GERMAN

NACH DEM TODE EINTRETENDE pH- UND TEMPERATURVERÄNDERUNGEN IN SECHS MUSKELN VON RINDERKADAVERN

P. J. V. TARRANT

Meat Research Department, Agricultural Institute, Castleknock, Co Dublin
Irland

Es wurden die nach dem Tode auftretenden pH- und Temperaturabnahmegeschwindigkeiten bei sechs Hauptmuskeln von Rinderkadavern untersucht. Das für den Versuch verwendete Vieh wurde unter ähnlichen Bedingungen geschlachtet und gekühlt wie sie im Handel üblich sind. Es wurden große Schwankungen der pH-Abnahmegeschwindigkeiten an verschiedenen Stellen der Kadaver beobachtet.

Am langsamsten war die pH-Abnahme im longissimus dorsi und in den äußeren Teilen der Muskeln von Rindskeulen, was ein Risiko der Schrumpfung durch Kälteeinwirkung und eine Zunahme der Zähigkeit in diesen Teilen mit sich brachte. Im Gegensatz dazu wurden hohe pH-Abnahmegeschwindigkeiten im psaos major und in den tiefergelegenen Teilen der Muskeln von Keulen beobachtet. In den tieferen Teilen der Keulen wurde eine geringe Wärmeverlustgeschwindigkeit gemessen und die an dieser Stelle auftretende Kombination von hoher Temperatur und niedrigem ph-Wert ergab wahrscheinlich eine Denaturierung von Muskeleiweiß und folglich eine Abnahme der Fleischqualität.

Die nach dem Tode bei Kadavern von Schlachtieren angestellten pH-Messungen werden weithin als Maßstab für die Fleischqualität verwendet. Diese Ergebnisse zeigen, daß die Geschwindigkeit der nach dem Tode eintretenden ph-Abnahme bei Rinderkadavern sehr unterschiedlich ist, sowohl zwischen verschiedenen Muskeln als auch in den einzelnen Muskeln selbst und unterstreicht die Notwendigkeit einer sorgfältigen Auslegung der Ergebnisse von den an bestimmten Stellen vorgenommenen ph-Messungen, bevor Schlüsse bezüglich des ganzen Kadavers gezogen werden können.

POSTMORTEM pH AND TEMPERATURE CHANGES IN SIX MUSCLES OF BEEF CARCASSES

P. J. V. TARRANT

Meat Research Department, Agricultural Institute, Castleknock, Co.Dublin
Ireland

The rates of pH and temperature fall post-mortem in six major muscles in the beef carcass were studied. The cattle used in the experiment were slaughtered and chilled under conditions similar to those used in commercial practice. Large variations in the rates of pH fall at separate locations in the carcass were observed.

The slowest pH fall was in the longissimus dorsi and in the superficial parts of the muscles of the beef round. As a result there was a risk of cold shortening and an increase in toughness in these parts. In contrast to this, rapid rates of pH fall were observed in the psoas major and in the deep parts of the muscles of the round. In the deep round, the rate of heat loss was slow, and the combination of high temperature and low pH which occurred at this location was likely to result in denaturation of muscle protein and consequently a decrease in meat quality.

Post-mortem pH measurements made on the carcasses of meat animals are widely used as indicators of meat quality. These results show that the rate of post-mortem pH fall in beef carcasses varies greatly both between muscles and within muscles and emphasises the necessity of careful interpretation of the results of pH measurements made at specific locations, before conclusions relating to the whole carcass can be drawn.

FRENCH

CHANGEMENTS DE pH ET DE TEMPERATURE POST-MORTEM DANS SIX MUSCLES DE BOEUFS

P. J. V. TARRANT

Département des Recherches sur la Viande, Institut Agricole, Castleknock, Co. Dublin. Irlande.

On a étudié les taux de chute de ph et de température post-mortem sur six muscles principaux du boeuf. Les bêtes utilisées dans cette expérience ont été abattues et réfrigérées dans des conditions similaires à celles employées commercialement. On a observé d'importantes variations des taux de chute du ph en des endroits distincts de la bête.

La chute de pH la plus lente s'est produite dans le longissimus dorsi et dans les parties superficielles des muscles de la cuisse du boeuf. En conséquence il y avait un risque de raccourcissement par le froid et une augmentation de la coriacité dans ces parties. A l'opposé, on a observé des taux rapides de chute du pH dans le psoas major et dans les parties profondes des muscles de la cuisse. Dans les parties profondes de la cuisse, le taux de perte de chaleur était lent et la combinaison d'une température élevée et d'un pH bas se produisant en cet endroit avait pour conséquence probable la dénaturation des protéines du muscle et par suite une diminution de la qualité de la viande.

Les mesures de pH post-mortem prises sur les carcasses d'animaux de boucherie sont largement utilisées à titre d'indicateurs de la qualité de la viande. Ces résultats montrent que les taux de chute du pH post-mortem se produisant dans les carcasses des boeufs varient largement d'un muscle à l'autre et à l'intérieur des muscles et ils soulignent la nécessité d'interpréter les résultats de mesures de pH prises à des endroits spécifiques, avant de tirer des conclusions pour l'ensemble de la bête.

Изменения pH и температуры в мягких мышцах говяжьих туш после убоя.

П. И. В. Таррант

Отделение исследования мяса, Земледельческий институт, Каслнок, Дублин, Ирландия

Исследовали скорость понижения pH и температуры после убоя в мягких больших мышцах крупной рогатой скота, которым пользовались был убой и охлаждали при условиях похожих на те, существующие в торговой практике. Наблюдали значительные расхождения в скорости понижения pH в отдельных мягких тушах.

Понижение pH являлось самым медленным в longissimus dorsi и в внешних частях мышц ляжек говядины. По этому здесь риск сокращения вызванного холодом и повышения жёсткости. Напротив, быструю скорость понижения pH наблюдали в psoas major и в внутренних частях мышц ляжек говядины. В внутренних ляжек говядины скорость понижения температуры оказалась медленной.

POSTMORTEM pH AND TEMPERATURE CHANGES IN SIX MUSCLES OF BEEF CARCASSES

P. J. V. TARRANT

Meat Research Department, Agricultural Institute, Castleknock, Co.Dublin
Ireland

Introduction

Post-mortem anaerobic glycolysis in muscle results in an increase in acidity, principally due to the formation of lactic acid. Determination of the rate of pH fall is a convenient way to measure the rate of post-mortem glycolysis (Bate-Smith and Bendall, 1949; Marsh, 1954).

The rate of post-mortem glycolysis has a profound influence on meat quality. A very slow rate of glycolysis allows the temperature of the muscle to fall below 10°C while the pH and adenosine triphosphate concentration are still high. In beef, this has been shown to result in an increase in meat toughness, due to 'cold-shortening' taking place, (Marsh & Leet, 1966; Bendall, 1972). On the other hand, an abnormally fast rate of glycolysis results in a low pH in the muscle while the temperature is still above 30°C. This condition results in abnormal protein denaturation with adverse effects on the water-holding capacity, colour and texture of the meat (see review by McLoughlin, 1969).

During normal chilling the muscles of beef carcasses cool at different rates, depending upon their location. This experiment was designed to study the rate of pH fall in six major muscles in the hindquarter, under conditions of slaughter and chilling similar to those frequently used in the meat industry.

Experimental Procedure

Twenty-eight Hereford heifers, aged about 18 months to 2 years and weighing approximately 350 kilogrammes, were bought at a local market and rested for at least a week before slaughter. The animals were stunned using a captive bolt pistol, exsanguinated and dressed by conventional methods. The kidney and channel fat was removed. The carcasses were cooled in a laboratory chill with an air flow of 1 m sec^{-1} at 3°C for 48 hours.

Measurements of pH and temperature were made on the intact carcasses. The six muscles used were m. longissimus dorsi (LD), m. psoas major (PM) and 4 muscles from the beef round:- m. semimembranosus (SM), m. semitendinosus (ST), m. biceps femoris (BF) and m. adductor (AD). Measurements were made at the centre (3 cm. depth) of the PM and LD (lumbar region) and at the superficial (1.5 cm depth), centre (5 cm depth) and deep part (8 cm depth) of the 4 muscles of the round.

pH measurement. A Radiometer pH Meter 29 with a combined probe electrode (GK 2321 C) was used for pH measurements. The meter was calibrated using standard buffers at pH 6.5 and 4.0. The measurements were made by inserting the probe electrode, to the specified depths, into the intact muscles in the beef carcasses.

To determine the relative accuracy of probe pH measurements made on intact muscle compared to pH measurements made on iodoacetate homogenates of muscle, fifty paired tests were made. The tests were made on beef carcasses between 0.5 and 3 hours post-mortem. Each test consisted of a probe pH measurement made on an intact muscle and a pH measurement made on the adjacent sample of muscle after it had been excised and homogenized in five volumes of sodium iodoacetate (0.005 M, pH 7.0). The mean of the probe measurements, 6.62 $\pm$ .03 s.e. was significantly lower ($p<0.01$) than the mean of the homogenate measurements, 6.65 $\pm$ 0.03. Nevertheless, there was sufficiently good agreement between the means of both sets of measurements to allow direct insertion of the probe to be used for carcass pH measurements. When 2 or more probe pH measurements were made on a muscle, at hourly intervals, it was found to be essential to use a fresh site in the muscle for each measurement. Use of the same site repeatedly would give false pH values, invariably too low.

Continuous temperature recordings were made on the contralateral muscles in six carcasses by inserting thermocouples into the muscles at the specified depths.

Results and Discussion

The post-mortem changes in pH and temperature in four muscles in the hindquarter are shown in Figure 1. The measurements were made at the centre of each muscle. The rate of pH fall was fastest in the PM and slowest in the LD. The muscles of the round had intermediate rates of pH fall, the rate being somewhat faster in the ST than in the BF, AD and SM. The results for the AD and BF are not shown in Figure 1 because they were not significantly different from those shown for the SM.

Because of their anatomical location, the LD and the PM cooled quickly to 10°C, in 8.5 and 9.3 hr respectively. The muscles in the round took about twice as long to cool to 10°C.

The slow rate of pH fall in the LD can be largely attributed to the fast drop in temperature in this muscle. A fall in temperature has been shown to cause a decrease in the rate of pH fall in beef muscle (Marsh, 1954; Cassens and Newbold, 1966). A slow rate of post-mortem glycolysis was also observed in the LD in beef carcasses, held under post-mortem conditions similar to the usual commercial procedures, by Bodwell et al (1965). An important aspect of the present results was that the pH in the LD in six of the twenty carcasses examined was equal to or above 6.4 when the temperature fell below 10°C. These carcasses were within the range of pH values, in the LD, associated with extensive toughening caused by cold shortening (Marsh & Leet, 1966; Bendall, 1972). An increase in toughness in the LD has been observed by Joseph (1974) using animals and experimental conditions similar to those in the present experiment.

In contrast to the LD, the PM had a low pH at 30 min post-mortem (6.37 $\pm$ .05) and a fast rate of pH fall subsequently. A low pH in the PM immediately post-mortem has been reported previously (Howard and Lawrie, 1957, Mothersill and McLoughlin, 1974) but has not yet been adequately explained, although it may be associated with muscular contractions at slaughter. In this context it is interesting to note that actomyosin (the contractile enzyme) from beef PM was reported to be significantly more active in the splitting of Mg ATP^{2-} than was actomyosin from beef LD (Mothersill and McLoughlin, 1974). When pH values below 6.0 are reached in muscle while the temperature is still high, changes occur in the properties of the sarcoplasmic and myofibrillar proteins which adversely effect meat quality (Bendall and Wismer-Pedersen, 1962; McLoughlin, 1963, Scopes 1964). It was considered unlikely that extensive protein denaturation occurred in the PM under the conditions of the present experiment, because the temperature at the centre of the muscle fell quickly (to 30° in 2 hours).

The pH and temperature fall at three locations in the SM, at the superficial (1.5 cm depth), at the centre (5 cm depth) and at the deep part of the muscle (8 cm depth), are shown in Figure 2. The pH at one hour postmortem was similar at all locations examined. Subsequently, during chilling of the carcass, the temperature gradient in the beef round influenced the rate of pH fall at different locations in the SM. The rate of pH fall was five times faster in the deep muscle and three times faster at the centre than at the superficial part of the SM (Figure 2). Similar results were obtained for the other muscles in the round (Table 1). In each case the rate of pH fall increased as distance from the surface increased. In the ST, BF and AD the postmortem pH fall was completed (pH 5.6 - 5.7) in the deep muscle before the temperature dropped below 30°C.

Scopes (1964) using beef sarcoplasmic protein extracts showed that combinations of high temperature and low pH, similar to those reported above for the deep round, caused denaturation. In the

present experiment it was frequently observed that the meat located in the deep round tended to be paler in colour, softer in texture and more susceptible to loss of drip than the superficially located meat. Preliminary experiments have indicated that the rapid fall in pH in the deep round may be prevented by excising the muscles at one hour postmortem. This procedure allowed the muscles to cool at a uniform rate throughout and eliminated the temperature gradient.

The present results support those of Follett et al (1974) who found that the rate of postmortem glycolysis in the anatomically deep tissue of the beef SM was retarded by early postmortem excision and air cooling. As a consequence of this procedure, the latter authors found a lower drip loss in the vacuum packed meat, minimal discolouration and an improvement in tenderness.

Post-mortem pH measurements (pH_1) have been widely used as indicators of meat quality, particularly in the case of pig carcasses. A similar measurement may also prove useful in determining beef quality. The results in this paper show that the rate of post-mortem pH fall in beef carcasses varies greatly, both between and within muscles and emphasises the necessity of careful interpretation of the results of pH measurements at specific locations.

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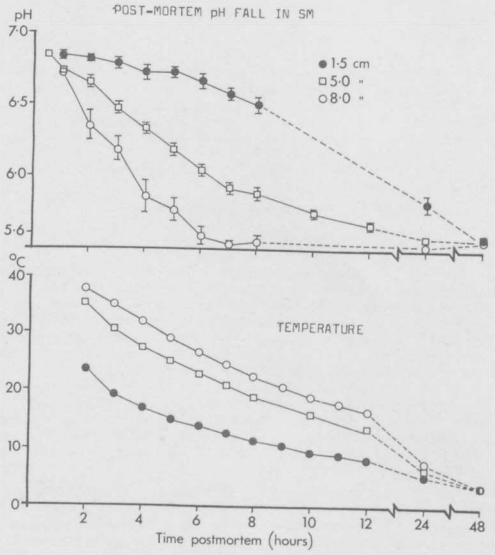

FIGURE 2. The pH and temperature changes in m. semimembranosus in situ in the carcass. Measurements were made at the superficial (1.5 cm depth), centre (5 cm depth) and deep (8 cm depth) parts of the muscle. The pH values at the 5 cm depth are means and standard errors for 28 heifers, the pH values at the 1.5 and 8 cm depths are for 8 heifers.

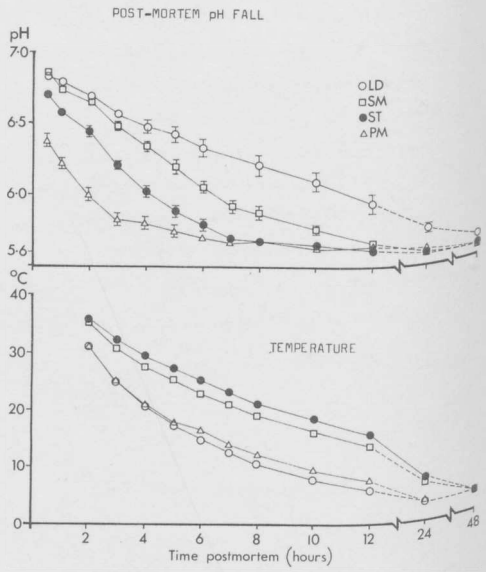

FIGURE 1. The pH and temperature changes at the centre of 4 muscles in situ in beef carcasses. The pH results for the LD and PM are means and standard errors for 20 animals, the results for the ST and SM are for 28 animals. The pH changes in the BF and AD are not included because they were not significantly different from those shown for the SM.

TABLE 1

RATE OF POST-MORTEM pH FALL AT THE SUPERFICIAL, CENTRE AND DEEP PART OF THE MUSCLES OF THE ROUND

Muscle	Depth (cm.)	Rate of pH fall (pH units/hr ± s.e.)[a]	Chilling (hours to 30°C)
ST	1.5	0.11 ± .01[c]	less than 2
	5.0	0.24 ± .01[b]	3.9
	8.0	0.37 ± .04[c]	5.7
SM	1.5	0.06 ± .01[c]	less than 2
	5.0	0.17 ± .01[b]	3.3
	8.0	0.29 ± .04[c]	4.7
BF	1.5	0.09 ± .01[c]	less than 2
	5.0	0.18 ± .01[b]	4.9
	8.0	0.31 ± .03[c]	6.4
AD	1.5	0.07 ± .01[d]	less than 2
	5.0	0.18 ± .01[d]	3.6
	8.0	0.31 ± .02[d]	6.4

a The rate of pH fall was calculated between pH 7.0 and 6.0

b Mean and standard error for 28 observations

c Mean and standard error for 8 observations

d Mean and standard error for 6 observations

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