EFFECT OF DIET ON GLUCOSE SYNTHESIS IN SHEEP

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Summary

Glucose entry rates, propionate production rates and the conversion of propionate into glucose were measured in sheep given diets varying in protein and energy content. Glucose entry rate increased linearly ($P<0.01$) with the estimated intake of digestible energy and with crude protein intake as did concentrations in the rumen of propionate and total VFA. There was, however, little variation in the proportion of glucose derived from propionate.

I. INTRODUCTION

Carbohydrates are femented in the rumen to form volatile fatty acids (VFA). Some glucose may be absorbed from the lower intestinal tract of sheep given roughage diets but the quantity probably does not exceed 5 g per day (Heald 1951; Porter and Singleton 1965). However, measurements of glucose entry rates in non-pregnant sheep given roughage diets have varied from 69 to 128 g per day (Kronfeld and Simesen 196 1; Leng, Steel and Luick 1967) indicating that gluconeogenesis is an important biosynthetic process.

The effect of diet on glucose entry rate in sheep has received little attention. The availability of glucogenic substrates such as propionate and amino acids may be important when glucose demands are high. It has been suggested that the initial cause of pregnancy toxaemia in sheep is a shortage of glucose for maternal tissues (McClymont and Setchell 1956) and there is some indication that rumen propionate concentrations, which are related linearly to production rates (Leng and Brett 1966) are associated with increased growth and fattening of lambs (Johns, Ulyatt and Glenday 1963; Ørskov and Allen 1966). As part of a study of factors which limit or control glucose entry rates, the contribution of propionate to glucose synthesis in sheep given various rations has been investigated.

II. MATERIALS AND METHODS

(a) Procedure

Adult Merino ewes fitted with permanent rumen cannulae were maintained in individual pens. They were given the rations shown in Table 1 at 0800 h each day for at least eight weeks prior to an experiment. Six days before each experiment, the sheep were transferred to metabolism cages and were given their ration in 24 equal quantities at hourly intervals using an automatic feeder (Minson and Cowper 1966). On the fifth day, the animals were infused intravenously with [U-^{14}C] glucose for 6 h and on the sixth day [2-^{14}C] propionate was infused intraruminally for 9 h by the methods described by Leng, Steel and Luick (1967) and Leng and Leonard (1965) respectively. Pre-infusion samples of blood were taken on the sixth day to determine residual activity in circulating glucose.

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TABLE 1

Diets given to sheep

Sheep No.	Sheep Liveweight (kg)	Ration (g/day)				Crude protein intake (g)	Estimated* digestible energy intake (kcal)
		Wheaten straw	Wheaten chaff	Lucerne chaff	Casein		
122	26.5	200	400	—	—	33.2	1208
125	27.0	200	600	—	—	48.2	1633
122	29.5	—	800	—	—	62.4	1703
125	27.5	—	677	123	—	76.8	1757
162	31.5	—	554	246	—	91.2	1811
81	32.5	—	430	370	—	109.5	1874
181	32.0	—	308	492	—	119.0	1920
162	31.0	—	185	615	—	122.8	1959
181	32.0	—	—	800	—	180.0	2086
181	34.0	—	—	800	76	199.4	2373
81	34.5	—	—	800	100	217.6	2478

*Estimates of digestible energy derived from total digestible nutrient and digestible crude protein values of similar feeds publishd by Morrison (1957).

(b) Chemical methods

Methods for VFA estimation, and the isolation and radio-assay of propionate, have been described by Leng and Leonard (1965). Plasma glucose concentrations were determined by the method of Huggett and Nixon (1957) and glucose was isolated and assayed for radioactivity as the pentaacetate derivative (Jones 1965). Crude protein content of the ration was determined by the method of Clare and Stevenson (19 64).

(c) Calculation of *Results*

Digestible energy contents of the rations shown in Table 1 were derived from the total digestible nutrient (TDN) and digestible crude protein (DCP) values for similar feeds published by Morrison (1957). The TDN values were adjusted for the higher energy value of DCP relative to that of digestible carbohydrate (Glover, Duthie and Dougall 1960) and it was assumed that 1 g of TDN was equivalent to 4.4 kcal of digestible energy (Swift 1957).

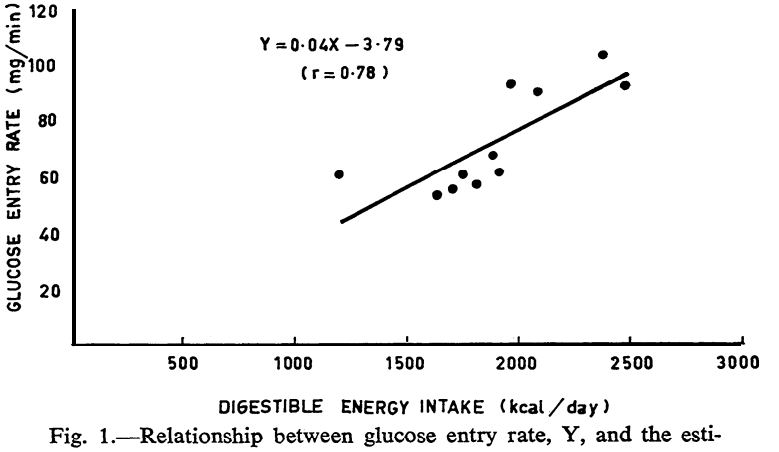

Fig. 1.—Relationship between glucose entry rate, Y, and the estimated digestible energy intake, X.

Glucose entry rates, propionate production rates and the proportion of glucose synthesised from propionate were calculated as described by Leng, Steel and Luick (1967).

III. RESULTS

Plasma glucose concentrations were approximately constant during the infusions of labelled isotope. The specific radioactivity of plasma glucose plateaued between 3 and 6 h from the start of a [U-^{14}C] glucose infusion. Glucose entry rate increased linearly ($P<0.01$) with the estimated digestible energy intake (DEI) (Figure 1') and with crude protein intake as did ruminal VFA and propionate concentrations (Figure 2). The molar proportions of VFA were similar except in sheep given casein where the molar proportions of isovaleric, isobutyric and valeric acids were increased.

The specific radioactivity of plasma glucose and rumen propionate were approximately constant between 6 and 9 h from the start of a [2-^{14}C] propionate infusion. The proportion of the glucose entry rate derived from propionate and the percentage of the propionate produced in the rumen which was converted into glucose are given in Table 2.

IV. DISCUSSION

The quantity of glucose synthesised by ruminants appears to be affected by the quantity and quality of the diet. Ford (1965) found that glucose entry rates were greater in sheep given spring grass than in sheep given hay and oats, and he attributed the increased glucose synthesis to the increased protein content of the grass. The energy content of these two diets was not given but it is likely that differences in protein intake were associated with differences in energy intake. In the present study, glucose entry rate was positively correlated with the estimated DEI but this relationship must be interpreted with caution since DEI and protein intake were

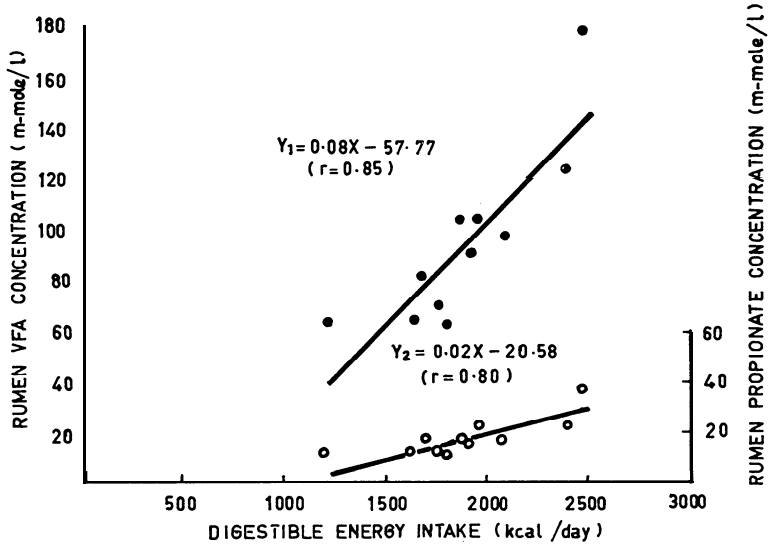

Fig. 2.—Relationship between rumen VFA, Y_1 (•) and propionate, Y_2 (o) concentrations and the estimated digestible energy intake, X.

TABLE 2
The conversion of propionate into glucose

Sheep No.	Crude protein intake (g/day)	Estimated digestible energy intake (kcal/day)	Glucose entry rate (g/day)	Glucose synthesised from propionate %	Propionate produced that was converted into glucose %
122	33.2	1208	88	50	69
125	48.2	1633	77	38	43
122	62.4	1703	80	68	67
125	76.8	1757	87	72	75
162	91.2	1811	82	—	—
81	109.5	1874	97	43	53
181	119.0	1920	87	57	64
162	122.8	1959	133	72	90
181	180.0	2086	129	45	76
181	199.4	2373	146	32	58
81	217.6	2478	133	62	54
Mean				54	65

confounded. It is apparent from Figure 1 that an increased intake of 1000 kcal of digestible energy led to the synthesis of approximately 58 g glucose. Since the caloric value of glucose is 3.75 kcal/g (White, Handler and Smith 1964), the increased synthesis of glucose was equivalent to 2 1.8 % of the DEI plus the energy cost of synthesis. The energy intake was estimated only approximately but the values appear reasonable since there was a significant correlation between the estimated DEI and rumen VFA concentrations. This relationship is consistent with the observations of Gray et *al.* (1967) who found that the energy available as VFA was a constant proportion of the DEI of roughage rations similar to those used in this study.

There was little variation in the proportion of glucose derived from propionate. This suggests that the contribution of propionate and amino acids to an increase in glucose synthesis was similar for the rations used in this study. The amount of protein made available to the animal as amino acids may be related to the production of VFA since energy for the synthesis of bacterial cells to replace those leaving the rumen arises during the fermentative process (Walker 1965; Hungate 1966).

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