THE EFFECT OF EARLY WEANING ON THE
CONCENTRATIONS OF NON-ESTERIFIED FATTY
ACIDS AND GLUCOSE IN THE PLASMA OF LAMBS

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(Received 27 March 1972)

ABSTRACT

Non-esterified fatty acids (NEFA) and glucose concentrations in the plasma of 9 lambs weaned from 3.5 to 9.5 weeks of age were compared with the concentrations found in 2 lambs suckling the ewe.

Lambs weaned at 3.5 weeks had markedly elevated plasma NEFA concentrations for up to 3 weeks after weaning. A similar trend was apparent for 2 days after lambs were weaned at 5.5 weeks of age. There was a highly significant negative correlation between plasma NEFA and energy intake in these groups of lambs for 30 days after weaning. The relationships for the later-weaned groups were not significant.

Weaning caused an immediate decrease in the plasma glucose concentration, irrespective of the age of the lamb. Glucose then increased slightly, but subsequently declined with time.

It was concluded that very early weaning resulted in mobilisation of body fat in response to a low energy intake.

INTRODUCTION

Mammals may mobilise their body fat in times of undernutrition or stress (Leites and Chou-Su 1963; Scow and Chernick 1970). The adipose tissues store fatty acids in the form of triglycerides, which, when mobilised, undergo hydrolysis to non-esterified fatty acids (NEFA), glycerol, and diglyceride. The NEFA and glycerol are released into the bloodstream.

Several workers have observed that the circulating concentration of NEFA in humans is related to the nutritional state of the subject (Dole 1956; Gordon and Cherkes 1956; Frederickson et al. 1958; Cahill et al. 1966). Studies in ruminants have also related energy intake to the plasma NEFA concentration (Patterson 1963; Kronfeld 1965; Holmes and Lambourne 1970).

The concentration of plasma glucose and whole-blood glucose declines with age in the young lamb and calf (McCandless and Dye 1950; Dye and Orsini 1952; Reid 1952; Vandersall et al. 1957; Nicolai and Stewart 1965). This developmental hypoglycaemia of the young

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N.Z. Journal of Agricultural Research (1972), 15: 802–7
ruminant has not been satisfactorily explained, although it is known that it is not primarily the result of forestomach development and the absorption of the end products of fermentation, or the digestion of forestomach anaerobes in the lower tract, or the change in diet from milk to solid feed (Reid 1952; Nicolai and Stewart 1965).

Body composition studies involving total empty body analysis of lambs have shown that early weaning results in body fat mobilisation (Fennessy 1971; Jagusch et al. 1971). The present experiment was designed to determine when this fat mobilisation occurred and to ascertain its possible causes.

MATERIALS AND METHODS

Animals and their management

Eleven Dorset Down × Coopworth wether lambs were used. All lambs were born at pasture and brought into the animal house as required. Two single lambs suckling the ewe were used as a control group. Their mothers were fed freshly cut lucerne and ryegrass-clover to appetite for 12 weeks. The remaining 9 lambs were weaned.

Three lambs were weaned at 3.5 weeks (one fed lucerne and two fed ryegrass-clover ad libitum). The other weaning groups (5.5, 7.5, and 9.5 weeks old at weaning respectively), each of two lambs, were fed ad libitum (one lucerne; one ryegrass-clover). The experimental treatments were carried out for 12, 6, 6, and 4 weeks after weaning for the respective groups.

Diet and intake

Lambs were fed twice daily. The metabolisable energy intakes were determined from the balance studies of Fennessy et al. (1972). The period mean intakes for the groups of lambs and the mean intake for the first 6 days after weaning are given in Table 1.

<table>
<thead>
<tr>
<th>Group</th>
<th>No.</th>
<th>Experimental period (days)</th>
<th>Initial LW (kg)</th>
<th>Final LW (kg)</th>
<th>Mean ME intake (Mcal/24 hr)</th>
<th>Mean ME intake days 1-6 (Mcal/24 hr)</th>
<th>LWG (g/24 hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suckling</td>
<td>2</td>
<td>87</td>
<td>11.88</td>
<td>30.76</td>
<td>—</td>
<td>—</td>
<td>217</td>
</tr>
<tr>
<td>Weaned 3.5 weeks</td>
<td>3</td>
<td>80</td>
<td>13.44</td>
<td>24.80</td>
<td>1.88</td>
<td>0.32</td>
<td>142</td>
</tr>
<tr>
<td>Weaned 5.5 weeks</td>
<td>2</td>
<td>41</td>
<td>15.18</td>
<td>21.78</td>
<td>2.46</td>
<td>0.78</td>
<td>161</td>
</tr>
<tr>
<td>Weaned 7.5 weeks</td>
<td>2</td>
<td>41</td>
<td>17.81</td>
<td>27.00</td>
<td>2.90</td>
<td>1.65</td>
<td>224</td>
</tr>
<tr>
<td>Weaned 9.5 weeks</td>
<td>2</td>
<td>27</td>
<td>33.80</td>
<td>37.20</td>
<td>4.48</td>
<td>3.42</td>
<td>126</td>
</tr>
</tbody>
</table>

— not determined
Blood sampling

Jugular blood samples were taken before the morning feed, as lambs seemed to be less excitable then than at any time of the day. Heparinised blood samples were drawn off and stored in a refrigerator for up to 3 hr before centrifugation at 2000 rpm for 2 hr. Plasma samples were drawn off and stored at \(-10^\circ C\) until they could be analysed. Lambs were sampled daily for the first 8 days of the experiment and thereafter twice weekly.

Analytical methods

The method of estimating plasma NEFA was that of Dole (1956) as modified by Patterson (1963). The glucose oxidase method (Huggett and Nixon 1957; Dahlqvist 1961) was used to measure plasma glucose, but was slightly modified in that plasma was diluted 12:1 with phosphate buffer.

RESULTS

Plasma NEFA

Fig. 1 summarises the results for plasma NEFA. Each is the mean for 2 days. Weaning at 3.5 weeks of age elevated plasma NEFA concentrations to three times that of suckling lambs of the same age. By 6 weeks, NEFA concentrations had fallen to within the range measured in suckling lambs of the same age. The concentration in the lambs weaned at 5.5 weeks was elevated for only 2–3 days after weaning. Plasma NEFA concentrations in lambs weaned at 7.5 and 9.5 weeks were similar to those recorded in lambs suckling the ewe.

Plasma glucose

Mean values for the plasma glucose concentration are given in Fig. 2. Plasma glucose of lambs decreased markedly at weaning compared with suckling lambs of the same age. Initial differences of 25, 35, 20, and 30 mg percent were recorded for the groups of lambs

<table>
<thead>
<tr>
<th>Group</th>
<th>b</th>
<th>r</th>
<th>r²</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weaned 3.5 weeks</td>
<td>-0.56</td>
<td>-0.78**</td>
<td>0.606</td>
<td>24</td>
</tr>
<tr>
<td>Weaned 5.5 weeks</td>
<td>-0.90</td>
<td>-0.90**</td>
<td>0.805</td>
<td>14</td>
</tr>
<tr>
<td>Weaned 7.5 weeks</td>
<td>-0.40</td>
<td>-0.30NS</td>
<td>—</td>
<td>16</td>
</tr>
<tr>
<td>Weaned 9.5 weeks</td>
<td>0.19</td>
<td>0.17NS</td>
<td>—</td>
<td>14</td>
</tr>
</tbody>
</table>

** highly significant \((P < 0.01)\)

NS not significant \((P > 0.05)\)

n number of 2-day means for plasma NEFA and intake
weaned at 3.5, 5.5, 7.5, and 9.5 weeks respectively. For a short time after weaning the plasma glucose concentrations tended to increase, but they then gradually declined.

**NEFA—intake relationship**

Table 2 gives the slope and correlation coefficients for the logarithmic relationships between plasma NEFA concentration (μEq/litre) and metabolisable energy intake (ME kcal/kg^{0.75} 24 hr) for the groups of weaned lambs during the 30 days after weaning, when the energy intakes were low for lambs weaned at 3.5 and 5.5 weeks of age. The individual values used in deriving the relationships were means of 2-day values for plasma NEFA and intake for each lamb. Highly significant negative relationships were obtained for the groups of lambs weaned at 3.5 and 5.5 weeks of age, but not for those lambs weaned later. Variations in energy intake accounted for 61% and 81% respectively of the variations in plasma NEFA concentration in the two early-weaned groups.

**DISCUSSION**

The elevated concentrations of plasma NEFA found in the lambs weaned at 3.5 and 5.5 weeks of age were primarily a response to an insufficiency of energy. This is indicated by the strong negative correlations between intake and plasma NEFA in these groups of lambs, which
had self-imposed low energy intakes in the early post-weaning period. In a concurrent experiment (Fennessy et al. 1972) lambs weaned at 3.5 weeks of age and offered lucerne or ryegrass-clover ad libitum did not achieve supermaintenance intakes for a considerable period after weaning. It thus seems likely that low energy intakes in the post-weaning period are the major cause of fat mobilisation in early-weaned lambs.

A general decline in the plasma NEFA concentration with age is apparent in the suckling lambs. Stress and excitement are known to cause elevated concentrations of plasma NEFA in ruminants (Patterson 1963; Mikelic and Taylor 1965; Holmes and Lambourne 1970). Thus the decline is possibly partly a result of training the lambs to the sampling routine with consequent reduction in stress. The declining contribution of milk to the diet could also be a factor, although Gordon and Cherkes (1956) found that giving high-fat meals to human subjects resulted in marked plasma lipaemia, but had a rather variable effect on plasma NEFA.

At weaning the concentration of plasma glucose in all groups decreased. Partial recovery of these concentrations was observed, which suggests that the lambs weaned as late as 7.5 and 9.5 weeks of age also suffered a weaning check. Hamada et al. (1970) observed a decline in blood glucose in calves weaned at 21 days of age, but these animals still had access to small amounts of milk. These workers suggested that the hypoglycaemic condition may become a stimulus to increase the intake of solids by a mechanism based on chemostatic regulation. Although plasma glucose in all groups of lambs declined at weaning, concentrations in all but the 3.5-week group subsequently recovered and reached values similar to those found in control lambs of the same age. This suggests that the plasma glucose concentration depends more on the total energy intake than on milk intake in the young lamb. Weaning has had no consistent effect on the rate of development of the hypoglycaemic condition, although the variability observed in plasma glucose concentrations makes interpretation difficult.

The highly significant negative correlations between intake and plasma NEFA reported for the early-weaned lambs in this experiment support the hypothesis that low intakes after weaning are the principal cause of fat mobilisation in early-weaned lambs.

Acknowledgments
One of the authors (P.F.F.) was in receipt of a New Zealand Wool Board Scholarship.

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