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Fructan and Free Fructose Content of Common Australian Vegetables and Fruit

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Fructans are not digested in the small intestines of humans. While many health benefits have been attributed to these carbohydrates, they can cause gastrointestinal symptoms in some individuals. We measured the total fructans in 60 vegetables and 43 fruits using the Megazyme fructan assay. Vegetables with the highest quantity of fructans included garlic, artichoke, shallots, leek bulb, and onions (range, 1.2−17.4 g/100 g fw). Fruits with low, but detectable, fructans included longon, white peach, persimmon, and melon (range, 0.21−0.46 g/100 g fw). The fructan assay was modified to provide an estimate of the average chain length (degree of polymerization) for high fructan vegetables. D-Fructose can also be malabsorbed in the small intestine of humans, so the D-fructose content in some foods was measured to supplement the current food tables. Research in this area will be facilitated through the availability of more comprehensive food composition data.

KEYWORDS: Fructan; fructose; food composition; vegetables; fruit

INTRODUCTION

Fructose is a six-carbon monosaccharide that is distributed widely in plant foods in a variety of forms including the free monosaccharide form, complexed with glucose to form the disaccharide sucrose, or polymerized to form fructans. Fructans are oligo- and polysaccharides consisting of short chains of fructose units with a single D-glucosyl unit at the nonreducing end (*1−3*). While the terminology in this area can be confusing, fructans with a short chain length (i.e., degree of polymerization, DP) of 2−9 units are generally referred to as fructooligosaccharides (FOS) or oligofructose, and the longer chain (DP ≥ 10) are called "inulins" (*2*, *4*). In this article, the term "fructan" will be used to refer to both FOS and inulins.

There has been considerable research interest in recent years as fructans may have wide-ranging beneficial effects on health. Proposed health benefits include suppressing the growth of potential pathogens in the colon (*5−8*), increased stool bulking capacity and prevention of constipation (*9*), increased calcium absorption (*10*), maintenance of the integrity of the gut mucosal barrier and increased colonic mucus production (*11−13*), stimulation of the gastrointestinal immune system (*14*), and reducing the risk of colorectal cancer (*6*).

Not all reported physiological effects of fructans, however, are positive. In humans, fructans trigger gastrointestinal symptoms including gastroesophageal reflux (*15*), flatulence, bloating, and abdominal pain (*16−19*). In healthy individuals, these gastrointestinal effects are usually evident only at high doses of fructans (>20 g/day) (*16−19*), while physiological benefits occur at lower well-tolerated doses (5−10 g/day) (*6*, *10*). Nevertheless, we have recent evidence to suggest that doses (10−20 g/day) may exacerbate symptoms in patients who suffer from irritable bowel syndrome (IBS) (*20*). IBS is a significant gastrointestinal disorder in developed countries such as Australia and the United States, affecting around 10−15% of the adult population (*21*, *22*).

The mechanisms underlying many if not all of these effects relate to the inability of the mammalian intestine to hydrolyze the glycosidic linkages with subsequent malabsorption and delivery of fructans to the large bowel. In the bowel, they undergo rapid fermentation by bacteria with the subsequent expansion of bacterial populations, especially of bifidobacteria (*5*, *23*, *24*). Oligosaccharide fructans (DP 2−9), by virtue of their small molecular size, are likely to exert an osmotic effect, leading to increased delivery of water to the large bowel (*25*). Byproducts of the fermentation include gases (carbon dioxide, methane, and hydrogen) (*25*, *26*). Distension of distal small and proximal large bowels by rapid gas production and the additional fluid load due to osmotic effects have been postulated to underlie the bowel symptoms (including pain, bloating, and altered bowel habit) that fructans can induce (*16−18*, *27*).

These physiological and postulated health effects of fructans may also be mimicked by malabsorbed fructose. The small intestine has a limited capacity to absorb free fructose, and approximately 50% of the population is unable to completely absorb a 25 g load of fructose; this increased to 75% for 50 g (*28*). As a result, foods and drinks that contain high levels of free fructose may result in malabsorbed fructose, leading to similar gastrointestinal effects and abdominal symptoms as fructans (*20*, *27*, *28*).

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Most studies conducted into the health-promoting effects of fructans have used supplements of fructans purified from rich sources such as Jerusalem artichokes and/or chicory root. The likelihood that the background fructan (or indeed fructose) content of the diet might confound interpretation of the effects of supplemented fructans has generally not been considered in these studies. A considerable limitation to controlling background levels of fructans, however, is the very limited information available on the quantities of these carbohydrates in foods (*29*−*32*). Comprehensive food composition tables are required to more fully appreciate the health impact of fructans (dietary or supplemented) on humans. In contrast, data on the fructose composition in foods are more widely available in the literature and are published in food composition tables (*33*, *34*).

Quantifying fructan levels in foods is a challenging area as food contains a complex mix of these compounds of varying chain length (DP) from two to 60 units (*29*). Generally, sophisticated analytical techniques including high-pressure liquid chromatography (HPLC), gas chromatography (GC), and high-performance anion-exchange chromatography with pulsed amperometric detection are required (*29*). However, because of the lack of suitable standards, the measurement of intact fructans via these approaches tends to be semiquantitative. A more reliable approach in quantifying levels of fructans in foods involves the enzymatic hydrolysis of fructans to release the free monosaccharides, glucose and fructose, which are measured separately via GC or HPLC (*29*, *30*). Accurate quantification of fructan levels using this approach, however, depends on prior removal or measurement of free glucose, fructose, and sucrose present in the food sample. One approach to measuring total fructans via enzymic hydrolysis has been described by McCleary and Blakeney (*35*). This approach utilizes highly purified and specific enzymes to hydrolyze sucrose, starch, and fructans (*35*) and is now commercially available in kit form (Megazyme Fructan HK Assay kit—AOAC Method 999.03 and AACC Method 32.32).

The present study has, therefore, aimed to use the Megazyme enzymatic approach to measure total fructan levels that occur naturally in a wide range of commonly consumed Australian fruits and vegetables and to extend this methodology to the estimation of the average chain length (DP) of fructans present in foods. A separate assay was used to measure free fructose in vegetables and fruits to supplement the current Australian food composition tables for fructose.

MATERIALS AND METHODS

Food Sampling and Processing. The food sampling procedure followed the protocol of Food Standards Australia New Zealand (FSANZ, Canberra, Australia). Fresh food samples (fruit and vegetables) were collected from five supermarkets and five green grocers located in the metropolitan area of Melbourne (Australia). Approximately 500 g (edible portion) of each food was chosen at random from these stores. The food was cut, and the edible portion from each store was prepared, pooled (that is, 10 × 500 g = 5 kg), and thoroughly mixed. From this 5 kg pooled sample, 500 g was taken and blended in a food processor to a homogeneous consistency, and 100 g of the homogenized sample was taken and stored frozen at −20 °C. The frozen samples were then freeze-dried (Operon Freeze-drier, Thermoline Scientific) until they reached constant dry weight. The dried sample was used for the fructan and fructose extraction.

Extraction of fructans. The method for extracting fructans is fully described in the Megazyme Fructan HK Assay Procedure (Megazyme International Ireland Ltd, Wicklow, Ireland), but involves millling or grinding dry samples with mortar and pestle to around 0.5 mm particle size. Dry sample (0.1 to 0.5 g) was weighed into a dry Pyrex beaker (100 ml capacity) and 80 mL of hot distilled water (pH 6) at 80 °C was added. The beaker was placed on a hot magnetic stirrer and stirred with heat (around 80 °C) for 15 min until the sample was completely dispersed. The solution was cooled to room temperature and then quantitatively transferred to a 100 mL volumetric flask, and the volume was adjusted to 100 mL with water.

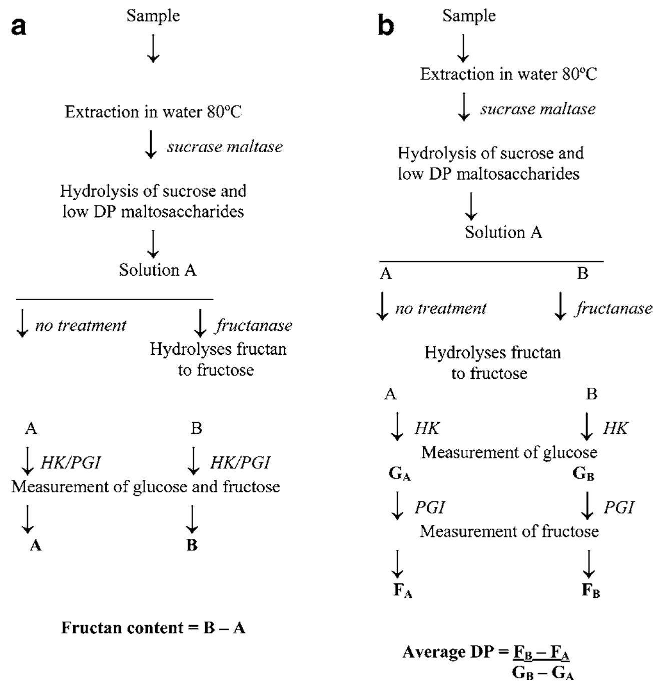

Figure 1. (**a**) Megazyme fructan assay and (**b**) modified Megazyme fructan assay for estimation of the average DP.

Samples were further treated by filtering the solution through a Whatman 1 (9 cm) filter circle followed by immediate analysis. If the solution was still turbid, it was filtered again through a Whatman GF/A glass fiber filter paper. If analysis could not be undertaken immediately, then filtered samples were stored frozen at −20 °C and then reheated to 80 °C and allowed to cool to room temperature before analysis (see below). This full extraction procedure was carried out on two separate occasions for foods containing "trace" amounts of fructans (<0.9 g/100 g dw) that were present and on at least three separate occasions for foods with fructans present >0.9 g/100 g dw.

Measurement of Fructans (FOS and Inulin). The total fructan content was measured in triplicate using the Megazyme Fructan HK Assay kit (AOAC Method 999.03 and AACC Method 32.32; Megazyme International Ireland Ltd., Wicklow, Ireland). Full details about the assay are contained in the kit instructions. Briefly, the assay involves parallel assays of two samples. In the first (sample A), all sucrose and lower DP maltosaccharides are removed via hydrolysis using a highly specific sucrase/maltase enzyme to release all glucose and fructose. Sample B is treated with purified fructanase, which hydrolyzes fructan to fructose and glucose. The concentration of glucose plus fructose is measured with a hexokinase/phosphoglucose isomerase (PGI)/glucose 6-phosphate dehydrogenase system. The fructan content is then measured by the difference between sample B and sample A (**Figure 1a**). The final calculation takes into account the conversion factor from free fructose and glucose to anhydrofructose (and anhydroglucose) as occurs in fructan.

This assay is unreliable at measuring total fructans in food when these carbohydrates are present at less than 1 g per 100 g food (dry weight basis). Consequently, results obtained in the range of 0−0.4 g/100 g dry weight were considered "not detectable" and in the range of 0.5−0.9 g/100 g dry weight were considered to be trace amounts only.

The fructan content was expressed relative to dry weight and to the wet (as eaten) weight. It was also expressed as g/serve. Information about the average serving size was obtained from the Foodworks Food Composition Program (Version 4, Food works, Brisbane, Queensland, Australia).

Estimation of Average DP. The average DP of fructans in food was measured using a modification of the Megazyme fructan HK assay. This approach is based on the fact that fructans consist of short chains of fructose units with a single D-glucosyl unit. Hence, knowledge about the total fructan content (Megazyme Fructan HK Procedure) plus the amount of fructan-associated glucose (using a modification of Megazyme sucrose, D-fructose, and D-glucose kit procedure) can be used to calculate the average DP of the fructans in a particular food (see **Figure 1b**).

To determine the degree of DP in our samples after fructan hydrolysis with fructanase, the concentration of glucose and fructose had to be measured individually. The concentration of glucose (B) and fructose (B) was measured using hexokinase/glucose 6-phosphate dehydrogenase (HK/G6P-DH) and PGI, respectively, which were obtained from the sucrose/D-fructose and D-glucose Megazyme kit. The concentration (units) of the individual enzymes was the same as in the combined mixture. Furthermore, to convert the absorbance values to μg glucose and μg fructose, a solution of glucose/fructose (0.5 mg/mL) was used as the standard.

After fructan hydrolysis, HK/G6P-DH was added to the samples and absorbance was read after 5 min. The glucose content was then determined by the difference between B and A. Following this, PGI was added and absorbance was read after 10−15 min. The fructan content was then determined by the difference between B and A. Determination ($n = 3$, mean ± SD) of fructans via this modified fructan method (25.8 ± 2.2 g/100 g dw) for the Dahlia standard supplied with the fructan kit did not differ significantly (t test, $P < 0.05$) from the standard method (26.7 ± 0.58 g/100 g dw).

The average DP is determined by the following equation:

$$\text{average DP} = F_B - F_A/G_B - G_A$$

Measurement of Free D-Fructose. The free D-fructose content in selected foods was obtained using the sucrose/D-fructose and D-glucose Megazyme kit (Megazyme International Ireland Ltd.) as per manufacturer's instructions. The fructose content was expressed as g/100 g fw. Some values for free fructose were also obtained from the Supplement to the Australian Food Composition tables (*33*).

RESULTS

Content of Fructans in Vegetables and Fruit. The total amount of fructans present in 60 common Australian vegetables is presented in **Table 1**. The vegetables with the highest amount of fructans (g/100 g as eaten) included garlic, 17.4 g > Jerusalem artichoke, 12.2 g > shallots, 8.9 g > leek bulb, 7.1 g > spring onion bulb, 6.3 g > brown onion, 2.1 g > Spanish onion, 1.8 g > white onion, 1.8 g > globe artichoke, 1.2 g. The vegetables with the highest amount of fructans when expressed as an average serving (fructan g/serve) were Jerusalem artichoke, 6.1 g/serve > shallots, 1.1 g > globe artichoke, 0.60 g > garlic, 0.52 g > Spanish onion, 0.30 g > beetroot, 0.27 g > white onion, 0.28 g > brown onion, 0.20 g > Brussels sprout, 0.12 g. By way of comparison, results of fructan composition published by two other investigators (*29*, *30*) are also shown in **Table 1**.

The total amount of fructans present in 43 common Australian fruits is presented in **Table 2**. The fruit with the highest amount of fructans (g/100 g as eaten) included longon, 0.46 g > white peach, 0.4 g > rambutan, 0.36 g > persimmon, 0.33 g > watermelon, 0.32 g > honeydew melon, 0.21 g. Fruits with the highest amount of fructans when expressed as an average serving (g fructan/serve) were watermelon, 0.92 g > persimmon, 0.55 g > white peach, 0.50 g > honeydew melon, 0.38 g > nectarine, 0.27 g. Results of fructan composition published by two other investigators (*29*, *30*) are also shown in **Tables 1** and **2**.

Content of D-Fructose in Vegetables and Fruit. Information about the free D-fructose content in these foods was also obtained using the sucrose/D-fructose and D-glucose Megazyme kit. Not all foods, however, were analyzed for free fructose content, and some values were also obtained from the Supplement to the Australian Food Composition tables (*33*). The fructose values for some common Australian vegetables are also given in **Table 1**. The vegetables with the highest amount of fructose (g/100 g as eaten basis) included spring onion bulb, 6 g > Spanish onion, 4 g > leek bulb, 3.4 g > Lebanese cucumber (peeled), white onion, and brown onion, 3.2 g > cherry tomato, 2.4 g > red chili, 2.3 g > red capsicum and common cucumber (peeled), 2.1 g > Lebanese cucumber (unpeeled), 2 g > shallot and Roma tomato, 1.8 g. The vegetables with the highest amount of fructose when expressed as an average serving (g fructose/serve) were leek bulb, 2.8 g > Lebanese cucumber (peeled), 2.4 g > common cucumber (peeled), 1.6 g > Lebanese cucumber (unpeeled), 1.5 g > cherry tomato, 1.3 g > leek (whole), 1.3 g > common cucumber (unpeeled), 1.2 g > cabbage (common), tomato (Roma), capsicum (red), and spring onion bulb, 1.0 g > savoy cabbage, 0.9 g.

The total amount of fructose present in common Australian fruits is presented in **Table 2**. The fruits with the highest amount of fructose (g/100 g as eaten basis) included red grapes, 10 g > Packham ripe pear (peeled), 9.8 g > Packham firm pear (peeled), 9.7 g > Packham ripe pear (unpeeled), 8.7 g > Packham firm pear (unpeeled), 8.2 g > Thomson grapes, 8.1 g > Ralli seedless grapes, 8.0 g > persimmon, 7.8 g > black muscatel grapes, 7.7 g > red globe grapes and lychee, 7.6 g > Granny Smith apple (peeled), 6.9 g > Jonathan apple (peeled), 6.6 g > Pink Lady apple (unpeeled), 6.4 g. The fruits with the highest amount of fructose when expressed as an average serving (g fructose/serve) were Packham ripe pear (peeled), 16.2 g > Packham firm pear (peeled), 16 g > Packham ripe pear (unpeeled), 14.4 g > persimmon, 13.3 g > Granny Smith apple (peeled), 11.4 g > Jonathan apple (peeled), 10.9 g > Jonathan apple (unpeeled), 10.7 g > Granny Smith apple (unpeeled), 10.6 g, and Pink Lady apple (unpeeled), 10.6 g > red grapes, 10.5 g > Pink Lady apple (peeled), 10.4 g > custard apple, 9.2 g. The fructose results obtained here using the Megazyme assay were compared with data recently published in the Supplement to the Australian Food Composition Tables (*33*) (**Tables 1** and **2**).

DP of Fructans in Vegetables and Fruit. Using a modification of the Megazyme procedure, the average DP was calculated for vegetables that had the highest fructan content (i.e., above 1 g fructans/100 g "as eaten" basis) (**Figure 2**). Most vegetables assessed had an average DP of 3−5, but spring onion bulbs, garlic, and leek bulb had much longer DP lengths (DP8−11). No fruits contained fructans above the 1 g/100 g "as eaten" level, and they were not included in the table.

DISCUSSION

This study provides for the first time comprehensive information about the total content of fructans in 60 common Australian vegetables and 43 common fruits. This information will greatly assist in more clearly defining the role of dietary fructans in health promotion and suppression.

The richest concentrations of fructans in Australian vegetables were found in members of the *Compositae*, *Amaryllidaceae*, and *Liliaceae* plant families, mainly comprising artichokes and the extended onion family. The same vegetables predominated when a typical serving size of these foods consumed was taken into consideration, although the order of content changed. These findings were not surprising since the presence of high levels of fructans in these plant foods has been previously established (*29*, *30*, *36*, *37*). The enzymic hydrolysis method that was

Table 1. Total Fructan and Free Fructose Composition of Common Australian Vegetables

	fructan							free fructose			
	% dw		g/100 g dw	g/100 g fw		g/serve fw		g/100 g fw		g/serve fw	
food	current[a]	average serve size[e]	current[a]	current[a]	others[b,c]	current[a]	others[b,c]	current[a]	NUTAB[d]	current[a]	NUTAB[d]
asparagus	16	71	0	0	2–3,[a] 0[c]	0	1.4–2.1,[b] 0[c]	0.8	0.8	0.6	0.6
artichoke, globe	17	50	7.0	1.2	2–6.8,[b] 0.24[c]	0.6	1–3.4,[b] 0.12[c]	–	0.3	–	0.2
artichoke, Jerusalem	25	50	48.8	12.2	16–20,[b] 5.8[c]	6.1	8–10,[b] 2.9[c]	–	0.4	–	0.2
beans, green	13	55	ND	ND	0[c]	ND	0[c]	–	0.2	–	0.1
beans, kidney					0.01[c]		0.005[c]	–	0.1		
bean sprouts	7	52	tr	tr	–	tr	–	–	0.5		0.3
beetroot	16	68	2.3	0.40	0[c]	0.27	0[c]	–	0	–	0
bok choy	10	85	ND	ND	–	ND	–	0.4	0.6	0.3	0.5
broccoli	15	44	ND	ND	–	ND	–	–	0.2	–	0.1
Brussel sprouts	19	44	1.4	0.27	–	0.12	–	–	0.8	–	0.4
cabbage, common	14	94	ND	ND	–	ND	–	–	1.1	–	1.0
cabbage, savoy	14	94	ND	ND	–	ND	–	–	1.0	–	0.9
capsicum, green	13	50	ND	ND	–	ND	–	–	0.9	–	0.5
capsicum, red	14	50	ND	ND	–	ND	–	–	2.1	–	1.0
carrot	20	27	ND	ND	0[c]	ND	0[c]	–	1.1	–	0.3
cauliflower	16	75	ND	ND	–	ND	–	–	0.9	–	0.7
celery			–	–	0[c]	–	0[c]		0.5		
chicory leaves	9	23	ND	ND	–	ND	–	–	0.4	–	0.1
chicory root			–	–	0.39[c]	–	–	–	–	–	–
chili, red	18	5	ND	ND	–	ND	–	–	2.3	–	0.1
chili, green	15	5	tr	tr	–	tr	–	–	0.3	–	0.0
chives	17	4	ND	ND	0[c]	ND	0[c]	1.3	1.9	0.1	0.1
choy sum	10	85	ND	ND	–	ND	–	0.2	–	0.2	–
corn, sweetcorn	24	156	ND	ND	–	ND	–	–	0.2	–	0.3
common cucumber, peeled	11	75	ND	ND	–	ND	–	2.1	1.1	1.6	0.8
common cucumber, unpeeled	11	75	ND	ND	–	ND	–	1.7	0.6	1.2	0.5
Lebanese cucumber, peeled	12	75	ND	ND	–	ND	–	3.2	1.0	2.4	0.8
Lebanese cucumber, unpeeled	9	75	ND	ND	–	ND	–	2	–	1.5	–
daikon			–	–	0[c]	–	0[c]	–	–	–	–
eggplant	11	41	ND	ND	0[c]	ND	0[c]	–	1.1	–	0.5
endive	10	40	tr	tr	0[c]	tr	0[c]	0.5	0.2	0.2	0.1
endive, baby	10	40	tr	tr	–	tr	–	0.3	–	0.1	–
fennel, bulb	12	49	ND	ND	ND[c]	ND	ND[c]	1.2	–	0.6	–
fennel, leaves	8	49	ND	ND	–	ND	–	0.5	–	0.3	–
garlic	39	3	45	17.4	9.8–16,[b] 0.39[c]	0.52	0.3–0.5,[b] 0.01[c]	–	0.6	–	0.0
garlic powder					0.16[c]				0.5		
ginger root	18	3	ND	ND	0[c]	ND	0[c]	–	0.9	–	0.0
lettuce, butter	15	23	ND	ND	–	ND	–	0.8	–	0.2	–
lettuce, cos	9	23	ND	ND	–	ND	–	1.0	1.0	0.2	0.2
lettuce, green coral	8	23	ND	ND	–	ND	–	0.5	–	0.1	–
lettuce, iceberg	9	23	ND	ND	0.05[c]	ND	0.01[c]	0.1	0.2	0.0	0.1
lettuce, red coral	7	23	ND	ND	–	ND	–	0.1	–	0.02	–
lettuce, radiccio	12	23	ND	ND	–	ND	–	1.0	–	0.2	–
lettuce, rocket	10	23	ND	ND	–	ND	–	0.3	–	0.07	–
leek, white bulb	26	83	24	7.1	–	5.9	–	3.4	–	2.8	–
leek, leaves	14	83	ND	ND	–	ND	–	0.9	–	0.8	–
leek, whole	9	83	5.4	0.5	3,[b] 0.09[c]	0.43	2.5,[b] 0.07[c]	1.5	–	1.3	–
mushroom, button	11	74	ND	ND	–	ND	–	–	0.1	–	0.1
okra	14	30	ND	ND	–	ND	–	–	–	–	–
onion, white	16	16	11.5	1.8	1.1–7.5,[b] 0.31[c]	0.28	0.18,[b] 0.05–1.2[c]	3.2	1.4	0.5	0.2
onion, brown	16	16	12.6	2.1	–	0.2	–	3.2	1.0	0.5	0.2
onion, Shallot	28	12	33	8.9	0.85[c]	1.1	0.10[c]	–	1.8	–	0.2
onion, Spanish	18	16	9.9	1.8	0.14[c]	0.30	0.02[c]	4.0	–	0.6	–
onion, spring											
onion, bulb	39	16	16.1	6.3	–	1.01	–	6.0	–	1.0	–
onion, leaves	16	16	ND	ND	–	ND	–	0.8	–	0.1	–
onion, whole	14	16	1.2	0.18	–	0.03	–	1.0	2.3	0.2	0.4
onion, Welch			–	–	0.11[c]	–	–	–	–	–	–
onion, yellow			–	–	0.26[c]	–	–	–	–	–	–
onion powder			–	–	4.5[c]	–	–	–	–	–	–
parsnip, unpeeled	21	63	ND	ND	–	ND	–	0.5	–	0.3	–
parsnip, peeled	21	63	ND	ND	–	ND	–	0.4	0.8	0.3	0.5
peas			–	–	0.01[c]	–	–	–	0.2	–	
peas, snap			–	–	0.11[c]	–	0.04[c]	–	–	–	
peas, snow	18	32	ND	ND	0.06[c]	ND		0.4	–	0.1	–
potato, unpeeled	20	140	ND	ND	–	ND	–	0.4	–	0.5	–

Table 1 (Continued)

	fructan							free fructose			
	% dw		g/100 g dw	g/100 g fw		g/serve fw		g/100 g fw		g/serve fw	
food	current[a]	average serve size[e]	current[a]	current[a]	others[b,c]	current[a]	others[b,c]	current[a]	NUTAB[d]	current[a]	NUTAB[d]
potato, peeled	23	140	ND	ND	–	ND	–	0.4	–	0.6	
potato, Idaho		–	–	–	0[c]	–	–	–	–	–	–
potato, sweet	24	140	ND	ND	0.02[c]	ND	0.03[c]	–	–	–	–
pumpkin, Japanese	16	60	tr	tr	–	tr	–	0.9	–	0.5	–
pumpkin, butternut	24	60	ND	ND	–	ND	–	0.9	0.3	0.5	0.2
radish	8	15	ND	ND	0.01[c]	ND	0.02[c]	–	0.8	–	0.1
taro root			–	–	0[c]	–	–	–	0.2	–	
tomato	9	55	ND	ND	0[c]	ND	0[c]	1.5	1.0	0.8	0.6
tomato, cherry	11	55	tr	tr	0[c]	tr	0[c]	2.4	1.2	1.3	0.7
tomato, Roma	9	55	ND	ND	0[c]	ND	0[c]	1.8	–	1.0	–
turnip	14	65	ND	ND	–	ND	–	–	1.3	–	0.9
spinach, baby	14	40	1.0	0.14	–	0.05	–	–	–	–	–
squash	12	57	ND	ND	0.04[c]	ND	0.02[c]	–	1.3	–	0.7
Swede	16	52	ND	ND	–	ND	–	–	1.3	–	0.7
whitlof	13	23	tr	tr	–	tr	–	1.2	–	0.3	–
yam			–	–	0.02‡	–	–	–	–	–	–
zucchini	12	57	2.4	0.29	0.0‡	0.17	0‡	–	0.9	–	0.5

[a] In the current study, results are an average of 2–3 separate determinations: –, not measured; ND, not detected via fructan Megazyme assay if fructan values were in the range of 0–0.4 g/100 g dw; tr, trace levels detected if fructan values measured via the Megazyme assay were between 0.5 and 0.9 g/100 g dw. Other published data for fructan values. [b] Range of fructan values measured (*29*). [c] Fructans DP2, DP3, and DP4 measured only (*30*). [d] Fructose values from Food Standards Australia New Zealand (*33*). [e] Average serving size values were obtained from Foodworks Version 4.

applied in the present study yielded similar results as those for nine vegetables and fruits when fructans were measured by HPLC and CGC (*29*). The current fructan content was higher across the board than that reported in a more comprehensive compositional study of about 26 fruits and 40 vegetables where fructans DP2 to DP4 only were measured by HPLC (*30*). The quantitative differences are expected since total fructan levels were measured in the present study.

There were, however, some significant discrepancies. For example, we did not detect significant quantities of fructans in asparagus in agreement with Campbell and colleagues (*30*), whereas Van Loo and co-workers reported their presence (*29*). There may be several reasons for this type of discrepancy as many factors affect fructan levels in foods including storage time and storage temperature, food variety, seasonal variation, and climate (*38*−*41*). In the present study, we attempted to minimize the impact of many of these variables and obtain a more "representative" food sample by pooling food from 10 different stores (see Materials and Methods). We also clearly defined which part of the plant was used for analysis, as fructan levels vary greatly within the same plant (e.g., root, stem, bulb, leaves, or whole plant). While cooking does affect the levels of fructan in foods (*29*), all foods in this study were analyzed raw.

Of commonly consumed fruits, peaches and watermelon had moderate amounts of fructans, which was comparable to that of onions (on a g/serve basis). There have been few previous assessments of the content of fructans in fruit, but bananas have been studied by two investigating groups (*29*, *30*). Both found bananas to have significant levels whereas the current study showed only negligible quantities in both the common and the sugar banana varieties that were either firm or ripe. Reasons for the different findings presumably relate to the issues addressed above.

There are some limitations to measuring total fructans using the Megazyme assay that should be noted. First, this assay is not sensitive at detecting very low levels of fructans in foods (below 1 g fructans/100 g dw food). Therefore, alternative methodologies such as HPLC and GC would be required for quantification of small amounts of fructans in foodstuffs. Second, this assay may not be accurate in quantifying fructan levels in processed foods to which fructan fragments have been added. The enzymic approach used in the present study relies on the hydrolysis of fructans to release the free monosaccharides—fructose and the terminal glucose—which are then measured separately. However, some products are now being used in foods in which chicory-derived inulin has been cleaved to produce smaller oligosaccharides (that is, oligofructose); these are comprised of fructose units but may not be terminated by a glucose unit. The quick and simple Megazyme fructan assay approach will, therefore, be most suitable for measuring fructans that are naturally present in foods and not in processed foods to which inulin-derived oligofructose products have been added.

In contrast to fructans, the current food composition tables provide information on fructose in a wide variety of fruit and vegetables. In the current study, the fructose content was similar to that found in current databases (*33*), and we were able to expand the compositional tables. The richest concentrations of fructose in commonly consumed Australian vegetables are spring onion bulbs, onions, leek bulb, cucumber, cherry tomatoes, and red capsicum and, for Australian fruits, are pears, apples, and grapes. The fructose content per weight or per serve is far greater (10−20-fold) for fruit than for vegetables.

In addition to providing much-needed data to complement current food compositional tables, the current study has provided key information of direct relevance to the design of dietary studies aimed at quantifying the normal daily intake of fructans and controlling baseline fructan (and fructose) levels in intervention studies investigating the physiological effects of including fructans in the human diet.

While it is clear that vegetables are the major sources of fructans in the diet and fruits are the major source of fructose, some foods may contain significant sources of both or indeed contain other short-chain carbohydrates that can be poorly absorbed by the small intestine. This group of carbohydrates has recently been collectively termed FODMAPs—fermentable oligo-, di-, and monosaccharides and polyols (*42*). FODMAPs include fructose, lactose, fructans, galactooligosaccharides (e.g.,

Table 2. Total Fructan and Free Fructose Composition of Common Australian Fruits

	fructan							free fructose			
	% dw		g/100 g dw	g/100 g fw		g/serve fw		g/100 g fw		g/serve fw	
food	current[a]	average serve size[e]	current[a]	current[a]	others[b,c]	current[a]	others[b,c]	current[a]	NUTAB[d]	current[a]	NUTAB[d]
Granny Smith apple, unpeeled	18	165	tr	tr	0.01[c]	tr	0.02[c]	6.4	5.5	10.6	9.1
Granny Smith apple, peeled	18	165	tr	tr	–	tr	–	6.9	–	11.4	–
Jonathan apple, unpeeled	18	165	tr	tr	–	tr	–	6.5	6.6	10.7	10.9
Jonathan apple, peeled	16	165	tr	tr	–	tr	–	6.6	–	10.9	–
Pink Lady apple, unpeeled	21	165	ND	ND	–	ND	–	6.4	–	10.6	–
Pink Lady apple, peeled	19	165	tr	tr	–	tr	–	6.3	–	10.4	–
avocado	34	80	ND	ND	–	ND	–	–	0.1	–	0.1
sugar banana, firm	35	100	ND	ND	–	ND	–	2.2	–	2.2	–
sugar banana, medium ripeness	36	100	ND	ND	–	ND	–	5.4	6.4	5.4	6.4
common banana, firm	29	100	ND	ND	0.07[c]	ND	0.07[c]	2.2	–	2.2	–
common banana, medium ripeness	28	100	ND	ND	0.3–0.7,[b] 0.2[c]	ND	0.3–0.7,[b] 0.2[c]	2.9	3.2	2.9	3.2
blackberry	19	80	ND	ND	0.02[c]	ND	0.02[c]	5.1	–	4.1	–
blueberry	22	80	ND	ND	0[c]	ND	0[c]	5.6	8.0	4.5	6.4
canteloupe/rockmelon	14	85	1.17	0.16	0[c]	0.14	0[c]	–	2.2	–	1.9
carambols, starfruit	13	95	ND	ND	–	ND	–	2.2	2.9	2.1	2.8
custard apple	35	165	tr	tr	–	tr	–	5.6	5.6	9.2	9.2
dragon fruit	20	95	tr	tr	–	tr	–	2.8	–	2.6	
durian	38	95	ND	ND	–	ND	–	1.6	–	1.5	–
gooseberry			–	–	0.01[c]	–	0.01[c]	–	–	–	–
grapes, black muscateel	22	105	tr	tr	0.02[c]	tr	0.02[c]	7.7	9.5	8.1	9.9
grapes, Ralli seedless	22	105	tr	tr		tr	–	8.0	–	8.4	–
grapes, Thompson	24	105	ND	ND	0[c]	ND	0[c]	8.1	–	8.5	–
grapes, red globe	20	105	ND	ND		ND	–	7.6	–	7.9	–
grapes, red	36	105	ND	ND		ND	–	10.0	–	10.5	–
grapefruit	17	100	1.4	0.23		0.23	–	2.3	–	2.3	–
kiwi fruit	28	70	ND	ND	0[c]	ND	0[c]	–	4.2	–	2.9
lemon juice	16	6	ND	ND		ND	–	1.3	0.6	0.08	0.04
longon	23	104	2.1	0.46		0.47	–	3.0	7.6	3.1	7.9
lychee	15	104	ND	ND		ND	–	7.6	–	7.9	–
mandarins, imperial	15	90	ND	ND		ND	–	1.9	2.1	1.7	1.9
mango	19	205	ND	ND		ND	–	3.1	2.9	6.3	6.0
melon, honeydew	12	138	1.8	0.21		0.38	–	–	1.9	–	2.6
nashi pear	20	108	ND	ND		ND	–	–	–	–	–
nectarine	17	130	1.3	0.21		0.27	–	–	1.3	–	1.7
orange, navel	16	130	tr	tr	0.03[c]	0.16	0.04[c]	2.5	1.9	3.3	2.5
paw paw	13	89	tr	tr		tr	–	–	3.3	–	2.9
packham pear, firm, unpeeled	21	165	ND	ND		ND	–	8.2	7.1	13.5	11.7
packham pear, firm, peeled	19	165	ND	ND		ND	–	9.7	–	16.0	–
packham pear, ripe, unpeeled	24	165	ND	ND		ND	–	8.7	–	14.4	–
packham pear, ripe, peeled	17	165	ND	ND		ND	–	9.8	–	16.2	–
pear, Bosc			–	–	0.01[c]	–	–	–	–	–	–
pear, d'Anjou			–	–	0.02[c]	–	–	–	–	–	–
peach, clingstone	21	145	ND	ND		ND	–	1.9	–	2.8	–
peach, white	19	145	2.2	0.4		0.5	–	1.9	–	2.8	–
peach, yellow	16	150	tr	tr		tr	–	1.8	–	2.6	–
peach, unspecified			–	–	0.04[c]	–	–	–	–	–	–
prickly pear	18	100	tr	tr		tr	–	5.7	3.9	5.7	3.9
persimmon	16	170	2	0.33		0.55	–	–	7.8	–	13.3
pineapple	19	89	tr	tr		tr	–	1.9	–	1.7	
plantain			–	–	0.04[c]	–	–	–	–	–	–
plum, red	19	76	tr	tr	0.02[c]	tr	0.015[c]	1.6	2	1.2	1.5
rambutan	23	104	1.6	0.36		0.37	–	3.0	–	3.1	–
raspberry	16	60	tr	tr	0.02[c]	tr		3.4	–	2.0	
rhubarb					0[c]				0.7		
strawberry	11	70	ND	ND	tr[c]			–	1.5	–	1.1
watermelon, seedless	10	286	3.2	0.32	0.02[c]	0.92		–	1.2	–	3.4

[a] In the current study, results are an average of 2–3 separate determinations: –, not measured; ND, not detected via fructan Megazyme assay if fructan values were in the range of 0–0.4 g/100 g dw; tr, trace levels detected if fructan values measured via the Megazyme assay were between 0.5 and 0.9 g/100 g dw. Other published data for fructan values. [b] Range of fructan values measured (*29*). [c] Fructans DP2, DP3, and DP4 measured only (*30*). [d] Fructose values from Food Standards Australia New Zealand (*33*). [e] Average serving size values were obtained from Foodworks Version 4.

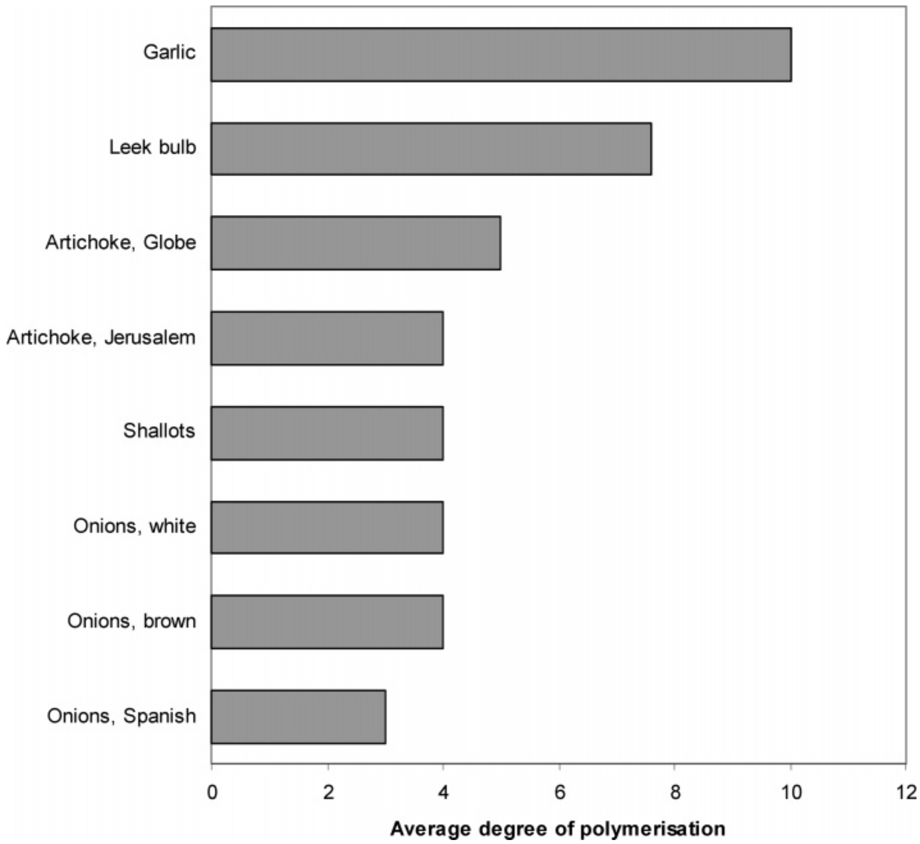

Figure 2. Average DP for fructans in selected vegetables.

stachyose, raffinose), and sugar alcohols (e.g., sorbitol, mannitol). In addition to the shortage of information about the fructan content of foods, current food composition tables rarely take into consideration galactooligosaccharides and sugar alcohols. The physiological effects of this category of carbohydrates have not been fully explored. Most research in this area has concentrated on the wide-ranging health benefits of fructans (*5*−*14*). However, it is important to note that there is a proportion of the population (around 10−15% in Australia and the United States) with functional gut disorders such as IBS (*21*, *22*). For these individuals, there is evidence that these poorly absorbed carbohydrates may be important triggers for gut symptoms (*20*, *28*, *43*−*47*).

Foods contain a mixture of fructans of different DP length ranging from two to several hundred (*48*). The importance of chain length to the induction of symptoms or to the putative beneficial effects of fructans has not been determined. However, there is some evidence to suggest that the rapidity by which fructans are fermented is related to their chain length, the shorter being more readily fermented (*18*). Furthermore, the smaller the molecule (and shorter the chain length), the greater will be its osmotic effect on a weight-for-weight basis. It might be hypothesized that fructans with a low average DP will be more likely to induce symptoms and be more troublesome in patients with a functional gut disorder, while those of a longer chain length may have the beneficial effects with less likelihood of gastrointestinal side effects (*18*). In other words, longer-chain inulin may be a better choice for therapeutic supplement of foods than shorter chain fructans. In this regard, vegetables with the longest average DP (DP8−11), spring onion bulb, garlic, and leek bulb, might be less troublesome in the diet than globe artichokes, shallots, and onions. Such concepts need to be directly addressed.

In conclusion, the present study provides more detailed information about fructan levels in vegetables and fruit and enhances current compositional tables on fructose content. This database will enable a more detailed analysis of the physiological consequences of including foods naturally high in fructans in the diet. It is important to note, however, that fructans also occur naturally in grains and cereals (*29*, *30*) and more comprehensive food composition tables that list total fructan level in a wide variety of grain and cereal products are also needed. The tools necessary to rationally design dietary approaches based upon increasing or decreasing fructan and/or fructose content to improve health and symptoms are slowly being assembled.

LITERATURE CITED

(1) Roberfroid, M. Dietary fibre, inulin and oligofructose: A review comparing their physiological effects. *Crit. Rev. Food. Sci. Nutr.* **1993**, *33*, 103−148.

(2) Roberfroid, M. B.; Delzenne, N. M. Dietary fructans. *Annu. Rev. Nutr.* **1998**, *18*, 117−143.

(3) Roberfroid, M. B. Introducing inulin-type fructans. *Br. J. Nutr.* **2005**, *93* (Suppl. 1), S13−S25.

(4) Englyst, H. N.; Quigley, M. E.; Hudson, G. J. Definition and measurement of dietary fibre. *Eur. J. Clin. Nutr.* **1995**, *49* (Suppl. 3), S48−S62.

(5) Roberfroid, M. B.; Van Loo, J.; Gibson, G. R. The bifidogenic nature of chicory inulin and its hydrolysis products. *J. Nutr.* **1998**, *128*, 11−19.

(6) Van Loo, J.; Clune, Y.; Collins, J. K. The SYNCAN projects: Goals, setup, first results and settings of the human intervention study. *Br. J. Nutr.* **2005**, *93*, S91−S98.

(7) Lewis, S.; Burmeister, S.; Brazier, J. Effect of the prebiotic on relapse of Clostridium difficile-associated diarrhea: A randomized, controlled study. *Clin. Gastroenterol. Hepatol.* **2005**, *3*, 442−448.

(8) Cummings, J. H.; Christie, S.; Cole, T. J. A study of fructo-oligosaccharides, in the prevention of travellers diarrhoea. *Aliment. Pharmacol. Ther.* **2001**, *15*, 1139−1145.

(9) Nyman, M. Fermentation and bulking capacity of indigestible carbohydrates: the case of inulin and oligofructose. *Br. J. Nutr.* **2002**, *87* (Suppl. 2), S163−S168.

(10) Abrams, S. A.; Griffin, I. J.; Hawthorne, K. M.; Liang, L.; Gunn, S. K.; Darlington, G.; Ellis, K. J. A combination of prebiotic short- and long-chain inulin-type fructans enhances calcium absorption and bone mineralization in young adolescents. *Am. J. Clin. Nutr*. **2005**, *82*, 471−476.

(11) Kleessen, B.; Hartmann, L.; Blaut, M. Fructans in the diet cause alterations of intestinal mucosal architecture, released mucins and mucosa-associated bifidobacteria in gnotobiotic rats. *Br. J. Nutr.* **2003**, *89*, 597−606.

(12) Kleessen, B.; Blaut, M. Modulation of gut mucosal biofilms. *Br. J. Nutr.* **2005**, *93* (Suppl. 1), S35−S40.

(13) Fontaine, N.; Meslin, J. C.; Lory, S.; Andrieux, C. Intestinal mucin distribution in the germ-free rat and in the heteroxenic rat harbouring a human bacterial flora: effect of inulin in the diet. *Br. J. Nutr.* **1996**, *75*, 881−892.

(14) Bengmark, S. Gut microbial ecology in critical illness: Is there a role for prebiotics, probiotics, and synbiotics? *Curr. Opin. Crit. Care* **2002**, *8*, 145−151.

(15) Piche, T.; des Varannes, S. B.; Sacher-Huvelin, S.; Holst, J. J.; Cuber, J. C.; Galmiche, J. P. Colonic fermentation influences lower esophageal sphincter function in gastroesophageal reflux disease. *Gastroenterology* **2003**, *124*, 894−902.

(16) Briet, F.; Achour, L.; Flourie, B.; Beaugerie, L.; Pellier, P.; Franchisseur, C.; Borbet, F.; Rambaud, J. C. Symptomatic response to varying levels of fructo-oligosaccharides consumed occasionally or regularly. *Eur. J. Clin. Nutr.* **1995**, *49*, 501−507.

(17) Stone-Dorshow, T.; Levitt, M. D. Gaseous response to ingestion of a poorly absorbed fructo-oligosaccharide sweetener. *Am. J. Clin. Nutr.* **1987**, *46*, 61−65.

(18) Rumessen, J. J.; Gudmand-Høyer, E. Fructans of chicory: Intestinal transport and fermentation of different chain lengths and relation to fructose and sorbitol malabsorption. *Am. J. Clin. Nutr.* **1998**, *68*, 357−364.

(19) Ten Bruggencate, S. J. M.; Bovee-Oudenhoven, I. M. J.; Lettink-Wissink, M. L. G.; Katan, M. B.; van der Meer, R. Dietary fructooligosaccharides affect intestinal barrier function in healthy men. *J. Nutr.* 2006, *136*, 70−74.

(20) Shepherd, S. J.; Gibson, P. R. Fructose malabsorption and symptoms of irritable bowel syndrome: Guidelines for effective management. *J. Am. Diet. Assoc.* **2006**, *106*, 1631−1639.

(21) Camilleri, M.; Choi, M. G. Review article: Irritable bowel syndrome. *Aliment. Pharmacol. Ther.* **1997**, *11*, 3−15.

(22) Fullerton, S. Functional digestive disorders (FDD) in the year 2000−Economic impact. *Eur. J. Surg.* **1998**, *582*, 62−64.

(23) Gibson, G. R.; Roberfroid, M. B. Dietary modulation of the human colonic micrbiota: Introducing the concept of prebiotics. *J. Nutr.* **1995**, *125*, 1401−1412.

(24) Van Loo, J.; Cummings, J.; Delzenne, N.; et al. Functional food properties of non-digestible oligosaccharides: A consensus report from the ENDO project (DGXII AIRII-CT94-1095). *Br. J. Nutr.* **1999**, *81*, 121−132.

(25) Rumessen, J. J. Fructose and related food carbohydrates. Sources, intake, absorption and clinical implications. *Scand. J. Gastroenterol.* **1992**, *27*, 819−828.

(26) Macfarlane, G. T.; Cummings, J. H. The colonic flora, fermentation and large bowel digestive function. In *The Large Intestine: Physiology, Pathophysiology and Disease*; Phillips, S. F., Pemberton, J. H., Shorter, R. G., Eds.; Mayo Foundation, Raven Press Ltd.: New York, 1991; pp 51−92.

(27) Gibson, P. R.; Newnham, E.; Barrett, J. S.; Shepherd, S. J.; Muir, J. G. Review article: Fructose malabsorption and the bigger picture. *Aliment. Pharmacol. Ther*. **2007**, *25*, 349−63.

(28) Beyer, P. L.; Caviar, E. M.; McCallum, R. W. Fructose intake at current levels in the United States may cause gastrointestinal distress in normal adults. *J. Am. Diet. Assoc.* **2005**, *105*, 1559−15566.

(29) Van Loo, J.; Coussement, P.; De Leenheer, L.; Hoebregs, H.; Smits, G. On the presence of inulin and oligofructose as natural ingredients in the Western diet. *Crit. Rev. Food. Sci. Nutr.* **1995**, *35*, 525−552.

(30) Campbell, J. M.; Bauer, L. L.; Fahey, G. C., Jr.; Hogarth, A. J. C. L.; Wolf, B. W.; Hunter, D. E. Selected fructooligosaccharide (1-kestose, nystose, and 1^F-β-fructofuranosylnystose) composition of foods and feeds. *J. Agric. Food Chem.* **1997**, *45*, 3076−3082.

(31) L'homme, C.; Peschet, J. L.; Puigserver, A.; Biagini, A. Evaluation of fructans in various fresh and stewed fruits by high-performance anion-exchange chromatography with pulsed amperometric detection. *J. Chromatogr. A* **2001**, *920*, 291−297.

(32) Hograrth, A. J. C. L.; Hunter, D. E.; Jacobs, W. A.; Garleb, K. A.; Wolf, B. W. Ion chromatographic determination of three fructooligosaccharide oligomers in prepared and preserved foods. *J. Agric. Food Chem.* **2000**, *48*, 5326−5330.

(33) Australia New Zealand Food Authority. *Supplement to NUTTAB95 Database*; New Zealand Food Authority: Canberra, Australia, 1999.

(34) Matthews, R. H.; Pehrsson, P. R.; Farhat-Sabet, M. *Sugar Content of Selected Foods: Individual and Total Sugars*; U.S. Department of Agriculture, Human Nutrition Information Service: Beltsville, MD, 1987; pp 1−39.

(35) McCleary, B. V.; Blakeney, A. B. Measurement of inulin and oligofructan. *Cereal Foods World* **1999**, *44*, 398−406.

(36) Darbyshire, B.; Henry, R. J. The distribution of fructans in onions. *New Phytol.* **1978**, *81*, 29−34.

(37) Polland, C. J.; Amuti, K. S. Fructose oligosaccharides: Possible markers of phylogenetic relationships among dicotyledonous plant families. *Biochem. Syst. Ecol.* **1981**, *9*, 69−78.

(38) Darbyshire, B. Changes in the carbohydrate content of onion bulbs stored for various times at different temperatures. *J. Hortic. Sci.* **1978**, *53*, 195−201.

(39) Benkeblia, N.; Onodera, S.; Shiomi, N. Effect of gamma irradiation and temperature on fructans (fructo-oligosaccharides) of stored onion bulbs *Allium cepa* L. *Food Chem.* **2004**, *87*, 377−382.

(40) Goggin, D. E.; Setter, T. L. Fructosyltransferase and fructan accumulation during development in wheat exposed to terminal drought. *Funct. Plant Biol.* **2004**, *31*, 11−21.

(41) Monti, A.; Amaducci, M. T.; Pritoni, G.; Venturi, G. Growth, fructan yield, and quality of chicory (*Cichorium intybus* L.) as related to photosynthetic capacity, harvest time, and water regime. *J. Exp. Bot.* **2005**, *56*, 1389−1395.

(42) Gibson, P. R.; Shepherd, S. J. Food for thought: Western lifestyle and susceptibility to Crohn's disease: The FODMAP hypothesis. *Aliment. Pharmacol. Ther*. **2005**, *21*, 1399−1409.

(43) Nelis, G. F.; Vermeeren, M. A.; Jansen, W. Role of fructose-sorbitol malabsorption in the irritable bowel syndrome. *Gastroenterology* **1990**, *99*, 1016−1020.

(44) Fernandez-Banares, F.; Esteve-Prado, M.; de Leon, R.; Humbert, P.; Cabre, E.; Llovet, J. M.; Cassull, M. A. Sugar malabsorption in functional bowel disease: Clinical implications. *Am. J. Gastroenterol.* **1993**, *88*, 2044−2050.

(45) Symons, P.; Jones, M. P.; Kellow, J. E. Symptom provocation in irritable bowel syndrome. Effects of differing doses of fructose-sorbitol. *Scand. J. Gastroenterol.* **1992**, *27*, 940−944.

(46) Goldstein, R.; Braverman, D.; Stankiewicz, H. Carbohydrate malabsorption and the effect of dietary restriction on symptoms of irritable bowel syndrome and functional bowel complaints. *Isr. Med. Assoc. J*. **2000**, *2*, 583−587.

(47) Andersson, D. E.; Nygren, A. Four case of long-standing diarrhoea and colic pains cured by fructose-free diet-A pathogenic discussion. *Acta Med. Scand.* **1978**, *203*, 87−92.
(48) Prosky, L.; Hoebregs, H. Methods to determine food inulin and oligofructose. *J. Nutr.* **1999**, *129*, 1418S−1423S.

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