The effect of chain length on glucose absorption and the related metabolic response[1]

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ABSTRACT The relative absorption of saccharides of different chain length has been reexamined. Whether glucose is administered as a monosaccharide, a disaccharide (maltose), an intermediate polysaccharide mixture with a mean chain length of five glucose units (Caloreen), or a polysaccharide (starch), the rate of rise and fall in blood glucose concentration is similar in healthy subjects. In a maturity onset diabetic, peak blood glucose is similar whether monosaccharide or Caloreen is ingested. Plasma insulin and plasma free fatty acid responses to glucose saccharide ingestion do not appear to be affected by chain length. The dietary form in which starch is administered, rather than chain length, is probably important. *Am. J. Clin. Nutr.* 31: 1998–2001, 1978

It is now known that hydrolysis of the disaccharide maltose, an oligosaccharide product of digestion, and sucrose proceeds rapidly at the small intestinal brush border and is not rate limiting (1). Nevertheless, a view that arose about 1920 (2) that the monosaccharide, glucose, is absorbed more quickly than starch, a glucose polysaccharide, persists in the literature (3, 4). There is already some evidence that, if this is so, it is not dependent on chain length (5–11). We have sought to clarify the role of saccharide chain length in glucose absorption by examining subjects following the ingestion of mono-, di-, "penta-", and polysaccharides consisting exclusively of glucose.

Materials and methods

Six healthy male volunteers ages 18 to 21 years and one male maturity onset diabetic age 68 were studied. Healthy subjects were divided into two groups. Group I was studied after the ingestion of glucose, Caloreen or starch (cornflour with a composition of 0.25 g protein for every 50 g carbohydrate). Caloreen is a commercially available glucose saccharide mixture that contains 3% glucose, 7% maltose, 5% maltotriose, and 85% polysaccharides of four to 15 (mean five) glucose units (12); it is referred to in this work as a "pentasaccharide". Group II was studied after the ingestion of glucose or maltose (Ajax Chemicals), a glucose disaccharide.

Three days before the first study and between each study, each subject was maintained on a 300-g carbohydrate-enriched diet in order to maximize and standardize glucose tolerance (13, 14). Studies were separated from each other by 3 to 7 days. The order of studies was randomized. The amount of carbohydrate administered was 50 g in each case. All carbohydrates were flavored with 2.5 ml vanilla essence because this made the cornflour starch more palatable. The volume of fluid accompanying each study was adjusted to 500 ml.

Before the series in which a subject participated, he assessed the rate at which he could comfortably ingest the cornflour starch preparation and the time taken was then applied to each saccharide when tested. The maximum time for ingestion was 5 min.

Whole blood glucose was measured by an automated glucose oxidase method (15); plasma insulin immunoreactivity measurements were based on the double antibody method of Hales and Randle (16); plasma free fatty acids (FFA) were assayed by the method of Trout et al. (17).

The significance of difference between events at given times after the ingestion of different saccharides were assessed by analysis of variance and also by the paired *t* test (18). Areas under curves were calculated by the trapezoidal rule (19).

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Results

For healthy subjects, the blood glucose concentration after ingestion of different glucose polymers is shown in Figure 1. In group I subjects, there was no significant difference between the time course of absorption of mono-, penta-, or polysaccharide. This is confirmed by an analysis of the area under the curves at hourly intervals (Table 1). With group II subjects, there were no apparent differences between the blood glucose concentrations after the ingestion of monosaccharide and disaccharide.

The patient with maturity onset diabetes also demonstrated a similar time course for blood glucose concentration after the ingestion of mono- and pentasaccharide (Fig. 2).

The plasma insulin responses to mono-, penta-, and poly-saccharide ingestion in group I subjects were not significantly different (Fig. 3; Table 2). In group II subjects, disaccharide ingestion did not induce an insulin response different from that seen with monosaccharide.

Plasma FFA were lowered maximally by 90 min and the overall FFA response found to be almost identical after ingestion of mono-, penta-, and polysaccharides (Fig. 4). Similarly, the FFA response to disaccharide was almost identical with that to monosaccharides.

Discussion

The present study allows the conclusion that chain length alone does not influence the rate of absorption of glucose significantly. Although Caloreen is not an oligosaccharide of uniform chain length, it is a mixture approximating a pentasaccharide. The small

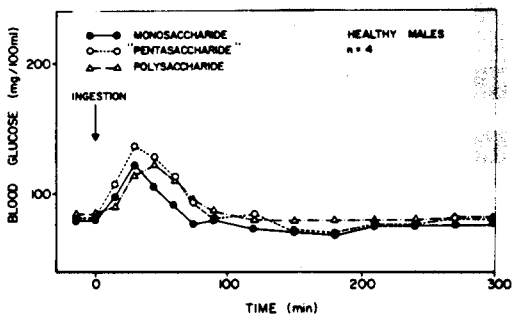

FIG. 1. Blood glucose concentrations in healthy males after ingestion of a monosaccharide (glucose), a pentasaccharide (Caloreen), or a polysaccharide (starch) in four individuals.

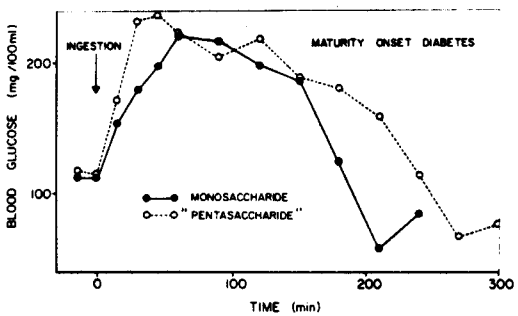

FIG. 2. Blood glucose concentrations in a maturity onset diabetic after ingestion of a monosaccharide (glucose) or a pentasaccharide (Caloreen).

TABLE 1
Area under blood glucose curve after ingestion of glucose polymers of different chain lengths[a]

Subject group	Saccharides[c]	Hours after ingestion[b]					
		1	2	3	4	5	Total
I	Mono	6184	4388	4223	4392	4583	23768
		±592	±973	±289	±292	±241	±2251
$n = 4$	Penta	6925[d]	5243[d]	4474[d]	4496[d]	4871[d]	26009[d]
		±330	±561	±222	± 84	±102	± 706
	Poly	6369[d]	5434[d]	4800[d]	4815[d]	4890[d]	26308[d]
		±319	±750	± 99	± 52	± 50	±1119
II	Mono	7590	6218	5100	5213	5273	29393
$n = 2$	Di	7306	4163	4710	4710	4980	25869

[a] Area was calculated with time as the abscissa in minutes and blood glucose concentration as the ordinate in mg/100 ml. [b] Mean ± SEM of the area is given for each hour after the ingestion of saccharide and for the total duration of the test period. [c] Significance of difference from monosaccharide in a given time period is indicated by ns $P > 0.05$. [d] Not significant.

proportion (3%) of glucose monomer present would not account for the similarity of monosaccharide and Caloreen blood glucose responses. If chain length were rate limiting in glucose absorption, starch should produce a more prolonged blood glucose response than Caloreen and this, in turn, a more prolonged response than the monosaccharide glucose. If anything, there was a tendency for the oligosaccharide mixture, Caloreen, to produce a slightly larger glucose rise and insulin response than either mono- or polysaccharide. However, any differences in glucose response are unlikely to be of any biological or practical consequence. For example, the recommendation of glucose over starch as such to produce a more rapid rise in blood glucose would appear to be ill-founded.

The present investigation answers the question of the effect of chain length on glucose absorption more directly than previous investigations that have examined saccharides of different carbohydrate composition (10, 11), not considered intermediate chain length saccharides (5–8, 11) or included saccharides in test meals where factors other than chain length could be important (5, 10). The similarity of plasma insulin and FFA responses to glucose absorption is further confirmation of the lack of importance of chain length in glucose absorption not available in other studies (5–9).

It is known that the ingestion of the disaccharide sucrose leads to lower blood glucose concentration than does monosaccharide ingestion (20), but this may reflect the different mode of assimilation of the fructose part of sucrose rather than chain length. Also, the disaccharide lactose, with its glucose and galactose components, is subject to rate limiting hydrolysis in the small intestine (1) and consequently would not necessarily produce

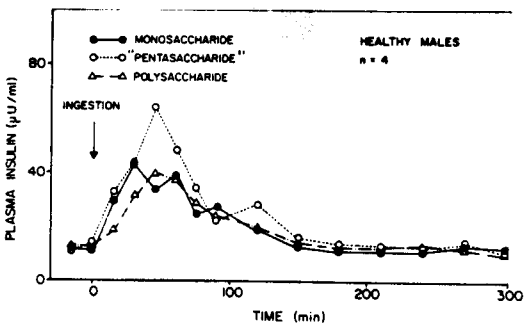

FIG. 3. Plasma insulin immunoreactivities in healthy males after ingestion of various glucose polymers. See legend to Figure 1.

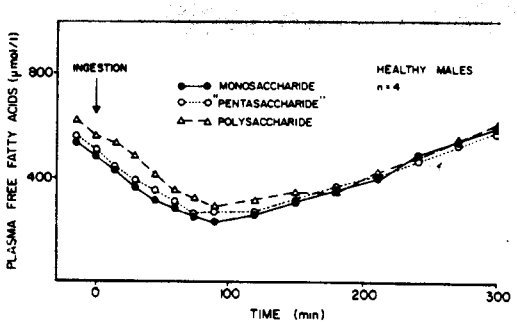

FIG. 4. Plasma free fatty acid concentrations in healthy males after ingestion of various glucose polymers. See legend to Figure 1.

TABLE 2
Area under plasma insulin curve after ingestion of glucose polymers of different chain lengths[a]

Subject	Saccharide	Hours after ingestion[b]					
		1	2	3	4	5	Total
I	Mono	1719	1562	858	685	672	5495
		±254	±469	±223	±140	±114	±1073
$n = 4$	Penta	2495[c]	1809[c]	1168[c]	753[c]	814[c]	7038[c]
		±496	±696	±343	±113	±167	±1674
	Poly	1715[c]	1513[c]	969[c]	742[c]	684[c]	5621[c]
		±234	±469	±217	±163	±136	±1169
II	Mono	2866	1635	1019	871	865	7256
$n = 2$	Di	2945	1581	890	715	773	6903

[a] Area was calculated with time as the abscissa in minutes and plasma insulin immunoreactivity as the ordinate in microunits per milliliter. [b] See footnotes to Table 1. [c] Not significant.

comparable rises in blood sugar concentration by comparison with monosaccharide.

Our studies do not exclude the possibility that dietary accompaniments may modify glucose absorption when chain length is comparable. There is an increasing literature on this subject, largely with respect to dietary fiber content (21). It has also been suggested that cooking renders starch more readily absorbable (22).

Our deductions about the lack of importance of chain length may also need to be qualified in the context of exocrine pancreatic deficiency, as in the first few weeks of life (23) and in exocrine pancreatic disease (8), where α-amylase is deficient.

The similarity of blood glucose concentrations after glucose saccharide and maltose ingestion is of additional interest inasmuch as maltose can be absorbed as such and metabolized after intravenous administration (24, 25). Nevertheless, maltose is usually hydrolyzed more rapidly than it can be absorbed (26). This, presumably, has been the case in the present study to allow blood glucose concentrations comparable to those after the same amount of ingested glucose monomer.

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