GLUCOSE METABOLISM AND GROWTH IN CATTLE GIVEN MOLASSES UREA BASED DIETS

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Two growth trials are described. In Experiment 1, 2 groups of 4 steers were given either a basal diet of molasses containing 4% (w/w) urea (Diet A) or the basal diet supplemented with 82 fish meal (Diet B). In Experiment 2, the steers were reallocated into three groups and given either Diet A (2 animals), Diet B (2 animals) or Diet C (4 animals; the basal diet supplemented with 12% fish meal). All diets included a mineral and vitamin supplement and each animal was given 1.5 kg cereal hay per day. Dry matter intake and liveweight change were recorded for each group for a period of 93 d and 51 d for Experiment 1 and Experiment 2 respectively . Glucose entry rates were estimated in both experiments from a single injection of [2-^{3}H] glucose. The parameters of glucose metabolism did not vary significantly when estimated at 6 hr intervals over a 24 hr period. Glucose entry rates varied between 7.4 to 14.5 g/kg/ /d and g growth rates varied between 300 and 700 g/d. Over the range of growth rates measured, there were significant linear relationships between glucose entry rate and growth rate, and between try ratter intake and glucose entry rate.

Key Words: Cattle, molasses/urea, bypass protein, growth, glucose entry rate

It is now well established that growth rate of cattle given sugar cane diets can be increased by supplementing the diet with rice polishings (see Preston 1977). This supplement provided large quantities of starch postruminally (Elliott et al 1978) and increased glucose entry rate proportionately with the quantity of rice polishings fed (Ferreiro et al 1979). It is not known whether the response to rice polishings is to extra energy or glucose per se and therefore it becomes important to establish base-line data and the relationship between glucose synthesis rates and dry matter intake and growth in cattle.

There appear to be close relationships between digestible energy intake and glucose entry rate in mature sheep (Judson and Leng 1968) and growing lambs (Kempton and Leng 1979). In addition, since there is a significant relationship between growth and the availability of glucose in lambs, and also because gluconeogenesis from propionate or amino acid requires energy, Kempton & Leng (1979) argued that glucose entry rate may closely represent glucose 'requirements' for specialised metabolic functions. In the studies presented here, weaner cattle were given a molasses based diet because there was little chance of glucose being absorbed per se from the digestive tract and therefore the estimates of the total

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glucose entry rate would closely approximate the rate of gluconeogenesis (Judson and Leng 1972). In addition, feed intake and growth rates could be manipulated readily by varying the bypass protein content of the diet.

Materials and Methods

Animals and their management: Eight Hereford weaner steers (about 8-10 months old) and between 137 to 178 kg liveweight were used in Expt. 1. The same eight steers were reallocated after completion of the first experiment and used in Expt. 2. They were then about 12-14 months old and between 189 to 226 kg liveweight.

Experiment 1: The steers were allocated at ransom into two groups and given free access to either a basal diet of 89% final molasses, 5% water, 4% urea, 1% calcium diphosphate, 0.5% NaCl and 0.5% of a mineral vitamin mix (Diet A) or the same molasses mixture supplemented with 80 g fish meal per kg of basal diet (Diet B). Each steer was given 1.5 kg of cereal hay per day at 0800 h and the molasses mixture was available at all times. The animals were given the diets for 93 d.

Experiment 2: The 8 steers from Expt. 1 were reallocated at random after an equilibration period of 14 d so that 2 animals received the basal diet (Diet A), 2 animals were given the basal diet supplemented with 80 g fish meal (Diet B) and the remaining 4 animals received the basal diet supplemented with 120 g fish meal per kg of diet (Diet C). The animals were given the diets for 51 d.

Experimental procedures: Feed intake was recorded daily for each animal and all animals were weighed every 7 d.

Measurement of glucose entry rate. Glucose entry rates, estimated using [2-^{3}H] glucose (Judson and Leng 1972), were determined in all steers during the last week of the growth trial. On the afternoon prior to the isotope injection, catheters were inserted into a jugular vein of each animal. At about 10.30 h on the following day [2-^{3}H] glucose (220 µC and 10 µmole in 10 ml 0.9% (w/v) saline) was injected intravenously via the catheter. Following injection, blood samples (10 ml) were taken into heparinized tubes every 30 min. for 3 h. The tubes were cooled in ice and the samples centrifuged at 3000 g for 20 min. and the plasma stored at -20°.

In 3 animals, 4 estimates of glucose entry rate were made by repeated single injections of [2-^{3}H] glucose at intervals of 6 h for a 24 h period, blood samples being taken immediately prior to injection and then at 30 min intervals for 3 h.

Chemical methods: Plasma glucose concentration was determined by the method of Frings, Ratliff and Dunn (1970) and glucose was isolated as the pentaacetate derivative (Jones 1965) and counted in a liquid scintillation spectrometer. Radioactivity in the glucose of the injected dose solution was also assayed as the pentaacetate derivative.

Calculations: The specific radioactivity-time curve of plasma glucose following a single injection of tracer was graphed on semi logarithmic co-ordinates and a straight line fitted by the method of least squares to the data between 30 min to 3 h post injection of isotope. Individual results indicated that the log specific radioactivity with time relationship could be described by a single exponential equation ($R^2 = 0.95$) and therefore pool size (g), half time (min) and total glucose entry rate (mg/min) were calculated assuming that first order dilution processes applied (Judson and Leng 1972).

Statistical analysis: Comparisons between treatment effects were made by analysis of variance. Regression analysis was used to obtain the relationships between feed intake, growth rate and the various parameters of glucose metabolism. Dry matter intake (DMI) was calculated as the mean of the two days preceding and including the day on which the glucose entry rates were measured.

Results

Parameters of glucose metabolism estimated at intervals over 24 h: No significant differences were found between the mean values of the estimates of glucose entry rate (mg/min), glucose pool size space (% Lwt), t1/2 (min) or plasma glucose concentration (mg/100 ml) (Table 1). In all subsequent Tables glucose entry rates are extra polated to daily glucose entry rates (g/d).

Table 1:
Parameters of glucose metabolism estimated in steers at intervals of 6 h over a 24 h period. All values are the mean of 3 observations

	Period				Significance of difference between means	S.E.M.
	1	2	3	4		
Glucose concentration (mg/100 ml)	77	81	83	88	n.s.	2.7
Glucose entry rate (mg/min)	445	414	434	417	n.s.	24
Glucose pool (g)	40	39	47	46	n.s.	2.6
Glucose space (% Lwt)	52	48	57	52	n.s.	3.6
T½ (mins.)	62	65	76	76	n.s.	4.3

Period 1 : 10 a.m. - 1 p.m.; Period 2 : 4 p.m. - 7 p.m.;
Period 3 : 10 p.m. - 1 a.m.; Period 4 : 4 a.m. - 7 a.m.

Animals had the molasses mixture available at all times

Table 2:
Initial live weight (kg), dry matter intake (kg/d), deed conversion ratio, glucose entry rate (g/d) and average daily gain (g/d) of steers given a basal diet of molasses and urea (Diet A) or the basal diet supplement with 8% (w/w) fish meal (Diet B) for a period of 93 days

	Diets		Significance of difference betweem means	S.E.M.
	A	B		
Initial liveweight (kg)	161	161	n.s.	3.4
Dry matter intake (kg/t)	3.9	4.8	**	0.10
Feed conversion ratio	11.2	7.7	*	0.48
Glucose entry rate (g/d)	427	731	***	19
Average daily gain (g/d)	354	630	***	32

Liveweight change, DMI, feed conversion ratio and glucose entry rate: Mean values for liveweight change, DMI, feed conversion ratio and glucose entry rate for animals in Expt. 1 are given in Table 2. Animals given Diet B had significantly ($P < 0.01$) greater DMI, liveweight gains, and glucose entry rates as compared with animals on the basal diet (A).

Mean values for liveweight change, DMI intake, feed conversion ratio and glucose entry rate for the animals used in Expt. 2 are given in Table 3. Liveweight gain, and glucose entry rates were significantly ($P < 0.05$) greater in cattle on Diets A and C as compared with those given Diet B.

Relationship between DMI and growth rate: The relationships between the rate of growth (Δw g/d) and DMI (kg/d) were not significantly different between experiments and the data were combined. The relationship for the combined data was:

$\Delta w = 177 (\pm 53)$ DMI - 297 $R^2 = 0.48$ RSD = 85 (1)

Relationship between glucose entry rate (GER) and growth rate: The relationships between GER (g/d) and DMI (g/d), and GER (g/d) and growth rate (Δw , g/d) were not significantly ($P < 0.05$) different in slopes or intercepts between experiments, and the data for cattle in the two experiments were combined. The relationships are:

$\Delta w = 0.87 (\pm 0.13)$ GER - 19 $R^2 = 0.80$ RSD = 53 (2)

GER = 195 (± 49) DMI - 287 $R^2 = 0.57$ RSD = 79 (3)

The relationship between growth rate (~w g/d) and GER per unit of metabolic body weight, (i.e. MGER, g/kg 0 75/d) was:

$\Delta w = 47 (\pm 9\ 3)$ MGER + 23 $R^2 = 0.68$ RSD = 67 (4)

Table 3:
Initial liveweight (kg), dry matter intake (kg/d), feed conversion ratio, glucose entry rate (g/d) and average daily gain (g/d) of cattle given the basal diet (Diet A}, or basal diet plus 8% fish meal (Diet B) or the basal diet plus 12% fish meal (Diet C) for a period of 51 days

	Diets			Significance of difference between means	S.E.M
	A	B	C		
Initial liveweight (kg)	234	215	216	n.s.	5.9
Dry Batter intake (kg/d)	4.8	4.7	5.0	n.s.	0.16
Feed conversion ratio	8.9a	11.7b	9.2a	*	0.26
Glucose entry rate (g/d)	650a	542b	633	*.	6.0
Average daily gain (g/d)	540a	400b	545a	*	14

Discussion

In these studies the steers were observed to feed intermittently but continuously throughout any 24 h period. Examination of quantitative turnover of glucose in these animals over a 24 h period also indicated that there was a steady rate of glucose synthesis. In these animals therefore, total glucose entry rate over a 24 h period could be estimated with confidence from a single injection of [2-^{3}H] glucose and sampling over 3 h.

In cattle given molasses based diets, the estimate of glucose entry rate is similar to the rate of glucose synthesis since little of the dietary carbohydrate appears to escape fermentation in the rumen (Marty and Sutherland 1970). In addition, although glucose is present in molasses in significant quantities (approximately 20% total carbohydrate) none is quantitatively absorbed from the rumen, since administration of [6-^{3}H] glucose in the molasses consumed in a single meal resulted in no significant amounts of radioactivity appearing in plasma glucose (unpublished observations).

Fish meal has been recognised as a bypass protein (Preston and Willis. 1970) that will increase the intake and growth of cattle on molasses based diets. This was confirmed in Expt 1. However, when the animals were changed from a diet supplemented with a bypass protein in Expt 1 to an unsupplemented diet in Expt 2, the animals maintained high DM intakes and growth rates in the second experiment. This may indicate that there was either a major carry over effect in the animal or in some function of digestion. The high intake and growth rates were so prolonged (over 50 d) that they suggest a change in the ratio of absorbed nutrients in these animals. For instance it has recently been demonstrated in cattle on this molasses diet (see Bird and Leng 1978) that the presence of protozoa in the rumen can decrease animal production. Although protozoa numbers were not measured in this experiment it is possible that there may have been fewer protozoa in the rumens of the cattle in the second experiment.

Results from this study show that in growing cattle, glucose synthesis rate increased linearly with DMI and growth rate (in the range of 300 to 700 g/d). This supports similar findings of Kempton and Leng (1979) for growing lambs. From these experiments with steers, for every 100 g of liveweight gain, 115 g of glucose was synthesized, as compared with lambs where 44 g glucose was needed to support an increase in growth rate of 100 g/d,

In these studies the most closely related parameters were between glucose entry rate and growth rate of steers (R^2 = 0.80) rather than between growth rate and DMI (R^2 = 0.48) or glucose entry rate and DMI (R^2 = 0.57). This may indicate that glucose entry rate rather than feed intake is possibly the best index of the potential rate of production in cattle. However, part of this variation may have arisen because of the separation in time of the two experiments and the necessity of using animals at different weights. Against this however was the fact that taking metabolic body weight into account decreased the significance of the regression of liveweight change on glucose entry rate.

It is of interest that at close to maximum growth rates in cattle the glucose entry rate (as determined by extrapolation using equation 2) may be 25 g/kg$^{3/4}$/d and in sheep at close to maximum growth rate (say 0.5 kg/d) the glucose entry rate calculated by extrapolation from the results of Kempton and Leng (1979) may be 22 g/kg$^{3/4}$/d. Glucose entry rates of 22 g/kg$^{3/4}$/d have been reported for maximum milk production in cattle (Wiltrout and Satter 1972). This suggests that the total glucose entry rates (requirements ?) are similar for maximum production in both sheep and cattle. These relationships for cattle were established in a growth period associated largely with lean meat production and the composition of the gain is obviously important in determining the "requirements" for glucose.

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