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Glucose absorption in the intestine of albino rats

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Abstract

Background: The ability to absorb substances from the external environment is one of the features that make animals different from inanimate objects. In mammalian species, this quality is mainly the role of the small intestine. The process of absorption mainly takes place in the small intestine. This study was carried out to investigate the rate of glucose absorption in the intestine of albino rats and the effect of calcium and ouabain on the rate of glucose absorption.

Methods: Albino rats weighing between 200 and 250 g were used for this experiment. Guts were isolated and cut to segments. Test solution was injected into each of the isolated segments, which were then assayed for glucose.

Results: The result revealed that the rate of glucose absorption in the intestine of albino rats were found to be 3.02×10^{-1} g/min at the mucosa-to-serosa surface and 3.00×10^{-1} g/min at the serosa-to-mucosa surface, indicating that glucose was absorbed at both surfaces and that the rate of glucose absorption was higher in the mucosa-to-serosa direction than in the opposite direction. The rate of intestinal glucose absorption at different regions of the intestine and the effect of varying concentrations of calcium on the rate of glucose absorption revealed that glucose absorption was highest at the duodenum and lowest at the ileum.

Conclusions: Ouabain blocked the rate of absorption of glucose in the intestine of albino rats.

Keywords: albino rat; calcium; glucose absorption; gut; Krebs Ringer bicarbonate (KRB) solution; ouabain.

Introduction

The ability to absorb substances from the external environment is one of the characteristics that make animals different from inanimate objects. In mammalian species, this quality is mainly the role of the small intestine. The small intestine is a coiled tube that links the stomach to the large intestine [1, 2]. It is the longest component of the digestive tract and the major site of digestion and absorption of nutrients, water, and electrolytes. It is divided into three unequal parts, namely the duodenum, jejunum, and ileum [3, 4]. The intestine is lined with epithelium, the surface of which is considerably enlarged by minute prolongations of membranes, 0.5–1.5 mm in length, called villi. The villi, which increase the surface area for better absorption, are numerous in the upper segment of the intestine (duodenum and jejunum) [2, 5, 6].

The process of absorption mainly takes place in the small intestine [7–9]. To a limited extent, absorption of some food items, such as pepper, alcoholic drinks, and other lipophilic molecules of moderate size, also takes place in the stomach [4]. The epithelial lining of the small intestine is well adapted for this purpose owing to the numerous small papilliform villi, which increase its surface area [2].

Earlier experiments on the absorption of glucose were carried out using hamsters (which is a hardy animal), guinea pig, turtles, and rats. Absorption has been studied by in vivo transfer from intestine to blood, by in vitro transfer into inverted intestinal sac, and by uptake into the epithelial cells from the mucosa [10–13]. This study investigated the rate of glucose absorption in the different regions of the intestine in vivo, the effect of varying calcium concentrations on the rate of glucose absorption, and the use of an inhibitor to reveal the energy source of glucose absorption by intestinal segments in vitro.

Materials and methods

Experimental animals

Albino rats weighing between 200 and 250 g were used for this experiment. They were obtained from the animal house of the Biochemistry Department, University of Ilorin, Ilorin, Nigeria.

*Corresponding author: Dr. Olalubi A. Oluwasogo, School of Allied Health and Environmental Sciences, Public Health Unit, College of Pure and Applied Sciences, Kwara State University, Malete, Nigeria, Phone: +2347036039078, E-mail: oluwasogo.olalubi@kwasu.edu.ng, <http://orcid.org/0000-0002-0322-577X>

Owoyele B. Victor and Ayinla M. Tayo: Department of Physiology, Faculty of Basic Medical Sciences, University of Ilorin, Ilorin, Nigeria

Akintunde J. Kehinde: Environmental Toxicology Unit, Department of Environmental Health Sciences, Faculty of Public Health, College of Medicine, University of Ibadan, Ibadan, Nigeria

The animals were kept and acclimatized for 2 weeks in the animal house of the Zoology Department, University of Ilorin. They were fed a diet of rat pellets (Premier Feed Mills, Ibadan, Nigeria) and given water ad libitum. The animals were maintained under standard laboratory conditions and were subjected to a natural photoperiod of about 12 h of light/dark cycle.

Isolation of the intestine

The animals were sacrificed by severing the spinal cord with bone shears to induce shock on the animal; this was preferred to anaesthetizing because the minimum dosage needed to keep the tissue alive could not be guaranteed and safely administered without killing the tissues. The animals were dissected, and the viscera were exposed. The visceral fold was pinned down on the dissecting tray to expose the abdominal content. Freshly prepared Krebs Ringer bicarbonate (KRB) solution was sprinkled intermittently to moisten and keep the tissue intact and alive.

A sharp gradient exists along the intestine, and to avoid the transitional regions, the intestine was cut about 2 cm below the pyloroduodenal junction and 2 cm above the ileocecal junction. Two 7-cm specimens were obtained from each section (duodenum, jejunum, and ileum) of the intestine from each dissected albino rat. The three sections were separated and placed in individual Petri dish and labeled for identification. The KRB solution (sugar free solution) was used to flush and clean the intestine of fecal remnants. Sacs were prepared using the method of Crane and Wilson [10], and each of the three sections was turned outward so that the epithelial mucosa is outside (for use as the serosa-to-mucosa surface).

Both ends of the isolated segments were tied, with one loosely placed and the other tightly placed. The test solution (glucose, 1 mL) was injected into each of the isolated segments (duodenum, jejunum, and ileum). After injection of the test solution (glucose), the loosely placed ligature was tightened, and this was done carefully to prevent leakage of the test solution after tying the second ligature. The isolated segments with the test solution in situ were suspended in KRB solution at room temperature for a period of 30 min to preserve the tissue. An aliquot was then taken for glucose assay using the anthrone method.

Ouabain was used as inhibitor in this study and was tested in two media: glucose in vitro and KRB in vivo. A 0.01 g ouabain was dissolved in 100 mL distilled water, from which 0.1 mL was pipetted out and dissolved in 100 mL glucose and 100 mL KRB solution, respectively. One milliliter of the respective solutions was injected into different sections of the lumen at both surfaces, i.e. from the mucosa to the serosa and vice versa. Each of the surfaces was then placed into the inhibitor-free KRB solution for 30 min. Then, glucose was assayed using the anthrone method, wherein 1 mL of inhibitor-free glucose was injected into the lumen at both surfaces as above. Each of the surfaces was later placed in KRB with inhibitor in vivo for 30 min. The glucose assay was again done using the anthrone method.

Each experiment has its own control part, and the amount of glucose absorbed by the part exposed to the inhibitor was compared with the amount of glucose absorbed by the control parts taken from the same animal.

Ethical considerations

This study has institutional ethical board approval.

Glucose assay

The isolated gut was suspended in KRB solution for 30 min and later removed. An aliquot solution was decanted into test tubes. Two milliliters of anthrone solution was added, and the solution was shaken vigorously and then placed in iced water for 10 min. Serial dilutions of glucose were prepared from a standard glucose solution containing 0.02 g of glucose stock in 500 mL of KRB solution. The rate of glucose absorption was obtained by finding the gradient of the graph of absorbance against glucose concentration. Its optical density was measured at 620 nm against the blank.

Results

Rate of glucose absorption at different surfaces of different parts of the intestine

Table 1 shows the rate of absorption of glucose at both the mucosa-serosa and the serosa-mucosa surfaces. The rate of glucose absorption at the mucosa-serosa surface was 3.02×10^{-1} per minute, whereas at the serosa-mucosa surface, the rate of glucose absorption was reduced to 3.00×10^{-1} per minute.

Effect of varying concentrations of calcium on glucose absorption

Figures 1 and 2 show the effect of different concentrations of calcium on glucose absorption. At the mucosa-serosa interface, the rate decreases from the duodenum to the ileum: duodenum, 8.5×10^{-2} ; jejunum, 6.2×10^{-2} ; ileum, 5.5×10^{-2} .

At the serosa-mucosa interface, the general rate of glucose absorption reduces from the duodenum to ileum: duodenum, 3.6×10^{-2} ; jejunum, 3.3×10^{-2} ; ileum, 1.1×10^{-2} .

Table 1: Glucose absorption at different surfaces of albino rats intestine.

Region	Optical density at 620 nm	Glucose concentration, mg/L	Rate of absorption, g/min
Mucosa-serosa surface			
Duodenum	7.5×10^{-2}	24.8×10^{-2}	3.02×10^{-1}
Jejunum	6.8×10^{-2}	22.5×10^{-2}	
Ileum	5.4×10^{-2}	17.8×10^{-2}	
Serosa-mucosa surface			
Duodenum	6.0×10^{-2}	19.8×10^{-2}	3.00×10^{-1}
Jejunum	5.0×10^{-2}	16.4×10^{-2}	
Ileum	4.0×10^{-2}	13.2×10^{-2}	

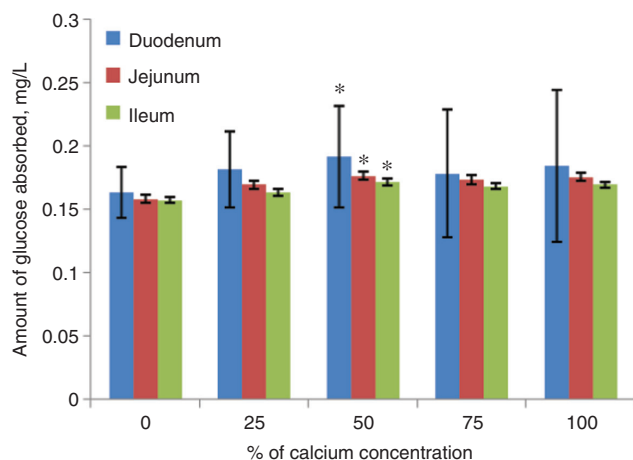


Figure 1: Effect of varying Ca^{2+} concentration on rate of glucose absorption at the mucosa-serosa interface.

* $p < 0.05$, significantly different among the groups.

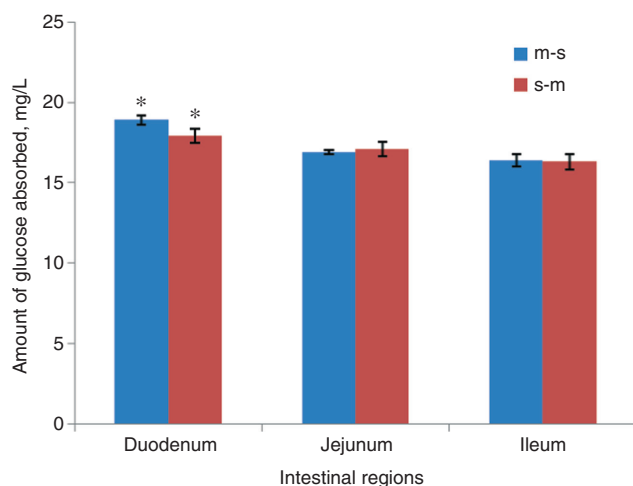


Figure 2: Effect of varying Ca^{2+} concentrations on the rate of glucose absorption at the serosa-mucosa interface.

* $p < 0.05$, significantly different among the groups.

The glucose absorbed at 50% concentration of calcium at the mucosa-serosa surface was 18.9×10^{-2} , compared with 8.5×10^{-2} obtained when the calcium concentration was 100%. This shows an approximately 46% reduction in the rate of glucose absorption.

The rate in the jejunum was 18×10^{-2} at 50% calcium concentration compared with 6.2×10^{-2} , which shows a reduction of approximately 33% in the rate of absorption. In the ileum, a rate of 17×10^{-2} was recorded, compared with 5.5×10^{-2} , with a 32% reduction in the rate of glucose absorption.

At the serosa-mucosa surface, the rate in the duodenum was 19.0×10^{-2} , compared with 3.6×10^{-2} per minute

with 84% reduction in the rate of absorption, whereas the rate was 17.9×10^{-2} , compared with 3.3×10^{-2} , in the jejunum, and 17.0×10^{-2} , compared with 1.1×10^{-2} , in the ileum, with 83% and 83.1% reduction in rate of glucose absorption, respectively.

Furthermore, ouabain, the metabolic inhibitor used in this study, caused a significant reduction in the rate of glucose absorption in this order: duodenum > jejunum > ileum. In addition, the rate of glucose absorption decreases from the region with the longest distance from the ileocecal valve to the region with the shortest distance from the ileocecal valve. The duodenum, which is the farthest, has the highest absorbance value, whereas the posterior ileum has the lowest absorbance value.

Discussion

The ability of the small intestine to transport sugar from low concentration in the mucosa to higher concentration in the serosa has been recognized for many years [10, 11, 14]. This absorptive mechanism exhibits a high degree of substrate selectivity, including stereospecificity, saturation kinetics, and competitive inhibition by low concentration of the glycoside phlorizin [15]. These characteristics suggest that sugar transport was mediated by distinct membrane components possessing enzyme-like properties located on or near the microvillus border of the epithelial cells. The combination of sugar with this carrier molecule is presumed to be a prerequisite for passage through the brush border into the absorptive cell [16].

The ability of intestinal cells to accumulate these salts, in order to achieve an intracellular concentration that exceeds the concentration in the luminal solution, and the dependence of the transport processes on the availability of metabolic energy have naturally prompted the idea that carrier mechanisms for sugar are directly linked to the flow of metabolic reactions [14].

The mucosa cell is primarily responsible for the intestinal function of absorption. This function is facilitated by the presence of an enormous number of small papilliform villi whose contraction constantly exposes the entire surface of the small intestine to the liquid material for maximum absorption [4].

Figure 2 shows that the absorption capacity was not equally or uniformly distributed along the small intestine because maximum absorption was obtained at the duodenal region and followed by the jejunum, with the least absorption at the ileal region at the mucosa-serosa interface.

This result is in agreement with the work of Fisher and Parsons [17], who also observed this trend in other experimental animals such as rabbits and guinea pigs. The rate of glucose absorption increases sharply with distance from the ileocecal valve, as observed in this study, with the duodenum having the highest rate of glucose absorption (8.5×10^{-2}) and the least in the ileum (5.5×10^{-2}) (Figure 2) when subjected to the same condition and within the same interface, i.e. mucosa-serosa. However, a lower absorption rate was observed in the serosa-mucosa interface when subjected to the same condition as in the mucosa-serosa interface. However, the rate of glucose absorption also increases sharply with distance from the ileocecal valve (Table 1); the increase in the rate of absorption of glucose in this order, duodenum>jejunum>ileum, could be due to the fact that the area of the luminal border in the duodenal region is greater than in the ileal region of the small intestine [5, 18], hence its increased surface area and absorptive capacity.

Table 2 shows the effect of inhibitor (ouabain octahydrate) on the amount of intestinal glucose absorbed at 50% Ca^{2+} concentration at different regions. The result revealed that ouabain caused a sharp decline in absorption of glucose from the duodenal to the ileal regions at both interfaces (as shown in Figure 3). From this result, it could be deduced that ouabain inhibits the rate of glucose absorption but not completely. The effect is minimal at the mucosa-serosa interface, but when added at the serosa-mucosa interface, it reduces the absorption of sugar.

Ouabain inhibits the active transport of sodium in many tissues, with some cooperative interaction. Sodium enters the cell with glucose release from the carrier and is then actively pumped out mainly on the serosa side by a transport system that is sensitive to ouabain. The result obtained here is in agreement with those of other researchers [14, 19, 20] who associated the transport of glucose with sodium, and this further revealed that the basic transport mechanism is the same in vertebrates.

Table 2: Effect of inhibitor on glucose absorption at different surfaces of the small intestine.

	Glucose with inhibitor	KRB with inhibitor
Mucosa-serosa		
Duodenum	0.068	0.076
Jejunum	0.059	0.060
Ileum	0.040	0.054
Serosa-mucosa		
Duodenum	0.047	0.036
Jejunum	0.031	0.030
Ileum	0.025	0.018

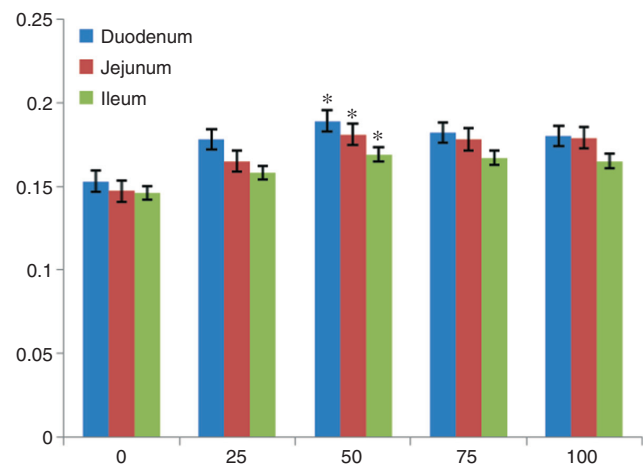


Figure 3: Effect of inhibitor on the rate of glucose absorption at 50% Ca^{2+} concentration (inhibitor+KRB).

* $p < 0.05$, significantly different among the groups.

In conclusion, the mucosa-serosa interface has the highest absorption rate (as shown in Figure 4). This is because of the higher concentration of villi at the mucosa surface, which favors greater glucose absorption through the active transport at the mucosa-serosa interface.

Reversing the tissue, i.e. at the serosa-mucosa interface, the injected glucose solution only gets in contact with the serosa wall (as shown in Figure 4), where there is negligible or absent villi. Thus, glucose is only passively absorbed by diffusion, hence the lower absorption rate. This is in line with a previous report that active and passive processes were involved in the transport of glucose across the intestinal lumen [21]. In addition, the higher pressure at the serosa wall could also force materials outward to

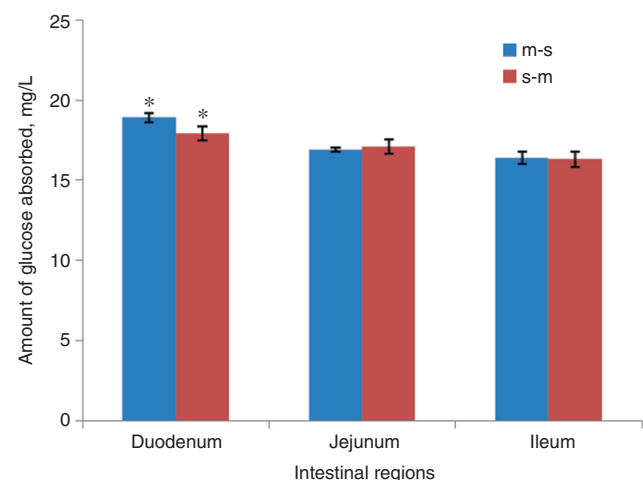


Figure 4: Effect of inhibitor on the rate of glucose absorption at 50% Ca^{2+} concentration (glucose+inhibitor).

* $p < 0.05$, significantly different among the groups.

the mucosa, going either to the blood capillaries or to the lymphatics, which also favor diffusion.

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