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Hormone and metabolite changes in the blood of pigs following loading and during transport and their possible relationship with subsequent meat quality

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Introduction

Two potentially serious problems in pigmeat production are susceptibility to stress and poor meat quality (particularly pale, soft, exudative, or PSE, meat). These problems frequently occur together, most commonly in the leanest pigs. As a result it has been suggested that there is a physiological association between carcass leanness, stress-sensitivity and poor meat quality (Lister 1971). The sensitivity to stress expresses itself in an inability to cope with the strains of modern production methods, but particularly transportation. The deleterious consequences of transportation are usually confined to inferior meat quality, but can result in death in transit - an effect of far greater economic importance.

In order to be able to investigate the physiological changes associated with stress in pigs it was first necessary to study temporal changes in the plasma levels of a number of hormones and metabolites during stress. Thereafter, the appropriate indicators were used to examine the effects of loading and transport on the metabolism of pigs both prior to slaughter and post-mortem.

Materials and Methods

Sixteen pork weight pigs (8 Pietrain, 8 Gloucester Old Spot) were fitted bilaterally with indwelling jugular vein catheters while under thiopentone-induced anaesthesia supplemented with nitrous oxide/oxygen inhalation. The pigs were placed in metabolism crates and allowed at least five days to recover from surgery prior to starting the experiment. During this time the pigs had access to food and water ad libitum. The catheters were frequently flushed with heparinized saline to maintain patency and to accustom the pigs to handling and sampling procedures.

Simulated loading stress

On the evening prior to experiment, access to food was removed from each pig. At 0530 on the morning of the experiment, resting blood samples were taken via a jugular vein catheter. The pigs were then subjected to a procedure designed to simulate the loading of pigs on to a lorry. This involved removing the pigs from their crates into a pen, shepherding the pigs around the pen and then reloading them back into their crates (Spencer, 1980). The procedure lasted 5 minutes and blood samples were then taken at timed intervals after the start of the stress. On another day a similar blood sampling procedure was undertaken but without the loading procedure (non-stress sampling experiment).

Transport stress

Approximately one week after the loading stress experiment the pigs were again starved overnight but, the following morning were loaded into a trailer and transported over a standard route for one hour covering a distance of about 20m. At the end of this period the pigs were unloaded and slaughtered after two hours in lairage. Blood samples were taken at the start of the experiment, after loading, after transport and while in lairage, at one and two hours after transport. In some cases blood samples were also taken mid-way through transport.

Analytical Methods

The blood samples were rapidly centrifuged and the plasma collected. An aliquot of plasma was deproteinised in 10 volumes of 0.33N perchloric acid and the glucose in the supernatant measured using the method of Werner, Rey & Wielinger (1970). A further aliquot of 1 ml was extracted in 5 ml of Dole's solution (Dole & Meinertz, 1960) and later assayed for free fatty acid levels (FFA) by a modification of the method of Duncombe (1963). Lactate levels were measured by the enzymatic method of Gutmann & Wahlefeld (1974) following deproteinisation with 2 volumes 0.6N perchloric acid.

Other aliquots were frozen at -20°C until later assayed for: cortisol (competitive protein binding assay; Amersham), thyroxine (radioimmunoassay; Pharmacia) and insulin (radioimmunoassay; Pharmacia).

Results

The changes in plasma levels of the various substances measured following simulated loading stress are shown in Figure 1a - 1f. There was no difference between Pietrain and Gloucester Old Spot pigs in the plasma concentrations of: glucose, lactate, insulin or thyroxine in the resting samples, but both cortisol and FFA levels were higher ($P<0.05$) in the Pietrains. Plasma levels of glucose, lactate and thyroxine all increased ($P<0.01$) rapidly to peak concentrations by about five minutes after stress and there were no differences in response between the two breeds. Insulin levels were transiently increased but only significantly so ($P<0.05$) in the Pietrains. Plasma cortisol levels increased ($P<0.01$) by similar absolute amounts (about 5 μg/100 ml) in both Pietrain and GLoucester Old Spot pigs but took 10-15 minutes to reach peak concentrations. The changes in plasma FFA levels were similar in the two breeds but were characterised by an immediate decrease ($P<0.05$) lasting for about 30 minutes followed by a steady rise in plasma concentrations reaching significantly elevated levels by 120 minutes after stress. There was no significant change ($P>0.05$) in the levels of any of these substances during the non-stress sampling experiment.

Since the levels of the other substances changed too rapidly to be useful as stress indicators without confounding the experiment with stresses to the procedure under study, cortisol was used as an indicator of stress in the transport experiment. As shown in Figure 2, plasma cortisol levels increased following loading to a level similar to that recorded during the simulated loading stress experiment. However, following transport the levels increased even further. In the six animals which were sampled mid-way through transport, the plasma cortisol levels were no different from those found at the end of transport (data not shown). The relative increase in cortisol was similar in both breeds, but plasma cortisol concentrations were still significantly elevated after 1 hour in lairage in the Pietrains while they had returned to resting levels in the Gloucester Old Spots.

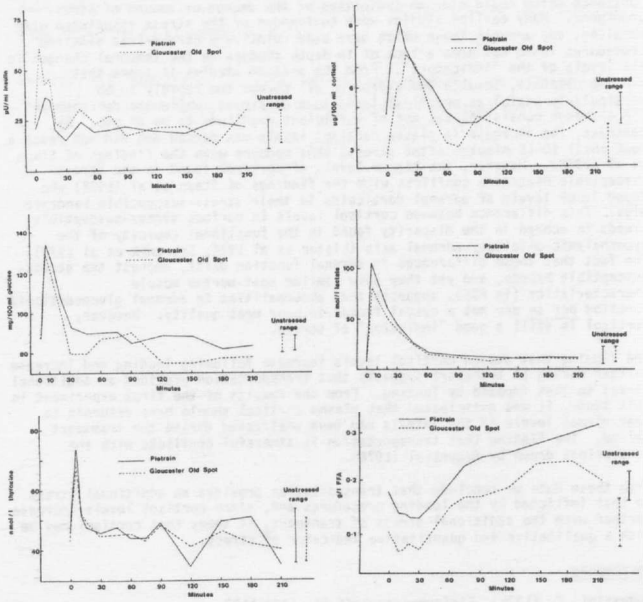

Figure 1.

Changes in the plasma concentration of (a) insulin (b) cortisol (c) glucose (d) lactate (e) thyroxine and (f) free fatty acids in Pietrain and Gloucester Old Spot pigs following simulated loading stress started at time 0 min. The unstressed ranges indicate the maximum and minimum concentrations measured in plasma taken during a similar period in the absence of loading stress.

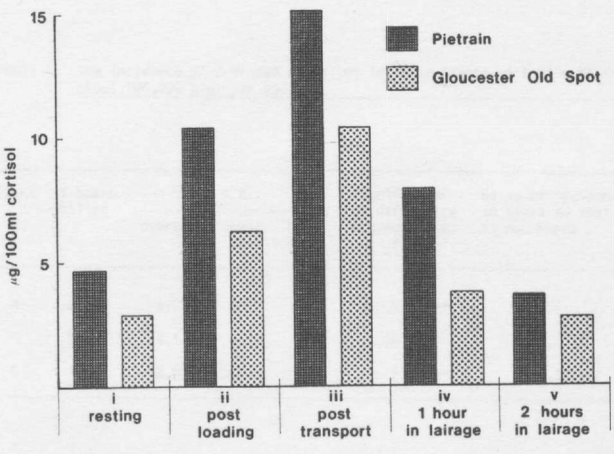

Figure 2.

Changes in the plasma concentration of cortisol in Pietrain and Gloucester Old Spot pigs during loading, transport and lairage. After 1 hour in lairage cortisol levels in the Pietrains are still significantly ($p<0.05$) elevated, while the levels in the Gloucester Old Spot pigs have returned to normal.

Discussion

In the past there have been a number of attempts to establish a single plasma indicator of stress. Of particular interest would be an easily measured substance which could give an indication of the degree or amount of stress undergone. Many earlier studies were confounded by the stress associated with sampling, and amongst those which have used relatively stress-free sampling procedures there has been a lack of in depth studies on the temporal changes in the levels of the "indicators". From the present studies it seems that glucose, lactate, insulin and thyroxine all change too rapidly to be particularly useful as practical indicators of stress, while the decrease in FFA although consistent was not of sufficient magnitude to be of use. By contrast, the increase in plasma cortisol levels was marked and did not reach a peak until 10-15 minutes after stress; this concurs with the findings of Staun et al (1972). However, the higher levels of cortisol found in the stress-susceptible Pietrains conflicts with the findings of Staun et al (1972) who found lower levels of adrenal corticoids in their stress-susceptible Landrace pigs. This difference between cortisol levels in various stress-susceptible breeds is echoed in the disparity found in the functional capacity of the hypothalamic-pituitary-adrenal axis (Lister et al 1972; Sebranek et al 1973). The fact that these differences in adrenal function exist, amongst the stress-susceptible breeds, and yet they show similar post-mortem muscle characteristics (ie PSE), suggests that abnormalities in adrenal glucocorticoid function *per se* are not a casual factor in poor meat quality. However, cortisol is still a good "indicator" of stress.

The finding that plasma cortisol levels increase following loading and increase further during 1h transport suggests that transportation provides an additional stress to that imposed by loading. From the results of the first experiment in this study, it was anticipated that plasma cortisol should have returned to near normal levels if the animals had been unstressed during the transport period. The finding that transportation is stressful conflicts with the conclusions drawn by Augustini (1976).

From these data we conclude that transportation provides an additional stress to that inflicted by the loading procedures and, since cortisol levels increase further with the additional stress of transport, it seems that cortisol may be both a qualitative and quantitative indicator of stress.

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