The digestion process of the sugar alcohol isomalt in the intestinal tract of the pig

2. Studies with administration of isomalt as a sweet

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In a study with ten pigs of 60–70 kg live weight, provided with a re-entrant cannula at the end of the ileum, and sixteen intact, non-cannulated pigs, the digestion and absorption of a dietary dose of 100 g isomalt/kg, and isomalt given between the meals as a 'sweet' on the basis of 50 and 100 g/kg feed consumption, were examined. In all three isomalt treatments slightly less than 0·40 of the isomalt consumed was digested in the small intestine when the calculations were based on ileal sugar passage. However, when basing the calculations on energy contents of ileal chyme, only approximately 0·10 was digested in the small intestine. The bacterial fermentation of the isomalt flowing into the large intestine was indicated by a decreased faecal energy digestibility and a slight reduction in faecal dry matter and nitrogen digestibility. The retention of the minerals sodium, potassium, magnesium, calcium and phosphorus was not influenced to any measurable extent when isomalt was fed.

Isomalt: Sugar digestion: Disaccharide alcohols: Pigs

In a previous paper (van Weerden & Huisman, 1993) the fate of 100 and 200 g/kg dietary doses of isomalt (an approximately equimolar mixture of two stereoisomeric disaccharide alcohols with α-glycoside bonds, α-D-glucopyranosyl-1,1-D-mannitol (GPM.2aq) and α-D-glucopyranosyl-1,6-D-sorbitol (GPS)) in the gastrointestinal tract of pigs was studied. It was found that 0·57–0·70 of the isomalt consumed passed the end of the ileum, but no isomalt components were identified in faeces. Values for ileal digestibility of energy demonstrated a secondary effect of isomalt on the digestion of the basal diet.

In order to come closer to the consumption level of man, a further study was done using levels corresponding to 50 and 100 g isomalt/kg diet. In addition, simulation of the daily pattern of sugar intake of man was attempted by offering the isomalt to the pigs between the meals as a kind of 'sweet'. The results of this study are presented in the present paper.

MATERIAL AND METHODS

Treatments and diets

Four treatment groups were involved. The doses of sucrose–isomalt applied are expressed as if they were given as a part of the feed: Group 1 100 g sucrose/kg, administered as sweet between the meals; group 2 50 g isomalt/kg, administered as sweet between the meals; group 3 100 g isomalt/kg, administered as sweet between the meals; group 4 100 g isomalt/kg, administered with the basal diet.

The basal diet in groups 1, 2 and 3 was fed twice daily at 08.00 and 20.00 hours, the sweets were administered by day between the meals at 10.00 and 14.00 hours. In group 4 the

Table 1. *Analysed composition of the basal diet and the test sugars (g/kg)*

	Basal diet	Isomalt	Sucrose
Dry matter	884	990*	1000
Crude protein (N × 6·25)	157	nd	nd
Gross energy (calculated; MJ/kg)	16·2	15·9	16·6
Ca	9·3	nd	nd
P	7·3	nd	nd
K	7·2	nd	nd
Na	1·4	nd	nd
Mg	1·9	nd	nd
GPM.2aq	nd	547	< D
GPS	nd	435	< D
Mannitol	nd	< D	< D
Sorbitol	nd	< D	< D
Sucrose	15	< D	> 990
Glucose	6	5	< D
Fructose	3	< D	< D
Maltose	4	< D	< D

GPM.2aq, α-D-glucopyranosyl-1,1-D-mannitol; GPS, α-D-glucopyranosyl-1,6-D-sorbitol; nd, not determined; < D, below detection level of 1 g/kg.
*The dry matter includes 2 H_2O in the GPM.2aq.

isomalt was fed together with the basal diet at 08.00 and 20.00 hours. For the determination of passage of isomalt and its components at the distal ileum, ten ileocaecal re-entrant cannulated pigs were used. These determinations were carried out in such a way that during 1 week all animals were given the four treatments in the order: diet 2, diet 1, diet 4, diet 3, and ileal contents were quantitatively collected during 24 h for each treatment. In the subsequent 2 weeks this scheme was repeated, so in total ileal chyme was collected during three 24 h periods for each pig and each treatment. The three separate 24 h chyme collections per animal per treatment were pooled and analysed.

The live weight of the pigs was in the same range as in the previous experiment (van Weerden & Huisman, 1993), therefore the same amounts of diet were fed (1600 g daily, sugars included). The amounts of basal diet and sweets, both fed twice daily, were: group 1 720 g basal diet and 80 g sucrose as sweet, group 2 760 g basal diet and 40 g isomalt as sweet, group 3 720 g basal diet and 80 g isomalt as sweet, group 4 720 g basal diet and 80 g isomalt with the diet.

The determinations of passage in the faeces were carried out with a separate group of sixteen non-cannulated pigs, distributed among the four groups in such a way that each group comprised four pigs. The live weight of these pigs was higher, therefore the amounts of basal diet and sugars fed were also higher. The following amounts were fed twice daily: group 1 873 g basal diet and 97 g sucrose as sweet, group 2 922 g basal diet and 48 g isomalt as sweet, group 3 873 g basal diet and 97 g isomalt as sweet, group 4 873 g basal diet and 97 g isomalt with the diet. The sugars administered between the meals (as sweet) were dissolved in 300 ml water and fed as a drink to both cannulated and intact pigs.

The composition of the basal diet was the same as in the previous experiment (van Weerden & Huisman, 1993). The analysed composition of this diet and of the sugars is presented in Table 1. The pigs were offered the diets as a wet mixture of 1 part feed and 2 parts water. Except with feed and sweets, no extra water was administered.

In the present experiment as well as in the previous study it was observed that ileal digesta flow was markedly higher in the isomalt groups than in the sucrose group. The

question arose as to whether or not the absorption of minerals might be affected. Therefore, the distal ileal passage of some minerals and their excretion with faeces and urine was examined. Mineral analyses were carried out on the basal diet and on the pooled samples of ileal digesta, faeces and urine.

Animals

The pigs were of the same cross as in the previous experiment (Dutch Landrace × Large White). The surgery and housing conditions were similar to those of the first experiment. In the experimental period the live weight of the cannulated pigs ranged between 64 and 72 kg, and of the non-cannulated pigs between 82 and 92 kg. To accustom the animals to isomalt consumption, an adaptation period of 7 d was included during which a diet with 100 g isomalt/kg was fed.

Collection of the ileal digesta and faeces and analytical procedures

Ileal passage was measured for each animal over three 24 h periods, so the values in the Tables and Figs are the mean values for ten pigs over 3 d. Faeces were collected in the intact pigs over five 24 h periods; the values in the Tables are the means of four animals over 5 d.

The collection procedures for ileal digesta and faeces and the storage conditions and analytical procedures for dry matter, N, gross energy and sugars are described in the previous experiment (van Weerden & Huisman, 1993).

To determine the contents of Na, K and Mg the samples were combusted at 500–550°, for 3 h, then treated with 4 M-HCl, followed by determination by atomic absorption spectrometry. To determine the contents of Ca and P the same pretreatments were carried out, but for the determination a Technicon AutoAnalyzer was used.

Statistical analysis

The data were analysed by means of one-way analysis of variance. The levels of the factors were the four different diets. The fact that all cannulated pigs received all four treatments was accounted for by using a block design for the ileal data, the ten animals being the ten blocks. The differences of means were tested by using the Least Significance Difference test (Snedecor & Cochran, 1980). All statements of significance are based on a probability of less than 0·05.

RESULTS

The results of ileal passage of sugars at the distal ileum are presented in Table 2. The sucrose administered as a sweet between the meals was almost completely digested and absorbed at the distal ileum. No sucrose and only minor amounts of glucose and fructose (components of sucrose and basal diet) passed the distal ileum.

In all three isomalt groups considerable amounts of intact isomalt (GPM.2aq plus GPS), together with its free constituents mannitol and sorbitol, passed the distal ileum. As observed in the previous experiment (van Weerden & Huisman, 1993), the passage of the third component of isomalt, glucose, was slightly increased. As was the case in the previous experiment, no detectable sugar levels were found in the faeces, indicating that the sugars that passed the distal ileum were completely broken down and disappeared in the large intestine.

There were no clear differences in passage or absorption rate when isomalt was administered with the diet or as a sweet between the meals (group 3 *v.* group 4).

Absolute and relative passage rates and absorption of intact isomalt and its components at the distal ileum were calculated from intake of isomalt and ileal passage. The values are given in Table 3 together with the results of the previous experiment with 100 and 200 g

Table 2. *Intake and ileal passage of sugars in pigs given doses of sugars equivalent to 100 g sucrose/kg diet and 50 and 100 g isomalt/kg diet*

	Intake (g/24 h)				Ileal passage (g/24 h)					
Diet...	100 g sucrose/kg as sweet	50 g isomalt/kg as sweet	100 g isomalt/kg as sweet	100 g isomalt/kg with diet	100 g sucrose/kg as sweet	50 g isomalt/kg as sweet	100 g isomalt/kg as sweet	100 g isomalt/kg with diet	SEM	df
Sucrose	181·6	22·8	21·6	21·6	×	×	×	×		
GPM.2aq	nd	43·8	87·5	87·5	nd	20·2^{a}	41·6^{b}	36·9^{c}	1·3	18
GPS	nd	34·8	69·9	69·9	nd	8·3^{a}	19·5^{b}	18·4^{b}	0·7	18
Glucose	8·6	9·5	9·4	9·4	10·0^{a}	14·0^{a}	22·4^{b}	25·2^{b}	1·9	27
Fructose	4·3	4·6	4·3	4·3	2·5^{ab}	2·3^{a}	2·4^{a}	3·1^{b}	0·2	27
Mannitol	nd	< D	< D	< D	nd	8·0^{a}	13·8^{b}	17·8^{c}	1·0	18
Sorbitol	nd	< D	< D	< D	nd	7·5^{a}	11·8^{b}	11·7^{b}	0·5	18
Total analysed sugars	200·3	121·6	198·2	198·2	12·5^{a}	60·2^{b}	111·6^{c}	113·0^{c}	3·0	27

^{a,b,c} Values with different superscript letters within a row differed significantly ($P < 0·05$).
nd, Not determined; < D, below detection level (0·5 g/kg).

Table 3. *The passage and absorption rates of isomalt determined at the distal ileum of pigs given doses of sugar equivalent to 100 g sucrose/kg diet and 50 and 100 g isomalt/kg diet*

Administration level of isomalt (g/kg)	Intake (g/24 h)	Passage rate* at the distal ileum		Absorption rate* at the distal ileum	
		g/24 h	As proportion of intake	g/24 h	As proportion of intake
50 as sweet	79	48	0·61	31	0·39
100 as sweet	157	99	0·63	58	0·37
100 with diet	157	100	0·64	57	0·36
100 with diet†	166	94	0·57	72	0·43
200 with diet†	315	220	0·70	95	0·30

* Based on the values for α-D-glucopyranosyl-1,1-D-mannitol (GPM.2aq), α-D-glucopyranosyl-1,6-D-sorbitol (GPS), free mannitol, free sorbitol and additional glucose.

† Previous experiment (van Weerden & Huisman, 1993).

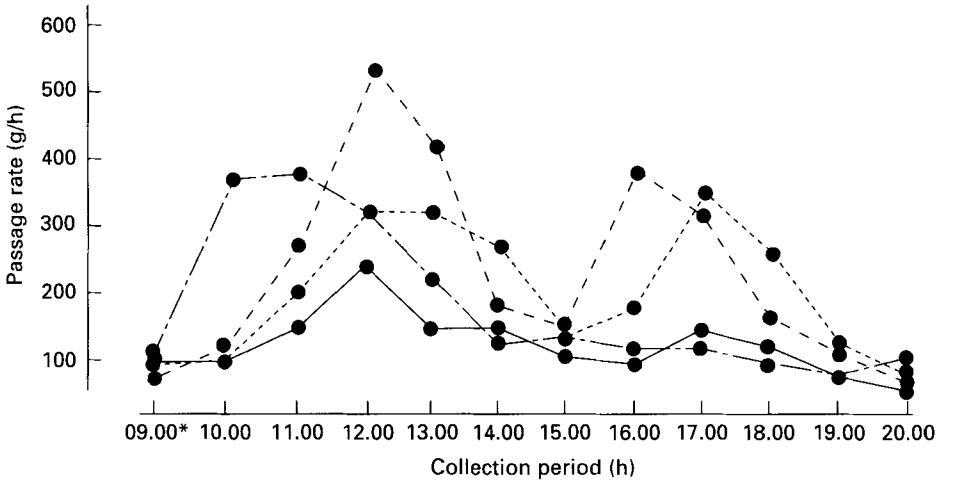

Fig. 1. Passage rate (g/h) of wet ileal digest of pigs fed on 100 g sucrose/kg as a sweet (——), 50 g isomalt/kg as a sweet (· · · ·), 100 g isomalt/kg as a sweet (– – – –) and 100 g isomalt/kg with diet (–·–·–). Each curve is the mean of thirty curves, ten pigs × 3 d. * Each collection period comprised the preceding 60 min. Feeding was at 08.00 hours, sweets were given at 10.00 and 14.00 hours.

dietary isomalt/kg. The ileal passage, expressed as proportion of intake, was slightly above 0·60 in all three isomalt groups in the present experiment and slightly below 0·60 in the 100 g/kg dose of the earlier experiment. The average value for absorption in the 50 and 100 g isomalt/kg doses is approximately 0·40. In the 200 g isomalt/kg group in the earlier experiment, ileal passage was 0·70 and absorption was 0·30 of intake.

The hourly passage rate of wet digesta at the distal ileum over the period 08.00–20.00 hours is presented in Fig. 1. In the period from approximately 1–4 h after administration of isomalt the ileal flow of chyme was considerably increased, whereas in the sucrose group flow was only slightly higher in this period. The total passage of wet ileal chyme (g) per 24 h was in the different groups: 100 g sucrose/kg, 3598; 50 g isomalt/kg, sweet, 4373; 100 g isomalt/kg, sweet, 4808; 100 g isomalt/kg, diet, 5057.

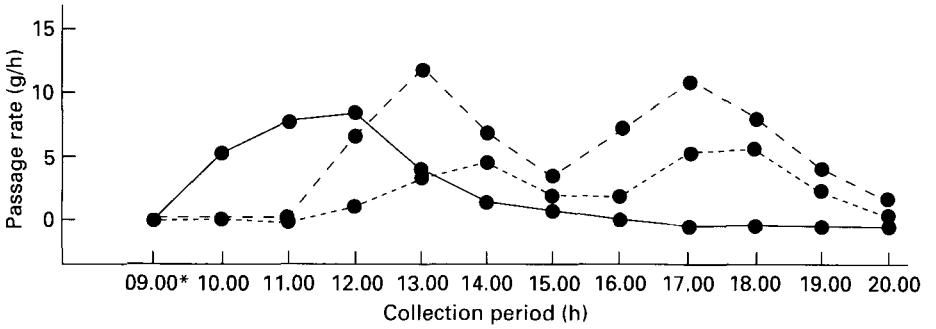

Fig. 2. Passage rate (g/h) of intact isomalt (α-D-glucopyranosyl-1,1-D-mannitol plus α-D-glucopyranosyl-1,6-D-sorbitol) at the terminal ileum of pigs fed on 50 g isomalt/kg as a sweet (· · · ·), 100 g isomalt/kg as a sweet (– – – –) and 100 g isomalt/kg with diet (——). Each curve is the mean of thirty curves, ten pigs × 3 d. * Each collection period comprised the preceding 60 min. Feeding was at 08.00 hours, sweets were given at 10.00 and 14.00 hours.

The hourly ileal passage of intact isomalt (GPM.2aq plus GPS) over the period 08.00–20.00 hours in the isomalt groups is shown in Fig. 2. The flow of mannitol plus sorbitol, not mentioned in Fig. 2, was only slightly increased after administration of isomalt, as was also observed in the previous experiment. The passage of intact isomalt components was, however, considerably increased during the period from 1 to 4 h after administration, especially in the 100 g/kg dose groups. Again the passage of isomalt components coincides with the peaks in ileal wet digesta flow, indicating the osmotic activity of isomalt components in the intestinal lumen.

The hourly pattern of ileal dry matter passage from 08.00 to 20.00 hours in the four groups was calculated from the amounts of wet chyme collected per h and the dry matter contents in these samples. The values are given in Fig. 3. When comparing the flow pattern of wet ileal chyme (Fig. 1) and that of ileal dry matter (Fig. 3), it is clear that the curves almost coincide. This was to be expected as in the earlier experiment it was found that during, as well as after, the peak in ileal flow in pigs fed on 200 g isomalt/kg the chyme was isotonic.

From the values for hourly passage of dry matter (Fig. 3) and sugars (Table 1) the ileal flow of non-sugar dry matter was calculated (Fig. 3). It was apparent that during the peaks in ileal chyme flow the flow of non-sugar components of the dry matter was also increased compared with the sucrose group. This finding indicates that the ileal passage of dry matter originating from the basal diet was increased during the peaks. The decreased ileal digestibility of dry matter and energy in the isomalt groups shown in Table 4 is, therefore, not only caused by the low digestibility of the isomalt, but also by the lower digestibility of the basal diet. Whereas the differences in ileal digestibility of dry matter and energy between the isomalt groups and the sucrose group are all significant, the differences for crude protein (N × 6·25) are only significant for both 100 g dietary isomalt/kg groups.

The faecal digestibility of dry matter and crude protein were only slightly lower for the isomalt groups than for the sucrose group. The decrease in protein digestibility is an indication of the excretion of extra bacterial mass as a result of the fermentative processes in the large intestine. The faecal digestibility of energy for the three isomalt groups was significantly ($P < 0{\cdot}05$) lower than that for the sucrose group.

Because the N-free extract (NFE) digestibility was not determined in the present experiment, no calculations could be made concerning which components contributed to the reduced energy digestibility in the isomalt groups. In the previous experiment (van Weerden & Huisman, 1993) it was calculated that about 50% of the decrease in faecal

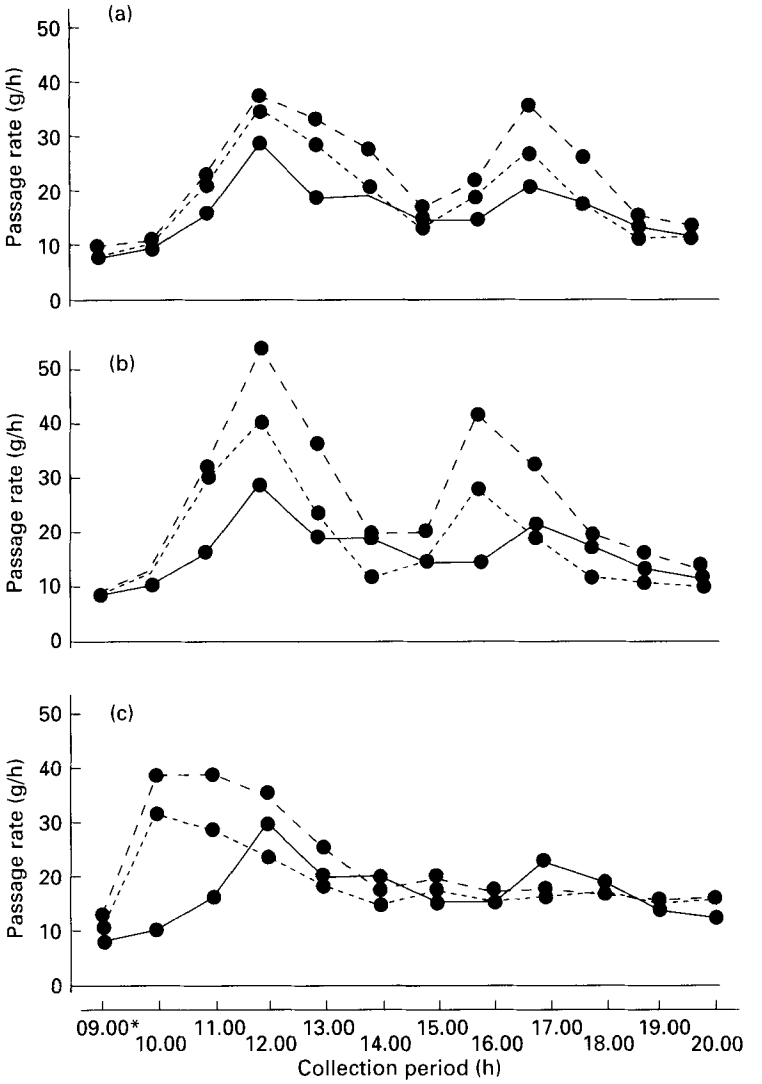

Fig. 3. Passage rate (g/h) of total ( ) and non-sugar (····) dry matter at the terminal ileum of pigs fed on (a) 50 g isomalt/kg as a sweet, (b) 100 g isomalt/kg as a sweet, (c) 100 g isomalt/kg with diet, each compared with 100 g sucrose/kg as a sweet (——). Each curve is the mean of thirty curves, ten pigs × 3 d. Each collection period comprised the preceding 60 min. Feeding was at 08.00 hours, sweets were given at 10.00 and 14.00 hours.

energy digestibility could be attributed to the lower N digestibility and the remaining 50% to the lower NFE digestibility.

The contents of N and energy in faeces were determined individually, and in urine in one pooled sample per treatment. The results for N are presented in Table 5. N excretion in faeces was increased for all three isomalt groups, but not significantly. The values for N excretion in urine were inconsistent, probably due to the fact that urine contents were analysed as one pooled sample for each group. The results for energy are presented in Table 5. Whereas the energy excretion with faeces was significantly increased in all three isomalt groups, energy excretion with urine was similar in all groups, as was the case in the earlier experiment.

Table 4. *Apparent ileal and faecal digestibility coefficients in pigs given doses of sugars equivalent to 100 g sucrose/kg diet and 50 and 100 g isomalt/kg diet*

	Ileal digestibility					Faecal digestibility				
	100 g sucrose/kg as sweet	50 g isomalt/kg as sweet	100 g isomalt/kg as sweet	100 g isomalt/kg with diet	SEM	100 g sucrose/kg as sweet	50 g isomalt/kg as sweet	100 g isomalt/kg as sweet	100 g isomalt/kg with diet	SEM
Dry matter	0·757[a]	0·698[b]	0·674[c]	0·654[d]	0·006	0·899[a]	0·872[b]	0·872[b]	0·869[b]	0·008
Crude protein	0·765[a]	0·747[ab]	0·740[bc]	0·723[c]	0·007	0·867	0·848	0·828	0·833	0·014
Gross energy	0·772[a]	0·709[b]	0·689[c]	0·663[d]	0·006	0·902[a]	0·875[b]	0·870[b]	0·868[b]	0·008

[a, b, c] Values with different superscript letters within a row of the ileal or faecal digestibility coefficients were significantly different ($P < 0·05$).

Table 5. *Nitrogen and energy intake, excretion with faeces and urine, and metabolizable energy and nitrogen balance in non-cannulated pigs given doses of sugars equivalent to 100 g sucrose/kg diet and 50 and 100 g isomalt/kg diet*

	100 g sucrose/kg as sweet		50 g isomalt/kg as sweet		100 g isomalt/kg as sweet		100 g isomalt/kg with diet		
	g/24 h	% of intake	g/24 h	% of intake	g/24 h	% of intake	g/24 h	% of intake	SEM
N intake	43·8	100	46·2	100	43·8	100	43·8	100	
N excretion with faeces	5·8	13·2	7·0	15·2	7·6	17·4	7·3	16·7	0·6
N excretion with urine*	17·5	40·0	17·9	38·7	16·7	38·1	18·1	41·3	
N balance	20·5	46·8	21·3	46·1	19·5	44·5	18·4	42·0	
	100 g sucrose/kg as sweet		50 g isomalt/kg as sweet		100 g isomalt/kg as sweet		100 g isomalt/kg with diet		
	MJ/24 h	% of intake	MJ/24 h	% of intake	MJ/24 h	% of intake	MJ/24 h	% of intake	SEM
Energy intake	31·38	100	31·26	100	31·23	100	31·23	100	
Energy excretion with faeces	3·08[a]	9·8	3·92[b]	12·5	4·04[b]	12·9	4·13[b]	13·2	0·24
Energy excretion with urine*	0·706	2·3	0·711	2·3	0·798	2·6	0·936	3·0	
Metabolizable energy†	27·60	87·9	26·63	85·2	26·39	84·5	26·17	83·8	

* Analysed in 1 pooled sample per treatment.
† Not corrected for N equilibrium.
[a, b] Values with different superscript letters within a row were significantly different ($P < 0·05$).

Table 6. *Intake and passage of minerals (g/24 h) at the distal ileum of pigs given doses of sugars equivalent to 100 g sucrose/kg diet and 50 and 100 g isomalt/kg diet*

(Values are based on one analysis in one pooled sample of ten pigs per treatment)

Groups...	100 g sucrose/kg as sweet	50 g isomalt/kg as sweet	100 g isomalt/kg as sweet	100 g isomalt/kg with diet
Na: Intake	2·0	2·1	2·0	2·0
Ileal passage	7·7	9·4	8·2	7·3
K: Intake	10·4	11·0	10·4	10·4
Ileal passage	3·1	3·9	4·9	5·2
Mg: Intake	2·7	2·9	2·7	2·7
Ileal passage	1·8	2·1	2·1	2·0
Ca: Intake	13·4	14·2	13·4	13·4
Ileal passage	8·6	9·0	9·9	10·6
P: Intake	10·6	11·1	10·6	10·6
Ileal passage	6·3	9·0	7·0	6·8

Table 7. *Intake and excretion of minerals (g/24 h) in faeces and urine of pigs given doses of sugars equivalent to 100 g sucrose/kg diet and 50 and 100 g isomalt/kg diet*

(Values are based on one analysis in one pooled sample of four pigs per treatment)

	100 g sucrose/kg as sweet	50 g isomalt/kg as sweet	100 g isomalt/kg as sweet	100 g isomalt/kg with diet
Na: Intake	2·4	2·5	2·4	2·4
Faeces	0·4	0·5	0·6	0·5
Urine	1·0	0·8	1·1	0·7
Balance	1·0	1·3	0·8	1·1
K: Intake	12·6	13·3	12·6	12·6
Faeces	1·8	2·6	3·1	2·5
Urine	6·7	4·7	5·6	4·9
Balance	4·1	6·0	4·0	5·2
Mg: Intake	3·3	3·5	3·3	3·3
Faeces	1·8	1·8	1·7	1·7
Urine	0·2	0·2	0·3	0·2
Balance	1·2	1·4	1·3	1·3
Ca: Intake	16·3	17·2	16·3	16·3
Faeces	10·1	10·6	10·1	10·4
Urine	0·3	0·2	0·3	0·2
Balance	5·9	6·4	5·9	5·6
P: Intake	12·8	13·5	12·8	12·8
Faeces	7·4	8·0	7·8	8·0
Urine	1·0	0·9	1·4	1·0
Balance	4·4	4·6	3·7	3·8

The results relating to mineral metabolism are shown in Tables 6 and 7. The intake of the non-cannulated pigs was higher (Table 7) because the amounts of diet fed daily were higher (see pp. 467–469). The distal ileal passage of Na was 3·8 to 4·5 times higher than the intake (Table 6). This observation is in accordance with reported findings (Partridge, 1978;

Den Hartog *et al.* 1985) and can be explained by an inflow of endogenous $NaHCO_3$ in the upper part of the small intestine. There were no great differences observed in the ileal passage of minerals between the sucrose and the isomalt groups. The ileal passage of K and Ca for the 100 g isomalt/kg groups was somewhat higher than that for the sucrose group. There was a tendency that the additional K flowing from the distal ileum into the large intestine was not completely absorbed in the large intestine, resulting in a slightly higher excretion of K with faeces (Table 7). However, this higher faecal K excretion was completely compensated by a lower K excretion in the urine (Table 7). The excretion of the other minerals Na, Mg, Ca and P in faeces and urine was not or hardly affected.

DISCUSSION

The question of whether and to what extent the fate of sugar alcohols like isomalt in pigs can provide a reliable prediction of the situation in man is still under debate. Whereas it is stated by Graham & Åman (1987) that 'of all domesticated animal species, the pig is in gastrointestinal physiology, diet and size most similar to the human', there are also differences. The length of the small intestine as well as that of the large intestine is considerably larger in pigs than in man of comparable live weight (Barth *et al.* 1990). The capacities of the different compartments of the gastrointestinal tracts as a proportion of the total tract differ between the species, the capacity of the small intestine being smaller in pigs and the capacity of caecum–colon being larger (Stevens, 1977; Parra, 1978). Considering, however, the relationship between intake of dry matter (man 500 g/d, pigs in our studies 1440 g/d) and length of small intestine (man 4·5–5 m, pig 15–20 m) in man and pig, both of approximately 70 kg live weight, the 'load' on the small intestine is not much different in both species when the difference in diameter of the intestinal lumen is ignored.

Moreover, the transit times of the digesta in the small intestine (2–4 h) and large intestine (20–50 h) seem to be rather similar in both species and protein digestibilities of mixed diets are similar (Ratcliffe, 1985). A more serious concern with respect to a study of sugar alcohols is the fact that the potency of bacterial fermentation in pigs' intestinal tract is greater than in man (Graham & Åman, 1987). This difference relates not only to the large intestine (Van Soest, 1982), but also to the upper part of the gastrointestinal tract (Ratcliffe, 1985). This activity is also evident from the presence of considerable levels of organic acids in the ileal chyme of pigs fed on sucrose as well as isomalt diets in the earlier experiment (van Weerden & Huisman, 1993). The difference in bacterial fermentation in the gastrointestinal tract between pig and man leads to the supposition that the values for the breakdown of isomalt in the small intestine found in our studies with pigs overestimate the situation in the small intestine of man.

Disappearance rates of isomalt in the small intestine in the three test groups in the present experiment were almost similar and were slightly below 0·40 of intake. This value is in reasonable agreement with the value of 0·43 absorption in the 100 g isomalt/kg group in the previous experiment (van Weerden & Huisman, 1993). The finding in the earlier study (van Weerden & Huisman, 1993) that only 0·30 of a dietary dose of 200 g isomalt/kg is absorbed in the small intestine may reflect the effects of an increased speed of passage of chyme along the small intestine caused by the osmotic properties of isomalt in the intestinal lumen.

The observation in the previous experiment (van Weerden & Huisman, 1993) that by doubling the amount of isomalt intake from 100 to 200 g/kg in the diet the daily passage of intact isomalt was nearly tripled was not confirmed in the present study with 50 and 100 g/kg dose levels. In the present experiment doubling isomalt intake from 79 to 157 g/d resulted in an increase in ileal flow from 28 to 61 g intact isomalt/d. Ileal passage of free mannitol and free sorbitol in these groups was also increased, but less than double.

Table 8. *Ileal energy digestibilities of diets* (y) *and gross energy intake from isomalt:gross energy intake from isomalt plus basal diet ratio* (x) *in the present and previous experiment* (*van Weerden & Huisman, 1993*)

	x	*y*	No. of replications
Present experiment	0	0·746	10
	0·049	0·709	10
	0·098	0·689	10
	0·098	0·663	10
Previous experiment	0	0·700	4
	0·110	0·661	4
	0·198	0·604	4

The energy digestibility of the basal diet was calculated from the figures for the basal plus sucrose groups assuming a 100% digestibility of the sucrose energy.

No important differences in ileal passage of sugars between administration of 100 g isomalt/kg with the feed or between the meals were observed. However, the values for ileal passage of intact isomalt in Fig. 2 suggest that flow pattern after administering isomalt in water as a sweet was more abrupt.

In the previous experiment (van Weerden & Huisman, 1993) indications were found of a reduction in ileal digestibility of components of the basal diet in the isomalt treatment groups. Therefore, in the present experiment a comparison was made between hourly ileal passage of total dry matter and non-sugar dry matter (Fig. 3). The increased ileal passage of non-sugar dry matter in the isomalt groups will effect the value for ileal digestible energy of isomalt. The calculation of the ileal digestible energy value of isomalt from the values for ileal energy digestibility of the diets found in the present and the previous experiment (Table 4, present experiment; Table 7 of van Weerden & Huisman, 1993) was carried out using linear regression, with y as ileal energy digestibility of the diets and x as gross energy intake from isomalt/gross energy intake from isomalt + basal diet. An estimator for the ileal energy digestibility of isomalt is the prediction of the digestibility y at $x = 1$, assuming a linear relation between dose of isomalt and energy digestibility coefficient. This is the model normally used when calculating the digestibility coefficient of a component from the coefficients of test and basal diets. The values in this formula are from Table 8.

The result of fitting the formula with the data from Table 8 is: $y = 0{\cdot}734 - 0{\cdot}626x$ (residual mean square 0·0020). Hence, the energy digestibility of isomalt is 0·11 (SD 0·10), or 11%. The wide 95% confidence interval (−0·09–+31) of this digestibility coefficient is a normal feature when extrapolating values obtained with relatively low inclusion levels of a test substance (50, 100 and 200 g/kg) in test diets to 100% test substance. In estimating the digestibility coefficient by means of extrapolation the assumption of linearity over the whole range is critical.

However, the value of about 10% ileal energy digestibility of isomalt, being considerably lower than the values of approximately 40% obtained by calculation on the basis of analysed sugars (Table 3), illustrates the important secondary effect of isomalt on digestibility of the basal diet components. It can be estimated from the previous calculations that in these studies only approximately 10% of the isomalt energy was absorbed as useful energy in the small intestine. This means that the main part of the energy from isomalt contributing to the energy supply of the animal comes from the compounds

(mainly acetic, propionic and butyric acids) formed in the bacterial decomposition of isomalt in the large intestine.

Because of the inherent inaccuracy of the measurement of ileal digestibility of isomalt energy together with the uncertainty regarding the energy losses in the bacterial fermentation in the large intestine, the estimation of the energy value of isomalt in these pig studies can only be a rather rough approximation. For confirmation an elaborate study is needed in which energy deposition is measured. Recently such a study was published by Fevrier & Pascal (1992). In that study with pigs of 63 kg live weight fed on diets with 210 g sucrose or isomalt/kg, it was calculated that the energy value of isomalt for maintenance was 49% of that of sucrose.

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