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Palmyrah palm and its products (Neera, Jaggery and Candy)—A Review on chemistry and technology

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ABSTRACT

The worldwide food sweetener market is projected to be valued at more than 100 billion dollars by the end of this decade, with the Asia-south Pacific region witnessing the highest market share growth. However, with increased awareness about the health hazards associated with the regular consumption of artificial sweeteners and ultra-processed cane sugar, the demand for natural, minimally processed, organic alternatives has also witnessed a surge. Palm jaggery is one such product. Made from the sap of the Palmyrah palm tree, this jaggery is believed to be a suitable alternative to sugar in all forms of food. This review provides a comprehensive look at all the advances made in the production and characterization of palm jaggery and its allied products. The review highlights the research carried out to understand the health benefits associated with consuming palm jaggery and palm candy.

1. Introduction

The palmyrah (*Borassus flabellifer L.*) is a member of the Arecaceae family of plants, which is a very old group of species. It is also known as sugar palm and toddy palm. It is a native species of tropical palm tree found in Indonesia, Malaysia, the Philippines, Sri Lanka, India, and various regions of East Africa. It is commonly found in South-East Asia and the Indian subcontinent and is simple to grow. It also develops on its own in the wild. Its cultivation is widespread from western India through Indo-China and the Indonesian smaller Sunda Islands and in parts of Socotra, Sri Lanka, China South-Central, Jawa, Bangladesh, Myanmar, Sulawesi, Thailand Cambodia, Laos, Malaya, and Vietnam (Rao et al., 2021). It enjoys special status as the state tree (since 1978) in the south Indian state of Tamil Nadu. It can also be found throughout India in Orissa, Bengal, Kerala, Andhra Pradesh, Bihar, and along the entire west coast. Plantations of the tree can be spotted on the Malabar coast and extend all the way to madras.

In India, palmyrah adorns the dry, sandy, lands of the semi-arid regions of Andhra Pradesh, Gujarat, Tamil Nadu, Odisha, West Bengal, Bihar, Karnataka, and Maharashtra. It is estimated that India is currently home to 102 million palms and half of them are in Tamil Nadu. Out of these more than 50% of palms in Tamil Nadu are concentrated in the Southern district of Thoothukudi. The worldwide distribution of palm is shown in Fig. 1.

The Indonesian palms are referred to as B. sundaica Becc and are called lontar locally. These trees have leaves on both sides, sans the scales, their petals present in the fruit tend to imbricate at the base; excrescences inside of the endocarp are 7-8 mm long.

They are observed to have a lateral axis of spadix 1-3. On the other hand, in the case of B. flabellifer scaly leaves are present on both sides, the petals in the fruit are not imbricate, there exist 6-7 lateral axes, and excrescences present within the endocarp are 3-4 mm long (Morton,1988). The characteristics of the palm sap for different species are shown in Table 1.

Although several parts of the palm tree are used for various purposes the fleshy fruits and the nectar or palm sap obtained by tapping the inflorescence are the most valuable products of the tree. The following are the various parts of the palmyrah palm tree and their associated applications:

1.1. Fruit

Fruits with black skin have skin that has less red coloring. Their yield is also lower than that of fruits with red skin. The seedlings they produce, though, are superior because they contain more starch and less fiber. The removal of pulp is simpler. Mineral, alkaloid and free amino acid concentrations are lower in fruits with red skin. There are differences between these fruits in the quantity of black pigment visible on their skin. These varieties produce much more fruit per tree. Significant pulp, sugar, and starch content can be found in the fruit. Lysine, necessary amino acids, and methionine are present in fruits with red and black skin (Rao et al., 2021).

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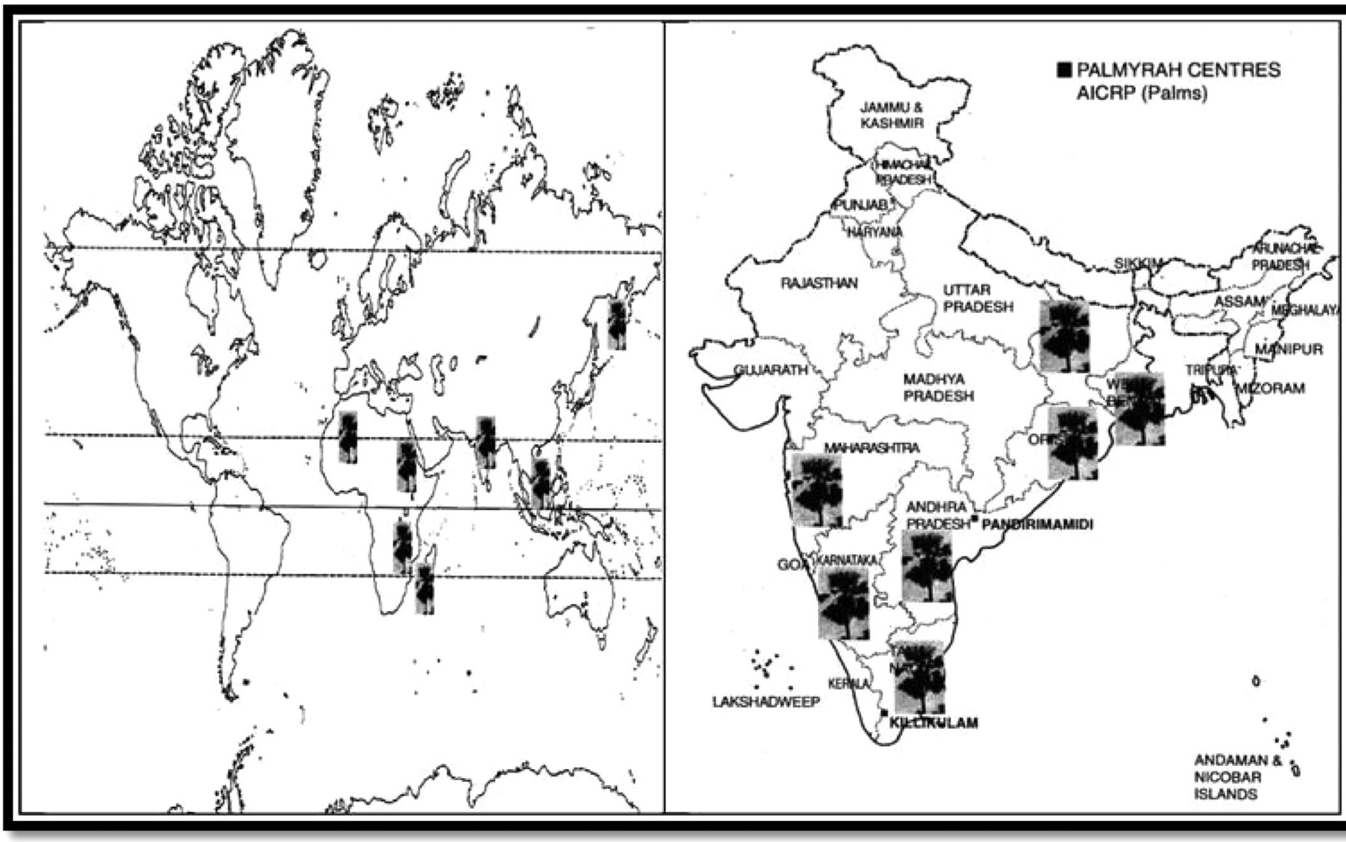

Fig. 1. Palmyrah palm distribution in Worldwide and India (Rao et al., 2021).

Table 1
Palm sap characteristics of various palm trees (Kurniawan et al.,2018).

No	Palm species	Age of the tree at the time of harvest	Rate of Sap production [litre/ (day. palm)]	Viability (for sap production)	Sugar content in palm sap (%)
1	Cocos nucifera	7	1.7 to 4.3	20 years	15 to18
2	Arenga pinnata	7 to10	10 to 15	Several years	10 to 20
3	Borassus flabellifer	15 to 30	6	30 to 100	9 to 17
4	Elaeis guineensis	6	-	10 to 15	9 to11
5	Nypa fruticans	4	0.2 to 2	50	15

1.2. Neera

Neera is a sap extracted from the palmyrah tree's inflorescence. It has a clear appearance, a pleasant aroma, and a sweet flavor. PC et al. (2017) stated that it has medicinal value and it also acts as a stimulant and anti-phlegmatic agent. It helps with inflammatory infections, digestive issues, and dropsy. The drink has high nutritive value, flavor, and a plethora of medicinal properties. It can be used as a supplement for iron and vitamin deficiency. It improves overall health upon regular consumption. It helps improve the consumer's appetite and digestion functions. Neera can also be consumed in fairly large quantities without causing any side effects. It can also provide relief for asthmatic, anomic, and leprosy patients as a supplement. It can also be used to make various confectionery goods such as ice cream and milk sweets as well as jaggery, sweet syrup, rab, palm sugar, toddy, sweet beverages, toffees, and palm candy (PC et al., 2017).

Neera includes glutamic acid, a mineral used by the body to make proteins, along with significant levels of thiamine, riboflavin, nicotinic acid, and ascorbic acid. Additionally, it includes significant amounts of vitamins and minerals, which strengthen the body's defenses against disease and boost immunity. It is also known to reduce the risk of cancer owing to the high quantities of phytochemicals, anti-bacterial agents, and antioxidants, such as Vitamin C present in it. Thus, it helps maintain one's overall health. As per Kalimuthu and Kalidas (2019), It is especially helpful in preventing certain types of cancers in our body, such as lung cancer, colon cancer, oral cavity cancer, etc. It reduces blood pressure thus helping with hypertension treatment. Neera is highly rich in potassium, which in turn improves blood circulation. It has high quantities of anti-bacterial and anti-oxidant agents which improve skin health and help slow down skin aging. Regular consumption of neera will thus help protect skin from the action of free radicals that cause oxidative damage (Kalimuthu and Kalidas, 2019). Fig. 2 depicts the processing flow chart for the production of neera.

1.3. Toddy

Fresh palm juice is white, very sweet, and not fermented. Sucrose is the main component of fresh toddy juice and accounts for about 12-15% of its weight. Fresh juice contains a small quantity of reducing sugars. Yeasts that are naturally present in the sap cause the fermentation of glucose to produce alcohol. This process is further aided by acetobacter, which then converts the alcohol to acetic acid (vinegar). Due to the minimum amount of vinegar content, the suitable time for fresh juice consumption is one day after tapping; After this, the juice turns increas-

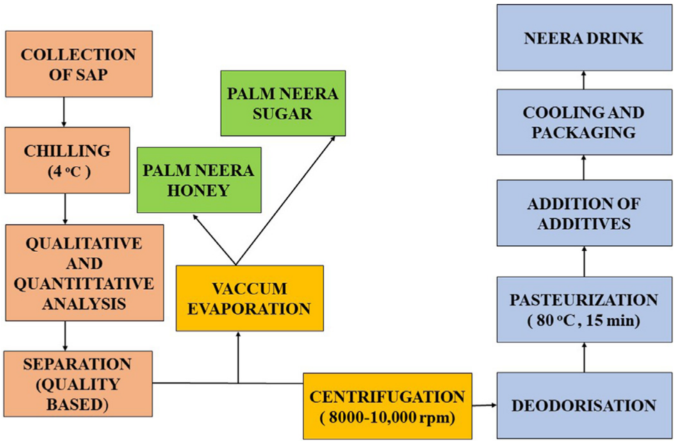

Fig. 2. Modified figure of Industrial scale processing of Neera (Asha et al., 2019).

ingly sour. The palm sap undergoes fermentation soon after its collection due to the yeasts naturally present in it. The fermented product is palm wine and contains about 4% alcohol. Palm sap left in the sun takes roughly two hours to turn into palm wine. Toddy has an alcohol content of about 5 %.

Toddy is the term used to describe the process by which nearby wild yeasts and bacteria ferment sugar sap (Kurian & Peter, 2007),. The sap undergoes unchecked natural fermentation. The fermentation process involves numerous yeast and bacterial strains. Neera has produced about 75 distinct LAB strains (Somashekaraiah et al., 2019). As a result, under carefully controlled laboratory conditions, the alcohol content of palm sap produced by fermentation with pure yeast cultures is 7.8%. Sucrose, glucose, and fructose make up the majority of the sugars in fermented toddy. However, throughout the fermentation process, they are gradually changed to ethyl alcohol.

1.4. Vinegar

Production of vinegar involves fermentation of the palm sap under direct sunlight for more than two hours. Acetic acid is the most important substance present in the vinegar formed. This acetic acid is produced from the fermentation of ethanol. The fermented product, ethanol is then partially oxidized to acetic acid by *Acetobacter aceti* bacteria. The fermentation vessel is covered with a cloth to prevent contamination. Upon completion of the alcoholic fermentation, the palm wine starts its conversion into vinegar. The palm wine undergoes acetic fermentation involving acetic acid bacteria. The types and number of organisms encountered present varies from one tree to another. The wine produced is allowed to undergo fermentation for four weeks. The process is allowed to take place at room temperature. At the end of the process, a thick film known as the mother of vinegar is removed via filtration to obtain the final product (Ghosh et al., 2012). The products prepared from the palm are summarized in Fig. 3.

1.5. Jaggery

Jaggery or Gur is an integral part of Indian cuisine. Its sweetness complemented by the earthy undertones that form the flavor profile of jaggery make it an extremely delectable delicacy. Even though it is consumed around the globe it enjoys special popularity and love in India where most sweet dishes aren't complete without the addition of Gur. Jaggery is also an integral part of several ancient Hindu rituals as well as of Ayurveda or ancient Indian medicine. Both sugarcane and palm jaggery are instant sources of heat and energy when consumed. Jaggery is a much healthier alternative compared to cane sugar.

The Palmyra palm is a strong, productive tree, and it has great cultural and functional significance. It is particularly used for its sweet sap, which is used to make sugar and both alcoholic and non-alcoholic beverages. Some species known as Toddy Palms have been harvested for this reason. The unfermented sap is used for Palm jaggery production. Palmyrah palm jaggery is the jaggery that is produced by boiling palm sap or Neera. It has an intense earthy taste and is slightly salty. It has a myriad of health benefits and medicinal applications. It is free of all chemicals and bleaches and has a cooling effect on the body. It is highly priced due to these reasons (PC et al., 2017). Made by concentrating *palmyra sap*, palm jaggery is a solid blend of reducing and non-reducing sugars (Lamdande et al., 2018). It has all the components of neera and is just as nourishing.

2. Palm jaggery and cane jaggery- a comparison

Upon comparison of Palm jaggery prepared with fresh *palmyra sap* with sugarcane jaggery, it was observed that palm jaggery is rich in vitamin C and calcium compared to sugarcane jaggery, and the remaining proximate composition is on par with sugarcane jaggery. Palm jaggery is hence on par with or better than sugarcane jaggery in terms of its overall acceptability (Manisha et al., 2022). Palm jaggery is thus the best substitute for sugarcane jaggery (Manisha et al., 2022).

Sugarcane jaggery is derived from the juice of sugarcane after boiling, filtering, and churning it through traditional methods. It is light to dark brown and hard to bite. This jaggery has many health benefits, for example; it helps in weight loss. Jaggery contains potassium which helps muscles to maintain electrolyte balance (Rao et al., 2007).

On the other hand, the sap from the palm trees' inflorescence is used to make palm jaggery. It is boiled, filtered, and then concentrated. This is similar to the processing of sugarcane jaggery. As palm jaggery ages, it gets saltier (PC et al., 2017). Moreover, if it tastes bitter, extra sweet, or has crystals, that means it has been caramelized or artificial sweeteners have been added. The comparison of the nutritional composition of sugarcane jaggery with palm jaggery is shown in Table 2.

The jaggery produced contains both reducing and non-reducing sugars. The percentage of non-reducing sugars is higher than that of reducing sugars. Its composition is similar to that of neera. Thus, it is as nutritious as raw palm sap. It also contains considerable quantities of minerals such as magnesium, potassium, and sodium. This is advantageous for people with conditions like hypertension, liver disease, and edema . Palm jaggery is also helpful as a supplementary super food for the treatment of conditions like diabetic acidosis and post-operative convalescence. It acts as a diuretic. It also helps balance out the loss of potassium from the body. Furthermore, Palm jaggery contains iron, carbohydrates, and some amount of protein. Apart from this palm jaggery

Table 2
Nutritional composition of cane and palm jaggery (Asha et al., 2019; Hirpara et al., 2020; PC et al., 2017).

Cane jaggery (as per 100 gm)		Palm Jaggery (as per 100 gm)	
Calories	383	Calories	380
Moisture content	3-10	Moisture content	8.50
Carbohydrates	98.96	Carbohydrates	91.48
Protein	0.9	Protein	2.19
Fat	0.1	Fat	0
Iron	11 mg	Iron	120- 130mg
Fructose and glucose	10-15	Sugar	83.78
Sucrose	65-85	Sucrose	65.80 mg
Calcium	80-100 mg	Calcium	900-1000 mg
Potassium	1000-1100 mg	Potassium	800-900 mg
Magnesium	160 mg	Magnesium	30-50 mg
		Thiamine	21.00 mg
		Nicotonic acid	5.24 mg
		Riboflavin	432.00 mg
		Ascorbic acid	11.00 mg

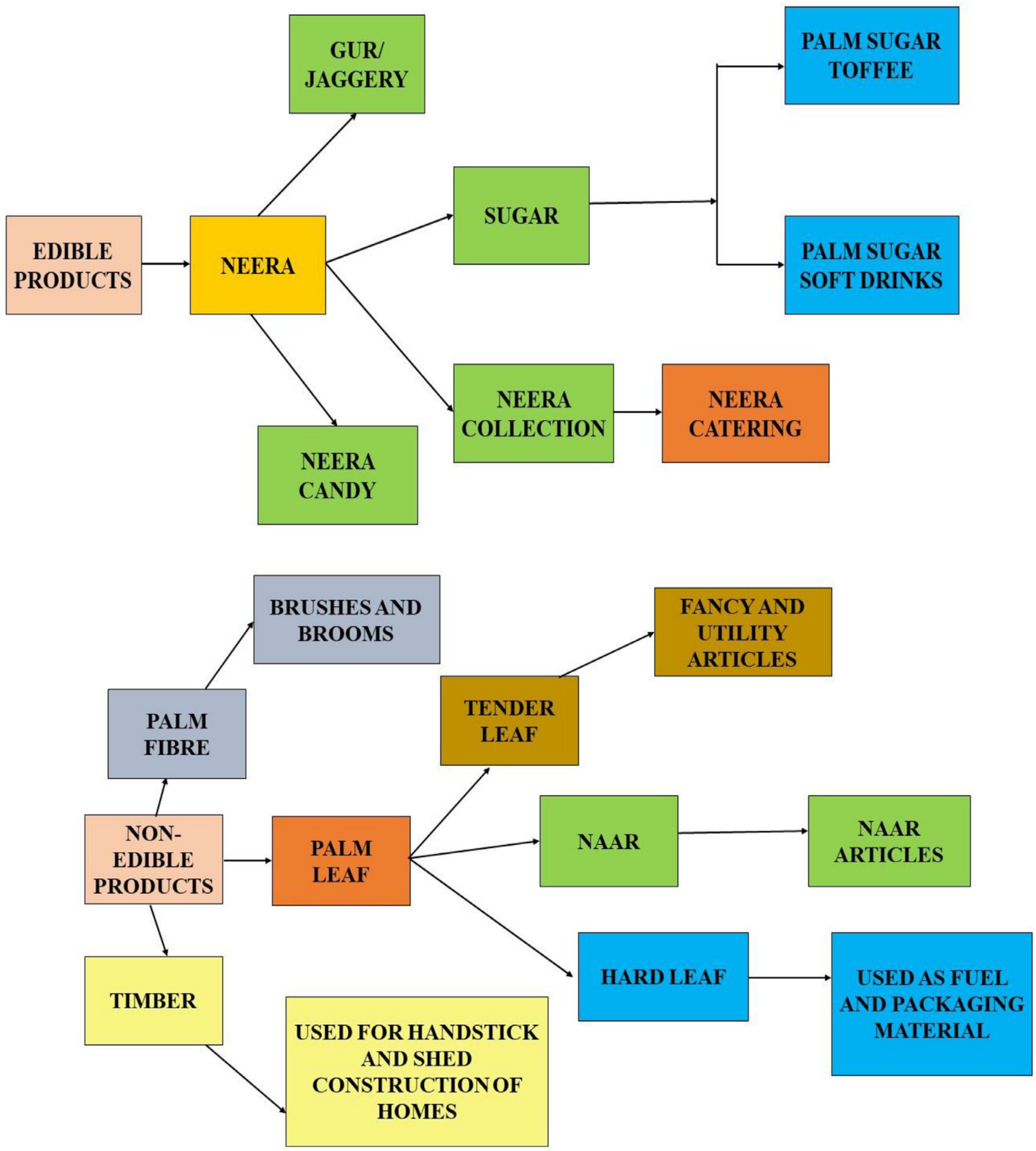

Fig. 3. Palmyrah palm and its products.

also has considerable quantities of vitamins like B12 and C (PC et al., 2017). Fig. 4 represents the image of palm jaggery.

3. Palm candy- characteristics

A common confectionary product called "palm candy" or "Tal mishrif" is manufactured from a mixture of palm jaggery, water, and many other types of sugars, with cane sugar being the most widely used one (Borse et al.,2007; Lasekan & Abbas, 2010). It is a sweet, translucent crystallized candy. It is a substantial economic contributor and a widely used product in several Indian states. Much like palm jaggery, palm sweets are a very good source of ascorbic acid, glutamic acid, nicotinic acid, riboflavin, and numerous minerals. Additionally, a considerable amount of protein and carbohydrates is present in palm candy . Palm candy is made by boiling neera until it reaches its striking point in a galvanized iron pan. After being poured into the molds, the mixture is left to cool at ambient temperature. After that, the candy is demolded and properly wrapped. Crystalline, delicious, and translucent describe the created sweets. It is well recognized for aiding with digestion, cough, urinary tract issues, colds, and ailments like chicken pox. Additionally, it is thought to be a beneficial and healthful meal for pregnant women (Devadas, Sundari and Susheela, 1969; Lata & Kamala 1966; Uzochukwu 1997). Fig. 5 represents the image of Palm candy.

4. Production process

4.1. Tapping and collection of palm sap

The mature, unopened flower of the palmyrah palm tree is tapped to obtain palm sap. At regular, predetermined intervals, the inflorescence's head is sliced open to harvest it. The inflorescence is tapped upon reaching maturity. It is deemed to be ready for tapping when it develops swelling at the base. Fresh neera is tapped from trees early in the morning between 6-7 A.M, using a sharp knife. The spathe is then cut twice in one day to collect the neera. Earthen pots that have been treated with lime and fastened to the inflorescences the day before collection are used to gather neera. The lime concentration in the pots can be varied. Nera ejaculates from the inflorescence throughout the night.

Fig. 4. Palmyrah palm jaggery.

Fig. 5. Palmyrah palm candy.

The pots are removed from the inflorescences the next day. The inflorescence is traditionally tapped by being placed inside an earthenware container. As it drips into the pot, the sap is gathered. In the open container, the sap begins to ferment over time. However, the collected sap may become contaminated by pollen, ants, insects, and other contaminants. In India, lime is applied to the interior of the earthen pot to stop inflorescence sap from fermenting. But only to a limited extent does this method stop fermentation (Hebbar et al., 2018).

4.2. Traditional method of sap collection

Mud, other sticky materials, or leaf extract is applied to the cut surface to prevent the sap from overflowing. It is believed to invigorate the collected sap. However, more importantly, this allows the cultivator to forestall internal leaks of sap in the space which is accessible between the peduncles. The sap is then collected in an open earthen pot or bamboo sac. This is placed at the highest point of the palm for a period of 8–24 h. To delay fermentation, lime is coated on the inner surface of the collection pots. The sap collected by this technique is transparent or white and has a pleasant odor. However, it is highly likely to be polluted with ants, dust, bugs, and residue particles (Asha et al., 2019).

4.3. Advanced method of sap collection

The sap chiller is used to gather palm sap. Just as the sap began to overflow, the coco-sap chiller is attached to the spadix. Ice cubes (0.5-0.75 kg, depending on the amount of sap used and the environment) or 3–4 gel ice bundles are used to line the cooler. A grove is created, after which a compartment or plastic food storage container with an O-ring is inserted. By placing a tube made of treated steel or plastic over the O-ring, the sap is shielded from contaminants, including plant matter. Through the spadix holder, the spadix is inserted. This is done to make sure the cut surface is directly above the channel's focal point. Once in this position, a resin or plastic cover is used to snugly fasten the spadix to the spadix holder. Ants and other insects are kept out by doing this. The box's top aperture is covered with a lid. The handles are then used to dangle the box from the tree's crown. The spadix is erect or upright while tapping. To enable the passage of sap from the cut surface to the collection container, a connector must be used. As soon as the spathe disc turns horizontal or flat, sap from the sliced surface drips directly into the container. There is no longer a need for the connectors. The rounded holder is removed twice daily (toward the beginning of the day and evening). The sap is subsequently transferred to a different cooler with a bigger capacity (Asha et al., 2019).

4.4. Juice filtration

Using a muslin cloth, the larger contaminants in the neera are removed. After this, the juice is given a few minutes to settle. Sedimentation is subsequently used to get rid of the contaminants.

4.5. Clarification

Clarification of the Neera which is collected is an essential process during jaggery production; the degree of clarification determines the color, quality, and storability of the jaggery. Fresh neera is rich in several organic and inorganic constituents which may be present in the form of soluble, suspended, or colloidal particles. The colloidal particles include inorganic salts, nitrogenous substances, silica, inorganic acids, pectic substances, starch, waxes, gums, etc. The suspended particles present may be in the form of fibrous straw, mud and bagasse particles. Precipitable impurities such as Albumins and phosphates may also be present. The insoluble impurities present are removed during the filtration and settling step however the soluble and suspended impurities require the clarification process for their removal. The jaggery produced without clarification is dull and has a murky coloration with undesirable white spots, blemishes, and a hazy appearance. Also, the color intensity of this palm jaggery does not meet the required standards. During the clarification process, two types of clarificants namely organic and inorganic are used. Organic clarificant are of vegetable origin like sulkali, bendi, and doela; whereas inorganic clarificants include lime, hydrous power, and superphosphate. The vegetable clarificants contain albumin that coagulates upon heating. This process results in agglomeration of the dehydrated colloids of juice. These rise to the surface in the form of scum. Clarificants such as lime, hydrous powder (sodium hydrosulphite), sodium carbonate, and super phosphate give palm jaggery a light golden-brown color. As the Neera is heated in the pan, the dissolved air escapes. Also, the gummy colloidal substances coagulate following the addition of the clarificant. The juice with clarificant is subjected to constant stirring (using a large ladle) during the heating process. This prevents the juice from sticking to the bottom of the pan. The clarified impurities rise to the top of the pan. This is referred to as scum and is removed continuously (Kharat et al., 2018).

Vegetable origin clarificants can be derived from roots, stems or seeds of the following plants: (Hirpara et al., 2020)

a) Doela (*Hibiscus ficulneus*)
b) Bark of Semal (*Bombax malabaricum*)
c) Bark of Falsa (*Grewia asicetica*)
d) Ground nut (*Arachis ypogea*)
e) Sukhlai (*Kydia calycina*)
f) Castor seed (*Ricinus communis*)
g) Bhindi (*Hibiscus esculentus*)

According to Rao et al. (2007), limestone (calcium hydroxide) is combined with just enough water to create lime milk, which is then utilized as a clarifier. The lime milk is gradually infused into the sap while it boils. Impurities might float on the surface as scum thanks to the addition of lime. These are periodically scraped off. The clarificant used should meet the following requirements and allow for: (Asokan & Rupa, 2007)

a. The removal of most non-sugar and all non-essential constituents of juice other than sucrose, reducing sugars, inorganics (phosphates, iron, and calcium), and organics (higher proteins and fats).
b. The curtailment of undesirable color development.
c. Control or prevention of inversion of sucrose during boiling and concentration.
d. Better crystallization.
e. Prevention of charring and overheating.
f. No adverse effect on jaggery taste and human health.
g. Longer storage life of the product.
h. Easy availability of clarifying agent.

5. Production methods- palm jaggery

5.1. Open pan system

After clarification and filtration using suitable clarificants, the cleared sap is transferred to a galvanised iron vessel. The vessel is then placed in a furnace. The entire process is however deemed unhygienic as boiling of juice is carried out with direct burning of bagasse using an open grate furnace. The combustion and heat utilization efficiency of the commonly used furnace by the farmers is as low as 20% and consumes a high quantity of bagasse. Also, the quality of the jaggery is negatively affected due to the smoke which is released and the contamination that occurs as a result of ash particles. This jaggery is thus not suitable, for export (PC et al., 2017).

5.2. Steam boiling system

The steam boiling method used to make cane jaggery from sugarcane juice has the potential to be applied to the manufacturing of high-quality palm jaggery. This process was initially created for the manufacturing of cane jaggery. A steam-jacketed pan with a tilting mechanism is attached to the steam boiling device. Additionally, it has a boiler, furnace, and steam lines that supply the pan with the created steam (Pandraju et al., 2020).

The system consists of a circular steam-jacketed pan made of food-grade stainless steel (SS304), which is encased in a steam jacket that permits steam to flow. An inlet is given on the side of the jacket via which steam can enter. The steam arriving from the boiler fills the annular gap between the steam jacket and the pan. The water in the juice boils and evaporates as a result. A shaft and bearings are used to attach the entire pan assembly to the stand. There is a tilting mechanism built inside the pan. This makes it simple to discharge the finished product into the attached collecting tray. An outlet is provided at the bottom of the jacket through which the condensed steam can be released.

The most important part of the entire system is the steam boiler. The boiler is fitted with attachments, which include a water pump responsible for driving water into a horizontal water tank (which consists of 60 tubes, pressure release protection valves, and a water gauge for inspection of the water level). Valves and steam pressure gauges are used to regulate steam pressure. The boiler furnace is responsible for burning the fuel to produce the required heat. This heat produced then gets transferred to the water via the tubes fitted with the water tank. This is a type of thermal conduction. Using insulated tubes, the generated steam is then transferred into the steam-jacketed pan. Steam flow rate is managed by steam control valves. They also aid in avoiding too much steam (Pandraju et al., 2020).

5.3. Two-pan furnace system

The IISR, Lucknow (India) first created this technique to increase the energy effectiveness of the cane jaggery production process (shown in Fig. 6). This setup can be changed to efficiently prepare palm jaggery from sap. In a circular main pan with a flat bottom, the neera is concen-

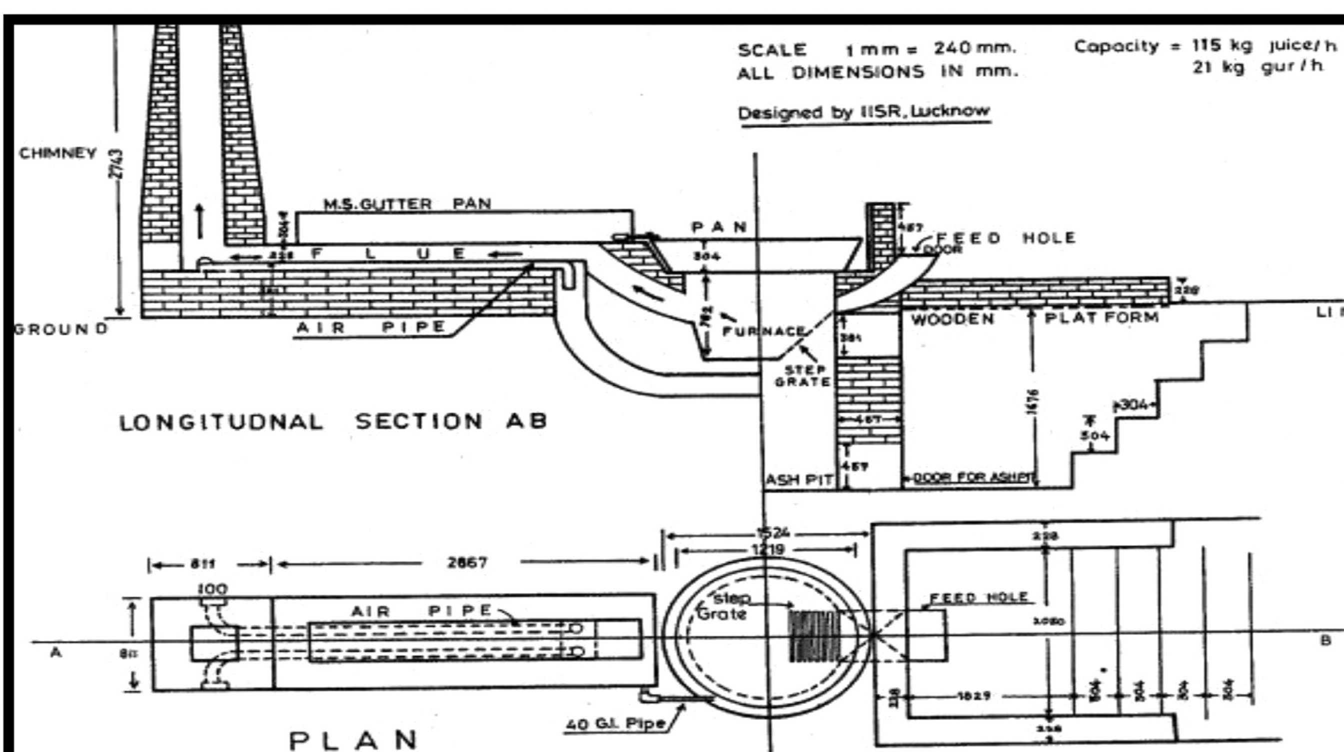

Fig. 6. Two-pan furnace system (Anwar, 2010).

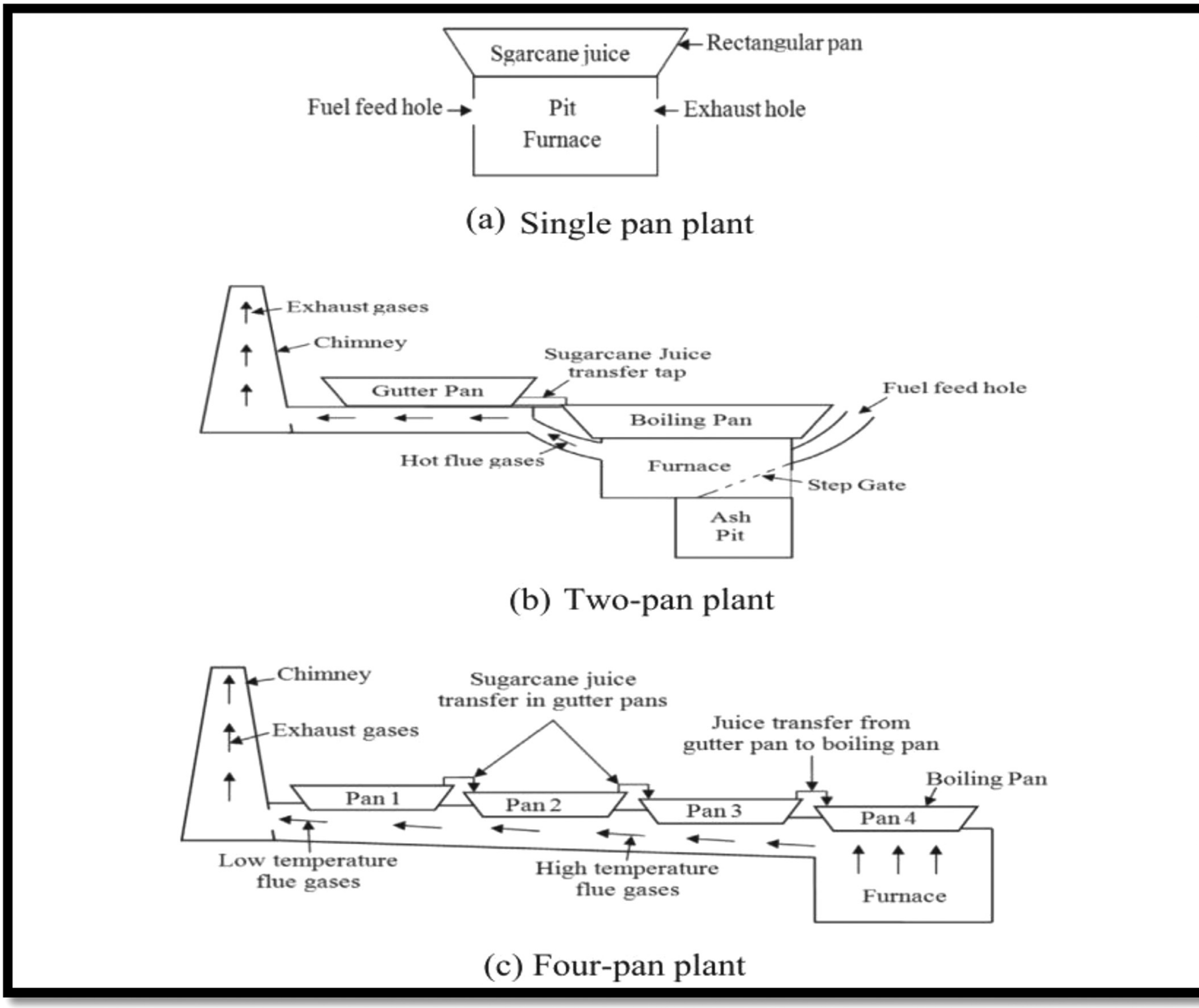

Fig. 7. Different jaggery making plants (Kumar & Kumar, 2018).

trated. A rectangular gutter pan that is provided across the path of the flue gas flow is also a part of the unit. Juice that will be condensed in later rounds is warmed up in this pan. Both these pans of the IISR furnace are provided with fins that are attached to the bottom of the pans. An insulating layer is formed as a result of the Combustion products and air. This drastically reduces the rate of heat transfer. The Fins provided break the insulating layer formed and also increase the metallic area available for heat transfer (Anwar, 2010).

Similarly, three-pan and four-pan jaggery-making units can also potentially be utilized for the production of jaggery efficiently (Fig. 7). This can help lower the fuel requirements and wastage associated with the heating process. One or two additional pans are arranged in sequence along the route of the waste flue gases in both the three-pan and four-pan jaggery manufacturing plants in addition to the main and gutter pans. This makes it possible to extract more heat. The neera is heated up using the first two pans. For this, thermal energy is extracted from the hot flue gases. The previously heated neera is then moved to the main or boiling pan. This has the highest temperature because it is directly over the flames. The juice flows in a direction opposite to the direction of motion of the hot flue gases thus allowing for better utilization of the thermal energy. Furthermore, a similar arrangement can be used for continuous cane and palm jaggery production (Kumar & Kumar, 2018).

6. Production methods- palm candy

6.1. Traditional method

To produce palm candy from jaggery first water is heated in an open pan. Upon achieving a temperature of 50-60°C a small amount of previously prepared candy crystals is added gradually. Solubility is increased by continuous agitation and heating. This is followed by the addition of palm jaggery. Next to achieve a homogeneous syrup and removal of all probable impurities, the syrup is filtered and transferred into the final cooking pan. The syrup is then concentrated by increasing the temperature until the required Brix is achieved. This is followed by heating the mixture until the striking point of the slurry is attained. The mixture is then poured into molds and allowed to cool down. The candy produced is then packed using appropriat packaging (Chauhanet al., 2015).

6.2. Improved method

The excessive amount of water utilized in the traditional candy-making process and the time needed for the evaporation of the surplus water cause an unnecessary increase in processing time and energy required for the process. This will lead to an undesirable increase in the intensity of color and amount of inverted sugar produced. It also leads to a decrease in sucrose yield, pH, and crystallization yield. This can be avoided by adding only the amount required of sugar and water (weighted exactly based on requirements). The water is then poured into a wide bottom pan followed by gradually adding palm jaggery to it. The syrup Brix is to be measured at regular intervals. This is followed by defoaming after which a homogeneous solution is obtained. The heating is stopped immediately at this stage.

6.3. Spray drying method

Traditionally used methods of palm candy production produce palm candy which has a dark brown coloration and a slightly bitter taste. The dark color is a result of high-temperature heating which results in excessive caramelization and browning. Heating at high temperatures and/or prolonged heating can also result in the loss of active components. This happens because of palm sap degradation. Therefore, selecting the right process and equipment is pertinent to improving the quality of the palm candy produced. One such technique involves the use of the spray drying process. The technique of converting a pumpable feed from a fluid condition to a particle dried form is called spray-drying. The automated feed is sprayed into a hot drying medium to accomplish this (Santos et al. 2018). This process can be used to turn palm sap into small sugar crystals. Intake fan, heat source, bag filter and/or electrostatic precipitator, air filter, feed source, atomizer, feed pump, drying chamber, cyclone separator, and exhaust fan are the fundamental components of a spray dryer. Air is drawn into the spray drier through a filter by a fan. The filter both protects the product from contamination and eliminates combustible particulate matter. Direct or indirect heating may be sued to heat the air. The feed solution of palm neera or sap is divided into individual droplets by the automizer. This determines the final shape, velocity, structure, and size of the droplets. It also decides the particle size distribution and nature of the candy produced. The impact of high-velocity air or other gases around it causes the feed to undergo atomization to form droplets. Drying chambers can be constructed using a variety of designs. The required heat exposure time determines the required volume of these chambers. Initial contact results in the formation of a hard outer shell. The liquid present in the inner parts of the droplet is drawn out of the particle as the particle moves down the chamber. Following that, the hot air in the chamber dries it. The base of the conical spray-drying chamber is often where the initial separation of the product from the air is done. After that, removal is accomplished using a screw conveyor or pneumatic system with a secondary separator. The finished product is then recovered using bag filters, cyclone separators, and electrostatic precipitators. Spray-dried palm candy has a lower water content and is simpler to preserve (Lasekan, 2014).

Despite all the benefits associated with spray drying of neera, the process is not without its faults. These include reduced product output, agglomeration in the drying chamber, and stickiness on the drying wall. Cohesion-adhesion forces, which can be described in terms of adhesion between the particle and the wall surface, are what cause the sticky powder to form. (Muzaffar, Nayik & Kumar, 2015). High thermoplasticity, hygroscopicity, and low glass transition temperatures (Tg) of low molecular weight compounds all contribute to stickiness while making palm candy with a spray dryer.

7. Flavour development

Huynh Thi Le et al. (2020) claimed that palm jaggery produced at temperatures higher than 100 °C contains significant amounts of 5-hydroxymethylfurfural (HMF). The cyclic aldehyde HMF (C6H6O3), a derivative of furan, is mostly formed as an intermediate as the Maillard reaction develops. It is one of the substances in charge of giving palm jaggery and its byproducts their distinctive smell and taste. It is created when carbohydrates, primarily hexoses like fructose, thermally degrade in the presence of amino acids or proteins (Verma et al., 2019). Additionally, it can result from the thermal dehydration of glucose, sucrose, and fructose under acidic conditions. The Maillard reaction depends on the reaction temperature and time, pH, and water content, as well as the kinds of sugars and amino acids present, to produce taste molecules. The precursors, thermal process variables, pH, and the ratio of amino nitrogen to reducing sugar are all impacted by the quantity and quality of volatile molecules. These in turn affect how the final flavor of palm jaggery develops.

Several volatile substances, including alcohols, ketones, and acids, can be found in palm jaggery. Six pyrazines, two phenols, two sulfurs of two different kinds, and one aldehyde are also present. The majority of the ketones in palm jaggery are 2,3-dihydro-3,5-dihydroxy-6-methyl-4-pyran-4-one, 1-hydroxy-2-propanone, 2,5-pyrrolidinedione, and pantolactone, which are in charge of giving it its pleasingly sweet, cotton candy-like, caramel-like, and coffee-like flavor. Depending on the amino acid and sugar composition of the food as well as the reaction pathways, the Millard reaction's end products can have a range of aromas, from a pleasant, flowery, and aromatic aroma to a burnt, pungent, nutty, and caramel-like stench. The palm jaggery and candy produced have a nutty, roasted, coffee-like, and earthy aroma thanks to the presence of 2,5,6, and 2,3,5-trimethylpyrazine. Aldehyde and phenol groups, such as 2-methoxy-phenol, 2,6-dimethoxy-phenol, and vanillin, on the other hand, may give the palm jaggery sweet, herbaceous, maple-like, caramel-like, and cotton candy-like aromas. The stable volatile chemicals found in palm jaggery play a major role in determining its flavor and taste in general (Huynh Thi Le et al., 2020).

8. Colour development

External appearance is the primary factor governing the consumer preference and marketability of both cane and palm jaggery. This comprises its appearance, feel, and capacity for storage (Kapur & Kanwar, 1983). Jaggery's low shelf life and darkening during manufacture are caused by its reducing sugar content. Numerous chemical components, such as amino acids, reducing and nonreducing sugars, inorganic anions, phenols, and cations, are present in the palm sap that is processed to make jaggery. Due to sucrose's acid inversion during thermo-evaporation, the reducing sugars found in palm sap are formed. They have a significant impact on how the jaggery acquires its distinctive color.

The primary browning reactants in many food products have been identified as sugars formed during the processing of neera or the storage of jaggery. Caramel is primarily produced through the hydrolysis of sucrose, specifically its byproducts namely glucose and fructose. Caramelization reactions and the Maillard reaction both involve colored compound synthesis in the presence and absence of nitrogenous chemicals (Hodge, 1953). The hydrolysis of sucrose by protonation of the glycosidic bond initiates the caramelization reaction. The H+ ion required for this step is produced either by the high-temperature dissociation of water (or perhaps sucrose) or by acidic reaction byproducts. Under neutral circumstances, sucrose hydrolysis yields D-glucose and a fructose oxocarbonium ion. This fructose carbocation is capable of regenerating the catalyst H+ by reacting with one water molecule, forming fructose. or (b) oligosaccharides are formed when another carbohydrate molecule (such as fructose, sucrose, glucose, or even another fructose carbocation) is present in the solution (Quintas et al., 2010). The generated fructose carbocation may proceed through many unidentified processes to produce a wide range of compounds, such as 5-hydroxymethylfurfural (HMF), anhydro saccharides, and organic acids. The extent to which these chemicals are produced depends on the reaction circumstances, which are often favored by extremely acidic and/or hot temperatures. During the hydrolysis of sucrose, water frequently acts as a solvent or reactant. However, molecular mobility is decreased in the system in concentrated solutions. Additionally, there are not enough water molecules present for the reaction to proceed, which causes a lag phase

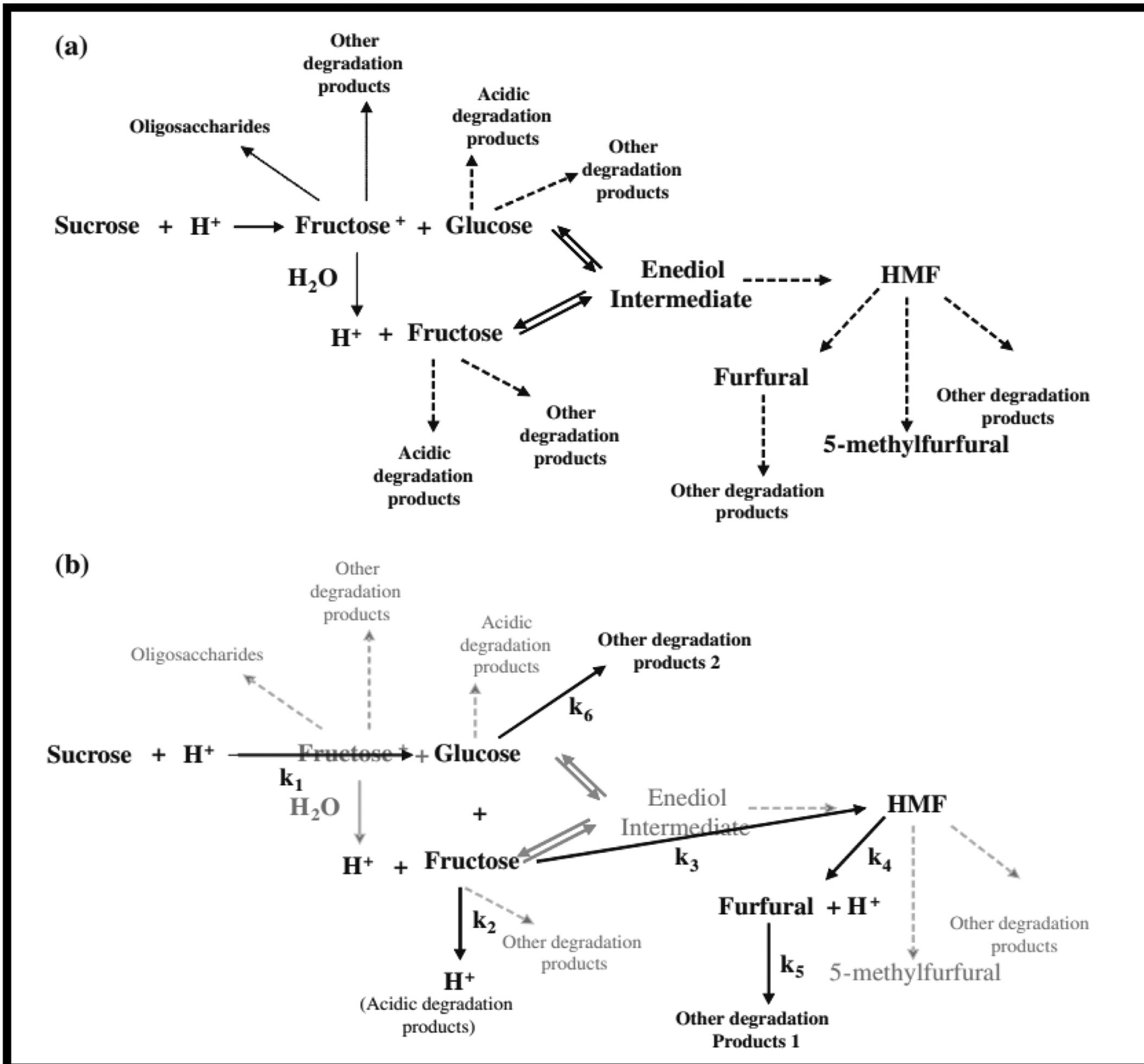

Fig. 7a. Mechanism of sucrose caramelization [(a)Theoretically hypothesised mechanism, (b) Experimentally determined mechanism] (Quintas et al., 2007).

(Quintas et al., 2010). Therefore, caramelization does not significantly influence color development in concentrated solutions. Fig. 7a represents the caramelization mechanism.

Subsequently, as the solution is further concentrated polymerization reactions occur. As noted before palm jaggery is prepared by Boling Neera in an open pan. Initially, when the temperatures are lower than 50°C, enzymatic browning is the primary reason for color development and product darkening caused by the activity of the enzyme polyphenol oxidase. This leads to the oxidation of the phenolic constituents present in the sap (shown in Fig. 8).

Enzymatic activity ceases once the temperature exceeds 50°C, but the darkening process continues until the jaggery's striking point temperature is reached, which is between 116°C and 118°C. This characteristic is explained by how the caramelization and Maillard reactions gradually produce dark-colored molecules called melanoidin (Hodge, 1953; Tomasik et al., 1989). During thermo-evaporation, fructose contributes more than glucose does to the darkening and colour development in both sugarcane juice and neera. This pattern in browning reactions can be explained by the aldose and ketoses' relative reactivities (Burton & McWeeny, 1963) (shown in Fig. 9). During Maillard reactions, it was found that the colour intensity produced by the reaction between fructose and amino acids was greater than the colour intensity produced by the interaction between glucose and amino acids. When palm sap is heated, both Maillard reactions and caramelization take place, which results in the jaggery's final colour becoming darker. According to studies, carbonyl—amine browning brought on by Maillard reactions does not become significantly significant until the sap's pH is higher than 6.0. At this point, the caramelization reaction's byproducts are the main cause of the sugars' browning.

The sugar for jaggery's colour development is sucrose. This is because it is generally inert at relatively low temperatures. However, under some circumstances, sucrose is hydrolyzed to produce glucose and fructose. These chemicals are also easily converted into caramel and carbonyl amine reactions, which give products their browning and

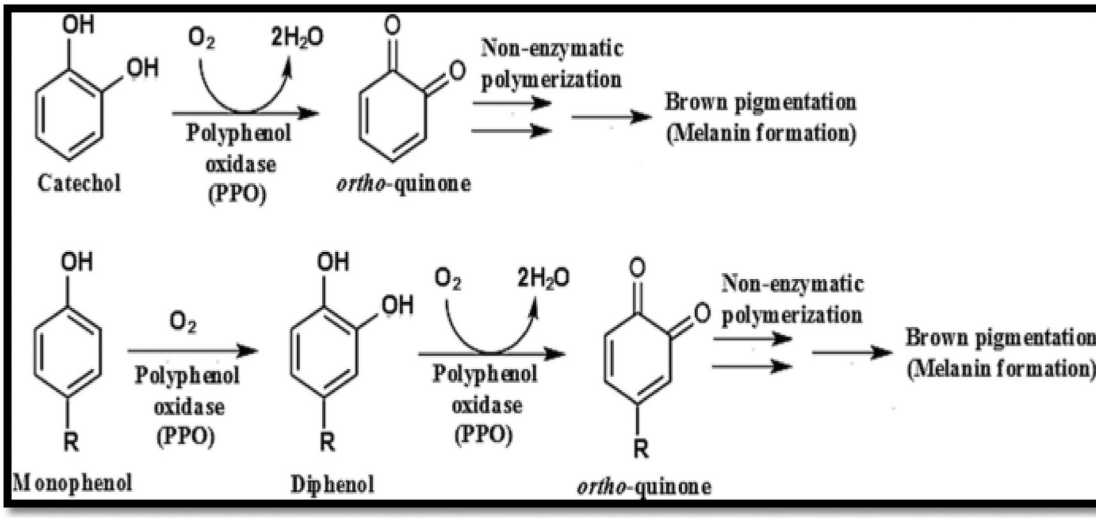

Fig. 8. Mechanism of enzymatic browning (Grotheer et al., 2019).

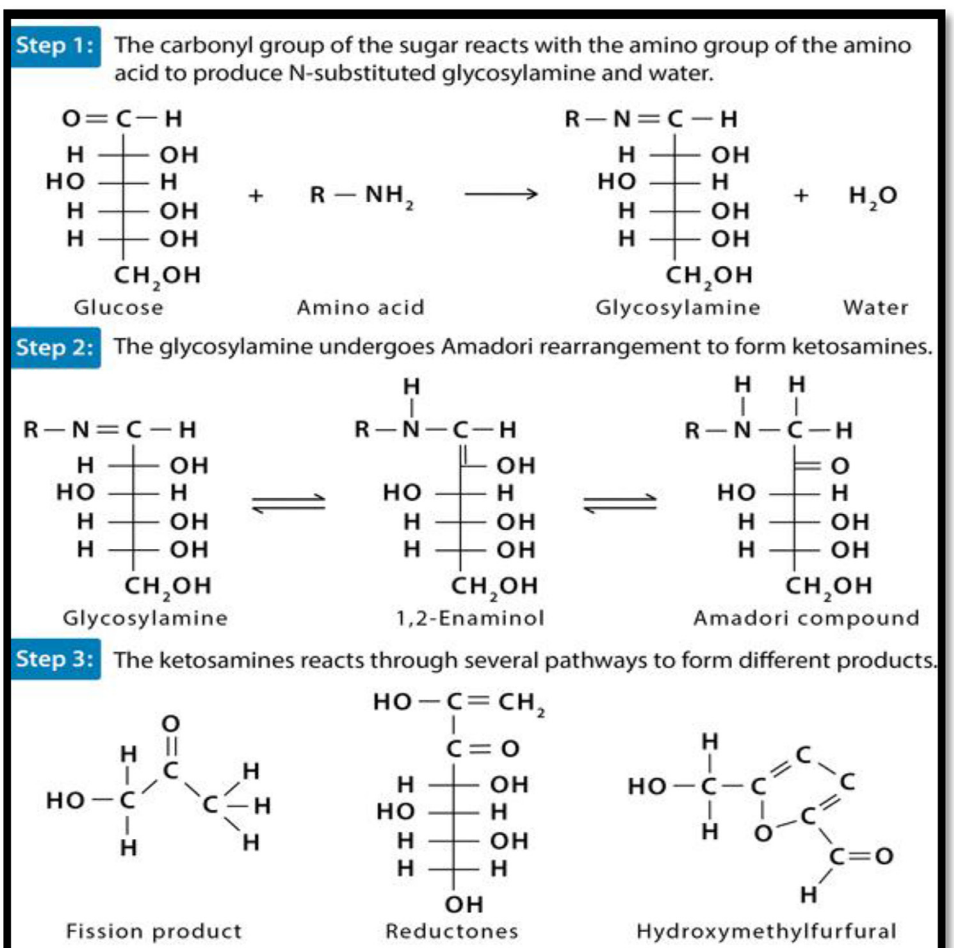

Fig. 9. Mechanism of Millard reaction (Namiki, 1988).

colour (Banerji et al., 2012). When compared to glucose and sucrose, fructose is known to contribute more to the non-enzymatic browning brought on by caramelization. This is valid when manufacturing palm jaggery from neera using the thermo-evaporation method. Furthermore, palm jaggery, which has a higher fructose content than cane jaggery, is darker in appearance than the latter specifically for this reason.

9. Health benefits of palm jaggery

Palm jaggery delivers the following health benefits (Gallen et al., 1998 and Yang J. et al., 2012; Huynh Thi Le et al., 2020)

i. **Rich in Minerals**- Palm jaggery contains important minerals in abundance. It is a good source of minerals like calcium, phosphorous and iron (PC et al., 2017). According to studies, palm jaggery contains 60 times more nutrients than white sugar. Furthermore, it contains a lot of vitamins B and C.

ii. **Improves Digestive Health**- Jaggery from palm trees has digestive properties. To promote efficient digestion, it is occasionally consumed in tiny amounts after meals in various parts of India. According to anecdotal evidence, it also stimulates the digestive enzymes and aids in intestinal and mouth cleansing.

iii. **Rich in Nutrients**- Palm jaggery is a good source of iron and magnesium. Regular consumption of iron-rich foods increases hemoglobin levels and helps treat anemia as well (Warner & Kamran, 2021). Similarly, Magnesium helps regulate the nervous system (Kirkland et al., 2018). Pal jaggery which is a natural sweetener helps protect the body cells from damage caused by free radicals due to its high antioxidant content. It is also rich in minerals like potassium, calcium, and phosphorus (Huynh Thi Le et al., 2020).

iv. **Acts as an Energy Booster**- Palm jaggery constitutes several composite carbohydrates. As a result, it can be digested faster than white sugar. It provides instant energy and hence be used as an energy booster. It helps the consumer stay fresh and active for hours after consumption.

v. **Acts as an Active Cleanser**- Palm jaggery helps clear the intestines, food pipe, lungs, stomach, and respiratory tract. It also removal of toxins from the body.

vi. **Helps relieve Constipation**- Palm Jaggery is enriched with dietary fibers. Hence, it helps relieve indigestion and constipation (Yang J et al., 2012). They can also help cleanse the system by flushing out any unwanted entities. Furthermore, it also stimulates bowel movement upon consumption.

vii. **Helps relieve several Common Ailments**- Palm jaggery has been historically utilized for its medicinal properties. It was used to treat dry cough and cold during ancient times. Palm jaggery helps dissolve the mucus present in the respiratory tract thus clearing it.

viii. **Helps Reduce Migraines**- Natural medicinal entities and minerals present in palm jaggery help to reduce this pain associated with the onset of migraines.

ix. **Helps with Weight Loss**- Palm jagger which is rich in minerals like potassium helps with weight loss (Huynh Thi Le et al., 2020). The high potassium levels associated with this raw sweetener help reduce water retention and bloating (Gallen et al., 1998) (Tal et al., 2019). Hence, it can very well be used as a supplement in one's weight loss regime.

x. **Boosts body immunity** - It has a plethora of antioxidants and micronutrients like iron, manganese, magnesium, etc. It is also adept at strengthening the bone marrow in young children, in a few weeks. It also helps boost their immunity and health as well.

xi. **Exhibits cooling effect**- Upon regular consumption palm jaggery has a cooling effect on the body owing to its alkaline nature. Therefore, it helps conserve the body's energy.

10. Need for development of palm jaggery as an alternative to cane jaggery

Palm jaggery has a lower glucose to fructose ratio as compared to cane jaggery. It also contains less glucose than fructose. Cane jaggery which is lighter in color as compared to palm jaggery generally contains upwards of 70% sucrose. It also contains less than 10% fructose and isolated glucose. Glucose is burnt in the presence of oxygen to produce energy. Fructose does not produce the same result. Sugar when consumed instantly results in a spike in blood sugar levels due to its rapid absorption. On the other hand, consumption of fructose does not raise blood sugar as quickly or to a very high extent. This is because fructose has to first be converted into glucose for it to be used as energy. This takes longer as fructose has to reach the liver for its metabolization and conversion into glucose. This involves a series of biochemical processes and pathways (Chaudhry and Varacallo, 2022). So, despite fructose being present in the blood, it does not affect the body's sugar levels like glucose does. Moreover, only about 40-50% of the fructose

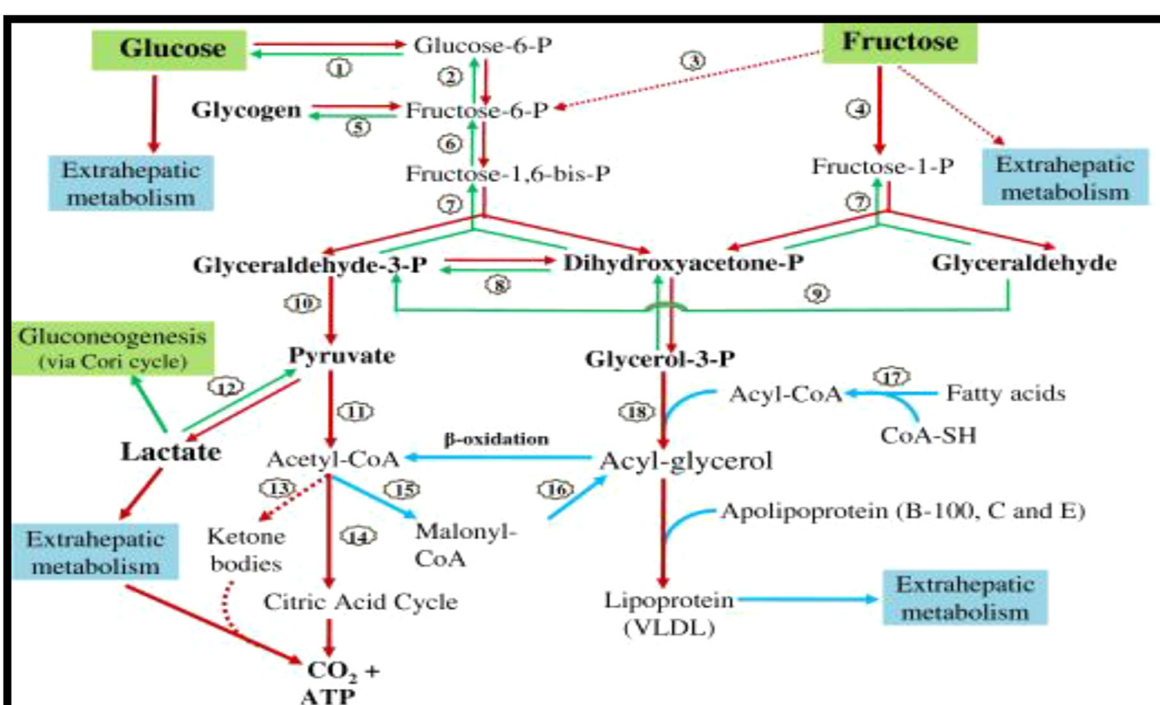

Fig. 10. Glucose and fructose metabolism in the human body (Sun & Empie, 2012).

absorbed upon consumption gets converted into glucose while the rest is simply excreted out (Sun & Empie, 2012). Palm jaggery consumption, therefore, does not cause a sugar shock which is often associated with the consumption of other sweeteners. This is the reason behind fructose being considered better that glucose and it is also why palm jaggery is better than any other available sweetener.

Sucrose is the primary sugar in cane jaggery along with some fructose. Therefore, cane jaggery is not much healthier than table sugar. Sugarcane jaggery has a higher glucose to fructose ratio. Its consumption can hence increase the level of glucose in the blood thus triggering a spike in the blood sugar level. This sugar acts as food for cancer cells and also lowers immunity. Furthermore, the pathogenic bacteria get all their energy from this sugar. Therefore, if the consumption of a sweetener does not flood the blood with sugar or glucose, it is considered to be healthier. Hence, although sugar consumption results in instant gratification, it is harmful in the long run. When sucrose is consumed, it splits to form glucose and fructose. These sugars are then individually metabolized as previously explained. Glucose is the sugar preferred by the body for energy production. It serves as the end-product of digestion. Thus, when sugar is directly consumed, we are directly taking in the end product of metabolism thus essentially blocking all the biochemical processes which would have otherwise taken place to produce glucose. The imbalance in the biochemical processes leads to disturbed or improper digestion (Barr, 2018). The metabolism of glucose and fructose in the human body is depicted in Fig. 10.

When compared to an isomolar glucose load, it was observed that fructose consumption only elicits a modest spike in blood glucose and insulin levels, all the while stimulating total carbohydrate oxidation and energy expenditure (Bantle, 2009).

11. Gap in research

Currently, the cost of palmyrah palm jaggery is nearly twice that of Cane jaggery. Hence, process optimization and development of advanced machinery is needed in the production process. This includes improving upon the palmyrah palm tree climbing device and the tapping system for extraction of palm sap from the trees. The collection process also needs to be improved. Further improvement can be done by reducing the chances of insects and overall contamination. Efforts also need to be made to improve the shelf life of palm neera and jaggery without sacrificing the flavor of the final product that makes these products a consumer favorite. Furthermore, the product needs to be marketed, targeted, and positioned correctly for it to become not only cost-effective but also economically viable for those involved in its production and supply. Products such as palm jaggery, palm candy, and liquid palm jaggery are not commercialized because the processes used for the preparation of these products are traditional, non-standardized practices that are often not hygienic and produce less storage life. There needs to exist a standardized procedure for the entire production process with a well-curated SOP and quality control criteria. Despite palmyrah sap and its products being of great economic importance, they has not attracted the attention of agricultural research workers, probably because the tree, found mostly in the wild state is very slow to grow. Hence there is an urgent need for the mechanization of the production process and for the development of value addition techniques (PC et al., 2017).

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Ethical statement - studies in humans and animals

There is no human and animal studies involvement in this as review work.

We look forward to hearing from you at your earliest convenience.

Declaration of Competing Interest

Authors do not have any conflict of Interest.

Data availability

The authors are unable or have chosen not to specify which data has been used.

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