

Journal of Clinical Gastroenterology

Issue: Volume 30(2), March 2000, pp 162-169

Copyright: © 2000 Lippincott Williams & Wilkins, Inc.

Publication Type: [Clinical Research]

ISSN: 0192-0790

Accession: 00004836-200003000-00008

Keywords: Gastrointestinal motility, Gastrointestinal transit, Gastric emptying, Electrophysiology, Electrogastrography, Carbohydrate absorption, Grape juice, Fruit juice, Hydrogen breath test

[Clinical Research]

Effect of Gastric Myoelectric Activity on Carbohydrate Absorption of Fruit Juice in Children

Moukartzel, A. A. M.D.; Sabri, M. T. M.D.

Author Information

From the Division of Pediatric Gastroenterology and Nutrition (A.A.M.), SUNY Health Science Center; and the Department of Pediatrics (M.T.S.), Maimonides Medical Center, Brooklyn, New York, U.S.A.

Submitted January 27, 1999. Accepted August 17, 1999.

Address correspondence and reprint requests to Dr. M.T. Sabri, 950 49th Street #10H, Brooklyn, NY 11219, U.S.A.

Abstract

Juices have a different rate of gastric emptying than other foods. This may alter the rate of delivery of carbohydrates to the small bowel for absorption. The aim of the study is to demonstrate that faster gastric emptying is associated with greater production of hydrogen through a randomized, cross-over study of 39 healthy children. The electrogastrography (indicator of the gastric myoelectric activities) and breath hydrogen tests (indicator of carbohydrate malabsorption) were performed at baseline and after ingestion of 240 to 330 mL of grape or pear juice given in a random order. The cutaneous electrogastrogram was analyzed by running spectral analysis to compute pre- and postprandial period dominant power (PDP) and running spectrum total power (RSTP). Postprandial PDP and RSTP were higher ($p < 0.02$) in the pear juice group than in the grape juice group, suggesting higher antral myoelectric activities. Twenty three percent of the subjects had significant movement artifacts that suggested discomfort after drinking pear juice compared to 5% after grape juice ($p < 0.03$). Breath hydrogen test was more frequently positive (increase >20 part per million [ppm] above baseline) after pear juice (52.2%; mean, 36 ± 33 ppm) than after grape juice (4.3%, 6 ± 6 ppm). In a multiple regression analysis, the most predictive independent variable of hydrogen concentration was found to be either postprandial PDP ($r^2 = 0.24$; $p < 0.002$), or RSTP ($r^2 = 0.37$; $p < 0.001$). Juices affect gastric myoelectric activity. Grape juice induces lower antral myoelectric activities and is better absorbed. The malabsorption of carbohydrates of juices is in part related to their effect on the gastric physiology.

Consumption of juice is steadily increasing. Since commercial production of orange juice began fifty years ago, there have been more varieties of fruit juice available and an increase in their consumption. Currently, the juices of choice for infants and toddlers are apple and grape juices. The estimated average intake varies from 150-200 mL/d by one year of age.¹ When consumed in greater quantity, some fruit juices may lead to gastrointestinal complaints because of a partial malabsorption of the carbohydrates present in the juice and their fermentation in the colon.²⁻⁵ Current understanding of absorption of sugars present in fruit juices may be summarized as follows 6-10: A threshold exists in the capacity of the human small bowel to absorb fructose. The absorptive capacity of fructose is dose-dependent unless fructose is combined with other sugars. Dietary fructose, if accompanied by an equivalent amount of glucose, is readily absorbed because of the existence of glucose-dependent fructose cotransport mechanism. In contrast, sorbitol may inhibit fructose absorption. Therefore, malabsorption of certain juices that contain fructose in excess of glucose, such as apple and pear juice, is considered a factor in chronic nonspecific diarrhea and recurrent abdominal pain. In contrast, grape juice that contains equivalent amounts of fructose and glucose without sorbitol is better absorbed.^{1,11}

Although a threshold in the absorption of fructose exists, this threshold seems to vary among individuals and depends on the mode of delivery of the fructose and the subject's age. Using breath hydrogen technique, Ravich et al.,⁶ then Montes et al.,¹² have reported that about 70% of adults malabsorb 50 g of fructose. Other studies 7-9 indicate that 50 g of fructose exceed the absorptive capacity of most adults. In contrast, studies using 25 g of fructose indicate that healthy individuals can fully absorb this amount. However, Rumessen and Guman-Hoyer⁹ have reported subjects who, by breath hydrogen measurements, malabsorb and are symptomatic with less than 25 g of fructose. Hoekstra¹⁰ studied 114 children aged 0.1-6 years. All children given fructose in a dose of 2 g/kg had abnormal peak hydrogen excretion. At 1 g/kg fructose, only 44% showed incomplete absorption. The percentage of incompletely absorbing fructose in the peak hydrogen value was significantly higher in children aged 1-3 years.

Although the amount of fructose contained in some juices may be less than the variable "threshold" reported to be well absorbed, other factors than those listed above may alter the absorption of juice carbohydrates. For instance, it is well known that different juices have different rates of gastric emptying. For carbohydrate beverages, the gastric emptying rate is primarily determined by the volume, the caloric content, and the osmolality of the fluid ingested.¹³ Gastric emptying rates vary among isocaloric beverages of different type (e.g., sucrose, fructose, galactose) or forms (e.g., maltodextrins, starches) of carbohydrate.¹⁴ For instance, gastric emptying is faster for a fructose solution than

for a isocaloric glucose or galactose solution. A maltodextrin or a sucrose solution empties faster than a glucose solution. This is possibly due to the greater inhibitory feedback associated with the introduction of glucose in the duodenum. In addition, fruit juices contain soluble fibers, which modulate furthermore the gastric emptying.¹⁴

One can speculate that if the rate of gastric delivery of the sugars to the small bowel is fast, their absorption by the small bowel may be decreased. What is not absorbed by the small bowel will then be delivered to the colon; the bacteria in the colon ferment the sugars, allowing the production of hydrogen. This speculation has never been addressed before.

The smooth muscle cells of the distal two thirds of the stomach exhibit a cyclic recurrent electric activity that is characterized by regular depolarization of the cellular membranes.^{15,16} Nowadays, cutaneous electrodes attached to the epigastric skin¹⁷ can measure myoelectric activity in the stomach. This noninvasive technique is known as cutaneous electrogastrography (EGG) and is, conceptually, the same technique as the Holter monitor of the heart applied to the stomach. EGGs are reasonably sinusoidal waves recurring at a rate of three cycles per minute (cpm) in humans. This predominant frequency is usually discernible by visual inspection of the signal, but computer analysis is helpful in the qualitative and quantitative study of EGG records. Electrogastrography allows study of the pattern of the electric activity and frequency of the gastric contraction and effect of meal and different conditions on this pattern.

We designed a randomized, double-blinded, crossover study to correlate the EGG pattern, and the carbohydrate absorption (measured by breath hydrogen excretion) of pear juice and white grape juice in 39 healthy children between 23 months and 14 years of age. The aim of the study was to demonstrate that the faster the gastric emptying is associated with more production of hydrogen. Therefore, the malabsorption of carbohydrates in the juices is in part related to their effect on the gastric motility and not only because of the limited ability of the small bowel to absorb. In addition, this study may lead to the description of the baseline values of EGG in normal children.

SUBJECTS AND METHOD

Subjects included in the study were healthy 23-month- to 14-year-old children, with no gastrointestinal, developmental, or nutritional disorders and on no antibiotic treatment. We excluded subjects that had a documented infection of the gastrointestinal tract for the previous six months. After informed consent was obtained, the parents were asked to fill out a questionnaire regarding the child's current and previous juice consumption. They were requested to keep the child fasting (overnight or at least eight hours) before the study and two appointments on two different days were given: one to study the pear juice and the other one, the white grape juice. The juice studied first was randomly assigned and blinded to the subject and the investigator. At each visit, the EGG and breath hydrogen test were performed at baseline and after ingestion of juice. The human subject protection committee approved this study and informed consent was obtained from both legal guardians.

The juices were given at room temperature in 8 oz (240 mL) serving for children less than six years and 11 oz (330 mL) serving for older children. This portion size provided 0.75-1 g/kg body weight fructose and represented the typical serving sizes for children at these ages. The specified amount of juice was consumed within 10 minutes. Because the child had been fasting and the portion sizes were not excessive, there was no problem with finishing of the juice. However, if the child refused to drink at least 75% of the specified amount, or if the time required to ingest the required amount of juice exceeded 10 minutes, he was excluded from the analysis. The investigator recorded accurately the timings of start of feeding, end of feeding, and the amount given.

The electrogastrogram was recorded during the thirty minutes preceding the juice ingestion (preprandial EGG or baseline) till thirty minutes after ingestion of the juice. The skin of the anterior abdominal wall was rubbed with a gel to decrease the resistance of the abdominal wall and hence increase its conductivity. Three electrodes were placed over the abdominal wall: the first over a point midway between the xiphoid process and the umbilicus, the second at the lateral one third of the left hemiabdomen 2 cm below the left costal margin, and the third electrode over the point that form an isolateral triangle with the two other electrodes. The three electrodes were connected to an ambulatory recording device that filters the signal at a frequency range of 0.5-18 cpm and digitizes it at a sampling frequency of 2 Hz (Synectics Medical, Inc., Stockholm, Sweden). Fixation of the electrodes to the abdominal wall was done through nonallergenic tape. Subjects were asked to limit their movements to decrease the artifacts that might arise with movements of the recording device.

Breath hydrogen tests were concomitantly performed before and after drinking the juice. Breath samples were collected in special collection bags before juice intake, then 40, 60, 75, 90, 105, and 120 minutes thereafter. No food or drink was permitted during the testing period. The collected breath samples were analyzed for hydrogen content using the SC Microlyzer (Quintron Instrument Co., Milwaukee, WI, U.S.A.) within four to eight hours of collection.

The second day of testing was scheduled 3-21 days after the initial tests. The same protocol was followed with the other juice.

Data Analysis and Management

All descriptive and analytic tests were performed with SOLO statistical analysis software (BMPD Statistical Software, Inc. Los Angeles, CA). Variance was expressed as standard deviation (SD), or, where indicated, as range of values. The means between the two groups were compared using the paired Student *t* test and the Fisher exact test when appropriate. Stepwise multiple regression analysis was also conducted. All values were considered significant at the $p < 0.05$ level. The minimal number of subjects ($n = 20$) was calculated to our best estimate using the available data to have a power of 95% ($\text{Beta} = 0.05$).

The peak hydrogen concentration was defined as the difference between the fasting hydrogen concentration and the highest hydrogen concentration; the time to peak (minutes) was defined as the time from the beginning of the juice ingestion to the peak hydrogen concentration; and the area under the breath hydrogen curve (ppm/min) was defined from the beginning of the juice ingestion till 120 minutes thereafter. A peak hydrogen concentration >20 ppm above baseline was considered a positive response.

Electrogastrographic recordings were considered to be of good quality if the artifacts were less than 5% of the recording time calculated by visually inspecting the raw EGG signal. Analysis of good quality electrogastrograms was carried out after removal of the artifacts. Thereafter, a running spectral analysis (Gastrosoft Inc., Synectics Medical, Stockholm, Sweden) using a fast fourier transform (FFT) was applied for assessing the frequency content and relative powers of the recorded EGG. Percentage activities of normal gastric slow wave (2-4 cpm), period dominant frequency (PDF), dominant frequency instability coefficient (DFIC), period dominant power (PDP), dominant power instability coefficient (DPIC), and running spectrum total power (RSTP) were computed.

The rationale and complete definition of the EGG analysis have been described elsewhere.¹⁷⁻¹⁹ A simplified explanation and definition of the analyzed EGG variables are provided. The graph in Figure 1 gives an idea of how the frequency and power of the EGG changes over the course of the analyzed periods. The lines in the graph are called "FFT lines." Each of these lines is the result of an FFT analysis of four minutes sixteen seconds of EGG data. There is a one-minute interval between each FFT line. A standard 30-minute pre- or postprandial period will be made up of 27 FFT lines. The highest frequency peaks for each FFT line are named "dominant frequencies." This dominant frequency may be in the normal gastric slow wave region (2-4 cpm), in the region of tachygastria (4-10 cpm), or in the region of bradygastria (0.5-2 cpm). The percentage breakdown of the frequency activity over the given period (30 minutes preprandial and 30 minutes postprandial for each subject during the study of both juices) was computed. The PDF is the mean "dominant frequencies" for a given period. The DFIC is a measure of how much the dominant frequency changes over the course of the period. It is computed by first calculating the mean and standard deviation of the individual dominant frequencies for the period in question. The standard deviation of the dominant frequencies is then divided by the mean of the dominant frequencies to give the DFIC that is reported as percentage. The PDP is the power of the PDF peak. The DPIC is a measure of how much the power of the dominant frequency changes over the course of the period. It is computed by first calculating the mean and standard deviation of the individual dominant frequency powers for the period in question. The standard deviation of the dominant frequency powers is then divided by the mean of the dominant frequency powers to give the DPIC that is reported as a percentage.

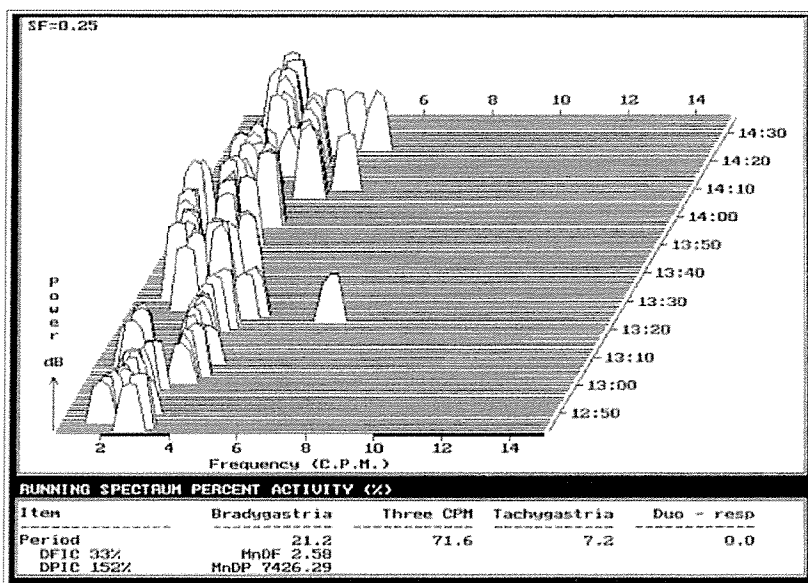


FIG. 1. The pseudo 3-D running spectrum graph and table.

Analysis of the total spectrum of the EGG data accounts for all the frequencies in each FFT line (Fig. 2). A breakdown of the power distribution of the EGG allows computing of the RSTP over the analyzed period in the whole spectrum in the normal gastric slow wave region (2-4 cpm), in the region of tachygastria (4-10 cpm), or in the region of bradygastria (0.5-2 cpm). The total powers are calculated as the sum of the areas under the FFT lines and reported in units of $\mu V^2 \times \text{cpm}$.

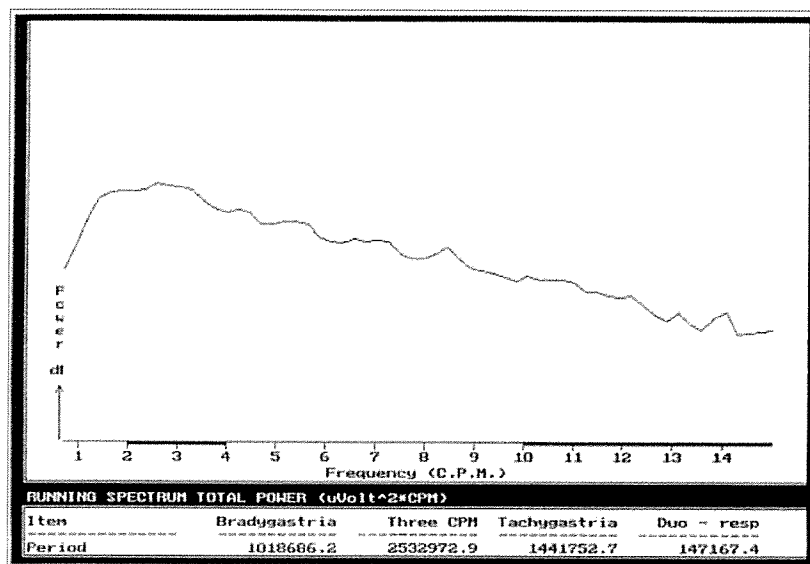


FIG. 2. The 2-D running spectrum total power graph and table.

RESULTS

Thirty-nine subjects completed the study with both juices. Because the application of the breath hydrogen tests in the pediatric population has required the development of a well-tolerated collection system that still requires some cooperation of the child or the toddler, 11, 12 only thirty subjects out of the 39 were tested for the breath hydrogen. Because of antibiotic therapy unrelated to the study protocol at the time of the second appointment, twenty-one did the hydrogen test twice with both juices, six did it once with the white grape juice and three did it once with the pear juice.

The thirty-nine subjects (21 males) were 5.7 ± 3.7 (SD) years. The average weight and height were 24 ± 21 kg and 107 ± 33 cm, respectively. They consumed an average of 268 ± 101 mL of juice each time in 5.8 ± 4.4 minutes. The amount of juice consumed and the drinking time were not different while drinking pear or grape juice.

Good quality electrogastrograms were obtained in 37 subjects while drinking grape juice (2/39 or 5% had artifact more than 5% of the postprandial period) and in 30 subjects while drinking pear juice (9/39 or 23% had artifact more than 5%). The number of good quality EGG recording was significantly lower while the subjects were drinking pear juice ($p = 0.023$ by Fisher exact test). The analysis of the EGG was therefore performed on 27 subjects who drank both juices and had good quality EGG (Table 1).

	Pear juice	Grape juice	p value	Pear juice	Grape juice	p value	Pear juice	Grape juice
	Baseline			Post juice			Baseline/post juice	
Bradygastria (%)	12.3 ± 10.8	8.8 ± 12.6	NS	10.4 ± 11.6	9.5 ± 11.8	NS	NS	NS
2-4 cpm (%)	77.7 ± 14.5	78.3 ± 15.5	NS	81.4 ± 13.2	80.8 ± 16.1	NS	NS	NS
Tachygastria (%)	9.5 ± 10	10.8 ± 10.3	NS	8.2 ± 6.9	9.84 ± 9.84	NS	NS	NS
PDF	2.84 ± 0.86	2.78 ± 0.97	NS	2.64 ± 0.61	2.80 ± 0.55	NS	NS	NS
DFIC	30.6 ± 14.7	33.2 ± 18.4	NS	27.4 ± 12.5	25.3 ± 10.8	NS	0.02	0.02
PDP	868 ± 1279	1841 ± 4720	NS	5141 ± 7517	2016 ± 2408	<0.02	0.01	NS
DPIC	105 ± 63	122 ± 63	NS	92 ± 41	108 ± 54	<0.05	NS	NS
RSTP-BRA	9392 ± 13702	35517 ± 118028	NS	70979 ± 128517	21371 ± 43895	<0.05	0.02	0.02
RSTP 2-4	26296 ± 39481	46953 ± 118028	NS	115048 ± 152109	50098 ± 59999	<0.02	0.005	0.005
RSTP-TAC	20358 ± 26864	30930 ± 63163	NS	78368 ± 95882	35186 ± 44648	<0.02	0.005	0.005
RSTP 0-10	56046 ± 78162	113401 ± 294106	NS	262395 ± 348583	106645 ± 140975	<0.02	0.005	0.005

The mean and standard deviations of the percentage activities of normal gastric slow wave (2-4 cpm), the percentage activities of the bradygastria, the tachygastria, the period dominant frequency (PDF), the dominant frequency instability coefficient (DFIC), the period dominant power (PDP), the dominant power instability coefficient (DPIC), the running spectrum total power in the region of bradygastria (RSTP-BRA), for 2-4 cpm (RSTP 2-4), in the region of tachygastria (RSTP-TAC), or in the whole spectrum (RSTP 0-10) are reported for both juices at baseline and after ingestion of the juice (post juice). The p values obtained by paired Student *t* tests comparing the means of the variables at baseline (column 4), postprandially (column 7), and while comparing the postprandial means to their baseline values for the pear juice (column 8) and for the grape juice (column 9) are given NS, non significant.

TABLE 1. EGG variables for pear juice and white grape juice

At baseline (preprandially), the EGG variables were not significantly different while drinking one or the other juice (paired Student *t* test). The percent activities of normal gastric slow wave (2-4 cpm) and the percent activities of the bradygastria or the tachygastria were not significantly different. No difference was noted in the PDF, the DFIC,

the DPIC, the PDP, or the RSTP in the region of bradygastria (for 2-4 cpm), in the region of tachygastria, or in the whole spectrum.

After ingestion of the juice (postprandial values), the percentage activities of normal gastric slow wave, the bradygastria, and the tachygastria were not significantly different while drinking pear or grape juice. The PDF and the DFIC were not different either. However, the PDP, the RSTP in the region of bradygastria (for 2-4 cpm), in the region of tachygastria, and in the whole spectrum were significantly greater after the subjects drank pear juice compared to grape juice. On the contrary, the DPIC decreased significantly after the subjects drank pear juice.

When comparing the preprandial (baseline) values to the postprandial values for the same juice, the percent activities of normal gastric slow wave, the percent activities of the bradygastria or the tachygastria, the PDF, and the DPIC were not significantly different. However, the RSTP in the region of bradygastria (for 2-4 cpm), in the region of tachygastria, and in the whole spectrum were significantly greater after the subjects drank the pear juice. On the contrary, the DFIC decreased significantly after the subjects drank any of the juice. The PDP increased significantly after ingestion of the pear juice but not after ingestion of the grape juice.

Breath hydrogen tests confirmed the greater excretion of breath hydrogen after ingestion of pear juice compared to grape juice (Table 2). The hydrogen concentrations were significantly greater at 40, 60, 75, 90, 105, and 120 minutes post ingestion of pear juice. The highest breath hydrogen concentration and the peak hydrogen (above baseline) were also significantly greater with the pear juice. Eighteen of the 23 studied children (78%) had a positive breath hydrogen (increase of at least 20 ppm above baseline) while only two of 23 (9%) were positive with the grape juice ($p < 0.00001$). The areas under the breath hydrogen curves showed similar results. The times to peak were not different.

Breath hydrogen values (ppm)	Pear juice n = 23	range	White grape juice n = 23	range	p value
40 min	19.7 ± 19.9	0-78	5.9 ± 5.0	0-17	<0.005
60 min	20.0 ± 19.6	0-94	7.8 ± 5.3	2-23	<0.01
75 min	26.8 ± 30.4	1-137	7.1 ± 4.4	0-16	<0.005
90 min	25.0 ± 24.6	0-85	8.1 ± 4.7	1-17	<0.005
105 min	36.5 ± 25.4	4-81	9.6 ± 5.5	0-22	<0.0001
120 min	33.5 ± 24.7	3-102	9.7 ± 4.9	3-19	<0.0002
Highest hydrogen	47.0 ± 33.2	6-137	13.4 ± 4.6	7-23	<0.0001
No. with highest hydrogen >20, ppm (%)	n = 18, 78.3%		n = 2, 8.7%		<0.0001
Peak hydrogen	35.6 ± 33.2	0-123	6.1 ± 6.0	0-20	<0.0005
No. with peak hydrogen >20, ppm (%)	n = 12, 52.2%		n = 1, 4.3%		<0.0005

Breath hydrogen values in ppm (mean ± SD and range) at different times, the highest hydrogen value, the peak hydrogen (defined as the difference between the fasting hydrogen concentration and the highest hydrogen concentration), and the number and the percentage of subjects with the highest hydrogen value and the peak hydrogen greater than 20 ppm are given with the p value of the paired Student t test.

TABLE 2. No caption available.

Of note, the increase of breath hydrogen correlated with the postprandial PDP ($r = 0.49$; $p < 0.002$), or postprandial RSTP bradygastria ($r = 0.60$; $p < 0.0001$).

In a stepwise multiple regression analysis, where the dependent variable is the peak hydrogen concentration, the most predictive independent variable was found to be the kind of juice ($r^2 = 0.25$; $p < 0.05$). If the discrete variable kind of juice is not included, then the most predictive variable for the peak hydrogen concentration is either postprandial PDP ($r^2 = 0.24$; $p < 0.002$), or postprandial RSTP bradygastria ($r^2 = 0.37$; $p < 0.0001$). Of note, taking more than one predictive variable does not significantly increase the confidence of the prediction.

DISCUSSION

Methods to measure the gastric mechanical function vary from invasive to noninvasive.¹⁴ Invasive methods may involve intubation and fixation of certain electrodes through the gastric walls that might alter the recording of the myoelectric activity and thus the gastric physiology. Scintigraphy and CAT scan expose the subject to a radiation load. Real-time ultra sonography though a valid technique lacks the power to assess the quality and the quantity of the normal 3 cpm that are effective to empty the stomach content. Electrogastrography is feasible in children, easy to perform, noninvasive, reproducible, and accurate. This study shows that it can be performed easily in children of variable age with no side effects. Its limitation is the movement artifact. The child needs to be relatively still during at least 30 minutes pre- then post-prandially. In this study 5 and 23% of children in the two groups failed to stay completely still for an appropriate, almost artifact-free recording. Our criteria for this research protocol were tight because we wanted to detect small qualitative differences among juices in healthy children. In clinical practice, more artifacts may not jeopardize the interpretation of the recording because the question would be more qualitative as to whether or not the EGG is abnormal suggesting an abnormal gastric activity.^{18,20} In addition, the EGG recording could

be repeated if the artifacts were frequent. Electrogastrography detects the quality as well as the quantity of the gastric electromyogenic activities that generates the gastric contractions and thereafter the gastric emptying.²¹ To our knowledge, this is the first study repeating, within three weeks in the same child, the baseline recording of the EGG and obtaining the same values proving the reproducibility of this method.

This study performed on normal children reports the normal EGG variables at baseline, variables that can be used to check if a child has a normal EGG fasting activity. In addition, the variations after a carbohydrate drink in normal children are reported. We conclude that in a normal child, the DFIC should decrease postprandially while the RSTP in the 2-4 cpm region should increase. This means that, postprandially, the dominant frequency should be more gathered around its mean value while its power should significantly increase (the antrum contracts more often 3 cpm and at a higher power). If the DFIC or the RSTP does not change in this manner, an abnormal EGG activity is concluded. This is not different from the EGG pattern reported in adults. Chen and McCallum¹⁹ and You et al.²⁰ independently reported that, in the normal adults, both EGG power and frequency are significantly lower and less stable throughout periods of motor activity than they are during motor quiescence. After eating, the EGG frequency tends to decrease from the baseline for a short period, subsequently rising gradually above the baseline. In addition, it appears that 3 cpm waves are strong and effective in emptying the stomach content.^{18,21}

While subjects' EGG behave normally after ingestion of both juices, the variables related to the power of the antral contraction (RSTP) increased significantly more after ingestion of the pear juice. This demonstrates higher myoelectric activity induced by the pear juice and possibly faster gastric emptying of the pear juice compared to the grape juice.

This finding might be explained by the higher osmotic pressure of the ingested fluid, which slows down the gastric emptying. The higher osmolality of the grape juice (1030 mOsm/L) compared to the pear juice (638 mOsm/L) will, therefore, explain the faster emptying of the latter. Foster et al.²² assessed the gastric emptying rates of isocaloric glucose and maltodextrin solutions. The authors reported that the 5% maltodextrin solution emptied faster than the isocaloric 5% glucose solution that is more osmolar. The influence of beverage osmolality on gastric emptying was also assessed by Sole and Noakes,²³ who measured the gastric emptying rates of a variety of carbohydrate solutions, including 15% solutions of glucose, fructose, and maltodextrin. The 15% fructose (9.5 mL/min) and maltodextrin (10 mL/min) solutions emptied significantly faster than the 15% glucose solution (5.7 mL/min). The rate at which the stomach empties into the duodenum depends on the osmotic pressure of the material entering the duodenum, sensed by "duodenal osmoreceptors."²⁴

In addition, another determinant of gastric emptying rate is the caloric content of the ingested juice.^{25,26} Some investigators²⁷⁻²⁹ have reported that solutions containing more than 2.5% carbohydrate tend to empty from the stomach more slowly than do water or dilute saline solutions. Naveri et al.³⁰ used radionuclide techniques to measure the gastric emptying characteristics of four carbohydrate solutions, including 3% glucose solution and 3%, 5%, and 10% maltodextrin solutions (mean chain length, 8 glucose units). The gastric emptying rates of the 3% glucose and 3% maltodextrin solutions were similar, while the 5% and 10% maltodextrin solutions slowed gastric emptying in proportion to their caloric contents. The authors concluded that the amount of carbohydrate ingested is a far more important determinant of gastric emptying than is the osmolality or type of carbohydrate ingested. This finding is consistent with the prevailing notion that the introduction of calories into the proximal small intestine inhibits gastric emptying.²⁵ Therefore, the grape juice containing more calories leaves the stomach slower than the pear juice that contains fewer calories.

Some authors^{22,23,28,31} have reported differences in gastric emptying rates among isocaloric drinks of varying carbohydrate type. Murray et al.³¹ assessed the gastric emptying rates of water and four isocaloric carbohydrate solutions in resting subjects. On five occasions, subjects ingested 400 mL of water or 6% solutions of glucose, sucrose, maltodextrin, and sucrose + glucose. The glucose and maltodextrin beverages exhibited significantly slower emptying characteristics; there were no differences in this measure among water, sucrose, and sucrose + glucose. They speculated that the slower gastric emptying associated with the glucose and maltodextrin solutions occurred because these fluids were composed of 100% glucose. The lower total glucose content of the sucrose and sucrose + glucose treatments may have induced a more rapid gastric emptying rates by reducing the overall inhibitory feedback from the small intestine that is associated with the introduction of glucose into the intestinal lumen.³² In addition, the presence of fructose may augment gastric emptying. Elias et al.²⁶ reported slightly faster gastric emptying for a 100% fructose solution compared with isocaloric glucose and galactose solutions. Therefore, the grape juice that contains three times more glucose than the pear juice with a similar amount of fructose should empty slower. This is concordant with the results reported herein.

The greater excretion of breath hydrogen after ingestion of pear juice compared to grape juice has already been reported by others.^{1,2,7,11} This has been previously attributed not only to the sorbitol contained in pear juice but also to its higher fructose to glucose ratio (Table 3). This higher fructose to glucose ratio also explains the higher production of breath hydrogen in the apple juice. Fructose and glucose are present in equimolar concentration with little sorbitol in the grape juice, making this juice almost completely absorbed.

Juice	Fructose	Glucose	Sucrose	Sorbitol
Apple	6.2	2.7	1.2	0.5
Pear	6.4	2.3	0.9	2.0
White grape	7.5	7.1	0.0	0.0
Orange	2.4	2.4	4.7	0.0

Modified from Hyams et al.¹¹ and Hardinge et al.³³

TABLE 3. Carbohydrate (in gm/100 mL) content of fruit juices

This is the first report in the literature of a significant correlation between the EGG variables related to the gastric activity and the rate of breath hydrogen production. The stronger the antral contraction, the greater the production of hydrogen. If the rate of gastric delivery of the pear juice to the small bowel is fast, its absorption by the small bowel decreases. What is not absorbed by the small bowel will then be delivered to the colon; the bacteria in the colon ferment the carbohydrates, allowing the production of hydrogen. The slow delivery of the grape juice to the small bowel allows a longer contact time leading to a more complete absorption without fermentation. In this study, 24-37% of the variability of the breath hydrogen production is explained by the variations in gastric activity ($r^2 = 0.24-0.37$ in the regression analysis). This denotes that the stomach physiology is another factor that can influence the breath hydrogen production other than the difference in the fructose to glucose ratio or the juice content of sorbitol. One can argue that this significant statistical association could be casual and not causal. Another way to demonstrate this conclusion would have required mimicking the rate of grape juice entrance into the small bowel by administering the pear juice as a slow constant infusion and show that carbohydrate malabsorption is lower. Of course, this would have required an invasive technique and thus not have been carried out in young children. But, it is certainly possible in adult volunteers. The problem is that adults may tolerate juices better than children. We are currently planning to administer two solutions of similar carbohydrate composition with different osmolalities reproducing those of the fruit juices and also two solutions with similar osmolality with carbohydrate composition mimicking those found in the fruit juices.

If partial juice malabsorption has been implicated in a number of entities, including chronic nonspecific diarrhea in children, toddler diarrhea, and recurrent abdominal pain,²⁻⁵ none of the studied subjects reported diarrhea or pain after ingesting one serving of juice. Although not included in the study design, there was a statistically significant difference in the number of movement artifact in the postprandial EGG recording. Five percent of the subjects had significant artifact after drinking grape juice compared to twenty-three percent after pear juice ($p = 0.023$). If movements occurring after juice consumption are assumed to be from discomfort related to the partial malabsorption, then pear juice induced more discomfort than grape juice. In another way, if more relaxation and fewer movements accompany the satiety or absence of discomfort, grape juice was more tolerated than pear juice. It could be speculated that because gastric emptying was slower with grape juice the subjects felt fuller for a longer time and, thus, less hungry and less fidgety and, therefore, moved less creating less artifact than when they ingested the pear juice. In addition, satiety would have been greater following ingestion of grape juice as this stayed in the stomach for a longer time.

Future studies should aim at studying how these juices affect gastric emptying. Is it achieved by way of their different composition in carbohydrate, their different caloric content, their different osmolality, or by the induction of different amount of gastric secretion? Does the type (glucose, sucrose, fructose) or form (e.g., maltodextrin, starches) of the carbohydrate play a major role? Fruit juices contain soluble fibers that modulate furthermore the gastric emptying. What is the role of manufacturing of the juice, its filtration, the modification of the physical properties, and the amount of the fibers? Is the difference in hydrogen production among different juices partially explained by the difference in gastric emptying alone or in association with a difference in the small bowel transit time? How can we modulate some of the properties of these juices to improve their absorption?

In summary, white grape juice is associated with fewer movement artifacts, lower gastric myoelectric activities, more absorption, and less hydrogen production than pear juice. The stomach seems to modulate the amount of carbohydrates malabsorbed from fruit juices.

Acknowledgment: This study was underwritten by a clinical grant from Welsh's (Concord, MA, U.S.A.).

REFERENCES

1. Smith MM, Davis M, Chasalow FI, Lifshitz F. Carbohydrate absorption from fruit juice in young children. *Pediatrics* 1995;95:340-4. SFX | [Context Link]

2. Hyams JS, Leichtner AM. Apple juice: an unappreciated cause of chronic diarrhea. *Am J Dis Child* 1985;139:503-5. [SFX](#) | [\[Context Link\]](#)
3. Smith MM, Lifshitz F. Excess fruit juice consumption as a contributing factor in nonorganic failure to thrive. *Pediatrics* 1994;93:438-43. [SFX](#) | [\[Context Link\]](#)
4. Dennison BA, Rockwell HL, Baker SL. Excess fruit juice consumption by preschool aged children is associated with short stature and obesity. *Pediatrics* 1999;99:15-22. [\[Context Link\]](#)
5. Rumessen JJ, Gudman-Hoyer E. Malabsorption of fructose-sorbitol mixtures. Interaction causing abdominal distress. *Scand J Gastroenterol* 1987;22:431-6. [SFX](#) | [\[Context Link\]](#)
6. Ravish WJ, Bayless TM, Thomas M. Fructose limited intestinal absorption in man. *Gastroenterology* 1983;84:26-9. [SFX](#) | [\[Context Link\]](#)
7. Kneepkens CMF, Vonk RJ, Fernandes J. Incomplete intestinal absorption of fructose. *Arch Dis Child* 1984;59:735-8. [SFX](#) | [\[Context Link\]](#)
8. Truswell AS, Seach JM, Thorburn AW. Incomplete absorption of pure fructose in healthy subjects and the facilitating effect of glucose. *Am J Clin Nutr* 1988;48:1424-30. [SFX](#) | [\[Context Link\]](#)
9. Rumessen JJ, Gudman-Hoyer E. Absorption capacity of fructose in healthy adults. Comparison with sucrose and its constituent monosaccharides. *Gut* 1986;27:1161-8. [SFX](#) | [\[Context Link\]](#)
10. Hoekstra JH, Van Kemper AAMW, Bijl SB, Kneepkens CMF. Fructose breath hydrogen tests. *Arch Dis Child* 1993;68:136-8. [\[Context Link\]](#)
11. Hyams JS, Etienne NL, Leichtner AM, Theuer RC. Carbohydrate malabsorption following fruit juice ingestion in young children. *Pediatrics* 1988;82:64-8. [SFX](#) | [\[Context Link\]](#)
12. Montes RG, Gottal RF, Bayless TM, Hendrix TR, Perman JA. Special communication: breath hydrogen testing as a laboratory exercise in gastrointestinal physiology for first year medical students. *Am J Physiol* 1992;262:525-8. [SFX](#) | [\[Context Link\]](#)
13. Moore JG, Christian PE, Brown JA, et al. Influence of meal weight and caloric contents on gastric emptying of meals in man. *Dig Dis Sci* 1984;29:513-20. [SFX](#) | [\[Context Link\]](#)
14. Moukarzel AA, Sabri MT. Gastric physiology and function: effects of fruit juices. *J Am Coll Nutr* 1996;15(suppl):18-25. [SFX](#) | [\[Context Link\]](#)
15. Cullen JJ, Kelly KA. Gastric motor physiology and pathophysiology. *Surg Clin North Am* 1993;73:1145-60. [SFX](#) | [\[Context Link\]](#)
16. Bauer AJ, Publicover MJ, Sanders KM. Origin and spread of slow waves in canine gastric antral circular muscle. *Am J Physiol* 1985;249:4800-6. [SFX](#) | [\[Context Link\]](#)
17. Abell TL, Malagelada JR. Electrogastrography: current assessment and future perspective. *Dig Dis Sci* 1988;83:806-11. [SFX](#) | [\[Context Link\]](#)
18. Chen J, McCallum RW. Frequency components of the electrogastrogram and their correlations with gastrointestinal motility. *Med Biol Eng Comput* 1993;31:60-6. [SFX](#) | [\[Context Link\]](#)
19. Chen J, McCallum RW. Electrogastrogram: measurement, analysis, and prospective applications. *Med Biol Eng Comput* 1991;29:339-50. [SFX](#) | [\[Context Link\]](#)

20. You CH, Chey WY, Lee KY, Menguy Y, Bortoff A. Gastric and small intestinal myoelectrical dysrhythmias associated with chronic intractable nausea and vomiting. *Ann Intern Med* 1981;95:449-51. [SFX](#) | [\[Context Link\]](#)
21. Van Der Schee ET, Grashuis JL. Contraction related, low-frequency components in canine electrogastrographic signals. *Am J Physiol* 1983;245:470-5. [SFX](#) | [\[Context Link\]](#)
22. Foster C, Costill D, Fink W. Gastric emptying characteristics of glucose and glucose polymers solutions. *Res Q* 1980;51:299-305. [SFX](#) | [\[Context Link\]](#)
23. Sole C, Noakes T. Faster gastric emptying for glucose-polymer and fructose solutions than for glucose in humans. *Eur J Appl Physiol* 1989;58:605-12. [SFX](#) | [\[Context Link\]](#)
24. Hunt JN, Knox MT. Regulation of gastric emptying. In: Code CF, ed. *Handbook of physiology: sec. 6. alimentary canal*, vol. 4. Washington, D.C.: American Physiological Society, 1968:1917-36. [\[Context Link\]](#)
25. Hunt JN, Smith JL, Jian CL. Effect of meal volume and energy density on the gastric emptying of carbohydrates. *Gastroenterology* 1985;89:1326-30. [SFX](#) | [\[Context Link\]](#)
26. Elias E, Gibson G, Greenwood L, Hunt J, Tripp J. The slowing of gastric emptying by monosaccharides in test meals. *J Physiol* 1968;194:317-26. [\[Context Link\]](#)
27. Houmard J, Egan P, Johns R, Neuffer P, Chenier T, Israel R. Gastric emptying during 1 h of cycling and running at 75% VO 2 max. *Med Sci Sports Exerc* 1991;23:320-5. [Ovid Full Text](#) | [\[Context Link\]](#)
28. Rehner N, Beckers E, Brouns F, Ten Hoor F, Saris W. Exercise and training effects on gastric emptying of carbohydrate beverages. *Med Sci Sports Exerc* 1989;21:540-9. [Ovid Full Text](#) | [\[Context Link\]](#)
29. Mitchell J, Costill D, Houmard J, Fink W, Robergs R, Davis J. Gastric emptying: influence of prolonged exercise and carbohydrate concentration. *Med Sci Sports Exerc* 1989;21:269-74. [Ovid Full Text](#) | [\[Context Link\]](#)
30. Naveri H, Tikkanen H, Kairento A, Harkonen M. Gastric emptying and serum insulin levels after intake of glucose-polymer solutions. *Eur J Appl Physiol* 1989;58:661-65. [SFX](#) | [\[Context Link\]](#)
31. Murray EE, Bartoli WP, Paul JL. Gastric emptying of water and isocaloric carbohydrate solutions consumed at rest. *Med Sci Sports Exerc* 1994;26:725-32. [Ovid Full Text](#) | [\[Context Link\]](#)
32. Lin HC, Elashoff JD, Gu YG, Meyer JH. Nutrient feedback inhibition of gastric emptying plays a larger role than osmotically dependent duodenal resistance. *Am J Physiol* 1993;28(Gastrointest Liver Physiol):G672-6. [\[Context Link\]](#)
33. Hardinge MG, Swarner JB, Crooks H. Carbohydrates in foods. *J Am Diet Assoc* 1965;46:197-204.

Key Words: Gastrointestinal motility; Gastrointestinal transit; Gastric emptying; Electrophysiology; Electrogastrography; Carbohydrate absorption; Grape juice; Fruit juice; Hydrogen breath test

IMAGE GALLERY

[Select All](#)



[Export Selected to PowerPoint](#)



Table 2



Table 3

Juice	Fructose	Glucose	Sucrose	Sorbitol
Apple	6.2	2.7	1.2	0.5
Pear	6.4	2.3	0.9	2.0
White grape	7.5	7.1	0.0	0.0
Orange	2.4	2.4	4.7	0.0

Modified from Hovms et al.¹¹ and Hantson et al.²⁰

Table 3

	Net area	Eng area	Volume	Max. dia.	Maximum	Area	Perimeter
	Mean			Mid point			
Engage 10	10.3 ± 0.2	10.2 ± 0.2	10.1	10.2 ± 0.2	10.1 ± 0.1	10.1	10.1
10.2 ± 0.2	10.2 ± 0.2	10.2 ± 0.2	10.2	10.2 ± 0.2	10.2 ± 0.1	10.2	10.2
10.3 ± 0.2	10.3 ± 0.2	10.3 ± 0.2	10.3	10.3 ± 0.2	10.3 ± 0.1	10.3	10.3
10.4 ± 0.2	10.4 ± 0.2	10.4 ± 0.2	10.4	10.4 ± 0.2	10.4 ± 0.1	10.4	10.4
10.5 ± 0.2	10.5 ± 0.2	10.5 ± 0.2	10.5	10.5 ± 0.2	10.5 ± 0.1	10.5	10.5
10.6 ± 0.2	10.6 ± 0.2	10.6 ± 0.2	10.6	10.6 ± 0.2	10.6 ± 0.1	10.6	10.6
10.7 ± 0.2	10.7 ± 0.2	10.7 ± 0.2	10.7	10.7 ± 0.2	10.7 ± 0.1	10.7	10.7
10.8 ± 0.2	10.8 ± 0.2	10.8 ± 0.2	10.8	10.8 ± 0.2	10.8 ± 0.1	10.8	10.8
10.9 ± 0.2	10.9 ± 0.2	10.9 ± 0.2	10.9	10.9 ± 0.2	10.9 ± 0.1	10.9	10.9
11.0 ± 0.2	11.0 ± 0.2	11.0 ± 0.2	11.0	11.0 ± 0.2	11.0 ± 0.1	11.0	11.0
11.1 ± 0.2	11.1 ± 0.2	11.1 ± 0.2	11.1	11.1 ± 0.2	11.1 ± 0.1	11.1	11.1
11.2 ± 0.2	11.2 ± 0.2	11.2 ± 0.2	11.2	11.2 ± 0.2	11.2 ± 0.1	11.2	11.2
11.3 ± 0.2	11.3 ± 0.2	11.3 ± 0.2	11.3	11.3 ± 0.2	11.3 ± 0.1	11.3	11.3
11.4 ± 0.2	11.4 ± 0.2	11.4 ± 0.2	11.4	11.4 ± 0.2	11.4 ± 0.1	11.4	11.4
11.5 ± 0.2	11.5 ± 0.2	11.5 ± 0.2	11.5	11.5 ± 0.2	11.5 ± 0.1	11.5	11.5
11.6 ± 0.2	11.6 ± 0.2	11.6 ± 0.2	11.6	11.6 ± 0.2	11.6 ± 0.1	11.6	11.6
11.7 ± 0.2	11.7 ± 0.2	11.7 ± 0.2	11.7	11.7 ± 0.2	11.7 ± 0.1	11.7	11.7
11.8 ± 0.2	11.8 ± 0.2	11.8 ± 0.2	11.8	11.8 ± 0.2	11.8 ± 0.1	11.8	11.8
11.9 ± 0.2	11.9 ± 0.2	11.9 ± 0.2	11.9	11.9 ± 0.2	11.9 ± 0.1	11.9	11.9
12.0 ± 0.2	12.0 ± 0.2	12.0 ± 0.2	12.0	12.0 ± 0.2	12.0 ± 0.1	12.0	12.0
12.1 ± 0.2	12.1 ± 0.2	12.1 ± 0.2	12.1	12.1 ± 0.2	12.1 ± 0.1	12.1	12.1
12.2 ± 0.2	12.2 ± 0.2	12.2 ± 0.2	12.2	12.2 ± 0.2	12.2 ± 0.1	12.2	12.2
12.3 ± 0.2	12.3 ± 0.2	12.3 ± 0.2	12.3	12.3 ± 0.2	12.3 ± 0.1	12.3	12.3
12.4 ± 0.2	12.4 ± 0.2	12.4 ± 0.2	12.4	12.4 ± 0.2	12.4 ± 0.1	12.4	12.4
12.5 ± 0.2	12.5 ± 0.2	12.5 ± 0.2	12.5	12.5 ± 0.2	12.5 ± 0.1	12.5	12.5
12.6 ± 0.2	12.6 ± 0.2	12.6 ± 0.2	12.6	12.6 ± 0.2	12.6 ± 0.1	12.6	12.6
12.7 ± 0.2	12.7 ± 0.2	12.7 ± 0.2	12.7	12.7 ± 0.2	12.7 ± 0.1	12.7	12.7
12.8 ± 0.2	12.8 ± 0.2	12.8 ± 0.2	12.8	12.8 ± 0.2	12.8 ± 0.1	12.8	12.8
12.9 ± 0.2	12.9 ± 0.2	12.9 ± 0.2	12.9	12.9 ± 0.2	12.9 ± 0.1	12.9	12.9
13.0 ± 0.2	13.0 ± 0.2	13.0 ± 0.2	13.0	13.0 ± 0.2	13.0 ± 0.1	13.0	13.0
13.1 ± 0.2	13.1 ± 0.2	13.1 ± 0.2	13.1	13.1 ± 0.2	13.1 ± 0.1	13.1	13.1
13.2 ± 0.2	13.2 ± 0.2	13.2 ± 0.2	13.2	13.2 ± 0.2	13.2 ± 0.1	13.2	13.2
13.3 ± 0.2	13.3 ± 0.2	13.3 ± 0.2	13.3	13.3 ± 0.2	13.3 ± 0.1	13.3	13.3
13.4 ± 0.2	13.4 ± 0.2	13.4 ± 0.2	13.4	13.4 ± 0.2	13.4 ± 0.1	13.4	13.4
13.5 ± 0.2	13.5 ± 0.2	13.5 ± 0.2	13.5	13.5 ± 0.2	13.5 ± 0.1	13.5	13.5
13.6 ± 0.2	13.6 ± 0.2	13.6 ± 0.2	13.6	13.6 ± 0.2	13.6 ± 0.1	13.6	13.6
13.7 ± 0.2	13.7 ± 0.2	13.7 ± 0.2	13.7	13.7 ± 0.2	13.7 ± 0.1	13.7	13.7
13.8 ± 0.2	13.8 ± 0.2	13.8 ± 0.2	13.8	13.8 ± 0.2	13.8 ± 0.1	13.8	13.8
13.9 ± 0.2	13.9 ± 0.2	13.9 ± 0.2	13.9	13.9 ± 0.2	13.9 ± 0.1	13.9	13.9
14.0 ± 0.2	14.0 ± 0.2	14.0 ± 0.2	14.0	14.0 ± 0.2	14.0 ± 0.1	14.0	14.0
14.1 ± 0.2	14.1 ± 0.2	14.1 ± 0.2	14.1	14.1 ± 0.2	14.1 ± 0.1	14.1	14.1
14.2 ± 0.2	14.2 ± 0.2	14.2 ± 0.2	14.2	14.2 ± 0.2	14.2 ± 0.1	14.2	14.2
14.3 ± 0.2	14.3 ± 0.2	14.3 ± 0.2	14.3	14.3 ± 0.2	14.3 ± 0.1	14.3	14.3
14.4 ± 0.2	14.4 ± 0.2	14.4 ± 0.2	14.4	14.4 ± 0.2	14.4 ± 0.1	14.4	14.4
14.5 ± 0.2	14.5 ± 0.2	14.5 ± 0.2	14.5	14.5 ± 0.2	14.5 ± 0.1	14.5	14.5
14.6 ± 0.2	14.6 ± 0.2	14.6 ± 0.2	14.6	14.6 ± 0.2	14.6 ± 0.1	14.6	14.6
14.7 ± 0.2	14.7 ± 0.2	14.7 ± 0.2	14.7	14.7 ± 0.2	14.7 ± 0.1	14.7	14.7
14.8 ± 0.2	14.8 ± 0.2	14.8 ± 0.2	14.8	14.8 ± 0.2	14.8 ± 0.1	14.8	14.8
14.9 ± 0.2	14.9 ± 0.2	14.9 ± 0.2	14.9	14.9 ± 0.2	14.9 ± 0.1	14.9	14.9
15.0 ± 0.2	15.0 ± 0.2	15.0 ± 0.2	15.0	15.0 ± 0.2	15.0 ± 0.1	15.0	15.0
15.1 ± 0.2	15.1 ± 0.2	15.1 ± 0.2	15.1	15.1 ± 0.2	15.1 ± 0.1	15.1	15.1
15.2 ± 0.2	15.2 ± 0.2	15.2 ± 0.2	15.2	15.2 ± 0.2	15.2 ± 0.1	15.2	15.2
15.3 ± 0.2	15.3 ± 0.2	15.3 ± 0.2	15.3	15.3 ± 0.2	15.3 ± 0.1	15.3	15.3
15.4 ± 0.2	15.4 ± 0.2	15.4 ± 0.2	15.4	15.4 ± 0.2	15.4 ± 0.1	15.4	15.4
15.5 ± 0.2	15.5 ± 0.2	15.5 ± 0.2	15.5	15.5 ± 0.2	15.5 ± 0.1	15.5	15.5
15.6 ± 0.2	15.6 ± 0.2	15.6 ± 0.2	15.6	15.6 ± 0.2	15.6 ± 0.1	15.6	15.6
15.7 ± 0.2	15.7 ± 0.2	15.7 ± 0.2	15.7	15.7 ± 0.2	15.7 ± 0.1	15.7	15.7
15.8 ± 0.2	15.8 ± 0.2	15.8 ± 0.2	15.8	15.8 ± 0.2	15.8 ± 0.1	15.8	15.8
15.9 ± 0.2	15.9 ± 0.2	15.9 ± 0.2	15.9	15.9 ± 0.2	15.9 ± 0.1	15.9	15.9
16.0 ± 0.2	16.0 ± 0.2	16.0 ± 0.2	16.0	16.0 ± 0.2	16.0 ± 0.1	16.0	16.0
16.1 ± 0.2	16.1 ± 0.2	16.1 ± 0.2	16.1	16.1 ± 0.2	16.1 ± 0.1	16.1	16.1
16.2 ± 0.2	16.2 ± 0.2	16.2 ± 0.2	16.2	16.2 ± 0.2	16.2 ± 0.1	16.2	16.2
16.3 ± 0.2	16.3 ± 0.2	16.3 ± 0.2	16.3	16.3 ± 0.2	16.3 ± 0.1	16.3	16.3
16.4 ± 0.2	16.4 ± 0.2	16.4 ± 0.2	16.4	16.4 ± 0.2	16.4 ± 0.1	16.4	16.4
16.5 ± 0.2	16.5 ± 0.2	16.5 ± 0.2	16.5	16.5 ± 0.2	16.5 ± 0.1	16.5	16.5
16.6 ± 0.2	16.6 ± 0.2	16.6 ± 0.2	16.6	16.6 ± 0.2	16.6 ± 0.1	16.6	16.6
16.7 ± 0.2	16.7 ± 0.2	16.7 ± 0.2	16.7	16.7 ± 0.2	16.7 ± 0.1	16.7	16.7
16.8 ± 0.2	16.8 ± 0.2	16.8 ± 0.2	16.8	16.8 ± 0.2	16.8 ± 0.1	16.8	16.8
16.9 ± 0.2	16.9 ± 0.2	16.9 ± 0.2	16.9	16.9 ± 0.2	16.9 ± 0.1	16.9	16.9
17.0 ± 0.2	17.0 ± 0.2	17.0 ± 0.2	17.0	17.0 ± 0.2	17.0 ± 0.1	17.0	17.0
17.1 ± 0.2	17.1 ± 0.2	17.1 ± 0.2	17.1	17.1 ± 0.2	17.1 ± 0.1	17.1	17.1
17.2 ± 0.2	17.2 ± 0.2	17.2 ± 0.2	17.2	17.2 ± 0.2	17.2 ± 0.1	17.2	17.2
17.3 ± 0.2	17.3 ± 0.2	17.3 ± 0.2	17.3	17.3 ± 0.2	17.3 ± 0.1	17.3	17.3
17.4 ± 0.2	17.4 ± 0.2	17.4 ± 0.2	17.4	17.4 ± 0.2	17.4 ± 0.1	17.4	17.4
17.5 ± 0.2	17.5 ± 0.2	17.5 ± 0.2	17.5	17.5 ± 0.2	17.5 ± 0.1	17.5	17.5
17.6 ± 0.2	17.6 ± 0.2	17.6 ± 0.2	17.6	17.6 ± 0.2	17.6 ± 0.1	17.6	17.6
17.7 ± 0.2	17.7 ± 0.2	17.7 ± 0.2	17.7	17.7 ± 0.2	17.7 ± 0.1	17.7	17.7
17.8 ± 0.2	17.8 ± 0.2	17.8 ± 0.2	17.8	17.8 ± 0.2	17.8 ± 0.1	17.8	17.8
17.9 ± 0.2	17.9 ± 0.2	17.9 ± 0.2	17.9	17.9 ± 0.2	17.9 ± 0.1	17.9	17.9
18.0 ± 0.2	18.0 ± 0.2	18.0 ± 0.2	18.0	18.0 ± 0.2	18.0 ± 0.1	18.0	18.0
18.1 ± 0.2	18.1 ± 0.2	18.1 ± 0.2	18.1	18.1 ± 0.2	18.1 ± 0.1	18.1	18.1
18.2 ± 0.2	18.2 ± 0.2	18.2 ± 0.2	18.2	18.2 ± 0.2	18.2 ± 0.1	18.2	18.2
18.3 ± 0.2	18.3 ± 0.2	18.3 ± 0.2	18.3	18.3 ± 0.2	18.3 ± 0.1	18.3	18.3
18.4 ± 0.2	18.4 ± 0.2	18.4 ± 0.2	18.4	18.4 ± 0.2	18.4 ± 0.1	18.4	18.4
18.5 ± 0.2	18.5 ± 0.2	18.5 ± 0.2	18.5	18.5 ± 0.2	18.5 ± 0.1	18.5	18.5
18.6 ± 0.2	18.6 ± 0.2	18.6 ± 0.2	18.6	18.6 ± 0.2	18.6 ± 0.1	18.6	18.6
18.7 ± 0.2	18.7 ± 0.2	18.7 ± 0.2	18.7	18.7 ± 0.2	18.7 ± 0.1	18.7	18.7
18.8 ± 0.2	18.8 ± 0.2	18.8 ± 0.2	18.8	18.8 ± 0.2	18.8 ± 0.1	18.8	18.8
18.9 ± 0.2	18.9 ± 0.2	18.9 ± 0.2	18.9	18.9 ± 0.2	18.9 ± 0.1	18.9	18.9
19.0 ± 0.2	19.0 ± 0.2	19.0 ± 0.2	19.0	19.0 ± 0.2	19.0 ± 0.1	19.0	19.0
19.1 ± 0.2	19.1 ± 0.2	19.1 ± 0.2	19.1	19.1 ± 0.2	19.1 ± 0.1	19.1	19.1
19.2 ± 0.2	19.2 ± 0.2	19.2 ± 0.2	19.2	19.2 ± 0.2	19.2 ± 0.1	19.2	19.2
19.3 ± 0.2	19.3 ± 0.2	19.3 ± 0.2	19.3	19.3 ± 0.2	19.3 ± 0.1	19.3	19.3
19.4 ± 0.2	19.4 ± 0.2	19.4 ± 0.2	19.4	19.4 ± 0.2	19.4 ± 0.1	19.4	19.4
19.5 ± 0.2	19.5 ± 0.2	19.5 ± 0.2	19.5	19.5 ± 0.2	19.5 ± 0.1	19.5	19.5
19.6 ± 0.2	19.6 ± 0.2	19.6 ± 0.2	19.6	19.6 ± 0.2	19.6 ± 0.1	19.6	19.6
19.7 ± 0.2	19.7 ± 0.2	19.7 ± 0.2	19.7	19.7 ± 0.2	19.7 ± 0.1	19.7	19.7
19.8 ± 0.2	19.8 ± 0.2	19.8 ± 0.2	19.8	19.8 ± 0.2	19.8 ± 0.1	19.8	19.8
19.9 ± 0.2	19.9 ± 0.2	19.9 ± 0.2	19.9	19.9 ± 0.2	19.9 ± 0.1	19.9	19.9
20.0 ± 0.2	20.0 ± 0.2	20.0 ± 0.2	20.0	20.0 ± 0.2	20.0 ± 0.1	20.0	20.0

Table 1

Juice	Fructose	Glucose	Sucrose	Sorbitol
Apple	6.2	2.7	1.2	0.5
Pear	6.4	2.3	0.9	2.0
White grape	7.5	7.1	0.0	0.0
Orange	2.4	2.4	4.7	0.0

Modified from Hovms et al.¹¹ and Hantson et al.²⁰

Table 3