Coconut inflorescence sap and its value addition as sugar – collection techniques, yield, properties and market perspective

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Fresh coconut sap (neera), if kept at room temperature for a couple of hours, undergoes fermentation. Fresh sap is golden in colour, with pH > 7 and has no foul odour. The traditional way of tapping, i.e. collecting the sap in a mud pot kept at the top of the palm under atmospheric temperature for 8–12 h, ferments the sap before collection itself. The colour turns whitish, pH drops to below 6 and odour of toddy (fermented smell) slowly develops. Hence the only way to avoid fermentation of sap is either keeping collection boxes at low temperature or to collect the sap every hour and store chilled. Central Plantation Crops Research Institute has developed 'coco-sap chiller' with ice cubes inside, which maintains the temperature at 2–3°C for 10–12 h, and also keeps the sap fresh and unfermented. The sap collected is sweet, non-alcoholic and also free from contaminants like ants, other insects, pollen, dust, etc. The fresh, hygienic and unfermented sap is called Kalparasa. It can be sold as a ready-to-serve health drink under refrigerated condition or can be processed into value-added natural products like sugar, jaggery, honey, syrup, etc. without the addition of chemicals.

Keywords: Coconut sap, health drink, market prospects, sugar content, tapping.

PALMS are believed to be among the oldest flowering plants in the world[1]. The five major economic palms of the world are coconut (*Cocos nucifera*), African oil palm (*Elaeis guineensis*), date palm (*Phoenix dactylifera*), betel nut palm (*Areca catechu*) and pejibaye (*Bactris gasipaes*). Among these, coconut produces inflorescences all through the year and so can be tapped. In India, it is called 'tree of heaven', 'tree of life', etc.[2]. For centuries, many palm species including coconut have been tapped to produce fresh juice (sweet toddy), fermented drinks (toddy, wine, arak), syrup (honey), sugar and jaggery. One of mankind's first sources of sugar was probably *Arenga pinnata*[1]. Evidence of the use of *Borassus flabellifer* sugar in India has been reported by the Greek historian Megasthenes in the 4th century BC. Evidence for extraction of sugar in India is more than 4000 years old[3], and jaggery and treacle from *Caryota urens* sap in Sri Lanka[4] has been reported. In Africa, the main traditional use of palm sap is for wine production. The same has been reported in Egypt (date palm) long before the birth of Christ[5] and on the Guinea coast by early navigators during the 15th century[6].

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Coconut sap or neera is one of the important drinks, being traditionally tapped from coconut spadix and consumed largely by rural population. It is the phloem sap[7], rich in sugars, protein, minerals, antioxidants, vitamins, etc. utilized by the plant for the growth and development of tender or mature coconut. As the flow of sap is slow and highly prone to fermentation, collection of unfermented sap is a challenging task. While tapping, lime is commonly used to inhibit fermentation. Even with lime, the sap becomes white with a foul smell making it unfit as a health drink. The fermented sap is called 'toddy', which has a strong odour that makes it unpalatable despite being nutritious. The lack of proper collection methods and suitable inhibitors to prevent fermentation led to the inclusion of both fermented (toddy) and unfermented (neera) sap under 'toddy'. Accordingly, the Karnataka Excise Act, 1965 (Act 21 of 1966) adapted from the Mysore Excise Act, 1901(Act No. V of 1901), The Hyderabad Abkari Act, 1316 (No. 1 of 1316 F) and the Madras Abkari Act, 1886 (Madras Act 1 of 1886) were enacted and tapping of coconut sap was prohibited. Coconut is included as an excise tree (Section 11A) and even the unfermented sap of coconut tree from which toddy can be produced is interpreted as toddy. However, unfermented sap and toddy are two different products, both chemically and nutritionally. In this article we

describe the coco-sap chiller developed by Central Plantation Crops Research Institute (CPCRI) to collect hygienic and unfermented coconut sap, its qualities, product diversification and market perspectives. The unfermented sap thus obtained is called as Kalparasa and registration under Trademark is awaited[8].

Rationale for tapping

Coconut produces 12–14 inflorescences (spadix) in a year, on an average one per month. Each spadix can support 20–25 tender or mature nuts. Tender nut requires 6–8 months, while mature nut takes almost a complete year for maturity. At a reasonably high water content of 500 ml per tender nut, the total water obtained from spadix is just 10–12.5 litre. The same spadix, if tapped, could produce 60–67.5 litre of sap in a period of just 40–45 days at a conservative yield of 1.5 litre/day. Moreover, it is rich in nutrients and phytochemicals compared to tender coconut water. Physiologically, tapping is more energy-efficient compared to allowing the spadix to produce nuts.

Tapping techniques

Selection of inflorescence and preparation

Coconut trees can be tapped at an early age as soon as they attain yield stability. The unopened inflorescence is used for tapping. The development of female flowers inside the spathe (about 60 cm long) causes a swelling at the base, the appearance of which is taken as the appropriate stage for tapping (Figure 1 *a*). The inflorescence selected for tapping is tied around with a strong coir or plastic rope to prevent it from bursting (Figure 1 *b*). The same is trained using a mallet, hand-massaged (using the palm) twice a day, in the morning and evening for a week. After 4–5 days of stroking, 7–10 cm of the tip is sliced-off and in a day or two sap starts oozing from the cut surface.

Traditional method of sap collection

The initial preparation of spadix to be tapped is the same as described above. As soon as the sap starts oozing out, tappers apply clay, some type of gummy material or leaf extract to the cut surface. It is believed to stimulate sap production, but in reality it was to prevent internal seepage of sap in the space available between the peduncles. Further, a coconut leaf lamina tied to the periphery of the cut surface allows the sap to trickle; otherwise it drifts along the surface as the coconut spadix is upright or vertical (forms an angle of 20°–30° to the main axis).

The sap trickling from the cut surface is collected in an open earthen pot or bamboo sac[9], which is placed at the top of the palm for at least 8–12 h (Figure 2). In order to prevent fermentation, lime is coated on the inner surface of the pot. The sap collected by this method is oyster white in colour and emanates a strong odour. It is also contaminated with insects, ants, pollen and dust particles. The sap collected without applying lime is used exclusively for the preparation of toddy, an alcoholic drink.

CPCRI method of sap collection

A PVC connector as described below fitted to the cut surface avoids the application of clay, leaf extract and tying of leaf lamina. Similarly, for sap collection, instead of an open earthen pot, a coco-sap chiller is connected.

PVC connectors: A PVC pipe of required size (approx. 50–63 mm diameter), closest to the diameter of spadix, excluding spathe is selected. One end is closed with an end cap. Sharp-edged groves of 3 mm are made at the

Figure 1. Spadix ready for tapping. ***a***, Ideal spadix with swollen base. ***b***, Stroking spadix using a mallet.

Figure 2. Traditional method of sap collection in open earthern pots.

open end, which fits tightly into the inflorescence (Figure 3). A hard tapering tubular pipe of 10 mm diameter is fitted 20 mm above the grooves. The connector is tightly screwed till the hard pipe touches the bottom side of the cut end and blocks the inter-peduncle space, ensuring free flow of sap through the pipe[10] (Figure 4). This avoids the need to apply clay, gummy material or leaf extracts[11].

Coco-sap chiller: This is a portable device consisting of a hollow PVC pipe whose one end of which is expanded into a box shape to house a sap collection container bound by ice cubes, while the other end is wide enough to insert and remove a collection container of 2 litre capacity[12]. Side walls of the pipe from outside are covered with an insulating jacket excluding the portion of spadix holder which maintains the inside temperature cool (2°–3°C) with ice cubes. It is light-weight, water-proof, easy to connect to the spadix (as shown in Figure 5), requires less ice and retains low temperature for longer periods (at least 10–12 h) compared to commercially available ice boxes. It is a new method of collecting unfermented sap from coconut and other palm trees and preserving its flavour and aroma without the use of preservatives[12].

Coconut sap collection using coco-sap chiller: The initial preparation of the spadix to be tapped is the same as that described earlier. Once the sap starts oozing out, the coco-sap chiller is prepared to be connected to the spadix[13]. Ice cubes (0.5–0.75 kg depending on climate and amount of sap) or 3–4 gel ice packets are spread inside the chiller. A container or plastic pouch of food-grade quality connected to an O-ring is placed in the grove made for the purpose. A stainless steel or plastic filter placed above the O-ring prevents contamination from pollen or plant material.

The spadix is inserted through the spadix holder, such that the cut surface is just above the centre of the filter (Figure 6 *a*). At this position the spadix is tightly fastened to the spadix holder using rexin or plastic cover, thus preventing the entry of ants and other insects. The top opening of the box is closed with a lid (Figure 6 *b*). The box is suspended from the tree crown using the handles provided (Figure 6 *c*).

During the initial few days of tapping, the spadix is upright or vertical and hence a connector is required for the flow of sap from cut surface to the collection container. Gradually, the spadix becomes flat or horizontal and sap from cut surface directly trickles to the container without the need of connectors. The filled container is taken out twice a day (in the morning and evening) and the sap is transferred to another ice box meant for further storage.

The most important aspect in sap tapping is the hygiene factor. Coco-sap chiller, filter and connectors are washed, while ice cubes and collection container are replaced and the box is reconnected as mentioned above. Each spadix requires one box and at a time 2–3 boxes can be connected per tree.

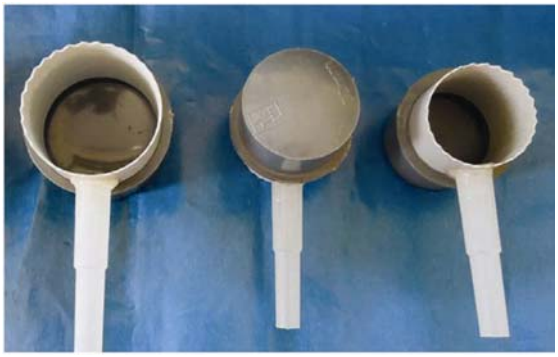

Figure 3. PVC connectors of different sizes attached with a hard tube.

Figure 4. Sap flow through the connector hooked to the cut surface.

Figure 5. 'Coco-sap chiller' developed by CPCRI for the collection of hygienic and unfermented sap.

Advantages of sap collection using the coco-sap chiller: This new method of sap collection using the coco-sap chiller surmounts the challenge of processing, i.e. 'purifying fermented sap (improving pH value, removing odour, etc.) into a palatable drink as in the traditional method'. This is a paradigm shift and has the following advantages:

- The sap collected is non-alcoholic, fresh, hygienic, sweet and delicious.
- Fresh and delicious sap can be collected at any time of the day.
- Sap is devoid of lime, clay, leaf extract, etc.
- It is free from contaminants like ants, other insects, pollen and dust particles.
- It is a highly nutritious, ready-to-serve natural health drink without the need for lengthy processing.
- It can be preserved fresh for a long duration under frozen or sub-zero condition.
- Chemical-free natural products, viz. coconut sugar, jaggery, confectionery and honey can be prepared.
- It is a closed system, with no emission of volatiles and does not attract harmful insects on coconut palm.
- Tapping can be done throughout the year, even during the rainy season.

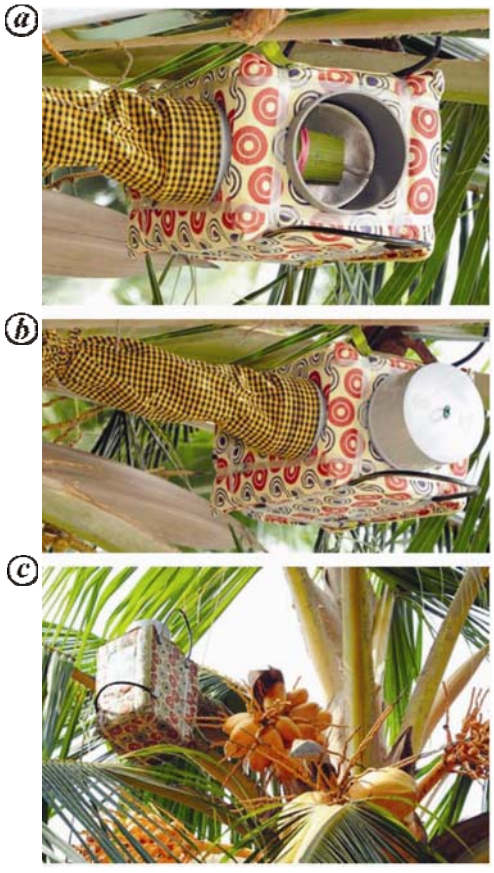

Figure 6. Preparation of coco-sap chiller for sap collection. ***a***, Spadix inserted through the spadix holder. ***b***, View of completely closed system. ***c***, Coco-sap chiller connected to the tree crown.

- Fabrication of the device is simple, cheap and from locally available material.
- The device is suitable for collection of sap from coconut and other palms.
- It is easy to operate. Hence skilled climbers can easily tap Kalparasa.

Tapping frequency

Tapping is done twice a day, in the morning and evening. Each time 1–2 mm spadix is sliced and it can be tapped in this way for 40–45 days depending on the tapper's skill, seasonal conditions and nature of the palm. A single spadix can be tapped until it is reduced to a stump of about 10–15 cm length. About three weeks before reaching this point, another spadix is prepared in order to ensure continuity of sap production. At a time, 2–3 spadices can be tapped from a tree.

Sap yield

Sap yield is influenced by both genotype and environment; it varies from day to day, season to season, spadix to spadix and tree to tree. In *B. flabellifer* and *Nypa fruticans* significant differences were seen for sap production between farms, months and sex of the palm, also the sap flow was higher during cool nights[14,15]. In coconut, sap production is more in talls and hybrids compared to dwarfs[16]. On an average a spadix can produce 1.5–3 litres of sap per day or 60–80 litres in a span of 40–45 days. Even if 6 of the 12 spadices produced are tapped and the remaining allowed to produce nuts, around 400 litres of sap and a few nuts can be harvested. The sap yield is again influenced by the skill of the tappers. Highly skilled tappers can tap the spadix for two months as against 30–45 days of average tapping.

Quality attributes of sap

Distinct differences are noticed between the sap collected by traditional method and CPCRI technique (Table 1 and Figure 7). Fresh sap collected by the CPCRI technique is slightly alkaline in pH, golden brown or honey-coloured, sweet and delicious.

Changes in pH and sugar content of fresh sap

Fresh sap has slightly alkaline pH (7.5–8, minor variation from tree to tree) (Figure 8). It begins to ferment within 2–3 h under ambient temperature and pH shows a declining trend. pH of the completely fermented sap is around 3.5. The sap stored in a deep freezer (–2°C to –1°C) remains fresh and no change in pH was observed. Fresh sap (pH 7.5) has around 15% sugars (Figure 8). It decreases

to about 6% at pH 4. During the same period, the reducing sugar level increases up to 5% (Figure 9). Fresh sap, when left exposed to the atmosphere undergoes initial lactic acid and final alcoholic fermentation due to the action of microorganisms.

Biochemical and mineral composition

Fresh sap is rich in sugars, minerals and proteins. It is also a rich source of phenolics and ascorbic acid and essential elements, viz. N, P, K, Mg and micronutrients Zn, Fe and Cu. Tables 2 and 3 give the biochemical constituents, mineral and vitamin composition of freshly collected sap.

Value-added products from Kalparasa

Coconut sap contains about 15% sugars and considerable amount of nutrients, which can be easily converted to prepare various value-added products. Coconut sugar, jaggery and honey are obtained by evaporating the water of unfermented sap at 115°C. The viscous and fairly thick hot sap (brix 75°–80°) is cooled to get coconut honey or syrup (Figure 10 *a*). Further heating of the sap to a more viscous and thicker consistency and pouring it into either coconut leaf or steel moulds helps in the preparation of coconut jaggery. Further heating of viscous sap with continuous stirring to avoid charring, turns it into crystal form, i.e. sugar granules (Figure 10 *b*). At this stage it is suddenly cooled. While cooling, it is continuously stirred to break the lumps. The product obtained is sieved to get uniform particle size and to produce quality sugar.

Coconut sugar is also known as coconut palm sugar, coco sugar or coco sap sugar. Unlike cane sugar which supplies only calories, coconut sugar supplies calories and nutrients. It has high mineral content compared to unrefined and refined cane sugar, and is a rich source of potassium, magnesium, zinc and iron (Table 4). In addition, it contains all essential amino acids required for protein synthesis, and is rich in vitamins like B1, B2, B3 and B6. Compared to unrefined cane sugar, coconut sugar has

Table 1. Quality attributes of sap collected using the CPCRI technique and traditional technique

Attribute	CPCRI technique	Traditional technique
Soluble solids (°Brix)	15.5–18	13–14
pH	7–8	6 or low
Colour	Golden brown or honey	Oyster white
Defects, decay, insects, pollen, dust	Absent	Present
Flavour	Sweet and delicious	Harsh odour
Pathogens, chemicals and extraneous matter	Absent	Present
Microbial load	Low	High

Figure 7. Coconut sap collected by coco-sap chiller (left) and traditional method (right).

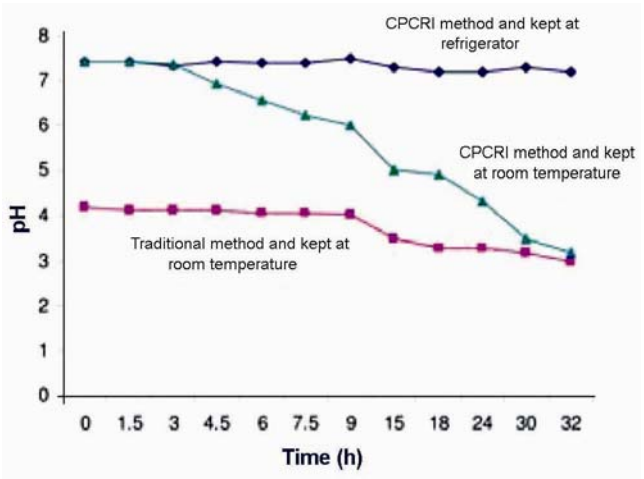

Figure 8. pH of coconut sap collected by CPCRI method and traditional method.

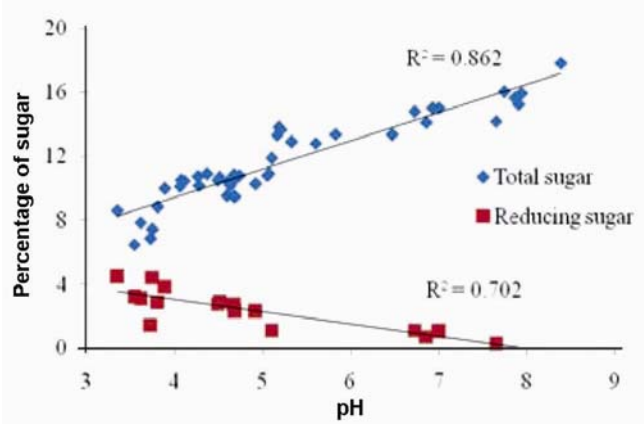

Figure 9. Relation between pH and total sugar and reducing sugar content of coconut sap.

two, four and ten times the amount of iron, magnesium and zinc respectively.

Market prospects

Kalparasa as natural health drink

Kalparasa and the market price it commands has fuelled ambitions of Indian coconut farmers who have been struggling to cope with unstable prices and rising labour costs. Palakkad Coconut Producers Company Ltd (PCPCL), Kerala, one of the largest coconut producing companies, is the first to adopt the CPCRI method of sap collection and also the first to commercialize the sale of fresh unfermented sap in the market. Fresh sap is collected from the farmers, transported to a storage centre and distributed to different kiosks where it is dispensed through juice dispensers (Figure 11). The market experience indicates that Kalparasa as a natural non-alcoholic beverage has high demand as an instant thirst quencher. Switching to Kalparasa tapping has improved the income of farmers, generated employment opportunity for the youth and tappers, and provided multiple advantages to the economy and consumers.

Table 2. Biochemical and mineral composition of freshly collected coconut sap (per 100 ml)

Biochemical parameters	Range	Average
pH	6.57–7.50	7.18
Total sugar (g)	10.08–16.50	15.18
Reducing sugar (g)	0.439–0.647	0.554
Amino acids (g)	0.123–0.338	0.245
Protein (g)	0.150–0.177	0.165
Sodium (mg)	69.4–117.5	90.6
Potassium (mg)	146.1–182.4	168.4
Phosphorus (mg)	2.0–6.4	3.9
Manganese (mg)	0.009–0.014	0.012
Copper (mg)	0.028–0.035	0.031
Zinc (mg)	0.018–0.026	0.020
Iron (mg)	0.049–0.058	0.053
Phenolics (mg)	4.80–5.40	5.10
Antioxidant activity (mM TE)	0.299–0.355	0.321

Source: Ref. 12.

Table 3. Vitamin content in freshly collected coconut sap

Vitamin	Value (mg/100 ml)
Thiamine	77.00
Riboflavin	12.20
Pyridoxal	38.40
Pantothenic acid	5.20
Nicotinic acid	40.60
Biotin	0.17
Folic acid	0.24
Inositol	127.70
Choline	9.00
Vitamin B12	Trace
Vitamin C	17.5

Source: Ref. 17.

Figure 10. Coconut sap value-added products. ***a***, Coconut honey. ***b***, Coconut sugar.

Table 4. Comparison of mineral nutrients composition of coconut sugar with unrefined and refined cane sugar

	Coconut sugar	Cane sugar	
		Unrefined (brown)	Refined (white)
Macro-minerals (mg/100 g dry wt)			
Nitrogen	202	10	0
Phosphorus	79	3	0.07
Potassium	1030	65	2.5
Calcium	6	24	6.0
Magnesium	29	7	1.0
Sodium	45	2	1.0
Sulphur*	26	13	2.0
Micro-minerals (μg/100 g dry wt)			
Boron*	30	0	0
Zinc	2100	200	120
Manganese	130	200	0
Iron	2190	1260	120
Copper	230	60	6

Source: CPCRI, Kasaragod[12]; *Philippines Coconut Authority[17].

Figure 11. Kalparasa stored in dispenser for sale.

Coconut sugar

In India, coconut sugar is prepared and sold by small-scale industries in Tamil Nadu, Andhra Pradesh, Kerala, Lakshadweep Islands and Karnataka. There is a huge demand for coconut sugar, however, production and supply are limited. The recent revelations on the health benefits of coconut sugar in comparison with cane sugar have led to a sudden surge in the demand for coconut sugar in the international market. Indonesia, the Philippines and Thailand are the major producers and suppliers of coconut sugar to the global market.

Future prospects

The recent advancements in coconut sap collection and its processing into natural value-added products and their associated health benefits have led to a sudden surge in domestic and international market for Kalparasa and coconut sugar. Apart from assuring stable and lucrative income to the coconut farmer, switching to Kalparasa tapping provides multiple advantages to the economy, environment, farmer and consumer as listed below.

It is estimated that even if 10% of the 2 million hectare area under coconut farming in India is tapped, with conservative yield of 1 litre/day, Rs 36,000 crores can be generated annually, of which 25–30% will be the farmer's share.

The potential to develop new and indigenous technologies for Kalparasa by-products (honey, sugar, jaggery) and value-added products (ice creams, toffees, syrups, jam, pudding, cake, snacks, etc.) would be a boost to the local economy. Coconut tree can produce as high as 19 tonnes/ha/yr sugar compared to 5–10 tonnes of sugarcane. As India is the second largest cultivator of coconut, it has high potential for coconut sugar production.

Experiences from countries where coconut is allowed for tapping like in South Sumatra and the Philippines suggest that it is 8–10 times more profitable than selling nuts. A tapper earns more than twice otherwise that of a field worker per day. An important advantage is that a tapper can earn daily income throughout the year.

Organic cultivation is practiced at least in certain regions of India, like Lakshadweep Islands. Many farmers have recently turned towards organic cultivation of coconut. Hence, there are huge prospects for production of organic coconut sugar/Kalparasa and its export in the international market.

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