Unnurtured and untapped super sweet nonsaccharifierous plant species in India

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Thirteen species of plants accumulating nonsaccharides as the sweet principles have been identified in India: most species being indigenous. The active sweet principles stored in these plants can be grouped under: terpenoides, steroidal saponins, dihydroisocoumarins, dihydrochalcones, proteins, etc. in nature.These are not only low in calorific values and therefore health compatibile but also are 100–10,000 times sweeter than sucrose on a unit weight basis. Common and scientific names of these plants along with their popular names in Indian languages; salient information on their distribution, propagation, morphological features; and the corresponding chemical structure of the sweet principles have been presented in this paper.

THE sacchariferous sweet plants (plants accumulating saccharide as the sweet principle) such as sugarcane, sugarbeet, sweet sorghum, few fruit trees, tuber crops, etc. are known to meet the requirement of sweeteners for human beings. However, due to fast burgeoning population, while the world's requirement for sweeteners is expected to double (≃ 250 mt sucrose) by 2025–2030, India's requirement will be ≃ 38–40 mt sucrose by 2015–2020. Since the geographical area of the earth cannot be increased, the vertical jump in sucrose productivity, although an arduous task, is the only available option. The discovery of nonsacchariferous sweet plant species (plants accumulating nonsaccharides as the sweet principle which are at present over 15 in number), the sweetening principles of which have been recorded as 100–10,000 times sweeter than sucrose on a unit weight basis[1], augur well for future breakthrough in meeting this requirement for additional sweet principles.

The nonsaccharide sweetening agents, having low calorific values and therefore health compatible, unlike sucrose[1,2], are: terpenoids, steroids, steroidal saponins, dihydrochalcones, proteins, etc. On the other hand, due to regular use of traditional saccharide sweetening agents, except fructose syrup, human diseases such as dental caries, cardiovascular disease, diabetes mellitus, obesity and micronutrients deficiency have increased alarmingly[3]. Furthermore, synthetic sweetening agents such as saccharin, aspartame, and cyclamate used as substitute for sucrose in USA have been found to be carcinogenic and more harmful than sucrose[4]. Hence, in Japan, China, USA, Australia and Europe the nonsaccharide sweeteners are being consumed. Thus, with the increase in their demand there is a necessity for identification of these nonsacchariferous plant species, as well as the identification of their active sweet principle. A schematic representation of the types of sweeteners and their origin is given below.

- Natural or vegetal sweeteners
  - Saccharide sweeteners (from sacchariferous sweet plants)
    - Sucrose, glucose, high fructose syrup, etc.
  - Nonsaccharide sweeteners (from nonsacchariferous sweet plants)
    - Terpenoids
    - dihydrochalcones
    - protein, etc.
- Artificial or synthetic sweeteners
  - Inorganic substituted salts
    - Saccharine, cyclamate, etc.
  - Organic salts
    - Acesulfam, aspartame, etc.

Sacchariferous sweet plants

The first plant fruit mentioned as 'sweet' in the *Bible* is fig (*Ficus carica* L.) (Moraceae); the dried fruit of which was recovered from excavation of Gezar located in Judean Mountains and is dated 5000 BC (ref. 5). The sucrose, derived from Sanskrit word *Sarkara*, was being extracted from sugarcane in India, and had been identified about 6000–10,000 BC as mentioned in *Rig* and *Atharva* Vedas. It was introduced in non-Asiatic continents by Alaxander the Great (c. 325 BC) (ref. 6). Another sweet plant, *Saccharum spontaneum*, (*Kush* in Sanskrit) has a mention in *Ramayana* by Maharishi Balmiki. The plant was used in cloning and culturing of a new child in the place of lost child 'Lav' (son of Goddess Sita). This plant accumulates saccharides as the active sweet principle; the structural and chemical formulae are mentioned in Figure 1.

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Sacchariferous sweet principles have high calorific values (3600–4000 cal g^{-1}). Raw form of sucrose, i.e. *Gur* and *Khandesari* and cane juice are also a source of energy. However, high fructose corn syrup (HFCS) is different. Since it has been found to be health compatible, it has replaced sucrose in soft drinks and food industries to an extent of 10% (ref. 7).

Nonsaccharіferous sweet plants

The oldest sweet-tasting plant containing nonsugar principles, for example glycyrrhizin, is Licorice, *Glycyrrhiza glabra* L., (Leguminosae). Its active sweet principle is 100 times sweeter than sucrose on a unit weight basis. It appears to have been in use approximately around 500 BC (ref. 8). Theophrastus (c. 300 BC), called it as sweet scythian root. *Thaumatococcus daniellii* (Bernett) Benth. (Marantaceae) was identified in 1855 by Deniell[9] from which thaumatin was extracted. This was found to be 10,000 times sweeter than 7% sucrose on a molar basis[10]. Subsequently in 1905, another intensely sweet plant, European polypody fern, *Polypodium valgare* L. (Polypodiaceae) was identified[11]. Sweet principle, osladin, was extracted from its rhizome[12]. Presently, as many as 15 species of nonsaccharіferous sweet plant have been identified. In this article, are the details relating to these in Indian context.

Artificial or synthetic sweeteners

Synthetic sweeteners are artificial sweeteners, found in the form of salts and also synthesized through chemical reactions. For example saccharin, an inorganic substituted artificial sweetening agent, is a white crystalline powder, odourless with alkaline and alkaline earth metal salts; while its salt formed with heavy metals are bitter. Sodium or ammonium salt of saccharin are sweet and came into use in USA and Europe at the beginning of 20th century[13]. The synthetic sweetening agents such as saccharin, cyclamate or sucaril, and P-4000 (Figure 2) have been found to be 300–500, 30–100, and 4000 times, respectively, as sweet as sucrose. Acesulfam-K, a pure organic salt synthetic sweetener, is 80 times sweeter than sucrose, whereas aspartame made from two amino acids is 130 times sweeter than 4% sucrose[7]. The chemical structures of some of these are mentioned here. Regular use of artificial sweetening agents results in disorders of liver, kidney, blood cells, digestion, thyroid functions, brain, neuroendocrine regulation, etc. and these are not

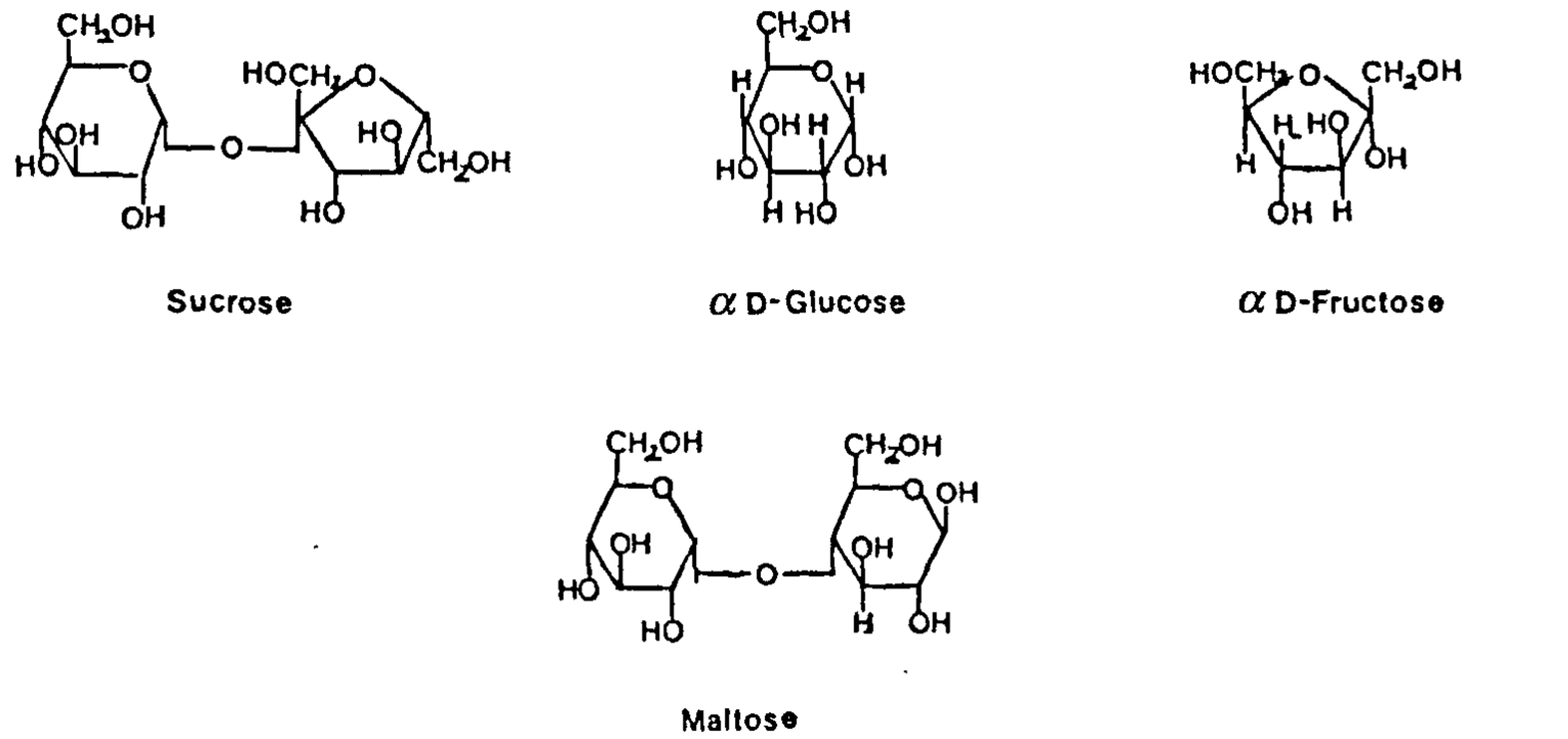


Figure 1. Accumulated active sweet principles of sacchariferous sweet plant, *Saccharum spontaneum*

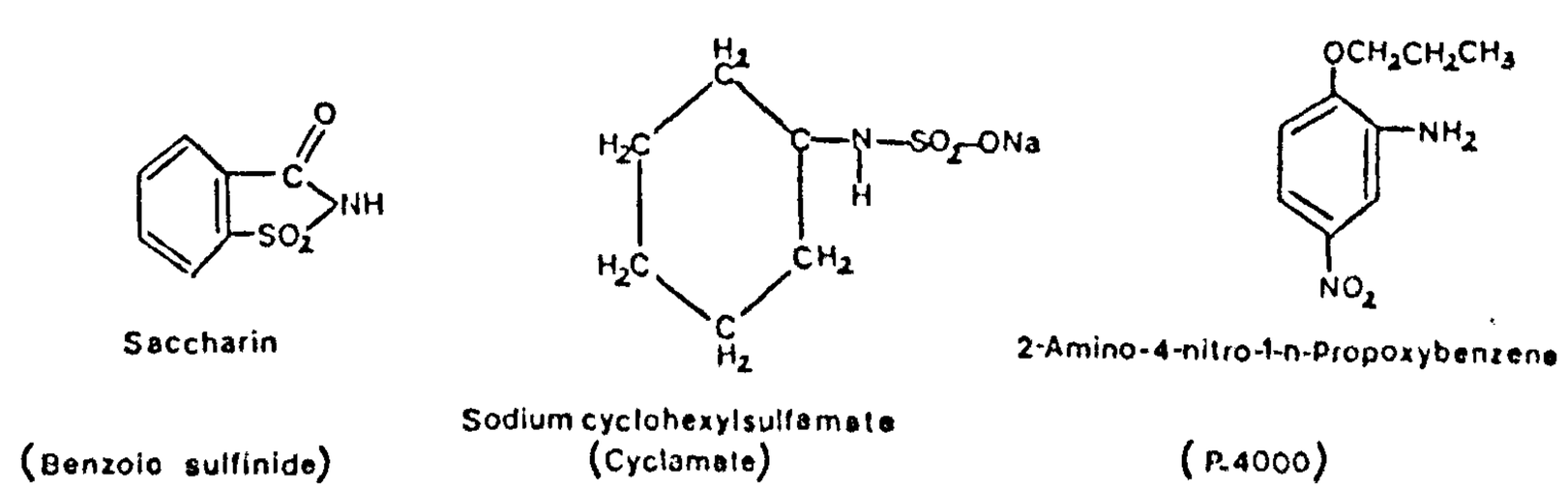


Figure 2. Some synthetic sweetening agents.

safe for human consumption, since these are non-nutritive and carcenogenic as declared by US Food and Drug Administration (FAD) (ref. 13).

Habitat of nonsaccharіferous super sweet plant species in India

A survey of literature and fields and collection of information from herbarium of National Botanical Research Institute, Lucknow; Central Institute of Medicinal and Aromatic Plant, Lucknow, its field station; Botanical Survey of India, Calcutta, Allahabad, Port Blair, Shillong and Coimbatore and Regional Research Laboratory Jammu and Bhavagar, were undertaken to find out the details of nonsaccharіferous sweet plant species in India. In the following section, information on sweet plant species is presented in order of sweet principles chemical configuration/group similarities.

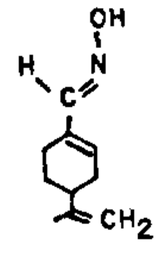
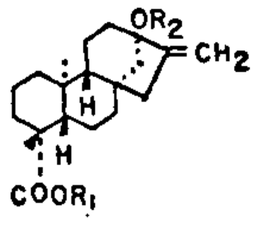
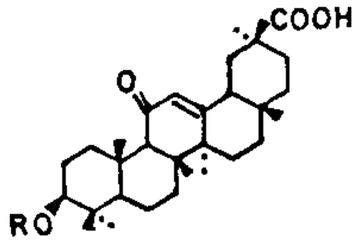
Group: Terpenoides

1. The plant species, *Perilla frutescens* (L.) Britton (Labiatae), commonly known in various regional languages as: *bhanjira* (Hindi); *ban tulsi* (Bengali); *jhutela* (Kumaun), is indigenous to India and found almost throughout Himalayas up to an altitude of 3500 m and on the hills of Assam and Bihar[14]. It is propagated mainly through seeds. Some of its characteristic features are: aromatic, bushy annual height 150 cm. Leaves; broadly ovate, acuminate, coarsely serrate or crenate. Flowers; small, white in axillary and terminal racemes. Nutlets commonly called seed: rounded, pale brown, with reticulate markings, weighing 250 mg to 1 g.

The sweet principle, Perillartin[15] is a type of monoterpenoid. Volatile oil is produced from leaves and flowering tops. Perrilla seeds contain 30–50% volatile oil. The volatile oil provides flavour to sauces, confectionery and is 370–450 times/2000 times sweet as sugar on a unit weight basis, and 4–8 time as sweet as saccharin[16] (Table 1).

2. The plant species *Stevia rebaudiana* (Bertoni) Bertoni (Compositae) is reported to be native to Paraguay and south Brazil, and cultivated in Japan, southeast Asia, USA, etc.[17,18], but grows in India as well at some semitropical areas, humid Himalayan hilly regions, and humid hills of Assam. It is propagated through seeds and cuttings. The seedlings raised from seeds are transplanted

Table 1. Super sweet principles of nonsaccharіferous sweet plant species

Botanical name and family	Active sweet principle	Chemical structure	Sweetness compared to sucrose (times on a unit wt. basis)	Native place of plant species	Refs
1. *Perrilla frutescens* L. (Labitae)	Group: monoterpenoid (Perillartine)		400–2000	India Sino–Japan Southeast Asia	15
2. *Stevia rebaudiana* Bertoni (Compositae)	Group: diterpenoid (Stevioside)	 R_1; R_2 represent: β-glc; β-glc^2-β-glc, (glc = D-glucorono pyranosyl)	200–300	Paraguay and South Brazil	20
3. *Glycyrrhiza glabra* L. (Leguminosae)	Group: triterpenoid (Glycyrrhizin) (Glycyrrhizic acid)	 R represents: β-gl CA^2-β-gl CA, (gl CA = D-glucurono pyranosyl)	100	Mediterranean Countries and China	21
4. *Abrus precatorius* L. (Leguminosae)	-do-			India	22
5. *Achras sapota* L. (Sapotaceae)	-do-	-do-		S. America	22

and shoot is harvested after 4–5 months of growth. The ratoon stalk/stubbles give rise to new plants. Its characteristic features are: branched bushy shrub, height usually 40–120 cm. Leaves; small, oblong, serrate and sweet. Flowers; small, usually white. Leaves are harvested for extraction of the sweet agent at the time of the emergence of flower primordea.

The sweet principle, Stevioside[19], is a type of diterpenoid, 200–300 times sweeter than sucrose on a unit weight basis[20] (Table 1). Many types of steviosides such as rebaudioside A, B, C, D and E and steviol x–xii are extracted from the leaves. The sweetness in the leaves is two times higher than of inflorescence.

3. The plant species *Glycyrrhiza glabra* L. (Leguminosae) is commonly known as licorice, liquorice; *madhuka* (Sanskrit), *mulhatti* (Hindi). It is native of Mediterranean region and cultivated in France, Italy, Spain, USSR, USA, Middle East and Asia. In India, it is found in Srinagar, Jammu, Deharadun, Baramulla, temperate Himalayan regions and southern Indian hilly districts[14]. Deep moist soil, particularly the banks of river which are subjected to periodical inundation, suits the growth of this plant. It is propagated through divisions of crown or rooted cuttings of underground stem. Some of its characteristic features are: Hardy herb or underground shrub with maximum height of 2 m. The underground growth of stem and roots is found to be higher than aerial parts of plants. Leaves; multifoliated and imperipinnate[14]. Flowers; axillary spikes, papilionaceous, lavender to violet, Pods; compressed containing reniform seeds. While the underground part in some varieties is made up of a root stock with a number of long branched stem, in other varieties the root stock is stout, and throws off a large number of perennial roots.

The sweet principle, glycyrrhizin (glycyrrhizic acid)[8] is a triterpenoid (Table 1). Calcium or potassium or magnesium salt of sweet trihydroxy acid, glycyrrhizic acid ($C_{42}H_{62}O$; m.p. 205°C-quick decomp.) is found in roots and rhizomes (Figure 3). Ammonium glycyrrhizin, the fully ammoniated salt of glycyrrhizic acid is commercially available and has been found to be 100 times sweeter than sucrose[21] (Table 1).

4. The plant species *Abrus precatorius* L. (Leguminosae) is commonly known as Indian liquorice, jequirity *gunja* (Sanskrit and Marathi), *ghungchi* and *rati* (Hindi), *kunni* (Malayalam), *kunch* (Bengali). It is indigenously found throughout India, even at altitudes up to 1200 m on the outer Himalayas. It is now naturalized in all tropical countries[14]. This plant species is propagated through seeds. Six species of *Abrus* are available. Two species, *A. precatorius* and *A. laevigatus*, are most common in India[14]. *A. precatorius* is a climbing shrub with peripinnate leaves, sensitive to light and changes in weather. The shiny seeds are of the size of small peas, usually bright scarlet and with black eyes, sometimes however white seeds with or without black eyes are also met with. Leaves taste more sweeter than roots. Seeds are poisonous and contain abrin, a poisonous principle. Leaves, roots and seeds are used for medicinal purposes (Figure 4). The sweet principle, glycyrrhizin, is same as that of liquorice[22] (Table 1). *Abrus precatorius* is a substitute for *Glycyrrhiza glabra* L.

5. The plant species *Achras sapota* L. (Sapotaceae) is indigenous to South America, but cultivated all over the world including India for its edible fruits. It is available in states of Maharashtra, West Bengal, Tamil Nadu, Karnataka, Kerala, etc.[14]. It thrives better in coastal areas. Rich and well-manured sandy soil supports good growth. It is propagated commonly through seeds. However, seed-raised trees are slow in growth and bearing, therefore layering, budding and grafting are practised which results in bearing of fruits within two years. In-arching is a common form of grafting in India.

Three species of *Achras* are found in India[14]. *A. sapota* L. is an evergreen 6–11 m high tree with a spreading crown. Flowers are seen throughout the year, and fruits ripen mainly during March, April, August and September. Fruit is round or oval berry of 5–10 cm diameter. The seeds

Figure 3. Rhizome of *glycyrrhiza glabra* L.

Figure 4. *Abrus precatorius* L.

(9–12 per fruit) are hard, black and about 2 cm long. Fruit has thin rusty brown skin. The flesh in ripe fruits is yellowish-brown, soft and sweet. The coagulated resinous latex derived from bark is used for making chewing-gum.

The sweet principle, glycyrrhizin[22] (Table 1) is present in the latex and fruit. Further studies are required on the quantity and intensity of sweet principle present in different parts of this plant.

Group: *Dihydroisocoumarin*

6. The plant species *Hydrangea macrophylla* (Thunb.) Seringe (Saxifraceae), commonly known as *amacha*. *H. macrophylla*, is indigenous to Japan, China and is found in North and South America, and temperate hills of India. It is widely distributed in Ravi east towards Assam, and in Himalayas at altitudes of 1300–3300 m, Garhwal, Kathmora and other hill stations in India[14]. It is propagated by cuttings, division or suckers. Five species of *Hydrangea* are found in India[14]. *H. macrophylla* Seringe is a shrub, about 4 m height. Leaves; elliptic to broadly ovate or abovote, 7–15 cm long, coarsely toothed, and almost glabrous. Flowers; pink, generally flowers on hill stations and requires high light intensity. Flowering is seldom on plains. Sometimes, due to absorption of aluminium on acidic soils, the flower colour changes from pink to blue[14].

The sweet principle, Phyllodulcin[23], is a type of dihydroisocoumarin. It is 300–400 times sweeter than sucrose[24] (Table 2).

Group: *Dihydrochalcones*

7. The plant species *Smilax glycyphylla* Sm. (Liliaceae) is known as *barichob-chini* (Hindi), *kukardara* (Kumaun), *harina-shuk-china* (Bengali). *Smilax glycyphylla* Sm, is indigenous to India and is found in Himalayas from Kashmir eastward in Naga to Khasi hills in Assam[14]. It is mainly propagated through rhizomes and tuberous roots. Twenty-four species of *Smilax* are found in India[14]. It is a climber with woody, smooth or sparsely prickled stem. Leaves; distant, alternate and ovate–lanceolate. Flowers; in umbels, very small, white berries light to darkblue.

The sweet principle, Glycyphyllin, is a type of dihydrochalcone glycoside[25]. The extracts of shoot or almost all parts provide sweetening agent. It is 100–200 times sweeter than sucrose[26] (Table 3).

8. The plant species *Symplococos paniculata* Miq. (Simplocaceae) is commonly known as sweetleaf, sapphire berry, *lodhra* (Sanskrit), *ludh* (Hindi). A large number of species of genus *Symplococos* are found in warmer parts of Asia, Australia, and America. *S. paniculata* Miq. is indigenous to India and commonly found in the Himalayas from Punjab to Assam and in the Khasi hills, occurring at altitudes between 600 and 2400 m[14]. It is mainly propagated through seeds. Sixty-eight species of *Symplococos* are found in India[14]. *S. Paniculata* Miq. is known as sweet leaf and sapphire berry. It is a deciduous shrub or a tree, 12 m in height. Leaves; obvate, 6.25 cm × 2.50–3.75 cm in size, softly pilos beneath. Flowers; white, fragrant, in terminal panicle. Fruits; blue, drupaceous, usually one seeded.

The sweet principle, Trilobatin, is a type of dihydrochalcone glycosides[27]. It is 400–1000 times sweeter than sucrose (Table 3). A water-soluble fraction from the bark has been reported to exhibit antioxidative activity. Seeds contain oil. Leaves are used as fodder. Further studies are required on quantity and distribution of sweet principles in different parts of this plant.

9. The plant species *Citrus aurantium* L. (Rutaceae) is commonly known as seville orange, *khatta* (Hindi), *karna* (Malayalam). This plant is indigenous to India[14] and is being cultivated on a large scale. Earlier its cultivation centred around Guntur district of Tamil Nadu, specially for its fruit, orange. It is propagated through seed and grafting. Plant is a medium-sized thorny tree with broadly winged leaf stalk. Flower; pentamerous, usually white, hermaphrodite, complete and hypogynous with enlarged and very conspicuous water secreting annular-shaped disk below the gynoecium. Fruit; round and orange in colour when ripe. Rind; aromatic bitter and pungent. Pulp; acidic.

The sweet principle is Neohesperidin dihydrochalcones[28]. The flavonoid parent compound neohesperidin is bitter and is present in the peels. Dilute alkali extracts the sweet principle. These are about 1000 times sweeter than sucrose[28] (Table 3).

10. The plant species *Citrus paradisi* Macf. (Rutaceae) is commonly known as grape fruit. It is indiginous to west Indies and cultivated in India both in subtropical and tropical areas[14]. It is propagated through seed and

Table 2. Super sweet principles of nonsaccchariferous sweet plant species

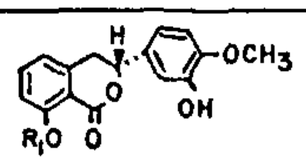
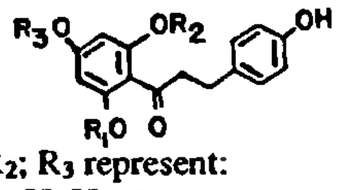
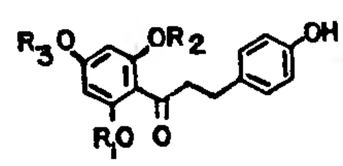
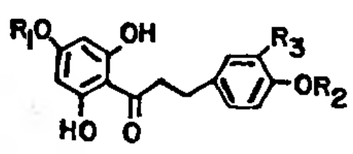
Botanical name and family	Active sweet principle	Chemical structure	Sweetness compared to sucrose (times on a unit wt. basis)	Native place of plant species	Ref.
6. *Hydrangea macrophylla* Seringe (Saxifragaceae)	Group: dihydroisocoumarin (Phyllodulcin)	 R_1 represents: H	300–400	Japan, China, America, temperate hills of India	24

Table 3. Super sweet principles of nonsaccharifferous sweet plant species

Botanical name and family	Active sweet principle	Chemical structure	Sweetness compared to sucrose (times on a unit wt. basis)	Native place of plant species	Refs
7. *Smilax glycyphylla* Sm. (Liliaceae)	Group: dihydrochalcone glycoside (Glycyphyllin)	 R_1; R_2; R_3 represent: α-rha; H; H, (rha = L-rhamnopyranosyl)	100–200	Temperate hills of India	26
8. *Symplococos paniculata* Miq. (Symplocaceae)	Group: dihydrochalcone glycoside (Trilobatin)	 R_1; R_2; R_3 represent: H; H; β-glc, (glc = D-glucopyranosyl)	400–1000	India	27
9. *Citrus aurantium* L. (Rutaceae)	Group: dihydrochalcone (I) (Neohesperidin)	 R_1; R_2; R_3 represent for: (I) β-glc^2 α-rha; CH_3; OH, and (II) β-glc^2 α-rha; H; H, (glc = D-glucopyranosyl; and, rha = L-rhamnopyranosyl)	1000	India	28
10. *C. paradisi* Macf. (Rutaceae)	Group: dihydrochalcone (II) (Naringin)		> 1000	West Indies	28
11. *C. sinensis* L. (Rutaceae)	Group: dihydrochalcone 4′-β-D-glucoside (Hesperetin)	Above reduced hesperidin skeleton with 4′-β-D-glucoside	300	India and China	28
12. *C. limon* L. (Rutaceae)	-do-	-do-	-do-	Northwest region of India	28

grafting. Plants are fairly large trees, 6–14 m high with smaller leaves than pummelo and peteoles less broadly winged than pummelo. Flowers; large, born singly or in small clusture in the axil of leaves. Fruits; round or pear shaped (Figure 5) with white or pink flesh. Juice; plentiful and sour.

The sweet principle, Naringin is a type of dihydrochalcone[28]. The flavonoid parent compound naringin is bitter and present in peels. Extract in dilute alkali gives sweet principle. It is somewhat less than 1000 times sweeter than sucrose[28] (Table 3), commercialized and could also be used to prepare neohesperidin.

11. The plant species *Citrus sinensis* L. (Rutaceae) is commonly known as betavian, sweet orange, *musambi* (Hindi), *narangi* (Bengali), *kamala* (Gujarati), *nembia* (Marathi)[14]. It is native of India and China and is being cultivated widely in subtropical regions as most valued commercial citrus of the world. It is cultivated widely in India[14]. It is propagated by seeds, cuttings, layering and budding. Seeds germinate in about 20 days after sowing. A spreading, evergreen tree attains a height of about 10 m. Petal; narrow and winged. Fruit; globose, rounded at the apex, golden yellow or orange when ripe, rind; fairly thick, tightly adherent. Pulp; yellow, orange or reddish, fairly sweet, juicy and nutritious.

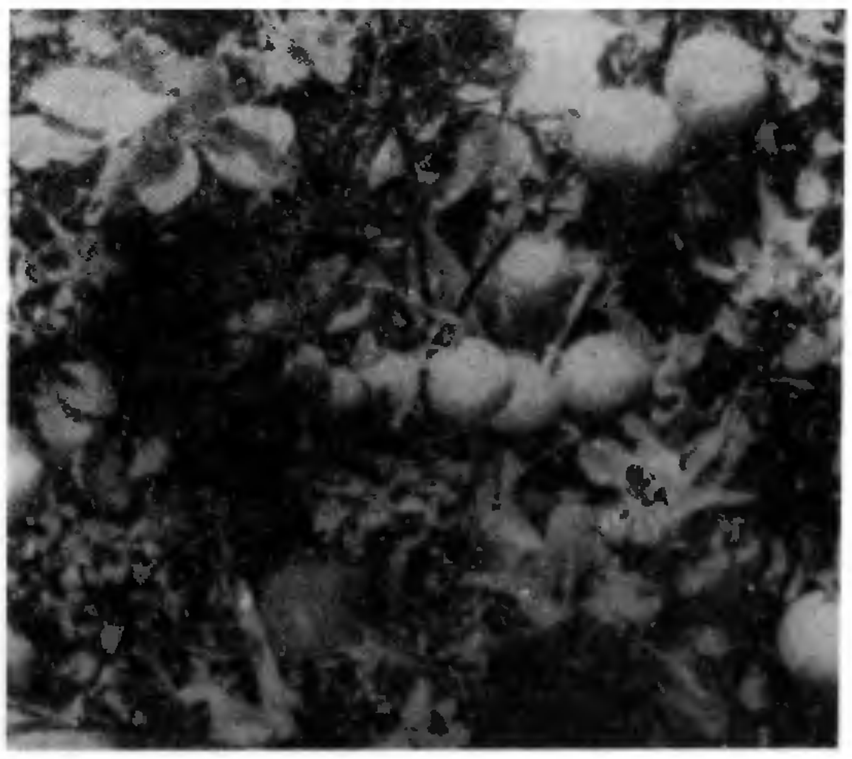


Figure 5. Fruits of *Citrus paradisi* Macf.

The sweet principle, Hesperetin dihydrochalcone 4′-β-D-glucoside (HDG), is present in peels/fruit[28]. The reduction of hesperidin (parent compound) in dilute alkali yields hesperidin dihydrochalcone. Partial hydrolysis of this compound, either by acid or by dissolved or immobilized enzyme, gives rise to sweet hesperetin

dihydrochalcone 4′-β-D-glucoside. This is 300 times sweeter than sucrose[28].

12. The plant species *Citrus limon* L. (Rutaceae) is commonly known as lemon, *baranibu* and *jambira* (Hindi), *idalimbu* (Marathi), *pariya* and *yelumichai* (Tamil). Wild stock of *C. limon* L. is native of northwest region of India ascending to 1335 m[14]. Lemon is cultivated in almost all parts of India. It is propagated through seed, layering, grafting and budding. Some of its characteristic features are: A straggling bush or small tree with thorny branches and attains a height of 3–4 m. Peteole; wingless or very slightly winged. Fruit; oblong or ovoid, usually with a nipple-shaped extremity, bright yellow. Rind; thick. Pulp; acidic, pale yellow.

The sweet principle is same as that present in *C. sinensis*[20] (Table 3).

Sweetness inducers

13. *Cynara scolymus* L. (Compositae) is commonly known as globe or burr artichoke, *hathichak* and *hathichoke* (Hindi), *hathichoke* and *hathichoke* (Bengali). It is native to cold humid mediterranean region/countries. It is cultivated as vegetable crop throughout India, on hills as well as on plains[14], and at places where winter is mild and moist. Medium to light soils are most suitable for its growth. It is propagated by seeds or suckers or offshoots. Plants raised through seeds flower in about 8 months, but those raised from suckers flower earlier and produce uniform-sized flowers. Usually, suckers are planted in plains during August–December and seedlings of 10–12 cm length raised through seeds are planted on hills during February–June. Thirteen spp. of *Cynara* are found in India[14]. *C. scolymus* L. is a thistle-like perennial herb of 1.0–1.8 m height. Two varieties, green globe and purple globe are cultivated. Leaves: medium size, bitter, in taste. The globular immature flowers are used as vegetable. Flowers are harvested for use before involucral bracts start opening. Thick receptacle are known as heart, and flesh base of involucral bracts from the main edible portion. Floral head is used by patients with diabetic.

The sweet principles cynarin and chlorogenic acid are responsible for making water taste sweet[29]. Cynarin is abundantly present in leaves. Caffeic acid (3,4 dihydrocinnamic acid) present in the plant is also responsible for sweetness in water[30]. (Table 4).

Market for nonsaccharides sweetening agents

The per capita consumption of sucrose (white sugar) in USA, Australia and China has reduced to half in the last several years[31], since regular use of sugar has been found hazardous to health. This has been possible because of the availability of four commercial nonsaccharide sweetening agents: ammoniated glycyrrhizin; thaumatin; stevoiside; and phyllodulcin (Table 5) besides some other alternative sources of sucrose available as well, for example high fructose corn syrup (saccharide)[2,23]. Since nonsaccharide sweetening agents are low in calorific values and most health compatible, their demand is on the increase in Japan, USA, Australia, Europe, China, Thailand, Brazil and other parts of the world. Recently, another sweetening agent, monellin (protein) has been in great demand in Europe[2].

Nonsaccharide sweeteners are also in great demand by diabetic patients whose number is 150 million at present in the world and is likely to double by the year 2025 as per WHO (ref. 33). In developing countries, their number at present is 80 million which is expected to touch the 200 million mark by 2025. India is importing

Table 4. Sweetness inducers

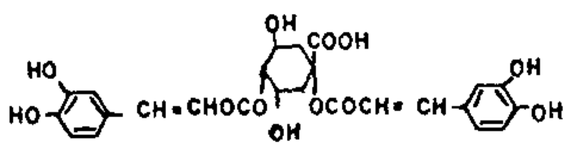
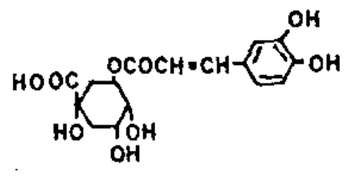
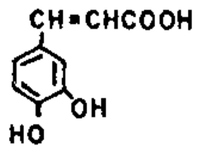
Botanical name and family	Active sweet principle	Chemical structure	Native place of plant species	Refs
13. *Cynara scolymus* L. (Compositae)	(Cynarin)	 1,4-bis (3,4-hydroxy cinnamoyl) quinic acid	Cold and humid mediterranean regions/countries	30
	(Chlorogenic acid)	 1,3,4,5-tetrahydroxy cyclohexane carboxylic acid		
	(Caffeic acid)	 3,4-dihydrocinnamic acid		

Table 5. Commercial nonsaccharide sweeteners (NSS), intensity of their sweetness and consumption in world

Commercial products of NSS	Sweetness as compared to sucrose (on unit wt. basis)	NSS consuming countries
1. Stevoiside (diterpenoid)	300	Japan, China, Brazil
2. Ammoniated glycyrrhizin (triterpenoid)	100	USA, and worldwide
3. Phyllodulcin (dihydroiso-caumarin)	400	Japan, Australia, Thailand
4. Thaumatin (protein)	10,000	European countries Japan, Australia, USA

nonsaccharide sweeteners from Japan, USA, and Brazil to meet the demand of its 20 million diabetic patients whose number is likely to reach 35 million by the year 2003 (ref. 33). Thus, to meet the requirement of growing population, in general, and of increasing number of diabetic patients, in particular, the future of non-sacchariferous sweeteners appears to be bright.

Conclusion

In India, 13 species of plants that accumulate nonsaccharides as the active sweet principle have been identified. These principles can be grouped as: terpenoides; steroidal saponins; dihydrochalcones; dihydroisocoumarins; proteins, etc. Collection, propagation, cultivation, and establishment of germplasm repository of these plant species are essential. For fast multiplication of these plants, development of suitable techniques are required not only to save them from becoming extinct but also to enable their large-scale cultivation. Furthermore, simple techniques for the extraction of these principles are required which could be adapted at small-scale level.

These nonsaccharide sweeteners are 100–10,000 times sweeter than sucrose; are health compatible; and eliminate saccharide-created health problems. Moreover, these sweeteners have a bright potential for earning foreign exchange as well. Thus, to meet the requirement of country through nonsacchariferous sweet plants, hardly 0.1 million ha land is needed for their cultivation as opposed to vast tracts of land required for sugarcane cultivation.

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