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Lambs selected for fast glucose clearance have high meat pH levels when stressed before slaughter

A.R. BRAY, S.M. FRANCIS, D. O'CONNELL AND R. BICKERSTAFFE

AgResearch, Canterbury Agriculture and Science Centre, P.O. Box 60, Lincoln, New Zealand.

ABSTRACT

The influence of selection for rapid (Fast GC) or slow (Slow GC) clearance of exogenous glucose on the pH of lamb meat was investigated using preslaughter stress, adrenaline and energy supplement treatments. Ultimate pH values were elevated ($P<0.001$) by a high level of preslaughter stress in the Fast GC line only. This response was suppressed by an oral energy supplement, indicating that recharge of muscle glycogen stores was impaired. The demonstration of this genetic relationship makes the selection lines valuable for study of the influence on meat quality of *post mortem* energy metabolism in muscles.

Keywords Lambs, glucose clearance, leanness, stress, meat quality.

INTRODUCTION

In the anaerobic conditions that follow slaughter, muscle glycogen is metabolised to lactic acid with a consequent reduction in muscle pH. The rate of pH decline and the level ultimately reached affect meat colour, tenderness, water holding capacity and storage life. When glycogen reserves are depleted before slaughter, ultimate pH levels are high, reducing the value of meat for premium end uses (Bray, 1988; Hood and Tarrant, 1981).

Francis *et al.*, (1990) described lines of sheep selected for slow and rapid clearance of exogenous glucose. It is possible that selection has affected the recharge of muscle glycogen stores in these animals and so predisposed them to production of high pH meat. This report presents results of experiments to investigate this proposition.

MATERIALS AND METHODS

Experiment 1

Plasma glucose responses were measured in 6 rams from each of 2 lines of Coopworth sheep selected for rapid (Fast GC) or slow (Slow GC) clearance of an intravenous dose of glucose (Francis *et al.*, 1990). They were aged 3.5 years and their mean live weight was 88 kg. Challenges of glucose, an oral energy supplement or adrenaline were administered approximately 1 hour after removal from pasture. During intervals of 4 or 5 days between tests the rams were fed sufficient grass-clover pasture to maintain liveweight.

The glucose challenge was 0.3 g glucose (as 50% dextrose solution) per kg liveweight, injected as a single dose into a jugular vein. The energy supplement (Ketol, Bomac Laboratories, Auckland) contained 80% w/v monopropylene glycol and was administered as an oral drench of 160 ml. Adrenaline treatment consisted of a subcutaneous injection of 0.125 mg adrenaline (David Bull Laboratories, Mulgrave, Australia) per kg liveweight.

Plasma glucose responses to the challenges were monitored for up to 6 hours.

Experiment 2

Ram lambs born in 1990 into Slow GC, Fast GC and Control selection lines (Francis *et al.*, 1990) were raised in a single mob on grass-clover pastures and gained liveweight at an average of 165 g/d over 9 weeks prior to slaughter. At 5 months of age a glucose challenge was administered as in Experiment 1 and the half-life of an intravenous dose of glucose was measured as described by Francis *et al.*, (1990).

Twenty eight hours before slaughter at 7 months of age lambs were removed from pasture and later transported 70 km to arrive at a commercial slaughter plant 23 hours before slaughter. Four treatment groups were formed by random allocation of lambs within sire groups and selection lines; Low Stress (n=51), High Stress (n=53), High Stress + Energy Supplement (n=26, Fast and Slow GC lines only) and Adrenaline (n=26, Fast and Slow GC lines only).

Lambs in High Stress treatments swam through a 15 m long cold water bath on 3 occasions 22, 16 and 4 hours prior to slaughter and were penned beside a busy raceway for the last 4 hours before slaughter. Low Stress groups were not injected, drenched nor washed before slaughter. The Energy Supplement treatment used the same material as in Experiment 1, given in 3 oral drenches each of 100 ml at 27, 17 and 4.5 hours before slaughter. Adrenaline treatment, also the same as in Experiment 1, was administered 4 hours before slaughter.

All carcasses were electrically stimulated within 20 minutes of death (MIRINZ, 1978) and were held at 5°C until the completion of measurements. Immediately after electrical stimulation the incidence of early *rigor mortis* in foreleg muscles was assessed by the ability to bend the legs sufficiently to include them within a standard commercial neck string. A 3 point scale was used with scores of 0, 1 and 2 indicating the number of forelegs that were included in the neck string.

Carcass, kidney and kidney fat weights and GR measurements (soft tissue depth 11 cm from the dorsal midline on the 12th rib) were recorded within 2 hours of slaughter. Measurements of ultimate pH were made 22 hours after slaughter in the *longissimus dorsi* (LD) muscle at the 13th rib using an Orion 8163 probe attached to a Hanna HI8424 pH meter.

RESULTS

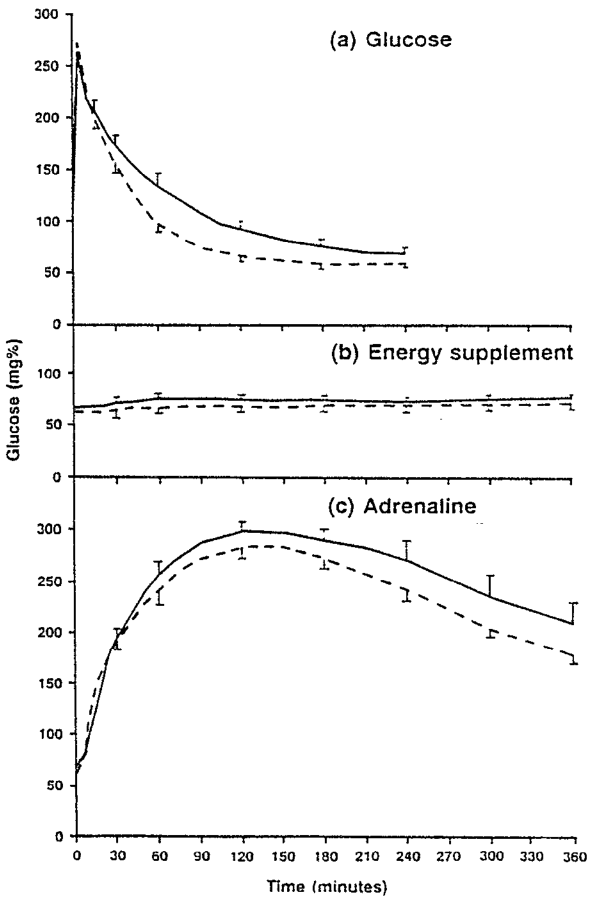
Experiment 1

Three minutes after injection of glucose, plasma glucose levels were 4 times greater than preinjection levels in both Slow and Fast GC lines. The decline in plasma levels was more rapid in the Fast GC line (Figure 1) as demonstrated by the shorter glucose half-life (55.8 v. 90.2 minutes, $P<0.07$) and 19% reduction ($P<0.05$) in area under the glucose curve compared with the Slow GC line.

Administration of a single dose of the energy supplement produced parallel responses in the two selection lines. A 10-12% increase in plasma glucose levels occurred within 90 minutes and levels were still elevated by 5% after 5.5 hours. The area under glucose curves did not differ significantly between Fast and Slow GC lines.

Adrenaline treatment produced 4 fold increases in plasma glucose levels in both selection lines. The difference between the lines increased up to 6 hours post-injection (Figure 1) but the area under the glucose curves was not significantly different.

FIGURE 1 Plasma glucose levels following administration of glucose, an oral energy supplement or adrenaline in mature rams of the Fast GC (— —) and Slow GC (———) selection lines in Experiment 1. Vertical bars indicate standard errors of means.



Experiment 2

Glucose half life values for the Fast and Slow GC lines differred from each other ($P<0.001$; Table 1) and from the Control line ($P<0.05$). There were no significant selection line or treatment effects on carcass weight. At the overall mean carcass weight of 18.5 kg, GR measurements of the Fast GC line were 1.1 mm greater than for the Slow GC line ($P<0.05$) and differences in kidney fat weight were not significant.

TABLE 1 Estimated half-life of injected glucose and physical carcass measurements

Selection line	Glucose half-life (min)	Carcass weight (kg)	Kidney weight[1] (g)	Kidney fat weight[1] (g)	GR measurement[1] (mm)
Slow GC	88.2	19.1	129	221	10.5
Control	82.0	18.2	126	215	11.2
Fast GC	75.0	18.8	124	205	11.6
max. LSD (5%)	5.8	2.6	10	31	1.1

[1] adjusted to the mean carcass weight by covariance

Early onset of rigor in forelegs was more common ($P<0.001$) in lambs treated with adrenaline than in the other treatment groups but there were no significant effects of other treatments (Table 2).

TABLE 2 Early rigor scores (0 = low, 2 = high incidence of rigor in forelegs)

Selection line	Treatment Low stress	High stress	High stress + Energy	Adrenaline
Slow GC	0.57	0.31	0.08	1.17
Control	0.44	0.64	N.A.	N.A.
Fast GC	0.43	0.56	0.25	1.21
max. LSD (5%)	0.69			

Ultimate pH values in all selection lines were similar when they were subjected to the low level of preslaughter stress (Table 3). In the Fast GC line, the higher level of stress caused a large increase ($P<0.01$) in pH that was prevented by the energy supplement. High Stress treatment with or without the energy supplement had no effect in the Slow GC line. Adrenaline treatment produced very high pH levels in both selection lines, higher than the High Stress ($P<0.05$) and Low Stress ($P<0.001$) treatments.

TABLE 3 Ultimate pH of *longissimus dorsi* muscle

Selection line	Treatment Low stress	High stress	High stress + Energy	Adrenaline
Slow GC	5.71	5.79	5.66	6.47
Control	5.82	5.88	N.A.	N.A.
Fast GC	5.79	6.19	5.71	6.40
max. LSD (5%)	0.21			

DISCUSSION

Experiment 1 established that the chosen doses of energy supplement and adrenaline elevated glucose levels in plasma for several hours. Presumably the energy supplement's effect was due to absorbtion of glucose produced from monopropylene glycol in the digestive tract. In the case of adrenaline it is assumed that glucose was mobilised from body energy reserves including muscle glycogen. The higher plasma glucose levels in the Slow GC line following these treatments were consistent with the slower clearance of injected glucose in the Slow GC line.

The differences in the half-life of glucose and GR measurements between selection lines in Experiment 2 were similar to those reported for earlier cohorts from the same selection lines (Francis *et al.*, 1990). They confirm that glucose clearance is positively associated with carcass fat levels.

The crude measure of early rigor was sufficient to detect responses to adrenaline treatment that were consistent with early rigor being due to rapid depletion of muscle energy stores after slaughter and electrical stimulation. An improved measurement method is required to detect more subtle effects.

The extent of the elevation of meat pH levels by preslaughter stress in Experiment 2 was similar to that reported by Bray *et al.*, (1989). Suppression of this response by the glucogenic supplement indicates that the elevation of pH was due to incomplete recharge of muscle glycogen stores after depletion by the High Stress treatment. The occurrence of the response in the Fast GC line suggests that it has either reduced uptake of glucose by muscles, e.g. lower insulin-insensitive glucose transport, or enhanced uptake by other tissues, e.g. more active insulin receptors in adipose tissue.

Elevated ultimate pH levels in the Fast GC line are in contrast with the findings of Shorthose (1970) who found no relationship between glucose tolerance and ultimate pH of the *longissimus dorsi* and a negative relationship in the *semitendinosus* muscle of Merino wethers. The difference between the studies may be due to genetic factors.

Apart from effects on leanness and muscularity, sheep genotype effects on meat qualities have received little attention and have been assumed to be small. However, measurement of elevated meat pH values in the Fast GC line when values in the Slow GC and Control lines were normal shows that genetic influences exist in sheep as in other livestock. It is noteworthy that genetically controlled perturbations of glucose and glycogen metabolism have been implicated in meat quality in pigs (Gregory *et al.*, 1977; Monin et al., 1986).

The presence of the defect makes the Fast and Slow GC selection lines valuable for studies of energy metabolism of muscles during their conversion to meat, and its influence on meat qualities.

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