Food Chemistry **46** (1993) 397–400

Analysis of free sugar and dietary fibre of some vegetables of Bangladesh

Nilufar Nahar, M. Mosihuzzaman & Sujit K. Dey

Department of Chemistry, University of Dhaka, Dhaka-1000, Bangladesh

(Received 13 May 1992; revised version received and accepted 11 August 1992)

Free sugar and dietary fibre (DF) contents and compositions of the edible parts of seven vegetables of Bangladesh were determined. Total free sugars in the fresh vegetables varied from 0·2 to 1·8% whereas dietary fibre ranged from 3·4 to 6·1%. Among the seven vegetables, elongated bean had the best combination of low free sugar and high dietary fibre. Glucose was the main constituent of the total polysaccharide of the vegetables but galactose was the major component of the soluble DF.

INTRODUCTION

Different kinds of vegetables are grown during the year in tropical Bangladesh, but very little is known about the chemical composition of local vegetables. A preliminary report lists the vitamin, protein and carbohydrate contents (Ahmed *et al.*, 1986) of some vegetables. Several oligosaccharides such as stachyose, sucrose and verbascose were reported (Akapapunamn, 1979) in elongated bean. Vegetables are good sources of dietary fibre (DF). High fibre-containing foods are advised for patients (Doi *et al.*, 1979; Vinik & Jenkins, 1988) suffering from high blood sugar and serum cholesterol. DF lowers blood sugars and serum cholesterol (Trowell, 1986) but free sugars are restricted for diabetic patients. With the increasing importance of dietary fibre in human diet, vegetables, the main source of DF, have become a focus of study. For better evaluation of DF, study of the corresponding free sugar contents of the vegetables is also important. We now report on the analysis of free sugars and DF of seven vegetables of Bangladesh. Earlier we have reported similar studies on fruits (Nahar *et al.*, 1990; Rahman *et al.*, 1991).

MATERIALS AND METHODS

Vegetable material

Good quality fresh vegetables were bought from the market of Dhaka city during 1989. Only the edible part of each vegetable was used for analytical purposes. About 1 kg of vegetable was dried at 40°C and ground to powder in a Cyclotec grinding machine with a 0·5 mm screen and used for DF analysis. Low-molecular weight carbohydrates (free sugars) were isolated from fresh vegetables.

General methods

All evaporations were carried out under reduced pressure at bath temperature not exceeding 40°C. GLC was conducted with a Pye-Unicam 4500 or Packard 427 instrument fitted with a flame ionization detector. Acetates and alditol acetates were separated on Cp sil 88 (quartz, 1250 cm × 0·02 cm i.d.) and OV-225 (glass, 2300 cm × 0·02 cm i.d.) capillary columns at 160–200°C, 4°C/min. Trimethylsilyl ethers were separated on a packed (SE-30) glass column (150 cm × 0·2 cm i.d.) at 150–210°C, 2°C/min. Quantitative evaluation of acetates was achieved by using an LKB 3390A integrator and evaluation of trimethylsilyl ethers was done manually. All results are averages of at least two determinations.

Determination of dry matter, ash, lignin, total polysaccharides and uronic acid

Dry matter and ash contents were determined by following standard methods (AOAC, 1977). For determination of polysaccharide constituents and lignin, the dry powder of the vegetables (100 mg) and myo-inositol (10 mg, as internal standard) was hydrolysed with H_2SO_4 (12·0 M at room temperature for 2 h followed by refluxing for 6 h after dilution to 0·36 M (Saeman *et al.*, 1954). The neutral sugar constituents of the hydrolysate were analysed (Swardeker *et al.*, 1965) by GLC as their alditol acetates and the insoluble residue was determined gravimetrically as Klason lignin.

Food Chemistry 0308-8146/93/$06.00

Table 1. Composition of the vegetables (% of dry matter)

Name		Dry matter	Ash	Lignin	Extractives	
Botanical	Common				Aq. 80% ethanol	Chloroform
Vigna synansis	Elongated bean	11·5	0·59	9·5	3·0	0·35
Ablemoscus esculentus	Lady's finger	8·8	0·62	12·5	3·7	0·43
Carica papaya	Papaya	7·5	0·37	3·6	3·4	0·23
Momordica charantia	Bitter gourd	8·5	0·62	9·0	1·4	0·19
Solanum melongena	Brinjal	9·0	0·38	3·4	4·3	0·07
Legnaria vulgaris	Water gourd	7·0	0·32	9·2	2·4	0·12
Musa paradisica	Green banana	17·0	0·51	3·3	1·4	0·14

Analysis of free sugars

Edible parts of fresh vegetables were extracted with sufficient amounts of ethanol to make the ethanol concentration of the aqueous solution 80% (Table 1). The lipophilic materials were removed by extraction with chloroform (Theander & Åman, 1976). The free sugars were isolated from the aqueous ethanol extract by following the procedure described earlier (Nahar *et al.*, 1990) and these were analysed (Table 2) as their trimethylsilyl ethers (Sweely *et al.*, 1963) and acetates (Swardeker *et al.*, 1965) (Table 3).

Determination of soluble and insoluble dietary fibre (DF) present in the vegetables

Dried and powdered vegetable samples (1 g) were extracted with aqueous 80% ethanol (100 ml × 3, 30 min each time) followed by chloroform (100 ml × 30, 30 min each time). The residue was dried at 40°C, suspended in phosphate buffer (0·1 M, pH 7·0) and treated with protease (*Streptomyces caespitosus*, purified type IV, Sigma) by incubation at 96% for 3 h. The protein-free material was collected by dialysis followed by freeze-drying. The freeze-dried material was again treated with termamyl (α-amylase) 120L (Novo AB Copenhagen) in acetate buffer (0·1 M, pH 5·0, 1 h) followed by amyloglucosidase (*Aspergillus niger*, Boehringer Mannheim) for 16 h at 96°C. The mixture was cooled and centrifuged. A small part of the supernatant (100 μl) was taken for determination of starch. The remainder of the supernatant was dialysed and freeze-dried (Theander & Westerlund, 1986; Nahar *et al.*, 1990) giving soluble DF (Table 4). The centrifugate was suspended in water, dialysed and freeze-dried giving insoluble DF (Table 4).

Table 2. Low molecular weight carbohydrates in the vegetables (g per 100 g fresh vegetables[a])

Vegetable	Glc	Fruc.	Sucr.	Myo-inositol	Total free sugar (%) of vegetables	
					Fresh	Dry
E. bean	0·47	0·28	0·10	0·02	0·85	7·39
L. finger	0·58	0·53	0·20	0·05	1·31	14·9
Papaya	0·70	0·56	0·45	0·09	1·71	22·8
B. gourd	0·38	0·18	0·38	0·35	0·94	11·1
Brinjal	1·04	0·68	0·08	0·05	1·80	20·0
W. gourd	0·52	0·42	0·02	0·02	0·96	13·7
G. banana	0·07	0·05	0·05	0·01	0·17	1·0

[a] Determined as trimethysilyl (TMS) ethers.

Table 3. Relative composition of neutral sugar constituents of the total polysaccharide of the vegetables (%)

Vegetable	Rha	Ara	Xyl	Man	Gal	Glc
E. bean	2·2	8·0	10·3	3·9	7·1	68·5
L. finger	10·4	5·3	7·7	3·2	22·5	50·9
Papaya	5·3	4·3	4·5	5·2	28·0	52·7
B. gourd	0·8	7·0	12·1	4·2	9·7	66·2
Brinjal	0·5	2·4	4·9	10·1	25·2	56·9
W. gourd	1·5	3·5	6·5	8·1	20·1	60·3
G. banana	0·3	1·2	0·8	1·1	25·6	70·7

Determination of starch

A small part (100 μl) of the supernatant from the DF determination was treated with glucose oxidase–peroxidase reagent (Boehringer Mannheim) and analysed by the colorimetric method. The starch contents (Table 4) of the vegetables were calculated from the value of glucose (Salomonsson *et al.*, 1984) obtained from the standard glucose curve.

Analysis of sugar constituents of soluble DF

Soluble DF (10 mg) and allose (1 mg, internal standard) were treated with trifluoroacetic acid (5 ml, 2 M) for 3 h at 120°C. The resulting sugars were analysed by GLC as their alditol acetates (Swardeker *et al.*, 1965). The uronic acid content of the soluble DF was determined by the carbazole method (Table 5).

Table 4. Dietary fibre contents of the vegetables

Vegetable	Dietary fibre content (% of fresh vegetable)			Total DF (% of dry vegetables)	Starch (% of dry vegetables)
	Soluble	Insoluble	Total		
E. bean	0·77	5·33	6·10	53·04	1·80
L. finger	0·69	3·02	3·71	42·16	0·20
Papaya	0·77	2·62	3·39	42·20	0·11
B. gourd	0·53	5·30	5·83	68·59	0·32
Brinjal	0·97	3·10	4·04	45·22	0·32
W. gourd	0·43	3·61	4·04	57·71	0·24
G. banana	0·65	4·35	5·00	29·51	9·54

Table 5. Relative compositions of polysaccharide constituents of the soluble DF of the vegetable (%)

Vegetable	Carbo-hydrate[a] (% SDF)	Rha	Ara	Xyl	Man	Gal	Glc	Uronic acid
E. bean	59·9	5·5	6·6	3·5	5·4	40·8	11·3	26·6
L. finger	65·5	24·4	1·7	1·0	2·2	38·3	4·3	28·3
Papaya	54·2	15·7	6·0	2·9	8·0	35·4	9·1	22·9
B. gourd	80·9	13·7	3·9	3·0	13·8	27·9	22·1	15·9
Brinjal	63·5	9·0	6·1	3·3	3·9	39·5	7·8	30·4
W. gourd	56·5	10·8	6·3	4·5	7·1	41·2	14·2	15·9
G. banana	48·1	7·2	5·1	4·0	12·2	22·2	35·5	14·8

[a] The values were not corrected for residual protein and ash content of the soluble DF.

RESULTS AND DISCUSSION

The present work involved seven local vegetables. The choice of vegetables was based on the availability of the vegetables around the year and also their popularity among Bangladeshi people. Fresh vegetables contained small amounts of dry matter (7—11%) except green banana (17% of dry matter). The ash contents of the vegetables were less than 1% and the lignin content varied from 3·3 to 12·5% (Table 1).

Free sugar

Free sugars in the aqueous 80% ethanol extract (neutral low molecular part) of the vegetables were determined as their acetates and trimethylsilyl ethers. The two methods gave similar results and the free sugar values, as obtained by determination as trimethylsilyl ethers, are given in Table 2. Total free sugar content (Table 2) of the vegetables varied from 0·2 to 1·8%. The values were much less than those of fruits (Wali & Hasan, 1965; Chan & Kwok, 1975; Wills *et al.*, 1986; Moriguchi *et al.*, 1990; Nahar *et al.*, 1990; Rahman *et al.*, 1991) but, higher than plant materials (Mosihuzzaman *et al.*, 1989). Interestingly, the glucose, fructose and *myo*-inositol contents of the vegetables were higher but the sucrose content much lower than almond, pecan and macadamia nuts (Fourie & Basson, 1990). Unlike plant materials (Mosihuzzaman *et al.*, 1989) no sugar alcohol was identified in the vegetables. The free sugar content of ripe papaya reported earlier (Rahman *et al.*, 1991) was higher than the value of free sugar obtained for green papaya (used as vegetables) in the present work. This was indicative of the increase in free sugar on ripening. Although the presence of stachyose and verbascose was reported (Akapapunamn, 1979) in elongated bean, we could not identify them.

Total polysaccharides, starch and dietary fibre

Analysis of total polysaccharides of the fruits (Table 3) showed that these materials were mainly polymers of glucose. Substantial amounts of galactose followed by xylose and arabinose in the total polysaccharides of the fruits indicated the presence of various other polysaccharides in the vegetables.

The total starch content (Table 4) of the vegetables studied was very small except for green banana (9·54% of dry matter). The DF contents of the vegetables were determined by removing the protein and starch by enzymatic hydrolysis. The sum of soluble and insoluble DF isolated from the protein and starch free material gave the total DF in the vegetables (Table 4). Elongated bean and bitter gourd contained relatively higher amounts of DF (6·10% and 5·83%, respectively) whereas papaya contained the lowest amount of DF (3·39%). On a dry weight basis, however, bitter gourd was found, to contain the highest (68·59%) and green banana lowest (29·5%) amount of DF. It may be seen from Table 4 that the amount of insoluble DF was 3–10 times higher than the soluble DF of the vegetables. These results are expected as cellulose and lignin formed the bulk of the insoluble DF. Similar higher insoluble DF was found in the fruits (Nahar *et al.*, 1990; Rahman *et al.*, 1991). From the present studies it was seen that elongated bean had the best combination of low free sugar and high DF content.

Analysis of soluble DF

Out of the total DF, the smaller amount of soluble DF is more likely to have biological importance as the insoluble DF is mainly constituted of cellulose and lignin. Therefore, the soluble DF was studied further for its polymeric carbohydrate constituents.

Total carbohydrate content (48·1–80·9%; Table 5) of the soluble DF was the sum of the individual neutral sugar constituents of the soluble DF analysed by GLC and uronic acid content determined by the quantitative carbazole test method. The values were relatively lower as they were not corrected for residual protein and ash present in the soluble DF materials.

The various sugar constituents present in the soluble DF of the vegetables were rhamnose, arabinose, xylose, mannose, galactose and glucose. The percentage of galactose (27·9–41·2%) was relatively higher than the other sugar constituents in all vegetables. Appreciable amounts of glucose were also found in the soluble DF of bitter gourd (22·1%) and green banana (35·5%). Uronic acid content of the soluble DF varied from 14·8 to 30·4%. The preponderance of galactose in the soluble DF of the vegetables indicated that isolation of individual polysaccharides may give interesting polymers.

ACKNOWLEDGEMENTS

The project was financially supported by the International Foundation for Science, Stockholm, and the International Program in the Chemical Sciences, Uppsala, Sweden.

REFERENCES

Ahmed, K., Malek, M., Jahan, K. & Salamatullah, K. (1986). *Nutritive Value of Food Stuff*, 3rd edn. Institute of Nutrition and Food Science, University of Dhaka, 12 pp.

Akapapunamn, A. K. M. (1979). Oligosaccharides of 13 American cultivers of cow peas (*Vigna synansis*). *J. Sci. Food Agric.*, **44**(5) 1317–18.

AOAC (1977). *Official Methods of Analysis*. Association of Official Analytical Chemists, Washington, DC.

Chan, H. T. & Kwok, H. C. M. (1975). Identification and determination of sugars in some tropical fruit products. *J. Food Sci.*, **40**, 770–1.

Doi, K., Matsuuara, M., Kawara, A. & Baba, S. (1979). Treatment of diabetes with glucomannan (konjac mannan). *Lancet*, **1**, 987–8.

Fourie, P. C. & Basson, D. S. (1990). Sugar content of almond, pecan and macadamia nuts. *J. Agric. Food Chem.*, **38**, 101–4.

Furda, I. (1987). Beneficial intestinal effects of non-starch polysaccharides. In *Industrial Polysaccharides*, ed. S. S. Stivala, V. Cresecnzi, V. & I. C. M. Dee. Gordon and Breach, New York, pp. 195–202.

Moriguchi, T., Ishizawa, Y. & Sanada, T. (1990). Differences in sugar composition in *Prunus persica* fruit and the classification of the principal components. *Engei Gakkai Zasshi*, **59**(2), 307–12.

Mosihuzzaman, M., Quddus, A. & Nahar, N. (1989). Comparative study of carbohydrates in the two major species of jute (*Corchorus capsularis* and *Corchorus olitorius*). *J. Sci. Food Agric.*, **48**, 305–10.

Nahar, N., Rahman, S. & Mosihuzzaman, M. (1990). Analysis of carbohydrates in seven edible fruits of Bangladesh. *J. Sci. Food Agric.*, **51**, 185–92.

Rahman, S. M. M., Mosihuzzaman, M. & Westerlund, E. (1991). Free sugars and dietary fibre in some fruits of Bangladesh. *Food Chem.*, **42**, 19–28.

Saeman, J. F., Moore, W. E., Mitchel, R. L. & Millett, M. A. (1954). Techniques for the determination of pulp constituent by quantitative paper chromatography. *Tappi*, **37**, 336–45.

Salomonsson, A. C., Theander, O. & Westerlund, E. (1984). Chemical characterization of some Swedish cereal whole meal and bran fraction. *Swedish J. Agric. Res.*, **14**, 111–17.

Swardeker, J. S., Sloneker, J. H. & Jeanes, A. R. (1965). Quantitative determination of monosaccharides as their alditol acetates by gas liquid chromatography. *Anal. Chem.*, **37**, 1602–4.

Sweely, C. C., Bently, R., Makita, M. & Wells, W. W. (1963). Gas liquid chromatography of trimethylsilyl derivatives of sugar and related substances. *J. Am. Chem. Soc.*, **85**, 2497–507.

Theander, O. & Åman, P. (1976). Low-molecular carbohydrate in rapeseed and turnip rapeseed meals. *Swedish J. Agric. Res.*, **6**, 81–5.

Theander, O. & Westerlund, E. (1986). Studies of dietary fibre 3. Improved procedures for analysis of dietary fibre. *J. Agric. Food Chem.*, **34**, 330–6.

Trowell, H. C. (1986). Development of the dietary fibre hypothesis of diabetes mellitus. *Hand Book of Dietary Fibre in Human Nutrition*, ed. G. A. Spillar. CRC Press, New York, pp. 345–7.

Vinik, A. L. & Jenkins, D. J. A. (1988). Dietary fibre in management of diabetes. *Diabetic Care*, **11**, 160–73.

Wali, Y. A. & Hasan, Y. M. (1965). Quantitative chromatographic survey of the sugars prevailing in some horticulture crops. *Proc. Am. Hort. Soc.*, **87**, 264–69.

Wills, R. B. H., Lim, J. S. K. & Greenfield, H. (1986). Composition of Australian foods 31. Tropical and sub-tropical fruit. *Food Technol. Aust.*, **38**, 118–23.