Food Chemistry **42** (1991) 19–28

Free Sugars and Dietary Fibre in Some Fruits of Bangladesh

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(Received 18 July 1989; revised version received and accepted 3 July 1990)

ABSTRACT

Free sugar and dietary fibre (DF) contents of ten fruits of Bangladesh were determined. Analysis of free sugars showed that all the fruits except karamcha (0·6%) contained substantial amounts of glucose (1·1–6·3%) and fructose (0·6–5·4%), whereas sucrose was either absent or present in a small proportion (0·1–1·2%). The total DF content of the fruits varied between 0·2 (tarmuj) and 4·9 (jalpai) per cent of fresh fruit material. The smaller amounts (0·02–0·97%) of water-soluble DF of all the fruits were mainly composed of uronic acid (54–85%), arabinose (3–20%) and galactose (4–24%) residues. The larger amounts (0·17–2·55%) of water-insoluble non-starch polysaccharides were mainly composed of glucose (30–68%), uronic acid (9–40%), galactose (3–25%), arabinose (1–17%) and xylose (3–11%) residues. Starch content of the fruits was very low (trace-0·015%). Karamcha, amloki and jalpai were rich (2·5–4·9%) in DF and, interestingly, these fruits were also low in free sugars. The results may be used to evaluate the nutritional status of the fruits.

INTRODUCTION

Dietary fibre (DF) is an important ingredient of our food (Spiller, 1986; Furda, 1987), and fruits and vegetables are convenient sources of DF. In

Food Chemistry 0308-8146/91/$03·50
Printed in Great Britain

tropical Bangladesh, fruits and vegetables grow in abundance, but reports on the sugar and/or DF for some of the more common fruits like mango, guava, pineapple, papaya and litchi (Chan & Kwok, 1975*a*; Lund & Smoot, 1982; Wills *et al.*, 1986; Candlish *et al.*, 1987) have appeared only in a scattered way. Moreover, the origin and the species of the fruits used in different studies varies widely. Therefore, for a better understanding and for nutritional evaluation of fruits of Bangladesh, we have recently undertaken a systematic study and communicated (Nahar *et al.*, 1990) the analysis of carbohydrates of seven common fruits of Bangladesh. In the present paper we report the free sugar and DF composition of ten more fruits.

MATERIALS AND METHODS

Fruits

Fully ripe fruits, purchased at the market of Dhaka during February to June 1987, were used (see Table 1).

Enzymes

Amyloglucosidase from *Aspergillus niger* (EC 3.2.1.3, 14 U/mg) was purchased from Boehringer Mannheim (FRG) and bacterial α-amylase (Termamyl 120L) was obtained from Novo A/S, Copenhagen, Denmark. The glucose-peroxidase reagent (Merkotest 3395), used in the determination of starch, was obtained from Merck (Darmstadt, FRG).

TABLE 1
Nomenclature, Season and Edible Parts of Fruits Analysed

Botanical name	*Common (local) names*	*Edible parts analysed*[a]	*Season*
Litchi chinensis	Lychee; Litchi	pulp	May
Phyllanthus disticus	The star gooseberry; Horbori	skin, pulp	June
Phyllanthus emblica	Indian gooseberry; Amloki	skin, pulp	February
Cucumis melo	Honey dew melon; Bangi	pulp	March
Citrullus vulgaris	Water-melon; Tarmuj	pulp	May
Syzygium cumini	Blackberry; Kalajam	skin, pulp	April–May
Syzygium samargense	Jamrul	skin, pulp	May
Elaeocarpus robustus	Jalpai	skin, pulp	March
Carissa carandas	Karamcha	skin, pulp	June
Carica papaya	Papaya; pepe	pulp	May–June

[a] The seeds were omitted in all cases.

General methods

Solutions were concentrated under reduced pressure at bath temperatures not exceeding 40°C. Dry matter was determined by oven-drying at 105°C for 18 h if not otherwise stated. Milling was performed on a Cyclotec apparatus with a 0·5 mm screen. Gas–liquid chromatography (GLC) was conducted on a Packard 427 instrument, fitted with flame-ionisation detector and a fused-silica capillary column. Low-molecular weight sugars were analysed as trimethylsilyl ethers (Sweely *et al.*, 1963) on a Cp sil 5 column (25 m × 0·25 mm i.d.; helium flow approximately 25 cm s^{-1}), using programming from 180°C (5 min initial temperature) to 215°C (50 min final temperature) at 4°C min. Alternatively, direct analysis of low-molecular weight sugars was performed by high performance liquid chromatography (HPLC) on silica gel using 75% (v/v) aqueous acetonitrile containing 0·01% (v/v) tetramethylpentamine as eluent (Wade & Morris, 1982). Neutral polysaccharide constituents were analysed as alditol acetates (Theander & Westerlund, 1986) on a Cp sil 88 column (9·5 m × 0·25 mm i.d., helium flow approximately 1 ml s^{-1}) programmed from 170°C to 220°C at 4°C min^{-1}. A Hewlett Packard 3390A integrator was used for calculation of peaks.

Extractions

The edible part (300–1900 g) of the fruit was sliced, chopped and extracted at room temperature for 24 h with aqueous 70–80% ethanol where the volume of ethanol to be added in each case was calculated by taking into consideration the water content of the particular fruit. The resulting insoluble residue was filtered off, air-dried, powdered and re-extracted with aqueous 80% ethanol (3 × 500 ml) by boiling for 30 min. The residue was then refluxed with chloroform (2 × 250 ml) for 30 min, dried and weighed. The ethanolic extracts were then combined. The ethanol was removed by rotary evaporation and the resulting aqueous solution was extracted with chloroform (2 × 200 ml) in a separatory funnel. The chloroform extracts were combined, dried with anhydrous sodium sulphate, filtered, concentrated to dryness and weighed. The chloroform-extracted aqueous layer was concentrated to dryness and, after weighing, a sub-sample was dried in a vacuum oven at 40°C to constant weight.

Analysis of low-molecular weight carbohydrates

A part (300·0–400·0 mg) of the 80% ethanolic extract from each fruit was dissolved in water and deionised by passing through columns (3 × 9 cm and 2·5 × 12 cm) of Dowex 50W X8 H^+ and Amberlite IR-45 OH^-, respectively.

TABLE 2
Content and Composition of Water-Soluble Non-Starch Polysaccharides in Fruits Analysed

Fruit	*Content*	*Relative composition of polysacchride constituents (%)*							
	(% of fresh fruit)	*Rhamnose*	*Fucose*	*Arabinose*	*Xylose*	*Mannose*	*Galactose*	*Glucose*	*Uronic acid*
Litchi	0·13	1	<0·1	20	<0·5	1	9	1	68
Horbori	0·07	3	<0·5	7	1	1	7	1	80
Amloki	0·63	2	1	11	2	1	24	5	54
Bangi	0·09	3	<0·5	4	<0·5	<0·5	5	2	85
Tarmuj	0·02	2	<0·5	7	5	<0·5	16	2	67
Jamrul	0·10	2	<0·5	7	2	1	6	4	78
Kalajam	0·20	2	<0·05	15	<0·5	<0·5	4	2	76
Jalpai	0·97	1	<0·5	10	<0·5	<0·5	10	1	77
Karamcha	0·27	1	<0·5	18	<0·5	<0·5	7	1	72
Papaya	0·38	3	<0·5	3	1	1	6	1	85

Duplicate portions (1·0 ml) of the deionised solution (100 ml) were concentrated to dryness after adding an aqueous solution of internal standard (*myo*-inositol or β-phenyl D-glucopyranoside, 1·0 mg ml^{-1}). The content of low-molecular weight sugars in these samples was then determined by silylation (Sweeley *et al.*, 1963) and subsequent GLC analysis (Theander & Westerlund, 1988). The results, which are given in Table 2, were calculated using *myo*-inositol as internal standard. In order to check for the presence of other sugars, the deionised solutions were also qualitatively analysed by HPLC (Wade & Morris, 1982).

Analysis of starch

Starch was determined according to the procedure of Salomonsson *et al.* (1984). Duplicate portions (75–125 mg) of milled extractive-free residues were incubated with α-amylase for 30 min at 96°C and then with amyloglucosidase for 16 h at 60°C. The glucose released was analysed by a glucose-peroxidase reagent. Starch was calculated as glucose × 0·9.

Analysis of dietary fibre

The method of Theander and Westerlund (1986) was used. Treatment of extractive-free residues (2·500–3·000 g) with α-amylase (96°C, 30 min) and amyloglucosidase (60°C, 16 h) was followed by centrifugation. The water-soluble fibre fraction was then isolated by dialysis and freeze-drying of the supernatant, whereas the water-insoluble fibre fraction was recovered by washing and drying of the insoluble residue in the centrifuge tube. The content of uronic acid residues in the fibre polysaccharide was determined in both fractions by a decarboxylation method (Theander & Åman, 1979). The content of neutral polysaccharide constituents was determined in both fractions by GLC after acid hydrolysis and preparation of alditol acetates of the resulting sugars. Lignin was determined gravimetrically as the insoluble material remaining after acid hydrolysis (Klason lignin) of the insoluble fibre fraction.

RESULTS AND DISCUSSION

Edible parts of ten common fruits of Bangladesh (Table 1) were taken for the present study. Most of these fruits are cultivated and presented as table fruits. Except for papaya and bangi these fruits are very much more liked by children and women than men. The present report complements a previous communication from the Dhaka laboratory (Nahar *et al.*, 1990).

TABLE 3
Composition of Fruit Samples (% of Fresh Edible Part)

Fruit	*Water*	*Extractives*		*Starch*	*Dietary fibre*			
		Hydrophilic	*Lipophilic*		*Non-starch Polysaccharides*		*Klason lignin*	*Total*
					Neutral	*Acidic*		
Litchi	86·7	13·0	0·40	0·015	0·28	0·23	0·24	0·75
Horbori	91·9	5·1	0·39	0·005	0·66	0·27	0·74	1·67
Amloki	82·4	11·2	0·16	0·004	2·49	0·58	0·16	3·23
Bangi	95·3	4·8	0·07	0·001	0·30	0·11	0·01	0·42
Tarmuj	95·4	5·5	0·07	0·001	0·11	0·08	0·01	0·20
Jamrul	92·9	4·5	0·13	0·003	0·98	0·30	0·37	1·65
Kalajam	84·9	10·0	0·47	0·006	0·65	0·45	1·00	2·10
Jalpai	87·5	5·0	0·02	0·005	2·55	0·98	1·36	4·89
Karamcha	90·3	4·9	1·33	0·004	1·29	0·60	0·56	2·45
Papaya	89·8	8·9	0·16	Trace	0·66	0·55	0·02	1·23

The water content (Table 3) of the ten fruits included in the present study was high (82–95%), as expected. Much of the dry matter of all the fruits was extractable with aqueous 80% ethanol. These hydrophilic extractives contain, in addition to free sugars, various soluble materials as salts and nitrogenous components. The amount of lipophilic extractives, obtained by extraction with chloroform, accounted for much less of the fresh fruit material. Only traces of starch ($<0{\cdot}015\%$) were present in all the fruits.

The DF content of the fruits (Table 3), calculated as the sum of non-starch polysaccharides and Klason lignin, varied between 0·2% (tarmuj) and 4·9% (jalpai). The dietary fibre values quoted by Wills *et al.* (1986) for litchi, bangi, tarmuj, papaya and jamrul were determined by a gravimetric method and are somewhat higher than our values, as are the values found by Candlish *et al.* (1987). The DF contents of the other fruits analysed are, to the best of our knowledge, reported for the first time. The above variations in DF content and those observed in free sugar content, as discussed below, may be due to differences in fruit season, cultivar, storage time and also in analysis procedures used.

The higher water-containing fruits, tarmuj and bangi, had the lowest DF contents followed by litchi and papaya. Incidently, these four fruits are eaten after removing the skin (Table 1), which, therefore, was excluded in the analysis. These fruit materials also had lower lignin content. The higher lignin contents in the other fruits, probably mostly coming from the edible skin, contributed significantly to their higher DF contents. The highest DF content was found in jalpai (4·9%), followed by amloki (3·23%) and karamcha (2·45%). Non-starch polysaccharides constituted the bulk of the total DF except in those fruits which had a higher lignin content than 0·02%. The amount of acidic polysaccharide residues, i.e., uronic acids, was always less than that of neutral non-starch polysaccharides. Analysis of the water-soluble DF (Table 2) showed that it was primarily constituted of uronic acid residues (54–85%). Arabinose and galactose were the main neutral sugar constituents of the soluble DF. On the other hand, glucose was the main neutral sugar constituent of the water-insoluble DF polysaccharides (Table 4). This was expected due to the presence of cellulose in these fractions. The uronic acid contents were also significant in the insoluble DF; so also was arabinose and galactose in most of the fruits.

The free sugars of the fruits were isolated by ion-exchange chromatography of the hydrophilic extracts and determined by GLC as their trimethylsilyl ethers. The total free sugar content varied between 0·7 (karamcha) and 12·9% (litchi) per cent of fresh fruit material (Table 5). Analysis of the individual sugar components revealed that glucose (0·6–6·3%) and fructose (0·1–5·4%) constituted the bulk of the free sugars (*cf*

TABLE 4
Content and Composition of Water-Insoluble Non-Starch Polysaccharides in Fruits Analysed

Fruit	*Content*	*Relative composition of polysaccharide constituents (%)*							
	(% of fresh fruit)	*Rhamnose*	*Fucose*	*Arabinose*	*Xylose*	*Mannose*	*Galactose*	*Glucose*	*Uronic acid*
Litchi	0·38	3	1	15	3	4	7	30	37
Horbori	0·86	4	1	5	5	4	14	41	25
Amloki	2·44	1	1	5	9	5	17	50	10
Bengi	0·32	1	1	2	10	6	3	68	10
Tarmuj	0·17	2	1	3	11	1	6	34	40
Jamrul	1·18	2	1	10	9	5	6	49	19
Kalajam	0·90	2	<0·5	17	5	3	7	33	33
Jalpai	2·55	1	1	6	5	4	25	48	9
Karamcha	1·62	2	1	15	7	3	9	38	25
Papaya	0·83	1	1	1	7	5	3	56	27

TABLE 5
Free Sugars in Fruits Analysed (g/100 g fresh fruit)

Fruit	*Free sugars*			
	Glucose	*Fructose*	*Sucrose*	*Total*
Litchi	6·3	5·4	1·2	12·9
Horbori	1·1	1·0	0·05	2·2
Amloki	1·1	1·8	<0·01	2·9
Bangi	0·61	1·7	0·18	2·5
Tarmuj	1·9	2·4	0·92	5·2
Jamrul	2·3	2·0	0·05	4·4
Kalajam	4·3	3·4	ND[a]	7·7
Jalpai	0·68	0·63	0·17	1·5
Karamcha	0·59	0·13	<0·01	0·7
Papaya	4·5	3·3	0·26	8·1

[a] ND = not detected.

Wills *et al.*, 1986). Except in litchi and tarmuj, where it was present in reasonable amounts, sucrose was either absent or present to a small extent (<0·3%). Invertase activity as reported in papaya (Chan & Kwok, 1975*b*) and litchi (Chan *et al.*, 1975) may be responsible for the lower values or absence of sucrose in the fruits in the present study, although enzyme activity in all the fruits is difficult to conceive. Our values for the total free sugar content of litchi, tarmuj, jamrul and papaya are in reasonable agreement with the available literature values (Wills *et al.*, 1986; Chan & Kwok, 1975*b*), whereas that of bangi is about 2% lower. Interestingly, the only fruits that had a lower content of free sugars than of DF were jalpai, karamcha and amloki. This is likely to make these fruits nutritionally and physiologically more important.

In some of the fruits, small amounts of sugar alcohols (mannitol and/or glucitol) were also present (*cf.* Nahar *et al.*, 1990). Small but definite amounts (0·001–0·02%) of *myo*-inositol was also present in all the fruits.

No immediate correlation between the sugar constituents in the non-starch polysaccharides and the DF contents could be made. Neither does any obvious relationship exist between free sugars and the polysaccharide constituents of the fruits. As expected, the sweeter fruits contained more free sugars. Individual polysaccharides in some of the fruits are being studied.

ACKNOWLEDGEMENTS

The International Program in the Chemical Sciences, University of Uppsala, Sweden, is acknowledged for financial support.

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