and ageing in beef, lamb and pig meats. These meats can be subjected to a variety of chilling and storage conditions leading to wide variability. In avian meats however the importance of these technological factors is less clear.

Variations in post-mortem metabolism, particularly the rate and extent of glycolysis have a large influence on tenderness. Cold-shortening can occur in chicken (Smith et al. 1969; Wood and Richards, 1974) and in turkey leg muscle (Marion, 1971) but it does not occur in turkey breast muscle (Jungk and Marion, 1970). Since there are no recommendations for the time required, turkey meat is rarely aged in the UK. The effectiveness of electrical stimulation and its effect on tenderness was therefore tested in turkey breast muscle exposed to normal rapid spin chilling and slower air chilling.

Materials and Methods

Turkeys

Hens from a flock of British United "Triple 8" Turkeys with an average live weight of 3.5 kg at 10 weeks were hand loaded into crates and transported by lorry 3 miles to the slaughterhouse. The birds were stunned and stuck conventionally and 16 carcasses assigned randomly to each of eight treatment groups in a factorial (2 x 2 x 2) design. The treatments were as follows:

Low Voltage Electrical Stimulation (ES), or non-electrically stimulated control (NES):

Spin Chilling (SC) for 45 mins, or Air Chilling (AC) for 24 hours at +1 C to +5 C:

Unaged (i.e. cooked immediately after thawing) or thawed and aged for 7 days at +1 C prior to cooking.

The ES group were stimulated for 30 sec. immediately after sticking, using a Medal Junior Low Voltage Electrical Stimulation Unit generating unidirectional 94 volt pulses of 5 msecs duration at 14.3 pulses/sec. The electrodes were attached to the head (wattle) and the frame holding the legs.

Meat

After sticking, the birds were conventionally bled, scalded, plucked, eviscerated and inspected before reaching the selection area, 20 minutes post slaugher. The birds were removed from the line and 1 g of M. Pectoralis thoracicus removed from the left breast and macerated in 10 ml of 5mM sodium iodoacetate, 150mM potassium chloride at pH 7. for pH measurements. The AC carcasses were placed in a chillroom running at +1 C overnight, and the SC carcasses replaced on the line to pass through the immersion spin-chillers. At this time the deep muscle temperature was about 35°C and was reduced to about 7°C after 45 minutes in the spin chiller. After spin chilling the carcasses were stored overnight in iced water. The following day, AC and SC breast muscles were dissected from the right side of each bird, vacuum-packed and frozen within 2 hours, before transporting to MRI at -20°C. On arrival at MRI the samples were allocated to treatment groups and stored for up to 2 months at -20°C until texture measurements could be made. Then the muscles were thawed for 24 hours at +1°C (± 0.05°C) and M. Pectoralis thoracicus removed for assessment.

pH and sarcomere length

Ultimate pH was determined on a 1:10 homogenate of meat to water using 10g of flesh from the end of the muscle. An adjacent strip was taken for sarcomere length determination by the optical diffraction technique of Voyle (1971).

Cooking and Texture

The muscle samples were weighed (110-190g), vacuum-packed and either cooked immediatly, or aged for 7 days at +1°C (± 0.5°C) before cooking. Muscles were heated to a centre temperature of 89°C (± 1°C) in a waterbath at 90°C (which took between 40 and 45 minutes), and then cooled for 45 minutes in running water (c. 12°C). Samples were drained and reweighed for calculation of total losses (cooking and drip due to storage) before being placed at =3°C (± 1°C) overnight. Toughness was determined on 10 blocks of muscle, each 15-30 mm long in fibre direction and 10 x 10 (± 0.5) mm cross section. They were sheared perpendicular to fibre direction using Volodkevich-type jaws (Rhodes et al. 1972). First yield force (kgf) was taken as a measure of toughness.

Results

a) Muscle pH and shortening (Table 1, Figure 1)

Twenty minutes after slaughtr the pH of control (non-stimulated) muscles varied from 6.2 to 6.8 and averaged 6.39. In electrically stimulated carcasses pH varied fom 5.8 to 6.3 and averaged 6.06. Figure 1 shows the distributions of pH at 20 minutes for 75 ES and 75 NES muscles. 81% of the NES muscles had pH values from 6.2 to 6.64 and the 9% which had very low pH (5.94 to 6.1) were not included in results in Table 1. Eighty seven percent of the ES muscles had pH less than 6.2. The ultimate pH, measured after thawing, averaged 5.74 and was similar for all treatment groups.

Spin-chilled muscles had shorter sarcomeres (1.6 um) than air-chilled muscles (1.9 um). Stimulated muscles, overall, had similar sarcomeres (1.8 um) to non-stimulated (1.7 um) and stimulation did not increase sarcomere lengths in either spin-chilled or air-chilled meats. Ageing for 7 days at 1°C had little effect on sarcomere lengths.

b) Texture (Table 1)

On cooking, meat which had been air-chilled lost 25% weight while that which had been spin-chilled lost 30%. Cooking losses in unaged meat were similar to those in aged meat. Toughness values ranged from 1.7 to 5.0 and averaged 2.8 kgf. Air chilling produced more tender meat. Toughness values were on average 3.0 kg after spin chilling and 2.5 kgf after air chilling. Of the 16 toughest muscles (representing 13% of the 126 examined) 14 were in the groups which had been spin chilled.

Ageing decreased toughness slightly. Values averaged 2.9 kgf in unaged and 2.5 kgf in aged muscles.

Electrical stimulation increased slightly the cooking losses from 26% to 28% of the thawed weight and caused a similar increase in both air and spin-chilled meat. Electrical stimulation did not significantly affect toughness values overall. Seven of the 16 toughest muscles had been stimulated.

The pH measured at 20 minutes after stunning was related to toughness. With spin chilling particularly, toughness was at a minimum of 2.4 kgf at pH 6.8. Figure 2 shows the relationship between pH and toughness for the 2 extreme treatments: spin chilled, unaged and air chilled, aged. Other treatments usually gave intermediate toughness values and have been omitted for clarity. In muscles with pH_{20} >6.3 spin chilling without ageing produced tougher than average meat and toughness increased with increasing pH_{20}, but in air chilled aged meat there was no affect of pH_{20} on toughness. In muscles with pH 6.1 to 6.3 there was little difference in toughness between SC and AC but aged meat (2.3 kgf) was slightly more tender than unaged meat (2.7 kgf). In meat with pH_{20} <6.1, toughness tended to increase with decreasing pH_{20}.

Discussion

Spin chilling is now common practice for poultry and, in this commercial system, the 3 to 4 kg carcasses were cooled to about 7°C in 45 minutes from the start of chilling and about 65 minutes from stunning. Carcasses were then held overnight in ice water and then frozen for 25 hours in tanks at -25 to -30°C. Although efficient in throughput and chilling such a system produced more variable texture and tougher meat than slower cooling in air. Similarly, slower cooling using spin chiller therefore would be expected to increase tenderness and maintain the good appearance (Grey et al., 1982).

The major cause of toughness in spin chilled meat was associated with high initial pH values and shorter sarcomeres. These results are therefore in conflict with those of Jungk and Marion (1970) who observed no cold-shortening in 10 breast muscles with temperatures down to 4°C. However, they did observe cold-shortening in thigh muscles and 'hot-shortening' in breast muscles with temperatures up to 35°C. Breast muscle in chicken also cold-shortens (Wood and Richards, 1974).

A significant but small tenderising effect occurred during ageing for 7 days at 1°C. In turkey carcasses, leg muscles require about 5 days for ageing (van-den Berg et al., 1964) which is slightly longer than breast muscle for which 3 days is sufficient (de Fremery and Streeter, 1969).

Although cold-shortening was induced in turkey breast muscle, electrical stimulation was not always effective in tenderising the meat. Stimulation reduced the initial pH by 0.33, on average, and tended to produce slightly paler meat (with Hunter L values of 45 compared with 47 for non-stimulated). Electrical stimulation, applied to excised muscles in order to determine rigor development, produced tougher meat than non-stimulated controls (de Fremery and Pool, 1960).

The anomaly that electrical stimulation can prevent cold-shortening toughness but not affect the toughness overall or even toughens meat, was resolved by demonstrating toughness in rapidly glycolysing muscles.

Rates of glycolysis can vary widely in turkey meat and rigor times can vary from 25 to 391 minutes (Ma et al. 1971). Some muscles will be in rigor prior to chilling whilst others may be completely chilled prior to rigor. A similar situation occurs in pig meat (Chadwick and Kempster, 1983) causing wide variations in texture (Dransfield & Lockyer, 1984). In the present experiment, muscles which were above pH 6.3, 20 minutes after stunning could be cold-shortened and toughness increased with increasing pH. However, toughness was at a minimum in muscles which had had a pH of about pH 6.2, 20 minutes after stunning. Less than 10% of non-stimulated muscles were very fast glycolysing with pH_{20} <6.2 but in older birds the incidence is higher (Vanderstoep and Richards, 1974). Electrical stimulation increased the rate of glycolysis and in most muscles was sufficient to increase their toughness. The situation is similar to that in pigs where electrical stimulation can prevent cold shortening but increase the incidence of PSE. The finding that rapidly glycolysing turkey muscles can be tough clearly explains why pre-slaughter stress can increase toughness (Ngoka et al, 1982; Khan and Nakamura, 1970) and why birds which are allowed to struggle freely give tougher meat than cold-stressed or anaesthetised birds (Froning et al. 1978).

Although toughness due to too rapid chilling or inadequate ageing can be reduced or eleviated by post-slaughter handling, toughness from rapid glycolysis can only be eliminated by screening and breeding programmes. By analogy with pigs (Allen et al. 1980) a systematic screening for creatine kinase activity and halothane sensitivity in turkeys should be undertaken. Only after rapid glycolysing birds have been eliminated from breeding flocks can the benefits of electrical stimulation and rapid chilling be used to produce tender meat.

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FIGURE 1

pH 20 minutes after sticking in electrically stimulated and non-stimulated carcasses.

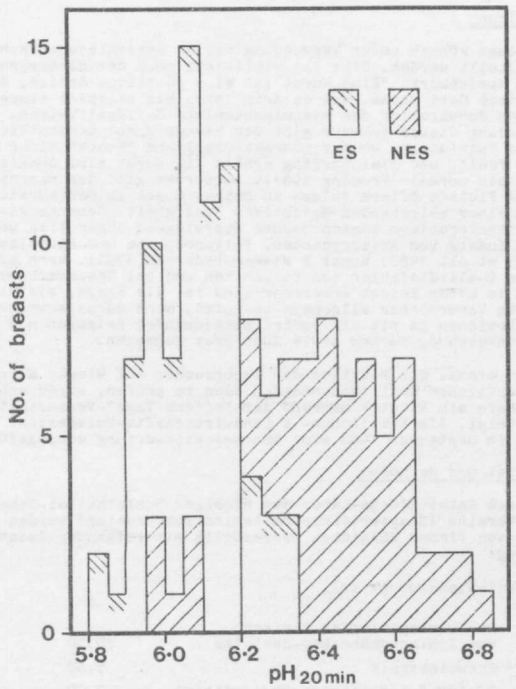

Table 1. Effect of stimulation and chilling on sarcomere length, cooking loss, texture and pH in aged and unaged turkey breast muscle.

Values are mean and standard deviation of 60 muscles for pH at 20 minutes and 30 muscles for the remainder of the measurements.

	STIMULATED		NON-STIMULATED	
pH (20 minutes)	6.06(0.12)		6.39(0.20)	
Chilling	Spin Chill	Air Chill	Spin Chill	Air Chill
UNAGED				
pH (ultimate)	5.8 (0.1)	5.7 (0.1)	5.7 (0.1)	5.7 (0.1)
Sarcomere length (μm)	1.6 (0.2)	1.8 (0.1)	1.5 (0.2)	1.8 (0.1)
Cooking Loss (%)	29.9 (1.6)	25.7 (2.1)	28.8 (1.5)	23.3 (2.0)
Texture (kgf)	3.0 (0.7)	2.8 (0.6)	3.2 (0.8)	2.7 (0.4)
AGED				
pH (ultimate)	5.8 (0.1)	5.7 (0.1)	5.7 (0.1)	5.7 (0.1)
Sarcomere Length (μm)	1.7 (0.1)	1.9 (0.1)	1.5 (0.2)	1.8 (0.2)
Cooking Loss (%)	31.4 (2.4)	25.1 (3.8)	29.6 (2.2)	23.9 (1.9)
Texture (kgf)	2.85 (0.7)	2.5 (0.6)	3.1 (0.8)	2.2 (0.3)

FIGURE 2

Relationship between pH at 20 minutes and toughness

⊙,Spin chilling, unaged

▲,Air chilling, aged