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Glucose Tolerance in Lambs As Affected by Type of Ration[1]

By W. H. HALE and R. P. KING

INTRODUCTION

Metabolism of glucose is little understood in the ruminant animal. It has been demonstrated that little or no carbohydrate passes into the intestinal tract of adult ruminants on an all roughage ration (Heald 1951). Soluble carbohydrates of roughages are fermented to volatile fatty acids in the rumen. Available data show that 70% of total cellulose digestion occurs in the rumen and 30% in the cecum and large intestine with little or no cellulose digestion occurring in the small intestine (Hale, et al. 1947 and Gray 1951). The end products of cellulose digestion are the volatile fatty acids and not glucose. It has been estimated that up to 80% of the metabolizable energy of the feed is provided by the volatile fatty acids (McClymont, 1952). On an all roughage ration the source of blood glucose must, therefore, be from propionic acid which is liberally produced by rumen fermentation.

In the United States high levels of carbohydrates are fed to ruminant animals during the fattening period. It would appear that considerable portions of this carbohydrate would escape rumen digestion and pass on into the intestinal tract. Oddly enough, no reliable data are available on the amount of carbohydrate digested in the small intestine of steers receiving a high feed of grain (i.e., fattening steers receiving 20 pounds of cracked shelled corn daily). Reid (1950) indicated that dietary intake in terms of roughage or concentrates has no effect upon blood glucose levels. However, in his studies the level of concentrate feeding is not high when compared to United States feeding regimes.

It may well be necessary for ruminants to adapt for enzymatic processes required for utilization of starch and glucose from the intestinal tract if fed high levels of grain. McCandless and Dye (1950) suggest that dietary regime regulates the tolerance level for injected glucose in the adult ruminant.

Reid (1952) found only slight rises in blood glucose when glucose was injected into the abomasum. He attributed this small rise in blood glucose to poor absorption from the intestinal tract as he has

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shown low utilization by the extrahepatic tissue for injected glucose. This indicates a low hexokinase activity of ovine intestinal mucosa if glucose absorption requires phosphorylation.

Little information is available on the digestion of starch in the small intestine. Larsen et al. (1956) have shown poor digestion of starch in the intestinal tract of 8 month old calves. However, they reported a rise in blood glucose when glucose or maltose was placed in the abomasum. Starch not digested in the small intestine would be subjected to bacterial digestion in the large intestine and in a digestion trial the area of digestion would not be indicated.

The objectives of this report were to determine effect with lambs of dietary carbohydrate level on tolerance of injected glucose and to determine the effect of abomasal injections of starch and glucose upon blood glucose.

Methods and Materials

The experimental lambs used in this study were approximately 9-10 months of age and can be considered mature ruminants in regard to rumen function and digestion. One half of the animals were placed on an all hay ration. Good quality alfalfa hay was fed free choice to this group. The second half of the animals were placed on a full feed of shelled yellow corn plus one-fourth pound of soybean oil meal per lamb daily. Alfalfa hay was limited fed so that each of these lambs received one-half pound of hay per day. The two groups of lambs remained on their respective ration for about two months before injections of the glucose and starch were started. The purpose of this time lag was to permit complete adjustment of rumen microorganisms as well as adaptation of any tissue enzymes required as the result of the difference in products that might be produced in rumen fermentation on the two rations.

Blood samples were taken just prior to injection of the glucose and starch to determine normal glucose values. The animals were not fed the morning feed on the day they were to be injected. All intravenous injections were made in the jugular vein at the rate of ½ gm. of glucose per kilogram of body weight. A 50% glucose solution was injected. Glucose injection into the abomasum was at the rate of one gm. of glucose per kilogram and starch injection into the abomasum at the rate of 1.5 gm. of starch per kilogram of body weight. Commercial grade of food starch was suspended in cold water for the starch injection. Injection into the abomasum was accomplished by setting the lamb up in a shearing position and inserting a syringe needle through the abdominal wall into the abomasum. Negative pressure was placed on the syringe and a flow of contents into the syringe indicated the needle was in the proper location. Blood glucose was determined by the method of Somogyi (1952). Animals

were handled as quietly as possible at all times to prevent excitement which might have effect on blood glucose. Blood samples were oxalated and aliquots were precipitated for the glucose determination within five minutes after the sample was drawn. Data are presented only for those lambs for which the sampling periods extended at least 90 minutes.

Results and Discussion

The effect of intravenous injection of glucose upon blood glucose for the experimental animals is presented in Table 1. In the case of the lambs on the high grain rations, normal blood values were approached by 90 minutes after injection and returned to normal by 150 minutes. Interpolation of the data shows the return to normal to be at approximately 105 minutes. With the lambs on the high hay ration, return to normal was much slower than with the grain fed lambs. Values at 90 minutes for the hay fed lambs were 135% above normal as compared with 24% for the grain fed lambs at the 90 minute period. Interpolation of data for the hay fed lambs shows the return to normal to be approximately 195 minutes or 90 minutes after the grain fed lambs. However, actual values observed show that the hay fed lambs were slightly above normal at 240 minutes. Although the above data are somewhat limited they indicate that rates of metabolism of glucose on the two feeding regimes are different.

Table 1

Blood Glucose Tolerance in Lambs Fed Different Rations

Lamb #	Blood Glucose Mgs. %, Minutes After Glucose Injection 0	15	30	90	150	240
			High Grain Ration			
105	51.6	164.6	116.2	53.6	44.0	
553	49.7	156.8	124.2	70.0	47.8	
247	44.0	148.5	112.2	57.2	44.4	
67	38.5	189.5	148.5	50.1	51.6	
65	53.6	146.4	127.0	64.5	49.0	
Av.	47.5	161.2	125.6	59.1	47.4	
			High Hay Ration			
839	48.5		207.7	108.0		
83	36.7	122.9	131.3	77.6		53.6
91	35.0	193.8	151.3	111.6		49.7
143	43.8	135.9	113.1	92.8		51.6
140	44.0	175.3	148.5	66.2		48.0
142	50.4	286.3	231.4	150.4	98.5	
Av.	43.1	182.8	163.9	101.1	98.5	50.7

The effects of glucose or starch injection into the abomasum of the lambs are presented in Table 2. Injection of glucose at the rate of 1 gram per kilogram of body weight resulted in only a 22.9 mg. % rise in blood glucose at 60 minutes after injection. This is com-

parable with a 50-75 mg. % for man ingesting the same dosage level of glucose. No rapid rise or rapid decline was noted throughout the 240 minutes at which the animals were sampled. In the case of all animals studied a rise in blood glucose occurred but the rate of rise or decline could not be associated with dietary treatment. A larger number of animals in this phase of the experiment would have permitted a better evaluation in regard to ration effect.

Table 2

Effect on Blood Glucose of Glucose or Starch Injections Into Abomasum of Lambs

Lamb #	Ration Treatment	Blood Glucose Mg. %, Minutes after Injection 0	15	30	60	90	165	195	240
				Glucose Injection					
141	G(a)	40.3		103.2	99.5	83.1		42.1	
145	H	59.8	72.9		75.8		59.8		
977	G	51.6	64.0		51.6		38.5		
977	G	42.6		49.7	55.6		53.8	68.4	
839	H	39.8	50.4	53.6		60.0	53.6		50.0
499	G	38.1		53.6	59.2	50.6			
Av.		45.4	62.4	65.0	68.3	64.6	52.9	55.8	50.0
				Starch Injection					
145	H	43.5			53.6	49.2			43.5
977	G	47.9			51.6	66.2			50.2
Av.		45.7			52.6	57.7			46.8

(a) G = Grain ration, H = Hay ration

The data obtained in this study agree in general with the interpretation of McCandless and Dye (1950) that type of nutrient available for absorption in the intestinal tract affects the glucose tolerance of ruminants. The above workers found the renal threshold of glucose for sheep to be about 170 mgs. %. (McCandless et al. 1948.) Decreases in blood glucose values below this would represent tissue metabolism of glucose or glycogen deposition and would give a true picture in regard to tissue utilization of this metabolite. It appears odd that animals with a normal blood glucose level of 40 mgs. % should have a renal threshold for glucose of 170 mgs. %. The data from this trial suggest that the lambs receiving the high grain ration could metabolize the injected glucose much more rapidly than the lambs on the hay ration.

Garner and Roberts (1955) have shown that rats fed a high fat diet for long periods exhibit a reduced tolerance to intravenously injected glucose. Normal blood glucose levels were maintained for the high fat fed rats but were reduced upon fasting. However, with ruminants little or no effect on blood glucose is observed due to fasting. There was some indication that hexokinase activity of kidney homogenates from high fed rats was depressed. Long (1953) reported hexokinase activity of intestinal mucosa was reduced by high fat

diets in rats. No effect was observed upon the hexokinase activity of intestinal muscle by high fat feeding.

Glucose or starch injections into the abomasum exerted no marked effect upon blood glucose. In general the abomasal injection of glucose resulted in a moderate rise in blood glucose which persisted for several hours. This is in agreement with Reid (1952) who suggested that rate of glucose absorption from the intestinal tract of sheep is probably about 25% of the rate in man. The disappearance of intravenously injected glucose appeared to be related to dietary history and this relationship did not appear to be true when glucose was injected into the abomasum.

Injection of starch into the abomasum had only a slight effect upon blood glucose. This suggests that the starch is poorly hydrolyzed and is in agreement with findings of Larsen et al. (1956).

It is well known that a considerable period of time is required to place steers on a full feed of grain from a roughage ration. This is thought to be due to necessary alterations in rumen microorganisms from a roughage type to a grain type. Another factor to be considered is possible changes in amylolytic secretions of the intestinal mucosa to hydrolyze the additional starch entering the small intestine. However, it may be that amylolytic secretions are constant regardless of ration and that the major portion of starch must be digested by the rumen microorganisms. Conflicting reports appear in the literature in regard to the ability of the ruminant to utilize glucose and starch posterior to the rumen. Details of such factors as age, dietary history and nutritional status of the animal have often been omitted. Discrepancies also exist between the bovine and ovine species. When these factors have been clarified a common denominator will probably appear describing the utilization of these nutrients by the ruminant.

It becomes apparent that glucose and starch digestion and metabolism is complex in the ruminant and may be modified by many factors such as age and dietary history. The hormonal and enzymatic effects on glucose and starch utilization in the ruminant need elucidation to determine if the differences observed between the ruminant and non-ruminant are due to the peculiar digestive processes of the ruminant.

Summary

This study was conducted to determine the glucose tolerance in lambs with functioning rumens as affected by type of ration. One group received a full feed of corn plus a limited amount of hay whereas the second group was fed only hay. The lambs were injected via the jugular vein with a 50% glucose solution at the rate of one-half gram of glucose per kilogram of body weight. Blood glucose

levels in the grain fed animals returned to normal by 150 minutes and were normal for the hay fed animals by 240 minutes. This indicated that the hay fed animals could not metabolize injected glucose as well as high grain fed animals. In a second portion of the study lambs were injected with glucose or starch into the abomasum and the effect of this injection on blood glucose observed. Only small blood glucose rises were observed following the injection of the glucose or starch. This indicates the mechanism for absorption of glucose and hydrolysis of starch in the intestinal tract of ruminants is poor when compared with the monogastric animals. The implications of these results in terms of current knowledge of carbohydrate utilization by the ruminant are discussed.

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