PALM SUGAR

EXPLORATION FOR BIOACTIVE COMPOUNDS AND ITS ROLE ON FUNCTIONAL FOOD DEVELOPMENT

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I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of my Master of Technology in Food Technology and Biochemical Engineering studies.

All information in this document have been obtained and presented in accordance with academic rules and ethical conduct.

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Certificate of Recommendation

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This is to certify that Ms. Megha Mukherjee has carried out the research work entitled "Palm sugar: Exploration for bioactive compounds and its role on functional food development" under my supervision, at the Department of Food Technology and Biochemical Engineering, Jadavpur University. I am satisfied that he has carried out this work independently with proper care and confidence. I hereby recommend that this dissertation be accepted in partial fulfilment of the requirement for awarding the degree of Master of Technology in Food Technology and Biochemical Engineering.

I am pleased to forward this thesis for evaluation.

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Palm sugar: exploration for bioactive compounds and its role on functional food development

Abstract:

Palm sap sugar is a sweetener which is made from the sap or nectar collected from different varieties/species of palm trees. It has huge scope as an alternative sweetener in Indian market. It is a natural alternative to extremely unhealthy refined cane sugar and is more beneficial for farmers as well. Some of its characteristic features are low GI value and its macro and micro nutritional content. Palm sugar also has impact on colour, aroma and taste profile of the final product. The taste, sensory profile and nutritional attributes of palm sugar vary on the basis of its species, region of growth and climatic conditions. At present, traditional processing of palm sap leads to lower yield and higher expenses. There is huge potential in the field of development in processing techniques to optimize the production of palm sugar. Palm sugar and other products from different parts of palm can be used to make a variety of other value added products like toffees, chocolates, cola, toddy wine, palm vinegar etc.

Introduction:

Sweetness in food products has a powerful sensory appeal for people of all age groups, especially children and young adults. Along with this hedonic appeal, lesser cost and the ubiquitous availability of sweeteners that contain energy have led to a burgeoning demand for the same. Food choices are often directed by sweetness and familiarity, especially with infants and small children. As per clinical studies, the scientific basis of the sensory pleasure derived from tasting sweet foods is “the activation of pleasure-generating brain circuitry”. Research has shown that sweet taste preferences may even be expressed before birth. The ability of new-borns to differentiate between different levels of sweetness, followed by consumption of the solution that tastes the sweetest is further demonstration of the power sweet tastes have in controlling children’s behaviours. There are noticeable age-related differences as well when it comes to consumption of sugar. The taste and preference of sugar is significantly higher in younger children and adolescents than in adults. Sugar has also been reported to have pain reducing and analgesic effects. A range of other factors like chronic disease, medication usage, genetics, ethnicity, race, chronic disease, addictions and nutritional deficiencies influence sweet taste preference but sweetness as a preferred hedonic trait is universally acknowledged. (Drewnowski et al., 2012)

However, different studies have shown increased health risk factors (chronic diseases) arising from consumption of added free sugars: cardiovascular disease, obesity, diabetes and non-alcoholic fatty liver disease. There is also chance of cognitive decline and some cancers. Many studies have established relation of reduced sugar intake with improved dietary quality and health. Even though the evidence so far is inconclusive, there is healthy level of scepticism towards excessive consumption of sugar. (Rippe & Angelopoulos, 2016b) Therefore, there is a push for cane sugar alternatives in diet.

There is an increasing public awareness about potential health impacts of added sugars in foods. This has led to a growing interest in “plant-derived, natural low-calorie or zero-calorie sweeteners”. Low-calorie sweeteners like saccharine, cyclamates, aspartame and acesulfame K became popular in the 1980s. However, such synthetic sweeteners have been embroiled in controversies and conflicts as well including allegations of serious health dangers like bladder and liver toxicity, foetus malformation, carcinogenicity etc. Although investigations have concluded that such sweeteners are more or less safe, yet there has been some level of loss of consumer trust. Consequently, certain artificial sweeteners are not permitted in different legislations. Hence, the need for natural sweeteners is crucial. Consumers perceive naturalness to be beneficial to food overall. Consumer research has consistently shown that consumers have an increasing awareness of food additives and most often choose natural additives over their artificial alternatives. (Drewnowski et al., 2012) Consequently, it can be concluded that consumer acceptance of natural sweeteners, provided they have adequate hedonic appeal, will be positive.

Palm sap sugar is made from sap/nectar collected from flowers of various species like palms, like sugar palm, nipa palm, and coconut palm. Palm sugars have been used as sweeteners in Asia for thousands of years. It is now gaining global popularity because of its natural source, minimal processing and healthiness. It has lower glycemic index as compared to cane sugar. It also has nutritionally significant quantities of vitamins and minerals. Additionally, it shows antioxidant activity. It is minimally processed, unrefined and its natural forms contain dietary fiber. It also contains 2,3- dihydro-3,5-dihydroxy-6-methyl-4(H)-pyran-4-one (DDMP). DDMP is known for its anti oxidative properties and can reduce the chance of colon cancer. (Saputro et al., 2017). Thus, palm sap sugar can be used as an alternative to cane sugar because of its popularity and high production in South and South East Asia (Indonesia, Malaysia, Thailand, Philippines, and India etc.), leading to economic benefits. Secondly, its sugar content and aroma profile creates distinct, unique characteristics, when added to food. Thirdly, its positive health effects make it a ready alternative to cane sugar. (Saputro et al., 2019)

It is predicted that by end of 2025, the global palm sugar market will be valued over 2,000 million USD. Its expected CAGR is around 3.4% over 2017-25 (the forecast period). The global palm sugar market is also predicted to reach 958,512 MT in terms of volume by the end of 2025 with a CAGR of 3.2%. At present, the market consists of a large number of regional and local players. Around 70-75% share of the market is held by local players. There is huge market potential in regions like Western Europe and North America because they are witnessing a rise in number of health conscious individuals who crave for healthy and organic food alternatives. In contrast to local players, the market share held by multinationals is very low (5-10%), owing to high prices of palm sugars. Indonesia is the largest producer of palm sugar. The annual output of India’s crude sugar is around 3,000,000 tons and around 10% of this output is derived from palms. At present, export from India is mostly to Belgium, U.K, Japan, France, Ireland, Italy, Canada, Germany, Australia, Philippines etc. The greatest opportunities of export can be in north western Europe because the consumers in this region have high per capita income and relatively higher share of disposable income to spend on higher cost natural sugar alternatives and are willing to try out new and unique food products like palm sugar. (Research, 2017)

This review discusses about the composition of palm sap, regulating factors, different sugar palm varieties in the Indian sub continent and their characteristic features, the existing traditional production techniques of palm sugar, alternative technologies and innovations to optimize production, the nutritional composition and physical properties of palm sugar and health benefits related to the consumption of palm sugar. It also outlines the value added products with palm, storage and preservation of palm sugar and future prospects of the industry in India.

Existing literature in this field separately talk about specific palm specie(s) or specific production and processing techniques for palm sugar. Reviews also cover salient features of palm sap anthology beginning from production and processing to value addition. The novelty of this review is that it collates the existing data and gives an in depth and comprehensive view of the journey of palm sugar from its sap stage to the finally marketed product. It also summarizes the sugar content of different palm varieties in Indian sub continent and nutritional composition of the final palm sugar produced from different palm varieties. To the best of our knowledge, these aspects with regards to palm sugar have not been covered in any paper before.

Composition of palm sap:

Nutritional composition of palm sap varies greatly depending upon factors the species, genus, geographical region of growth, tapping duration and variety. The content of water in the sap is variable depending and the total sugar content is around 66% (Table 1). Out the total sugars present in palm sap, sucrose is in largest amount followed by glucose, fructose, inositol and raffinose sugars in minor quantities. Sugar obtained from *Borassus flabeliffer* and *Phoenix sylvestris* sap is healthier than cane sugar because the calcium and protein content of these palm sugars is 1.32 and 3.63 and times greater than cane sugar respectively. (Sarma et al., 2022) Several studies corroborate that sugars that have higher sucrose levels are better from a health perspective. This is because sucrose does not have as much of fattening effect as starch or glucose. There is no weight gain reported even with an increase of energy consumption by 15%. Additionally, the glycemic index (GI) value of sugars rich in fructose and sucrose is low. Thus, palm sap has low GI value. (Hebbar et al., 2018)

Fresh palm sap is rich in amino acids. The amino acids present in fresh palm sap are mainly asparagines and glutamine. These amino acids have polar side chains. 17 acids are present in palm sugar. Amino acids are building units of proteins. They are also instrumental in maintaining neutral pH. These amino acids play a prominent role in Maillard reaction, where free amino acids are released. Based on heating time and cooking temperatures, the amino acid substrates that are released may either catalyze sucrose to monosaccharides or take part in retro aldol reactions, producing C2-C5 dicarbonyl compounds. These dicarbonyl compounds react with amino acids to produce aldehydes and a-amino ketones. This is followed by chain reaction in the later stage including cyclization, dehydrations, retro aldolizations and isomerizations. The amino acids present in palm sap are tryptophan, lysine, histidine, arginine, aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, valine, isoleucine, leucine, tyrosine and phenylalanine. The amino acid profile of palm sap varies depending on the species. For example, the glutamic acid content of *Cocos nucifera* has 34.20 g/ 100 mL palm sap whereas *Phoenix dactylifera* contains only 1.18 g/100 mL concentration of glutamic acid. In general, *Cocos nucifera* has relatively higher amino acid content as compared to other palm saps. *Phoenix dactylifera* has relatively lesser amino acid content. (Hebbar et al., 2018; Saputro et al., 2019)

Palm sap also has a wide range of vitamins and minerals. 13 minerals were reported in palm sap. These consist of 8 microelements (P, Mg, Si, Cl, Na, S, Ca and K) and 5 oligoelements (Cu, Fe, Mn, Br and Zn). Vitamins contained in palm sap include vitamin C and B. For *Borassus flabellifer*, the amount of Vitamin C is around 13.25 mg/ 100 cc.

Phenolic compounds are important because they impact the colour, nutritional, antioxidant and sensory properties of foods. Flavonoids are composed of dietary phenols (two-third) and the rest is composed of phenolic acid. Phenolic acids show anti oxidant nature and numerous health advantages of phenolic acids have been reported. Fresh sap contains around 0.33 g/L phenolic compounds. The phenolic content rises during fermentation up to a peak of 1.24 g/L at 58 h, beyond which there is very little change. Phenolic compounds are also produced by activity of some microorganisms. Presence of gallic acid, protocatechuic acid, galangin, caffeic acid and p-coumaric acid has also been reported in palm sap. (Hebbar et al., 2018; Saputro et al., 2019)

Table 1. Composition of palm sap

Component	Amount	Reference
Ash	1.8%	(Luis et al., 2012)
Moisture	35.2%	
Sugars		
Glucose	9.5%	
Fructose	4.8%	
Sucrose	37.9%	
Maltose	<0.5%	
Monohydrate lactose	<0.5%	
Total sugars (in glucose)	66.0%	
Fat	0.20%	
Water soluble Vitamins		
C	<5 mg/kg	
B_1	0.20 mg/kg	
B_2	< 0.10 mg/kg	
B_3	31.7 mg/kg	
B_6	< 0.40 mg/kg	

B_9	0.10 mg/kg	
B_{12}	4.90 µg/kg	
Fat soluble vitamins		
A	< 0.50 mg/kg	
D	< 5.00 mg/kg	
E	< 0.50 mg/kg	
K	< 1.00 µg/kg	
Micro nutrients		
Fe	1.16 mg/100 g	
Zn	0.22 mg/100 g	
Cu	0.18 mg/100 g	
Mn	0.05 mg/100 g	
Ni	0.06 mg/100 g	
Macro nutrients		
K	451 mg/100 g	
Na	59.7 mg/100 g	
Mg	17.4 mg/100 g	
Ca	2.43 mg/100 g	

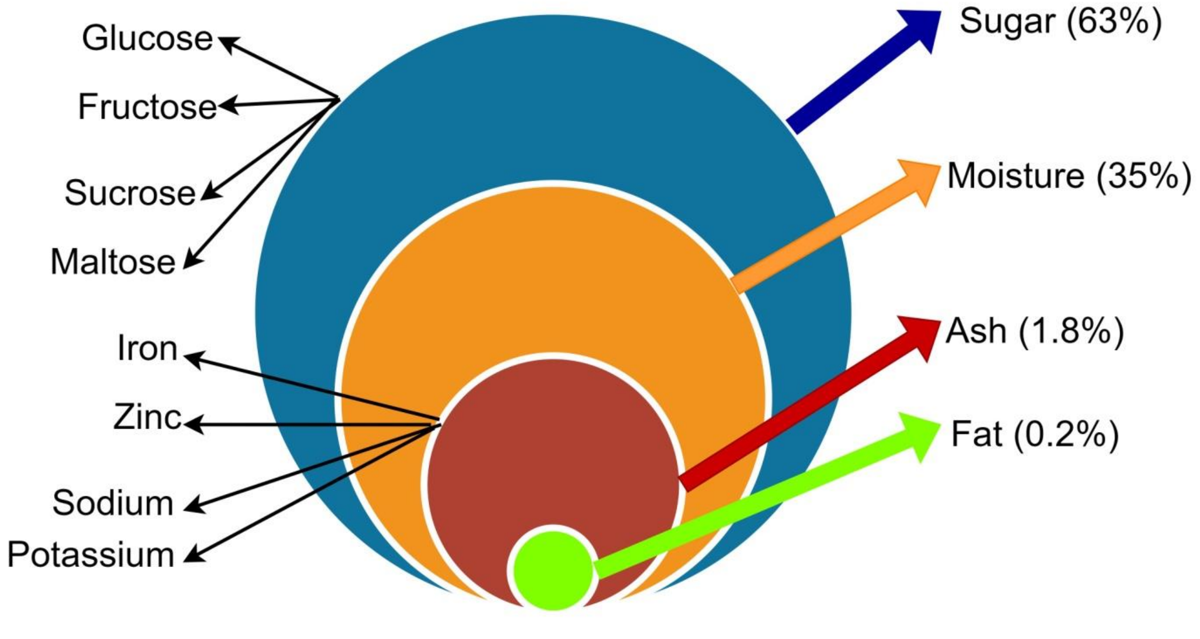

Figure 1

3. Regulating factors for palm sap quality

To process the palm sap, first the nectar is tapped/harvested. Initially, the flowers are cut and then a bamboo container collects the nectar. Natural fermentation may occur before the sugar processing, resulting in physical and microbiological changes. The fermentation process consists of three stages, namely initial lactic acid fermentation, a middle alcoholic fermentation, and a final acetic acid fermentation. Thus, the different levels of fermentation impact the quality profile of the sugar produced by the farmer. (Saputro et al., 2019)

There is a chance of contamination of palm sap as the tapping process is done in an open condition. As a result of contamination, sugar gets consumed by microbes. This results in greater concentrations of acids. Afterwards, there is change in amount of reducing sugar and amino acids as well. Hence, good hygiene, sanitary facilities and equipment are very important in maintaining palm sap quality.

The timing and duration of palm sap tapping also influences the composition of the sap. Even morning and afternoon sap have minor difference in composition. Sap tapping duration also influences physical, chemical and microbiological properties. Climatic conditions, the variety of palm tree, age of inflorescence and fertility of soil are other important factors that influence palm sap quality. (Saputro et al., 2019)

The yield of palm sap is influenced by various factors like “species, seasons, spathes of the same tree and time of tapping (morning/evening)”. The biotic and abiotic stress also heavily influences the yield of sap from palm trees. Yellowing affected trees show low or no sap production. Some abiotic factors like nutritional deficiencies, wind and drought also lead to the low yield. On the other hand, rains positively affect yield and greater yield is seen in monsoon season. (Sarma et al., 2022)

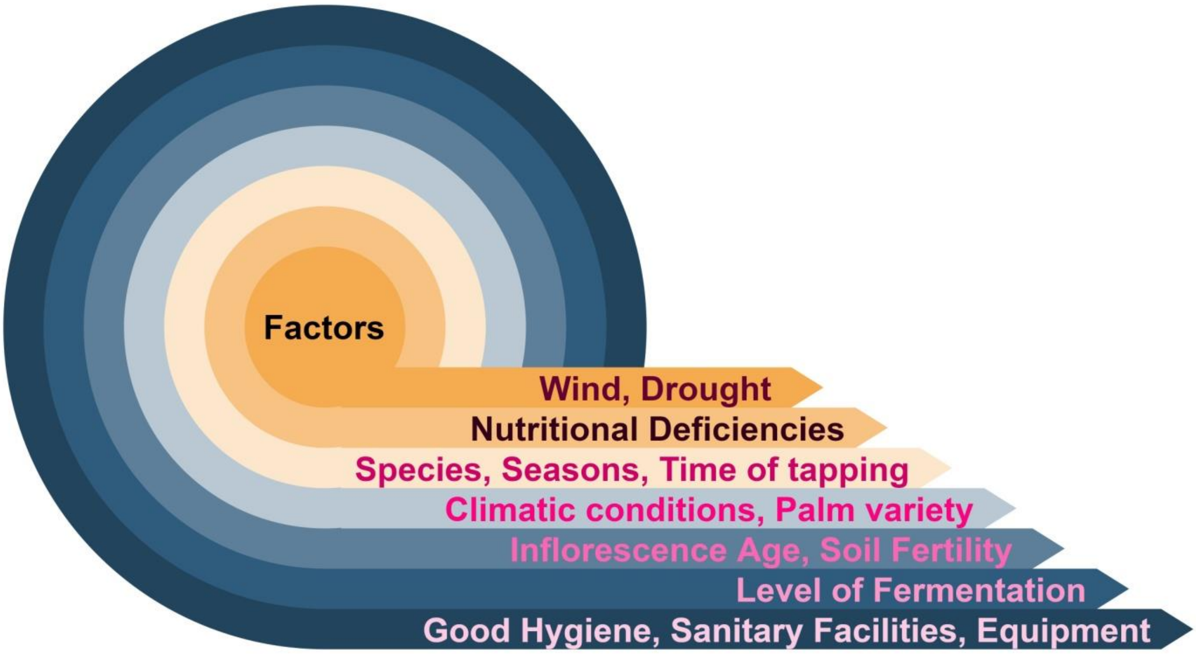

Figure 2

4. Sugar palm varieties in Indian subcontinent

Table 2. Sugar palm varieties in Indian subcontinent

Palm variety	**Geographical availability**	**Amount of sap produced (L/Palm/Day)**	**Sugar percentage**	**Reference**
Areca catechu	Tropical rainforests of South, South east Asia and East Africa: India, Indonesia	1.5-3		(Sarma et al., 2022)
Arenga pinnata	Humid areas of tropical Southeast and South Asia (Papua New Guinea, Thailand, Sri lanka, Vietnam, Indonesia and India)	3-6	10-20	(Kurniawan et al., 2018; Sarma et al., 2022)
Arenga wightii	India	2		(Sarma et al., 2022)
Borassus aethiopum	Tropical zone from West Africa through India and Southeast Asia to New Guinea and Australia	10	7-15	(Sarma et al., 2022; Zongo et al., 2020)
Borassus flabellifer	Tropical countries of Asia (Sri Lanka, Nepal Malaysia, India, Indonesia, Vietnam, Philippines)	6-10	9-17	(Kurniawan et al., 2018; Sarma et al., 2022)
Caryota mitis	India, Brunei, Malaysia, Myanmar, Indonesia, Thailand, Vietnam	1.5-3		(Sarma et al., 2022)
Caryota urens	Humid areas of South and Southeast Asia (Indonesia, India, Sri Lanka, Philippines, Malaysia and Sri Lanka.)	45	13-17	(Kapilan, 2015; Sarma et al., 2022)
Cocos nucifera	Common in tropical lands	1.7-4.3	15-18	(Kurniawan et al., 2018; Sarma et al., 2022)
Corypha umbraculifera	Tropical rainforest of South and Southeast Asia (Sri Lanka, Cambodia, Thailand, India and Myanmar)	20		(Sarma et al., 2022)

Corypha utan	Widely distributed in open and dry areas of Asia (Bangladesh, India, Philippines, Australia, Sri Lanka, Indonesia and Malayasia)	45	17	(Dalibard, 1999; Sarma et al., 2022)
Nypa fruticans	Tidal areas with slow movement and soft mud for eg. Coastlines, mangrove forests and estuaries (Sri Lanka, Cambodia, Bangladesh, Nigeria, Philippines Thailand, Malaysia, Burma and Indonesia)	1.3	15	(Kurniawan et al., 2018; Sarma et al., 2022)
Phoenix sylvestris	Arid and desert areas of South Asia, Middle east and north Africa (Pakistan, Bangladesh, India, Iran, Arabian Peninsula)	1.2-2.5	10-14	(Dalibard, 1999; Sarma et al., 2022)

In India, palm is majorly concentrated in north eastern and eastern Himalayan regions, The Andaman Nicobar forests and Western ghats. As many as 13 genera and 24 species are found in Andaman Nicobar islands. *B. flabellifer*, *C. urens* and *P. sylvestris* are spread throughout peninsular India but the other species are limited to specific geographical locations and regions of India. *Nypa fruticans* is solely found in certain mangrove species in salt marshes of Andaman Nicobar and Sundarban. Most forest palms see growth under the shade of dominant trees along streams and slopes in humid and warm conditions. Most forest palms grow in shade of dominating forest trees along hill slopes and streams under warm and humid conditions. However, some like *B. flabellifer* and *P. sylvestris* grow under full exposure to sunlight. A typical characteristic of most palms is tall or dwarf woody trunk. Branching of aerial trunk is uncommon and is produced by damage to terminal growing bud. This phenomenon has been reported in *Cocos nucifera* (coconut palm) and *B. flabellifer* (Palmyra palm). Regular annual flowering and fruiting is observed. But, the Corypha species shows flowering and fruiting only once in its lifespan after the attainment of complete vegetative growth (around 40 years) and then dies, leaving behind huge seed population to extend its progeny. Palms of this kind are known as monocarpic. In *Caryota sp.* (fishtail palm), the topmost bud of the trunk becomes a huge drooping flowering axis and is followed by buds on the successive basal older nodes of the trunk. This phenomenon is referred to as basipetal flowering. Of all *Caryota* sp., *C. urens* is the most widespread in India and *C. mitis* is restricted to Andaman-Nicobar islands. (Mulani, 2020)

5. Processing of palm sugar

5.1 Traditional processing

In the traditional method of palm sugar preparation, the processing is done by taking a large pan/vessel and then filtered palm sap is poured into it. The palm sap is heated and cooked by stirring and manual agitation for around 3 to 4 hours until water evaporates and highly viscous and sticky appearance is attained. This appearance is indicative of high levels of brown sugar concentration (around 93 g/ 100 g). The sugar is brown in colour due to Maillard reaction. This is poured into a coconut, wood or bamboo mold. The sugar cools and hardens within 1 hour. (Kurniawan et al., 2018)

Disadvantages of the method include undesirable colour (dark brown). Also, antioxidant properties and phenolic content of palm sugar reduce due to long heat treatment. Since an open pan evaporator is used, the observed sucrose inversion is also greater. Also, hydroxyl methyl furfural is formed. The taste of the sugar formed is a little bitter. (Jayanudin et al., 2019; Kurniawan et al., 2018)

5.2 Spray drying

Filtered palm sap is placed in a spray dryer feed tank. The inlet and outlet temperature of the spray dryer are set. The optimum inlet and outlet temperatures are 220°C and 85°C respectively. It is observed that at lower inlet temperatures (140, 160, 180 and 200°C), the sugar is prone to a sticky appearance and formation of big lumps. However, the dark colour of the sugar formed also increases with increase in temperature. The first stage is contact with the flowing air and heater. Palm sap starts flowing from the feed tank to the nozzle, where it gets atomized. It also comes in contact with heated air. Operating parameters that strongly affect palm sugar formation process are feed rate, inlet and outlet temperature, drying air temperature, colour of particles, size of particles, bulk density, nutrient and moisture content. (Jayanudin et al., 2019; Kurniawan et al., 2018)

This method is highly effective under optimal conditions. The sugar formed by this method has lower moisture content than that formed by spray drying and can be more conveniently stored. The initial moisture content (wet basis) is around 1.06-2.95% and increases to 1.15-3.10% after 6 months of storage at a temperature of 30°C. The antioxidant content is also maintained, unlike in the conventional method. Although this method uses a higher temperature than conventional heating, its phenolic content is higher than the latter. This is because of the short contact time between the sap droplets and hot air. (Jayanudin et al., 2019; Kurniawan et al., 2018)

One disadvantage of this method is that the drying walls of the spray dryer become sticky due to adhesion-cohesion phenomenon. In cohesion, the particles stick to each other to form lumps. On the other hand, in adhesion, particle powders stick to the walls. Undesirable lumps are a major challenge in this process. The final yield of the product is also quite low. (Jayanudin et al., 2019; Kurniawan et al., 2018)

5.3 Membrane technology

There are many fields in the sugar industry, where membrane technology is used. For example, juice treatment following liming (ultrafiltration), liquid thickness post evaporation is treated using ultrafiltration, molasses are treated using ultrafiltration or electrodialysis, and raw materials can be utilized by using ultrafiltration. The raw materials in case of juice are salt, protein, acid and pectin. Calcium oxide (CaO) can deposit organic acids and magnesium and ferri- hydroxides. UF membranes can remove high molecular weight compounds before the process of liming. They can decrease the usage of calcium oxide. (Kurniawan et al., 2018)

In membrane technology, a commonly used membrane is the ultrafiltration membrane. This method concentrates the solution and separates while also retaining desirable components. A membrane that is widely used in this method is the ceramic membrane. In this method, the sap undergoes microfiltration followed by ultrafiltration and finally, evaporation and crystallization. (Kurniawan et al., 2018)

There is a chance of fouling in this method. Raw materials may be affected which reduces the sugar content in sap syrup. There is reduction in sucrose and pectin content. The phenolic content of sugar produced by conventional method is higher than that of produced by membrane technology but anti-oxidant activity is lesser. The phenolic content of sugar produced by conventional method is 352.3 mg GAE/mL as compared to 328.36 mg GAE/mL of total polyphenols. The anti-oxidant activity sugar from thermal process is 3.76 mg/mL whereas the antioxidant activity of sugar from ultrafiltration is 4.93 mg/mL. Since the antimicrobial content depends on total phenolic content, it can be inferred that antimicrobial content with thermal process is greater than in membrane technology. (Kurniawan et al., 2018)

5.4 Vacuum drying

Vacuum drying reduces the loss of phenolic compounds and antioxidant characteristics. The optimum vacuum drying parameters is at 40°C for 3 hours. It also decreases the phenomenon of sucrose inversion. This method has low efficiency, high cost of set up and maintenance and requires skilled labour. (Muhammad Tuseef Asghar; Yus Aniza Yusof; Mohd Noriznan Mokhtar; Mohammad Effendy Yaacob; Hasanah Mohd Ghazali and Lee Sin Chang, 2021)

Table 3. Palm sugar processing techniques

Processing techniques	**Key feature**	**Advantages**	**Disadvantages**	**Reference**
Traditional processing	Long heating time (3-4 hrs), Dark brown sugar formed	Does not require skilling up of labour	Very dark colour, reduction in antioxidant and phenolic content, sucrose inversion, bitter taste of sugar	(Jayanudin et al., 2019; Kurniawan et al., 2018)
Spray drying	Short heating time at higher temperature	Low moisture content, convenient storage, higher phenolic content, higher antioxidant activity	Stickiness to spray dryer wall, undesirable lump formation, low yield	(Jayanudin et al., 2019; Kurniawan et al., 2018)
Membrane technology	Usage of ultrafiltration using membranes like ceramic membranes	Higher anti-oxidant activity	Chance of fouling, lesser phenolic content	(Kurniawan et al., 2018)
Vacuum drying	Optimum efficiency at 40°C for 3 hours	Decreases phenolic compound and anti-oxidant loss, reduces sucrose inversion	Low efficiency, expensive	(Muhammad Tuseef Asghar; Yus Aniza Yusof; Mohd Noriznan Mokhtar; Mohammad Effendy Yaacob; Hasanah Mohd Ghazali and Lee Sin Chang, 2021)

6. Proximate composition of palm sugar

The largest constituent of *Borassus flabeliffer* granulated sugar is sugar which makes up about 91.04-93.28% of the entire composition. It is observed that sugar content is higher when the temperature is more (100°C) than at lesser temperatures (80 or 90 °C). The content of reducing sugar ranges from 5.55-6.61%. Reducing sugar content reduces marginally when the drying time and temperature are increased. This may be because the reducing sugars take part in maillard reaction which leads to browning of the sugar. Degradation of reducing sugar with time creates different MRPs and intermediates like melanoidins, organic acids and α-dicarbonyl compounds. The different values of reducing sugar and total sugar and the difference between the two indicate contamination with lactic acid bacteria. This is because sucrose can be converted fructose and glucose as well as to alcohols or organic acids. The mineral composition of *Borassus flabeliffer* includes high concentration of sodium, phosphorus, iron and potassium with potassium being the maximum in content. Palm from Palmyra palm also has significant vitamin content like riboflavin, thiamine, niacin and vitamin A. (Le et al., 2020)

The moisture content of nipa palm syrups are in the range between 28.9-31.5%. The major constituent is sugar which makes up 93.1-93.6 % of the entire composition. The protein levels in *Nypa fruticans* is 2.0-2.9% on dry weight basis. Ash content varies between 3.8 to 4.2 %. The presence of fibers and lipids is negligible and at times, completely absent in the samples. (Saengkrajang et al., 2021)

The most abundant component of date palm syrup is sugar and of the total sugar, reducing makes up about 10.63 to 11.37%. Ash content is between 2.13-2.16 %. Potassium was the mineral with the highest presence in date palm. (Ben Thabet et al., 2009)

The solid and moisture content in *Phoenix canariensis* syrup are 64.7% and 35.3% respectively while the ash content is 1.78%. Among the carbohydrates, sucrose, glucose and fructose are the most abundant in that order. Fats have negligible presence (less than 0.2%). Fat soluble vitamin presence is lesser than water soluble vitamin presence. The presence of fat soluble vitamins in *Phoenix canariensis* is in the order: A, E, D and K respectively with D and K having a very minor presence. Niacin was the most abundant among the water soluble vitamins. Potassium and iron have the highest concentration among macro and micro elements respectively. (Luis et al., 2012)

4. Sugar palm varieties in Indian subcontinent

	***Borassus flabeliffer* (granulated)**	***Nypa Fruticans* (syrup)**	***Phoenix dactylifera* (syrup)**	***Phoenix canariensis* (syrup)**	***Arenga pinnata* (granulated)**	**Reference**
Protein	-	2.0-2.9 g/ 100 g	0.30-1.30 g/ 100 g	–	–	(Ben Thabet et al., 2009; Saengkrajang et al., 2021)
Fat	-			<0.20 g/ 100 g	0.11 g/ 100 g	(Choong et al., 2016; Luis et al., 2012)
Total sugar	91.04-93.28 g/100 g	93.1-93.6 g/100 g	58.49-75.28 g/100 g	66.0 g/ 100 g	95.29 g/ 100 g	(Ben Thabet et al., 2009; Choong et al., 2016; Le et al., 2020; Luis et al., 2012; Saengkrajang et al., 2021)
Reducing sugars	5.55-6.61 g/100 g	10.0-19.6 g/100 g	6.65-8.10 g/ 100 g	–	9.31 g/ 100 g	(Choong et al., 2016; Le et al., 2020; Luis et al., 2012; Saengkrajang et al., 2021)
Ash	-	3.8-4.2 g/100 g	2.13-2.60 g/ 100 g	1.78 g/ 100 g	0.47 g/ 100 g	(Ben Thabet et al., 2009; Choong et al., 2016; Luis et al., 2012; Saengkrajang et al., 2021)
Moisture	2.91-5.12 g/100 g	28.9-31.5 g/100 g (fw)	20.79-39.06 g/100 g	35.3 g/ 100 g	4.11 g/ 100 g	(Ben Thabet et al., 2009; Choong et al., 2016; Le et al., 2020; Luis et al., 2012; Saengkrajang et al., 2021)
HMF	2.18-41.92 mg/100 g	5-18 mg/kg	–	–	–	(Le et al., 2020; Saengkrajang et al., 2021)

Total phenolic content	2.77-8.94 mg/100 g	16.9-44.3 mg GE/100 g	147.6-224.5 mg FAE/kg	_	1943 µg of GAE/g	(Ben Thabet et al., 2009; Choong et al., 2016; Le et al., 2020; Saengkrajang et al., 2021)
Mineral						
Ca		20-60 mg/kg	1.68-1.87 mg/ 100 g	2.43 mg/ 100 g		(Ben Thabet et al., 2009; Luis et al., 2012; Saengkrajang et al., 2021)
Fe	1.88–2.05 mg/kg	15-23 mg/kg	0.55-1.11 mg/100 g	1.16 mg/100 g		(Ben Thabet et al., 2009; Le et al., 2020; Luis et al., 2012; Saengkrajang et al., 2021)
K	688.45–705.27 mg/100 g	10260-12500 mg/kg	939.6-1149.3 mg/ 100 g	451 mg/ 100 g		(Ben Thabet et al., 2009; Le et al., 2020; Luis et al., 2012; Saengkrajang et al., 2021)
Na	23.10-24.50 mg/100 g	3400-4740 mg/kg		59.7 mg/ 100 g		(Le et al., 2020; Luis et al., 2012; Saengkrajang et al., 2021)
P	_	520-710 mg/kg	57.2-67.1 mg/ 100 g	_		(Ben Thabet et al., 2009; Saengkrajang et al., 2021)
Mg		260-340 mg/kg	26.9-30.7 mg/100 g	17.4 mg/ 100 g		(Ben Thabet et al., 2009; Luis et al., 2012; Saengkrajang et al., 2021)
Si		210-430 mg/kg		_		(Saengkrajang et al., 2021)

Vitamin						
A	1.54-1.95 mg/100 g			<0.50 mg/kg		(Le et al., 2020; Luis et al., 2012)
B_1	0.66-1.06 mg/100 g			0.20 mg/kg		(Le et al., 2021; Luis et al., 2012)
B_2	0.04-0.07 mg/100 g			<0.10 mg/kg		(Le et al., 2021; Luis et al., 2012)
B_3	1.88-2.19 mg/100 g			31.7 mg/kg		(Le et al., 2021; Luis et al., 2012)
B_5	0.40-0.74 mg/100 g			–		(Le et al., 2020)
B_6	0.08-0.21 mg/100 g			<0.40 mg/kg		(Le et al., 2021; Luis et al., 2012)
Folic Acid	2.51-3.33 µg/100 g			0.10 mg/kg		(Le et al., 2021; Luis et al., 2012)
C	2.78-4.01 mg/100 g			<5.00 mg/kg	1.76 mg/ 100 g	(Choong et al., 2016; Le et al., 2021; Luis et al., 2012)
D_2	2.11-2.23 mg/100 g			<5.00 µg/kg		(Le et al., 2021; Luis et al., 2012)
E	52.15-55.12 mg/100 g			<0.50 mg/kg		(Le et al., 2021; Luis et al., 2012)

Fw : free weight **GAE:** Gallic Acid Equivalent **FAE:** Ferric Acid Equivalent

7. Physical properties

7.1 Colour

Maillard reaction occurs during the production of palm sugar. Thus, a darker colour is formed. Caramelization and Maillard reaction result in a reduction in L* value and the a* value increases (L* a* b* colour system) because of greater heating time and temperature. (Saputro et al., 2019)

In *Arenga pinnata*, the production of granulated sugar is done by boiling palm sap up to a temperature of 127 ^{O}C with total suspended solids more than 93%. It is followed by continuous stirring till the granules appear. In the entire process, L* values show a small increase at the start i.e., the values rise from 24.6 to 29.0. After this, the value shows a sharp rise to 42.6 with the production of granulated sugar. The a* and b* values show a different trajectory. The a* values initially increase from 1.9 to 6.7, followed by a small increase to 7.4. On the other hand, the b* value increases from 2.8 to 7.3, followed by a major increase to 13.5. (Victor, 2018)

7.2 Aroma and Flavour

The aroma profile is alike to other thermally processed foods. Sc-, O- and N-heterocyclic compounds are there in palm sugar in good amount. As many as 36 volatiles have been reported in palm sugar. Six aromatics, four acids, two ketones, two aldehydes, five furans, fourteen pyrazines and two furanones have been identified. In separate studies, 30 and 27 volatile compounds have also been reported. (Saputro et al., 2019)

The unique flavour of palm toddy comes from acetoin, 2-acetyl-1-pyrroline, ethylhexanoate and 3-isobutyl-2-methoxypyrazine. Acetoin gives a buttery flavour whereas 3-I'sobutyl-2-methoxypyrazine gives an earthy flavour.(Ho et al., 2007)

The time-temperature curve of heating process of palm sap shows that in the first half hour, the temperature of sap shows a drastic increase up to 76.9^{O}C. Then, the sample temperature increases up to 100 ± 5^{O}C at 60-minute time of heating for 2 hours. The temperature then continuously increases and the final temperature of approximately 150^{O}C at 4 hours. Thus, there is a drastic increase of the sap temperature twice during the entire process. The first increase for the first one hour of the process is partially due to water dehydration from the sap. This evaporation is important because it brings down the water activity to a moderate level, thus creating a fertile environment for inducing subsequent reactions. However, the second increment is related to formation of a volatile compound that imparts a sweet caramel and roasted nutty flavour to the final sugar product. (Ho et al., 2007)

Some important volatile compounds identified during heating process for palm sugar production and their characteristic flavours are: 2- Methyl pyrazine and 5- Methyl furfural give a nutty flavour; 2,5(6)-Dimethyl pyrazine gives a sweet, nutty and roasty flavour; 2-Ethyl pyrazine and 2-Ethyl-5-methyl pyrazine give a sweet and roasty flavour; 2,3-Dimethyl pyrazine gives a roasted nut, peanut, nutty, coffee and sweet flavour; 2-Ethyl-3,5-dimethyl pyrazine and 2,3-Diethyl-5-methyl pyrazine give an earthy and roasty flavour; 2-Furfural gives a burnt and smoky flavour; 4-Hydroxy-2,5-dimethyl-3(2H)-furanone gives a burnt sugar, sweet, caramel and strawberry-like flavour. (Ho et al., 2007)

Thus, the entire process of heating of palm sap is essential to attain the typical aroma associated with the final palm sugar. Many flavour compounds are formed in the course of heating including compounds resulting from Strecker degradation, lipid oxidation and maillard reaction. Additionally, to obtain the characteristic sweet, nutty and roasty aroma of palm sugar, the temperatures of heating need to be considerably greater than 110^{O}C. (Ho et al., 2007)

7.3 Crystal behavior

The factors that influence the crystallisation of palm sugar are: reducing sugar, processing conditions, acidity, storage conditions and formulation. Crystallization affects the hardness of palm sugar. Hardness enables a material to resist deforming when penetration or compression is applied to it. Greater intermolecular bonding leads to greater hardness. The textural properties of palm sugar include stickiness and hardness. Stickiness is the phenomenon of a material adhering to a surface. This depends on temperature, water and food ingredients. Water-solid interaction is the prime cause of stickiness in low moisture food. Hardness and stickiness of palm sugar range from 30.83-69.00 N and 0.11-0.33 N respectively. The main sugar in palm sugar is sucrose. Sucrose gets hydrolyzed to glucose and fructose during heating under acidic conditions. Reducing sugar, fructose and glucose can retard sugar crystallization and lead to low hardness of the final product. (Naknean, 2010)

8. Bioactive composition of palm sugar

8.1. Phenolic compounds:

Antioxidants are molecules (exogenous or endogenous) that diminish oxidative stresses and their results. Phenolic compounds are the most abundant antioxidants which can be found in fruits and plants. An aromatic ring is present in phenol in hydroxylated form. This is what imparts redox properties to phenolic compounds. The phenolic compounds benefit overall health of humans and do not show any harmful side effects.

Phenolic components are present in the palm sap itself and the content increases during heating because bound polyphenols are released in this case. It has been observed from different studies that phenolic content is highest in at around 80^{O}C. But when the temperature is increased to a temperature of 90 or 100^{O}C, the total phenolic content reduces because of its destruction during the heating. Phenolic content and antioxidant activity are closely related. In relation to the phenomenon of scavenging of free radicals, mechanisms affect antioxidation potential of the palm sugars. It was reported that DPPH % was highest for (100^{O}C, 90 min) and lowest for (80^{O}C, 60 min). The reason for the former having a higher DPPH activity is because of more caramelization and maillard reaction products. Also, samples prepared at greater temperatures and for longer periods of time show greater FRAP activity. (Le et al., 2020)

Palm sugar syrup shows greater amount of phenolic content than palm sugar powder and both show higher amount of phenolic content than refined cane sugar.

Derivatives of cinnamic acid and p-hydroxybenzoic acid have been detected in several types of palms. The acid predominantly present in the palm varieties is p-hydroxybenzoic acid. Additionally, ferulic acid and tiny amounts of p-coumaric acid are also present. Gallic, vanillic, syringic and catechuic acids are some other phenolics that are derivatives of benzoic acid and have been found in pam varieties. Their aldehydic forms like vanillin (present in coconut); syringaldehye, protocatechuic aldehyde and p-hydroxybenzoic aldehyde (present in leaves and some other tissues) have been detected as well. Ferulic, sinapic, chlorogenic and caffeic acids are present in mesocarp of several varieties. In *E. guineensis*, caffeoylshikimic acid isomers constitute the major component of phenolic compounds. These isomers have also been found in ripened fruits and seeds of fruits in *P.dactylifera* and has also been detected in flowers of palm. Many of these phenolic acids and their derivatives show antifungal and antibacterial properties apart from antioxidant activities. (Genovese et al., 2008)

Another bioactive compound, resveratrol and its methoxy analogs also show antioxidant properties and studies have indicated preventive effects on cancer as well. Fruits of *E. oleracea*, *O. bataua* and *E. edulis* have shown the presence of this compound. An unrecognized stilbene has been isolated from the fruit of *H. thebaica.* (Kok et al., 2011)

Table 5. Benzoic and cinnamic acids in palms

Species	**Plant Part**	**Benzoic acids**	**Cinnamic acids**	**References**
Areca catechu L.	fruit	p-Hydroxybenzoic	p-Coumaric, Ferulic	(Kumar et al., 2012)
Cocos nucifera L.	coconut husk fiber	p-Hydroxybenzoic, Vanillic, Gallic, Syringic	Ferulic, Chlorogenic	(Shahidi & Chandrasekara, 2010)
Cocos nucifera L.	coconut oil	_	p-Coumaric, Caffeic, Ferulic	(Agostini-costa, 2018)
Nypa fruticans	fruit	p-Hydroxybenzoic, Protocatechuic, Gallic	Chlorogenic	(Kffuri et al., 2016)
Borassus flabellifer	fruit	p-Hydroxybenzoic	p-Coumaric, Ferulic	
Euterpe edulis	fruit	p-Hydroxybenzoic, Protocatechuic, Vanillic, Gallic, Syringic	p-Coumaric, Caffeic, Ferulic, Sinapic, Chlorogenic, Stilbene	(Schulz et al., 2015)
Butia capitata	fruit	_	p-Coumaric, Caffeic, Ferulic	(Ho et al., 2007)
Euterpe oleracea	pulp	p-Hydroxybenzoic, Protocatechuic, Vanillic, Gallic, Syringic	p-Coumaric, Caffeic, Ferulic, Chlorogenic	(Dias-Souza et al., 2018)
Hyphaene thebaica	fruit	_	Caffeic, Chlorogenic, Stilbene	(Paniagua-Zambrana et al., 2015)
Mauritia flexulosa L. f.	fruit	Protocatechuic	p-Coumaric, Caffeic, Ferulic, Chlorogenic	(Agostini-costa, 2018)
Mauritia flexulosa L. f.	leaves	_	Caffeic, Chlorogenic	(Srimany et al., 2016)

Phoenix dactylifera L.	date fruit	p-Hydroxybenzoic, Protocatechuic, Vanillic, Gallic, Syringic	p-Coumaric, Caffeic, Ferulic, Sinapic	(Khelil et al., 2016)
Phoenix dactylifera L.	stem	p-Hydroxybenzoic	Stilbene	(Wu et al., 2004)
Oenocarpus distichus Mart.	Bacaba-de-leque fruit	Syringic	p-Coumaric, Caffeic, Ferulic, Sinapic, Chlorogenic	(Wang et al., 2007)
Oenocarpus distichus Mart.	Patawa fruit	Syringic	Caffeic, Chlorogenic, stilbene	(Wang et al., 2007)

8.2. Pigments

The fruit, *E. precatoria* is rich in anthocyanin and studies have shown that anthocyanin can prevent Alzheimer. Cyanidin-3-O-rutinoside and cyanidin-3-O-glucoside are mainly responsible for pigmentation in fruits of palms. Peonidin-3-O-glucoside, peonidin-3-O-rutinoside and pelargonidin-3-O-rutinoside are present in the fruits of *E. edulis*. (Agostini-costa, 2018)

8.3. Flavonoids, Flavones and Flavanols

Flavonoids have polyphenolic structures. They are actually a part of plant secondary metabolites. Flavonoids have fifteen carbon skeleton where 2 aromatic rings are linked by a 3-carbon chain, creating a heterocyclic oxygenated ring. Flavonoids are classified into flavones and flavan-3-ols. In flavan-3-ols, C3 position has a hydroxyl group and in flavones, the position between C3 and C2 is unsaturated and C4 has a carbonyl group. They have positive health effects like antioxidant effects. They have protective impact like prevention of diseases like Alzheimer's disease, cancer, atherosclerosis etc. Palm sugars have high flavonoid content. Palm sugars sugar syrup has higher flavonoid component as compared to palm sugar powders. (Agostini-costa, 2018)

The most commonly prevalent components of palm leaf extracts are tricin and flavon-C-glycosides. Tricin has anti-viral, immunomodulatory, antioxidant, anti-inflammatory, anti-tubercular, anti-cancer and anti-ulcerogenic nutraceutical properties. The major constituent of several species of *Attalea* genus are free tricin, tricin-7-glycosides, flavone C-glycosides and tricin-5-glycosides. *B. capitata* leaves contain luteolin 7-O-glucoside and tricin 7-O-rutinoside. A comprehensive table outlining different flavones present in different palm leaves and fruits is given below

Table 6. Flavones present in palm leaves and fruits

Palm variety	**Flavones present**	**Reference**
Leaves		(Agostini-costa, 2018)
B. capitata	tricin 7-O-rutinoside, luteolin 7-O-glucoside	
M. flexuosa	apigenin 6-C-arabinoside, luteolin 8-C-glucoside, apigenin 6-C-arabinoside-8-C-glucoside, tricin 7-O-rutinoside, luteolin 6-C-glucoside	
Phoenix loureiroi	tricin 7-neohesperidoside, tricin 7-O-glucoside, isoorientin, luteolin 7-neohesperidoside, orientin 7-O-glucoside, apigenin 6-C-glucoside	
Phoenix canariensis	tricin 7-neohesperidoside, flavone C-glycosides, tricin 7-glycosides, luteolin 7-rutinoside	
Fruits		
Butia odorata	hesperitin	
P. dactylifera	luteolin, apigenin, diosmetin 7-O-arabinosyl apioside, diosmetin 7-O-apioside	
M. flexulosa	Chrysoeriol 8-C-glucoside, apigenin 8-C-glucoside,	
E. oleracea	isovitexin, apigenin 6,8-C-hexoside, luteolin 7-O-glucoside, orientin, apigenin 6-C-pentoside-8-C-hexoside, isoorientin, 5,4'-dihydroxy-7,3',5'-trimethoxyflavone, luteolin 7,3'-dimethyl ether	
H. thebaica	luteolin O-rutinoside, chrysoeriol O-rutinoside	
E. edulis	6-O-Methylapigenin	

The characteristic feature of flavonols are O-glycosidic linkages. Free isorhamnetin and quercetin occurs more commonly in cocosoid palm leaves, as compared to the rest of palmae family. Quercetin, along with its derivatives, has been garnering attention because of its antiviral, anti-carcinogenic, anti-inflammatory and antioxidant effects. The flavonols detected in various palms are listed in the following table.

Table 7. Flavonols present in palm species

Palm species	Part	Flavonols	References
B. capitata	leaves	Isorhamnetin-3-O-rutinoside, quercetin-3-O-rutinoside, kaempferol-3-O-rutinoside	(Agostini-costa, 2018)
M. flexuosa	leaves	Rutin, nicotiflorin	
Phoenix loureiroi	leaves	Quercetin-3-glucoside	
P. dactylifera	Pollen and fronds	Quercetin & isorhamnetin malonyl derivatives	
H. thebaica	fruit	Narcissoside, isoquercitrin	
P. dactylifera	fruit	Quercetin-3-O-rhamnoside, quercetin, rutin	

Dihydroflavonoids have also been reported in palm species. The trunk and leaves of *M. flexuosa* show the presence of naringenin. Naringenin, along with dihydrokaempferol and dihydrotricin are present in the stems of *Calamus formosanus.* Becc. The fruits of *E. oleracea* show the presence of eriodictyol, dihydroquercetin, aromadendrin 3-O-glucoside, aromadendrin and taxifolin deoxyhexose. Taxifolin and aromadendrin have also been found in the pulp of *E. edulis*. Recently, pinocembrin has been detected in the fruits of *B. odorata*. (Agostini-costa, 2018)

Procyanidins and flavan-3-ols are present in different parts of different palm species. Flavan-3-ols like epicatechin and catechin show a positive effect on coronary heart health. Epigallocatechin gallate shows ant-inflammatory, antioxidative and antiproliferative effects. *E. guineensis* leaf extract contains catechin, epigallocatechin, epicatechin, epicatechin gallate and epigallocatechin gallate. Catechin-based procyanidins with varying degrees of polymerization are present in *A. catechu* nut. The antioxidant activity is higher when the polymerization degree is greater. The fruits of *P. dactylifera* contain procyanidin oligomers whereas the seeds contain procyanidin dimers and trimers. The seeds also contain epicatechin and catechin. Presence of these flavan-3-ols is similarly observed in the seed of *S. coronata* and husk fiber of coconut. (Agostini-costa, 2018)

Pinoresinol, lariciresionol, dihydroconiferyl alcohol and syringaresinol are lignan precursors, present in the fruits of *E. oleracea.* Salcolin A and calquiquelignan A were detected in the *Calamus formosanus* stems. The complete chemical profile of many lignans found in palms has not been established yet.(Agostini-costa, 2018)

8.4. Volatiles

38 volatile compounds have been identified in palm sugar. The volatile compounds present in palm sugar are further subdivided into pyrazines, ketones, aldehydes, carboxylic acids and furan derivatives. Palm sugars having a higher volatile content have roasty and nutty taste. Also, these volatiles impart sweet aroma to the palm sugar. Furaneol has a kind of caramel like flavour. Thus, the sweet caramel like qualities of palm sugar may be due to these volatiles. Palm sugars with higher pyrazine contents are shown to have increased roasty and nutty flavour but have reduced burnt and caramel like flavours. Thus, every volatile compound can possibly and distinctly reduce, enhance or cover the sensory qualities of food products like palm sugars. (Le et al., 2021)

The volatile components that are present in greater quantity in palm sugar syrup include 2,3-dihydro-3,5-dihydroxy-6-methyl-4 H-pyran-4-one, R-(R',R')-2,3-butanediol, 2-propenoic acid, S-(R, R')-2,3-butanediol, benzoic acid and dimethyl sulfoxide. On the other hand, the volatile components that are present in lower amounts include 3-methyl-1,2-cyclopentanedione, 4,5-dihydro-2-methyl-3(2H)-furanone and 5-methyl-2-pyrazinylmethanol. S-(R, R')-2,3-butanediol is believed to have a role in imparting the typical flavour associated with palm syrup. 9 kinds of acids are present in palm syrup with 2-propenoic acid having the highest concentration among them all in both ultrafiltration and thermal processes. Though acid content tended to show a reduction at greater temperatures, several volatile components were retained which do not impart any aroma. On the other hand, the 12 types of ketone compounds identified increased in content when the temperature was raised. Ketone compounds impart different flavours and odours to the palm syrup e.g., 2,3-dihydro-3,5-dihydroxy-6-methyl-4 H-pyran-4-one produces caramel, maple type, sweet odour. The volatile compounds that contain sulphur show anti-cancer and antioxidant characteristics but also produce an untoward odour so excessive amounts are undesirable. The number of volatiles was higher with thermal process as compared with ultrafiltration process. (Le et al., 2021)

9. Health beneficial effect

9.1 Anti diabetes

Palm sugar has low GI. This enhances the glucose absorption in body and thus reduces the need for insulin. Thus, palm sugar can protect against diabetes and cancer. Phenolics, phytochemicals and flavonoids protect a person from hyperglycaemia. Phytonutrients improve glycogen phosphorylase activity and inhibit glycogen synthase activity. Thiamine triphosphate helps in regulating levels of blood glucose and reduces the chance of alloxan induced cytotoxicity. Also, alpha glycosidase property leads to reduction of chance of diabetes. Low GI foods including palm sugar can prevent obesity. (Sarma et al., 2022)

9.2 Immunity enhancer

Glutamic acid present in palm sap acts as precursor in protein production. Electrolytes and vitamins present in palm sap can increase immunity because of their role as cofactors and coenzymes. Also, certain probiotic species like *lactobacilli* are present in palm sap and such species interact with gut cells to boost immunity. (Sarma et al., 2022)

9.3 Anti hypertension

Hypertension not only plagues the person's health but may also lead to brain strokes or kidney failure. Studies have shown that consumption of coconuts reduces cholesterol and pressure levels. The potassium present in sap has regulatory effects on blood circulation and consequently, can reduce blood pressure. Palm sap consumption shows decreased hypertension. Palm sugar consumption may lead to regulation of kidney functioning due to presence of calcium, potassium, magnesium, free amino acids, vitamin c etc. L-arginine, a free amino acid can regulate nitric oxide pathway. This reduces the chance of atherogenesis. Also, improved functioning of endothelial tissues and increase in peripheral resistance reduces blood pressure. The amino acid cysteine together with vitamins A and C show antioxidant activity and the subsequent reduction in oxidative stress prevents hypertension. (Sarma et al., 2022)

9.4 Anti-cancer

Antioxidants and phytochemicals present in palm sugar prevent damage to the cell and thus, reduce the chance of cancer developing in such cells. Free radical formation is reduced by the presence of vitamin C and antioxidants. Higher ascorbic acid concentrations in fresh sap compared to post fermentation ascorbic acid concentration, means that fresher sap has better radical scavenging potential. In spite of low ascorbic acid concentrations, fermented sap can prevent damage to the DNA because of polyphenolic compound formation during fermentation. Neoplastic cell activity can lead to oral, lung and colon cancer and palm sap has preventive effect on such activity. (Sarma et al., 2022)

9.5 Skin protection

Skin cells undergo auto oxidation (formation of free radicals) and are prone to fungal and bacterial infections. Due to anti-fungal, anti-oxidant and anti-bacterial properties associated with palm sap, skin gets some protection from different infections and oxidative stresses. CC 517, a phenolic compound extracted from *Areca Catechu* has been shown to slow down skin aging by inhibition of elastase activity. (Sarma et al., 2022)

9.6 Improvement of digestive health

The phosphorous present in palm sap improves food digestion. The absorption of niacin and riboflavin by the intestine is enhanced by phosphorus. Niacin and riboflavin act as cofactors in energy production. Other functions include prevention of neurological disorders and improved cognition and emotional control. Phosphorus can act as a laxative and hence, regularizes bowel movements by prevention of constipation. Certain probiotic organisms are present in palm sap that improve gut health and defend the existing intestinal flora from attack by damaging microorganisms. These probiotic organisms produce organic acids that provide cytoprotection under stressful situations and play a vital role in homeostatic regulation. (Sarma et al., 2022)

9.7 Weight control

Obesity is a serious health condition which has become rampant worldwide and it can further lead to other comorbidities like diabetes, cardiovascular diseases, cancer and inflammation. The high Vitamin C content helps to regulate the release of glucocortisoid from kidney and improves adipocyte lipolysis. Both these phenomena combinedly reduce glycosylation. A hormone called leptin gets secreted by adipocytes. Leptin vitalizes energy expenses and impedes food intake through hypothalamic leptin receptors. Ascorbic acid helps in synchronizing the impediment to leptin secretion and reduces the impact of inflammatory response. Since this entire process occurs in an organized manner, there is a noticeable decrease in body weight and this subsequently helps in weight control and prevention of cardiovascular diseases. (Sarma et al., 2022)

9.8 Thermal regulation in body

The high mineral content in palm sap helps in maintaining electrolytic balance in the body. This decreases dehydration and stabilizes temperature of the body. Palm sap can be used as a healthy body drink to maintain fluid balance in the body and is also regarded as a potent post operation drink for rejuvenation. The palm sap contains inositol, which is a popular component in health drinks because of its ability of conversion of nutrients to energy. It also plays a role in osmoregulation, growth factors and hormone regulation. (Sarma et al., 2022)

9.9 Protective effects on nervous system

Palm sap has high inositol and thiamine content, which are needed for proper working of nervous system. Thiamine is essential for regenerating glial and neuronal cells which are required for proper functioning of the brain. Thiamine triphosphate and thiamine diphosphate (derived from vitamin B_1) act as cofactors for enzymes associated with pentose phosphate and tricarboxylic acid pathways and glucose metabolism respectively. Both the aforementioned pathways take part in carbohydrate metabolism and therefore, thiamine is instrumental in ensuring that the energy obtained from consuming carbohydrate in food is properly utilized by glail and neuronal cells. (Sarma et al., 2022)

9.10. Health and strength of bones

Phosphorous and calcium are vital minerals for the maintenance of the health and strength of bones. Palm sap contains phosphorous which improves calcium absorption in the body. The recommended daily intake of phosphorus (100 mg/day for an adult human) is met by the phosphorus content present in the sap. Thus, uptake of calcium is enhanced and bones and teeth are strengthened. (Sarma et al., 2022)

10. Value added product with palm

10.1. Palm sugar

Palm sugar is a popular alternative sweetener in countries like Indonesia, India, Philippines and Thailand. It is traditionally produced from palm sap locally. Philippines and Indonesia are leaders in palm sugar production globally. Palm sugar not only adds sweetness but it also impacts the colour, texture and flavour of the food product. Palm sugar has lower glycemic value than cane sugar. Palm sugar has rich nutritional profile consisting of amino acids, antioxidants, dietary fibres and vitamins. Thus, from a health perspective, palm sugar has a wide array of nutritional benefits. (Sarma et al., 2022)

10.2. Toddy

Microorganisms naturally present in palm sap initiate fermentation of the sap into a white milky substance, commonly known as toddy or palm wine. Palm wine has alcohol content of around 4-4.5%. It is a popular drink in tropical areas of South America, Africa and Asia. The most popular toddy drinks in India are made from coconut palm, silver date palm and palmyra palm. Palm wines display a wide diversity in tastes and sensory profile because of influence of species and geographical location. Toddy also shows some antibacterial and nutraceutical properties. (Sarma et al., 2022)

10.3. Palm jaggery

Palm jaggery is colloquially known as palm gur. Jaggery is produced from unfermented sap. It has an intense and earthy taste, very similar to that of chocolate. In the beginning, earthen pots are treated with calcium hydroxide and palm sap is collected here. The sap then undergoes sedimentation and is filtered after that. Next, the sap is shifted to a furnace where boiling takes place at a temperature of 110°C. This leads to the formation of a thick sticky fluid that is kept in moulds to solidify. (Srivastava & Bishnoi, 2017)

Palm jaggery is expensive because of its mineral rich nutritional composition and therapeutic effects. Additionally, it is deficient in sodium and rich in potassium, ascorbic acid and vitamin B12. This composition leads to reduction in possibility of health ailments like oedema, anaemia and hypertension. (Sarma et al., 2022; Srivastava & Bishnoi, 2017)

10.4. Treacle

To prepare a treacle, the sap is first concentrated by heating at a temperature below 107°C up to approximately one-sixth of its volume. A viscous syrup is subsequently formed which is dark and thick in appearance. A temperature more than 107°C will lead to darkening and caramelization of the sugar. Treacle is an excellent alternative to sugar. (Mani et al., 2018)

10.5. Palm toffee

The ingredients to make palm toffee are palm fruit pulp, glucose, skimmed milk powder, sugar, starch and refined wheat flour. The aforementioned ingredients are mixed thoroughly by continuously stirring for 40 min. After heating is completed, the mixture is spread over a tray. The tray should be made of aluminium and butter or oil must be spread over it. After 24 hours, toffees are cut into desirable shapes and sizes and packaged accordingly. (Srivastava & Bishnoi, 2017)

10.6. Palm sap vinegar

Palm vinegar has several applications as food preservatives, additives and medicinal agent. It is widely popular in countries of pacific islands and Asia. For the production of palm vinegar, alcoholic and acetic acid fermentations are done successively. The produced acetic acid gives characteristic odour and flavour to the vinegar. Palm vinegar has also been associated with hypoglycaemic effect. (Sarma et al., 2022)

10.7. Palm tamarind candy

To make palm tamarind candy, heating of palm syrup is done for two hours. This creates syrup with consistency, akin to that of honey. The syrup is pored over mud pots and seedless, shelled, dry and ripe tamarind fruits are added to the neera. The pots are clamped strongly with clothes and preserved in a dry and cool place for 130-180 days. Crystallization of sugar takes place in the seams of tamarind to transform the fruits into tasty candies.(Srivastava & Bishnoi, 2017)

10.8. Palm cola

The ingredients to make palm cola are palm sugar, citric acid, food colour and cola concentrate. Addition of palm sugar to milk is followed by heating at 110-115°C for purification. After the solution is cooled, cola essence is added at the rate of 250 ml/1000 bottles. (Mani et al., 2018)

11. Storage and preservation of palm sugar

To maintain and preserve the quality of a food product, it is vital to keep in check the decay and decline of sensory and nutritional aspects of stored food. This is to be done by extending shelf life of food products and reducing non enzymatic browning. For example, nonenzymatic browning reactions are heavily influenced by processing techniques used for coconut palm sugar syrup. Adequate steps need to be taken at both the production, as well storage stage. It has been reported that microbes that cause deterioration of jaggery blocks grow the fastest 30°C and moisture content of around 10%. For storage, the ideal moisture content is 7-8% and relative humidity 40-45%. During rainy season, crystallinity, colour and sweetness of blocked sugar remain unaffected if it is kept in air tight containers. Sugar blocks with greater moisture content are more prone to deterioration. An alkathene film can be used to wrap sugar blocks. A plastic pouch can be used to cover the film and a paper box used for final packaging. The above steps can ensure quality is retained better for long periods of time. (Muhammad Tuseef Asghar; Yus Aniza Yusof; Mohd Noriznan Mokhtar; Mohammad Effendy Yaacob; Hasanah Mohd Ghazali and Lee Sin Chang, 2021)

To extend the shelf life of fresh palm sap, sterilization or pasteurization may be done. But for such thermally processed palm sap, there is a chance of murkiness developing, while being in storage. Interaction between proteins and polyphenolic compounds creates insoluble particles that get dispersed throughout the sap. Formation of brown pigments also contribute to cloudiness. So, gelatin, polyvinylpolypyrrolidone, chitosan and bentonite may be added to enhance quality. Similar clarifying agents can be used for palm syrup as well but the biggest challenge concerning palm syrup is the development of crystals. This can happen within one or two days. Ensuring high viscosity or adding sugars like corn syrup can inhibit crystallization. Also, appropriately formulating the product can kinetically inhibit crystal formation. Significant inhibition of nucleation is necessary to avoid undesirable crystal formation. (Srikaeo et al., 2019)

Heating increases viscosity and decreases water activity. Cubic and powdered sugars are produced by evaporation sap till a water activity lower than 0.60 (for powdered sugar) is attained. The hygroscopic nature of palm sugars require dry and cool storage conditions, as well as appropriate packaging like food grade moisture absorbers. Maltodextrin and other bulking agents may also be added. (Srikaeo et al., 2019)

12. Conclusion and future perspective

Palm sugar is a natural and healthy alternative to the conventional cane sugar as well as artificial sweeteners. It has a wide variety of functional and nutraceutical properties. Processing of palm sugar which is done minimally helps in retention of different phytonutrients. There are a range of bioactive components like polyphenols, antioxidants, flavonoids and volatile compounds present in palm sugar, which are both beneficial to health and impart characteristic sensory attributes as well.

In India and other countries, the production and processing of palm sugar is still localized and small scale. Moreover, commercial scale production of palm sap incurs huge expenses. More modern technologies need to be developed to enable large scale production of palm sugar which meet national and international market standards.

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Chapter 2

Preparation and comparative analysis of sweetened dahi using sugar and palm sugar (Tal misri) and subsequent analysis of colour, texture, syneresis, moisture and nutritional profile of the samples

1. Introduction

Yoghurts are a popular class of food produced by fermenting milk with bacterial cultures. (*Lactobacillus delbrueckii*, *Streptococcus thermophilus* etc.). The active cultures that are used in making yoghurt are called yoghurt cultures. Lactic acid is produced by the fermentation of milk sugars. The characteristic flavour and texture of yoghurt are imparted due to the interaction between lactic acid and protein. (Lee, W.J; Lucey, 2010) Dahi is a popular Indian variant of yoghurt made by mixing thermophilic and/or mesophilic bacteria. The most commonly used bacteria for making dahi is Lactococcus lactis and its subspecies. Dahi can be incubated within a temperature range of 25^{O} C to 45^{O} C based on the composition of active culture used to make dahi. The flavour compound responsible for the characteristic taste and flavour of dahi is diacetyl. Dahi is a ubiquitous food item in Indian households and is known for its numerous heath benefits. The rich nutrient profile of milk is present in dahi as well, except for the nutrient changes that occur due to heat treatment, fermentation and growth of microbes. Dahi is more easily digestible than plain milk because of dispersion of casein particles in the curd due to microbial action. Additionally, dahi shows immunity improvement, antimicrobial, antidiabetic, antiatherogenic, antiallergenic, antioxidative and anticarcinogenic effects. Dahi can be consumed as plain, salted, spiced and sweetened curd. (Mudgal & Prajapati, 2017) Sweetened dahi, commonly known as “mishti doi” in Bengal, is a staple across sweet shops.

Sweetened dahi is made by incorporation of sugar into the dahi making process. At present, conventional cane sugar is mostly used to make sweetened dahi. Cane sugar has a high GI value and has been associated with risks of obesity, cardiovascular diseases, fatty liver disease and increased blood pressure. (Rippe & Angelopoulos, 2016a) Palm sugar is potential alternative to conventional cane sugar because of its lower GI value due to minimal processing as compared to refined cane sugar. Palm sap sugar has also been reported to be rich in vitamins, antioxidants, various minerals and dietary fibres. 2,3-dihydro-3,5-dihydroxy-6-methyl-4(H)-pyran-4-one (DDMP) is an antioxidant present in palm sap sugar which is believed to have the potential to decrease chance of colon cancer developing. (Saputro et al., 2019)

In this paper, sweetened dahi is prepared using both refined cane sugar and palm sugar. A comparative analysis is done between the two on parameters like colour, texture, moisture, syneresis, proximate composition and sensory attributes. It examines the viability of replacing sugar with palm sugar in dahi. To the best of our knowledge, any study on preparation of dahi using palm sugar and compositional analysis has not been undertaken before and this is a completely original piece of work.

2. Materials and methods

2.1. Raw materials

The following list outlines the raw materials used for making sweetened dahi with palm sugar and sugar

Milk (Amul India), Curd (Amul India), Palm sugar (Shrutys Palmyra), Sugar (Fortune) were brought from local markets and Amazon India.

2.2. Chemicals

The following list outlines the list of chemicals used for analyzing sweetened dahi with palm sugar and sugar

Folin-Ciocalteau reagent, potassium di-hydrogen phosphate, methanol, sodium potassium tartarate, sodium bicarbonate, sodium nitrite (NaNO2), glucose, DPPH, potassium ferricyanide, anthrone, aluminium chloride ($AlCl_3$), hydrochloric acid (HCL), Sulphuric acid (H_2SO_4), bovine serum albumin, glucose, Copper sulphate ($CuSO_4$), folic acid, bromine, 2,4-Di Nitro Phenyl Hydrazine, phosphate buffer

2.3. Process of preparation of sweetened dahi

To prepare sweetened dahi, milk was boiled and sugar added to it at the concentration of 10 g/ 100 ml. (Karnopp et al., 2017; Mudgal & Prajapati, 2017) The boiled milk was cooled to an ambient room temperature and poured over earthen pots. This was followed by inoculation with a spoon of (around 1.5%) starter culture. The earthen pots were kept in an incubator at $35^{O}C$ for 24 hours. (Mudgal & Prajapati, 2017)

The same process was repeated by replacing sugar with palm sugar.

2.4. Moisture content

2 metal dishes were taken and weighed using digital weight balance (Sartorious, India). Then 5 g of the dahi samples were weighed and placed in the dishes. The samples were then placed in a hot air oven for 3 hours. Weight became constant at this point. The samples were kept in a desiccator for around 15 minutes to cool the samples to room temperature. The final weights of the samples were measured. (AOAC: Official Methods of Analysis, 1990)

The formula used to calculate moisture content is

$$\text{Moisture content} = [(\text{initial weight} - \text{final weight})/\text{initial weight}]*100$$

2.5. Texture

The texture of dahi samples are analyzed using Instron (TA.HD Plus Texture Analyzer, USA). A cylindrical probe made of Aluminium was fit into the analyzer and allowed to penetrate the dahi samples at the centre. Average thickness of the probe was 2-3 cm at a post test speed of 5.00 mm/sec and depth of 10.0 mm. The factors related to the texture of the dahi sample that were measured are: hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness and resilience were measured. (Bourne, 1990)

2.6. Colour

The colour coordinates ere determined using Hunter Lab color measurement system ((Color Flex 45/ 0, D 65, 10° observer; Hunter Associates Laboratory Inc. Reston, VA, USA). A standard plate (about 3.5 cm with L*=93.45, a*=-1.07, b*=10.6) was used to calibrate the instrument. L* stands for lightness and ranges from 0 (completely black) to 100 (completely white). a* stands for redness and ranges from –∞ to +∞ coordinates (green to red). b* stands for yellowness and ranges from -∞ to +∞ coordinates (blue to yellow). Three readings were taken and average was calculated for L*, a* and b* values. (Granato & Masson, 2010)

$$\text{Hue angle } (h^*) = \tan^{-1}(b^*/a^*)$$

$$\text{Chrome } (C^*) = (a\text{^}2+b\text{^}2)\text{^}(1/2)$$

2.7. Extraction of samples

Sample extracts were prepared by taking 1 g of samples and mixing with 20 ml of 80% methanol. The mixture was then sonicated for about 10 minutes. (Trans-O-Sonic/ D150-1M, Mumbai) for homogenization and reduction of particle size. Then, centrifugation was done (Hanil, Supra 22K, Korea) at 8944×g for about 10 minutes (4^{O}C). The prepared extracts were kept in tubes.

2.7.1 . Antioxidant content and antioxidant activity

Total phenolic content

1.8 ml distilled water and 0.2 ml extracted sample were mixed. 0.2 ml of Folin ciocalteu agent was added to the aforementioned mixture by manual shaking for 5 minutes. Following this, 2 ml of 7% sodium carbonate solution and 0.8 ml distilled water were added respectively. The samples were incubated in the dark for 90 min and absorbance was absorbed at 750 nm [U 2800, Hitachi, Japan]. TPC was calculated using standard curve of gallic acid. (Sharma & Gujral, 2010)

Total flavonoid content

1 ml of extracted sample, 4 ml od distilled water and 0.3 ml of $NaNO_2$ were mixed. 2 ml 1 M NaOH and 0.3 ml $AlCl_3$ were added to the solution. The solutions are incubated for 25 minutes in light and absorbance was measured in the spectrophotometer at 510 nm. TFC was measured using standard curve of catechins. (Xu & Chang, 2007)

Antioxidant activity by scavenging power

0.002 g of 2,2-diphenyl-1 picryl hydrazyl radical (DPPH) was taken and mixed with ethanol (50 ml) in a volumetric flask. The flask was kept in dark under ice cold conditions. 3.9 ml of DPPH solution and 0.1 ml of sample were mixed in a test tube. Then it was kept in a darkness for about 45 minutes. Absorbance was measured by the spectrophotometer at 515 nm.(Yu et al., 2002)

$$\text{Total antioxidant activity} = ((\text{Blank-Sample})/\text{Blank}) * 100$$

Antioxidant activity by reducing power (FRAP)

2.5 ml and 0.2 M phosphate buffer at pH 6.6 and 2.5 ml of 1% potassium ferricyanide were taken. Sample extract was mixed with them. The mixture was incubated at 50^{O}C for 20 minutes. Then, 2.5 ml of 10% trichloroacetic acid was mixed and the mixture was centrifuged (3000 rpm, 10 minutes). The supernatant (2.5 ml) was mixed with 2.5 ml of distilled water and 0.5 ml of 0.1% ferric chloride solution. The absorbance was measured using spectrophotometer at 700 nm. The antioxidant activity was measured using standard curve for ascorbic acid. (Oyaizu, 1986)

2.8. Protein content- Folin Lowry

The standard used to measure protein content is bovine serum. 4.5 ml of reagent I [4 ml of 2 % Na_2CO_3 in 0.1 N NaOH + 1 ml 1% NaK Tartarate in H_2O+ 0.5% $CuSO_4.H_2O$] was added to the sample and incubated for about 10 minutes. Then, 0.5 ml of reagent II [1:1 Folin phenol: water] was added. The test tubes were incubated for half an hour. Then, reagent II was prepared [1:1 Folin phenol: water] and mixed. The test tubes were incubated for half hour. Absorbance at 660 nm was measured using spectrophotometer. (LOWRY et al., 1951)

2.9. Ash content

Samples were kept in crucibles. The initial weight was measured. The samples were then kept in muffle furnace at 550^{O}C for four hours until the formation of ash. The weight was measured and the process repeated until constant weight was attained.

$$\% \text{ Of ash} = (\text{weight of ash/weight of the sample}) *100$$

2.10. Syneresis measurement

Syneresis values of the samples were measured by taking 20 g yoghurt samples in centrifuges cups. They are centrifuged at 350×g for 10 minutes at 4^{O}C. A clear and transparent supernatant is formed at the top. The supernatant is weighed and syneresis calculated by the following formula. (Han et al., 2016)

$$\text{Syneresis } (\%) = (\text{weight of supernatant in g/ weight of yoghurt sample in g}) * 100\%$$

2.11. Sensory analysis by hedonic scale

Sweet dahi made from palm sugar and sugar were coded and handed to 25 panel members for sensory evaluation by hedonic scale. The panel members were made familiar with the analysis techniques. Before tasting, the mouth was cleaned by rising with water. And same was done after tasting. Anonymized trials were conducted. The 9-point hedonic scale was used to score the samples for appearance, smell/aroma, taste, texture/mouth feel and over all opinion. In this scale, 1 stands for "Like extremely" and 9 stands for "Dislike extremely" (ISO, 2007)

3. Results and discussions

3.1. Texture

From the texture analysis, it was seen that palm sugar dahi was harder, chewier and gummier than dahi made from conventional cane sugar. A possible reason for this can be the fact that palm sugar that was used was tal misri i.e. big crystals and the sugar had smooth particles. Palm sugar dahi was more resilient than conventional sugar dahi. The other parameters showed a minor difference between the two with sugar dahi being slightly more springy and cohesive than palm sugar.

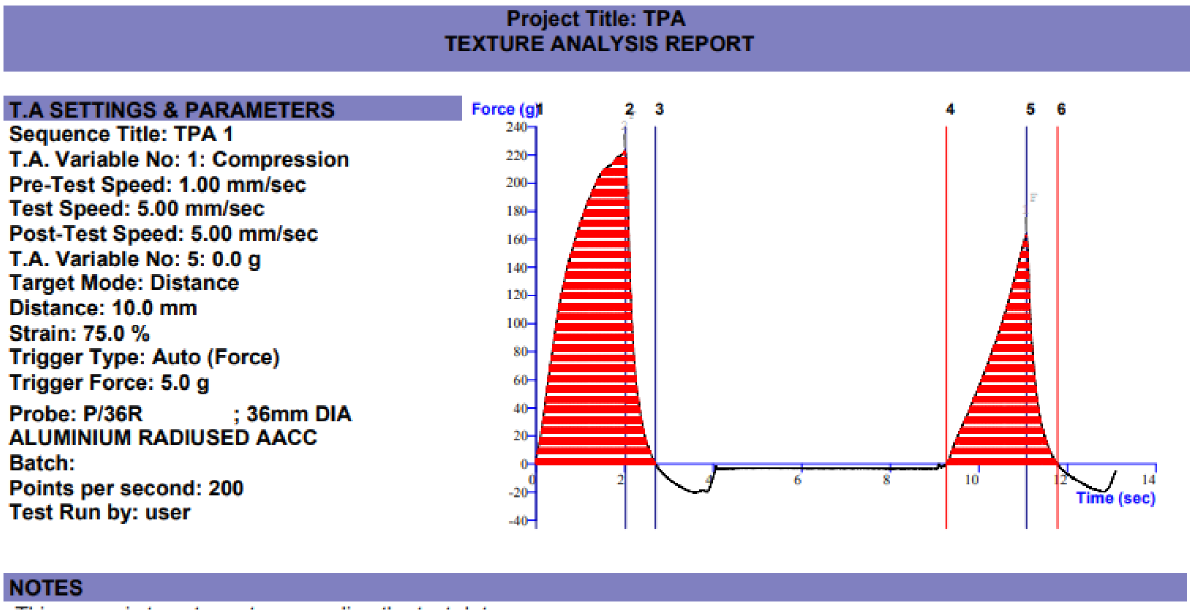

Fig.1. Texture analysis report of dahi sweetened with sugar

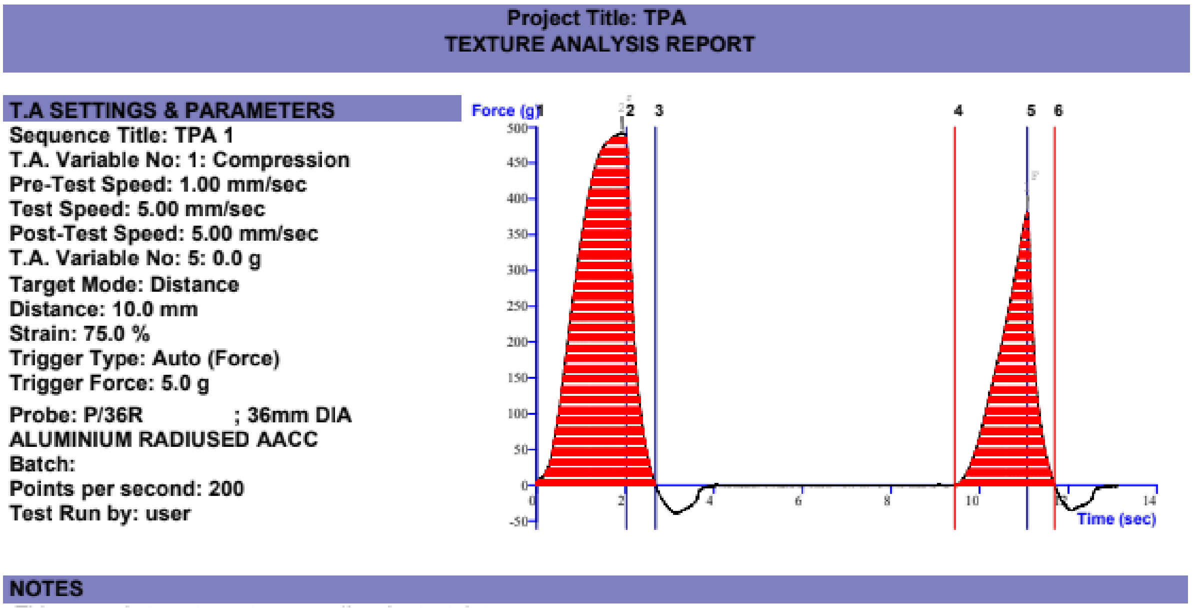

Fig. 2. Texture analysis report of dahi sweetened with palm sugar

Table 1. Comparison of texture parameters between sugar dahi and palm sugar dahi

Texture component	Sugar dahi	Palm sugar dahi
Hardness (g)	222.926	491.732
Adhesiveness (g sec)	-34.701	-32.038
Springiness	0.894	0.807
Cohesiveness	0.473	0.463
Gumminess	105.358	227.667
Chewiness	94.171	183.820
Resilience	0.130	0.164

3.2. Colour

Colour is an important physical attribute by which food items are judged since it is the first aspect of a food a consumer sets his eyes upon. The significant colour imparting pigments in foods are anthocyanins, chlorophylls, flavonoids, betalains and carotenoids. (Vieira et al., 2020)It was observed that L* values for palm sugar dahi were lower than L* values for sugar dahi i.e., palm sugar dahi was darker in colour than cane sugar dahi. This is possibly because palm sugar is minimally processed, and hence more brownish in colour as compared to cane sugar which is highly processed and much whiter in colour. The h* and C* values for palm sugar dahi were calculated to be 84.03^{O} and 20.46 respectively. The h* and C* values were calculated to be 84.16^{O} and 15.04 respectively.

Table 2. L*a*b* values of sugar dahi and palm sugar dahi

Coordinates	Sugar dahi	Palm sugar dahi
L*	86.08	91.92
a*	1.94	-1.53
b*	20.37	14.97

3.3. Antioxidant content and antioxidant activity

Antioxidant content was measured by the means of total phenolic content and total flavonoid content while antioxidant activity was measured by DPPH and FRAP. The total flavonoid and polyphenolic content of the palm sugar dahi was found to be greater than the flavonoid and polyphenolic content of sugar dahi. The antioxidant activities were also found to be greater. This indicates that addition of palm sugar enhances the antioxidant properties of dahi and adds to the health benefits. Similarly, antioxidant activity was found to be greater for palm sugar dahi than cane sugar dahi.

Table 3. Antioxidant content and activity of sugar and palm sugar dahi

	Sugar dahi	**Palm sugar dahi**
Total phenolic content (mg of gallic equivalent/g of dry weight)	8.8	15.6
Total flavonoid content (mg of catechin equivalent/g of dry weight)	118.61	126.40
DPPH (%)	33	41
Frap (µmol of ascorbic acid equivalent/mg of extract)	304	346

3.4. Proximate composition

From the proximate composition of the two curds, it can be observed that the carbohydrate content of palm sugar dahi was found to be lesser than carbohydrate content of sugar dahi. Ash content i.e., inorganic mineral content of sugar dahi was higher than that of palm sugar dahi. Protein content of both the types of dahi was almost equal.

Table 4. Proximate composition of sugar dahi and palm sugar dahi

	Sugar dahi	**Palm sugar dahi**
Carbohydrate	20.6%	14.4%
Moisture	72.6%	76.8%
Ash	1.13%	0.86%
Protein	4.6%	4.3%

3.5. Syneresis

Syneresis is a kind of texture defect in a yoghurt sample. It is indicative of whey separation the yoghurt samples. It is caused by reorganization of micelles of casein. This leads the gel matrix to shrink and subsequent expulsion of water. (Rani et al., 2012). The syneresis of sugar dahi was found to be 12.6% and that of palm sugar dahi was found to 10.4%.

3.6. Sensory evaluation

The mean of all scores in sensory evaluation was taken and the sensory profiles of both dahi s is very close to each other in terms in appearance, aroma, taste and overall opinion. The sugar dahi was reported to have a better texture/mouthfeel.

Table 5. Hedonic scale evaluation of sugar dahi and palm sugar dahi

	Sugar dahi	**Palm sugar dahi**
Appearance	7.8	7.5
Smell/aroma	8.2	7.7
Taste	7.6	7.3
Texture/mouth feel	8.1	7.2
Overall opinion	8.1	7.9

4. Conclusions

The most significant effect of incorporation of palm sugar into dahi as a replacement for sugar was the increase in antioxidant content and activity of the dahi. Differences in colour, texture and carbohydrate were observed as well, owing mainly to the minimal processing done for palm sugar. Syneresis of dahi incorporated with palm sugar was found to be lower than that of dahi incorporated with sugar. All of the above findings indicate scope for creating a robust market for palm sugar incorporated dahi. The most significant challenge to the same is the higher cost of palm sugar and lack of significant change in sensory appeal as compared to sugar dahi. Future research can move in this direction

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Chapter 3

FUTURE PROSPECTS

Palm trees are a rich source of edible and non edible products. Functional foods made from palm sugar and other parts of palm have caught attention of food scientists and researchers in recent years. There is further scope for research in palm sugar incorporated *sandesh,* chocolates, toffees, colas, cookies, soft drinks etc. Many different palm species are present in India, of which palmyra palm and date palm are the most popular. Functional food development with different palm species and their nutritional and sensory attributes can be evaluated. Apart from palm sugar, there are various other products from palm trees like palm jaggery, palm candy, palm fruit pulp etc. which too can be used in functional food development. For example, similar comparative analysis can be done using palm jaggery incorporated dahi and palm fruit pulp incorporated dahi as well.

While doing this research, we observed that entire nutritional profile of many species of palm sap and palm sugar made from palm sap are not done yet. Vitamin and mineral content analysis of many palm species is a lingering gap in this field of research. We also observed that nutritional analysis of granulated palm sugar was limited as compared to the analysis in palm syrup stage. Since palm sugar is expected to find a much greater market in its granulated form, research can be done in this direction as well.

Lastly, the costs of palm sugar processing are much higher at present compared to cane sugar processing. Moreover, most of the processing of palm sugar in India is still done in a traditional and localized manner. Hence, this causes lesser focus on existing quality regulations in India and other countries. This acts as a roadblock to the export of palm sugar and jaggery from India. Consequently, reducing the costs of palm sugar processing and adoption of cost-efficient modern technologies in this field is need of the present time. Additionally, training and increasing awareness among traditional toddy tappers of India can lead to better quality compliance on their part and make these products fit for international markets.

Indeed, this fast developing and fast-growing field and can overall transformative effects on food industry.