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Chemical composition of jackfruit (*Artocarpus heterophyllus* Lam.) selections of Western Ghats of India

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Abstract

Chemical composition of bulbs from 24 different firm-type jackfruit clones was analyzed to study the variability. These jackfruits were selected for dessert purposes through an extensive survey in Western Ghats, part of India, presumably the centre for origin and diversity of jackfruit. A wide variation in the TSS, acidity, TSS:acid ratio, sugars, starch and carotenoid contents was observed in the bulbs of jackfruit types considered in the present investigation. The results of the study are helpful for attempting crop improvement and selection of superior desirable jackfruit genotypes for bringing to cultivation.

Keywords: Jackfruit; Chemical composition; Western Ghats; India

1. Introduction

Jackfruit (*Artocarpus heterophyllus* Lam.) is native to India and grows wild in the rain forests of Western Ghats of India (Reddy, Patil, Shashikumar, & Govindaraju, 2004). Jackfruit grows in many parts of Asia, but is abundant in India and Bangladesh. Its distribution is continuous on the western coast of India with high rainfall up to Konkan and sporadic in the areas with low rainfall. In Western Ghats, it is found up to 1500 m and has tremendous diversity (Muralidharan, Ganapathy, Velayudhan, & Amalraj, 1997).

The jackfruit is an evergreen tree, producing more yield than any other fruit tree species and bears the largest edible fruit (Alagiapillai, Kuttalam, Subramanian, & Jayasekhar, 1996). The popularity of jackfruit as a commercial crop is very meagre due to the wide variation in fruit quality, the long gestation period of plants raised from seeds and the widespread belief that excessive consumption of bulbs leads to certain digestive ailments (Samaddar, 1985).

In India, the fruit is popular in the eastern and southern parts. Flakes of ripe fruits are rich in nutritive value, containing 18.9 g carbohydrates, 0.8 g minerals, and 30 IU vitamin A and 0.25 mg thiamine for every hundred grammes (Samaddar, 1985). In spite of its richness in nutritive value, the jackfruit is unsuitably called 'Poor man's food' in eastern and southern parts of India.

Jackfruits usually reach 10–25 kg in weight at maturity (Rahman, Enamal, Mian, & Chesson, 1995). There are reports of individual fruit weight varying between 2.10 and 20 kg (Mitra & Mani, 2000; Reddy et al., 2004). The large sized jackfruits, however, weigh as much as 50 kg (Selvaraj & Pal, 1989). On an average, in ripe jackfruit, the bulbs, seeds and rind form 29%, 12% and 59% of the bulk, respectively (Bhatia, Siddapa, & Lal, 1955). The edible bulbs have 5.1 pH, about 25% carbohydrates and 1% total

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ash (Nanjundaswamy, 1990). An average TSS of 13 clusters (44 genotypes) of jackfruits had a range from 15.1 to 25.9°Brix (Maiti, Wangchu, & Mitra, 2002). However, the highest TSS of 40.5°Brix was recorded in ACC. No. G-18 (Reddy et al., 2004). Variation in the starch, total sugar and reducing sugar contents of soft and firm types of jackfruits has been reported (Nandini, 1989; Rahman, Nahar, Mian, & Mosihuzzaman, 1999). The total acidity in jackfruit is low (0.13% as citric acid) at the ripe stage and it showed little change during ripening (Bhatia et al., 1955). Variation in the aroma volatiles from two forms of jackfruit has also been reported (Maia, Andrade, & Zoghbi, 2004).

Many authors feel that the jackfruit is not liked by the consumers due to its intense flavour (Bhatia, 1953; Schnell, Olano, Campbell, & Brown, 2001). Productivity of the crop is relatively high (25.71 t/ha). But as the varieties are of local types and are mostly of seed origin, the quality of most fruits is not accepted by consumers (Anonymous, 1992). However, jackfruit is gaining popularity, even in the United States, due to emerging ethnic and mainstream marketing opportunities (Campbell & El-Sawa, 1998; Campbell, El-Sawa, & Eck, 1998; Schnell et al., 2001).

The jackfruit types differ among themselves in the shape and density of spikes on the rind, bearing, size, shape, latex, flake size, flake colour, quality and period of maturity. Innumerable variations in sweetness, acidity, flavour and taste are observed among jackfruit-growing areas. Such a wide diversity among clones in Western Ghats of India, the home of jack, offers tremendous scope for improvement of this crop by clonal selection (Samaddar, 1985). Therefore, in the present study an attempt has been made to know the variability in chemical composition of firm jackfruit types selected for dessert purposes through an extensive survey of the Western Ghats region of Karnataka in India.

2. Materials and methods

2.1. Fruit samples

Jackfruit types used for the study were selected, based on a survey conducted with the assistance of farmers, fruit merchants and officials of State Department of Horticulture and Forestry, Government of Karnataka. The region of Western Ghats of Karnataka covered for the study included the Shimoga district falling, in *hilly* zone, an agro-climatic region of the state.

The fruits of dessert type were harvested at the mature unripe stage. The fruits were then transported to the laboratory to study the chemical parameters of their *bulbs* (edible parts in jackfruit) at the edible ripe stage. The jackfruit types studied in the present investigation are given with location and code in Table 1. The minimum sample size in each clone was three and each fruit was considered as a replication.

2.2. Biochemical parameters

2.2.1. Total soluble solids (TSS)

The juice extracted from fresh fruit by squeezing the homogenized fruit pulp (*bulbs*) through muslin cloth was used to measure the TSS. It was determined by using an ERMA hand refractometer for each entry and triplicated and the mean was expressed in °Brix after temperature corrections.

2.2.2. Titrable acidity

Five grammes of fresh homogenised pulp were made up to 100 ml and filtered through muslin cloth. Then, 10 ml of the filtrate were taken for titration against 0.1 N NaOH solution, using phenolphthalein as indicator. The appearance of a light pink colour was considered as the end-point. The acidity was calculated and expressed as per cent citric acid (Anonymous, 1984).

2.2.3. Reducing sugars

The reducing sugar content of the pulp was determined by the dinitrosalicylic acid (DNSA) method (Miller, 1972). A known volume of alcoholic extract (1 ml) was taken and the alcohol was allowed to evaporate completely by placing on boiling water bath. The sugar residues were collected and diluted to known volume (10 ml) with distilled water. One ml aliquot extract was mixed with 0.5 ml of DNSA reagent in test tubes and kept on a boiling water bath for 5 min. The tubes were cooled and the volume was made up to 20 ml. The per cent transmittances of the standard (prepared from D-glucose) and the sample against reagent blank were read at 540 nm. The reducing sugars were determined and expressed in percentage (g of reducing sugars/100 g of fresh pulp).

2.2.4. Total sugars

The alcoholic extract after expulsion of alcohol was subjected to inversion. The reducing sugar content of hydroly-

Table 1
List of dessert purpose jackfruit selections studied from hilly zone of Karnataka (India)

District/taluka	Selections with code	Total
Shimoga	74°38′–76°04′ longitude (E), 13°27′–14°39′ latitude (N)	
Thirthahalli	SMG-24, SMG-25, SMG-26, SMG-27, SMG-28, SMG-29, SMG-31	7
Sagara	SMG-17, SMG-22, SMG-23, SMG-20, SMG-21	5
Soraba	SMG-1, SMG-2, SMG-3, SMG-4, SMG-5, SMG-6, SMG-7, SMG-8, SMG-12, SMG-13, SMG-14, SMG-15	12
Total selections		24

sate was determined by following the DNSA method (Miller, 1972), as described above. The values of the total sugars were expressed as g/100 g of fresh pulp.

2.2.5. Starch

The residue obtained by filtering the alcoholic extract of the sample constituted the alcohol-insoluble matter. A known amount of alcohol-insoluble matter was hydrolysed by using perchloric acid (52%). The hydrolysed fraction was centrifuged at 3000 rpm for 10 min. The supernatant was collected and pooled. This process was repeated thrice, increasing the centrifugation time from 10 to 15, 25 and 30 min, and collecting the supernatant each time. This supernatant, containing hydrolysed starch, was made up to a known volume (50 ml) and was used for estimating sugars, as explained in the reducing sugar section. The amount of starch was computed by multiplying the value of reducing sugar fraction by the factor 0.90 to get the percentage of starch on a fresh weight basis (Ranganna, 1986).

2.2.6. Carotenoids

Five grammes of fruit sample were ground, in a clean mortar, to a fine pulp with addition of 20 ml of 80% acetone. The extract was centrifuged (5000 rpm for 5 min) and supernatant was transferred to a 100 ml volumetric flask. Residue was ground again with 20 ml of 80% acetone, centrifuged and the supernatant was transferred to the same flask. This process was repeated until the residue was colourless. Pestle and mortar were washed thoroughly with 80% acetone and the clear washings were collected in the same flask. The final volume was made upto 100 ml with 80% acetone and the absorbance was read at 480 and 510 nm against the solvent (80% acetone) as blank (Saini, Sharma, Dhankar, & Kaushik, 2001). The carotenoids were determined and expressed in mg per 100 g of pulp.

3. Results and discussion

3.1. TSS, acidity and TSS:acid ratio

A wide variation in the TSS content was observed in the bulbs of jackfruit types considered in the present investigation (Table 2). The TSS was found to be highest in the jackfruit selection SMG-5 (35.00°Brix), followed by SMG-4 (34.33°Brix) and SMG-2 (33.67°Brix). However, SMG-2, SMG-4 and SMG-5 were statistically similar. Among the selections, the lowest TSS was observed in SMG-3 (19.87°Brix). The variation in TSS content of jackfruits is in agreement with previously published reports (Mitra & Mani, 2000; Reddy et al., 2004). The maximum TSS (40.50°Brix) reported by Reddy et al. (2004) was higher than that in the present study and this substantiates the vast diversity existing in jackfruit in the land of its origin.

Acidity in the bulbs of jackfruit clones covered showed a range from 0.190% to 0.595%. An almost similar variation in acidity (0.180–0.680%) has been reported in earlier work (Reddy et al., 2004). The maximum acidity was found in SMG-4, while the minimum was registered in the jackfruit type SMG-22. The titratable acidity content of SMG-4 was significantly higher than those of all the remaining types. Many selections were found to have lower acidity levels and were found to be statistically similar to SMG-22. The total acidity in jackfruit is low at the ripe stage (0.130%) and it shows little change subsequently (Bhatia et al., 1955). Nandini (1989) reported that firm types have lower acidity (0.300%) than soft (0.550%) types. However, all the jackfruit types analyzed in the present study were firm fleshed and a wide variation observed in their acidity is due to the greater number of jackfruit trees covered for the study from the Western Ghats region of India, which is the centre of diversity for *Artocarpus* spp. (Soepadmo, 1991).

Table 2
Mean values of acidity, TSS and TSS:acid in dessert type jackfruits of hilly zone of Karnataka (India)

Sl. No.	Selection	Acidity (%)	TSS (°Brix)	TSS:acid ratio
1	SMG-1	0.204	26.80	131
2	SMG-2	0.431	33.67	78.1
3	SMG-3	0.269	19.87	73.9
4	SMG-4	0.595	34.33	57.7
5	SMG-5	0.276	35.00	127
6	SMG-6	0.483	31.00	64.2
7	SMG-7	0.212	28.33	134
8	SMG-8	0.246	30.33	123
9	SMG-12	0.487	28.20	57.9
10	SMG-13	0.280	28.80	103
11	SMG-14	0.324	28.70	88.6
12	SMG-15	0.341	29.86	87.6
13	SMG-17	0.288	22.60	78.5
14	SMG-20	0.250	32.93	132
15	SMG-21	0.262	22.30	85.1
16	SMG-22	0.190	30.33	160
17	SMG-23	0.192	21.00	109
18	SMG-24	0.211	21.66	103
19	SMG-25	0.403	21.83	54.2
20	SMG-26	0.384	24.90	64.8
21	SMG-27	0.211	21.60	102
22	SMG-28	0.307	24.60	80.1
23	SMG-29	0.211	24.00	114
24	SMG-31	0.192	25.80	134
Mean		0.302	27.02	97.6
SEM		0.018	1.028	6.80
LSD 1%		0.068	3.902	25.8

The TSS:acid ratio is an economically important biochemical parameter as it determines the taste and acceptability of jackfruits (Maiti et al., 2002; Reddy et al., 2004). In this investigation, maximum TSS:acid ratio was associated with the jackfruit type SMG-22 (159.63) and the least was noticed in SMG-25 (54.17). Although TSS contents of SMG-2, SMG-4 and SMG-6 were more than 30°Brix, their TSS:acid ratios were lower on account of their higher acidity content. On the other hand, the jackfruit type SMG-22, with TSS slightly above 30°Brix, had the highest TSS:acid ratio due to the inherently minimum acidity associated with its fruits. The TSS is an indicative of the sugar level in the fruit. Low acidity and high sugars are responsible for the sweet taste of jackfruit (Selvaraj & Pal, 1989).

3.2. Total and reducing sugars

The total and reducing sugar contents in jackfruit types studied exhibited a range from 19.1% (SMG-27) to 32.1% (SMG-5) and 8.63% (SMG-21) to 14.6% (SMG-15), respectively (Table 3). The values are in conformity with the various previously published works (Maiti et al., 2002; Mitra & Mani, 2000; Reddy et al., 2004). No statistical difference was found to exist among SMG-2, SMG-4 and SMG-6 or among SMG-2, SMG-5, SMG-4, SMG-6, SMG-15, SMG-13 and SMG-14 with respect to total and reducing sugars, respectively. Mitra and Mani (2000) concluded that jackfruits with TSS of more than 25°Brix and total sugars of more than 20% were suitable for table purposes. Jackfruits of all the clones in the present study showed total sugars of more than 20% except SMG-3, SMG-25 and SMG-27. However, total sugars are not the only qualitative factor that determines the sweetness as taste is also affected by the level of acidity (SMG-2, SMG-4 and SMG-6). It is the combined perception of colour, texture, TSS, total sugars, reducing sugars, acidity level, TSS:acid ratio and flavour of the flakes which determines the organoleptic quality and suitability of jackfruits for table purposes.

3.3. Starch

The starch content of jackfruit samples was determined by the Ranganna (1986) method. The jackfruit type SMG-3 had a significantly higher starch content (5.13%), while the minimum was found in SMG-5 (0.63%), followed by SMG-20 (0.69%) (Table 3). Most clones had starch contents below 3% with the exception of SMG-3 and SMG-23. The jackfruit types with less than 1% of starch in their flakes were SMG-2, SMG-4, SMG-5, SMG-6, SMG-8, SMG-14, SMG-15, SMG-20 and SMG-22. At the edible ripe stage, the starch content in jackfruits of all the selections was lower than the level of sugars. Hydrolysis of starch and generation of free sugars and other soluble substrates during the ripening has been commonly observed in fruits, including jackfruit (Rahman et al., 1995), mangoes (Selvaraj & Pal, 1989) and banana (Chacon, Viquez, & Chacon, 1987; Garcia & Lajalo, 1988). The variation in the starch content of ripe fruits of different jackfruit clones in the present study might be due to the difference in the inherent capacity to accumulate starch and amylase activity in the bulb tissues, leading to differences in the rates of hydrolysis of starch of genetically dissimilar jackfruit selections. A variation in starch content and in the activities of enzymes associated with ripening has been reported by Rahman et al. (1995) in ripe jackfruits of the soft form and the firm form.

Table 3
Mean values of total sugars, reducing sugars and starch in dessert type jackfruits of hilly zone of Karnataka (India)

Sl. No.	Selection	Total sugars (%)	Reducing sugars (%)	Starch (%)
1	SMG-1	22.4	10.2	2.01
2	SMG-2	30.1	14.1	0.98
3	SMG-3	19.2	9.3	5.13
4	SMG-4	31.3	13.4	0.72
5	SMG-5	32.1	14.4	0.63
6	SMG-6	29.5	13.1	0.87
7	SMG-7	24.6	10.1	1.01
8	SMG-8	27.2	9.13	0.93
9	SMG-12	26.2	11.4	1.92
10	SMG-13	25.9	14.1	1.22
11	SMG-14	23.1	13.6	0.91
12	SMG-15	27.7	14.6	0.73
13	SMG-17	21.4	8.92	1.77
14	SMG-20	28.0	12.4	0.69
15	SMG-21	20.2	8.63	2.22
16	SMG-22	27.1	12.1	0.83
17	SMG-23	20.3	9.03	3.11
18	SMG-24	20.1	8.73	2.71
19	SMG-25	19.4	10.1	1.86
20	SMG-26	21.0	11.1	2.03
21	SMG-27	19.1	9.16	2.21
22	SMG-28	21.4	11.4	1.14
23	SMG-29	21.1	10.4	1.09
24	SMG-31	21.1	10.0	1.39
Mean		24.2	11.2	1.59
SEM		1.05	0.583	0.237
LSD 1%		3.97	2.21	0.900

Table 4
Mean values of edible portion and carotenoids in dessert type jackfruits of hilly zone of Karnataka (India)

Sl. No.	Selection	Edible portion (%)	Cartoteinoids (mg/100 g)	Bulb colour
1	SMG-1	42.24	0.606	Yellow
2	SMG-2	27.10	0.879	Deep saffron
3	SMG-3	40.15	0.712	Deep yellow
4	SMG-4	35.65	0.857	Saffron
5	SMG-5	24.91	0.581	Yellow
6	SMG-6	37.38	0.740	Orange
7	SMG-7	47.52	0.408	Light yellow
8	SMG-8	33.41	0.512	Yellow
9	SMG-12	34.22	0.378	Cream
10	SMG-13	30.69	0.363	Cream
11	SMG-14	25.49	0.642	Light saffron
12	SMG-15	39.87	0.698	Saffron
13	SMG-17	34.16	0.678	Yellow
14	SMG-20	30.73	0.771	Saffron
15	SMG-21	36.74	0.683	Deep yellow
16	SMG-22	41.48	0.497	Yellow
17	SMG-23	39.54	0.544	Yellow
18	SMG-24	43.64	0.592	Yellow
19	SMG-25	35.97	0.581	Yellow
20	SMG-26	39.67	0.505	Yellow
21	SMG-27	36.05	0.462	Lemon yellow
22	SMG-28	38.70	0.477	Cream
23	SMG-29	37.14	0.509	Lemon yellow
24	SMG-31	19.49	0.544	Yellow
Mean		35.50	0.592	
SEM		1.022	0.026	
LSD 1%		3.879	0.099	

3.4. Carotenoids

A great diversity was seen in the carotenoid contents of jackfruit types under study. The highest carotenoid content was obtained with SMG-2 (0.879 mg; 100 $g^{-1}$of edible portion), followed by SMG-4 (0.857 mg; 100 g^{-1} of edible portion) and the lowest was recorded in SMG-13 (0.363 mg; 100 g^{-1} of edible portion). However, the total carotenoids present in SMG-2 and SMG-4 did not differ statistically from each other. Interestingly, the intensity of colour of flakes, as revealed visually, was directly related to the amount of carotenoids found in each jackfruit type. Thus, deep saffron-(SMG-2), saffron-(SMG-4, SMG-15, SMG-20), orange-(SMG-6) and deep yellow-(SMG-3, SMG-21) coloured flakes were found to have higher carotenoid contents than those of yellow, light yellow and cream colour (Table 4).

4. Conclusion

Jackfruit, being highly cross pollinated and mostly seed-propagated, exists in innumerable types or forms, with different fruit characteristics. Fruits differ among themselves in the colour, sweetness, acidity, flavour and taste of flakes. A wide diversity among clones in western Ghats of India, presumably the centre of origin and diversity of jackfruit, offers scope for selecting the better ones. The results of the study are helpful for understanding the variability and attempting the selection of superior desirable jackfruit genotypes for bringing to commercial cultivation.

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