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Pediatrics 2000;105;e4

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ABSTRACT. ***Objective.*** **To compare the absorption of carbohydrate in particular from a lower (10 mL/kg^{-1}) quantity than that previously tested, of white grape juice and pear juice after a single feeding and after ingestion twice daily for 2 weeks, and determine their respective effects on stool water content, in healthy infants.**

Study Participants. **Twelve healthy, well-nourished infants, 5 to 9 months of age, who were recruited from the general population.**

Design/Methods. **Infants underwent a breath hydrogen test after a serving of pear juice. Three to 5 days later, the test was repeated after a serving of white grape juice. Infants were randomly assigned to receive a 10 mL/kg^{-1} serving of grape juice or pear juice twice daily for 2 weeks. The breath tests were repeated after the ingestion of the juices in the same sequence. With the second breath test with pear juice, a charcoal marker and 20 mg ^{13}C fructose, a stable, nonradioactive isotope, were mixed with the juice. Water content of the stools was compared before and after the 2-week feeding of the juice, and fecal samples were analyzed for ^{13}C enrichment by mass spectrometry.**

Results. **After the ingestion of the fruit juices, only 1 infant had an abnormal peak hydrogen (H_2; ≥10 ppm), which followed the pear juice. That same infant was the only one who had H_2 levels ≥10 ppm after grape juice. There was no significant difference in the peak breath H_2 levels after grape juice and pear juice either at the beginning of the study or 2 weeks after taking the juice assigned (2.8 ppm ± 2.9 vs 6.2 ppm ± 9, respectively). The difference in breath H_2 response before and after the 2 weeks of fruit juice intake was not significant. Mean (±standard deviation) fecal ^{13}C enrichment at baseline was 3.0 Δ%o (±2.4), which was not significantly different from after 2 weeks of juice intake (2.4 Δ%o [±1.5]), regardless of the juice assigned: 2.7 Δ%o (±1.6) for grape juice and 2.2 Δ%o (±1.5) for pear juice. Mean (±standard deviation) percentage of fecal water at baseline was 24.1% (±5.1), which was not significantly different from after 2 weeks of juice (22.5% [±6]), regardless of the juice received: 21.8% (±5.8) for grape juice and 23.2% (±6.7) for pear juice.**

Conclusion. **When either grape or pear juice is administered in a dosage of 10 mL/kg/day, the carbohydrate is well absorbed, produces no adverse gastrointestinal symptoms, and has no effect on stool water in healthy infants.** ***Pediatrics*** **2000;105(1). URL: http://www.pediatrics.org/cgi/content/full/105/1/e04;** ***fruit juice, carbohydrate absorption, breath hydrogen test.***

ABBREVIATIONS. H_2, hydrogen; CNRC, Children's Nutrition Research Center; SD, standard deviation.

Fruit juices have become a common component of an infant's diet at a very early age.[1,2] For a variety of reasons, among which is a misinterpretation of appropriate quantities of healthy weaning foods, infants sometimes are fed large amounts of fruit juice. Carbohydrate malabsorption from fruit juices may cause diarrhea and abdominal pain[3–9] and is more likely to occur with juices that contain sorbitol and with those in which the fructose-to-glucose ratio is >1.[3–10] Sorbitol not only is incompletely absorbed in the small bowel, but also interferes with fructose absorption,[11] which is facilitated by equimolar amounts of glucose.[12,13] The carbohydrate composition of white grape juice and orange juice favors carbohydrate absorption, whereas that of apple and pear juice is less conducive to complete absorption (Table 1).[5–10] White grape juice has an almost equimolar amount of glucose and fructose and contains no sorbitol. Apple and pear juices contain more fructose than glucose and also have sorbitol. In addition, depending on the industrial processing, fruit juices can differ substantially from each other by the amount of soluble fiber, another source of hydrogen production.

When carbohydrate is incompletely absorbed by the small bowel, it reaches the colon, where it is fermented by intestinal bacteria. Among the byproducts of this fermentation are gases such as hydrogen (H_2), which is partially absorbed through the colonic mucosa, transported to the lungs, and exhaled in the breath, where it can be measured.[14] Some authors have postulated that fructose, not sorbitol, is the sugar responsible for H_2 production after apple juice consumption.[15,16] Carbohydrate arriving in the large bowel also attracts water; therefore, whenever substantial carbohydrate malabsorption occurs, stools are looser. When a large amount of carbohydrate is malabsorbed on a daily basis, the pH of the colonic lumen falls below the pK of the enzymes that bacteria use to ferment carbohydrate, and H_2 production decreases.[17]

Most of the studies performed so far regarding the absorption of different fruit juices involve breath sampling for H_2 after a single feeding of the juice tested,[4–10] with volumes ranging from 15 to 20 mL/kg^{-1}. Those volumes, however, may be too large for

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The contents of this publication do not necessarily reflect the views or policies of the US Department of Agriculture, nor does mention of trade names, commercial products, or organizations imply endorsement from the US Government.

Received for publication Mar 13, 1999; accepted Jul 12, 1999.

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TABLE 1. Carbohydrate Composition of Fruit Juices (g/dL)[9]

Juice	Fructose	Glucose	Fructose/ Glucose	Sucose	Sorbitol
Apple	6.2	2.7	2.3	1.2	0.5
Pear	6.4	2.3	2.8	.9	2.0
White grape	7.5	7.1	1.1	0	0

the infant's intestinal absorptive capacity.[18] This study was designed to: 1) compare the absorption of carbohydrate from white grape juice and pear juice after the intake of what we consider an appropriate volume of juice; 2) compare the malabsorption of fructose from each type of juice, using a stable isotope methodology; 3) determine whether feeding either juice twice daily, for a 15-day period, would affect the fermentative capacity of the colonic bacteria, as measured by H_2 production; and 4) determine whether the fecal water content was affected by feeding either juice on this feeding schedule.

METHODS

Infants 5 to 9 months of age were recruited from the general population by contacting women who had delivered their infants at local hospitals. The study was explained over the telephone. To qualify for study participation, infants had to be healthy and well nourished and had not received antibiotics for at least 10 days before the initiation to the study, nor more than 3 fruit juice servings per week. Fourteen infants, 3 of whom were female, were enrolled. Mothers who agreed to participate received, by mail, written instructions, 2 plastic containers with airtight lids, and several wooden spatulas. Mothers were instructed to collect on different days an aliquot of a stool specimen that had not been contaminated with urine. Specimens were frozen immediately. Within the following 2 weeks, infants were brought to the metabolic research unit of the Children's Nutrition Research Center (CNRC) in the morning, after a 5-hour fast. Mothers brought the frozen fecal specimens and signed an informed consent.

Infants received a serving of 10 mL/kg^{-1} of pear juice (Table 1). Breath samples were collected with a face mask, equipped with a low-resistance, unidirectional flow valve, and a small bag. Samples were obtained before the juice was ingested and at 30, 45, 60, 90, and 120 minutes afterward. Aliquots of breath samples were transferred to 60-mL plastic syringes with a 3-way stopcock in the tip. Infants were fed their regular meal and discharged home. Three to 7 days later, infants returned to the CNRC and the breath test was repeated after the infants received a serving of the same volume of the white grape juice (Table 1). Infants were randomly assigned to receive either grape juice or pear juice. Mothers were supplied with an appropriate amount of the juice and instructed to administer 2 daily servings of 10 mL/kg^{-1}each for the following 2 weeks. Juices were provided to us, bottled in coded containers by Welch Foods Inc (Concord, MA).

At the end of that 2-week period, infants returned to the CNRC and underwent another breath test after ingestion of pear juice. Mixed with the juice were 3 mL of diluted charcoal, a nonabsorbable colorant marker, and 20 mg of ^{13}C fructose (Cambridge Isotope Laboratories, Andover, MA), a stable, nonradioactive, and thus harmless isotope of the monosaccharide. The dose of stable isotope was calculated to increase the fructose content of grape juice (the juice containing the lower amount of fructose) by no more than 3%, and to be sufficient so that if ≥10% of fructose was malabsorbed, it could be detected in stools.[19]

Mothers collected an aliquot of the fecal specimen that contained the colorant marker; if it was contaminated with urine, an additional aliquot from a fecal sample not contaminated with urine was collected in a different container. Infants returned a fourth and final time to the CNRC for another breath test after ingesting the same-sized serving of grape juice received. Mothers brought the second set of frozen fecal specimens. The summary of the experimental design is shown in Fig 1.

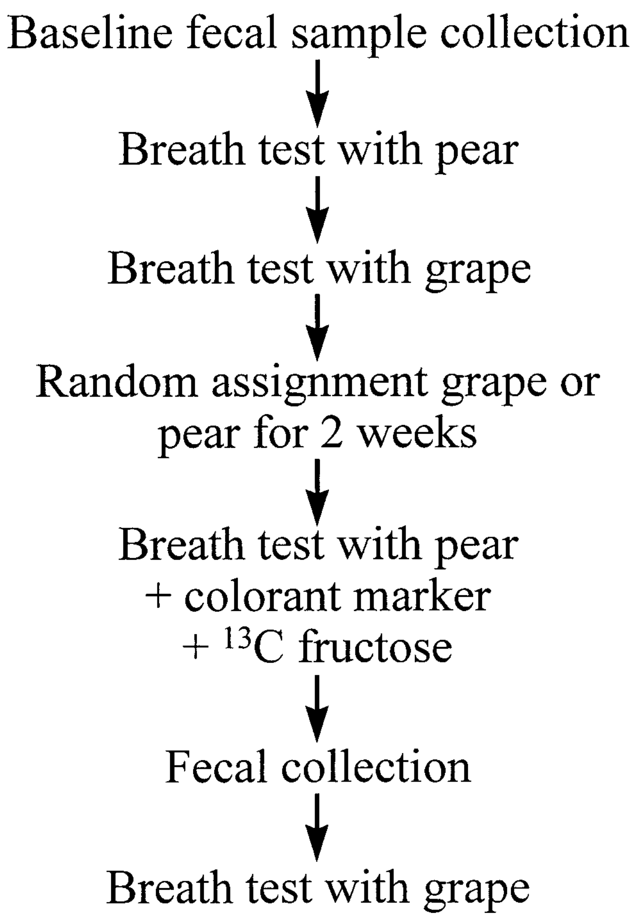

Fig 1. Protocol design.

Breath Samples

Samples were analyzed for H_2 content using a Quintron DP Microlyzer (Quintron, Menomonee Falls, WI) within 3 hours of collection. Results are expressed as parts per million. Peak breath H_2 levels were calculated by subtracting from the highest breath H_2 level obtained during the test the lowest preceding level. Peak breath H_2 levels of 10 ppm over baseline were considered indicative of significant carbohydrate malabsorption.[20]

Stool Samples

Aliquots of the fecal specimens obtained at baseline and at the end of the study were placed in preweighed glass tubes, weighed again, and placed in a Speedvac concentrator (Savant, Farmingdale, NY) for drying. Vials were weighed again and percentage of dry matter was calculated. For ^{13}C enrichment, an aliquot of ~3 mg of each fecal sample was placed in a 8 × 5 mm tin capsule (Europa Scientific Inc, London, UK) and dried under vacuum in a Speedvac concentrator. The capsules were then wrapped and were ready for analysis. Carbon dioxide gas was produced by a combustion and purification unit (Roboprep-CN Biological Sample Converter, Europa Scientific Inc). The carbon dioxide gas was analyzed in a mass spectrometer (Europa 20–20 Stable Isotope Analyzer) with an abundant sensitivity in the order of 50 ppm. The δ values were obtained in reference to Pee Dee Belminte value of $^{13}C/^{12}C$ = .0112372.

Data Analysis

Results of peak breath H_2 after servings of grape juice versus pear juice at baseline and at the end of the study were compared within subjects by paired *t* test. One-way analysis of variance, with the juice received during the 2-week period as a covariate, was used to compare the results at baseline and at the end of the study for the following: breath H_2 response after ingestion of grape juice and pear juice, percentage of water in feces, and isotopic enrichment of feces after ^{13}C fructose administration. Because of the presence of a single outlier in the breath H_2 test results, the Wilcoxon rank test for nonparametric analysis was used.

RESULTS

Two male infants failed to complete the study; the mother of 1 of the boys did not collect the fecal sample at the end of the study, and the other mother only brought her son to the CNRC for the first breath test. Mean (±standard deviation [SD]) age of the remaining 12 infants who completed the study was 7.5 (±1.3) months (range: 5–8.5 months), and mean weight 8.3 (±.3) kg. After ingestion of the fruit juices, only 1 infant had a peak H_2 level that would be considered abnormal (34 ppm), and that was after pear juice. He did not develop any symptoms. The same infant was the only one who had H_2 levels ≥10 ppm (11 ppm) after grape juice consumption. There was no significant difference in the peak breath H_2 levels after grape juice (mean [±SD]; 1.6 ppm [±1.1]) and pear juice (2.7 ppm [±2.8]) at baseline or 2 weeks after taking the juice assigned (2.8 ppm [±2.9] vs 6.2 ppm [±9], respectively). The juice assigned did not modify the H_2 response to any of the juices fed. Using the Wilcoxon rank test, a significant difference was found in breath H_2 levels only between grape juice and pear juice ($P = .05$) at the time of the second testing. Although higher after pear juice, all but 1 peak breath H_2 level were <10 ppm.

Mean (±SD) percentage of water in fecal matter at baseline was 24.1% (±5.1), which was not significantly different from that after 2 weeks of juice (22.5% [±6]), regardless of the juice received: 21.8% (±5.8) for grape juice and 23.2% (±6.7) for pear juice (Table 1).

Mean (±SD) fecal isotope enrichment at baseline was 3.0 Δ‰ (±2.4), which was not significantly different from after 2 weeks of juice intake (2.4 Δ‰ [±1.5]), regardless of the juice assigned: 2.7 Δ‰ (±1.6) for grape juice and 2.2 Δ‰ (±1.5) for pear juice. This indicates that none of the ^{13}C-labeled fructose administered with the juices was detected in stools.

DISCUSSION

Consumption of fruit juices by the pediatric population has increased dramatically over the past decade, beginning at 4 to 6 months of age.[1,2] Because fruit juices are considered a snack, there are no recommendations for the amount that infants should ingest.[21–24] The US Department of Agriculture has determined that 180 mL of juice is the equivalent of 1 fruit serving.[25] According to manufacturers, infants consume an average of 150 mL of juice per day.[26] If this volume were administered in 2 servings a day, infants between 6 and 12 months of age would receive approximately between 7.5 and 12 mL/kg^{-1} per serving. In most cases, when fruit juices are consumed in reasonable amounts, they produce no problems.[18] Some parents, however, offer an unlimited amount of juice, which can result in excessive gas, abdominal pain, and even chronic diarrhea.[5–9] In addition, nutritional changes have been noticed in association with fruit juice ingestion.[27,28] It has been reported that children who ingest >360 mL per day of fruit juice are either shorter or heavier than their counterparts who do not ingest as much juice.[27] This association has been questioned by others.[29] The diarrhea and abdominal pain caused by fruit juice consumption have been attributed to the carbohydrate composition of the juice. In contrast, fermentation in the colon is a normal phenomenon and the formation of H_2 is one of its consequences and should not be equated with discomfort or pain. Many breastfed infants produce H_2 and are completely asymptomatic and well.

Although all juices contain fructose, not all contain sorbitol. Sorbitol is a carbohydrate that is not completely absorbed in the small bowel (~10% is absorbed), and it also interferes with fructose absorption.[11] When a solution of fructose is administered with equimolar amounts of glucose, fructose absorption is greater than when fructose is administered alone.[12,13] Apple juice and pear juice have a high fructose-to-glucose ratio and contain sorbitol, a carbohydrate combination that results in their incomplete small bowel absorption. Other juices, such as grape juice and orange juice, have an equimolar content of fructose and glucose and no sorbitol, which results in more complete carbohydrate absorption.

Studies to investigate digestibility of carbohydrate from fruit juice have used the breath H_2 test.[4–8,10,26] The breath H_2 test provides a semiquantitive measure of carbohydrate malabsorption. Breath H_2 levels depend on a series of factors, including the amount of carbohydrate that arrives in the colon, the rate at which it arrives, the capacity of the fecal flora to produce the gas, and the proportion of the gas that is absorbed, opposed to what is expelled as flatus.[14–17] Most studies of fruit juice absorption have focused on the comparison of breath H_2 values after a 1-time serving of ~15 mL/kg^{-1} of the juices in question. To identify the malabsorbed carbohydrate in juices containing different amounts of fructose and glucose, some investigators have administered solutions containing combinations of the carbohydrates present in the different fruit juices.[15] We have attempted to address several questions related to fruit juice ingestion. The first goal of our study was to compare the absorption of carbohydrate from grape juice and pear juice using the breath H_2 test, after the intake of a juice at a somewhat lower volume than in previous studies. After the administration of 10 mL/kg^{-1} of juice, only 1 infant had a peak breath H_2 level ≥10 ppm, and that was after pear juice. There was no significant difference in the peak breath H_2 levels between grape juice and pear juice at the initiation of the study, although a trend toward higher levels of H_2 was seen after pear juice ingestion. When the tests were repeated after 2 weeks of 2 daily servings of either grape juice or pear juice, peak breath H_2 levels after pear juice became significantly higher than after grape juice, regardless of the juice they had received during that period. The statistical significance was reached primarily by the presence of 1 outlier value of 34 ppm after pear juice in an infant who experienced no symptoms. This finding probably was attributable to variability of breath H_2 production and not a consequence of the fruit juice received for the 2-week period. Previous studies using somewhat larger volumes of juice were able to demonstrate carbohydrate malabsorption after apple juice (which has a carbohydrate composition similar to that of pear juice). Smith et al[26] administered to infants 6 months of age .78 g/kg^{-1} of fructose as apple juice and 1.02 g/kg^{-1} in the form of grape juice, although in their study design they did not adjust the amount of tested juice to the children's weights. We only administered .64 g/kg^{-1} and .75 g/kg^{-1}, respectively. We cannot determine whether the 18% difference of fructose in the juice from which carbohydrate malabsorption is more likely to occur explains why Smith et al found evidence of carbohydrate malabsorption among 54% (4 of 7) of the children after apple juice and only in 19% after grape juice. Although the juice we administered in our study was pear and not apple, the fructose-to-glucose ratio of both juices is very similar, although pear juice has a higher concentration of sorbitol. It is possible that the difference of .14 g/kg^{-1} of fructose, which constituted 2.5 mL less per kilogram of body weight, could have made the difference. Despite the fact that pear juice has an even higher fructose-to-glucose ratio and a higher sorbitol content than apple juice, carbohydrate malabsorption was only detected in 1 of the 12 infants.

The second goal was to compare the malabsorption of fructose from each type of juice. It has been reported that fructose is the carbohydrate malabsorbed in apple (and pear) juice, that is responsible for the breath H_2 elevation and symptoms of diarrhea and abdominal pain.[8,9,12] A recent study demonstrated that carbohydrate malabsorption persisted even when the juices were treated with yeast, which leads to a major reduction in fructose and glucose.[15] This indicates that sorbitol is also responsible for the breath H_2 response obtained after the administration of certain fruit juices. To estimate the extent of fructose malabsorption, we administered a tracer amount of the stable isotope ^{13}C fructose. The abundance of ^{13}C in the human body and excreta depends primarily on the natural abundance of ^{13}C of the foods ingested. Even if $<10\%$ of the dose had been malabsorbed after ^{13}C fructose administration, it would have been detected in the stool as an enrichment of ^{13}C over baseline.[19] We anticipated that the grape juice would be better absorbed than pear juice because of its carbohydrate composition, a premise supported by previous reports.[8–10,26] Therefore, we administered the ^{13}C fructose with the juice from which it was more likely that fructose would be malabsorbed, which was pear juice, because of its high fructose-to-glucose ratio and sorbitol content. Based on the fact that sorbitol interferes with fructose absorption, we would have expected a greater ^{13}C fecal enrichment when the stable isotope was administered with pear juice than with grape juice. However, that did not occur, which indicates that at the volumes administered, ^{13}C fructose malabsorption was negligible. It is possible that a certain amount of ^{13}C fructose might have reached the colon, where it was fermented by bacteria and transformed into short-chain fatty acids that were absorbed through the colonic mucosa. In addition, it might be speculated that the higher breath H_2 levels observed after pear juice, although too low to denote significant carbohydrate malabsorption, might have been caused by colonic bacterial fermentation of sorbitol, as well as fructose. To confirm this hypothesis, additional studies would need to be conducted, administering ^{13}C sorbitol with the juices.

The third goal of our study was to determine whether feeding the juices twice a day, for a 15-day period, would affect H_2 production. It has been demonstrated that daily malabsorption of carbohydrate impairs the H_2 response. As a consequence of repeated carbohydrate malabsorption, the luminal concentration of short-chain fatty acids is high, the colonic luminal pH falls below the bacterial pK, and thus, fermentation is inhibited.[17] We were unable to prove this point because of the low breath H_2 levels of our subjects at the time of the first study. However, significant carbohydrate malabsorption most likely did not occur, because none of the mothers reported that their infants manifested discomfort or diarrhea.

The fourth goal was to determine whether fecal water would be affected by feeding the infants a juice containing carbohydrates which could not be completely absorbed, over a 15-day period. We found no significant difference in the proportion of fecal water between baseline and after feeding either grape juice or pear juice.

CONCLUSIONS

In summary, our results indicate that at the volumes administered, there was no significant malabsorption of carbohydrate from grape juice or pear juice. In contrast to our previous hypothesis,[30] administration of the juices for a 15-day period did not modify the water content of the stool. It would seem that at the volume of pear juice administered in our study, fructose malabsorption is low. As has been previously suggested,[18] young infants who ingest apple or pear juice in lower amounts should not experience any side effects from malabsorbed carbohydrate.

ACKNOWLEDGMENTS

This work is a publication of the USDA/ARS Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, TX. This project has been funded in part with federal funds from the US Department of Agriculture, Agricultural Research Service under Cooperative Agreement 58-6150-6-001.

We thank Welch Foods Inc for partial financial support; Linda Peas'ant, RN, the nurses at the Metabolic Research Unit of the Children's Nutrition Research Center, and Herbert Bohanna for their assistance in carrying out the protocol; Leslie Loddeke for editorial review; Jiang-Ping Wen, PhD, for stable isotope analysis; O'Brian Smith, PhD, for the statistical analysis; and Fima Lifshitz, MD, for his encouragement.

REFERENCES

1. Stinson W, Dhurandhar NV. Fruit juice consumption. *Pediatrics*. 1997; 100:728–730
2. Dennison BA. Fruit and vegetable intake in young children. *J Am Coll Nutr*. 1998;17:371–378
3. Hoekstra JH, van den Aker JH, Ghoos YF, Hartermink R, Kneepkens

CM. Fluid intake and industrial processing in apple juice induced chronic non-specific diarrhoea. *Arch Dis Child*. 1995;73:126–130

4. Hoekstra JH. Fructose breath hydrogen tests in infants with chronic non-specific diarrhoea. *Eur J Pediatr*. 1995;154:362–364
5. Kneepkens CMF, Hoekstra JH. Fruit juice and chronic nonspecific diarrhea. *J Pediatr*. 1993;122:499
6. Lifshitz F, Ament ME, Kleinman RE, et al. Role of juice carbohydrate malabsorption in chronic nonspecific diarrhea in children. *J Pediatr*. 1992;120:825–829
7. Kneepkens CMF, Jakobs C, Douwes AC. Apple juice, fructose, and chronic nonspecific diarrhoea. *Eur J Pediatr*. 1989;148:571–573
8. Hyams JS, Etienne NL, Leichtner AM, et al. Carbohydrate malabsorption following fruit juice ingestion in young children. *Pediatrics*. 1988;82:64–68
9. Hyams JS, Leichtner AM. Apple juice: an unappreciated cause of chronic diarrhea. *Am J Dis Child*. 1985;139:503–505
10. Nobigrot T, Chasalow FI, Lifshitz F. Carbohydrate absorption from one serving of fruit juice in young children: age and carbohydrate composition effects. *J Am Coll Nutr*. 1997;16:152–158
11. Rumessen JJ, Gudmand-Høyer E. Malabsorption of fructose-sorbitol mixtures: interactions causing abdominal distress. *Scand J Gastroenterol*. 1987;2:431–436
12. Kneepkens CMF, Vonk RJ, Fernandez J. Incomplete intestinal absorption of fructose. *Arch Dis Child*. 1984;59:735–738
13. Fujisawa T, Riby J, Kretchmer N. Intestinal absorption of fructose in the rat. *Gastroenterology*. 1991;101:360–367
14. Levitt MD. Production and excretion of hydrogen gas in man. *N Engl J Med*. 1969;281:122–127
15. Hoekstra JH, van Kempen AAMW, Kneepens CMF. Apple juice malabsorption: fructose or sorbitol? *J Pediatr Gastroenterol Nutr*. 1993;16:39–42
16. Hoekstra JH, van den Aker JHL, Hartemink R, et al. Fruit juice malabsorption: not only fructose. *Acta Paediatr*. 1995;84:1241–1244
17. Perman JA, Modler S, Olson AC. Role of pH in production of hydrogen from carbohydrates by colonic bacterial flora. *J Clin Invest*. 1981;67:643–650
18. Klish WJ. Use of fruit juice in the diets of young children. *Pediatrics*. 1995;95:433
19. MacLean WC Jr, Fink BB, Schoeller DA, Wong W, Klein PD. Lactose assimilation by full-term infants: relation of [^{13}C] and H_2 breath tests with fecal [^{13}C] excretion. *Pediatr Res*. 1983;17:629–633
20. Bond JH, Levitt MD. Use of pulmonary hydrogen measurements to quantitate carbohydrate absorption. *J Clin Invest*. 1972;51:1219–1225
21. Lifshitz F. Weaning foods: the role of fruit juice in the diets of infants and children. *J Am Coll Nutr*. 1996;15:1–3. Supplement
22. Kennedy E, Riddick H, Kramer-LeBlanc C, Davis C. Fruit juice consumption. *Pediatrics*. 1997;100:728–730
23. Skinner JD, Carruth BR, Houck K, et al. Transitions in infant feeding during the first year of life. *J Am Coll Nutr*. 1997;16:209–215
24. Dennison BA. Fruit juice consumption by infants and children: a review. *J Am Coll Nutr*. 1996;15:4–11. Supplement
25. US Department of Agriculture, US Department of Health and Human Services. *The Food Guide Pyramid*. Washington, DC: US Government Printing Office; 1992. Home and Garden Bulletin 252
26. Smith MM, Davis M, Chasalow FI, Lifshitz F. Carbohydrate absorption from fruit juice in young children. *Pediatrics*. 1995;95:340–344
27. Dennison BA, Rockwell HL, Baker SL. Excess fruit juice consumption by preschool-aged children is associated with short stature and obesity. *Pediatrics*. 1997;99:15–22
28. Levine AA. Excessive fruit juice consumption: how can something that causes failure to thrive be associated with obesity? *J Pediatr Gastroenterol Nutr*. 1997;25:554–555
29. Skinner JD, Carruth BR, Moran J III, Houck K, Coletta F. Fruit juice intake is not related to children's growth. *Pediatrics*. 1999;103:58–64
30. Lifschitz CH. Fruit juice. *Pediatrics*. 1995;96:376–377. Letter