POLISH JOURNAL OF FOOD AND NUTRITION SCIENCES
Pol. J. Food Nutr. Sci. 2003, Vol. 12/53, SI 1, pp. 32–34

INTESTINAL ABSORPTION OF XYLITOL AND EFFECT OF ITS CONCENTRATION ON GLUCOSE AND WATER ABSORPTION IN THE SMALL INTESTINE OF RAT

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Key words: polyols, xylitol, intestinal absorption, perfusion, rat

In an experiment on rats, xylitol absorption and its influence on water and glucose absorption was determined using perfusion technique of the small intestine. Perfusion fluid contained 2.5, 5, 10 and 20 g of xylitol and 2 g of glucose per liter. Quantitatively, xylitol absorption increased with the increase of this substance in the perfusion liquid. However, relative absorption was the same in all groups and accounted for 19-20% of xylitol incorporated to the beginning of the small intestine. An introduction of a substance possessing osmotic properties to the perfusion fluid caused a decrease in water and glucose absorption. The addition of xylitol to liquid resulted in a significant lowering of glucose absorption from 80.8 g/h/rat in control group to 60.8 g/h/rat in group with the greatest amount of xylitol. A dose-dependent decrease in water absorption was reported to range from 12 mL/h/rat in control group to 0.17 mL/h/rat in group containing the highest amount of xylitol in the perfusion liquid.

INTRODUCTION

Understanding the gastrointestinal tract response to foods and meal is critical to understanding the metabolic effect of functional foods [Schneeman, 2002]. This opinion concerns also sugar alcohols (polyols), which are widely used as non-cariogenic sweeteners and sugar substitute [Zumbe *et al*., 2001]. In 2000/2001, the sale of all polyols amounted to 1.4 milion tones. Sorbitol had the largest share on the market (48%), followed by xylitol (12%), mannitol (11%) and maltitol (10%) [Anonymous, 2002].

It is supposed that sugar-free products containing polyols are completly safe under condition of intended use, although there may be the cause of transient discomfort when consumed in excessive amounts [Livesey, 2001]. It is commonly known that sugar alcohols are fermented in the colon, which results in the formation of relatively large amount of gases [Würsch *et al*., 1990; Piva *et al*., 1996]. Mineo *et al*. [2002] and Goda *et al*. [1998] reported that sugar alcohols enhance calcium transport from rat small and large intestine epithelium *in vitro*. The degree of absorption of polyols varies depending on their flow rate in the small intestine; for example, that of sorbitol may vary from 2% up to 80% [Beaugerie *et al*., 1990]. There is relatively little information published regarding the influence of polyols on intestinal absorption of other nutrients. Better understanding of this process is very important because daily intake of sugar alcohols (for example in chewing gum and candies) can be relatively high. Studies of Ishiwata *et al*. [2002] indicate that the daily intake of most food additives differed with age of consumers. The daily intake of xylitol was approximately ten times higher in small children and children than in the aged. It is known that young children are at greatest risk of diarrhoea from polyols consumption [Livesey, 2001].

In this context, determination of the intestinal absorption of xylitol in the small intestine of rats and the effect of different concentration of xylitol on the absorption of glucose and water was the aim of this work.

MATERIAL AND METHODS

In situ technique in an open system based on controlled flow of perfusion fluid through the small intestine of anaesthetised rats [Fisher & Gardner, 1974] was used to determine the gut absorption. Each experimental group consisted of 16 male rats weighing over 200 g. Animals were anaesthetised (subcutaneous administration of 20% urethane, 1.2 mL per 100 g body weight) and placed on a heated operating table. Following tracheotomy and laparotomy, two drains were inserted into the small intestine: inlet – right below the duodenum and outlet – above the blind gut. Perfusion fluids were administered, at a temperature of 37°C, into this limited section of the small intestine, following washing with physiological saline solution (0.9% NaCl). Regular administration (1 mL/min), close to a physiological rate, was ensured by a peristaltic pump PA-SK 8 (IKA-labortechnik, Janke Kunkel). Control rats (group C) were given Krebs-Henseleit fluid (NaCl – 6.9, KCl – 0.35, $CaCl_2$ – 0.28, KH_2PO_4 – 0.16, $MgSO_4$ – 0.2, $NaHCO_3$ – 2.09, Na-Pyruvat – 0.22 g/L) with the addition of glucose (2 g/L). Experimental liquids were based on the control fluid supplemented with xylitol: 2.5 (group C+2.5), 5 (group C+5.0), 10 (group C+10.0) and 20 g/L (group C+20.0).

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Perfusion lasted 1 h and was preceded by a 20-min introductory period. The differences in the composition of perfusion fluid prior to and after passing through about 70 cm of the small intestine allowed us to determine the amounts of absorbed components: glucose, xylitol and water.

All procedures were accepted by the Local Council for Animal Experiments.

The glucose content was measured enzymatically using a diagnostic Cormay GS-120 set. The content of xylitol in perfusion liquid was determined by HPLC using a Shimadzu system, which consisted of the following components: a LC-10AD pump, a SCTL system controller, a RID-10A refraction index detector, and CLASS VP software. Conditions of separation entailed a NH_2 LUNA column (5 μm, 4.6 250 mm, Phenomenex), mobile phase acetonitrile: water (72:28; v/v), a flow rate of 1.5 mL/min, an injection volume of 20 μL.

The results were worked out statistically using one-way analysis of variance and the Duncan's multiple range test at the significance level of $p<0.01$ and $p<0.05$.

RESULTS

Table 1 presents the results of xylitol absorption. Its absorption increased together with a higher concentration of this substance in the perfusion fluid (from 25.3 mg/h/rat in group C+2.5 to 203.5 mg/h/rat in group C+20.0). However, relative xylitol absorption in the small intestine of rats was alike. It was about 19–20% of xylitol introduced to the beginning of the small intestine.

TABLE 1. Xylitol absorption[1].

Group	Amount of given xylitol [mg/h/rat]	Amount of excreted xylitol [mg/h/rat]	Xylitol absorbed [mg/h/rat]	Xylitol absorbed [% of given]
C+2.5	138.79±4.4	113.45±8.4^{D}	25.30±7.1^{D}	18.33±5.3
C+5.0	276.00±8.4	218.40±18.7^{C}	57.50±18.8^{C}	20.83±6.7
C+10.0	552.50±13.2	443.30±36.9^{B}	109.20±30.7^{B}	19.81±5.8
C+20.0	1094.23±7.2	889.90±80.5^{A}	203.50±63.6^{A}	18.65±6.0

[1] – values are means ±SD, n=16, values in the same column with different superscripts are significantly different at $p<0.01$

The results of perfusion of the small intestine with the fluid containing xylitol are presented in Tables 2 and 3. The addition of xylitol reduced glucose and water absorption in comparison to the control group without this substance. In the case of water it was a dose-dependent decrease. Xylitol significantly reduced water absorption from 12 mL/h/rat in control group to 0.17 mL/h/rat in a group with the highest content of this substance. Respectively, water absorption was reduced from 22% in the control group to 0.3% in the group containing 2% of xylitol in the perfusion liquid. In the latter one, also highly significant reduction of glucose absorption (to 60.8 mg/h/rat from 80.8 mg/h/rat in control one) was observed. In groups containing 0.25, 0.5 and 1.0% of xylitol also significant decrease of glucose absorption was noted. However, in these groups glucose absorption was at the same level (about 73 mg/h/rat). In the control group, a relative glucose absorption was about 75% of one given to the small intestine, whereas in group containing 20 g of xylitol in 1 L of perfusion liquid it was only 50%. On the other hand, an increase in blood glucose concentration was observed in all experimental groups from 281.8 mg/dL in control group to 342.2 mg/dL in group containing 1% of xylitol in the perfusion liquid (Table 2).

TABLE 2. Water absorption[1].

Group	Amount of given H_2O [mL/h/rat]	Amount of excreted H_2O [mL/h/rat]	H_2O absorbed [mL/h/rat]	H_2O absorbed [% of given]
C	54.3±1.2	42.32±1.8^{Cab}	12.00±1.6^{Aa}	22.1±2.6^{Aa}
C+2.5	55.4±2.2	45.50±2.9^{Bb}	9.94±3.1^{Ab}	17.9±3.7^{Ab}
C+5.0	54.8±1.8	48.00±4.0^{Ba}	6.74±2.9^{Bab}	12.3±5.4^{Bab}
C+10.0	55.3±1.3	52.30±2.6^{Aab}	3.02±3.1^{Cab}	5.4±4.8^{Cab}
C+20.0	54.2±2.5	54.04±3.0^{Aab}	0.17±2.2^{Dab}	0.3±2.6^{Dab}

[1] – values are means ±SD, n=16, values in the same column with different small and capital letters are significantly different at: $p<0.05$ and $p<0.01$, respectively.

TABLE 3. Glucose absorption[1].

Group	Amount of given glucose [mg/h/rat]	Amount of excreted glucose [mg/h/rat]	Glucose absorbed [mg/h/rat]	Glucose absorbed [% of given]
C	110.0±3.2	29.2±6.9^{Cb}	80.8±7.0^{Aa}	73.45±7.4^{Aa}
C+2.5	109.1±3.7	35.7±9.0^{Bca}	72.9±10.0^{Ab}	66.81±5.9^{A}
C+5.0	111.4±3.8	38.4±9.9^{Bab}	72.9±9.8^{Ab}	65.41±6.1^{Ab}
C+10.0	113.3±2.5	39.6±7.7^{Bab}	73.8±8.0^{Ab}	65.14±6.0^{Ab}
C+20.0	112.0±4.0	51.2±8.5^{Aab}	60.8±7.7^{B}	54.19±5.6^{B}

[1] – values are means ±SD, n=16, values in the same column with different small and capital letters are significantly different at: $p<0.05$ and $p<0.01$, respectively.

DISCUSSION

Polyols are widely used sugar replacers. They seem to be safe for human health possessing even some profitable properties (low glycemic response, reduction of dental caries risk). Although, it is suggested not to excess their consumption [Davis, 1995; Lina *et al*., 1996; Zumbe *et al*., 2001].

The presented results of xylitol absorption (about 19–20%) are similar to these obtained by Langkilde *et al*. [1994] who observed poor absorption of polyols in their experiment. Also Livesey *et al*. [1993] reported low absorption of polyols in the small intestine. Even after glucose addition to the perfusion fluid, Beaugerie *et al*. [1997] did not record any increase in sorbitol absorption in the human small intestine. High absorption of sorbitol and maltitol observed by Beaugerie *et al*. [1990] was caused only by determination of polyols absorption in the whole intestine, which confirms that polyols are metabolised mainly in the large bowel.

Polyols are thought to be hardly digestible and absorbable in the upper alimentary tract [Langkilde *et al*., 1994; Livesey *et al*., 1993]. However, still little is known about the influence of polyols on the absorption and utilization of other nutrients. Well documented is only their effect on mineral absorption, especially Ca and Mg [Goda *et al*., 1998; Coudray *et al*., 2003; Mineo *et al*., 2002]. Polyols possess osmotic properties [Zumbe & Brinkworth, 1992; Lee *et al*., 1994]. Therefore Langkilde *et al*. [1994] suggested

that polyols, because of their osmotic properties, can modify absorption of other nutrients. It was confirmed in our experiment where a strong dose-dependent reduction in water absorption was observed after the addition of xylitol to the perfusion liquid. Only 0.3% of given water was absorbed in a group containing the highest level of xylitol in the perfusion fluid. It was 66-fold lower than in the control one. A significant decrease in glucose absorption was also determined (from 75% to 50% of given substance).

CONCLUSIONS

The results obtained suggest that polyols act rather in the lumen and the wall of small intestine than in the whole body. They can reduce absorption of some nutrients, especially water, which may result in an increase in laxative symptoms.

ACKNOWLEDGEMENTS

This work was in a part financially supported by EU *Centre of Excellence* project CA 7-CT-2000-70017.

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