10

The effects of fasting and transport on carcass yield and meat quality in sheep

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Introduction: In a survey of 120 thousand sheep killed at two plants in the UK it was found that the time from leaving the farm or market to the time when the animals were slaughtered could be up to 30 hours (Bevis and Young, in preparation). They may have been deprived of food for longer than this, particularly if sold through auction markets. About 40% of the sheep had been subjected to a journey of up to 3 hours and three-quarters had travelled for 6 hours or less to the slaughterhouse. The deprivation of food during much of the marketing procedure and the stress associated with transport may reduce the yield of carcass and edible offal and could affect meat quality. These possibilities were examined in two experiments in which sheep were subjected to either fasting for up to 72 hours or transport for up to 6 hours.

Materials and Methods:
Castrated male crossbred lambs were housed indoors and fed a complete pelleted diet ad libitum until slaughter at a live weight of about 30 kg. To investigate the effects of fasting, forty sheep were slaughtered directly off feed, and forty each after 24, 48 and 72 hours from food withdrawal. During fasting they had free access to water. The effects of transport were examined using a further 160 lambs. They were killed after having been subjected to either no transport on the day of slaughter or a journey lasting for either 1, 3 or 6 hours. In this experiment food, but not water, was withdrawn from all animals 21 hours before slaughter. Transported animals did not have access to water during the journey. All lambs were allowed to rest in lairage for 1 hour before slaughter.

Sheep were weighed at the start of each experiment (initial live weight) and immediately before slaughter (preslaughter live weight). They were slaughtered according to normal commercial practices. At exsanguination a sample of blood was collected for measurement of plasma glucose, free fatty acids (FFA), total plasma protein, urea N_2 and cortisol Samples of liver and m. semitendinosus (ST) were excised within twenty minutes of death and frozen pending analysis for glycogen. The weights of various body components were recorded and samples of rumen contents taken from animals in the fasting experiment for estimation of dry matter content. Cold carcass weights were determined after chilling at 2°C for 24 hours. Measurements of ultimate pH (pHu), water holding capacity (WHC) and fibre optic probe (FOP) value of the ST were also made on the day after slaughter. Biochemical analyses and measurements of meat quality were carried out as described by Warriss and Lister (1982) and Warriss, Kestin, Brown and Wilkins (1984). In the analyses of variance all weights were corrected for variation in the initial live weight by covariance analysis.

Results:
On average, 97% of the live weight was accounted for by the recorded body components. The main component not weighed was the blood lost at exsanguination and there was some gain in weight by fleeces which accidentally became wetted during pelt removal.

Effects of fasting: fasting had a significant effect on the weights of all body components except the fleece and feet (Table 1).

Table 1. Influence of fasting on weights (kg) of body components in sheep

	Fast (h)				s.e. diff.	F
	0	24	48	72		
Preslaughter live wt.	32.3^{a}	30.6^{b}	29.8^{c}	29.2^{d}	0.18	110.7***
Hot carcass	16.4^{a}	16.0^{ab}	15.7^{bc}	15.4^{c}	0.18	10.2***
% Loss in chilling	4.7	4.7	4.5	4.2	0.19	2.5NS
Liver	0.63^{a}	0.52^{b}	0.48^{c}	0.45^{c}	0.014	58.8***
Head + pluck	1.97^{a}	1.95^{a}	1.92^{a}	1.87^{b}	0.034	3.1*
Fleece + feet	4.24	4.11	4.12	4.02	0.088	2.0NS
Empty gut	3.20^{a}	3.09^{a}	2.80^{b}	2.63^{b}	0.049	55.7***
Gut contents	4.57^{a}	3.62^{b}	3.65^{b}	3.31^{b}	0.165	21.4***
Rumen contents : wet	3.49^{a}	2.96^{b}	2.87^{bc}	2.58^{c}	0.149	13.1***
dry	0.65^{a}	0.33^{b}	0.20^{c}	0.11^{d}	0.026	153.0***

Each value is the mean of 40 animals. Means with different superscripts are significantly different ($P<0.05$).

Live weight was lost slightly more rapidly over the first 24 hours after food withdrawal and much of this initial loss was accounted for by the 20% decrease in weight of the gut contents, principally those of the rumen, during this time. As well as a reduction in volume, the rumen contents became more watery with longer fasting. The overall rate of live

weight loss between 0 and 72 hours was 0.14% per hour. Some loss of carcass weight was apparent 24 hours after food deprivation although 48 hours were required to produce a significant loss. The rate of loss was 0.085% per hour. Carcasses from sheep fasted longer tended to lose slightly less weight during chilling but the differences were not significant and the overall effect of fasting on carcass weight was maintained. Liver weight was lost most rapidly (0.69% per hour) over the initial 24 hours but loss continued throughout the experiment (0.28% per hour). Associated with the initial decrease in liver weight was a rapid loss of glycogen ($P<0.001$) (Table 2) so that negligible quantities remained 24 hours after food withdrawal. Plasma glucose levels also fell ($P<0.001$) during the first 24 hours,

Table 2. Liver glycogen and blood profile of fasted sheep

	Fast (h)				s.e. diff.	F
	0	24	48	72		
Liver glycogen (mg/g)	32.8^{a}	2.1^{b}	1.2^{b}	1.3^{b}	2.04	117.3***
Glucose (mg/100ml)	86.3^{a}	73.5^{b}	72.7^{b}	75.8^{b}	1.99	19.9***
FFA (mol/l)	168^{a}	587^{b}	774^{c}	945^{d}	57.4	67.8***
Urea N_2 (mg/100ml)	23.8^{a}	29.5^{b}	30.2^{b}	27.1^{c}	1.10	13.6***
Protein (g/100ml)	6.50^{a}	6.98^{b}	7.23^{c}	7.12^{bc}	0.107	18.2***
Cortisol (ng/ml)	28.3^{a}	36.9^{b}	25.8^{a}	29.6^{a}	3.52	3.6*

Each value is the mean of 40 animals. Means with different superscripts are significantly different ($P<0.05$).

then remained constant as energy needs were increasingly met by FFA, the concentration of which rose ($P<0.001$) progressively with longer food deprivation. There was also a small rise in urea N_2 ($P<0.001$) perhaps indicating increased protein catabolism. Plasma total protein concentration increased ($P<0.001$), the extent of apparent dehydration amounting to about 10% of the plasma volume. Cortisol concentrations were elevated in sheep killed after a 24 hour fast but returned to non-fasted levels thereafter. Fasting progressively and significantly ($P<0.001$) reduced muscle glycogen concentrations (Table 3) but the effect on pHu was complex. The pHu was higher in the unfasted animals and those fasted 72 hours than

in those fasted 24 or 48 hours. Neither was there a consistent effect on WHC which was significantly lower in animals fasted 48 hours but returned to a value comparable to that of unfasted animals by 72 hours. FOP was not influenced by fasting.

Table 3. Influence of fasting on measurements of meat quality

	Fast (h)				s.e. diff.	F
	0	24	48	72		
Muscle glycogen (mg/g)	14.1^{a}	13.7^{a}	12.1^{b}	11.5^{b}	0.67	6.8***
pHu	5.59^{a}	5.55^{b}	5.57^{b}	5.61^{a}	0.01	7.7***
Fibre optic probe value	46.3	46.4	48.5	47.4	0.94	2.4NS
WHC	1.38^{a}	1.38^{a}	1.18^{b}	1.42^{a}	0.062	6.1***

Each value is the mean of 40 animals. Means with different superscripts are significantly different ($P<0.05$).

Effects of transport: Transport had no significant effects on the weights of any body components (Table 4). Nevertheless, hot carcass weight tended to be lower in sheep transported for 3 or 6 hours when compared with those either not transported or transported for 1 hour and carcasses from animals transported for longer also tended to lose less weight during chilling. The effect of transport for 3 or 6 hours was a reduction in killing-out percentage by about one percentage point. The weight of the liver was not reduced by transport but its glycogen content increased slightly ($P<0.05$) with longer journeys (Table 5). Overall, the glycogen concentrations were low and reflected the deprivation of food for 21 hours in these animals. Plasma glucose was higher in transported sheep and this was significant after 1 and 3 hours ($P<0.001$). FFA concentrations decreased ($P<0.001$) and urea N_2 fell slightly ($P<0.05$) but transport had no effect on either total protein or cortisol concentrations. Neither were muscle glycogen, pHu or WHC influenced by transport (Table 6). FOP value was lower ($P<0.05$) in sheep transported 1 hour.

Table 4. Effect of transport on weights (kg) of body components in sheep

	Transport (h)				s.e. diff.	F
	0	1	3	6		
Preslaughter live wt.	29.3	29.6	29.0	29.3	0.22	2.3NS
Hot carcass	15.9	16.0	15.6	15.6	0.22	1.3NS
% Loss in chilling	3.8	3.8	3.5	3.5	0.31	0.5NS
Liver	0.53	0.53	0.55	0.55	0.014	1.0NS
Head + pluck	1.95	1.98	1.95	1.95	0.026	0.6NS
Fleece + feet	4.11	4.04	4.11	3.97	0.094	1.0NS
Empty gut	3.18	3.21	3.15	3.16	0.051	0.5NS
Gut contents	3.41	3.29	3.24	3.50	0.167	0.9NS

Each value is the mean of 40 animals.

Table 5. Liver glycogen and blood profile of transported sheep

	Transport (h)				s.e. diff.	F
	0	1	3	6		
Liver glycogen (mg/g)	2.4^{a}	4.6^{a}	4.7^{a}	9.0^{b}	2.07	3.5*
Glucose (mg/100ml)	74.1^{a}	96.2^{b}	91.6^{b}	81.1^{a}	4.78	8.7***
FFA (mol/l)	829^{a}	679^{b}	556^{c}	590^{bc}	55.6	9.5***
Urea N_2 (mg/100ml)	31.3^{a}	29.5^{ab}	30.6^{a}	27.2^{b}	1.29	3.7*
Protein (g/100ml)	6.86	6.71	6.97	6.78	0.11	1.9NS
Cortisol (ng/ml)	34.7	40.0	43.3	24.3	10.6	1.2NS

Each value is the mean of 40 animals. Means with different superscripts are significantly different ($P<0.05$).

Table 6. Effect of transport on measurements of meat quality

	Transport (h)				s.e. diff.	F
	0	1	3	6		
Muscle glycogen (mg/g)	12.3	11.4	11.9	12.0	0.75	0.5NS
pHu	5.72_{ab}	5.74_{a}	5.68_{ab}	5.70_{b}	0.027	1.6NS
Fibre optic probe value	46.0^{ab}	44.8^{a}	46.0^{ab}	46.9^{b}	0.68	3.2*
WHC	1.45	1.40	1.52	1.46	0.071	0.9NS

Each value is the mean of 40 animals. Means with different superscripts are significantly different ($P<0.05$).

Discussion:

The haemoconcentration seen in the fasted animals, together with the tendency for carcasses from sheep deprived of food longer to lose less weight during chilling, suggests that some weight loss may have been caused by dehydration despite water being available to the animals during fasting. Over the initial 24 hours of fast liver glycogen was mobilised to supply energy requirements. Nevertheless, circulating glucose levels were reduced although, overall, concentrations were high in comparison with normal values for grazing sheep. This may be attributable to the concentrate diet. The lowered glucose levels in the fasted animals could reflect the reduced amounts of propionate available from the rumen for gluconeogenesis. The increased circulating concentrations of FFA and urea N_2 indicate greater reliance on breakdown of fat and protein reserves for energy needs.

The raised plasma glucose levels in transported sheep could have been caused by the stress associated with transport but the small progressive increase in liver glycogen and the decreases in FFA and urea N_2 during transport are difficult to explain. There was no evidence of dehydration in these animals. Circulating cortisol concentrations were very variable in both experiments but there was no evidence that long fasting or transport times led to increased activity of the adrenal cortex and could thus be considered obviously stress-inducing. However, any effects may have been masked by possible reactions to stressful stimuli associated with the normal preslaughter handling procedures.

Fasting caused weight losses from most body components. Much of the 5.3% loss in live weight over the initial 24 hour fast was accounted for by the 20% reduction in gut contents. Of economic importance were those losses from the carcass and liver. An effect was seen even after 24 hours, although this was only statistically significant in the liver, the losses amounting to 2.4% carcass and 17% liver weight. A 48 hours fast led to a significant 4.2% loss in carcass weight and 24% loss of liver yield. In contrast to fasting, transport had little apparent effect on the weight of body components. There was some evidence of a small (1.7%) reduction in the carcass yield from sheep transported for 3 or 6 hours but these losses were not statistically significant. Fasting reduced muscle glycogen levels, however this had no material consistent effect on the subsequent pHu, colour or WHC. Similarly, there was no major or consistent influence of transport on meat quality measurements.

The animals in these experiments were fed a concentrate diet, rather than being taken off pasture, as would usually occur in commercial practice, in order to reduce variation in gut fill between individuals. Sheep on high-roughage pasture would be expected to have larger weights of gut contents and this might influence the time of onset and intial rate of loss of weight of some of the body components during subsequent fasting. Also, the provision or otherwise of water during this time may be important. Even so, the results suggest that commercially-important losses in yield can result from marketing procedures which are likely to occur in the UK and that most of the potential loss is probably attributable to food deprivation rather than transport. The potential effects of marketing on meat quality appear negligible.

References

Warriss, P.D. and Lister, D. 1982. Meat Science 7, 183-187.
Warriss, P.D., Kestin, S C., Brown, S.N. and Wilkins, L.J. 1984. Meat Science 10, 53-68.