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Free sugars in fruits and vegetables

by C. Y. Lee, R. S. Shallenberger, and M. T. Vittum

INTRODUCTION

The carbohydrates are especially prominent constituents of plants and usually form over one-half of the total plant substance. They serve not only as a source of available energy but also as reserve food and as structural materials. They are one of the main groups of food substances (carbohydrates, proteins, and fats) to be synthesized in the plant from simple organic substances. The empirical composition of carbohydrates may be expressed by the formula $C_nH_{2n}O_n$. With regard to their specific chemical properties, carbohydrates may contain a potential aldehyde, -CHO, or ketone, C=O, group.

In general, the substances belonging to this class of compounds may be divided into three broad groups: monosaccharides, oligosaccharides, and polysaccharides. Monosaccharides have five carbon atoms (pentoses) or six carbon atoms (hexoses) and have a sweet taste. The second group of carbohydrates, oligosaccharides, is made up of two or more monosaccharide units linked to one another through a glycosidic bond. These are the disaccharides, trisaccharides, tetrasaccharides, etc., and may or may not have reducing properties. No sharp line of distinction can be drawn between the oligosaccharides and the third group of carbohydrates, the polysaccharides, which represent large aggregates of monosaccharide units (starch, cellulose, pectin, etc.).

The main function of carbohydrates upon ingestion by an animal organism is that of a fuel. They are metabolized to other products with the release of carbon dioxide, water, and energy. In addition, certain products of carbohydrate metabolism aid in the breakdown of many food stuffs, acting as catalysts in biological oxidations. Carbohydrates can also be used as a starting material for the biological synthesis of other types of compounds in the body, such as fatty acids and certain amino acids. Regardless of the form in which a carbohydrate happens to be ingested, it must be transformed into a monosaccharide for absorption and metabolism, thus emphasizing the significance of monosaccharides in food stuffs.

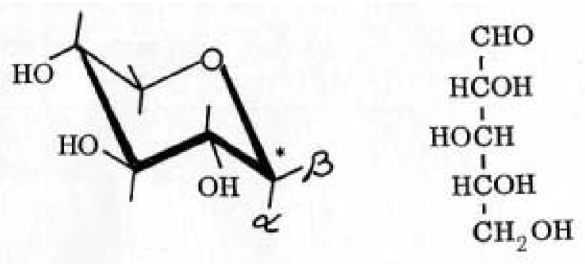
In spite of the increasing awareness of the specific carbohydrate role as human food, however, many problems in this field are far from being solved owing to chemical and structural complexity of the sugars. The types of sugar and their concentration in foods are only known approximately and in general terms. The free hexose and pentose content of many foods is generally reported only as "total reducing sugars,' and the oligosaccharide content of foods is usually reported as "nonreducing sugar" calculated to be sucrose. It is now apparent that the "nonreducing sugar" fraction of foods may have, as the major sugar present, higher molecular weight and more complex homologues of sucrose such as raffinose, stachyose, and verbascose. Recently, Shallenberger and Moores (1) and Shallen-berger and Moyer (2) were able to apply paper chromatographic techniques to identify those common monosaccharides and oligosaccharides in foods by quantitative chromatographic methods in the range of standard deviation of less than 5 μg for 10–200 μg of sugar.

With the rapidly developing role of individual specific sugars in metabolic processes, it is becoming increasingly imperative that the specific sugars in foods be identified and their concentration tabulated. The specific purpose of this study was to identify and determine the concentration of the major free sugars which occur in common foods of plant origin.

STRUCTURE AND PROPERTIES OF FREE SUGARS IN FRUITS AND VEGETABLES

Pentoses

Eight aldo-pentose sugars are known, four belonging to the D-series, and four enantiomorphic compounds, belonging to the L-series. Only four occur naturally, but not in any great abundance in the free state. These are D-xylose, D-ribose, and D- and L-arabinose. *D-xylose*



D–Xylopyranose *Aldehydo*–D–Xylose

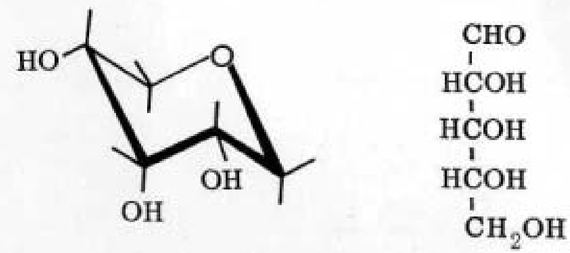
This pentose sugar is configurationally related to D-glucose. In the β–D-anomer, all -OH groups are equatorial. Because of this element of conformational stability, it is the most widely distributed pentose sugar in Nature, much as β–D-glucose is the most abundant hexose. In polymeric form, as a xylan, generally in a β–1→4 glycosidic union, D—xylose is found universally in higher plants. Here it is a major component of hemicellulose material in plant cell walls. It is often found, quite naturally, as a free sugar in plants, but always as a trace, or very minor component of the free sugar extracts. The usual crystalline form of D-xylose is that of the α–D-anomer, m.p. 145°, and $[\alpha]_D$ + 93.6° → + 18.8° (3). The enantiomorph, L-xylose is also known as the α-isomer, but is not known to occur naturally. Xylose constitutes about 70 per cent of corn-cob holocellulose.

Free xylose, in trace amounts, has been reported in onion, strawberries, prunes, apples, pears, grapes, juniper berries, barley malts, brewhouse worts, maple syrup, asparagus, the white and the yolk of eggs, corn, tomatoes, apricots, bamboo shoots, potatoes, beans, alfalfa, beer, and mangoes.

Xylose is not generally fermented by yeasts (and hence appears in wines). Large quantities in the diet cause cataracts in rats. It is also reported to be a minor component of citrus pectic acid and a component of the glycosidic moiety of the alkaloid tomatin found in tomatoes.

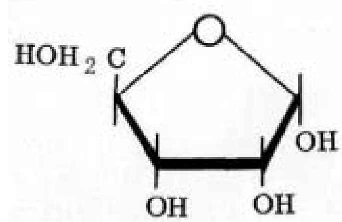
*α and β indicate the position of the OH group on this carbon atom for the α– and the β–D or L isomers respectively.

D–Ribose



D–Ribopyranose *Aldehydo*–D–Ribose

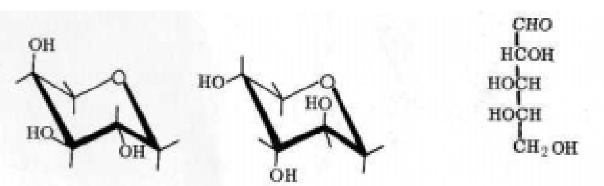
Configurationally related to P-allose. Source: hydrolysis of nucleic acid. Not generally fermented by yeasts. No reports of existence in the free state. In natural products in glycosidic linkage, the furanose form persists,



α–D–Ribofuranose

m.p. 86–87°, $[\alpha]_D$ – 23.1° → – 23.7° (presumably a β–D–anomer). L–isomer, m.p. 87°, $[\alpha]_D$ + 20.3° → + 20.7°.

Arabinose



L–Arabopyranose D–Arabopyranose *Aldehydo*–L–Arabinose

Configurationally related to the lower 5 carbon atoms of glucose.

Both D- and L- enantiomorphs of arabinose occur in nature, particularly the L-isomer.

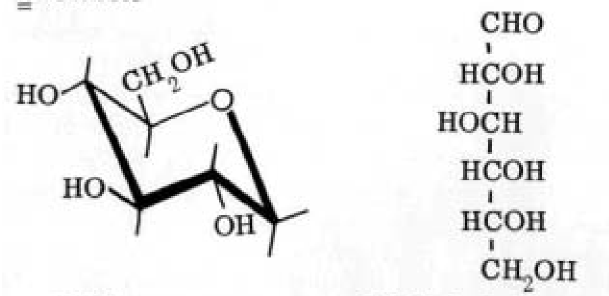
α–L-arabinose (4) has m.p. 160°, and $[\alpha]_D$ - 14.6° → + 105°. The β–L-anomer has $[\alpha]_D$ + 190.6° → + 104.5° (3). D-arabinose, prepared irom D-glucosamine has m.p. 153°, $[\alpha]_D$ - 104.6. L-Arabinose occurs as a glycosidic component of hemicellulose, gum, and pectin.

Arabinose is reported to be a free, but minor sugar component of onions, grapes, strawberries, commercial beer, corn, and alfalfa.

Hexoses

Of the 16 possible aldohexose sugars, only one occurs free to any extent. This is D-glucose, D-galactose is occasionally encountered in trace amounts, and because of its distribution in mannans, D-mannose may be occasionally encountered. The L -series of aldo-hexoses is not known to occur in the free state.

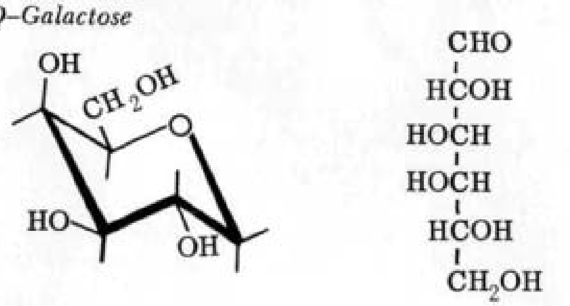
D–Glucose



D–Glucopyranose *Aldehydo*–D–glucose

As might be noted, the most prevalent hexose to occur in nature, both in free-form and in glycosidic union, D-glucose is very closely related to the most prevalent pentose, D-xylose. Both anomeric forms are known in the crystalline state. α–D-glucose has m.p. 146°C and $[\alpha]_D$ +112° → + 52°. β–D-glucose has m.p. 148-150°C and $[\alpha]_D$ + 18° → + 52°. It is the central carbohydrate. The reserve food starch is a polymer of the α–D-anomer, and the plant structural material cellulose is a polymer of the β–D-anomer. In commerce, α–D-glucose is known as dextrose.

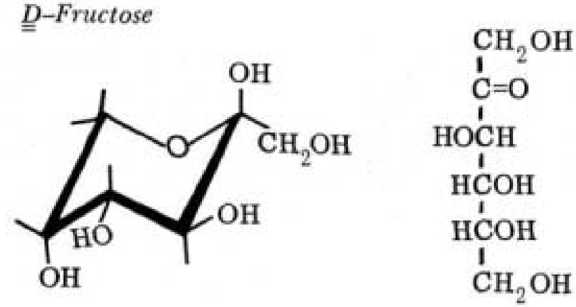
D–Galactose



D–Galactopyranose *Aldehydo*–D–Galactose

D -galactose is epimeric with D-glucose at the fourth carbon atom. Both the α–and β–D-anomers are known. It has m.p. 167°C. Thefor the β-anomer is + $[\alpha]_D$).7° → 80.2°. Thefor the β -anome $[\alpha]_D$ is 52.8° → 80.2°. Occasionally, D-galactose is found in trace amounts in the free state. More often, it is found in glycosidic union. With D glucose, galactose makes up lactose, the reducing disaccharide of mammalian milk. In plants, it is part of the molecule of the sugars known as the raffinase series of oligosaccharides.

D–Fructose

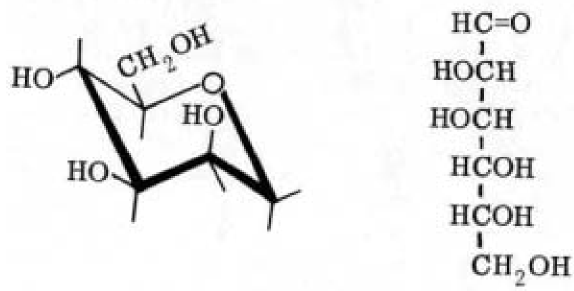


β–D–Fructopyranose Keto–D–Fructose

D -fructose is a ketose sugar. It is known in only one crystalline anomeric form, that of the β–D-anomer shown. Its m.p. is 102-104°C, and shows $[\alpha]_D$ - 132.2° → - 92.4°. Hence, while D -glucose is dextrarotatory, and is also known as dextrose, D -fructose is levorota-tory, and is also known as levulose.

D -fructose is widely distributed in Nature, either as the free sugar, or in glycosidic combination, as in the disaccharide sucrose. It is the sweetest sugar known.

D–Mannose



D–Mannopyranose Aldehydo–D–Mannose

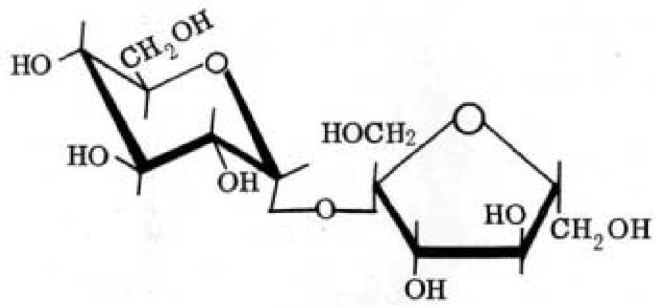
Reports of the occurrence of free mannose occurring in Nature are scarce. The sugar is the 2-epimer of D -glucose. Both the α–D- and the β–D-anomers are known. The former has $[\alpha]_D$29.3→ 14.2°. The latter has $[\alpha]_D$ - 17.0 → 14.2°. The m.p. are 133°C and 132°C respectively. The β–D-anomer is the only known monosaccharide which has a distinctly bitter taste.

Oligosaccharides

Sucrose

Sucrose occurs almost universally throughout the plant kingdom. Commercially it is obtained from sugar cane, sugar beets, and other sources. Therefore, it is often called cane sugar or beet sugar. Sucrose forms an important constituent of the human diet, both directly and in combination in various commercially prepared foodstuffs.

Structurally, in addition to glucose, it contains a fructofuranose unit and the given chemical name is α–D -glucopyrosyl β–D-fructofuranoside.

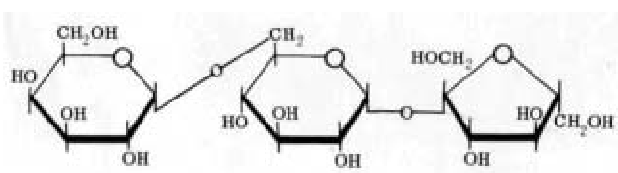


sucrose

Both potential aldehyde and ketone groups are blocked by the manner of linkage; hence, sucrose is non-reducing and does not undergo mutarotation. Its $[\alpha]_D^{20}$ + 66.5 and m.p. is 186°C. Upon hydrolysis by acids and by enzymes, sucrose gives rise to a molecule each of glucose and fructose. The hydrolysis of sucrose is called "inversion" and the product is called "invert sugar" because the optical rotation changes from dextro- to levo- due to the high levorotatory power of the D-fructose.

Raffinose

Raffinose is the most abundant trisaccharide found in Nature and occurs almost as widely in the plant world as sucrose. Raffinose crystals possess m.p. 78° and $[\alpha]_D^{20}$ + 105.2°. In addition to sucrose, it contains a galactopyranose unit. Upon complete acid hydrolysis, it gives one mole each of D-glucose, D-fructose, and D-galactose. Mild acid hydrolysis affects only one linkage, and melibiose and D-fructose are produced.

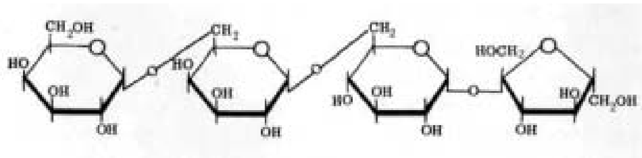


O–α–D-Galactopyranosyl-(1 → 6)-O–α–D-glucopyranosyl-(l →2) β–D-fructofuranoside

Treatment with invertase also affords D-fructose and melibiose whereas α–D-galactosidase, an enzyme which specifically breaks the α-galactoside link, leads to D-galactose and sucrose.

Stachyose

Stachyose occurs in the roots of many plant species and is associated with sucrose and raffinose. It is the best known sugar of its class, the classical tetra-saccharide. The best source of stachyose is the rhizome of *stachys tuberifera* (Japanese artichoke). In addition to raffinose, it contains another galactopyranose unit which is called O–α–D-galactopyranosyl-(l → 6)-O-α–D-galactopyranosyl-(l → 6)-O-α–D-glucopyranosyl—(1 → 2)-β–D-fructofuranoside. Its m.p. is 167—170°C and $[\alpha]_D^{20}$ + 148°. Hydrolysis by acid or invertase cleaves it to a trisaccharide (manninotriose) and D-fructose in equimolar amounts.



MATERIALS AND METHODS

Source of Materials

Plant materials belonging to a certain botanical genus were selected for the sample according to their botanical family and species. Most raw material was grown locally at the Northeastern Regional Plant Introduction Station at Geneva during the 1966, 1967, and 1968 crop seasons using normal cultural practice. When it appeared that maturity within a variety or species might be important, sequential harvests were used. Some food materials were also obtained from other sources.

Analytical Procedures

Extraction and Purification of Samples Selected samples were sliced or dried and 50.0 g of raw material was placed in a 400 ml Mason jar and covered with 300 ml of boiling 80% ethanol. After simmering for several hours in a steam bath, the jars were sealed, then stored at room temperature. For the analyses, each sample was homogenized in a Waring blendor for 3-5 minutes at high speed and then filtered through a Buchner funnel using a vacuum source. The residue in the funnel was extracted twice again, using 150 ml of 80% ethanol each time. The extracts were then combined and volume reduced in a rotating evaporator. This served to remove the alcohol. The extracts were then purified further by passing first through a column of Dowex 50 resin in the H+ form and then through a column of Dowex 3 resin in OH^- form. The extracts were then combined and concentrated in the rotating evaporator until the extract contained sugars at the range of between 0.5 and 3.0%, as indicated by refractive index measurements.

Paper Chromatography Reagents

Chromatographic Solvents: Acid solvent: Butanol-Acetic acid-Water, 4:1:5 v/v mixture. Neutral solvent: Butanol-Ethanol-Water, 40:11:19 v/v mixture.

Spray Reagents: Silver nitrate spray reagent: In 20 ml of acetone, 0.1 ml of saturated silver nitrate was added. Sodium hydroxide spray agent: Mixed 5 ml of 50% sodium hydroxide solution with 100 ml of 95% ethyl alcohol.

Sugar Reagents: Reagent A: Dissolve 25 g of anhydrous sodium carbonate, 25 g of Rochelle salt, 20 g of sodium bicarbonate, and 200 g of anhydrous sodium sulfate in about 800 ml of water and dilute to 1:1. Reagent B: Prepare 15% cupric sulfate containing 1 to 2 drops of concentrated sulfuric acid per 100 ml.

Arsenomolybdate Reagent (Nelson's Reagent): Dissolve 25 g of ammonium molybdate in 450 ml of distilled water, add 21 ml of concentrated sulfuric acid, 3 g of sodium orthoarsenate heptahydrate dissolved in 25 ml of water, mix and incubate at 37 °C for 24 hours.

Invertase Solution: Dissolve 0.1 g of invertase (Melibiase free, Nutritional Biochemicals Co., Cleveland, Ohio) in 10 ml of water. Prepared fresh.

Determination of Individual Sugar

Quantitative determination of individual free sugar by paper chromatography was conducted according to the methods of Shallenberger and Moores (1) and Shallenberger and Moyer (2). Five ml samples of purified extract containing 5 to 30 μg/μl of sugar were spotted 3 cm apart on Whatman No. 1 filter paper, 57 X 46 cm. Glucose, fructose, sucrose, maltose, raffi-nose, and stachyose were spotted in concentration of 50 μg for location purpose and for use as standards. Their Rg values in acidic and neutral solvents are shown in Table 1.

TABLE 1.—Rg Values for Sugars in Order of Increasing Numerical Values

Sugar	Acid solvent	Neutral solvent
stachyose	0.04	0.07
manninotriose	0.08	0.10
raffinose	0.18	0.22
gentiobiose	0.29	0.32
lactose	0.29	0.33
melibiose	0.29	0.33
melizitose	0.30	0.34
maltose	0.41	0.45
trehalose	0.44	0.49
sucrose	0.59	0.63
turanose	0.59	0.66
galactose	0.90	0.91
sorbose	1.16	1.10
fructose	1.24	1.18
mannose	1.23	1.19
arabinose	1.30	1.20
xylose	1.50	1.38
lyxose	1.57	1.45
ribose	1.71	1.52
fucose	1.86	1.59
rhamnose	2.42	1.91

The papers were equilibrated with the solvent in the chamber and then developed for 72 hours by the descending technique. The chromatograms were dried at room temperature and then spray reagents were applied for location of the sugar on the survey strips. Location of the sugars on the unsprayed chromatograms is facilitated by calculating the Rf or Rg value for each sugar. The areas containing the sugars were circumscribed with a pencil, and the circles or rectangles of paper were cut into blood sugar tubes graduated at 1 to 5, 10, 15, and 25 ml.

A circle of paper about 30 mm in diameter containing no sugar was cut into a tube and was used for calculating absorbance interference. Three ml of water was added to each tube. After the sugars were eluted, 1 drop of 1% invertase solution was added to the tubes containing sucrose, raffinose, and stachyose, and they were allowed to stand overnight. Tubes containing reducing sugars were analyzed immediately after the elution. One ml of copper reagent (made by mixing 25 parts of sugar reagent A to 1 part of sugar reagent B) was added to each tube and it was placed in a boiling water bath for 45 minutes. The test tubes were then cooled in cold water, and 1 ml of arsenomolybdate reagent was added. After the contents of the tubes were reacted with Nelson's reagent, the solutions were diluted to 10 ml and finally decanted through a plug of glass wool. The absorbance was determined with a Beckman Model B spectrophotom-eter at 500 mμ by setting the blank determination to 100% transmittance.

The concentration of sugar was calculated by the following equations:

$$\text{Sugar concentration} = \frac{Ac}{a}$$

A: absorbance of the sugar of unknown concentration corrected for the paper present, c: concentration of the standard sugar, a: absorbance of the standard corrected.

$$\text{Absorbance correction} = \frac{Pb}{p}$$

P: area of the paper containing the sugar of unknown concentration. p: area of the standard size piece of paper. b: absorbance of the standard size piece of paper.

$$\text{Oligosaccharide concentration} = \frac{Oa \times Gc}{Ga} \times \frac{Gb}{Ob}$$

Oa: oligosaccharide absorbance corrected for filter paper. Gc: concentration of a nonchromatographed glucose standard. Ga: absorbance of a nonchromatographed glucose standard. Gb: the slope of the nonchromatographed glucose standard curve, 225. Ob: the slope of the oligosaccharide curve:
200 for sucrose
140 for raffinose
87 for stachyose

Measurement of Optical Rotation

Polarimetric measurement is the most widely used method in the analysis of sugar. In order to confirm the results of chemical analysis for individual sugar, optical rotation was measured on each sugar extract with Rudolph Polarimeter Model 80 equipped with an oscillating polarizer and a photoelectric read-out attachment at 20°C. The observed value was compared with the calculated value and found in good agreement at a correlation coefficient of 0.98, as shown in Figure 1.

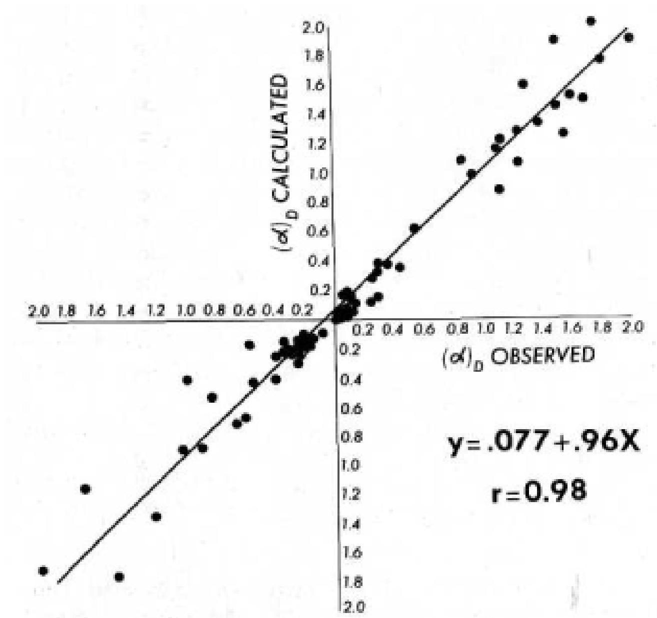


Fig. *1.—Regression of observed optical rotation of plant extracts upon the optical rotation calculated from individual sugar found in the extracts.*

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DISTRIBUTION OF FREE SUGARS IN VEGETABLES

Code No	Common Name	Scientific Name	Variety	Total Solids	Glucose	Fructose	Sucrose	Raffinose	Stachyose	Unidentified Sugar #1	Unidentified Sugar #2
				% Fresh Basis							
1	Asparagus	*Asparagus officinalis* L.	Mary Washington	8.99	**1.02**	**1.40**	0.30			0.02(N0.36)	
2			UC 309	**9.30**	0.82	**1.20**	**0.26**				
3	Beet	*Beta vulgaris*	Perry's Detroit Dark Red	**11.17**	0.08	**0.12**	**6.64**	**0.06**	**0.04**		
4			Ruby Queen (size 3)	11.20	**0.28**	**0.20**	**5.58**				
5	Broccoli	*Brassica oleracea* var. *botrytis*	Primo	12.28	**0.60**	**0.52**	**0.40**	0.10	**0.18**	0.10(N 0.34)	
6			Spartan Early	11.08	**0.86**	**0.87**	**0.50**				
7			Waltham 29	12.51	**0.74**	**0.62**	**0.36**	**0.16**	**0.22**	0.06(N0.22)	0.06(N0.34)
8	Brussel sprout	*Brassica oleracea* var. gemmifera	Jade Cross	**11.72**	**0.52**	0.60	**0.40**	**0.16**		0.10(N0.35)	
9			Long Island Improved Catskill Strain	**11.19**	**0.80**	**0.90**	**0.42**	**0.22**		0.20(N 0.35)	
10	Cabbage	*Brassica oleracea* var. *capitata* Linn.	Early Head	**5.97**	**1.40**	**1.14**	**0.26**			0.10(N0.08)	
11			Glory 61	**6.62**	**1.62**	**1.06**	**0.02**				
12			Red	**9.06**	**2.06**	1.74	0.50	**0.10**	**0.06**		
13			Special Golden Acre	**7.42**	1.72	**1.40**	**0.16**	**0.06**		0.08(N 0.34)	
14	Chinese cabbage	*Brassica pekinensis*	Michihli	**5.04**	**0.82**	**0.64**					
15	Carrot	*Daucus carota*	Danvers 126	**12.42**	**0.92**	**0.94**	**4.24**				
16			Imperator 408	**12.49**	0.74	**0.84**	4.50			0.03(N0.56)	
17			Nantes Long Strain	**11.45**	**0.92**	**0.82**	3.68				
18			Red Core Chantenay	**11.64**	**0.82**	**0.80**	**4.54**				
19	Cauliflower	*Brassica oleracea* var. *botrytis*	Agway Early Snow Ball	7.92	1.06	0.98	1.02				
20			Seneca Snow Ball	**8.49**	0.62	0.50	0.54	0.06	**0.08**	0.08(N 0.34)	
21			Super Snow Ball	7.75	**0.81**	0.74	**0.46**	**0.02**		0.02(N 0.34)	
22	Celery	*Apium graveolens*	Early Fortune	8.37	0.36	0.36	**0.24**				
23			Tall Green Light	**8.67**	0.68	0.64	**0.28**				
24			Tall Utah 52-70	7.84	**0.44**	0.30	0.42				
25	Cucumber	*Cucumis sativus*	Ashley	4.40	0.82	0.82	0.08				
26	Cucumber		Crusader	**3.50**	0.87	0.97	**0.07**				
27			Spartan Dawn	**3.56**	**0.88**	0.80	**0.04**			0.02(N0.15)	
28			SMR 18	**2.36**	0.88	0.86	**0.04**			0.02(N0.11)	
29	Dandelion	*Taraxacum offwinale*	Wild	**14.17**	**0.50**	0.38	**1.46**			0.12(N0.28)	
30	Eggplant	*Solarium melongena* var. *esculentum*	Black Beauty	7.68	1.36	1.36	**0.08**			0.11(N 0.34)	
31			Black Magic	**9.29**	1.66	1.70	**0.42**				
32	Endive	*Cichorum endivia* Linn.	Green Curled	**5.60**	0.07	**0.16**	**0.07**				
33	Escarole	*Cichorum endivia* Linn.	Florida Deep Heart	**6.15**	**0.16**	**0.32**	**0.10**				
34	Kale	*Brassica oleracea* var. *acephala*	Curled Halftall Green Scotch	**10.61**	**0.30**	0.24				0.06(N 0.35)	
35			Vates	8.86	0.24	**0.17**					

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Code No.	Common Name	Scientific Name	Variety	% Fresh Basis							
				Total Solids	Glucose	Fructose	Sucrose	Raffinose	Stachyose	Unidentified Sugar #1	Unidentified Sugar #2
36	Kohlrabi	*Brassica oleracea* var. *gongylodes*	Early White Vienna	7.55	1.34	1.24	0.58				
37	Leek	*Allium porrum* Linn.	Beyersdorf Special	13.67	0.88	1.56	1.44			0.96(N0.10)	0.24(N0.13)
38			Large American Flag	10.23	1.08	1.38	0.68	0.12	0.56		
39	Lettuce	*Lactuca sativa*	Grand Rapids Waldmann's Strain	5.06	0.17	0.24	0.10	0.12		0.07 (N 0.24)	
40			Paris Island Cos	6.55	0.32	0.64	0.12				
41			Pennlake	4.14	0.22	0.54	0.06			0.03(N0.52)	
42			White Boston	4.14	0.30	0.40	0.12				
43	Melon (Honeydew)	*Cucumis melo*		25.48	2.56	2.62	5.86			0.06(N0.37)	
44	(Musk)	*Cucumis melo* var. *reticulatus*	Decconinck Bender	8.73	1.60	1.90	2.36				
45			Saticoy Hybrid	12.94	1.84	2.16	4.76			0.14(N0.10)	0.04(N 0.35)
46	(Water)	*Citrullus vulgaris*	Grey Belle	10.59	1.80	3.50	3.72				
47			Sugar Baby	8.54	1.82	3.58	0.97			0.06(N0.34)	
48	Okra	*Hibiscus esculentus* L.	Emerald	10.70	1.03	1.06	0.75				
49	Onion	*Allium cepa*	Autumn Splendor Hybrid	11.68	2.08	1.26	1.00	1.06	1.16		
50			Iowa 44	12.47	2.10	0.94	0.94	1.06	0.98	1.30 (N 0.10)	1.24CN0.21)
51			Premier Hybrid	10.27	1.76	1.18	0.84	0.66	0.32		
52			Southport White Globe	11.82	2.34	1.00	0.80	0.42	0.24	0.46(N 0.35)	
53	Green Onion	*Allium cepa*	Evergreen White Bunching	9.59	0.56	0.76	0.86	0.04	0.06		
54	Parsley	*Petroselinum hortense*	Peerless	11.37	0.08		0.26				
55			Perfection	11.18	0.12		0.14				
56	Parsnip	*Pastinaca sativa*	Harris Model	20.99	0.18	0.24	2.98		0.01		
57	Pepper	*Capsicum frutescens*	Early Galwonder	5.93	1.06	0.86	0.06				
58			Pimento	6.93	0.76	0.92	0.20	0.06			
59			Staddons Selection	5.77	0.88	0.82	0.06				
60	Potato	*Solatium tuberosum*	Katahdin	19.27	0.06	0.01	0.04				
61			(stored) *		0.96	1.16	1.72	0.05	0.09	0.02 (N 0.44)	
62			Kennebec	19.87	0.10	0.12	0.10				
63			(stored) *		1.32	1.48	1.88	0.12	0.12	0.10(N0.35)	
64			New York 3	24.41	0.14	0.12	0.16			0.02(N0.36)	
65			Norgold Russet	19.21	0.22	0.12	0.24				
66			(stored) *		0.94	0.98	2.56				
67			Peconic	20.36	0.30	0.14	0.12	0.08			
68			(stored) *		1.14	1.22	1.32				
69			Russet Burbank	21.71	0.08	0.10	0.20				
70			(stored) *		0.82	0.90	0.96	0.10	0.16	0.10(N 0.28)	
71	Pumpkin	*Cucurbit a pepo*	Small sugar	8.33	1.84	1.66	1.80	0.04	0.06	0.02 (gala)	0.04(N 0.34)
72			Young's Beauty	5.92	1.54	1.20	0.80	0.10	0.16	0.01 (gala)	0.02(N 0.34)

73	Radish	*Raphanus sativus* Linn.	White Icicle	4.40	0.84	0.30					
74			Champion	5.46	**1.34**	**0.74**	**0.22**				
75	Rhubarb	*Rheum rhaponticum* L.	Chipman's Canada Red	5.71	**0.46**	**0.44**	0.10				
76			Victoria	6.69	0.38	0.34	0.07				
77	Rutabaga	*Brassica napobrassica*	American Purple Top Yellow	10.97	1.66	1.42	0.72			0.04 (Maltose)	
78	Spinach	*Spinacia oleracea*	Chesapeake Hybrid	8.25	0.12	0.05	0.10				
79			Packer Hybrid	8.55	**0.10**	0.04	0.08				
80			Virginia Savoy	7.31	0.05	0.03					
81	Spinach (New Zealand)	*Tetragonia expansa*	New Zealand	4.42	0.03	0.01	0.02				
82	Squash (Summer)	*Cucurbita pepo*	Crookneck F-l	6.76	0.70	0.82	0.16			0.06(N 0.35)	
83			Hybrid Ambassador	5.12	1.02	1.14	0.10				
84			Seneca Zucchini	4.78	0.58	0.50	0.02				
85	(Winter)	*Cucurbita maxima*	Butternut	11.64	1.18	1.52	1.42	0.02	0.03	0.03(gal)	
86			Green Hubbard	16.54	1.05	1.15	0.66				
87			Mammoth Table Queen	10.75	0.60	0.76	3.60	0.09	0.08	0.05(gal)	
88			Red or Golden Hubbard	13.38	1.02	1.20	0.74	0.04	0.14	0.03(gal)	0.04(N 0.34)
89	Sweet Corn	*£ea mays* Linn.	F. M. Cross	20.06	0.20	0.20	2.72				
90			Seneca Arrow	23.13	0.40	0.42	2.62		0.20		
91			Seneca Chief	21.47	0.52	0.56	3.10				
92			Seneca Explore	22.08	0.20	0.15	2.96				
93			Seneca 60-V	26.63	0.15	0.11	2.76				
94			Tastyvee	22.77	0.54	0.40	4.00			0.04(N0.50)	
95	Swiss Chard	*Beta vulgaris* var. *cicla*	Fordhook Giant	9.20	0.17	0.09	0.06				
96	Sweet Potato	*Ipomoea batatas Poir*		22.53	0.33	0.30	3.37			1.32(N0.48)	
97	Tomato	*Lycopersicon esculentum*	Fireball	4.86	1.25	1.48					
98			Galaxy	4.67	1.08	1.46	0.01				
99			Heinz 1548	5.04	0.88	**1.08**					
100			New Yorker	6.18	1.20	1.34	0.02			0.01 (gal)	
101			Rocket	5.42	1.17	1.47					
102	(Paste)		Belerina	5.58	1.20	1.46	0.02				
103			Harvester	6.16	1.22	1.35	0.03			0.01 (N 0.29)	
104			Bouncer	5.01	1.00	1.22	0.01				
105			Roma V. F.	5.20	1.04	1.30	0.03	0.01		0.06(gal)	0.04(N0.35)
106	Turnip	*Brassica rapa*	Purple Top White Globe	7.40	1.50	1.18	0.42				

*Stored potatoes at 35°F for 4>£ month. In parenthesis shows the preliminary identification, gal = galactose, and Rg value in neutral solvents (N).

DISTRIBUTION OF FREE SUGARS IN FRUITS % Fresh basis

Code No.	Common Name	Scientific Name	Variety	Total Solids	Glucose	Fructose	Sucrose	Maltose	Unidentified Sugar #1	Unidentified Sugar #2
1	Apple	*Pyrus Malus*	Cox Rome	14.46	0.72	6.50	4.44	0.08	0.18*	0.60(A 0.76)
2			Farmer Spy	15.19	1.08	5.28	3.84			
3			Golden Delicious	18.83	0.98	7.10	3.80	0.38	0.32*	0.72(A 0.77)
4			Mclntosh	15.00	1.32	6.12	3.00			
5			Rhode Island Greening	14.44	1.30	5.20	3.96			
6			Vance Delicious	17.84	1.64	6.04	3.64			
7	Apricot	*Prunus Armeniaca*	Alfred	13.86	1.86	0.92	5.82			
8			Curtis	15.02	1.60	1.63	5.86	0.06		
9	Blackberry	*Rubus* sp.	Darrow	14.89	2.18	1.76	0.60	0.96		
10			Hedrick	15.66	2.78	2.54	0.58	0.36		
11	Blueberry	*Vaccinium corymbosum*	Blue Crop	15.68	3.92	4.04	0.24	0.12		
12			Rancocas	16.11	3.60	3.60	0.14	0.04		
13	Currant	*Ribes sativum*	Red Lake (Red)	15.96	2.92	3.18	0.82			
14			Wilder (Red)	14.71	3.60	3.98	0.54			
15		*Ribes nigrum*	Consort (Black)	22.53	3.64	4.12	1.26	2.54		
16		*Ribes sativum*	White Imperial (White)	17.50	3.14	3.44	1.16			
17	Gooseberry	*Ribes grossularia-R. hirtellum hybrids*	Downing (White)	14.74	3.20	3.80	0.92			
18			Poorman (Red)	15.95	3.60	3.96	1.70			
19			Welcome (Red)	13.74	3.08	3.94	1.02			
20	Grape	*Vitis Labruscana*	Concord	16.40[1]	6.94	6.78	1.26	0.10	0.42**	
21			Delaware	22.40[1]	7.28	7.60	2.72	2.62	3.04**	
22			Himrod	17.50[1]	5.54	8.48	2.10	0.98	0.96**	
23			New York Muscat	20.20[1]	7.68	8.50	2.90	2.98	1.32**	
24		*Vitis vinifera*	Riesling	21.70[1]	6.36	6.34	1.90	3.08	3.62**	
25			Seibel 1000	15.80[1]	3.78	3.70	0.32	2.82	0.74**	
26			Seibel 5898	16.40[1]	5.90	5.94	1.74	0.68	0.90**	
27	Peach	*Prunus Persica*	Babygold	12.60	0.72	1.10	5.84			
28			Champion	14.92	1.08	1.40	9.94	0.04	0.12*	0.08 (A 0.79)
29			Elberta	14.51	1.26	1.40	7.12			
30			Red Haven	9.27	0.66	0.80	4.92	0.52		0.18(A 0.73)
31			Red Skin	12.68	0.82	1.20	6.80	0.02		0.18 (A 0.74)
32	Pear	*Pyrus communis*	Bartlett	12.47	1.00	7.88	1.28	0.48	0.18*	0.36(A 1.06)
33			Bosc	14.74	1.08	6.22	2.46	0.10	0.04*	
34			Clapp's Favorite	13.53	0.76	6.20	1.10	0.36	0.40*	
35	Plum	*Prunus domestica*	Green Gage	14.71	3.35	1.48	5.48			
36			Italian Prune	23.24	4.64	2.40	5.68	0.46		
37			Stanley	15.97	2.48	0.72	3.68			
38	Raspberry (Red)	*Rubus idaeus*	Cuthbert	20.67	2.40	1.58	3.68			0.16(A 0.54)
39	(Black)	*Rubus occidentalis*	Huron	28.22	4.56	4.84	1.90			0.40 (A 0.21)
40	Sour Cherry	*Prunus cerasus*	Early Richmond	15.28	5.17	3.32	1.02			
41			English Morello	13.77	4.68	3.44	0.58			
42			Meteor	14.89	2.88	2.63				
43			Montmorency	16.26	4.49	3.74				

44	Sweet Cherry	*Prunus avium*	Black Tartarian	26.91	16.14	8.64			**
45			Emperor Francis	22.30	6.98	10.22	0.44	0.24	
46			Napoleon	22.49	6.14	**6.14**			**
47		•	Schmidt	20.31	6.32	5.94	0.64		0.20
48			Windsor	19.93	6.86	5.98			0.16
49	Strawberry	*Fragaria chiloensis* var. *ananasso*	Earlidawn	8.42	1.98	2.28	0.50		
50			Sparkle	10.48	2.20	2.52	1.56	0.14	

Solids expressed as soluble solids. Values in parenthesis are the Rg values in the acid solvent (A).

* Preliminary results indicate a pentose.

** Preliminary results indicate a trisaccharide.

DISTRIBUTION OF FREE SUGARS IN FOODS OF THE LEGUMINOSAE FAMILY

				% Fresh Basis						
Cod No.	Common Name	**Scientific Name**	**Variety**	**Total Solids**	**Glucose**	**Fructose**	**Sucrose**	**Ramnose**	**Stachyose**	**Unidentified Sugar #1**
1	Dry Bean	*Phaseolus vulgaris*	Michelite				**2.40**	0.80	3.40	
2	Fava Bean	*Viciajaba*	Broad improved long pod	16.61		**0.18**	3.36	0.66		0.40 (N 0.26)
3	Lima Bean	*Phaseolus lunatus*	Early Thorogreen	28.65	0.02	**0.10**	2.68	0.56*	0.70	0.42(N 0.30)
4			Green Seeded Fordhook	25.45	0.02	0.06	2.74	**0.12***	0.22	0.02(N 0.35)
5			Milres	27.75	0.16		2.88		0.94	
6			S-400	22.74	0.02	0.12	2.78		**0.26**	
7			Thaxter	29.09		0.10	1.86	**.0.32***	0.72	0.06(N 0.32)
8	Mung Bean	*Phaseolus aureus*					**1.19**	**0.40**	**1.75**	0.04 (gala)
9	Pea Bean	*Phaseolus vulgaris*					2.55	0.65	3.06	0.05 (gala)
10	Pole Lima Bean	*Phaseolus lunatus*	Sieva Pole	24.58	0.18		**2.26**	0.32*	0.60	0.20(N 0.36)
11	Pole Snap Bean	*Phaseolus vulgaris*	Kentucky Wonder	**10.21**	0.48	**1.30**	0.28	0.26*		0.06(N 0.34)
12	Red Kidney Bean	*Phaseolus vulgaris*	Red Kidney				2.73	0.56	3.44	0.02 (gala)
13	Snap Bean	*Phaseolus vulgaris*	Earlygreen (size 2)	8.51	1.32	**1.42**	**0.32**		0.28	
14			(size 4)	9.30	1.24	**1.38**	0.26	0.52	0.30	0.08(N 0.42)
15			(size 5)	**10.07**	1.08	1.28	0.40	**0.14**	0.28	
16			Earlywax (size 2)	**4.92**	1.43	1.78	**0.12**			
17			(size 4)	5.22	0.92	1.06	0.34		0.08	0.24(N 0.35)
18			(size 5)	5.76	0.84	**0.90**	0.06	**0.14**	0.38	0.02(N 0.36)
19			Kinghorn Wax (size 2)	4.92	**0.49**	0.50		0.07	0.05	0.04(N 0.34)
20			(size 5)	5.58	**0.23**	**0.25**	**0.10**			0.03(N 0.37)
21			Romano (size 4)	8.24	**1.14**	**1.28**	0.30			0.08(N 0.35)
22			Tendercrop (size 2)	**8.03**	**1.38**	1.64	0.78	0.40*	1.02	0.16(N0.36)
23			(size 4)	8.31	**1.26**	1.06	0.12	**0.14***	**0.18**	0.74(N 0.37)
24			(size 6)	8.95	**1.28**	1.48	0.16	**0.18***	**0.24**	0.16(N 0.37)
25			White Seeded Tender Crop (size 2)	9.23	**1.36**	1.34	0.18			
26			(size 4)	9.67	**1.10**	1.40	0.32			
27			(size 5)	**10.27**	**1.14**	**1.30**	**0.34**			
28	Pea	*Pisum sativum*	Alaska (size 4)	28.54		0.08	3.00	0.06	0.68	

DISTRIBUTION OF FREE SUGARS IN FOODS OF THE LEGUMINOSAE FAMILY

Code No.	Common Name	Scientific Name	Variety		Total Solids	Glucose	Fructose	Sucrose	Rafnnose	Stachyose	Unidentified Sugar #1
					% Fresh Basis						
29			Allsweet (size 4)		**23.13**	0.82	0.24	4.78	0.10	**0.04**	1.06(N0.36)
30			(size 5)		**25.18**	0.92		5.40	1.60	0.30	. .
31			Perfected Freezer 60	(size 3)	20.72	0.04	0.04	**6.06**			
32				(size 4)	**21.88**	0.26	1.30	4.77	**1.04**	1.35	0.91 (N 0.40)
33				(size 5)	**21.24**	0.02	0.04	4.44	0.08	0.04	
34			Early Perfection 326	(size 3)	21.16	**0.12**	0.10	6.54	0.24		
35				(size 4)	23.13	0.24		**5.90**	1.22	1.46	0.72(N 0.37)
36				(size 5)	25.68	0.10	0.10	4.28	0.32	0.80	0.06(N 0.17)
37	Cow Pea	*Vigna sinensis*	Arkansas 203		39.30	0.08	0.06	1.86	0.10	1.66	0.48(N0.31)
38	Edible Podded Pea	*Pisum sativum*	B67-339		14.72	2.20	0.08	2.20			0.10(N 0.34)
39			B67-340		11.95	2.04	**0.16**	1.60			0.08(N 0.35)
40	Dry Pea Seed	*Pisum sativum*	Allsweet			0.37		3.74	2.12	7.30	
41			Fasc. 8b			0.25		**3.07**	0.63	0.89	
42			Freezer 37			0.23		4.45	2.76	10.36	
43	.		Lincoln			0.29		4.23	1.39	9.27	
44			Anthocyanin Line			0.23		2.58	1.33	6.83	
45			Miragreen			0.29		5.85	1.97	8.66	
46			Perfection			0.03		2.96		8.46	
47			Pixie			**0.19**		4.72	3.35	9.55	
48			Thos. Laxton			0.27		5.42	2.19	10.29	

* Contains a trace amount of manninotriose.
Parenthesis shows the Rg value in neutral solvent(N), and gala = galactose.

Editor's Note

This is a new series that replaces the former Research Circular series published by the New York State Agricultural Experiment Station at Geneva. It results from an intensive study made by a special committee, which recommended that all existing publication series be streamlined and modernized to better answer today's needs of both scientific and general audiences. It was thought important to identify each publication with its appropriate subject matter discipline, such as Biological Sciences, Food Sciences, or Plant Sciences, as well as with a departmental designation.