# Metabolism in Compensatory Growth: VI. Effect of Energy Yielding Substrates

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**ABSTRAK**

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Suatu percobaan dirancang untuk meneliti pengaruh dari beberapa tingkat infusi glukosa yang diberikan pada ternak yang diberi pakan dasar dengan tarnbahan protein tidak tercerna (HCRO-casein). Dua betas ekor domba Merino jantan dibagi menjadi 3 grup perlakuan yang menerima tingkat infusi glukosa yang berbeda, 10 mmole/jam, 20 mmole/jam dan 30 mmole/jam. Konsumsi daD daya cerna bahan kering pakan tidak terpengaruh oleh.infusi glukosa. Infusi glukosa menaikkan retensi N dengan menurunkan N dalam feces daD N dalam urin. Diperhitungkan bahwa per unit glukosa yang diinfus, ternak menyelamatkan 0,15 g *N/mmole* glukosa/jam. Efisiensi dari retensi N adalah 28%, 35% dan 44% masiI1g-masing untuk infusi glukosa 10 mmole/jam, 20 mmole/jam dan 30 mmole/jam. Laju pemasukan urea menurun dengan naiknya tingkat infusi glukosa. Perkiraan protein yang terselamatkan oleh glukosa dengan perhitungan berdasarkan retensi N dan laju pemasukan urea masing-masing adalah 20 g dan 25 g per 100 g glukosa yang diinfus. Produksi glukosa (GER) yang berasal dati asam amino menurun dengan naiknya tingkat infusi glukosa yaitu, 21%, 17% dan 14% masing-masing untuk 10 mmole/jam, 20 mmole/jam dan 30 mmole/jam glukosa yang diinfus. GER, persentase glukosa yang teroksidasi dan kontribusi glukosa pacta produksi CO2 naik dengan naiknya tingkat infusi glukosa. Tetapi, laju pemasukan CO2 tidak terpengaruh oleh tingkat infusi glukosa. Penyerapan glukosa dalam otot naik dengan naiknya tingkat infusi glukosa daD sangat erat berkorelasi dengan GER daD kandungan insulin dalam plasma. Ada kecenderungan menurunnya kandungan asam amino esensial dalam sirkulasi darah dengan naiknya tingkat infusi glukosa, terutama asam amino bercabang (BCAA) pada tingkat infusi glukosa 30 mmole/jam. Menurunnya kandungan asam amino dalam darah, kandungan urea dalam plasma daD laju pemasukan urea menunjukkan adanya kenaikan jumlah asam amino yang tergabung ke dalam protein.

Kata kunci: Pertumbuhan kompensatori, glukosa, retensi N, asam amino

**ABSTRACT**

MAHYUDDIN, PRAPTI. 2002. Metabolism in compensatory growth: VI. Effect of energy yielding substrates. *J1TV* 7(1): 1-11.

An experiment was designed to investigate the effect of different rates of glucose infusion into animals fed a maintenance diet supplemented with undegraded protein (HCHO-casein). Twelve Merino wether Iambs were divided into 3 treatment groups receiving different rates of glucose infusion, 10 mmolelh, 20 mmolelh and 30 mmolelh. The intake and digestibility of dry matter were not affected by glucose infusion. The infusion of glucose increased N retention by reducing both faecal and urinary N. It was estimated that per unit of glucose infused, animal retained 0.15 g *N/mmole* glucoselh. The efficiency of N retention were 28%, 35% and 44% for glucose infusion rate of 10 mmolelh, 20 mmolelh and 30 mmolelh respectively. Urea entry rate decreased as glucose infusion rate increased. The estimation of protein spared by glucose infusion calculated from N retention and urinary excretion rate gave a value of 20 g and 25 g per 100 g glucose infused respectively. The proportion of glucose entry rate (GER) that could potentially derived from amino acids reduced as the rate of glucose infusion increased, being 21%, 17% and 14% for 10 mmolelh, 20 mmolelh and 30 mmolelh of glucose infused respectively. The GER, percentage of glucose oxidized and its contribution to CO2 production increased as the rate of glucose infusion increased. However, CO2 entry rate was not significantly affected by rates of glucose infusion. Glucose uptake by the hind-limb muscles increased with increasing rates of glucose infusion and strongly related with both GER and plasma insulin concentration. There was a tendency for circulating essential amino acids to reduce as the rate of glucose infusion increased, and was more prominent for branched chain amino acids (BCAA) at 30 mmolelh of glucose infusion. The reduction of amino acids in the blood circulation occurred concurrently with the reduction in plasma urea concentration and urea entry rate indicated increased net incorporation of amino acids into protein.

**Key words**: Compensatory growth, glucose, N retention, amino acid

## INTRODUCTION

The demand for both glucose or glucose precursors and amino acids is high in growing ruminants (LENG and BALL, 1978). It appears that the requirements for these substrates are interdependent. It has been recognized that glucose has a "N sparing" effect, i.e. it spares amino acids which otherwise would have been used for glucose synthesis. The provision of glucose to animals fed a maintenance energy level could increase N retention by reducing either urinary N (ASPLUND *et at.,* 1985) or both urinary and faecal N (ESKELAND *et at.,* 1973; 1974). Other studies have shown that an additional growth response can be achieved in lambs when glucose is infused into the abomasume (KEMPTON *et at.,* 1978) or when rice polishing is added to a diet with adequate protenr-(PRESTON and LENG, 1978).

In the previous experiment (MAHYUDDIN, 2001) showed that the amino acids made available by the protein supplement (HCHO-casein) were not fully used for protein synthesis since the amino acids evidently were used as energy-yielding substrates. Even the amino acids available in sheep fed the pelleted lucerne diet at maintenance energy level were evidently utilized as energy-yieldIng substrate. Previous studies by KUSW ANDI (1988) had demonstrated that on such diet, the addition of 60 g/h/d of HCHO-casein was the maximum amount of protein, which could stimulate increased glucose entry rate (GER) in growing lambs. Beyond this level, no further significant increase in GER in response to incremental increase in amino acids availability might be expected.

It is clear that an increased availability of an energyyielding substrate, particularly glucose, in lambs fed a high protein diet, would facilitate the redirection of amino acids from oxidation to protein synthesis.

The following experiment was designed to investigate the effect of different rates of intravenous infusion of glucose into animals fed a maintenance basal lucerne diet, supplemented with HCHO-casein.

## MATERIALS AND METHODS

### (a). Experimental design

The experimental design was a. randomized block design. Twelve Merino wethers were used. Six of the lambs were from the previous experiment (MAHYUDDIN, 2001). Three ofthese were previously on the maintenance (M) diet and the other three were on the M + 60 g HCHO-casein diet. These six animals were stratified into two categories based on previous treatment while the remaining six were stratified into two liveweight categories of 3 animals. The animal from each category were randomly allocated to 3 treatment groups. The treatment were intravenous infusion of glucose at nominal rates of: 10 mmole/h; 20 mmole/h; and 30 mmole/h.

### (b). Experimental procedure

#### Feeding, surgery and glucose infusion

The six new lambs had already undergone the preliminary feeding which all the animal were subjected to in the previous experiment (MAHYUDDIN, 2001). At the start of the experimental period all the animals were transferred to individual metabolism cages where they were fed pelleted lucerne at maintenance energy level, plus HCHO-casein at 60 g/hdJd, continuously through automatic feeders for 21 days (experimental period).

The HCHO-casein supplement was prepared as described by HEMSLEY *et at.* (1973). Common salt was added to the supplement at 1% (w/w) to improve the palatability.

Measurements were undertaken on these animals from day 8 of the experimental period, over a period of 14 days. Before the measurement period each animal was surgically prepared with a chronic indwelling catheter in the left and right external jugular veins and a femoral artery. A day before glucose biokinetics measurements were undertaken, a catheter was inserted into a lateral saphenous vein of each animal as described by MAHYUDDIN (2001). These catheters were to facilitate the simultaneous use of the isotope dilution and arteriovenous (A V) difference technique.

Each animal was intravenously infused with glucose, via jugular catheter, at its appropriate nominal rate (see above) from day 14 over a period of 8 days.

#### Digestibility and N balance

Feed residues, faeces and urine excreted were collected daily from day 8 over a period of 14 days for the determination of feed digestibility and N balance.

#### Isotope infusion and blood sampling

On days 18, 19 and 21 of the experimental period, urea, glucose and CO2 entry rates were estimated respectively by radioisotope dilution using the continuous infusion technique.

Approximately 1.85 MBq of e4C] urea was infused into a jugular vein for 9 h for the determination of urea entry rate. Arterial blood samples were collected at half-hourly intervals from the femoral artery over the last 3 hours of infusion.

For the determination of GER approximately 2.59 MBq [U_14C] glucose was infused continuously at a constant rate. During isotope infusion, blood flow across the hind-limb muscle bed, was estimated, between the 8th and 9th h of isotope infusion, using TOR technique described by ODDY *et at.* (1981). Blood

samples collected during blood flow estimation were also for the determination of glucose biokinetics. Blood samples for blood gas and $^{14}C02$ determination were collected at 15 minutes intervals, half an hour before and after blood flow estimation.

Carbon dioxide entry rate was determined by infusion of 3.3 MBq of NaH14C03 continuously at a constant rate for 12 h. Blood samples were collected at half-hourly intervals over the last 3 hours and treated as esscribed by ODDY *et al.* (1984).

**Sample preparation and laboratory analyses**

Measurements conducted on plasma included glucose, urea, FF A, lactate, amino acids, growth honnone and insulin concentrations. Blood concentrations of CO2 and O2 and radioactive of glucose, urea and CO2 were also determined. The samples were prepared and analysed according to procedure described by MAHYUDDIN (2001).

**Calculation of results**

Calculation of entry rates of metabolites and oxidation of glucose were carried out according to procedure described by MAHYUDDIN and TELENI (1995).

**Statistical analysis**

Data were subjected to the analysis of variance based on the Randomized Block Design. Differences between treatment means were examined using LSD test (STEEL and TORRIE, 1980).

All data were computed using the Statistix 3.0 program (NH Analytical Software, USA).

## RESULTS AND DISCUSSION

**Dietary intake and digestibility**

The intake of DM, organic matter and DOM did not change with glucose infusion. Since all animals were fed the same amount of feed, the ME intake also did not change (Table 1). There was a small difference in DM and organic matter digestibility of the diet before and after glucose infusion was started. However, levels of glucose infusion did not affect digestibility. Also the change in digestibility between the pre-infusion and infusion period were not significantly affected by the different infusion rates

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**Table 1**. The mean liveweight intake of dietary dry matter, organic matter and estimated. metabolisable energy (ME) and the digestibility of dry matter and organic matter in the periods before (B) and during (D) glucose infusion in lambs fed Lucerne pellets, at maintenance energy level, plus HCHO-casein at 60 g/hd/d

| | Glucose infused (mmole/h) | | | | SE | P |
|---|---|---|---|---|---|---|
| | Period | 10 | 20 | 30 | | |
| *Intake (g/d):* | | | | | | |
| Dry matter | | 436 | 428 | 426 | | |
| Organic matter | | 382 | 375 | 373 | | |
| Digestible organic matter | B | 227 | 206 | 214 | 8.8 | NS |
| | D | 229 | 220 | 323 | 8.8 | NS |
| ME (MIl d) | B | 3.37 | 3.07 | 3.20 | 0.13 | NS |
| | D | 3.40 | 3.30 | 3.48 | 0.13 | NS |
| *Digestibility* (%): | B | 59.0b | 56.1b | 56.4" | 0.9 | <0.05 |
| Dry Matter | D | 60.7 | 59.5 | 61.5 | 1.4 | NS |
| | D-B | 1.1 | 3.4 | 5.1 | 2.1 | NS |
| Organic matter | B | 51.7" | 49.1b | 49.4b | 0.8 | <0.05 |
| | D | 52.3 | 51.9 | 53.2 | 1.2 | NS |
| | D-B | -0.2 | 2.7 | 3.7 | 1.6 | NS |

Values (in each row) with different superscripts differ significantly (P<0.05)

*ME (MIl kg) = 0.15 x organic matter digestibility (%DM) x dry metter intake (kg) (MAFF, 1975)

**Nitrogen balance**

During glucose infusion the N retention increased significantly as the rate of glucose infusion increased (Figure 1). The mean value for N retention in lambs infused with glucose at 20 mmole/h was not statistically different from that of animals infused at 10 mmole/h (Table 2). However, when the mean incremental increase in N retention, between the periods before and during infusion of glucose, for infusion rates were compared, the differences between means were significant (Table 2). This incremental increased with increasing rate of glucose infusion. The efficiency of N retention increased with the levels of glucose infusion. The incremental increase in efficiency of N was also increased as the levels of glucose infusion increased.

During the period of glucose infusion, faecal N was not different between treatment groups, but there was a tendency for a reduction in faecal N as the rate of glucose infusion increased. The mean incremental reduction in faecal N excretion in each group, between the periods before and after glucose infusion, was highest (approximately 19%) in the group, which received the highest rate of glucose infusion. Similarly, urinary N excretion was reduced by glucose infusion and the reduction increased as the rate of infusion increased. It can be concluded that the infusion of glucose increased N retention by reducing both faecal and urinary N. This finding is consistent with that in the experiment described by MAHYUDDIN (1997). and with that found by ESKELAND *et at.* (1973, 1974). If the regression line of N retention on glucose infusion rate is extrapolated to zero glucose infusion (Figure 1) the value of N retained would be 3.6 g/d. This value is lower than that observed in the experiment by MAHYUDDIN (1997). The rate of N retained per unit of glucose infused, as estimated from Figure 1, was 0.15 g N/mmole glucose/h.

From Table 2, N retention expressed as percentage of N intake by lambs infused with glucose at 10, 20 and 30 mmole/h were 28%, 35% and 44% respectively. The value for N retained during infusion of 30 mmole/h was higher than the value of 33% found by ESKELAND *et al.* (1973) who infused glucose at the rate of approximately 2.09 MJ/d. This is equivalent to approximately 30.5 mmole glucose/h and was approximately 23% of total energy intake by the experimental animals, which were fed at maintenance energy level. The infusion of glucose, in the present study, at 30 mmole/h represented 37% of total ME intake. However, the incremental increase in N retention due to glucose infusion of 10, 20 and 30 mmole glucose/h only gave values of 5%, 14% and 27% of N intake respectively. The latter value was similar to that observed in experiment by MAHYUDDIN (1997) and by ESKELAND *et at.* (1973).

**Figure 1**. The response curve of N retention to rates of glucose infused into lambs fed lucerne pellets, at maintenance energy level, plus HCHO-casein at 60 g/hd/d
(*) 10 mmole/h;(<) 20 mmole/h; (♦) 30 mmole/h

**Table 2**. Nitrogen (N) balance and urea biokinetics in the periods before (B) and during (D) glucose infusion in lambs fed lucerne pellets, at maintenance energy level, plus HCHO-casein at *60* g/hdJd

| | Glucose infused (mmolelh) | | | | SE | P |
|---|---|---|---|---|---|---|
| | Period | 10 | *20* | *30* | | |
| *Nitrogen* (N) *balance (gld):* | | | | | | |
| Nitrogen intake | | 18.9 | 18.9 | 18.8 | | |
| Faecal N | D | 5.5 | 5.2 | 5.1 | 0.26 | NS |
| | B-D | 0.6a | 1.1 ab | 1.2b | 0.24 | *<0.05* |
| Urine N | | 8.2b | 7.0b | 5.4a | 0.56 | *<0.05* |
| | | 0.5a | 0.9a | 3.8b | 0.28 | *<0.05* |
| Nitrogen retention | D | 5.2a | 6.8" | 8.3b | 0.50 | *<0.05* |
| | B-D | *1.0"* | 2.7b | 5.1e | 0.27 | *<0.05* |
| Efficiency *of* N retention (%)* | D | 27.7a | 34.8b | 44.2e | 2.1 | *<0.05* |
| | D-B | 56: | 12.6b | 27.2e | 1.6 | *<0.05* |
| *Urea biokinetics (gld):* | | | | | | |
| Plasma urea (mg/dl) | | 54.9b | 42.0" | 37.8" | 3.36 | *<0.05* |
| Urea entry rate | | 45.1b | 34.7" | 31.4" | 1.88 | *<0.05* |
| Urinary urea | D | 10.5 | 11.8 | 8.93 | 1.18 | NS |
| | B-D | 7.9"b | 5.5" | 9.2b | 1.13 | *<0.10* |
| Urea transferred to the gut** | | 37.6b | 22.9" | 22.4" | 1.94 | *<0.05* |

Values (in each row) with different superscripts differ significantly (P<0.05).
* Calculated as N retention! N intake; ** Calculated by the defference between urea entry rate and urinary urea

Although the animals used in the present experiment were younger than those used in the previous experiment by MAHYUDDIN (1997), overall, the mean N retention in animals used in this experiment was lower. However, the incremental increases in N retention due to glucose infusions were in the same order as those found in the previous experiment.

**Urea biokinetics**

Plasma urea concentration was highest at the lowest rate of glucose infusion. There was a tendency for plasma urea concentration to decrease with increasing rates of glucose infusion. Similarly, urea entry rate also decreased as glucose infusion rate increased (Figure 2).

The estimated urea transferred to the gut was highest in lambs infused at the lowest rate of glucose infusion (Figure 2). On average 71% of urea entering the plasma pool was degraded in the gastrointestinal tract (GIT).

From the urinary urea excretion rate, the rate of gluconeogenesis from amino acids in an animal might be estimated if it were assumed that, under steady state conditions, the rate of N transferred from the rumen to the blood and vice versa were equal. If it were assumed that for every 100 g protein degraded, 35 g urea were synthesized (KREBS, 1964), then for urea excretion values of 18, (before glucose infusion) 11.8, 10.5 and 8.9 gld in animals infused with 0, 10, 20 and 30 mmole glucoselh respectively, it might be estimated that these amounts of urea were formed from degradation of 51, 34, 30 and 25 g prot_in respectively. Thus it might be suggested that 26 g protein were spared when animals were infused with 30 mmole glucoselh (129.6 g glucose/d). This is equivalent to approximately 20 g protein spared per 100 g of glucose infused. This value is close to the value (21 - 27 g protein spared) obtained by ASPLUND *et at.* (1985) who estimated this value from animals on a protein-free diet.

The amount of protein spared by glucose infusion may also be estimated from N retention. Infusion of 30 mmole glucoselh or 129.6 g/d resulted in spare of 5.1 g N (32 g protein). **In** other words, for 100 g glucose infused, the animal can spare 25 g protein from being catabolised.

The protein degradation of 34, 30 and 25 g/d could potentially produce 19, 16 and 14 *gld* or 4.4, 3.7 and 3.2 mmolelh of glucose respectively. Since GER increased proportionally as the rate of glucose infused increased (Figure 3.), the GER in animals on the M + HCHO-casein diet can be estimated; that is, by the difference between GER and the rate of glucose infused or by using the .regression equation in Figure 3. Thus for animals infused with 10, 20 and 30 mmole glucoselh, the values are 21.4, 22.2 and 22.1 mmolelh respectively. The proportions of these GERs that could potentially be derived from amino acids would be 21%, 17% and 14% respectively. These values are in the range of values proposed by LINDSAY (1980).

**Table 3**. Glucose biokinetics in lambs fed pelleted lucerne, at maintenance energy level, plus HCHO-casein at 60 g/hd/d

| | Glucose infused (mmole/h) | | | SE | P |
|---|---|---|---|---|---|
| | 10 | 20 | 30 | | |
| *Whole body* | | | | | |
| Plasma glucose (mM) | 4.1" | 5.2"b | 6.8b | 1.57 | |
| Glucose entry rate (mmole/h) | 31.4" | 42.2b | 52. Ie | 1.12 | |
| Glucose entry rate (mmole.h/kg L W) | 1.5" | 1.97b | 2.2ge | 0.08 | |
| Glucose oxidised (%) | 41.5" | 48.6b | 52.3b | 1.53 | |
| CO2 entry rate (mmole/h) | 254 | 271 | 284 | 12.47 | |
| CO2 from glucose | 30.8" | 43.3b | 58.3e | 2.91 | |
| *Hind-limb muscle* | | | | | |
| Blood flow (mVmin/kg) | 131.4" | 97.3" | 115.8" | 9.6 | |
| Glucose A V cone difference (mM) | 0.17" | 0.39b | 0.37b | 0.02 | |
| Glucose extraction (%) | 4.2" | 7.9b | 5.5b | 0.6 | |
| Glucose uptake (umole/min/kg muscle) | 22.3" | 37.9b | 42.8b | 2.8 | |
| Glucose glycolysed (%) | 42.9b | 16.3" | 8.6" | 6.63 | |
| 02 A V concn difference (mM) | 1.85 | 1.64 | 1.41 | 0.29 | |
| Potential glucose oxidation (%) | 85 | 165 | 152 | 15.9 | |

Values (in each row) with different superscripts differ significantly (P<0.05)
* Assuming 2 moles of lactate are produced from 1 mole of glucose
** Assuming 6 moles of 02 are required for each mole of glucose oxidised

Reduction of plasma urea by provision of energy-yielding nutrients had been reported by several workers (JUDSON and LENG, 1973; ESKELAND *et at.,* 1974; KENNEDY *et at.,* 1981; NORTON *et at.,* 1982; ASPLUND *et at.,* 1985; TELENI *et at.,* 1989). Such observations are consistent with that in this study where not only plasma urea concentration but also urea entry rate was reduced by the addition of glucose to the blood circulation of the experimental lambs.

**Glucose kinetics**

Data on glucose biokinetics in the experimental lambs are summarized in Table 3.

**Whole body**

In this experiment, unlike the previous one (MAHYUDDLN, 1997) the arterial glucose concentration increased with increasing rate of glucose infusion. At the infusion rate of 30 mmole/h of glucose the arterial glucose concentration was 1.5 times that in plasma of lambs infused with 10 mmole/h. The values are higher than the normal range (3 - 4 mM) in sheep (BERGMAN, 1983). The sheep in this study excreted urine at approximately 0.6 ml/min and the urinary glucose content was approximately 0.12 mg/m!. Thus there must have been a very active reabsorption of glucose in the kidney tubules. The increased plasma glucose concentration above the normal value due to intravenous glucose infusion was also found by WEST and PASSEY (1967), JUDSON and LENG (1973) and TELENI *et at.* (1989).

The GER increased as the rates of glucose infusion increased. Similarly, the percentage of glucose oxidized and its contribution to CO2 production were increased as the rates of glucose infusion increased. However, CO2 entry rate was not significantly affected by rates of glucose infusion (Table 3). Therefore, there must have been a depression in oxidation of other metabolites such as amino acids and free fatty acid (FFA).

Across treatments, the relationships between glucose infusion rates and glucose concentrations or GERs and between GERs and percentages of glucose oxidized or percentage of CO2 derived from glucose are illustrated in Figure 3.

**Hind-limb muscle**

Blood flow across the hind-limb muscles of lambs infused with glucose ranged from approximately 97 to 131 ml/minlkg muscle. The highest blood flow was observed in animals infused with 10 mmole glucose/h

and the lowest was observed in those infused with 20 mmole glucose/h (Table 3).

The AV concentration difference of glucose was significantly lower in animals infused with 10 mmole glucose compared to those infused with 20 or 30 mmole glucose/h. No significant in AV glucose concentration difference was observed between the latter two groups of animals.

The percentage extraction of arterial glucose by muscle was higher in Iambs infused with glucose at 20 mmolelh than in animals in the other two groups in which the values of glucose extraction did not differ significantly from each other.

Glucose uptake by the hind-limb muscles increased with increasing rates.of glucose infusion; and the uptake being the highest in the hind-limb muscles of lambs infused with 30 mmole glucose/h. The relationship between GER and glucose uptake by hind-limb muscles of Iambs across treatments is shown in Figure 4.

In this experiment glucose uptake by the hind-limb muscles was strongly related to both GER and plasma insulin concentration (Figure 4). Using the regression equation from Figure 4, it might be predicted, that for a 149.4 mmole/h infusion rate of glucose (PRIOR *et al,* 1984), 2.09 mmole/h/kg muscle would be taken up by the hind-limb muscles. The hind limb of cattle has been estimated in our laboratory, to be approximately 16% of fasted live weight and that approximately 60% of the hind limb is muscle (KARTIARSO and TELENI, unpublished data). Using these data, it might be estimated that an uptake (by the hind-limb muscles of steers of 375 kg live weight - PRIOR *et aL,* 1984) of 99 mmole glucoselh would be equivalent to 2.75 mmole glucose/h/kg muscle. This value and that predicted from the regression equation for lambs in Figure 4 are similar suggesting that metabolic response by sheep and cattle to exogenous glucose loading would probably be similar.

If all the glucose, taken up by the hind-limb muscles of lambs infused with 20 or 30 mmole glucose/h, was oxidized, it would be more than that accounted for the oxygen taken up by the same tissue. It might only be assumed that a large amount of glucose was assimilated into muscle glycogen.

**Lactate, growth hormone and insulin**

Table 4 shows the arterial concentrations of lactate, growth hormone and insulin and the A V concentration difference of lactate across hind-limb muscles.

Increasing glucose infusion rate increased the arterial plasma concentration of lactate and insulin but reduced the concentration of growth hormone. The highest values for lactate and insulin and the lowest value for growth hormone were observed in Iambs infused with glucose at 30 mmolelh. Although there was an apparent trend of decreasing growth hormone:insulin ratios with increasing glucose infusion rates, the difference between treatment means were not significant.

At the highest level of glucose infusion lactate was taken up by the muscle, however, at the lower 2 levels there was an output. The estimated percentage of glucose (taken up by muscle) which was glycolysed to lactate was reduced as the glucose infusion rate was increased (Table 3)

The responses to the provision of additional energy to lambs in this study were most probably mediated through hormones, in particular insulin (BERGMAN, 1983). The increase in plasma insulin concentration with the increasing level of glucose infusion (Table 5) is consistent with this suggestion.

Table 4. The effect of different rates of intravenous glucose infusion on the circulating levels of lactate, growth hormone and insulin and the arteriovenous (A V) concentration differences of lactate across the hind-limb muscles of animals fed pelleted lucerne, at maintenance energy level plus HCHO-casein at 60 glhdJd

| | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| Whole body | | | | | |
| Arterial concentration | | | | | |
| Lactate (mM) | 0.27a | 0.27a | 0.84b | 0.25 | 0.10 |
| Growth hormone (ug/L) | 5.3b | 2.6a | 3.1ab | 1.00 | 0.05 |
| Insulin (mM) | 26.3a | 33.4b | 4.5c | 1.95 | 0.05 |
| Growth hormone (ug/L): Insulin (mM) | 0.23 | 0.09 | 0.07 | 0.06 | NS |
| Hind-limb muscle | | | | | |
| AV concentarion difference | | | | | |
| Lactate (mM) | -0.14a | -0.13a | 0.03b | 0.021 | 0.05 |
| Glucose to lactate (%) | 42.9b | 16.3a | 8.6a | 6.63 | 0.05 |
| | | | | | |

The increase in plasma insulin was associated with increases in glucose uptake by the hind-limb muscle during intravenous glucose infusion (Fig 4). PRIOR *et at.* (1984) also found an increase (three fold) in glucose uptake by the hind half of steers when they were intravenously infused with 149.4 mmolelh glucose. However, the effect of the infusion on plasma insulin concentration was not reported. When PRIOR *et at.* (1984) infused the steers with insulin (1.4 IV/min) the uptake of glucose by the hind half also increased.

**Amino acids**

The arterial blood concentrations of amino acids are summarized in Table 5.

**Essential amino acids**

Of the essential amino acids, only phenylalanine and arginine were significantly affected by treatments. Although there were no significant differences in the arterial concentration of most of the essential amino acids between treatments, there was a tendency for concentrations to decrease as the levels of glucose infusion increased. This is particularly so if comparison is made with the zero level of glucose infusion (Table 5). This apparent reduction, particularly for branched chain amino acids (BCAA), was more prominent at 30 mmolelh of glucose infusion. GARLICK *et at.* (1988) found in rats that infusion of BCAA + glucose was as effective as the complete mixture of essential amino acids + glucose in promoting protein synthesis. It might be suggested therefore that the removal of these amino acids + glucose from the circulation (resulting in the observed apparent reduction in their arterial blood concentration), might have resulted in increased rate of protein synthesis in lambs infused yvith higher levels of glucose. Furthermore, the reduction in the concentration of these amino acids, which occurred concomitantly with the reduction in plasma urea and urea entry rate, is consistent with the suggestion that the increasing reduction of amino acid concentration in the arterial blood as glucose infusion rate increased, indicated increased net incorporation of amino acids into proteins. It is possible that a reduction in the rate of protein degradation might have contributed to the increased net incorporation of amino acids into protein. Such a possibility would have been facilitated by increased insulin secretion (WEEKS, 1986).

The estimated uptake of essential amino acids by the hind-limb muscles was too variable to suggest any meaningful effect due to glucose infusion.

**Non - essential amino acids**

There were no significant differences in the arterial concentration of non-essential amino acids with increasing levels of glucose infusion, except in the case of glutamate (Table 5). Although statistically there were no differences between treatments in the mean arterial concentration of non-essential amino acids there was a tendency for the amino acids concentrations to increase as the rate of glucose infusion increased. POTTER *et at.* (1968) also found a similar trend where concentrations of non-essential amino acids were increased. It was suggested by ESKELAND *et at.* (1974) that the increase in arterial concentration of non-essential amino acids was due to continued synthesis of these amino acids, which may limit protein synthesis.

The uptake of the non-essential amino acids was also too variable to indicate any significant difference between treatments.

Figure 4. The relationships between glucose entry rate or plasma insulin concentration and glucose uptake by the hind-limb muscles of lambs fed pelleted lucerne, at maintenance energy level, plus HCHO-casein at 60 g/hd/d and intravenously infused wihh glucose
(.) 10 mmolelh; (-<}) 20 mmolelh; (.) 30 mmo1e1h

**Table 5**. The effect of different rates of intravenous glucose infusion on circulating levels of blood amino acids in animals fed pelleted lucerne, at maintenance energy level, plus HCHO-casein at 60 glhdld

| | Dietary treatments | | | | SE | P |
|---|---|---|---|---|---|---|
| | 0* | 10 | 20 | 30 | | |
| Arterial concentration () | | | | | | |
| *Essential* | | | | | | |
| Valine | 219b | 197 | 195 | 129 | 51.3 | NS |
| Leucine | 126 | 114 | 102 | 74 | 24.4 | NS |
| Isoleucine | 74 | 62 | 59 | 45 | 13.2 | NS |
| Phenylalarllne | 27 | 57b | 51ab | 388 | 5.1 | <0.05 |
| Histidine | 60 | 50 | 62 | 47 | 12.3 | NS |
| Lysine | 173 | 155 | 144 | 153 | 33.9 | NS |
| Thereonine | 155 | 75 | 116 | 119 | 42.6 | NS |
| Arginine | 22 | 27b | 68 | 118b | 4.2 | <0.05 |
| *Non-essential* | | | | | | |
| Thyrosine | 55 | 79 | 96 | 61 | 20.1 | NS |
| Alanine | 96 | 96 | 83 | 95 | 17.7 | NS |
| Glutamate | 135 | 290b | 1868b | 1698 | 41.3 | <0.05 |
| Glutamine | 59 | 64 | 113 | 105 | 30.9 | NS |
| Glycine | 342 | 335 | 382 | 545 | 138.5 | NS |
| Aspartate | 13 | 16 | 18 | 19 | 3.8 | NS |
| Serine | 77 | 49 | 48 | 83 | 22.6 | NS |
| Asparagine | 37 | 28 | 29 | 34 | 5.8 | NS |

Values (in each row) with different superscripts differ significantly (P<0.05)
*Data (from Experiment Mahyuddin, 2001) from lambs fed the basal lucerne pellet + 60 glhdld HCHO-Casein. These are not included the statistical analysys but are presentented for the purpose of comparison only

## CONCLUSIONS AND RECOMMENDATION

The infusion of glucose.increases N retention, glucose entry rate, percentage of glucose oxidized and its contribution to CO2 production, reduces essential amino acids concentration, plasma urea, urinary urea and urea entry rate.

It was estimated that every 100 g of glucose infused, 20 g to 25 g protein can be spared for protein synthesis. The indication of increased net incorporation of amino acids into protein was shown by the reduction of essential amino acids in blood circulation, plasma urea concentration and urea entry rate.

Since animal undergoing compensatory growth has the preference of depositing protein, and glucose infusion could increase amino acids incorporation into protein, investigation toward sustaining the optimal ratio of amino acids: glucose during this period may be required.

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