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Evaluation of FODMAP Carbohydrates Content in Selected Foods in the United States

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Abstract

We analyzed the fermentable oligosaccharide, disaccharide, monosaccharide, and polyols (FODMAP) content of several foods potentially low in FODMAP which are commonly consumed by children. We determined that several processed foods (eg, gluten free baked products) had unlabeled FODMAP content. Determining FODMAP content within foods distributed in the United States may support educational and dietary interventions.

Keywords

irritable bowel syndrome; FODMAP; intolerance

Irritable bowel syndrome (IBS), a functional gastrointestinal disorder that affects up to 20% of children worldwide, has significant negative effects on childhood quality of life.^{1, 2} IBS is multifactorial with potential contributors including visceral hyperalgesia, microbiome alterations, low-grade gut inflammation, psychosocial distress, and diet.¹ Diet is important to children with IBS as more than 90% perceive at least one food exacerbates their gastrointestinal symptoms.³

One dietary therapy which has been demonstrated via randomized controlled trials to be highly effective in both children and adults with IBS is a low fermentable oligosaccharide, disaccharide, monosaccharide, and polyols (FODMAP) diet.^{4, 5} FODMAP carbohydrates may exacerbate gastrointestinal symptoms in those with functional bowel disorders.^{6, 7} In susceptible individuals, the malabsorption of FODMAP carbohydrates may worsen

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symptoms by increasing abdominal distention via both increased osmotic activity and gas production.⁸ Thus FODMAP carbohydrates, which may be both difficult to absorb and fermentable, are comprehensively restricted. These carbohydrates include lactose, fructose, fructans, galactans and sugar alcohols. Following several weeks of comprehensive restriction, foods with FODMAP content are then slowly re-introduced to determine the tolerance of the patient with IBS.⁹

One important facet to following the low FODMAP diet is knowledge regarding the FODMAP content of foods. FODMAP content guidance has been provided via scientific and lay publications and other outlets for many foods; however, to date the majority of analyzed foods are from Australia.¹⁰ The lack of clear FODMAP content guidance for American foods may, in part, contribute to the high level of discordance found among United States academic center based low FODMAP food lists.¹¹ A lack of FODMAP content guidance may both increase the complexity of following a FODMAP diet, and increase the difficulty of providing a FODMAP dietary intervention in the research setting. Therefore, in preparation for a low FODMAP pediatric clinical trial we sought to analyze the FODMAP content of the foods which would be used.⁶

METHODS

Selection of Foods

A research dietitian selected foods which were felt to be potential candidates for usage as low FODMAP foods in a pediatric clinical trial. Foods were selected for their palatability, successful usage in previous childhood dietary intervention trials, resistance to spoiling, previous identification as a potentially low FODMAP food (e.g. vegetables), and lack of identification of FODMAP carbohydrates if a nutrition label was present. Foods suspected as likely to have excessive FODMAP content (e.g. whole dairy milk) were excluded. Meats, which are uniformly low FODMAP, were excluded. A mixture of fruits, vegetables, beverages, dairy products, grains and cereals, snacks (pretzels, potato chips, fries), peanut butter, and condiments (e.g., mustard) were selected. (Table). Foods were obtained as available to the public (e.g. grocery store) either from Kroger supermarkets in the Houston metropolitan area or were obtained from US Foodservice delivery to the Children's Nutrition Research Center.

Fermentable Sugar Composition Analysis

Food samples were cut, and 0.5 gram of the edible portion of each food was placed on ice. Samples were sent overnight for analysis to the Whistler Center for Carbohydrate Research and then stored at -20° until analyzed.

The sugar composition in each food stuff was measured using Megazyme assay kits (Megazyme International Ireland Ltd, Wicklow, Ireland). The assay kits included: D-Fructose/D-Glucose Assay Kit (K-FRUGL, detection limit 0.66 mg/L); Lactose/Galactose Assay Kit (K-LACGAR, detection limit 2.96 mg/L); D-Mannitol/L-Arabitol Assay Kit (K-MANOL, detection limit 0.5 mg/L); D-Sorbitol/Xylitol Assay Kit (K-SORB, detection limit 0.2 mg/L); Fructan HK Assay Kit (K-FRUCHK, detection limit 67.4 mg/L); and

Raffinose/D-Galactose Assay Kit (K-RAFGA, detection limit 21 mg/L) to quantify fructose, glucose, lactose, mannitol, sorbitol, fructooligosaccharides, and galactooligosaccharides. According to the procedure delineated for each of the kits, samples were prepared for sugar component analysis. Sample preparation varied based on the characteristics of the selected foods. Colored beverages were treated by adding polyvinylpolypyrrolidone (PVPP, 2% w/v, Sigma-Aldrich, St. Louis, MO, USA) to decolorize the liquid food samples. Dairy products were mixed with Carrez I and II solutions (Sigma-Aldrich, St. Louis, MO, USA) and sodium hydroxide (NaOH, 100 mM, Fisher Scientific, Hampton, NH, USA) to deproteinize the samples. Mayonnaise and peanut butter were placed on a hot plate and heated above the melting point of the fat. Water was added to the heated samples, and they were then stored in a refrigerator for 20 min and filtered through filter paper (Fisher Scientific, Hampton, NH, USA) to obtain a filtrate. Baked products, fruits, vegetables, grains, cereals, and snacks were homogenized by blending for 7 min using a commercial blender (Waring Commercial Inc., Columbus, OH). The amount of individual sugars in the food samples was determined by reading the absorbance of sample solutions on a 96 well plate at 340 nm using a microplate reader (SpectraMax 190, Molecular Devices, Sunnyvale, CA), and calculation of their concentration was done using formulas described in the kit procedures. Samples were weighed and values normalized per 100 g weight. All foods were analyzed raw except for the rice and potato fries which were cooked. When fructose was identified in a sample, the amount of fructose in excess of glucose was calculated, as glucose has been found to facilitate fructose absorption in vivo.⁹

Each analysis was completed in duplicate. A positive control for fructooligosaccharides was provided through the use of a mixture of inulin and short chain fructooligosaccharides (Jarrow Formulas Inc., Inulin-FOS). A negative control was used by including maltodextrin (Honeyville, Inc.) for analysis.

RESULTS

Fruits and Vegetables

All of the analyzed fruits contained fructose; however, the glucose content was greater in all cases (Table). Only a small concentration of fructooligosaccharides was detected in banana. Tomato had FODMAP content given the amount of fructose; however overall this was both less than both the amount of glucose and less than the amount of fructose identified in the other analyzed fruits. Though all the evaluated vegetables had FODMAP content identified, the concentrations were low.

Dairy and Milk Products

As expected lactose was identified in butter and cheese products. Lactaid 2% milk (which has been treated to hydrolyze lactose) and Rice DREAM rice milk (which does not contain dairy) did not have lactose identified.

Beverages

Though none of the beverages had known FODMAP ingredients marked on their labels, all tested brands had both fructose (significantly greater than glucose) and

fructooligosaccharides detected. All the tested beverages would be considered to be high in fructose content.¹²

Grains and Cereals

The three gluten free products evaluated contained both fructose (in excess of glucose) and fructooligosaccharides. Nabisco saltine crackers did not have FODMAPs detected. The evaluated rice products were free of FODMAP content; however, Corn Chex^M and Rice Chex^M were not. Both Chex products had fructose and fructooligosaccharides; though only Rice Chex^M had excessive fructose relative to glucose.

Snacks and Miscellaneous

All the snacks evaluated (pretzels, potato chips, fries) had excess fructose relative to glucose. They also had fructooligosaccharides at relatively low levels.¹² Both the assessed mayonnaise and mustard were FODMAP free. A small amount of fructose (less than glucose) and fructooligosaccharides were identified in the assessed peanut butter.

Controls

As expected, Inulin-FOS had a very high concentration of fructooligosaccharides. In comparison, maltodextrin only had negligible amounts of glucose detected.

DISCUSSION

In evaluating foods which were being considered for usage as low FODMAP foods we found several processed foods, such as gluten free baked products and manufactured beverages in particular, had excessive FODMAP content. None of the foods with identified high FODMAP content had the FODMAP content identified on their nutritional label. Based on these data, further FODMAP content evaluation of manufactured foods distributed in the US is recommended. FODMAP content data can then be incorporated into educational programs which are being recommended to both adults and children with functional bowel disorders. Specific FODMAP content information may help those on a low FODMAP diet better choose the food and manufacturer for their dietary needs. In addition, research trials may use the specific FODMAP content information to tailor FODMAP related dietary interventions.

There are several ways in which FODMAP content may be evaluated. The enzymatic hydrolysis based methods used in our study have been used by others to assess FODMAP food content and conform to international analytic standards.^{10, 13–15} Alternative analytic methods may include the use of high performance liquid chromatography. However, high performance liquid chromatography may be more technically challenging and may not appropriately identify the total amount of fructans.¹⁰ Excessive amounts of maltodextrins in liquid enteral formulas have previously been identified to lead to overestimation of fructan content via the enzymatic hydrolysis based methods used in our study; however, we did not assess enteral formulas and we did not find excessive fructooligosaccharide content in the assessed beverages.¹⁶ Supporting the validity of our approach are that the FODMAP content

identified in fruits and vegetables in our study largely parallel previously published reports.
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Per United States federal regulations, food manufacturers are required to declare certain nutrients on food product labeling. Carbohydrate labeling contains both mandatory and voluntary requirements. Mandatory labeling includes “total carbohydrate”, “dietary fiber” (which may encompass fructooligosaccharides and/or galactooligosaccharides); “total sugars” (sum of all free mono- and disaccharides), and “added sugars” (either added during the processing of foods or during packaging). Voluntary labeling includes “sugar alcohol” (which contain polyols). These labeling requirements may not facilitate low FODMAP diet adherence given that they do not require the specific identification of individual FODMAP carbohydrates. For example, the beverages and gluten free baked goods which were evaluated and found to contain high FODMAP content did not have the identified FODMAP carbohydrates on the label. Two of the beverages contained lemon juice which may account for the high fructose content. These data serve as an important notice both to the importance of testing foods for FODMAP content and subsequently to the potential challenges with following a low FODMAP diet. Given the potential health implications of FODMAP carbohydrates on individuals with functional bowel disorders (which affects millions of Americans) we recommend consideration of the addition of a “FODMAP content” label be added.

Gluten free products have generally been recommended in a low FODMAP diet as they may have a lower fructooligosaccharide content as compared with non-gluten free products. However, as was identified in Australian manufactured breads, the fructose content which is added in gluten-free bread may be higher than their non-gluten free counterparts.¹³ Knowing the exact amount of fructose and/or fructans may be helpful as tolerance of one FODMAP carbohydrate vs. another may differ.⁹

The current study has both limitations and strengths. A limitation includes both the relatively small number of foods and the limited number of sources used to obtain the foods as compared with that available to the public. However our initial focus was to identify a cadre of foods to be used in clinical trials. Further studies are needed to more fully analyze a broader array of American (and other cultural) foods. One strength of this study is the broad array of foods from several categories which were analyzed. The analyzed foods ranged from fruits and vegetables to processed foods. An additional strength is the rigorous analysis protocol which was followed and inclusion of both positive and negative controls to ensure quality control.

In conclusion, unlabeled high FODMAP content may be found in American foods. Based on current nutrition labeling requirements, this content may not be readily apparent. Further analysis of food distributed in the US (and other cultural foods) may be helpful with the implementation of a low FODMAP diet.

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Abbreviations

FODMAP	fermentable, oligosaccharides, disaccharides, monosaccharides, and polyols
IBS	irritable bowel syndrome

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TABLE 1
Fermentable Oligosaccharides, Disaccharides, Monosaccharides, and Polyols Content (g/100g of sample) in Analyzed Foods

Food	Fructose	Glucose	Excess fructose	Lactose	Mannitol	Sorbitol	FOS	GOS
Baked Products								
G.F. Bread, Udi's®	0.52	0.27	0.25	ND	ND	ND	0.06	0.03
G.F. Hamburger Bun, Udi's®	0.34	0.19	0.15	ND	ND	ND	0.04	ND
G.F. Banana Bread muffin, Udi's®	3.27	1.29	1.98	ND	ND	ND	0.01	ND
Saltine Cracker, Nabisco®	ND	ND	-	ND	ND	ND	ND	ND
Beverages								
Lemonade, Simply	6.34	3.19	3.15	ND	ND	ND	0.01	ND
Cranberry juice, Ocean Spray®	5.81	2.84	2.97	ND	ND	ND	0.01	ND
Sweet tea, Gold Peak®	4.99	2.09	2.9	ND	ND	ND	0.01	ND
Half n' half, Snapple	10.11	4.03	6.08	ND	ND	ND	0.03	ND
Dairy Products								
Butter, Glenview Farms	ND	ND	-	1.54	ND	ND	ND	ND
2% milk, Lactaid®	ND	ND	-	ND	ND	ND	ND	ND
Mild Cheddar, Kraft®	ND	ND	-	1.91	ND	ND	ND	ND
Cheese Heads, Frigo®	ND	ND	-	2.13	ND	ND	ND	ND
Rice milk, Rice DREAM™	0.01	ND	0.01	ND	ND	ND	ND	ND
Fruits (all fresh)								
Banana, firm	3.21	5.93	-	ND	ND	ND	0.15	ND
Grapes, red	7.04	12.11	-	ND	ND	ND	ND	ND
Orange, navel	2.01	3.01	-	ND	ND	ND	ND	ND
Pineapple	1.91	2.97	-	ND	ND	ND	ND	ND
Strawberry	1.31	1.71	-	ND	ND	ND	ND	ND
Tomato	1.01	1.21	-	ND	ND	ND	ND	ND
Vegetables								
Bean, green, frozen	ND	ND	-	ND	0.02	0.01	ND	ND
Broccoli, Monarch, frozen, Kroger	ND	ND	-	ND	ND	0.04	ND	ND

Food	Fructose	Glucose	Excess fructose	Lactose	Mannitol	Sorbitol	FOS	GOS
Corn, frozen, Kroger	ND	ND	-	ND	ND	0.04	ND	ND
Lettuce, fresh	0.1	0.12	-	ND	ND	ND	0.01	ND
Spinach, frozen, Birds Eye	ND	ND	-	ND	ND	ND	0.14	ND
Grains and Cereals								
Brown rice, cooked	ND	ND	-	ND	ND	ND	ND	ND
White rice, Success, cooked, Success	ND	ND	-	ND	ND	ND	ND	ND
Corn Chex™	1.53	1.81	-	ND	ND	ND	0.61	ND
Rice Chex™	0.81	0.43	0.38	ND	ND	ND	0.42	ND
Snacks								
Pretzel (regular), Snyder's of Hanover®	0.21	0.12	0.09	ND	ND	0.02	0.53	ND
Potato chips, Lay's®	0.45	0.23	0.22	ND	ND	ND	0.31	ND
French Fried Potatoes Fries (microwave-able), Ore-Ida® Extra Crispy Crinkles, frozen	0.25	0.19	0.06	ND	ND	ND	0.27	ND
Miscellaneous								
Maltodextrin	ND	0.01	-	ND	ND	ND	ND	ND
Inulin FOS	0.01	ND	0.01	ND	ND	ND	94.16	ND
Mayonnaise, Hellmann's	ND	ND	-	ND	ND	ND	ND	ND
Peanut butter, Skippy®	0.91	1.01	-	ND	ND	ND	0.02	ND
Mustard, French's®	ND	ND	-	ND	ND	ND	ND	ND

FOS= Fructooligosaccharide; G.F= Gluten free; GOS= Galactooligosaccharide; ND = not detected