

# PLASMA GLUCOSE CONCENTRATION, DIURNAL PROFILE AND UTILIZATION RATES IN GROWING GOATS

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## SUMMARY

Plasma glucose concentration, diurnal profile, and utilization rates were studied in growing goats for a duration of six months. Plasma glucose concentration was measured by the hexokinase method. The glucose utilization rates were determined by single intrajugular infusion of <sup>14</sup>C-glucose. During the growing period of six months plasma glucose concentration dropped from 7.9 mM to 4.5 mM. Initiation of hay feeding facilitated the drop in plasma glucose concentration. The glucose utilization rate declined from 60 mmol/d.kg b.w.<sup>0.75</sup> to 27 mmol/d.kg b.w.<sup>0.75</sup> during the same period. The glucose utilization rates were 20 mmol/d.kg b.w.<sup>0.75</sup> and 14 mmol/d.kg b.w.<sup>0.75</sup> in 24 h fasted and 48 h fasted goats respectively. The glucose utilization rate was positively correlated with their corresponding plasma glucose concentration ( $r = 0.79$ ). The variation of plasma glucose diurnal profile was slight and ranged from 4.20 mM to 4.86 mM during the 24 h period. Three conclusions are made from this study. These are: glucose metabolism is of equal importance in young goats as it is in mature goats, glucose utilization rate is an indicator of amount of available fuel (energy) supply in the body and determination of plasma glucose in goats may be a useful parameter to indicate the stage of growth and in formulation of appropriate weaning periods.

## INTRODUCTION

Glucose predominates in the blood of monogastrics and ruminants over the other monosaccharide and plays unique metabolic functions. It is an indispensable fuel substrate for nervous tissue (Lindsay and Setchell 1974), erythrocytes (Leng and Annison 1962) and maintains optimal levels of glycogen in muscle and liver (Jarret *et al.*, 1976). During lactation 60-80 % of the available blood glucose is utilized for lactose synthesis by the mammary gland, a major fuel source for neonates (Linzel, 1974).

Blood glucose plays unique role in metabolic regulation. The concentration of glucose in the blood is regulated by insulin

and glucagon secreted into the blood by the  $\beta$  and  $\alpha$  cells of the pancreas respectively (Hove, 1974). Insulin and glucagon are potent anabolic and catabolic hormones respectively and regulate the body glycogen, protein and lipid pools syntheses and degradation (Brockman *et al.*, 1975a).

Glucose is found in lower concentration in the blood of ruminants than in monogastric animals. In adult goats like other adult ruminants, blood glucose supply is mainly derived from the gluconeogenesis in the liver and kidney. The rate at which glucose is utilized in the animal body is a reflection of glucose supply from gluconeogenesis (Judson and Leng, 1973).

Glucose supply in ruminants may

thus be investigated by measurement of glucose utilization rate. It has been found that plasma glucose utilization rate is positively correlated with plasma glucose concentration in sheep under different physiological situations and feeding regimes (Bergman *et al.*, 1974) as well as in lactating cows (Thilsted, 1984). In the present study plasma glucose concentration and its association with plasma glucose utilization rate were investigated in goats from one month up to six months of age.

## MATERIALS AND METHODS

### Animals and feeding.

Fourteen (14) Norwegian goats were used from day one old through the weaning period until they were 6 months old. The goats were housed individually in separate pens. The temperature in the pens was thermostatically maintained at 25°C. From day 1 up to an age of 4 weeks, the kids were allowed to suck their dams. One litre of whole goat milk was divided into two equal halves and each half was fed daily by hand to each kid at 06.30 h and 14.30 h respectively when the kids were 5 weeks old until when they were 8 weeks old. From the age of 9 weeks until the age of age 27 weeks, 0.5 l of whole goat milk, 100 g concentrate and hay *ad-libitum* were fed to each goat daily. The kids had free access to water.

### Blood sampling, treatment and analysis of samples.

Blood samples for determination of plasma glucose concentration were drawn from the left jugular vein of each kid starting from when the kids were 1 day old until they were 6 months old at an interval

of 1 week. Four out of the 14 kids, at the age of 24 weeks were used to study the diurnal profile of plasma glucose. Blood was drawn from the left jugular vein of the 4 goats at an interval of two hours throughout a 24 h period. The blood samples were drawn using needles and heparinized plastic test tubes containing trace amounts of sodium fluoride to arrest *in vitro* glycolysis.

Glucose utilization rates were determined in 4 fed kids at the age of 4, 14, 24 and 27 weeks. In addition, two more glucose utilization rates were determined both in 27 weeks old kids; one in 24 h fasted and the other in 48 h fasted kids.

An isotopic tracer, <sup>14</sup>C-labelled glucose was administered through one jugular vein while blood samples were taken from the other. Before the injection of the tracer, animals were anaesthetized by injecting sodium phenobarbital (Jansen Firm) in the right jugular vein at a dose of 28 mg/kg body weight. An in dwelling teflon catheter was attached to a needle and introduced into the left jugular vein of each of the goats to allow injection of the <sup>14</sup>C- glucose and withdrawal of blood samples. The injection of <sup>14</sup>C-glucose was performed after the goats had recovered from the anaesthesia. Single intrajugular injection of <sup>14</sup>C-glucose at a dose of 10 µCi/kg body weight was performed at 08.00 h before the morning feeding. Blood samples for determination of activity of <sup>14</sup>C-glucose and glucose concentration in the plasma were drawn at 15 minutes interval after injection of the <sup>14</sup>C-glucose for a period of 90 minutes. The blood was centrifuged at 2500 rotation per minute for 10 minutes. Part of the plasma was immediately analyzed for activity of <sup>14</sup>C-glucose. To analyze glucose activity the method described by Jones (1967) was used. The procedure is based on the principle that glucose reacts with anhydride acetic acid to

form crystals of glucose pentaacetate (GPA) on cooling. The GPA crystals are dissolved in toluene and the activity of  $^{14}\text{C}$ -glucose in the solution is counted by using liquid scintillation counter.

The rest of the plasma was used to determine glucose concentration by the hexokinase method (Darrow and Colowick 1962). The method is based on the principle that glucose is phosphorylated to glucose-6-phosphate by ATP in the presence of the enzyme hexokinase. Glucose-6-phosphate reacts with NADP to form 6-phosphogluconolactone and NADPH. The amount of NADPH formed which is measured at 365 nm spectrophotometrically is proportional to the concentration of glucose in the sample.

#### Calculation of glucose utilization rates.

The size of the glucose pool was calculated by dividing the injected dose with specific activity of plasma  $^{14}\text{C}$ -glucose at  $t=0$ . Glucose turnover rate (F) was calculated using the following equations (Shipney and Clark 1972):

$$\text{Log } S = \text{log } S_0 - kt$$

$$F = Q \cdot k \quad Q = D/S_0$$

where S is the specific activity of  $^{14}\text{C}$ -glucose at time t (min) after injection;  $S_0$  is the specific activity when  $t=0$  and k is the turnover rate constant. Q is the size of the glucose pool and D is the injected dose of  $^{14}\text{C}$ -glucose. The glucose utilization rate was obtained by multiplying the glucose pool size by glucose turnover rate.

## RESULTS

### Plasma glucose concentration during growth of goat kids.

The results of plasma glucose concentration in growing goat kids are shown in Figure 1. The glucose levels in the plasma showed progressive change with age. The glucose content of the plasma increased from 5.00 mM to 5.7 mM during the first week of life and peaked to 7.90 mM at day 28 of age. From this age it decreased gradually until it reached 6.9 mM at day 56 of age decreasing further steeply to 5.6 mM at 70 days of age. From day 77 onwards the plasma glucose concentration continued to decrease but at relatively slow rate and reached 4.5 mM at 168 days. Most of the decrease in plasma glucose levels occurred when hay was the main part of their feed ration which started being given to the animals when they were 63 days old.

### Plasma glucose diurnal profile within 24 hours.

The plasma diurnal profile is shown in Figure 2. Feed uptake was associated with a slight rise in plasma glucose levels with peak concentration occurring 1-1.5 h after feeding followed by constant postprandial glucose level.

### Plasma glucose concentration and the corresponding utilization rates during growth of goat kids.

Plasma glucose concentration and the corresponding utilization rates were higher in young kids aged 4 weeks old than in 6 months old goats (Table 1). The glucose utilization rate dropped from 60 to 28 mmol/d  $\text{kg}^{0.75}$  body weight by the time the

Table 1. Glucose utilization rates in growing goat kids.

Goat no	Age Weeks	Bodyweight Kg	Plasma glucose (mM)	Turnover rate Min <sup>-1</sup>	Pool size mmol	Utilization rate mmol/d Kg <sup>0.75</sup>
55	4	11.5	7.12	0.017	15.2	60
56	14	14.9	5.40	0.015	13.2	40
57	24	18.5	4.50	0.012	12.4	28
58	27	26.5	4.10	0.012	10.9	27
59*	27	26.0	3.30	0.009	14.8	20
60**	27	27.5	2.70	0.005	14.2	14

Regression equation relating glucose utilization rate to plasma, glucose concentration,  $Y = -0.528X + 0.0196$   $r = 0.79$ , Feeding: 4 weeks old kid fed milk, 14 - 24 weeks old kid fed milk, concentrate and hay, \* Fasted for 24 hours, \*\* Fasted for 48 hours

goats reached the age of 24 weeks. The glucose utilization rate was positively correlated with plasma glucose concentration ( $r = 0.79$ ).

## DISCUSSION

### Plasma glucose concentration during growth of goats kids

The observed values for glucose concentration in kids during the first few weeks of life (Figure 1) resemble those of monogastrics at similar age and are slightly higher than those of adult monogastrics (Davis and Brown 1962). The plasma glucose concentration at day 1 of age was similar to those of adult monogastrics and increased sharply to reach peak values at day 21 of age. The similarity of glucose levels at day 1 of age to that of adult monogastrics is most likely due to

consumption of colostrum which is rich in glucose and mobilization of large glycogen reserves in the body. Dawes (1968) reported that foeti accumulate large reserves of glycogen in their livers, muscles and the lungs towards the last month of their gestation period. These are the reserves which help tide the neonates over the transitional period after birth, when the animals are left to depend on their own resources until efficient suckling is established. The sharp increase in plasma glucose from day 1 to day 21 of age was due to increased amounts of glucose absorption from the small intestine resulting from absolute ingestion and digestion of milk lactose into glucose and galactose.

The large drop in plasma glucose from day 56 may be attributed to the commencement of feeding hay *ad-libitum*. Bassett (1974a) found similar results in lambs.

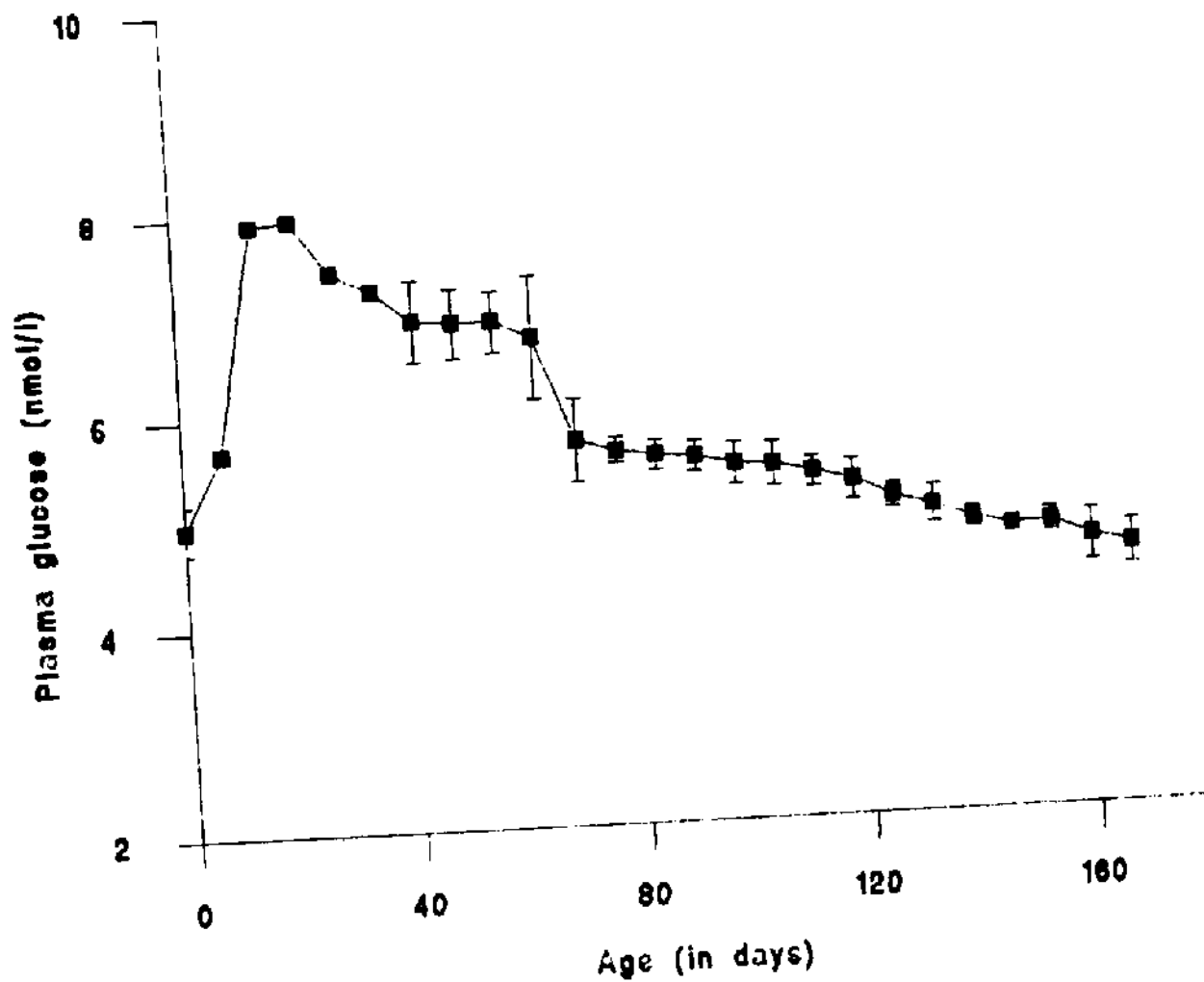


Fig 1: Influence of Age on Plasma Glucose Concentration In Goats (n=14)

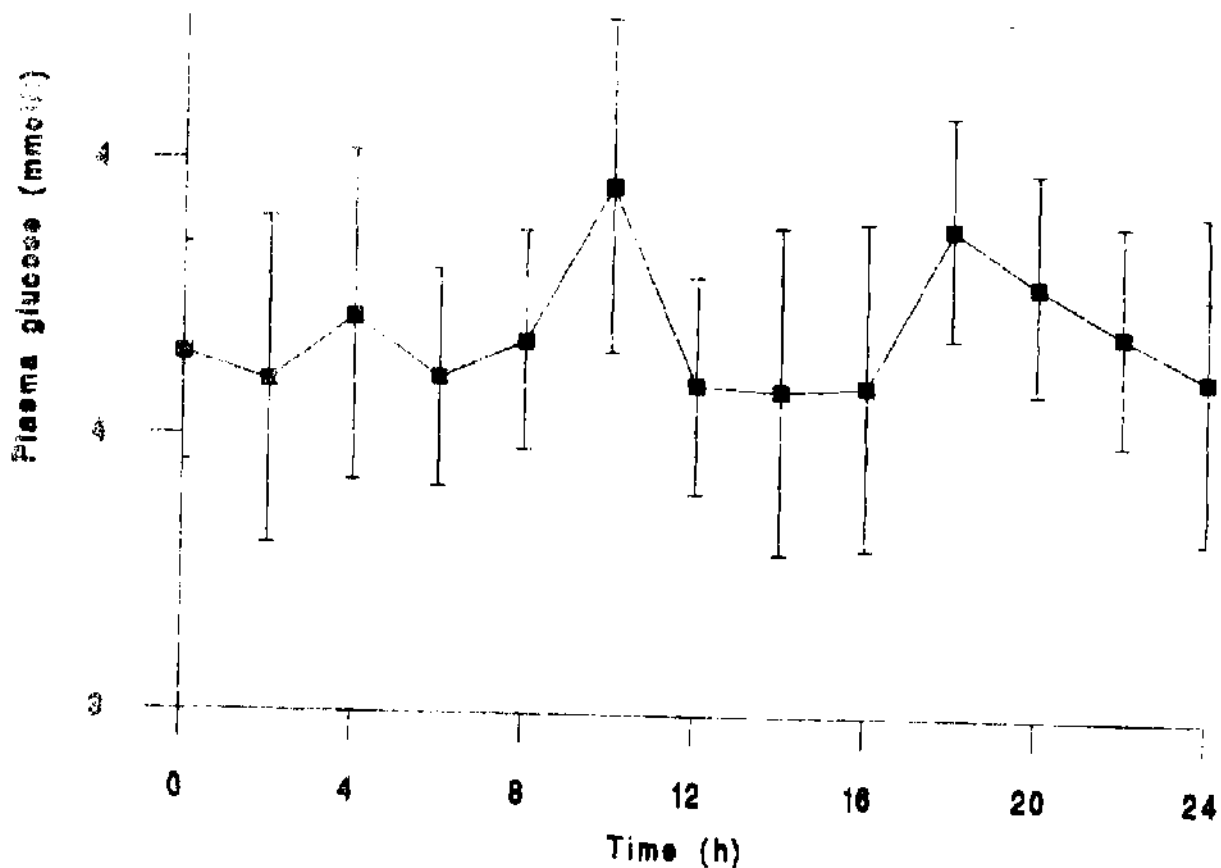


Fig 2: 24-h Plasma glucose profile in goats (n=4)

Hay feeding stimulates the development of the reticulo-rumen (Topps *et al.*, 1968). The development of the reticulo-rumen is associated with shift from digestion and absorption of carbohydrates as glucose to absorption of volatile fatty acids (VFA) which are acetic, propionic and butyric acids. The fermentation of hay in the reticulo-rumen produces small amounts of propionic acid, which is the main glucogenic substrate in ruminants. The drop in glucose concentration in growing kids may therefore be used as an indicator in the evaluation of reticulo-rumen development. This, in turn, may be of use in feed formulation systems in ruminants.

#### Plasma glucose diurnal profile.

The 24 h plasma glucose profile revealed fairly constant levels of plasma glucose throughout the 24 h with only slight increases at 1-1.5 h after feeding. Sier and Trehkle (1973) also found that the plasma glucose concentration in pigs increased rapidly after feeding them a diet with high proportion of starch and the increase was followed by low postprandial plasma glucose concentration. Blom *et al.*, (1976) observed high plasma glucose concentration with high post-feeding variation in bulls fed high proportion of concentrate in the diet. However feeding high proportion of roughage in the diet to the bulls resulted into

relatively low variations. The fairly constant levels of plasma glucose concentration found in the plasma of the kids with slight postprandial changes may be due to high levels of hay in the diet. The high amount of hay in the feed coupled with slow pace of hay fermentation in the reticulo-rumen reduced plasma glucose variations.

#### Glucose utilization rates.

The glucose utilization rates varied from 14-60 mmol/d. kg<sup>0.75</sup>. These values are similar to those reported by other workers (Bergman 1963, Ballard et al; 1969 Riis and Grummer 1969). The values obtained in the current study showed that glucose is of equal importance in young goat kids as it is for adult goats.

The glucose utilization rate decreased proportionally with decrease in plasma glucose concentration. The correlation coefficient between plasma glucose concentration and glucose utilization rate was 0.79 (Table 1). Riis and Herstad (1967) and Riis and Grummer (1969) observed the same pattern in laying hens and pigs respectively. It can therefore be concluded that glucose utilization rate is an indicator of amount of available fuel (energy) supply in the body.

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