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Distribution of free sugars and fatty acids in jackfruit (*Artocarpus heterophyllus*)

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The free sugars and fatty acids (both free and bound) of different parts of jackfruit (*Artocarpus heterophyllus*) were isolated. The sugars and fatty acids were identified and quantified by gas–liquid chromatography as their trimethylsilyl derivatives and methyl esters, respectively. Fructose, glucose and sucrose were found to be the major sugars in all parts of jackfruit, except in the bark, which is devoid of glucose. Capric, myristic, lauric, palmitic, oleic, stearic, linoleic and arachidic acids were found as major fatty acids with varying proportions in different parts of jackfruit. © 1997 Published by Elsevier Science Ltd

INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* L.), locally known as Kathal, belongs to the family Moraceae (Bhattacherjee, 1986; Bose, 1985; Prain, 1981). Jackfruit is a compound fruit and comprises five different parts in its mature stage. There is seed with seedcoat in the edible part. All parts of the fruit except the outer bark are edible and it is comparatively cheap. It substitutes (considerably) the diet of the people of Bangladesh both as a vegetable and as a nutritious food during the season; jackfruit is known as 'poor man's' food in South East Asia (Bose, 1985).

The gross composition of jackfruit, its vitamin content and some of the volatile compounds contributing to its flavour have been reported (Bhattacherjee, 1986; Bose, 1985; Ahmed *et al.*, 1986; Narasimham, 1990). The water-soluble sugar content of the ripe perianth has been determined (Wills *et al.*, 1986; Selvaraj & Pal, 1989) and some low molecular weight components have been isolated and characterized (Hossain *et al.*, 1990) from the ripe edible part. Recently, extensive work on the mature and immature perianth of two different varieties of jackfruit has been carried out (Motiar Rahman *et al.*, 1995). Jacalin, an α-D-galactose-binding lectin from jackfruit seed, has aroused considerable interest (Kumar *et al.*, 1982). Very little work (if any) on other parts of jackfruit has been reported. The present study has been undertaken with a view to investigate the free sugars and fatty acid composition of different parts of jackfruit, and to explore the food value of its edible parts.

MATERIALS AND METHODS

Fruit samples

A ripe jackfruit (*Artocarpus heterophyllus* L.) of soft variety (5.7 kg) was collected from the local market of Dhaka city. The different parts, including (1) the fertilized fleshy perianths (edible part) containing seed with seedcoat inside the perianth (2.6 kg), (2) the unfertilized thinner edible perianths (0.4 kg) occupying the space between the fertilized fleshy perianth and the unfertilized perianths, (3) the unfertilized thinner non-edible perianths (0.7 kg) surrounding the fertilized and unfertilized edible perianths, (4) the inner fleshy inflorescence axis (inner stick, 0.8 kg) and (5) the outer spiny rind (outer bark 1.2 kg), were separated manually. The seed with the seedcoat (1.1 kg) was separated from the fertilized edible perianths. Except for the seed with seedcoat, all five parts were sliced and chopped separately; these were marked as (1) EP, (2) IEP, (3) INEP, (4) IS and (5) OB. These abbreviated notations are used throughout the investigation unless otherwise stated.

General methods

The chemicals and solvents used in all analytical work were AnalaR grade procured from E. Merck (Germany) and BDH (UK). Distilled solvents were always used and all solutions were concentrated under reduced pressure at bath temperatures not exceeding 40°C. Milling was performed on a Cyclotec apparatus with 0.5 mm screen. Dry matter was determined by oven-drying at 105°C for

18 h unless otherwise stated. Gas–liquid chromatography (GLC) was conducted on a Pye Unicam 4500U instrument with flame ionization detector and a fused silica capillary column. Low molecular weight sugars were analysed as their trimethylsilyl (TMS) ethers (Sweely *et al.*, 1963) on CP Sil-88 (1250 cm×0.02 cm i.d.) and OV-225 (2000 cm×0.2 cm i.d.) columns, with programming from 170°C (5 min initial temperature) to 220°C at 4°C min^{-1}. The methyl esters (Sarwar *et al.*, 1991) were analysed in a glass column SE-30 (15 cm×0.2 cm i.d.). All results are averages of at least two determinations.

Extractions

The jackfruit samples EP (150 g), IEP (50 g), INEP (50 g), IS (130 g) and OB (100 g) were separately extracted at room temperature with occasional shaking for 24 h with aqueous 75–80% ethanol (500 ml); the volume of ethanol to be added in each case was calculated by taking into consideration of the water content of the specific part. The residue was filtered, air-dried, powdered and re-extracted with aqueous 80% ethanol (2×200 ml) by boiling for 30 min. The residue was then refluxed with chloroform (2×150 ml) for 30 min. The ethanol extracts were combined and the ethanol was removed by rotary evaporation. The resulting aqueous solution was extracted with chloroform (2×100 ml) in a separatory funnel. The chloroform extracts were combined, evaporated to dryness and weighed. The aqueous layer was freeze-dried.

Determination of dry matter, percentage of extractives and total carbohydrates

Dry matter and percentages of extractives of different samples were determined (Table 1) by standard methods (AOAC, 1977). The total carbohydrates of the samples were estimated (Table 2) colorimetrically (Dubois *et al.*, 1956).

ANALYSIS OF LOW MOLECULAR WEIGHT CARBOHYDRATES

A part (300–400 mg) of the 80% ethanolic extract from each jackfruit sample (EP, IEP, INEP, IS and OB) was dissolved in water and deionized by passing through columns (27 cm×2.5 cm and 25 cm×2.5 cm) of Dowex 50 W×8H$^+$ and Amberlite IR 45 OH$^-$, respectively (Theander & Aman, 1976). The deionized solutions were concentrated and freeze-dried to obtain the neutral fractions (Table 2).

A portion of the neutral fraction (2–3 mg) of each sample was dissolved in distilled water and allose (1 mg) was added as an internal standard. The solution was evaporated to dryness and the contents of low molecular weight sugars in these samples were then determined (Table 3) by GLC analysis (Theander & Westerlund, 1988) as their TMS derivatives (Sweely *et al.*, 1963).

Isolation and analysis of fatty acids

Dried chloroform extracts (EP, 3.2 g; IEP, 1.07 g; INEP, 705 mg; IS, 391 mg; OB, 456 mg) were separately dissolved in minimum volumes of chloroform and each part was extracted with petroleum ether (b.p. 40–60°C, 2×200 ml) in a separatory funnel. The petroleum ether extract was evaporated to dryness and the free and bound fatty acids were isolated from the residual dry mass (Sarwar *et al.*, 1991) (Table 4). Portions (3–5 mg) of the free and bound fatty acids were converted to their methyl esters and analysed by GLC using benzoic acid as an internal standard (Sarwar *et al.*, 1991) (Tables 4 and 5).

Table 1. Composition of the different parts of jackfruit (g per 100 g fresh fruit)

Jackfruit part	Dry matter	Aqueous 80% ethanol extract	Chloroform extract
EP	19.9	12.7	2.2
IEP	21.0	7.6	2.1
INEP	24.6	3.3	0.5
IS	27.5	3.7	0.3
OB	31.1	3.6	0.5

EP, edible part; IEP, inner edible perianth; INEP, inner non-edible perianth; IS, inner stick; OB, outer bark.

Table 2. Total carbohydrates and neutral fraction of different parts of jackfruit (g per 100 g of aqueous 80% ethanol extract)

Jackfruit part	Total carbohydrates	Neutral fraction
EP	65.5	54.1
IEP	61.2	79.0
INEP	61.7	84.8
IS	84.8	81.2
OB	60.1	79.1

For abbreviations, see text and Table 1.

Table 3. Low molecular weight carbohydrates in different parts of jackfruit (determined as TMS derivatives)

Jackfruit part	Sugar			Total amount of free sugars
	Fructose	Glucose	Sucrose	
EP	44.2 (4.53)	20.1 (2.06)	14.6 (1.49)	78.9 (8.08)
IEP	37.1 (1.12)	30.6 (0.92)	12.9 (0.39)	80.6 (2.43)
INEP	33.6 (1.43)	20.8 (0.88)	16.2 (0.60)	70.6 (3.00)
IS	39.3 (1.56)	17.1 (0.67)	15.9 (0.63)	72.3 (2.86)
OB	32.7 (0.93)	—	15.8 (0.50)	48.5 (1.43)

Values not in parentheses are expressed as mg per 100 g of neutral fraction; values in parentheses are expressed as g per 100 g of fresh fruit.
For abbreviations, see text and Table 1.

RESULTS AND DISCUSSION

The dry matter of jackfruit was found to be highest in OB (31.1 g per 100 g) and lowest in EP (19.9 g per 100) (Table 1). The dry matter of EP is in agreement with previously published values (Selvaraj & Pal, 1989; Motiar Rahman *et al.*, 1995). With the exception of semiwild Lukluki (50.2%), the dry matter contents of all parts of jackfruit are higher than those of other edible fruits (Nahar *et al.*, 1990; Rahman *et al.*, 1991) and vegetables (Nahar *et al.*, 1993).

The percentages of aqueous 80% ethanol extract and chloroform extract of different parts of jackfruit vary, but both are maximal in EP. It is observed that the amount of aqueous alcohol extract increases with increasing softness of the various parts of the fruit. The chloroform extract of EP and IEP are both much higher than the values for some edible fruits (Rahman *et al.*, 1991) and vegetables (Nahar *et al.*, 1993) of Bangladesh. The other values for alcohol extracts and chloroform extracts (Table 1) are comparable to edible fruits and vegetables of Bangladesh.

The total carbohydrates (Table 2) were found to be highest (84.8 g per 100 g) in IS, but the values for the other parts were close (60–65 g per 100 g) to each other.

The aqueous 80% alcohol extracts of all the samples were fractionated by passing through a cation-exchange column followed by an anion-exchange column. The neutral fractions obtained (Table 2) were found to be highest in INEP (84.8%) and lowest in EP (54.1%). The neutral fractions were analysed further, but the acidified fractions have not been studied in this work.

Free sugars

The low molecular weight carbohydrates of all the neutral fractions were identified and quantified by GLC as their TMS derivatives (Sweeley *et al.*, 1963) (Table 3). The total free sugar was found to be highest in the edible part (EP) and lowest in the outer bark (OB). It can be seen from Table 3 that the free sugars present in aqueous alcohol extracts of different parts of jackfruit are glucose, fructose and sucrose. The relative proportions of these sugars vary from part to part but they are common in all parts except OB, where glucose was not detected. Glucose, fructose and sucrose are the main sugars of the edible part of both soft and firm varieties of ripe jackfruit (Motiar Rahman *et al.*, 1995).

The presence of mannitol in ripe jackfruit was also reported in amounts representing 2% of the firm fruit and 7% of the soft fruit. Ribitol was also detected in ripe fruit but not in immature fruits (Motiar Rahman *et al.*, 1995). In this present study, mannitol and ribitol were not detected.

The presence of high percentages of sucrose, glucose and fructose is quite consistent with the findings from other fruits (Chan & Kwok, 1975; Wills *et al.*, 1986; Whitins, 1970; Moriguchi *et al.*, 1990; Nahar *et al.*, 1990; Rahman *et al.*, 1991) but higher than plant materials (Mosihuzzaman *et al.*, 1989) and vegetables (Nahar *et al.*, 1993).

Fatty acids

The various parts (EP, IEP, INEP, IS, OB) of jackfruit were dissolved separately in minimum volumes of chloroform and extracted with petroleum ether (b.p. 40–60°C). The amount of extract was highest in EP (9.9 g per 100 g chloroform extract) and lowest in IEP (5.0 g per 100 g chloroform extract) (Table 4).

The free and bound fatty acids were isolated (Sarwar *et al.*, 1991) and it was found that, in all parts of jackfruit, the amounts of fatty acids existing in the free state were less than the fatty acids associated with lipids or esterified to other organic compounds (Table 4).

Both free and bound fatty acids of all the parts of jackfruit were converted to their methyl esters (Sarwar *et al.*, 1991) and analysed by GLC. The fatty acids present in each part were identified and quantified by comparison with the retention time of the standard samples (Tables 5 and 6).

The analysis of free fatty acids (Table 5) showed that all parts of jackfruit contain palmitic and oleic acids in varying proportions. However, analysis of bound fatty acids (Table 6) revealed that palmitic, oleic, stearic, linoleic and arachidic acids were present with varying proportions in all parts of jackfruit. In addition to these fatty acids, EP, IEP and IS contain myristic and lauric acids, INEP contains lauric acid and EP contains capric

Table 4. Petroleum ether extract and fatty acids in different parts of jackfruit

Jackfruit part	Petroleum ether extract[a]	Free fatty acids[b]	Bound fatty acids[b]
EP	9.9	30.5	37.0
IEP	5.0	19.9	67.0
INEP	6.4	24.4	51.1
IS	8.9	28.6	45.7
OB	8.1	32.4	45.9

[a]Expressed as g per 100 g of chloroform extract.
[b]Expressed as mg per 100 g of petroleum ether extract.
For abbreviations, see text and Table 1.

Table 5. Free fatty acids in different parts of jackfruit

Jackfruit part	Fatty acids present		Total amount of fatty acids
	Palmitic	Oleic	
EP	17.8 (57.0)	14.1 (48.3)	31.9 (105)
IEP	22.7 (85.4)	17.6 (66.3)	40.3 (152)
INEP	33.7 (15.2)	20.6 (9.3)	54.3 (24.5)
IS	41.9 (14.7)	29.4 (10.3)	71.3 (25.0)
OB	23.0 (8.5)	11.3 (4.1)	34.3 (12.6)

Values not in parentheses are expressed as mg per 100 g of petroleum ether extract; values in parentheses are expressed as mg per 100 g of whole fruit.
For abbreviations, see text and Table 1.

Table 6. Bound fatty acids in different parts of jackfruit

Jackfruit part	Fatty acids present								Total amount of fatty acids
	Capric	Myristic	Lauric	Palmitic	Oleic	Stearic	Linoleic	Arachidic	
EP	1.9 (6.2)	2.1 (6.7)	2.2 (7.1)	21.7 (69.8)	15.1 (48.6)	13.5 (43.2)	4.5 (15.5)	17.2 (55.4)	78.2 (253)
IEP	—	0.5 (1.9)	0.8 (3.2)	22.2 (83.9)	23.5 (88.2)	7.9 (29.8)	9.5 (35.7)	16.9 (63.4)	81.3 (306)
INEP	—	—	2.2 (1.0)	18.4 (8.3)	16.1 (7.2)	8.9 (4.0)	3.4 (1.6)	9.4 (4.3)	58.4 (26.4)
IS	—	0.9 (0.3)	1.9 (0.7)	8.6 (3.0)	6.3 (2.2)	6.1 (5.6)	19.0 (6.7)	14.9 (5.3)	57.7 (23.8)
OB	—	—	—	13.7 (5.1)	7.0 (2.6)	5.4 (2.0)	17.7 (6.5)	16.3 (6.0)	60.1 (22.2)

Values not in parentheses are expressed as mg per 100 g of petroleum ether extract: values in parentheses are expressed as mg per 100 g of the whole fruit.
For abbreviations, see text and Table 1.

acid. The presence of fatty acids in all parts of jackfruit is common in betel nut (Gulshan Ara *et al.*, 1989), apart from myristic acid. It is apparent from Tables 5 and 6 that only two fatty acids (palmitic and oleic) have been identified in all parts of jackfruit as free fatty acids but a number of fatty acids were found as bound fatty acids. Among these, palmitic, oleic, stearic and linoleic acids are common in butter (2.5%) (Austin, 1988). On the other hand, arachidic acid is present in all parts of jackfruit in considerable proportions, but oils from soyabean, cottonseed, corn, linseed and coconut and butter are devoid of this acid (Austin, 1988).

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