THE OCCURRENCE OF DARK-CUTTING BEEF

P V TARRANT

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

A preliminary report of an investigation into dark-cutting beef in an Irish meat plant is presented. The ultimate pH (pH_u) was measured in 2,261 beef carcases over a period of eight months. The relation between the pH_u and season, breed, sex and muscle was examined.

There was a big increase in the percentage of carcases with high pH_u during the period August to December. Prior to and after this period, less than three percent of carcases were affected. High pH_u was observed particularly in the l. dorsi (loin) and three muscles of the round, semitendinosus, adductor and semimembranosus. Other muscles were not affected by high pH_u, these included five forequarter muscles, psoas major (fillet) and biceps femoris (outside round).

CAS DE BOEUF A COUPE SOMBRE

P.V. TARRANT

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

Un rapport préliminaire sur des recherches faites sur le boeuf à coupe sombre dans une usine de viande irlandaise est soumis. Le pH final (pH_u) a été mesuré sur 2261 boeufs abattus sur une période de huit mois. Le rapport entre le pH_u et la saison, la race, le sexe et le muscle a été examiné.

Il y avait une augmentation importante du pourcentage de bêtes à pH_u élevé au cours de la période allant d'août a septembre. Avant et après cette période, moins de trois pour cent des bêtes étaient affectées. Un pH_u élevé a été particulièrement observé dans le l.dorsi (aloyau) et trois muscles de la sous-noix, le semitendinosus, l'adductor et le semimembranosus. D'autres muscles n'ont pas été affectes par le pH_u élevé, parmi lesquels cinq muscles antérieurs, le psoas major (filet) et le biceps femoris (tranche grasse extérieure).

B8:2

DAS AUFTRETEN VON DUNKEL SCHNEIDENDEM RINDFLEISCH

P V TARRANT

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

Unterbreitung eines vorläufigen Berichtes einer Untersuchung über dunkel schneidendes Rindfleisch in einer Irischen Fleischfabrik. Der End-pH (pH_u) - Wert worde bei 2261 Rinderkadavern über einen Zeitraum von acht Monaten gemessen. Untersucht wurde die Beziehung zwischen pH_u-Wert und Jahreszeit, Zucht, Geschlecht und Muskel.

Während des Zeitraumes August bis Dezember erhöhte sich der Anteil von Kadavern mit hohem pH_u-Wert beträchtlich. Vor und nach diesem Zeitraum waren weniger als drei Prozent der Kadaver betroffen. Ein hoher pH_u-Wert wurde vor allem im l. Dorsi (Lende) und in den drei Muskeln der Keule, Semitendinosus, Adduktor und Semimembranosus beobachtet. Andere Muskeln waren von dem hohen pH_u-Wert nicht betroffen, so u.a. fünf Vorderviertelmuskeln, Psoas major (Filet) und Biceps femoris (äuBere Rindskeule).

ПОЯВЛЕНИЕ ГОВЯДИНЫ ТЕМНОГО ЦВЕТА

Г.В.ТАРРАНТ
Агрономический Институт, Отдел Исследования Мяса, Каслнок,Дублин, Ирландия

В предварительном сообщении представлены данные об исследовании, касающемся говядины темного цвета и проведенном на мясном заводе в Ирландии.В течении восьми месяцев проводилось измерение конечного pH (pH_u) в 2261 говяжьей туше. Исследовалось соотношение между pH_u и временем года, породой, мясом и мышцами.

Установлено, что значительное повышение процента туш с высоким pH_u происходит в месяцах с августа до декабря. В течение времени до и после этого периода оказалось затронутыми меньше чем 3 % туш. Высокое pH_u наблюдается особенно в L.dorsi и в трех мышцах ссека говядины semitendinosus, adduktor, seminembranasus.
Другие мышцы не были затронуты высоким pH_u, включая сюда пять мышцев передней части, psoas major (филе) и biceps femoris (внешний ссек говядины).

THE OCCURRENCE OF DARK-CUTTING BEEF

P.V. TARRANT

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

INTRODUCTION

Dark-cutting (dark, firm, dry) beef is undesirable because it has an abnormal colour and is more susceptible to bacterial spoilage than normal beef. The aetiology of the condition has been partly elucidated (Hedrick, 1958; Lawrie, 1958) and some estimates of the incidence of the condition have been made. A four year investigation at a Canadian meat plant gave an average incidence of 8% in the steer kill, with the highest occurrence in the fall (Munns and Burrell, 1966). In the USA dark-cutting was also observed more frequently in the fall, following first frosts (Hall et al 1944).

The pH and colour of meat are closely related. The immediate cause of dark-cutting in beef is an abnormally high ultimate pH (pHu), caused by a deficiency of glycogen in the muscle at the time of slaughter (Hall et al 1944; Lawrie, 1958; Hedrick, 1958). At normal pHu values of 5.4 to 5.6 the colour of beef muscle is bright cherry red, at 5.8 the colour is 'shady' or dark red and at 6.2 to 6.8 it is purplish black (Hedrick, 1958). The rate of oxygen consumption by muscle mitochondria is greater at a high pHu than at the normal pHu (Lawrie, 1958; Ashmore et al 1972) and the surface layer of oxymyoglobin is greatly decreased in the case of high pH beef, causing an increased concentration of myoglobin and a darker colour.

Depletion of muscle glycogen can be caused by ante-mortem stress. In the USA, dark-cutting resulted when steers, normally accustomed to favourable conditions, were subjected to rigorous exposure and three days without feed (Hall et al 1944), dark-cutting also resulted after periodic excitement for 24 hr antemortem or adrenaline injection (Hedrick, 1958). In Australia, Howard and Lawrie (1956) observed that 28 days fasting and 1½ hr enforced exercise failed to raise the pHu, although steers slaughtered in an excited condition after prolonged train journeys had a high pHu in the psoas muscle. Occasionally, the carcases of well fed and rested steers had a high pHu; this was attributed to excitement or fear which caused a depletion of glycogen reserves, perhaps by short-range muscular tension or tremor (Howard and Lawrie, 1956). Similarly, a higher proportion of dark-cutting has been observed in young bulls than in steers or heifers (Fredeen et al 1974 ; Fell et al 1973; Riordan 1973) and this was attributed to increased stress in the bulls due to a more excitable temperament (Fell et al 1973).

In the Republic of Ireland about 1 million cattle are slaughtered annually. The incidence of dark-cutting beef has not been investigated, although it has been suggested in the industry that the condition may be more prevalent in the autumn than in other seasons. In the present work the incidence and some characteristics of dark-cutting carcases were investigated at a large factory.

EXPERIMENTAL

Random samples of beef carcases were taken at intervals of two weeks, for eight months, at a large factory. A total of 2261 carcases were taken, 90% were from steers and 10% from heifers. All the cattle were slaughtered by the Kosher method and chilled by normal factory procedures. The range of sample sizes was 59 to 262 carcases, except on December 22nd when only 32 carcases were available for pH measurements.

The pHu was measured at approximately 48 hr post mortem in the round, striploin and shoulder, as it was felt that a single measurement near the quartering point would not adequately represent the entire carcase. The measurements were made at the l. dorsi at the 3rd lumbar vertebra, the semimembranosus and the triceps brachii, caput laterale. Carcases with a pHu equal to or greater than 6.0 in the l. dorsi were considered to be dark-cutting (Munns and Burrell, 1966; Fredeen et al 1974) and in these the extent of dark-cutting was determined by measuring the pHu in seven hindquarter and five forequarter muscles, between them representing a large part of the carcase, viz: semitendinosus, biceps femoris (outside round); semimembranosus, adductor (inside round); gluteus medius (butt); psoas major (tenderloin); l. dorsi (striploin); triceps, trapezius, infraspinatus (clod); supraspinatus (chuck tender) and longus colli. Fewer results are available for the forequarters because they were frequently removed from the carcases within 48 hr of slaughter.

The pH measurements were made by direct insertion of a probe-type electrode into the carcase. A Radiometer pH Meter 29 with a combined electrode (GK 2321 C) was used. The meter was calibrated using standard buffers at pH 6.5 and 4.0 and was checked at intervals during use with buffer pH 6.5.

RESULTS

The mean pHu value in the l. dorsi for all carcases was 5.65 and 90.8% of the values were in the range 5.50 to 5.75 (Table 1). There were 135 carcases (5.97%) with pHu values at 6.0 and above in the l. dorsi and these were classified as dark-cutting. The mean pHu was significantly lower in the semimembranosus and significantly higher in the triceps than in the l. dorsi (Table 1). Also, there were fewer values

at and above pH 6.0 in the semimembranosus (2.52%) and triceps (2.38%) than in the l. dorsi.

The percentage of dark-cutting carcases in each sample is shown in Figure 1 for the period June 1975 to March 1976. The incidence of dark-cutting was high in the autumn and winter (mid-August to mid-January) averaging 9.2% with a range of 3.3% to 21.9%. The incidence was much lower for the remainder of the period studied, averaging 2.2% from mid-June to mid-August and averaging 0.9% from mid-January to March and the range during these two periods was also much smaller (0 to 2.7%).

A high pHu did not occur in all the muscles of dark-cutting carcases but was largely confined to certain characteristic muscles in the hindquarter. In Table 2 the mean pHu values in twelve muscles of dark-cutting carcases are shown, values from normal heifers killed at the laboratory are shown for comparison. The muscles with the highest pHu values were the l. dorsi (6.37), semitendinosus (6.37), adductor (6.00) and semimembranosus (5.99). The gluteus medius was also significantly higher than in normal beef, while the psoas major and the biceps femoris showed no significant increase in pHu compared to normal beef. In the forequarter muscles the differences between dark-cutting and normal carcases were quite small. The mean pHu was slightly though significantly higher in the trapezius, supraspinatus and longus colli of the dark-cutters, but there was no significant difference in the infraspinatus or triceps (2.4% of all carcases had pH values above 6.0 in the triceps (Table 1) but the majority of these were not dark cutters).

The sex of the cattle had little effect on dark-cutting, 10% of all carcases examined were from heifers and 90% from steers, while 9% of the dark-cutting carcases were from heifers and 91% were from steers. The mean pHu was lower for heifers than for steers in the semimembranosus (5.56 and 5.58 respectively, $p < 0.05$) and l. dorsi (5.63 and 5.65 respectively, $p < 0.1$) whereas it was higher in the triceps (5.74 and 5.69 respectively, $p < 0.02$).

Sufficient data are not yet available for an accurate analysis of breed influence on pHu and dark-cutting, although the results available so far do not suggest any major influence.

DISCUSSION

Preliminary results for the period June to February gave an average incidence of dark-cutting carcases of 5.97%. Due to a pronounced seasonal increase within the period examined the average yearly incidence may be somewhat lower. The large increase in dark-cutting in the autumn and winter would be expected to cause meat quality problems. A high incidence of dark-cutting was also encountered in the fall in North America and was thought to be related to the onset of the first frosts (Hall et al 1944; Munns and Burrell, 1966). The present increase was not caused by the stress of harsh weather because conditions were mild during August and September and practically no frost was recorded by the meteorological service until mid-October and not until the beginning of November in the vicinity of the factory. The onset of cooler weather cannot be discounted as a source of stress but it is likely that other factors were also involved.

The ability of cattle to withstand ordinary pre-slaughter stress may be lower in the autumn and winter, due to a general reduction in tissue glycogen reserves at that time. A seasonal variation in glycogen levels has been observed in some laboratory animals (Pessacq and Gagliardino, 1975; Gourley et al 1969) and may occur in cattle. Also tissue glycogen levels in cattle may be reduced by the decline in the quantity and nutritive content of grass in the autumn (Corbett et al 1966) and by the change to winter feeding. Possible seasonal variations in bovine glycogen levels are being investigated at this laboratory.

Of some value in determining the cause of dark-cutting may be the observation that high pHu is specifically associated with certain muscles, particularly the semitendinosus and l. dorsi, whereas other muscles in dark-cutters, such as the psoas and biceps femoris, are practically always normal. High pHu is caused by a deficiency of glycogen due to antemortem glycogenolysis (Hall et al 1944; Lawrie 1958; Hedrick 1958). The glycogen reserves in the affected muscles may be reduced or eliminated by specific contractile activity in these muscles before slaughter. Alternatively, the glycogen reserves of the affected muscles may be more labile under the hormonal influences and anaerobic conditions associated with pre-slaughter stress. It is important to determine why these muscles are specifically affected.

The association of high pHu with certain muscles in dark-cutters is also of interest to meat processors. Beef with a high pHu is unsuitable for vacuum packaging because of increased bacterial growth and spoilage (Johnson, 1974). In carcases which are dark-cutting at the quartering-point, many of the major muscles may have normal pH values and be suitable for packaging. The muscles with a high pHu have a better water-holding capacity (Hamm, 1974) and are suitable for processing into comminuted or cooked meat products.

ACKNOWLEDGEMENTS

I wish to thank Mr John Sherington for the statistical analysis of results and Mr Patrick Ward and Mr Michael Keating for technical assistance.

TABLE 1. MEAN pH_u VALUES IN THREE MUSCLES OF FACTORY-KILLED STEERS AND HEIFERS

Muscle	Mean pH_u	± s.e. (N)	Percent ≥ 6.0
l. dorsi	5.65[1]	± 0.004 (2261)	5.97
semimembranosus	5.58[1]	± 0.003 (2261)	2.52
triceps brachii	5.69[1]	± 0.005 (712)	2.38

[1]The differences between the means are all significant at the 0.1% level of probability.

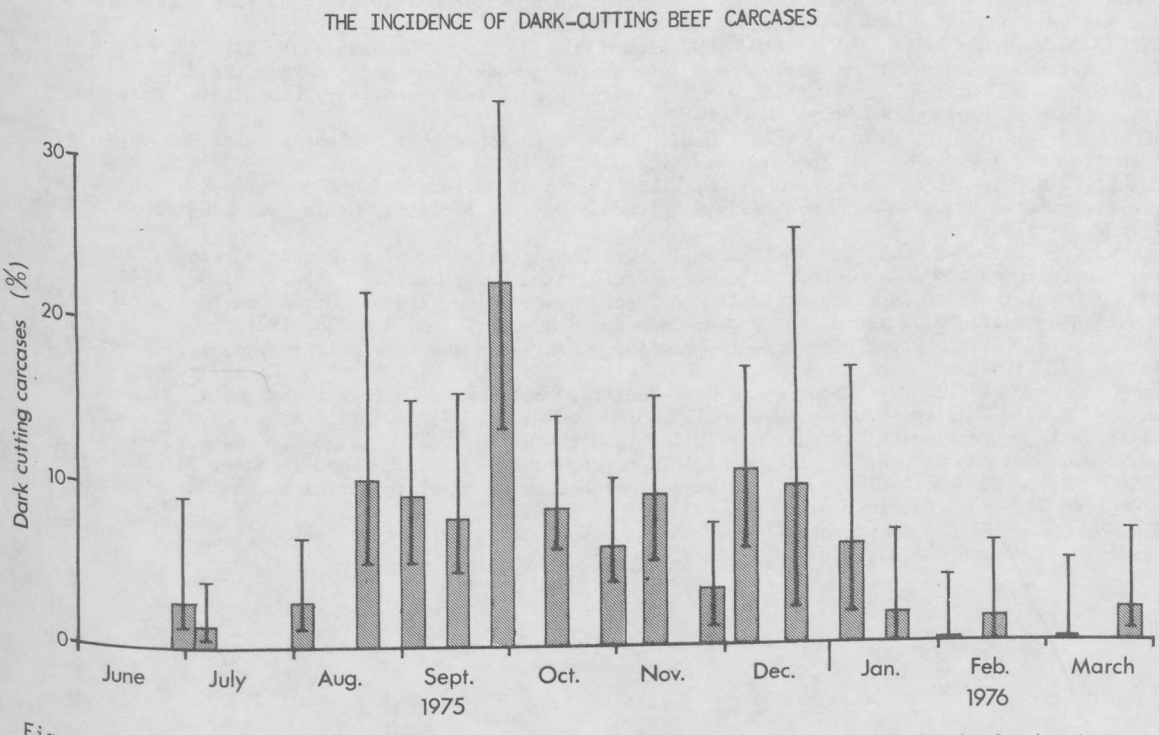

Figure 1. The percentage of carcases per sample with a pH_u at and above 6.0 in the l. dorsi. The vertical bars are the 95% confidence limits.

TABLE 2. A COMPARISON OF THE pHu IN TWELVE MUSCLES OF DARK-CUTTING AND NORMAL BEEF CARCASES

	Dark-cutting beef mean ± s.e. (N)	Normal beef mean ± s.e. (N)	Mean difference	Significance of difference
hindquarter:				
l. dorsi (striploin)	6.37 ± 0.02 (145)	5.66 ± 0.01 (14)	0.71	***
semitendinosus (outside round)	6.37 ± 0.03 (106)	5.58 ± 0.01 (")	0.79	***
adductor (inside round)	6.00 ± 0.03 (110)	5.61 ± 0.02 (")	0.39	***
semimembranosus (")	5.99 ± 0.03 (145)	5.55 ± 0.02 (")	0.45	***
gluteus medius (butt)	5.85 ± 0.03 (82)	5.59 ± 0.02 (")	0.26	**
psoas major (tenderloin)	5.69 ± 0.02 (107)	5.61 ± 0.02 (")	0.08	N.S.
biceps femoris (outside round)	5.68 ± 0.02 (106)	5.60 ± 0.01 (")	0.08	N.S.
forequarter:				
trapezius (clod)	5.93 ± 0.03 (22)	5.70 ± 0.03 (")	0.23	***
supraspinatus (chuck tender)	5.89 ± 0.03 (27)	5.74 ± 0.02 (")	0.15	**
infraspinatus (clod)	5.85 ± 0.03 (27)	5.85 ± 0.03 (")	0.00	N.S.
triceps (")	5.78 ± 0.02 (50)	5.73 ± 0.03 (")	0.05	N.S.
longus colli	6.07 ± 0.04 (22)	5.93 ± 0.04 (")	0.14	*

* = significant at 5% level of probability
** = significant at 1% level of probability
*** = significant at 0.1% level of probability
N.S. = not significant

REFERENCES

ASHMORE, C.R., PARKER, W. and DOERR, L. Respiration of mitochondria isolated from dark-cutting beef; post mortem changes. J. Anim. Sci. 34 46-48, 1972.
CORBETT, J.L., LANGLANDS, J.P., McDONALD, I. and PULLAR, J.D. Comparison by direct animal calorimetry of the net energy values of an early and a late season growth of herbage. Anim. Prod. 8, 13-27, 1966.
FELL, H.R., BOUGHEY, R. and LUCAS, I.A.M. Report on bull beef. Advisory Council for Agriculture and Horticulture in England and Wales, November, 1973.
FREDEEN, H.T., MARTIN, A.H. and WEISS, G.M. Changes in tenderness of beef longissimus dorsi as related to muscle colour and pH. J. Food Sci. 39, 532-536, 1974.
GOURLEY, D.R.H., TAE Kyu Suh and BRUNTON, L.L. Seasonal differences and the effect of insulin on pyruvate uptake, oxidation and synthesis to glycogen by frog skeletal muscle. Comp. Biochem. Physiol., 29, 509-524, 1969.
HALL, J.L., LATSCHAR, C.E. and MACKINTOSH, D.L. Characteristics of dark-cutting beef. Survey and preliminary investigation. Tech. Bull. Kans. agric. Exp. Sta., No. 58, Part IV, 55-86, 1944.
HAMM, R. Waterholding capacity of meat. In- Meat: Proc. University of Nottingham Twenty-first Easter School in Agricultural Science, ed. D.J.A. Cole and R.A. Lawrie, p. 321-338, 1974.
HEDRICK, H.B. Etiology and possible preventative measures in the dark cutter syndrome. Veterinary Medicine 53, 466-472, 1958.
HOWARD, A. and LAWRIE, R.A. Studies on Beef Quality. Spec. Rep. Fd Invest. Bd, Lond., No. 63, 1956.
JOHNSON, B.Y. Chilled vacuum-packed beef. CSIRO Fd Res. Q. 34, 14-20, 1974.
LAWRIE, R.A. Physiological stress in relation to dark-cutting beef. J. Sci. Food Agr. No. 11, 721-727, 1958.
MUNNS, W.O. and BURRELL, D.E. The incidence of dark-cutting beef. Food Technol. 20, 1601-1603, 1966.
PESSACQ, M.T. and GAGLIARDINO, J.J. Glycogen metabolism in muscle: its circadian and seasonal variations. Metabolism 24: 737-743, 1975.
RIORDAN, E.B. Report on young bull beef carcases sent to Dusseldorf in February 1973. The Agricultural Institute, Sandymount Ave., Dublin, 4, 1973.