EFFECT OF FEEDING FREQUENCY ON CHANGES IN PLASMA GLUCOSE AND THE MOLAR RATIO OF INSULIN TO GLUCAGON IN SHEEP

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Introduction

It is well known that only small amounts of glucose are absorbed from the gut in ruminants, because most of carbohydrate in the diet is fermented in the rumen. The process of gluconeogenesis is therefore important for maintaining constant blood glucose levels in ruminants. The liver is the central organ for gluconeogenesis and that function is controlled by many factors. Pancreatic hormones affect glucose metabolism with the liver as their first target organ. Unger (1971) suggested that the balance of insulin and glucagon is one of the indicators of nutrient metabolism. Bassett (1975) reviewed the control of hormones regulating carbohydrate metabolism in ruminants and pointed out that a low insulin/glucagon (I/G) ratio is needed to maintain gluconeogenesis in ruminants. The purpose of this experiment was to clarify the effects of feeding pattern on plasma glucose levels and on the molar ratio of insulin to glucagon (I/G ratio) in sheep.

Materials and Methods

Four female sheep weighing 42-45 kg were used. They were housed in metabolic cages and water was available continuously. The total amount of diet supplied was fixed at 1500 g lucerne pellets and 300 g orchard grass hay a day. In Expt 1, the total ration was given at 12:00 h. In Expt 2, the same amount of diet was divided and two equal meals were given at 12:00 and 24:00 h. In Expt 3, three equal amounts of feed were given at 12:00, 20:00 and 04:00 h. Sheep were accustomed to each feeding condition for at least two weeks before the measurements were made. On the day of an experiment, a catheter was inserted into the carotid loop 3 h before feeding. The catheters were flushed and filled with 3.8% tri-sodium citrate. Blood samples were withdrawn from the carotid artery at 0.5-1 h intervals for a 24 h period. Plasma was separated and glucose, insulin and glucagon concentrations were determined. Results are expressed as means with SE of the mean. To compare the diurnal mean levels for each feeding frequency, the mean values for plasma glucose, insulin and glucagon concentrations were calculated from all 25 samples taken at 1 h intervals on any one day. Duncan's multiple range test was used for statistical analysis.

Results and Discussion

In all cases, food was generally consumed within 2 h after the beginning of feeding. Plasma glucose levels decreased rapidly immediately after the beginning of feeding in all experiments. At the same time, both insulin and glucagon and the I/G ratio were increased in peripheral plasma. These changes in glucose and pancreatic hormones after feeding were also reported by Bassett (1974) and de Jong (1981). The decrease in plasma glucose suggests an increased utilization of glucose by peripheral tissues, especially the gastro-intestinal organs. High levels of insulin will also favour hypoglycaemia. Table 1 shows the mean values for plasma glucose, insulin and glucagon concentrations and the I/G ratio over the 24 h period for the three feeding conditions. The mean glucose concentration was elevated by more frequent

TABLE 1. MEAN PLASMA GLUCOSE, INSULIN AND GLUCAGON CONCENTRATIONS AND I/G RATIO FOR THREE FEEDING FREQUENCIES

Feeds/day	1	2	3
Glucose (mg/100ml)	60.1 ± 0.8^{a}	60.9 ± 0.6^{a}	63.0 ± 0.7^{b}
Insulin (μU/ml)	14.9 ± 1.0^{a}	15.5 ± 1.1^{a}	19.2 ± 1.3^{b}
Glucagon (pg/ml)	199 ± 2^{a}	192 ± 3^{ab}	187 ± 2^{b}
I/G ratio	1.8 ± 0.1^{a}	2.0 ± 0.1^{ab}	2.4 ± 0.1^{b}

^{ab}Means in the same row with different superscripts are significantly different ($p < 0.05$) with Duncan's multiple range test.

feeding ($p < 0.05$). The mean insulin level was higher and the glucagon level lower with three meals a day ($p < 0.05$). Sutton et al. (1988) reported that frequent feeding decreased plasma glucagon levels, but plasma insulin was not changed in dairy cows. In our study, more frequent feeding of fixed amounts of feed maintained high glucose levels in sheep. This effect may be due to a constant supply of glucose precursors from the rumen and is not due to the pattern of pancreatic hormone response. The physiological factors controlling insulin and glucagon release are not clear, but it is clear that the changes in plasma glucose did not control the release of insulin and glucagon immediately after feeding. Our results suggest that more frequent feeding leads to a hormone balance of insulin and glucagon favouring an anabolic direction of metabolism in sheep.

(**Key Words**: Sheep, Feeding, Glucose)

Literature Cited

Bassett, J.M. 1974. Diurnal patterns of plasma insulin, growth hormone, corticosteroid and metabolite concentrations in fed and fasted sheep. Aust. J. Biol. Sci. 27:167-181.

Bassett, J.M. 1975. Dietary and Gastro-intestinal control of hormones regulating carbohydrate metabolism in ruminants. In "Digestion and Metabolism in the Ruminant"(Ed. by I.W. McDonald and A.C.I. Warner) The Univ. of New England Pub. Unit, pp.383-398.

de Jong, A. 1981. The effect of feed intake on nutrient and hormone levels in jugular and portal blood in goats. J. Agric. Sci. 96:643-657.

Sutton, J.D., J.C. Hart, S.V. Morant, E. Schuller and A.D. Simmonds. 1988. Feeding frequency for lactating cows: diurnal patterns of hormones and metabolites in peripheral blood in relation to milk-fat concentration. Br. J. Nutr. 60:265-274.

Unger, R.H. 1971. Glucagon and the insulin: glucagon ratio in diabetes and other catabolic illnesses. Diabetes 20:834 838.