PREPARATION AND CHARACTERISATION OF PALM CANDY

A thesis submitted towards the partial fulfilment of the requirements for the degree of Master of Technology in Food Technology and Biochemical Engineering course affiliated with the Faculty of Engineering and Technology, Jadavpur University

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ABSTRACT

Palm candy, also known as palm sugar or jaggery, is a natural sweetener obtained from the sap of some palm trees. Asians have used palm sugar as a traditional sweetener for thousands of years. It is gaining popularity across the world owing to its natural origin, little processing, and health advantages. The manufactured product has undergone nutritional compositional analysis as well as phytochemical analysis (total polyphenol content and total flavonoid content). The FRAP(Ferric Reducing Antioxidant Activity), DPPH(2.4.3 2,2-Diphenylpicrylhydrazyl Radical Scavenging Capacity) and ABTS(2, 2′-Azinobis (3-Ethylbenzothiazoline-6 Sulfonic Acid) Radical Scavenging Property) tests were useful in determining product optimisation. Scanning Electron Microscopy and Energy Dispersive X-Ray spectroscopy analysis were critical in determining the morphology of the product with its elemental analysis. X-Ray Diffraction data was used to investigate the crystal polymorphism. Fourier Transform Infrared Spectroscopy investigation revealed the functional groupings. To determine the hardness of produced Palm candy, a Texture Profile analysis test was performed. Colour analysis was useful in improving the product's processing conditions, and sensory analysis revealed the outcome of all optimisations. The goal of this study is to improve the process conditions for traditionally manufactured "Tal Mishri" (palm candy), followed by nutritional analysis, colour, textural, crystal features, micro textural analysis, and antioxidant potential. The produced samples' shelf life has also been investigated.

LIST OF ABBREVIATIONS

pH - Potential of Hydrogen

g - Gram

°F - Degrees Fahrenheit

LMT - Lakh Metric Tons

Mha - Mega hectare

FCI - Food Corporation of India

EBP - Ethanol Blended Petrol Programme

FRP - Fair and Remunerative Price

CRA - Central Record Keeping Agency

UP - Uttar Pradesh

mg - milligram

DNA - Deoxyribonucleic Acid

Pgi - Phosphoglucose isomerase

°C - Degrees Celsius

TSS - Total Soluble Solid

L/h - Litre per hour

GAE - Gallic acid equivalent

% - percentages

CIE - Commission Internationale de l'Elcairage

°Bx - Degrees Brix

i.e. - that is

N - Normality

NaOH - Sodium Hydroxide

HCl - Hydrochloric acid

ml - millilitre

e.g. - exempli gratia

l - litre

$NaCO_3$ - Sodium Carbonate

$AlCl_3$ - Aluminium Chloride

$NaNO_2$ - Sodium Nitrite

nm - nanometre

s - second

kVA - kilo Volt-Ampere

Hz - Hertz

viz. - videre licet

min - minute

kJ - kilo Joule

kg- kilogram

LPG - Liquefied Petroleum Gas

UV - Ultraviolet

ET - Electron transfer

nA - Nano Ampere

cm - Centimetre

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CHAPTER 1

INTRODUCTION

1. INTRODUCTION

1.1 **AN INTRODUCTION TO PALM CANDY**

Palm candy, also known as Palm Sugar or Jaggery, is a natural sweetener derived from the sap of certain palm trees. For millennia, numerous civilizations throughout the world have employed this traditional sweetener. Making Palm Candy entails tapping the flower buds of palm trees, extracting the sap, and then boiling it down to eliminate the water content. The sap hardens into solid blocks or granules as it cools, preserving its unique brown hue and rich, caramel-like flavour.

Palm Candy's distinct flavour finds a home in traditional Asian cuisines, notably in South Asian and Southeast Asian dishes. It is popular in a variety of candies, desserts, and even savoury foods. It is also used as a natural sweetener in beverages including herbal teas, smoothies, and traditional health drinks, boosting their overall flavour profile while giving a healthier alternative to refined sugars. It is a prominent ingredient in traditional Asian cuisines, notably in South Asian and Southeast Asian dishes, due to its earthy, caramel-like flavour with a hint of smokiness. Palm Candy includes antioxidants and prebiotic qualities that enhance general health and digestive well-being in addition to its culinary purposes. It is a more healthy option since it contains critical vitamins and minerals such as iron, magnesium, potassium, and calcium. Furthermore, Palm Candy has a lower glycemic index than refined sugar, resulting in a slower and more consistent rise in blood sugar levels. This feature makes it an excellent alternative for people who have diabetes or want to better regulate their blood sugar levels. However, because Palm Candy is still a kind of sugar, excessive consumption might lead to the health problems associated with heavy sugar consumption (Saputro et al., 2019).

1.2 **HISTORY OF PALM CANDY**

<u>Palm Candy History: A Sweet Journey Through Time</u>

Palm candy, an all-natural sweetener derived from the sap of palm trees, has a rich and diverse history that spans centuries and multiple cultures. This delightful sweetener has been cherished for its unique flavour and nutritional benefits, making it a popular choice in traditional cuisines and medicinal practices.

<u>Ancient Origins: From Nectar of the Gods to Culinary Delicacy</u>

The origins of Palm Candy can be traced back to ancient civilizations, where the sap of certain palm trees was revered for its divine and healing properties. In various cultures, the sweet sap was considered the "nectar of the gods" due to its natural sweetness and perceived mystical qualities. The Date Palm tree (*Phoenix dactylifera*) was one of the primary sources of this sweet sap and played a crucial role in the development of Palm Candy.

Ancient palm sap collectors would skilfully tap the flower buds of the palm trees to extract the sap, which was then boiled down to create a concentrated syrup. This syrup was later cooled and solidified into delectable palm candy blocks or granules. The process of making Palm Candy was often a communal activity, passed down through generations, and remained an integral part of cultural practices (Johnson, 1992).

Global Spread and Cultural Significance

Over the centuries, Palm Candy travelled across continents and became an essential ingredient in various traditional cuisines. In South Asia, particularly in India, Palm Candy is a significant component of many beloved sweets and desserts. From Payasam, a creamy rice pudding, to Laddoo, a delectable Indian sweet treat, Palm Candy has a prominent place in celebratory feasts and festivals.

In Southeast Asia, countries like Thailand, Indonesia, and Malaysia also embraced Palm Candy in their culinary traditions. It is an essential ingredient in numerous traditional sweets, sauces, and beverages, adding a distinctive caramel-like flavour to dishes.

Beyond its culinary significance, Palm Candy held a special place in ancient medicinal practices. Ayurveda, the ancient Indian system of medicine, recognized the health benefits of Palm Candy and used it as a natural remedy for various ailments. Its rich mineral content and prebiotic properties were believed to support digestive health, making it a popular choice to treat digestive disorders (Ho et al., 2008).

Preserving Tradition in Modern Times

As modernization and globalization have influenced food choices, traditional sweeteners like Palm Candy faced competition from refined sugars and artificial alternatives. However, health-conscious individuals and culinary enthusiasts have recognized the value of preserving the age-old tradition of Palm Candy.

With growing awareness about the negative impacts of refined sugars on health, there has been a resurgence of interest in using natural sweeteners like Palm Candy. Its low glycemic index, antioxidant content, and absence of chemical additives make it an appealing choice for those seeking healthier alternatives (Lee et al., 2009).

Moreover, efforts to sustain traditional practices and support local communities involved in Palm Candy production have gained momentum. By choosing Palm Candy, consumers not only indulge in a delightful and unique flavour but also contribute to the preservation of cultural heritage and sustainable practices.

Palm Candy's history is a tale of time-honoured traditions, cultural significance, and a culinary journey that has transcended generations. From its ancient origins as the "nectar of the gods" to its continued presence in modern kitchens, Palm Candy remains a symbol of natural sweetness and cherished heritage. As we savour its caramel-like flavour and reap its nutritional benefits, we honour the artisans and cultures that have preserved this sweet treasure through the ages (Naknean et al., 2009).

1.3 **SIGNIFICANCE AND HEALTH BENEFITS OF PALM CANDY**

Palm Candy: Embracing the Natural Sweetness and Health Benefits

In a world where processed sugars and artificial sweeteners dominate the market, Palm Candy stands out as a wholesome and natural sweetening option. This delightful sweetener, derived from the sap of select palm trees, carries immense cultural and historical significance while offering an array of health benefits. In this article, we explore the significance of Palm Candy and uncover the various ways it promotes well-being.

Cultural Heritage and Historical Significance

Palm Candy's history is deeply intertwined with ancient civilizations, where it was revered as a divine gift due to its natural sweetness and mystical properties. It played a vital role in religious ceremonies and cultural practices in various regions, particularly in South Asia and Southeast Asia, where palm trees thrived. The traditional process of tapping the palm tree flower buds to collect the sap and transforming it into Palm Candy has been passed down through generations, preserving cultural heritage and culinary traditions.

In modern times, as we seek to rediscover natural and sustainable practices, Palm Candy has regained popularity as a healthier and environmentally friendly sweetener. Its significance lies not only in its delightful flavour but also in its connection to the roots of diverse cultures (Sapuan et al., 2018).

Health Benefits of Palm Candy: A Sweet and Nourishing Choice

1. **Rich Nutritional Profile**: Palm Candy retains essential nutrients during its preparation, making it a nutritious sweetener. It contains vital minerals like iron, magnesium, potassium, and calcium, contributing to overall health and supporting bodily functions.

2. **Low Glycemic Index**: The low glycemic index of Palm Candy ensures a gradual release of sugar into the bloodstream, preventing sudden spikes and crashes in blood sugar levels. This characteristic makes it a preferable option for individuals with diabetes and those concerned about managing their blood sugar.

3. **Antioxidant Powerhouse**: Palm Candy is a natural source of antioxidants, which play a crucial role in neutralizing harmful free radicals and reducing oxidative stress in the body. Antioxidants support a robust immune system and aid in disease prevention (Sanyang, 2015).

4. **Gut Health Support**: With its prebiotic properties, Palm Candy fosters the growth of beneficial gut bacteria. A healthy gut microbiome is essential for efficient digestion, nutrient absorption, and overall digestive well-being.

5. **Free from Chemical Additives**: Palm Candy is produced using traditional methods that involve no harmful chemicals or additives. As a result, it is a purer and safer alternative to refined sugars (Bachtiar et al., 2012)

Incorporating Palm Candy into Your Diet

Integrating Palm Candy into your diet is a simple and delicious way to experience its benefits. In various Asian cuisines, it is used as a primary sweetening agent in an array of traditional dishes. From mouthwatering desserts like Halwa and Gulab Jamun to savoury sauces and dressings, Palm Candy adds its unique caramel-like flavour to elevate the taste of various dishes.

Palm Candy can be dissolved in herbal teas, milkshakes, and smoothies for those seeking healthier beverage options, offering a natural and flavourful sweetness.

Palm Candy goes beyond being a mere sweetener; it is a symbol of cultural heritage and a health-conscious choice. Embracing this natural sweetness allows us to reconnect with our roots and appreciate the wisdom of ancient traditions. Its nutritional benefits, low glycemic index, and pure form make it an ideal substitute for refined sugars and artificial sweeteners. So, let us savour the goodness of Palm Candy, celebrating its richness in flavour and significance while nourishing our bodies with a healthier, natural alternative (Amin et al., 2010).

1.4 IMPORTANCE OF SUGAR IN THE FOOD INDUSTRY

Sugar (sucrose) is a colourless crystalline chemical compound consisting of one molecule of D-glucose and one molecule of D-fructose following the elimination of one molecule of water. Sugar is perhaps the most cost-effective food in terms of calories generated per acre tilled. Sugar provides energy nutritionally. The sugar business is India's second largest agro-based sector, contributing considerably to rural socio-economic development (Solomon, 2011). Sugar is used in the creation of thousands of culinary products ranging from cured meats to preserves and frozen fruits to confections.

Because sucrose improves the palatability of many meals high in proteins, minerals, or vitamins, it also serves a nutritional purpose in addition to providing calories (Cotton et al., 1955). For example, adding sucrose to processed orange juice high in vitamin C but with a low sugar-acid ratio makes the juice more palatable, resulting in the use of an important product that would alternately go to waste. Additionally, sugar improves the shelf life of canned orange juice and many other items. Thus, it appears that appropriate sugar usage is both nutritionally and economically beneficial. Wilcox et al. discovered that giving sugar to cattle ahead of their slaughter could enhance meat quality and dressing percentage. Sucrose, when used before drying, enhances the duration of the shelf life of dried eggs. Colour can appear in frozen peaches during storage and thawing. Sucrose was compared to dextrose and high-conversion corn syrup in the manufacturing process of frozen peach packs. The sucrose samples exhibited the best colour out of the packets produced with a single kind of sweetening agent. Sugars have a vital role in the development of colour in meat curing. According to Wilcox et al., sugars here have the role of modifying colour by assisting in the development of reducing conditions, preventing oxidation of ferrohaemoglobin to ferri-haemoglobin in storage, and assisting in the conservation of the meat during curing by its protein-sparing action. The Maillard reaction, which occurs under heat between sugars (predominantly glucose and fructose) and amino acids (proteins), is responsible for the golden-brown crust of baked goods such as biscuits and toasted bread. The production of caramel demonstrates sucrose's amazing adaptability once more. Caramel is colloidal, and its isoelectric point, or the pH at which it coagulates and precipitates, is critical in foods that use it for colouring and flavouring, such as beer, soft drinks, syrups, soups, pickles, candy, and so on. Sucrose has significant antioxidant capacities. This is essential for colour, flavour, and ascorbic acid retention. Strawberry and black currant juices, jams, and a variety of other foods have been reported to slow the autoxidation of ascorbic acid. When enough sucrose is added to apricot, peach, plum, and guava nectars, as well as different blends, they may be produced and kept at 0° F for a long time with no loss of fresh fruit flavour. The addition of sugar delayed the development of oxidative rancidity in sunflower oil. Sucrose when applied to eggs before spray drying hindered loss of vitamin A and beating power. Adding 4 g of sucrose per litre of milk with or without the addition of enzyme, produced a cheese-like coagulation, whereas adding lactose or glucose produced a gelatinous one. The role of sugar in gel formation is essentially one of dehydration. Sugar, in the form of molasses, has a strong dehydrating impact that food technologists can employ as a control tool in moisture determination. The high sugar content inhibits microbial development and degradation by raising osmotic pressure, which restricts microbial growth and extends the shelf life of these goods. Sugars are also at the core of alcoholic fermentation, which is the conversion of sugars to ethanol (alcohol) by yeasts and utilised to manufacture alcoholic drinks (Ilyas et al., 2017).

1.5 **CURRENT SCENARIO OF SUGAR-BASED FOOD INDUSTRY**

India, the world's second-largest sugar exporter, has risen to become the world's leading producer, consumer, and exporter of sugar. The sugarcane and sugar industry is India's second-largest agro-based sector after cotton. In Sugar Season (October-September) 2021-22, a record of more than 5000 LMT of sugarcane was produced in the country out of which around 3574 LMT of sugarcane was crushed by sugar mills to make about 394 LMT of sugar (Sucrose). Out of this, 35 LMT of sugar was redirected to ethanol production and 359 LMT of sugar was generated by sugar mills. Sugarcane is one of the most important industrial crops in the country, covering approximately 5.0 Mha. Because sugar mills are located in rural areas and provide large-scale employment to the rural population, the sugar industry provides substantially to the rural economy. About 0.5 million people in sugar mills and 50 million sugarcane farmers, their families and a vast mass of agricultural labour are engaged in sugarcane cultivation, harvesting and associated activities, constituting 7.5% of the rural population. The sugar business in India has played an important role in expediting socioeconomic development in villages by mobilising rural resources, creating jobs, a rise in revenue, and an overall improvement in transportation and communication facilities. Furthermore, many sugar mills have built schools, colleges, medical centres, and hospitals for the welfare of the rural population. A significant amount of sugar factories have diversified into product-based industries, investing in and establishing distilleries, organic chemical plants, paper and particle board factories, and co-generation plants. The Indian sugar industry is green i.e. self-reliant in its energy demands and also creates excess exportable electricity through co-generation. The multiple by-products of the sugar industry also offer economic growth by fostering a myriad of subsidiary industries. Sugarcane has evolved into a multi-product crop, serving as the primary raw material for the production of sugar, ethanol, electricity, paper and board, and a variety of ancillary products. Sugarcane green tops are an important source of bio-energy (cattle feed) and are in high demand in rural areas. Molasses is an essential feedstock for distilleries, and the distilleries in the nation satisfy a major portion of the country's ethanol demand (Solomon, 2011).

India produced 35.8 million tonnes during the marketing year 2021-2022. It is predicted to reach 36.5 million tonnes in the marketing year 2022–2023. In 2022, Maharashtra overtook Uttar Pradesh to reclaim India's top spot in sugar production. The bedrock of the Indian sugar industry is sugarcane, a hefty and perishable product. It cannot be retained for a prolonged amount of time since the sugar within is lost. As a result, the enterprises are strategically located near sugarcane growing regions to provide a consistent supply of sugarcane and to save transportation expenses. Entrepreneurship is helping to expand the sector. Private sugar mill ownership is widespread in Uttar Pradesh. Farmers own and operate the remainder of the sugar mills as cooperatives. Maharashtra is home to a large number of sugar mills with this sort of ownership. To assist the sector in dealing with the problem of excess output and low sugar prices, the government developed a sugar buffer stock. Sugar buffer stocks are managed collectively by the mills, as opposed to wheat and rice buffer stocks, which are overseen by the government through FCI. The EBP initiative was developed to promote ecologically friendly fuels (by increasing the usage of ethanol) and reduce energy imports. The EBP scheme ensures a continuous market for ethanol, which helps the sugarcane sector. The 2018 National Biofuel Policy expands the spectrum of raw materials accessible for the production of ethanol by authorising the utilisation of sugarcane juice and other sugar-containing materials such as sugar beet and sweet sorghum, among others. The prosperity of the sugar industry is the result of synchronous and collaborative efforts by the Central and State Governments, farmers, sugar mills, and ethanol distilleries, as well as a very supportive overall business environment in the country. Timely Government interventions over the previous 5 years have been vital in strengthening the sugar industry step by step from pulling them out of financial difficulty in 2018-19 to the point of self-sufficiency in 2021-22.

1.6 **PROBLEMS ASSOCIATED WITH CANE SUGAR AND OTHER COMMON SOURCES OF SUGAR**

Sugarcane is a crop that demands a lot of water. 1 kg of sugar normally requires 1500-2000 kg of water. However, based on existing water use patterns, only about half of the demand will be met by 2030. Water productivity is the amount of revenue created per cubic metre of extracted fresh water. Sugarcane and paddy consume more than 70% of the irrigation resources in India. Because groundwater supplies account for most of this, it has had a severe detrimental influence on many locations' water tables. However, despite the continual rise in sugarcane prices, the primary source of challenges for the sugar business over the past few years has been the declining/stagnant price of sugar. Sugar mills struggle to purchase sugarcane from farmers due to the high FRP and restrictions enforced by the CRA. Payments are therefore postponed as a result, affecting subsequent agricultural seasons. According to Food Ministry statistics, mills acquired sugarcane worth Rs 33,023 crore in UP during the 2020-21 season, with 15.3% still due on September 30, 2021, the season's end. Every authorised mill must buy from cane farmers in the cane reservation zone, and farmers must sell to the mill. This structure, however, limits the farmer's capacity to bargain. He must sell to a mill even if there are cane arrears. Furthermore, mills are limited by the quality of cane supplied by local farmers. In our country, mechanisation in sugarcane agriculture is frequently less than 40%. The sector is increasingly unstable due to personnel shortages and high manufacturing costs. (Huzaifah et al., 2017)

1.7 **PALM CANDY AS AN ALTERNATE SOURCE OF SUGAR**

Palm candy, also known as "Tal mishri," is made from palm tree sap/nectar (neera). Jaggery, often known as gur, is a sugary food product made all over the world. Various palm types account for approximately 30% of total jaggery products produced in India. Palm candy, a crystalline transparent sweet candy, is one of the most popular items enjoyed widely in several Indian regions. Palm candy has certain health advantages, including its usage for urinary problems, cough and cold, digestion, and chicken pox, as well as its use during pregnancy. Palm jaggery-based candy was effectively produced, and the alterations that occurred throughout the preparation were meticulously calculated. The physicochemical properties, predominantly the crystalline structure of the foods, have much significance in the product quality, stability and mouthfeel during product ingestion (Chauhan et al., 2017).

The majority of Palmyra palms have been tapped to generate fresh or fermented juices, syrup, and sugars. They provide sugar yields that surpass sugarcane production. A large volume of filtered palm sap is transferred into a large wok for traditional palm sugar production, where the filtered palm saps are heated on a wood-fired stove for a few hours at around 100 degrees Celsius until they become concentrated to obtain their typical scent. During the heating process of palm sap, two primary processes occur- the Maillard reaction and caramelization. After the palm sap liquid has been heated, it is poured into bamboo moulds to make pure solid palm sugar that is ready for consumption. For thousands of years, Asians have used palm sugar as a traditional sweetener. It is becoming increasingly popular across the world due to its natural origin, little processing, and health benefits. One of the most important health claims is its glycemic index (GI). Furthermore, palm sugars are unprocessed, little processed, and include natural sugars. They may include nutritionally important amounts of minerals and vitamins and antioxidant capabilities. According to research, palm sugar (gula anau) has the highest amount of antioxidant activity compared to other cane sugar forms, with an antioxidant activity comparable to 1.7 mg of vitamin C per 1 g of sugar. Unrefined sugars, as elements of non-centrifugal cane sugars, have nutritionally and functionally substantial amounts of minerals, vitamins, and phenolics, among other components, as well as antioxidant capabilities, according to recent papers. Palm sugars come in a variety of types. Because fresh palm sap has a short shelf life, it can be prolonged using typical thermal processing methods such as pasteurisation or sterilisation. Cloudiness may occur during the storage of thermally treated palm sap. This loss in quality might be a result of either the dispersion of undissolved particles, which is generally induced by the interaction of polyphenol chemicals and proteins, or the development of brown pigments. Clarification using chemicals such as polyvinylpolypyrrolidone, bentonite, gelatin, and chitosan might enhance the quality. Clarifying agents might similarly be utilised in the case of palm syrup. On the other hand, the most serious issue with palm sugar syrup is crystallisation. Without sufficient management, crystallisation usually happens within a few days of storage. To avoid crystallisation, several measures might be taken. The system must have enough low molecular mobility (high viscosity) to prevent molecules from forming crystals, or crystallisation must be hindered by the addition of inhibitory substances such as corn syrup and other sugars. Proper formulation inhibits crystallisation kinetically. The shelf life of items where crystallisation is undesirable is frequently directly proportional to the induction time for nucleation under storage circumstances. To prevent unwanted crystallisation, nucleation must be significantly prevented. Because palm sugars are lightly processed, they contain natural phytonutrients, which have several biological roles that benefit human health. These include significant levels of polyphenols and flavonoids, excellent antioxidant capabilities, and the capacity to protect DNA from harm. Palm sugars have a lower pGI when utilised in carbohydrate dishes. There is growing awareness of the detrimental effects of present global food consumption habits, and natural and organic goods are becoming more popular (Srikaeo et al.,2019).

1.8 **PREVIOUS LITERATURE RELATED TO PALM CANDY AND PALM SUGAR**

According to (Maryani et al., 2020), the effect of spray dryer inlet temperature on the characterization and total phenolic content of palm sugar has been studied. The spray dryer operating conditions used were 160°C- 220°C inlet temperature with a feed flow rate of 2 L/h, while for outlet temperature was 85°C. The high inlet temperature produced a higher crystallinity of sucrose and did not agglomerate and was not sticky. However, the high temperature of the spray dryer inlet produced palm sugar that was browner than the low temperature one. The effect of increasing the temperature of the spray dryer produced irregular total phenolic. The total phenolic at 220°C was higher than 200°C. Likewise, the temperature of 180°C generated total phenolic was higher than the temperature of 160°C. The total phenolic of palm sugar analyzed in this study was quite large within the range of 49 ± 0.01 to 63.6 ± 0.01 mg of GAE/100 g samples.

Palm sap sugar is a natural sweetener made from sap/nectar collected from the flowers of several species of palm trees. This sugar has been used as a traditional and alternative sweetener in the Southeast and South Asian regions. In these regions, the species of palm trees are found in abundance, with Indonesia and the Philippines being the largest palm sap sugar producers in the world. This sugar is widely used as a sweetener for beverages and foods. It does not only provide the sweetness to the products, but also develops their colour, aroma, and taste. In this review, sugar production (composition, factors influencing the quality of sap/nectar), processing, composition, aroma profile, factors influencing the quality, health benefit and potency of palm sap sugar are discussed (Saputro et al., 2019).

The palm syrup is from naturally grown palm trees. Owing to its unique odour and taste, the syrup has a high potential to be a new sweetener that is natural and chemical-free. Thus, this research was to develop the crystallized sugar formulation and processes. Besides palm syrup, brown sugar was added in the production steps. Mixture ratios of syrup and brown sugar were varied to get the final solution concentration before crystallization occurred. The crystallization temperature was controlled throughout the experiment. The result showed that 83±1 °Brix of 60% syrup and 40% brown sugar mix achieved a high yield of 3-4 mm crystal size. As the crystallization period increased, the CIE colour values (L*, a* and b*) increased which indicated the brighter colour of the mixture solution. Focus group result showed a favour of the natural brown colour and taste of the crystals despite their slow dissolving in the beverage. The sweetness was perceived even with a small amount of crystals added. Since it is natural and chemical free, the crystallized sugar produced by this process has good colour, unique taste and a possibility to be a new form of natural sweetener in the market (Suwansri et al., 2009).

Sinthiya R. stated that to make osmotic dehydrated ginger candy, Palm sugar syrup is used as an osmotic agent. Ginger is pretreated and osmosis is done with palm sugar syrup. The water is drained after the osmosis process. The product left after draining is dried, packed and stored. The acceptability of the product is evaluated using 5 5-point hedonic scale.

According to (Arsad et al., 2015), five samples were prepared using Palmyra jaggery at different concentrations of 10, 20, 30, 40 and 50 g, while sugar and water were kept constant at 100 g for each sample. The samples were mixed thoroughly and then heated in an open pan made of stainless steel at 105°C ± 6°C; the heating continued until the concentrate achieved a total soluble solids (TSS) value of 70°Brix. The concentrate was allowed to crystallize for 5 days in an incubator at 30°C.

According to (Upadhyaya et al., 2023), 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. Store-bought Neera, a mix of palm sap, cane sugar, and water, was filtered through a fine muslin cloth followed by heating in a flat bottom aluminium pan. The samples were heated till the temperature reached 90°C, after which lime was added to the mix at concentrations of 0.2 to 0.6%. Five samples were prepared by boiling at temperatures of 90−130°C (Using lime at optimal concentration). Boiling times of 140 to 190 min were used to optimize the process.

1.9 **AIMS AND OBJECTIVES OF THE STUDY**

The research aims to optimise the process condition for traditionally prepared “Tal Mishri” (Palm candy) followed by its nutritional analysis, colour, textural, crystal characteristics, micro textural analysis, and antioxidant potential. The shelf life of the prepared samples has also been studied.

CHAPTER 2

MATERIALS AND METHODS

2.1 **PRODUCTION OF PALM CANDY**

2.1.1. **LIST OF INGREDIENTS**

For the production of Palm candy, all the ingredients that have been used are:

a. Cane Sugar : M-30 White Cane Indian Sugar is finished from Organic Sugar Cane. The Colour of Grains is Sparkling White and Grain Size is Medium to Bold. M-30 White Cane Sugar is the most demanded Sugar Grade of India.
b. Palm candy syrup: Palm candy syrup has been used for the production of Palm candy.
c. Palm jaggery: The Jaggery is processed from the unfermented Palmyra tree sap called neera. It is highly priced due to its medicinal properties. It has an intense, earthy taste or reminiscent of chocolates in its taste. The palm jaggery obtained after processing is darker and richer in colour. It is slight salty to taste but much healthier of the two. Due to its cooling effects over human body, it is of high value. It does not have the bone meal content which is used for whitening processed sugar.
d. Water: Clean potable has been used in the preparation of Palm candy.

A total of 22 trial runs have been completed to optimize the process of Palm Candy preparation.

2.1.2 **INSTRUMENTS USED**

a. Digital Weight Scale: A Digital Weight Scale(i-05) of the brand i-Scale has been used to carefully weigh all the raw ingredients before the process of making Palm candy.

b. Refractometer: Brix refractometers are a standard tool for determining the sugar level of a solution. Increasing the sugar content raises the refractive index. The sugar concentration may be determined by passing light through a sample and measuring the refraction, or the amount that the light bends. The Brix scale is used to calibrate refractometers, with one-degree brix (°Bx) equaling 1% sucrose by mass. For this study, an ERMA refractometer of the range 58-92 °Bx has been used.

c. Digital Temperature Probe: A Thermocare Digital Thermometer has been used to measure the temperature of the mixture during processing.

2.1.3 **APPARATUSES USED**

a. Gas oven: A dual benchtop Gas Stove has been used in this study for the preparation of Palm Candy.

b. Incubator: This research has employed the use of a PHC Laboratory Incubator to control the temperature of the candy mixture during crystallisation to facilitate the process. It has been observed that a temperature of 35°C is optimum for the process of crystallisation in Palm Candy.

2.1.4 **PROCEDURE TO PREPARE PALM CANDY**

The following process was employed in the preparation of Palm candy:

1. The Brix values of Palm jaggery(86°Bx) and Candy syrup(15°Bx) were checked.
2. All the ingredients were accurately weighed using a Digital weight scale and kept in separate containers.
3. A deep stainless steel pan was put on the flame.
4. 375 ml water and 650 g sugar were poured on it and allowed to melt.
5. Then, 250 g of Candy Syrup(pH=5.6) and 10 g of Palm jaggery(pH=6.2) were poured into the pan.
6. It was mixed well with a ladle and allowed to boil while stirring occasionally.
7. The temperature of this mixture was checked using a Digital Temperature Probe.
8. It was allowed to boil for approximately 15 minutes until the Brix value of the mixture reached 83°.
9. The temperature of this mixture was checked and found to be 122°C.
10. This mixture was then poured onto a deep tray.
11. The tray containing the mixture was put over a thermocol plate and kept inside the incubator at 35° C, covered with a cloth.
12. The tray was kept inside for 7 days undisturbed and allowed to crystallise.
13. After 7 days, the tray was taken out and uncovered. Then, the tray was put upside down on a strainer and kept for 24 hours to drain out all the liquid. The drained-out liquid i.e. the sap was collected in a beaker and weighed.
14. The solid hardened mixture was then broken down into smaller chunks and sun-dried for 5-6 hours to get the final product which was then further examined.

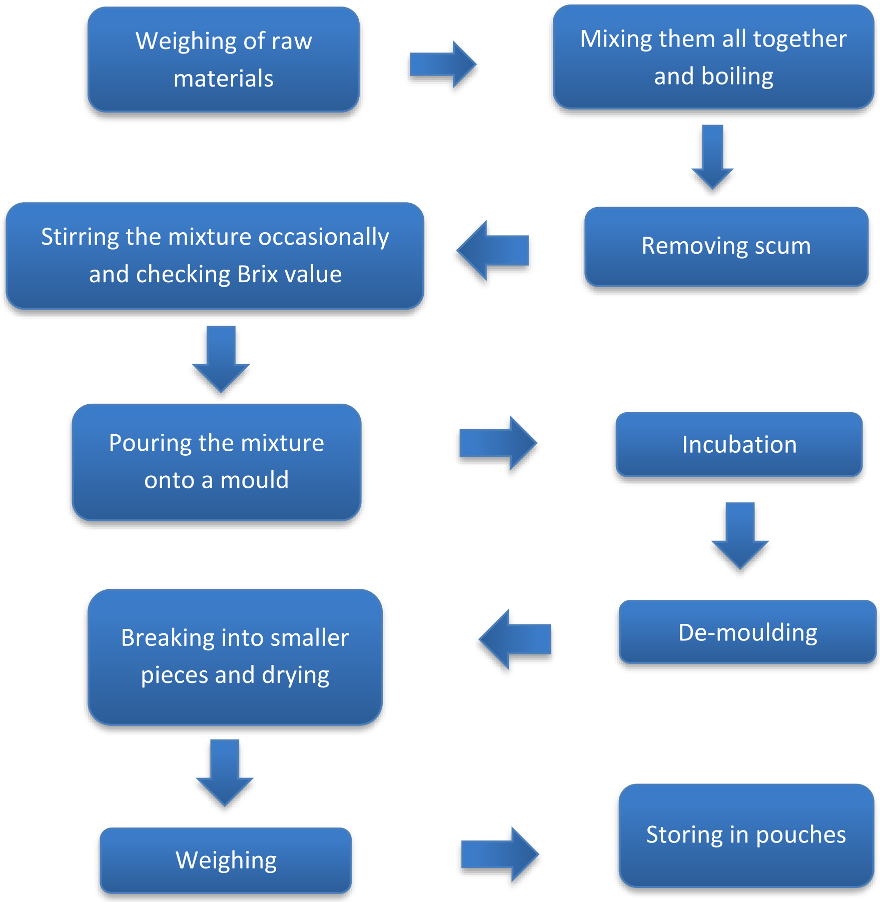


Figure 1: A flowchart showing the complete process of Palm Candy production

2.1.5 ENDPOINT PARAMETERS

The Endpoint Parameters that have been checked and duly noted down are:

a. Brix - Brix can be measured in the field, on a plant, or at a shop. It indicates the number of dissolved solids in a liquid measured via its specific gravity (SG). One degree Brix is 1 g of sucrose in 100 g of solution (1°Brix = 1% sugar).

b. Temperature – The end point temperature has been found to be more than 110°C for all the trial runs.

Other than this, the total time taken for the preparation of Palm candy has also been observed.

2.2 NUTRITIONAL COMPOSITION ANALYSIS

Moisture content, protein, fat, carbohydrate, and ash content were analyzed according to previously described methods (Kaur & Goswami, 2020; Sawant et al., 2015).

2.2.1 **DETERMINATION OF MOISTURE CONTENT**

Principle: All foods contain solids, water and other chemicals. The moisture contained in a material comprises all those substances that vapourize on heating and lead to weight loss of the sample. The weight is determined by a balance and interpreted as the moisture content. According to this definition, moisture content includes not only water but also other mass losses such as evaporating organic solvents, alcohols, greases, oils, and aromatic components, as well as decomposition and combustion products (Maryani et al., 2021). The moisture content, also called "moisture assay", is one of the most important analyses performed on most food products.

Moisture content is the quantity of water contained in a food material. Moisture content is used in a wide range of scientific and technical areas and is expressed as a ratio, which can range from 0 (completely dry) to the value of the materials' porosity at saturation. It can be given on a volumetric or mass (gravimetric) basis. Moisture content is expressed as a percentage of moisture based on total weight (wet basis) or dry matter (dry basis). Wet basis moisture content is generally used. A dry basis is used primarily in research. The moisture content is expressed by the following formulae -

$$M_w \text{ (Wet basis)} = \{(w-d)/w\}*100$$

$$M_d \text{ (Wet Basis)} = \{(w-d)/d\}*100$$

Where,

M_w is the moisture content of the food material on a wet basis,

M_d is the moisture content of the food material on a dry basis,

w is the initial weight of the food material and

d is the final weight of the food material after drying

Apparatus Required:

a. Porcelain dish with cover
b. Thermostatically controlled Hot Air Oven
c. Desiccator
d. Digital weight scale

Samples:

Prepared Palm Candy, White Cane Sugar, Palm candy syrup and Palm Jaggery

Procedure:

A definite amount of each of the samples was weighed and put into a clean porcelain dish. The dishes were then put inside a thermostatically controlled Hot air Oven at 105°C for 3 hours initially. After that, the dishes were taken out of the Oven and put inside the Desiccator for 5 minutes to let them cool down. The weight of the porcelain dishes was observed. The dishes were then put inside the oven again for another 30 minutes and this whole process was continued till two successive weight values were observed to be the same.

2.2.2 **DETERMINATION OF ASH CONTENT**

Principle:

Ash content represents the inorganic residue (minerals) remaining after ignition and complete oxidation of organic matter. Dry ashing involves heating the sample in a muffle furnace at 500 – 600 ^{o}C. Since some elements such as Fe, Se, Pb and Hg may be partially volatilized during dry ashing, wet ashing can also be done using acids or oxidizing agents or combinations to oxidize organic substances (Marshall, 2010). This method is especially preferred when ashing is a preliminary step for elemental analysis (i.e. determination of specific minerals present in the sample).

*Ash content % = (Weight of ash/Weight of food sample)*100*

Apparatus Required:

a. Silica Crucible with cover
b. Muffle Furnace
c. Digital weight scale

Samples:

Prepared Palm Candy, White Cane Sugar, Palm candy syrup and Palm Jaggery

Procedure:

Each sample was weighed and put into a different silica crucible which was put on a heater to get rid of any free moisture. Then, they were put inside the Muffle furnace at 550°C for 3-4 hours until the samples were completely charred and only ash remained. They were then put inside a desiccator for 30 minutes after which their weight was noted down.

2.2.3 **DETERMINATION OF PROTEIN CONTENT**

Principle:

The determination of protein content by the Kjeldahl method is used for the quantitative determination of nitrogen contained in organic substances plus the nitrogen in inorganic ammonia and ammonium. Other forms of inorganic nitrogen, for instance, nitrate, are not included in this measurement. A food sample is digested with a strong acid so that it releases nitrogen which can be determined by a suitable titration technique. The amount of protein present is then calculated from the nitrogen concentration of the food (Sáez-Plaza et al., 2013)

The Kjeldahl method can be conveniently divided into three steps:

Digestion: The food sample is heated in the presence of Sulphuric acid (an oxidising agent that digests the food), anhydrous Sodium sulfate (to speed up the reaction by raising the boiling point) and a catalyst such as Copper (to speed up the reaction). It converts any nitrogen in the food (other than that which is in the form of nitrates or nitrites) into ammonia and other organic matter to Carbon dioxide and water. Ammonia gas is not liberated in an acidic solution as Ammonia is in the form of ammonium ion which binds to the sulfate ion and thus remains in solution.

Neutralisation: The solution in the digestion flask is made alkaline by the addition of Sodium hydroxide, which converts the Ammonium sulfate into ammonia gas that moves out of the digestion flask and enters the receiving flask – which contains an excess of standard acid.

Titration: The solution in the receiving flask is titrated with an acidic solution using an indicator.

$$Nitrogen\,\% = \frac{Vol * N * F * Mol.Wt.of\ Nitrogen}{Wt.of\ sample * 10}$$

Where,

Vol = (initial – final) volume of 0.1N HCl in the Burette

N = Normality of HCl (i.e. 0.1)

F = Acid Factor of HCl (i.e. 1)

Mol. Wt. of Nitrogen = 14.0067

$$Crude\ Protein\ \% = Nitrogen\ \% * F' * 10$$

Where,

F’ = 6.25 (depends on the sample)

10 = Actual volume of digested sample taken

Apparatus Required:

a. Kjeldahl flask
b. Heater
c. Kjeldahl’s trap
d. Condenser
e. Round Bottom Flask
f. Burette
g. Burette stand
h. Conical flask
i. Digital Weight scale

Samples:

Prepared Palm Candy, White Cane Sugar, Palm candy syrup and Palm Jaggery

Procedure:

2-3 g of a sample was taken in a Kjeldahl flask. 10g Potassium bisulfate, 10g Copper sulfate and 25ml of conc. Sulfuric acid was added to the flask. The mixture was heated at 80°C for about 3 hours until a green-coloured solution was obtained. After properly cooling, the solution was washed with distilled water and 10 ml aliquot of this solution was taken in a Kjeldahl flask to which glass beads were added to prevent bumping. During distillation, before the heat was applied, 50 ml of 40% NaOH solution was added dropwise to the 10 ml of digested sample with 50 ml distilled water mixed with it. The solution turned blue with the addition of NaOH. This process was continued until all ammonia had passed over into 30ml 4% Boric acid solution in a conical flask. 2-3 drops of Methyl Red indicator were added to the 100 ml solution in the conical flask and titrated against 0.1 (N) HCl until the colour changed from light yellow to faint pink.

The same process was repeated for the other samples.

2.2.4 **DETERMINATION OF FAT CONTENT**

Principle:

In the laboratory, a fat extractor (Soxhlet extractor) is used for extraction. The fat extractor uses the solvent reflux and siphon principle to continuously extract the solid matter by pure solvent, which saves the solvent extraction efficiency and high efficiency. The solid material is ground before extraction to increase the area of solid-liquid contact. The solid material is then placed in a filter paper holder and placed in an extractor. The bottom end of the extractor is connected to a round bottom flask containing a solvent and is connected to a reflux condenser. The bottom flask is heated to boil the solvent, the vapour rises through the branch pipe of the extractor, is condensed and drops into the extractor, and the solvent is contacted with the solid for extraction. When the solvent surface exceeds the highest point of the siphon, the solvent containing the extract is siphoned back. The flask, thus extracting a portion of the material, is repeated such that the solid material is continuously taken as a pure solvent and the extracted material is concentrated in the flask (Nielsen et al., 2017, Castejón et al., 2018).

$$Crude\ fat\ \% = \frac{Weight\ of\ extracted\ fat}{Weight\ of\ sample}\ x\ 100$$

Apparatus used:

a. Soxhlet extractor
b. Round bottom flask
c. Reflux condenser
d. Thimble

Samples:

Prepared Palm Candy, White Cane Sugar, Palm candy syrup

Procedure:

Dried samples were weighed and put in a thimble. Once the flask was heated, the solvent was evaporated and moved up to the condenser, where it was converted into a liquid and collected into the extraction chamber containing the sample. When the solvent passes through the sample, it extracts the fats and carries them into the flask. This extraction process typically lasts several hours, i.e. 5-6 hours depending on the sample. After completion of the extraction, the solvent was evaporated, and the mass of lipid remaining was measured and used to analyze.

2.2.5 DETERMINATION OF CARBOHYDRATE CONTENT

The total carbohydrate content of foods has, for many years, been calculated by difference, rather than analysed directly. Under this approach, the other constituents in the food (protein, fat, water, alcohol, ash) are determined individually, summed and subtracted from the total weight of the food. This is referred to as total carbohydrate by difference and is calculated by the following formula:

100 - (weight in grams [protein + fat + water + ash + alcohol] in 100 g of food)

It should be clear that carbohydrate estimated in this fashion includes fibre, as well as some components that are not strictly speaking carbohydrate, e.g. organic acids (Merrill et al., 1973). Total carbohydrate can also be calculated from the sum of the weights of individual carbohydrates and fibre after each has been directly analysed.

2.3 **QUANTITATIVE PHYTOCHEMICAL ANALYSIS**

Sample extract preparation: 1g of each sample i.e. white sugar, palm candy syrup, palm jaggery and Palm candy has been mixed well with 15ml ethanol and 15ml distilled water. Then, the solution has been put inside an Ultrasonicator (Trans-O-Sonic, Mumbai, Model no: D150/IH) for 30 minutes and then filtered (Whatman filter paper no. 1) and stored in a refrigerator (4°C) to get the sample extract solution required for phytochemical analysis and antioxidant activities.

2.3.1 **TOTAL POLYPHENOL CONTENT**

Sarkar et al., 2020 technique was used to calculate total polyphenol content (TPC). In a total of nine test tubes, 20 l of sample extract from each sample and the blank were combined with distilled water (1.58 ml), Folin-Ciocalteu reagent (100 l), and a solution of sodium carbonate (NaCO3; 300 l). The well-mixed solutions were then stored in the dark at 40°C for 30 minutes, following which absorbance for all solutions was measured at 765 nm and results were represented in mg gallic acid equivalent (GAE)/100 g dry basis (DB).

2.3.2 **TOTAL FLAVONOID CONTENT**

Subudhi et al., 2014 developed a technique for calculating total flavonoid content (TFC). Each sample extract (2.5 ml) was combined with 5% aqueous Sodium Nitrite (NaNO2; 150 l) in this technique. In addition to the sample extract, an aqueous methanol (80%) blank was made. After 5 minutes at 27 3°C, 1 M NaOH (1 ml) and 10% aqueous aluminium chloride (AlCl3; 150 ml) were combined into the five test tubes (four samples and one blank), and the absorbance was measured at 510 nm and the findings were reported as mg quercetin/100 g.

2.4 **ANTIOXIDANT ACTIVITIES**

2.4.1 **FERRIC REDUCING ANTIOXIDANT ACTIVITY**

The ferric-reducing antioxidant activity (FRAP) of all four samples was estimated using the Yahya et al., 2017 technique (Mastura et al., 2017). The samples treated with FRAP reagent were incubated for 30 minutes at 37°C. All samples had their absorbances measured at 593 nm against a prepared blank solution. The results were represented in millimolar of ascorbic acid equivalent (mM AAE) per 100 g sample.

2.4.2 **2, 2′-AZINOBIS (3-ethylbenzothiazoline-6 sulfonic acid) RADICAL SCAVENGING PROPERTY (ABTS)**

To calculate the ABTS value of the samples, we utilised the (Sanchez-Restrepo et al., 2020) technique. The ABTS reagent-treated samples were stored in the dark for 2 hours, and the absorbance of all samples was measured at 734 nm in comparison to a prepared blank solution. The results were given as percentages (%).

2.4.3 **2,2-diphenylpicrylhydrazyl RADICAL SCAVENGING CAPACITY(DPPH)**

Sánchez-Riao et al. (2019) described a technique for estimating 2, 2-diphenylpicrylhydrazyl (DPPH) scavenging capability (Mastura et al., 2017). After 30 minutes in the dark, the DPPH reagent-treated samples were measured for absorbance at 517 nm against a prepared blank solution. The results were given as percentages (%).

2.5 **X-RAY DIFFRACTION (XRD) ANALYSIS**

X-ray diffraction (XRD) is based on analysis of the diffracted/scattered intensity of an X-ray beam hitting a sample that varies with change in incident and scattered angle, polarization, and wavelength or energy.

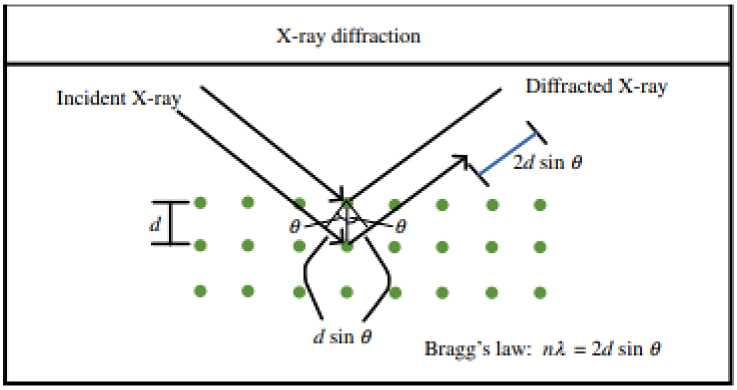


Figure 2: Schematic representation of X-ray diffraction (XRD)

The diffracted/scattered X-rays follow Bragg's law, shown below –

$$n\lambda = 2d \sin\theta$$

where n is the positive integer, λ is the wavelength of the incident X-ray, d is lattice separation, and θ is the scattering angle.

X-ray diffraction data can be utilized to understand crystal polymorphism and the fraction of crystalline and amorphous content. There are various software applications available for the simulation of diffraction data, such as Crystal Diffract, MAUD, or X'Pert High Score Plus. Crystallinity is generally determined by considering the area under the crystalline peak and the area under the total diffractograph. On the other hand, the crystalline polymorph is determined by using the position of the peak at a particular 2θ (Purohit et al., 2019).

The following elements impact palm sugar crystallisation: reducing sugar, processing conditions, acidity, storage conditions, and formulation. Crystallisation impacts the hardness of palm sugar. Hardness allows a substance to resist deformation when subjected to penetration or compression. Hardness increases as intermolecular bonding increases. Most sugars, particularly non-reducing sugars, can crystallise. However, because anomers and ring isomers are present in the solution, making the reducing sugars intrinsically "impure," producing some reducing sugars in crystalline form can be difficult. As a result, the presence of reducing sugars may hinder non-reducing sugar crystallisation.

Sugar crystallinity samples were studied by using powder X–ray diffraction (XRD, Shimadzu 7000 Maxima–X). Radiation of Cu–Kalpha was used for the sample analysis. The angle of diffraction was in the range of 5-50°, the step angle was 0.02° and the rate of scan was 1 s for each step.

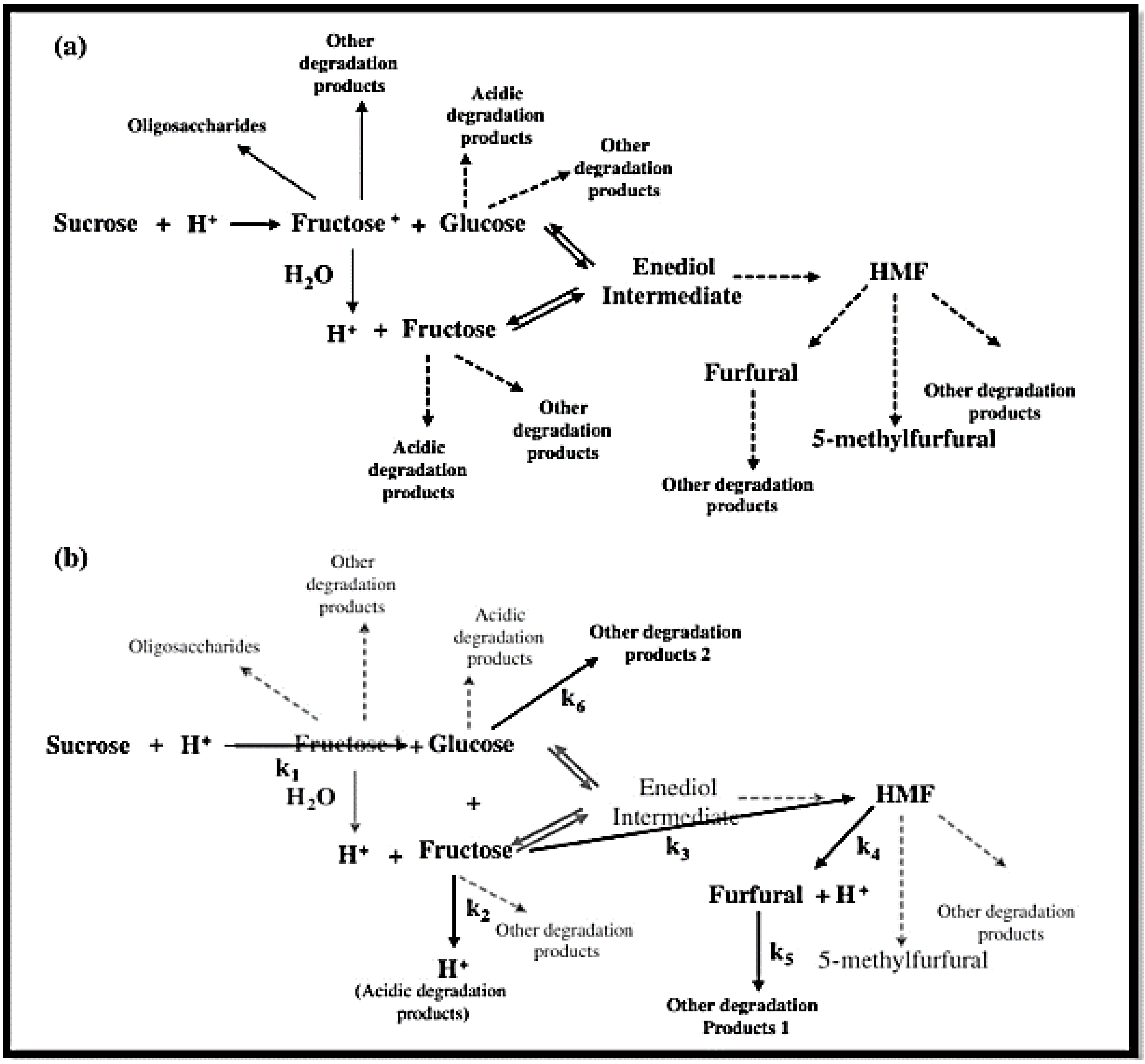


Figure 3: Mechanism of Sucrose caramelisation (Upadhyaya et al., 2023)

2.6 **SCANNING ELECTRON MICROSCOPY (SEM) ANALYSIS**

Scanning electron microscopy (SEM), which is also recognized as SEM analysis or SEM technique, has been used worldwide in many disciplines. It can be regarded as an effective method in the analysis of organic and inorganic materials on a nanometer to micrometre (µm) scale. SEM works at a high magnification reaching 300,000x and even 1000000 (in some modern models) producing images very precisely of a wide range of materials. Materials that can be used in SEM are organic and solid inorganic materials including metals and polymers (Mohammed et al., 2018).

SEM is a tool by which invisible worlds of micro space and nanospace can be seen. Details and complexity that are inaccessible by light microscopy can be revealed by SEM. This all can be achieved through the following process, which is well described by Goldstein et al. The analysis will be done by applying a beam of electrons (having high energy) in the range of (100-30,000 electron volts). Usually, a thermal source is used for electron emission. The analysis will be done by applying a beam of electrons (having high energy) in the range between (100-30,000 electron volts). Usually, a thermal source is used for electron emission. The image of the specimen is formed point by point depending on the movement of the scan coils, which causes the electron beam to move to discrete locations in the form of straight lines until a rectangular raster is produced on the surface of the specimen. The electron detector is to detect the emitted electrons (signals) from the scanned sample. In the absence of the detectors, each signal generated due to the interaction between the electron beam and the surface of the sample can generate an image alone, which is understandable. Both secondary electrons (SE) and backscattered electrons (BSE) are used in SEM image production (Mohammed et al., 2018).

Morphological analysis of the palm candy sample was carried out using a HITACHI SU3800 scanning electron microscope (SEM) with an EDS facility. It has a single-phase voltage of 100-240, a Vacuum power of 1.5kVA and a frequency of 50-60 Hz. Palm candy powder was coated with gold to prevent burning during the analysis.

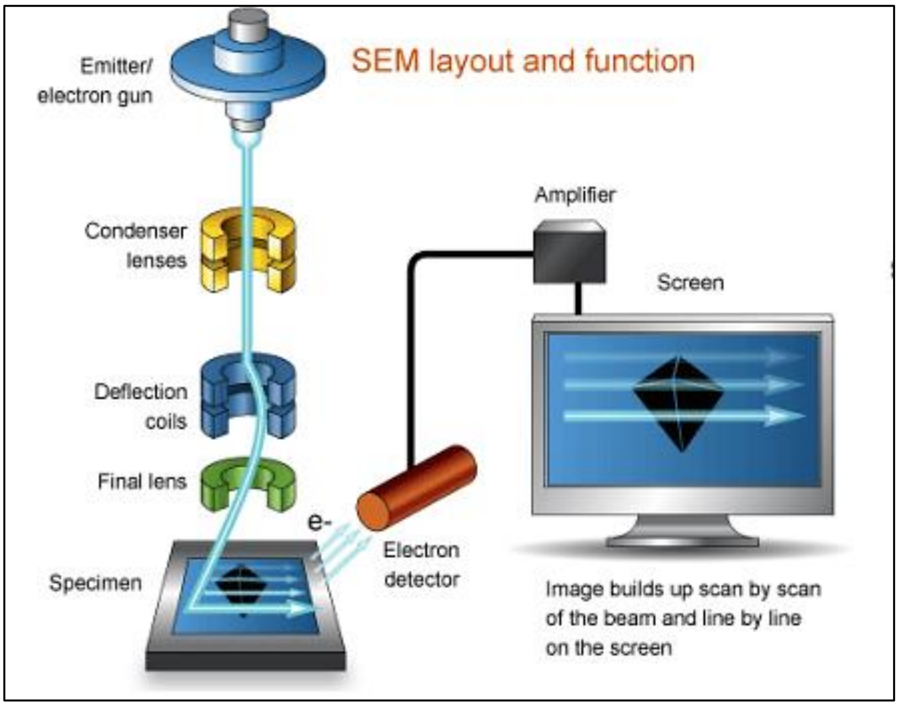


Figure 4: All SEM Components

2.7 **ENERGY DISPERSIVE X-RAY SPECTROSCOPY(EDS) ANALYSIS**

X-ray is generated when the electron beam, which is emitted from the gun, penetrates and interacts with volume beneath the surface of the sample. The principle is defined very well in physics, when electrons enter the coulomb field of a specimen it will decelerate and the loss of electron energy will emitted as a photon. So, the same principle works in SEM analysis and x-ray photons will be emitted. Those photons have energies particular to specimen elements; these will provide the SEM with the capabilities called characteristic x-rays (Mende et al., 2016). The EDS detector takes the responsibility of separating the x-ray characteristics of various elements within the sample into energy spectrum. Then the spectrum will be analyzed by EDS system software to determine the amplitude of specific elements (photon energy will be converted into electrical signals). Finally, the chemical composition maps of the elements can be determined both qualitatively and quantitatively (Xavier et al., 2023).

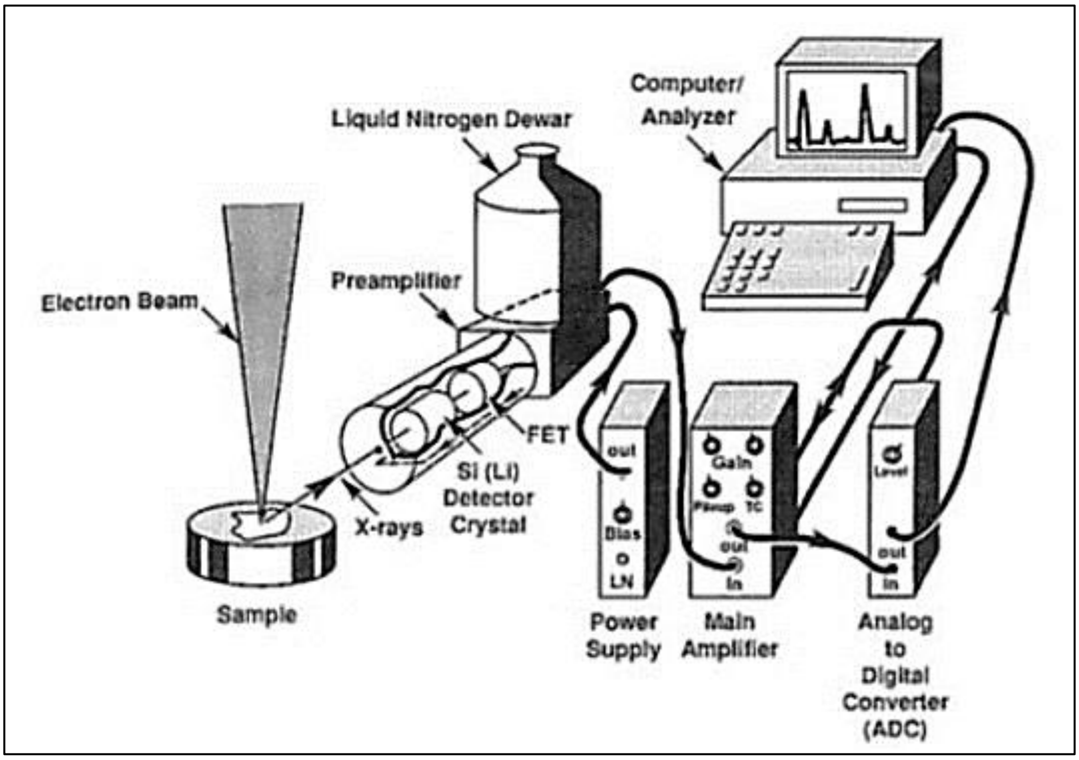


Figure 5: Schematic diagram of EDX spectroscope

2.8 **FOURIER TRANSFORM INFRARED SPECTROSCOPY (FTIR) ANALYSIS**

FTIR is an extremely useful technique for confirming the identity of pure compounds but has limited value if used for mixtures of compounds. The technique is based upon the identification of functional groups within molecules where such groups vibrate (either through stretching or bending in various ways) when irradiated with specific wavelengths of light. These vibrations and their intensity (% transmission) are plotted against the frequency of light (cm^{-1}) to which the sample is exposed to produce an FTIR spectrum. Portions of the FTIR spectrum are unique to the compound under test (this is called the fingerprint region). Unfortunately, because the majority of seized samples are mixtures of compounds, FTIR has limited practical use in the analysis of street samples of drugs of abuse. However, it does have the advantages of being nondestructive and not requiring derivatization (Makhdoumi et al., 2023).

Functional group analysis of palm sugar was analysed by Fourier transform infrared spectroscopy (FTIR) from spectrophotometer Shimadzu IR, KBr Pellet: Absorbance of IR by Solid samples are measured in KBr pellets, which is prepared by pressing a mixture of 1:100 solid sample: KBr, wavenumber operated with a range between 400 and 4000 cm^{-1}.

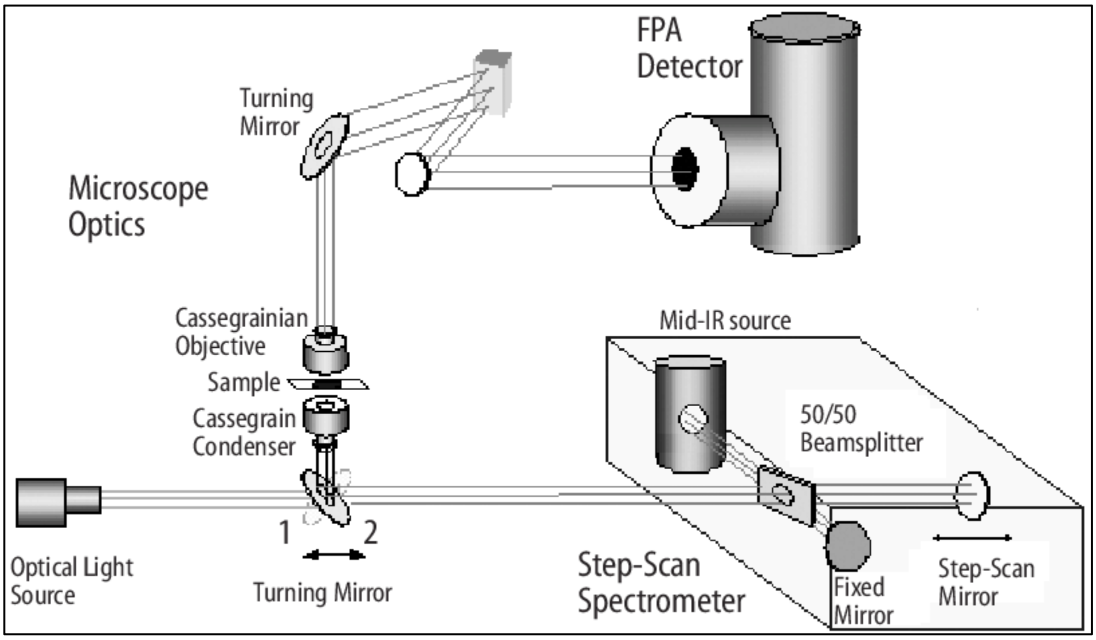


Figure 6: Schematic diagram of a FTIR Spectrometer

2.9 **TEXTURE PROFILE ANALYSIS**

The texture profile analysis test is a method developed for the texture of food texture. The unique two-pressure action mode simulates the bite pattern of the human oral cavity (Mali et al., 2023). After analysis of the pattern analysis tool, it can provide nine important texture parameters for testers at one time -

Hardness :
An indicator of the most direct response to taste, directly affecting Chewiness, Gumminess, and Cohesiveness in texture profile analysis.

Fracturability :
It is unique to samples with a crisp outer shell (outer skin). Most samples cannot measure this parameter. Generally, if this parameter cannot be measured, the software will automatically hide.

Adhesiveness :
After the sample is subjected to pressure deformation, if the surface of the sample is sticky, a negative force will be generated. In the food field, it can be interpreted as a sticky mouthfeel.

Springiness :
The height at which food can recover between the end of the first bite and the beginning of the second mouth.

Chewiness :
Chewability is defined as the Gumminess x Springiness. It can be interpreted as the energy required to chew solid food. It is difficult to measure accurately because chewing involves compression, shearing, puncture, comminution, tearing, cutting, etc., and is also related to oral conditions (saliva secretion, body temperature). This parameter is mainly used in the description of the solid, semi-solid mouthfeel.

Gumminess :
Adhesion is defined as hardness x cohesiveness. One of the characteristics of semi-solid foods is low hardness and high cohesion. Therefore this indicator should be used to describe the taste of semi-solid foods.

Cohesiveness :
Cohesion is defined as the ratio of the first compression to the second compression positive force area. Tensile force is a manifestation of cohesion. If a better sample is condensed, the display probe is also easier to keep clean. Cohesion is usually tested as a lesser parameter than brittleness, chewiness and adhesion.

Resilience :
Resilience is an indicator of how a sample recovers from deformation, including both speed and strength. Defined as the ratio of the area before the deformation target to the area after the deformation target when the first depression is applied. Attention should be paid to the recovery of the sample during the measurement. Generally, a slower test speed is used to achieve sufficient time for the sample to recover. It also ensures the accuracy of this feature.

The texture analyzer (model: TA.XT Express, Stable Micro Systems, Surrey, UK) fitted with the P5 probe, a 5 mm smooth end cylindrical aluminium body, was used to measure the hardness of the palm candy. After placing a sample of the candy on an aluminium base, the P5 probe was pushed down freely at a velocity of 2.5 mm/s and allowed to compress the candy sample. The direction of the compressive force was chosen to be perpendicular to the centre of the sample. Hardness was defined as the greatest indicative force in the force-deformation curve (Omolola et al., 2015).

2.10 **SHELF-LIFE TESTING:**

The shelf life and keeping quality of candy mostly depends on the atmospheric humidity and temperature condition in which it is stored. In most of the cases candy is spoiled due to higher humidity present in the atmosphere during monsoon season. Palm candy storage is difficult because of the presence of invert sugars and mineral salts which are hygroscopic in nature. The non-sucrose constituents present in candy such as glucose, fructose and protein, etc. generates hygroscopicity (Singh, 2000). In India near coastal region the atmospheric humidity is very high as well as the higher rainfall during monsoon, in such a climatic condition it is very difficult to store candy for long period. As the candy absorbs moisture from the environment it gives favourable conditions for growth of different types of bacteria and fungi which leads to the production of alcohols, organic acids and complex decomposition products. In fresh sugar cane juice yeast and contaminating microorganisms viz., *Leuconostoc mesentroides, Leuconostoc dextranicum, Aerobactor arogenes,* and *Bacillus mesenteries* have been identified (Fu et al., 1993; Payasi et. al., 2009). Hence it is very important to take care of Palm candy manufacturing plant and post-harvest quality management of candy because it is consumed in large scale by rural masses.

2.11 **COLOUR ANALYSIS**

The surface colour of each palm candy sample was measured using a Hunter colorimeter (colour Flex 45/0, D 65, 10° observer; Hunter Associates Laboratory Inc. Reston, VA, USA), which was calibrated with a standard white plate (L*= 93.49; a*= 1.07; b*= 1.06; X= 79.22; Y= 84.10; Z= 88.76) and a standard black plate. The colour values were stated in terms of L, a*, and b*. All tests were repeated three times, and the average values were used as the final result (Onwude et al., 2017).

2.12 **SENSORY ANALYSIS**

A semi-trained panel of 20 Jadavpur University members, comprising 5 male and 15 female members, did sensory analysis within the laboratory. All samples were evaluated for colour, flavour, texture, mouthfeel, and overall acceptability using a nine-point hedonic scale (9 = excellent, 8 = very good, 7 = good, 6 = sufficient, 5 = neither good nor awful, 4 = bad, 3 = moderately poor, 2 = poor, 1 = worst) (Sarkar et al., 2019). Randomly coded samples were presented to panel members at room temperature under ambient environmental conditions. Between two sensory evaluations, the panellists received crackers and drinkable water. All of the average values of the hedonic ratings (colour, flavour, texture, mouthfeel, and so on) were used for sensory analysis (Chambers et al., 2003).

2.13 **STATISTICAL ANALYSIS**

Analysis of variance (ANOVA), test of significance, and comparison of means using Tukey's test were performed using Minitab® ver. 17, with a confidence level of 95%. The samples were randomized for all the analyses described above (Woo et al., 2015).

CHAPTER 3

RESULTS AND DISCUSSION

3. **RESULTS AND DISCUSSION**

3.1 **PALM CANDY PROCESSING:**

TRIAL RUN	INGREDIENTS WITH QUANTITY (in g)	END-POINT BRIX VALUE (°Bx)	END-POINT TEMPERATURE (°C)	CRYSTALLISATION TIME (in days)	TOTAL TIME (min)
1	W= 200, CS= 666.66, PJ= 26.66, S= 533.34	83°	138	3	36
2	W= 300, CS=1000, PJ= 40, S= 800	83°	138	7	29
3	W= 300, CS=1000, PJ= 40, S= 800	83°	138	7	29
4	W= 400, CS= 400, PJ= 30, S= 800	83°	120	7	32
5	W= 750, CS= 750, PJ= 56.25, S= 1500	83°	124	7	24
6	W= 750, CS= 750, PJ= 56.25, S= 1500	83°	118	7	35
7	W= 750, CS= 750, PJ= 56.25, S= 1500	83°	118	5	45
8	W= 750, CS= 750, PJ= 56.25, S= 1500	83°	117	10	45
9	W= 750, CS= 750, PJ= 56.25, S= 1500	83°	115	7	27
10	W= 750, CS= 750, PJ= 56.25, S= 1500	83°	118	7	40
11	W= 750, CS= 750, PJ= 56.25, S= 1500	83°	114	5	37
12	W= 750, CS= 750, PJ= 56.25, S= 1500	83°	120	7	50
13	W= 750, CS= 750, PJ= 56.25, S= 1500	83°	120	5	50
14	W= 750, CS= 750, PJ= 56.25, S= 1500	83°	116	7	40
15	W= 750, CS= 750, PJ= 56.25, S= 1500	83°	116	5	40
16	W= 750, CS= 750, PJ= 20, S= 1300	83°	117	7	33
17	W= 750, CS= 750, PJ= 20, S= 1300	83°	117	5	33
18	W= 750, CS= 750, PJ= 20, S= 1500	83°	121	5	35
19	W= 750, CS= 750, PJ= 20, S= 1300	83°	121	7	35
20	W= 375, CS= 375, PJ= 10, S= 650	83°	118	7	22
21	W= 375, CS= 250, PJ= 10, S= 650	83°	122	7	15
22	W= 375, CS= 750, PJ= 10, S= 1500	83°	118	7	22

Table 1: A table detailing the ingredients with their quantity, end-point Brix value and temperature and the total time taken to prepare all the trial runs for Palm Candy

Note: W is potable water, CS is Candy syrup, PJ is Palm jaggery and S is Cane Sugar crystals

From the above table, it can be seen that the end-point brix value for the Palm candy mixture is 83° for all the trial runs. Since 1° Bx means 1g of sucrose in 100g of solution, 83° Bx signifies the presence of 83g of sucrose in 100g solution. The final mixture is sticky to the touch and forms thread-like strands when squeezed between two fingers.

TRIAL RUN	ENERGY CONSUMPTION (in KJ)	YIELD$_1$ %	YIELD$_2$ %
1	9654	68	92
2	11330	72	108
3	10520	66	88
4	11326	74	110
5	13006	74	112
6	11024	55	76
7	10854	60	93
8	12056	52	80
9	9986	75	116
10	10264	63	98
11	10634	78	102
12	11542	44	68
13	10832	53	82
14	10794	49	76
15	11456	50	78
16	10368	65	104
17	10008	71	114
18	9082	83	132
19	8364	79	126
20	6820	54	93
21	7862	74	104
22	6986	81	130

Table 2: A Table showcasing the amount of energy consumed during processing and the yield percentages of all the trials.

Note: Yield$_1$ is measured based on of the weight of all raw materials except water and Yield$_2$ is measured based on weight of Cane Sugar

The values of energy consumption as mentioned in the above table for all the trial runs are calculated by multiplying the amount of LPG gas required to process the palm candy mixture with the calorific value of LPG gas(i.e. 55000 kJ/kg).

The yield percentages for all the trials have been calculated twice in separate ways. To calculate Yield$_1$, the weight of the final product i.e. the palm candy has been compared against the combined weight of all the raw ingredients needed to make the product (except water, i.e. sugar, palm candy syrup, palm jaggery). On the other hand, to calculate $Yield_2$, the weight of the final product has been divided by the weight of Cane sugar.

Crystal structure in the palm candy has formed for all the trial runs varying in quantity and size. One common problem noted for many trials was that crystal formation was limited to the top layer of the mould and the sides leaving the bottom layer unsatisfactory sometimes. Even, the big-sized crystals that formed were present on the top and middle layers always.

Figure: 1

Figure: 2

Figure: 3

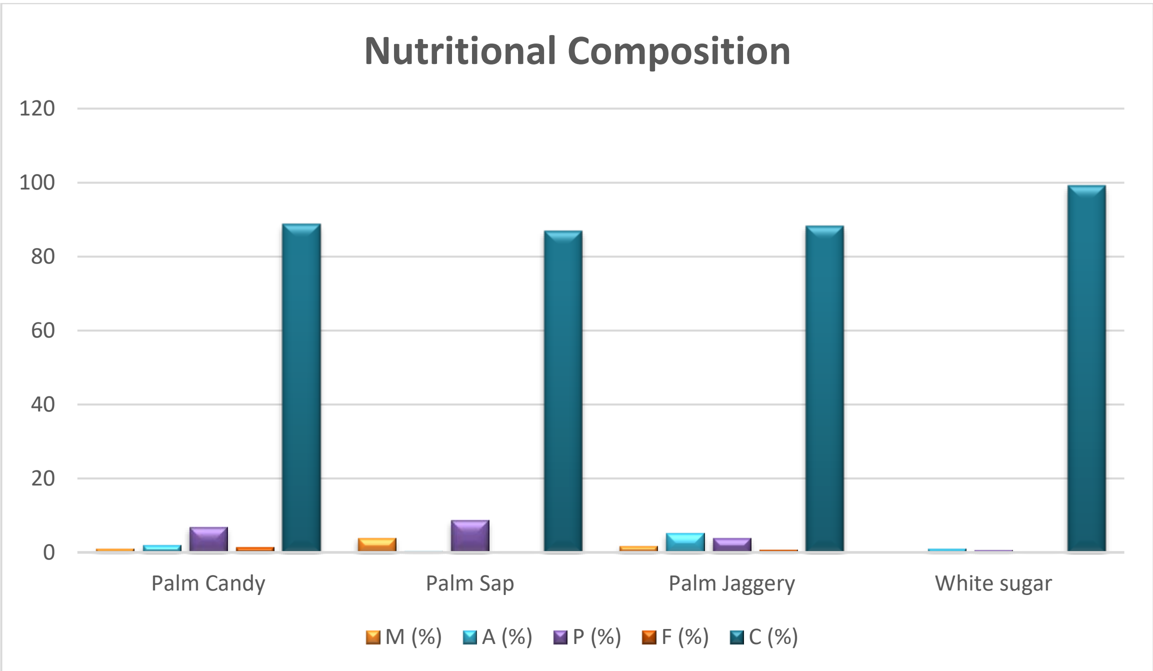
Figures 1-3: A few pictures of prepared Palm Candy

3.2 **NUTRITIONAL COMPOSITION ANALYSIS**

	MOISTURE (%)	ASH (%)	PROTEIN (%)	FAT (%)	CARBOHYDRATE (%)
PALM CANDY	1.01 ± 0.95^{a}	1.98 ± 1.15^{b}	6.88 ± 0.52^{a}	1.40 ± 1.27^{c}	88.73 ± 1.52^{c}
PALM CANDY SYRUP	3.95 ± 1.05^{b}	0.42 ± 0.02^{a}	8.69 ± 0.64^{a}	0.20 ± 0.08^{b}	86.94 ± 1.25^{a}
PALM JAGGERY	1.81 ± 0.55^{a}	5.22 ± 0.85^{a}	3.94 ± 1.21^{b}	0.78 ± 0.46^{b}	88.25 ± 1.98^{c}
WHITE SUGAR	0.08 ± 0.06^{c}	0.98 ± 1.26^{c}	0.69 ± 0.98^{c}	0.11 ± 0.75^{a}	99.12 ± 2.28^{b}

<u>Table 3</u>: The nutritional analysis of prepared Palm Candy along with its ingredients

Note: Results were expressed as mean ± standard deviation. The different superscript letters a–c in the table represent the significant differences ($p < .05$).



<u>Figure 4</u>: A Chart showcasing the nutritional composition of Palm Candy, Palm candy syrup, Palm jaggery and white sugar

Note: M=Moisture, A=Ash, P=Protein, F=Fat, C=Carbohydrate

The nutritional compositional analysis is presented in the above Table. Water is contained in almost all foods, and it is important to dissolve several chemicals. The capability of dissolving more substances is higher than any other liquid (Lasekan et al., 2010). Determination of water and moisture content is one of the most common tests in food because it has an important relationship with chemical, physical and microbiological changes during storage. Determination of ash content has to do with the mineral content in an ingredient and is used as a parameter of nutritional value in food, while determination of fat content will show total fat content which will affect health (El-Esawi et al., 2018). In this study, moisture content, ash content, protein content and fat content were carried out on palm candy, palm candy syrup, palm jaggery and sugar crystals.

According to the Figure, the chart clearly shows that the carbohydrate percentage of all the samples is much higher compared to the other compositional parameters. In particular, carbohydrate quantity is the highest for sugar, with its moisture, ash, protein and fat levels nearly nothing which is expected as Sugar is a carbohydrate. It is a form of carbohydrate that the body converts into glucose for energy. As for other samples, the fat content is slightly higher for the prepared palm candy compared to its raw ingredients. The protein content is the highest in Palm candy syrup, gradually decreasing in Palm candy and Palm jaggery, and finally negligible in sugar. The ash content of Palm jaggery is higher than the other samples where it is comparable. This signifies the presence of a high quantity of inorganic residue left in the jaggery after ignition and the complete oxidation of organic matter.

3.3 **QUANTITATIVE PHYTOCHEMICAL ANALYSIS**

3.3.1 **TOTAL PHENOLIC CONTENT ANALYSIS**

SAMPLES	**TPC (mg GAE/100 g)**
White Sugar	54.68
Palm Candy syrup	60.23
Palm Jaggery	30.46
Palm Candy	58.73

Table 4: TPC values of all the samples

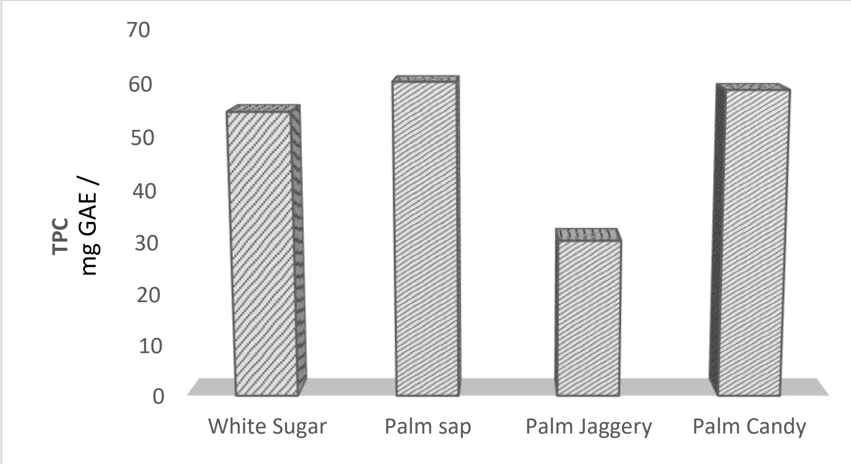


Figure 5: Bar plots of Total Phenolic content (TPC) values of white sugar, palm candy syrup, palm jaggery and palm candy

A hydroxyl group and an aromatic ring are frequent features of phenolic substances. Chemical features, such as the arrangement or quantity of phenolic rings, are used to classify these substances. Flavonoids, phenolic acids, tannins, quinones, and lignans are examples of such groupings (Sun et al., 2009). Phenolic chemicals have antibacterial, antioxidant, and anti-mutagenic properties (Sun et al., 2009). Plant phenolic chemicals are involved in metabolic processes and contribute to taste and colour (Kermasha et al., 1995). According to the above data, the TPC value for jaggery is lower than for the other samples, which might be due to high heat increasing the rate of phenolic loss in a food sample during processing.

3.3.2 **TOTAL FLAVONOID CONTENT ANALYSIS**

SAMPLES	**TFC (mg Quercetin/100 g)**
White Sugar	70.14
Palm Candy syrup	220.76
Palm Jaggery	118.23
Palm Candy	22.36

Table 5: TFC values of all the samples

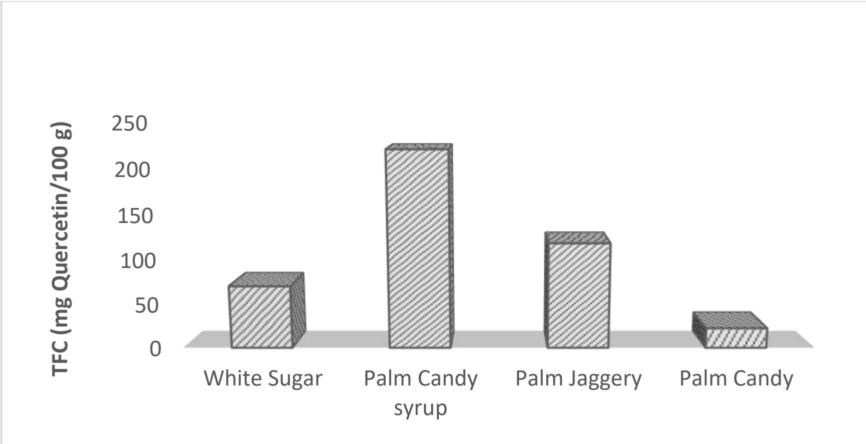


Figure 6: Bar plots of Total Flavonoid content (TFC) values of white sugar, palm candy syrup, palm jaggery and palm candy

Flavonoids are structurally diverse secondary metabolites in plants, with a multitude of functions. These span from functions in regulating plant development, pigmentation, and UV protection. Phenolic and flavonoid molecules are important antioxidant components that are responsible for deactivating free radicals based on their ability to donate hydrogen atoms to free radicals. One of the important underlying mechanisms of action of dietary flavonoids and related polyphenols is associated with their inhibition of oxidative stress and related downstream responses including inflammatory diseases (Safe et al., 2021). Palm candy and sugar have lower levels of TFC compared to Palm jaggery and specially to Palm candy syrup.

3.4 QUANTITATIVE PHYTOCHEMICAL ANALYSIS

SAMPLES	FRAP (mm AAE /100 g)
White Sugar	2.36
Palm Candy syrup	9.57
Palm Jaggery	7.58
Palm Candy	8.98

Table 6: FRAP values of all the samples

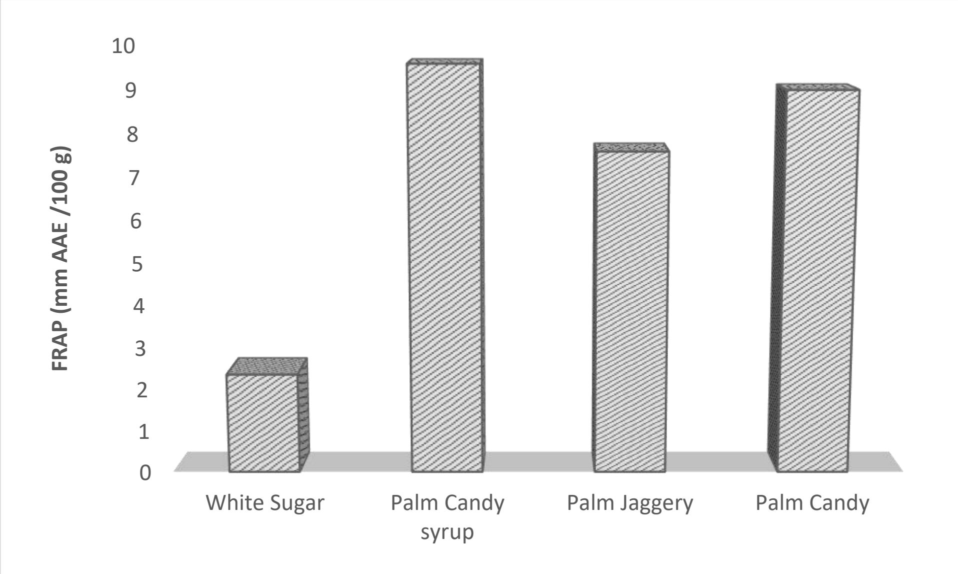


Figure 7: Bar plots of FRAP values of white sugar, palm candy syrup, palm jaggery and palm candy

The ferric reducing antioxidant power (FRAP) assay is a typical ET-based method that measures the reduction of ferric ion (Fe3+)-ligand complex to the intensely blue-coloured ferrous (Fe^{2+}) complex by antioxidants in an acidic medium. Antioxidant activity is determined as the increase of absorbance at 593 nm, and results are expressed as micromolar Fe^{2+} equivalents or relative to an antioxidant standard. Unlike other ET-based methods, the FRAP assay is carried out under acidic pH conditions (pH 3.6) to maintain iron solubility and, more importantly, drive electron transfer. This will increase the redox potential, causing a shift in the dominant reaction mechanism (Gil et al., 2000). Although the original FRAP assay uses tripyridyltriazine (TPTZ) as the iron-binding ligand, alternative ligands have also been employed for ferric binding, such as ferrozine for ascorbic acid–reducing power evaluation (Zhong et al., 2015). All the samples other than Cane sugar i.e. Palm candy, Palm jaggery and Palm candy syrup have high levels of FRAP value compared to the sugar as they facilitate iron solubility more.

SAMPLES	**ABTS (%)**
White Sugar	22.25
Palm Candy syrup	43.01
Palm Jaggery	48.36
Palm Candy	45.78

Table 7: ABTS values of all the samples

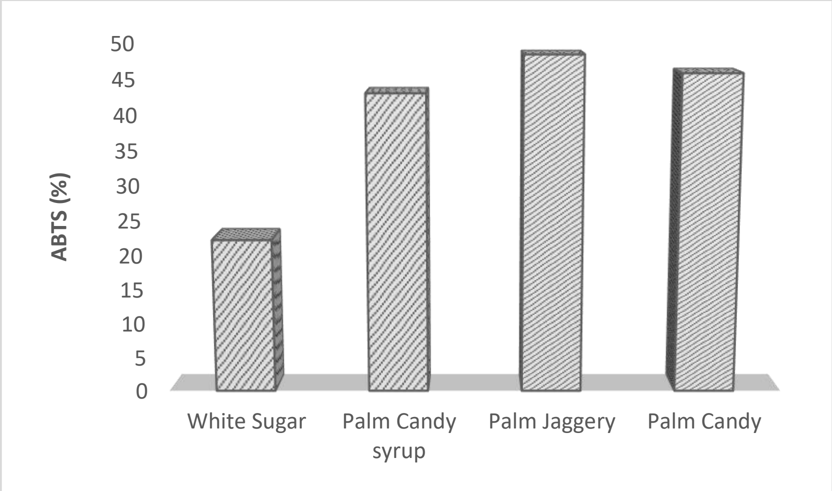


Figure 8: Bar plots of ABTS values of white sugar, palm candy syrup, palm jaggery and palm candy

The ABTS assay measures the relative ability of antioxidants to scavenge the ABTS generated in the aqueous phase, as compared with a Trolox (water-soluble vitamin E analogue) standard. The ABTS is generated by reacting with a strong oxidizing agent (e.g., potassium permanganate or potassium persulfate) with the ABTS salt. The reduction of the blue-green ABTS radical by hydrogen-donating antioxidants is measured by the suppression of its characteristic long-wave absorption spectrum. The method is rapid and can be used over a wide range of pH values, in both aqueous and organic solvent systems. It also has good repeatability and is simple to perform; hence, it is widely reported. The method, however, has not been correlated with biological effects; hence, its actual relevance to in vivo antioxidant efficacy is unknown (Opitz et al., 2014). All the samples other than Cane sugar i.e. Palm candy, Palm jaggery and Palm candy syrup have high levels of ABTS value compared to the sugar as they have more antioxidant capacity.

SAMPLES	**DPPH (%)**
White Sugar	2.52
Palm Candy syrup	54.37
Palm Jaggery	67.38
Palm Candy	*62.59*

Table 8: DPPH values of all the samples

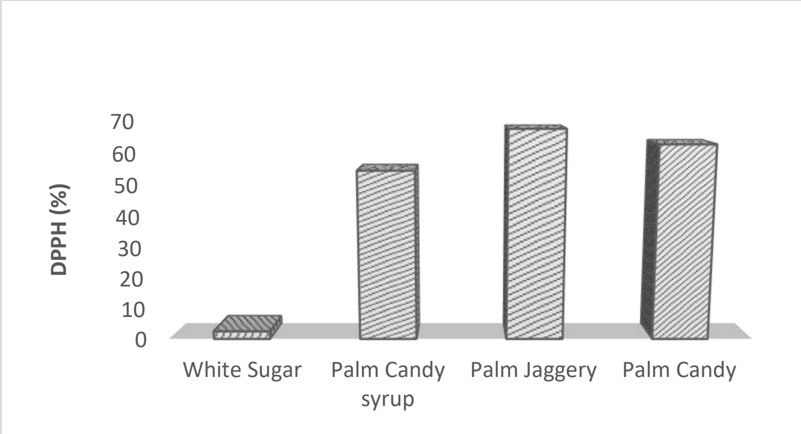


Figure 9: Bar plots of DPPH values of white sugar, palm candy syrup, palm jaggery and palm candy

The free radical DPPH, which is widely used to evaluate the ability of compounds to operate as free-radical scavengers and hydrogen suppliers, is a rapid, simple, and inexpensive method for testing antioxidant capabilities. The DPPH test relies on the elimination of DPPH, a stabilized free radical. DPPH is indeed a dark-coloured crystalline compound made up of free-radical particles that are stable. In particular, it is a well-known radical and a popular antioxidant test. Once, reduced and transformed into DPPH-H, the DPPH radical has a dark purple hue in solution, but when reduced as well as transformed into DPPH-H, it turns colourless or light yellow []. In vitro, several extractions of plants have been shown to neutralize DPPH radical scavenging activity. Furthermore, DPPH free radicals are scavenged by several tea extracts consisting of a variety of polyphenols (Baliyan et al., 2022).

3.5 **X-RAY DIFFRACTION ANALYSIS**

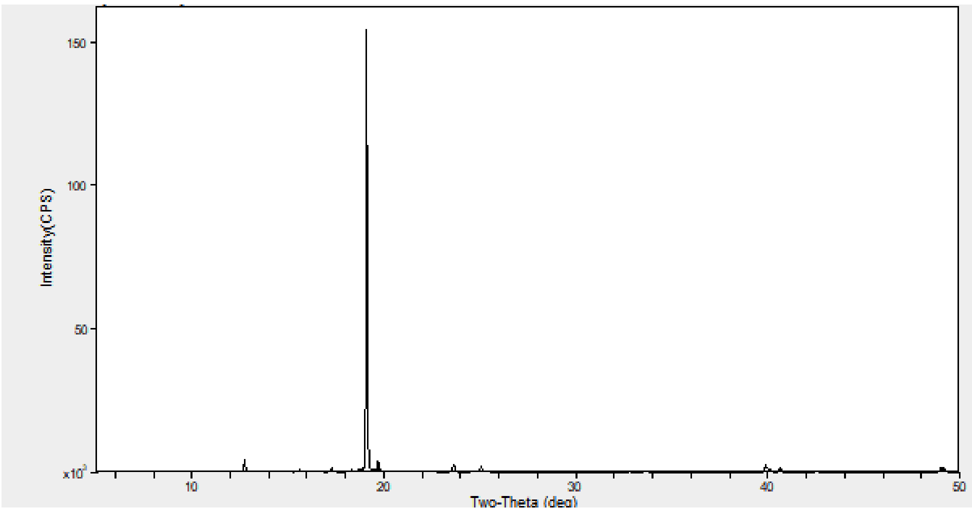


Figure 10: X-ray scattering of Palm candy

The candy showed a characteristic sharp peak at 2θ of 19.238 and five small peaks at 12.926, 19.894, 23.580, 24.921 and 40.34 which represent the crystalline state of the sucrose and other sugars present.

The chief compound observed in the sample is Cholesterol Acetate($C_{29}H_{48}O_2$) with an intensity of 1.5405 x 10^3 counts per second. It is a cholesterol ester obtained by formal acylation of the hydroxy group of cholesterol by acetic acid. It has a role as a human metabolite. It is a cholesteryl ester and an acetate ester.

Other compounds which are also present in the sample are: β-1-Palmityl-3-laurylglycerol, β-1-Stearyl-2-lauryl-3-palmityl-glycerol, β-1-Stearyl-2-myristyl-3-palmityl-glycerol, β''-1-Stearyl-2-palmityl-3-capryl-glycerol, β-Glucoheptonic acid lactone, β-Trielaidin, γ-Lauric acid, 1-Caprylglycerol, 1-n-hexyl-2,4-dihydroxybenzene, 2,6-Dimethoxybenzoic acid, 2-Benzylnaphthalene, 2-Hydroxy-3,6-dimethylbenzoic acid, 2-Hydroxy-5-methoxybenzoic acid, 2-Vinylnaphthalene, Cyclohexanone-4-carboxylic acid, Lithocholic acid, O-Phenylphenol and Resorcylic acid.

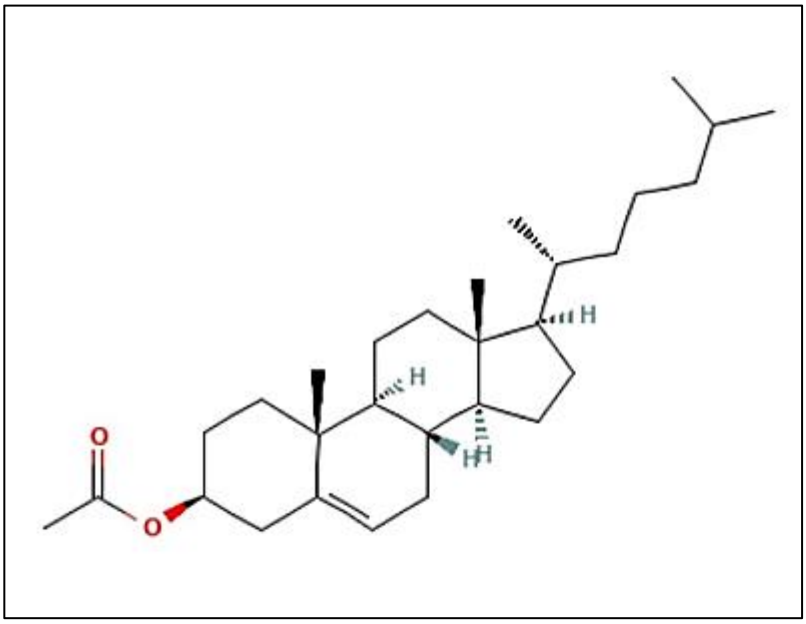


Figure 11: Cholesterol acetate

3.6 **SCANNING ELECTRON MICROSCOPE ANALYSIS**

The morphological characteristics of the palm candy were studied by scanning electron microscopy. The results revealed that the candy crystals were smooth with significantly varying dimensions.

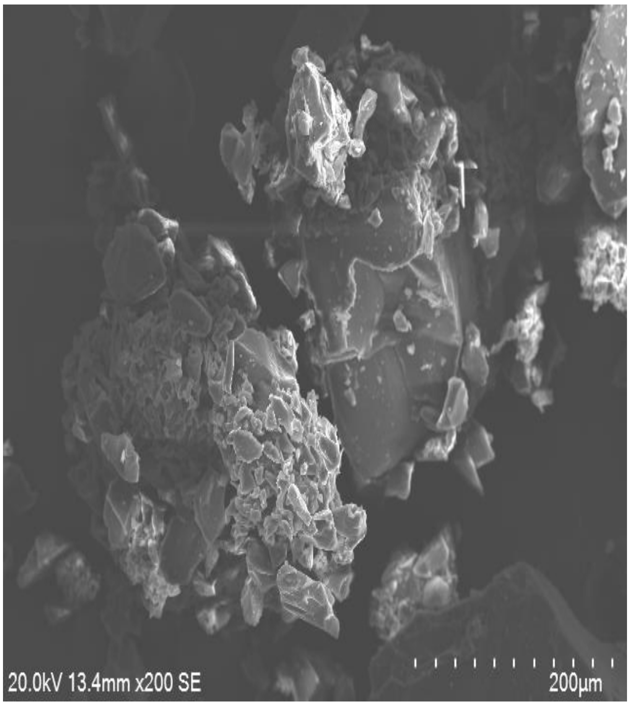


Figure: 12

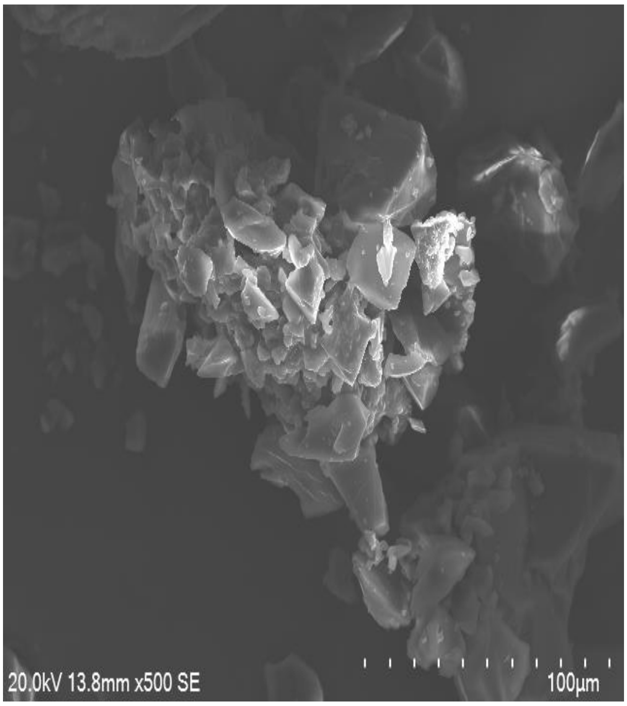


Figure: 13

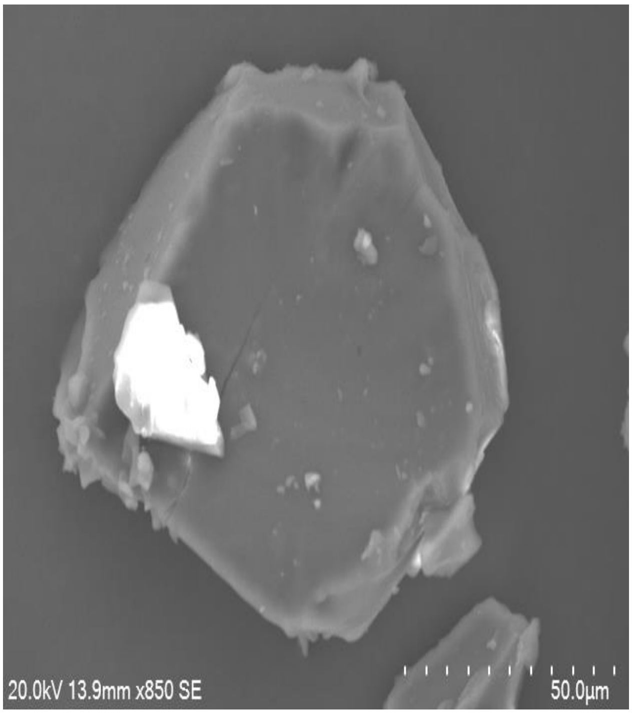


Figure: 14

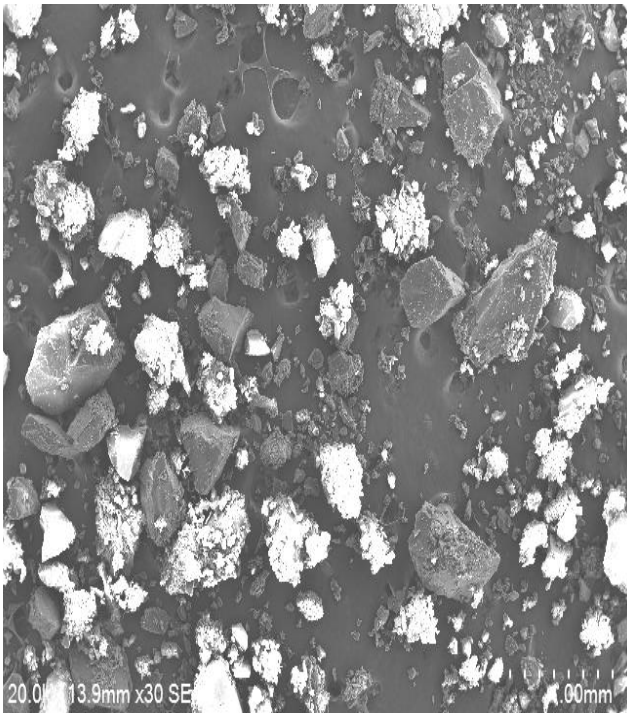


Figure: 15

Figures 12-15: Scanning Electron micrographs of Palm Candy

Figure “a” with 200x magnification, 13.4mm working distance and emission current of 64000nA shows a wide cluster of Palm candy crystals. Figure “b” with 500x magnification, 13.8mm working distance and emission current of 65000nA displays an even wider cluster of Palm Candy crystal. Figure “c” with the highest 850x magnification, 13.9mm working distance and emission current if 63000nA focuses on a single crystal and displays its surface. Finally, figure “d” with 30x magnification, a working distance of 13.9mm and an emission current of 61000nA exhibits the Palm candy crystal surface with a low focal length.

This rectangular shape was almost the same as the morphology of commercial jaggery. However, Fig. c shows a sticky and agglomerated product. The agglomeration most likely occurred due to caramelization that occurred when the sucrose with high remaining moisture was exposed to heat.

3.7 **ENERGY DISPERSIVE X-RAY SPECTROSCOPY ANALYSIS**

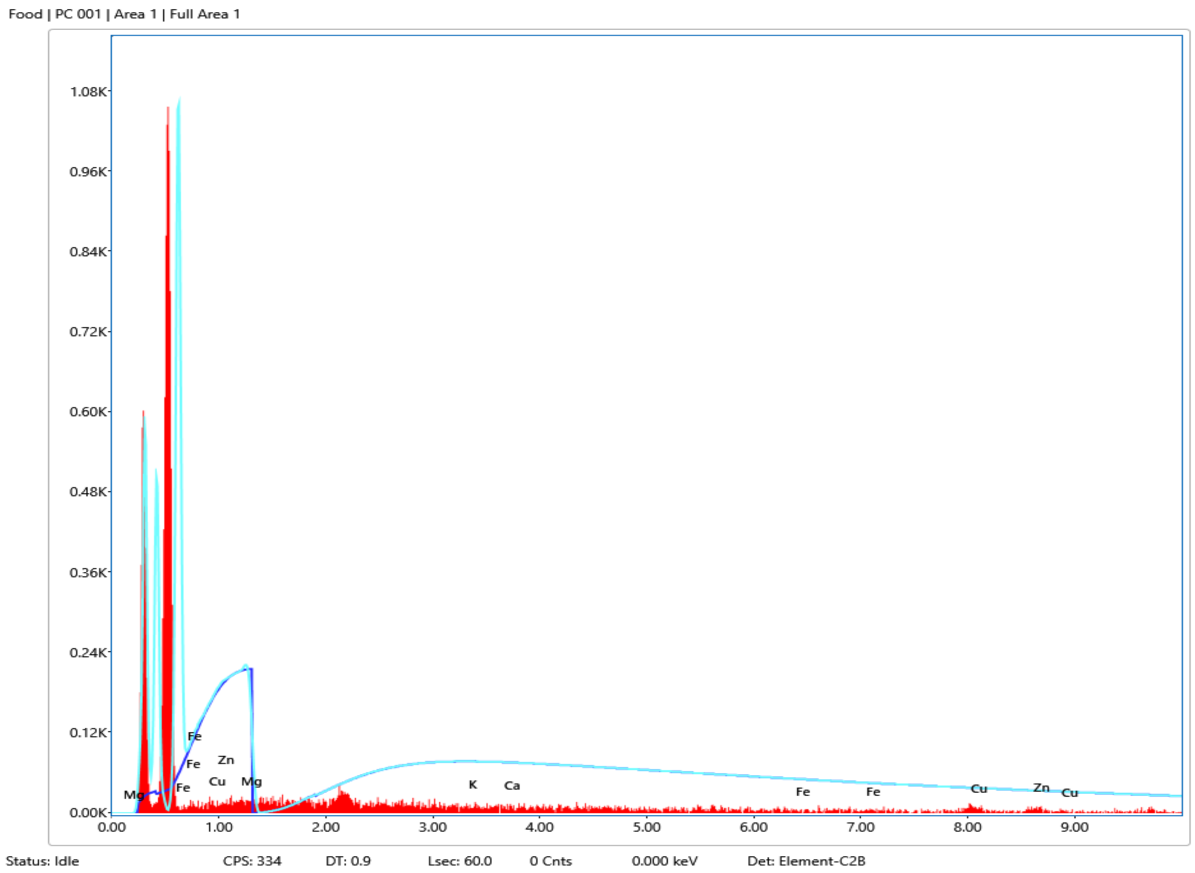


Figure: 16

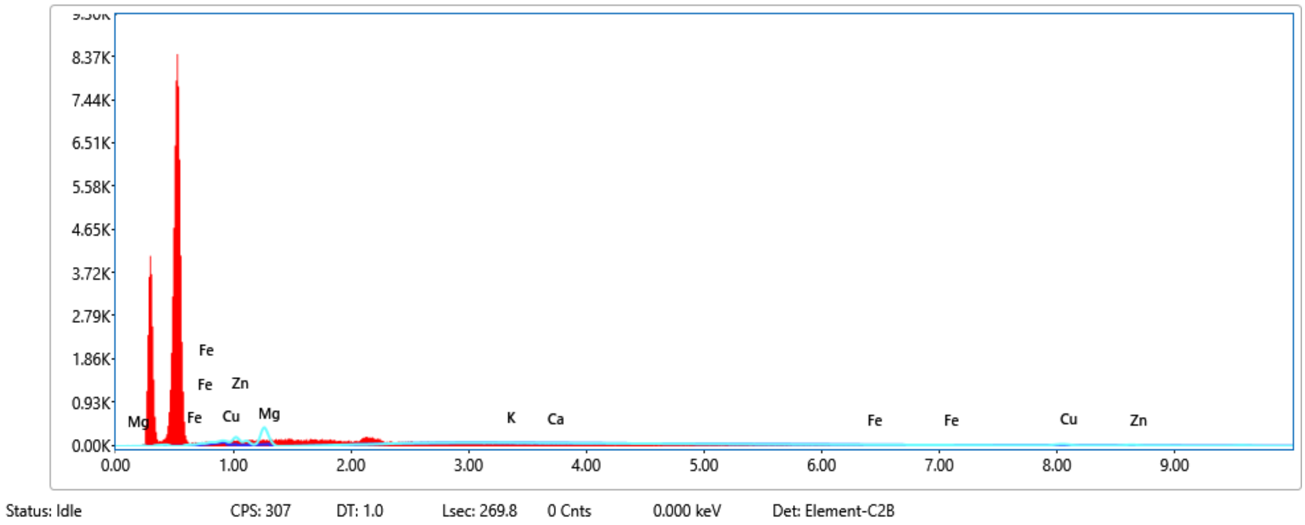
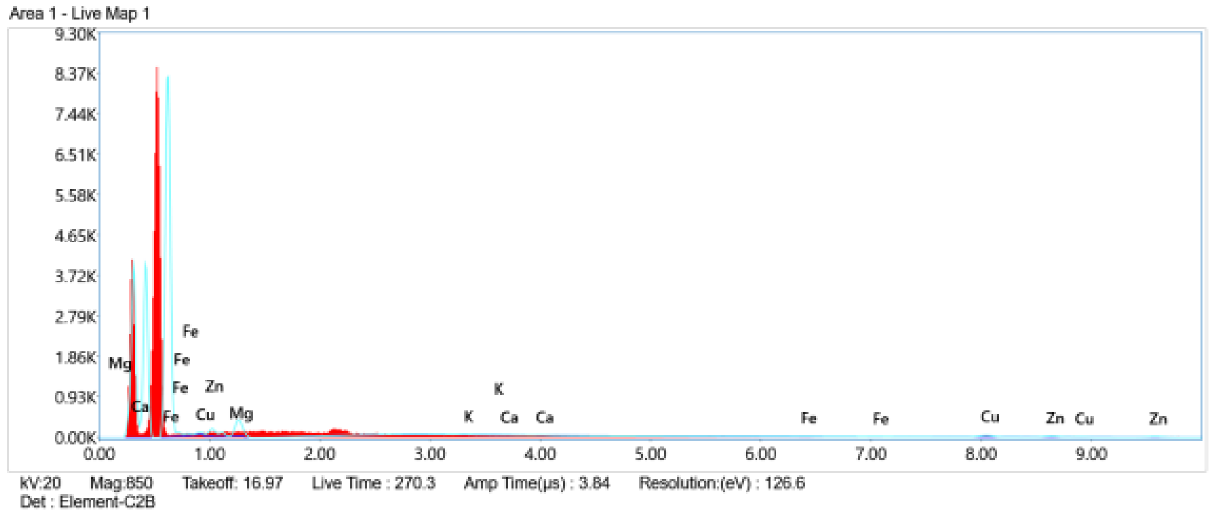


Figure: 17

<u>Figures 16-17</u>: EDX analysis of Palm Candy



Element	Weight %	Atomic %	Error %	Net Int.	R	A	F
Mg K	67.62	84.28	12.26	8.61	0.8882	0.1236	1.0015
K K	1.00	0.77	75.31	0.26	0.9176	0.5493	1.0267
Ca K	0.34	0.26	77.07	0.09	0.9213	0.6284	1.0363
Fe K	1.20	0.65	68.00	0.26	0.9426	0.9076	1.2366
Cu K	16.20	7.72	21.59	2.00	0.9536	0.9512	1.0872
Zn K	13.64	6.32	21.78	1.38	0.9574	0.9570	1.0693

<u>Figure 18</u>: Elemental analysis of Palm Candy

The elemental study for the Palm candy is shown in the above figure. It can be seen that Magnesium is the most abundant mineral with 67.62% in weight, followed by Copper and Zinc with 16.2% and 13.64% respectively. Iron(1.2%), Potassium(1%) and Calcium(0.34%) are also present.

3.8 **FOURIER TRANSFORM INFRARED SPECTROSCOPY ANALYSIS**

Fourier transform infrared (FTIR) spectroscopy is a form of vibrational spectroscopy that is useful in the study of a variety of soil chemical processes. In the mid-infrared (mid-IR) range, vibrations arise from many environmentally important molecules such as organic acids, soil organic matter, mineral phases, and oxyanions (Makhdoumi et al., 2023). It is possible to utilize FTIR spectroscopy as a quantitative analytical method and also as a tool to determine bonding mechanisms in solids and on surfaces. Molecular vibrations can be related directly to the symmetry of molecules, and so it is often possible to determine precisely how a molecule is bonding on surfaces or as a component in a solid phase from its infrared spectrum.

Analysis of Fourier Transform Infra-Red (FTIR) Spectrophotometer was used to determine the peak absorbance of functional groups from palm Candy.

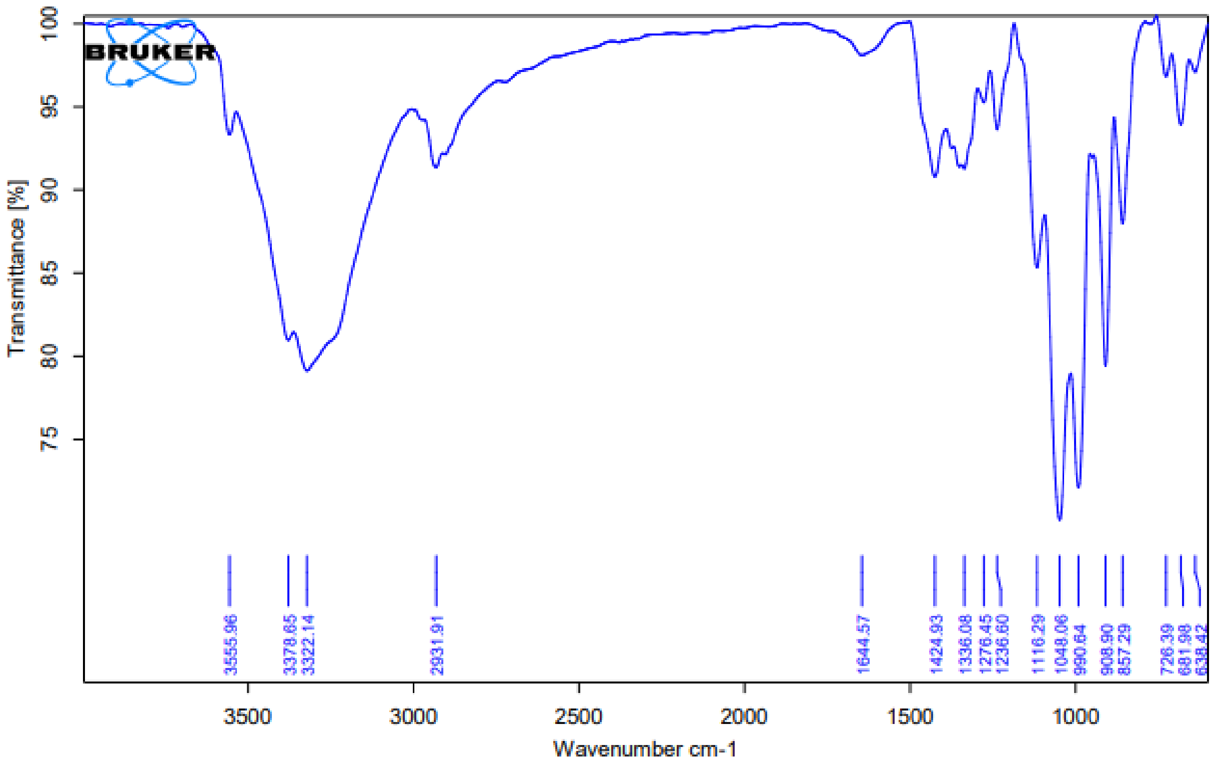


Figure 19: Graph showing Transmittance vs. Wavenumber for Palm candy sample

A small peak at 3555.96 cm^{-1} indicates the presence of an alcohol compound with an OH-stretching group(intermolecular bonded). Two comparative big peaks at 3378.65 cm^{-1} and 3322.14 cm^{-1} show that aliphatic primary amine compounds with NH-stretching groups are present. A small peak at 1931.91 cm^{-1} indicates the presence of an alcohol compound with an OH-stretching group(intramolecular bonded). Five small peaks at 1644.57 cm^{-1}, 1424.93 cm^{-1}, 1336.08 cm^{-1}, 1276.45 cm^{-1}, 1236.60 cm^{-1} directs to the presence of alkene compound with C=C stretching group(cis disubstituted), carboxylic acid with OH-bending group, alcohol with OH-bending group, aromatic amines with C-N stretching group and alkyl aryl ether compounds with C-O stretching group. Anhydride compounds with CO-O-CO groups, alkene compounds with C=C bending groups(monosubstituted) and alkene compounds with C=C bending groups(vinylidene) are present in the sample due to the presence of peaks at 1048.06 cm^{-1}, 990.64 cm^{-1} and 908.90 cm^{-1} respectively. Finally, a small peak at 681.98 cm^{-1} points to halo compounds with the C-Br stretching group.

3.9 **DISCUSSION ON SHELF-LIFE OF PALM CANDY**

The shelf-life of the prepared Palm candy has been tested for a few months. Three samples previously weighed have been put in three separate types of packaging containers to test which on is better suited for the post-production storage of palm candy. The three packaging containers are: Aluminium foil packet (SSSG Silver plastic foil bag), green pouch(DEERA ziplock airtight green reusable polyethylene pouch) and plastic ziplock pouches(Themisto Vibhu Ziplock pouch bags). After 4 months of testing, it has been found that both the green pouch and plastic ziplock pouch showed almost little to no loss of weight of the sample inside, while a little weight loss could be seen in aluminium pouch as it was not air-tight.

3.10 **TEXTURE PROFILE ANALYSIS**

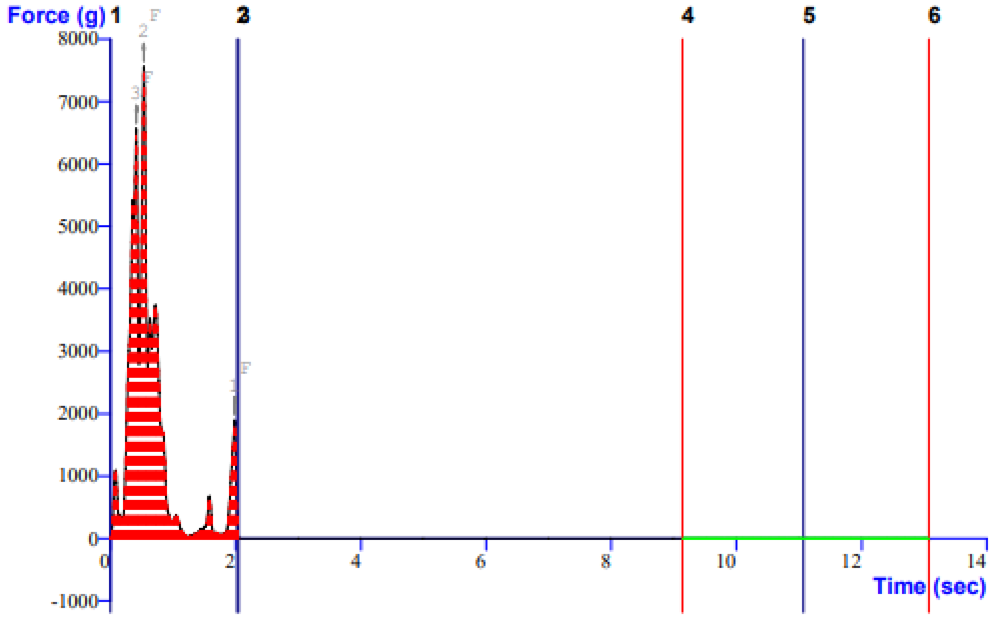


Figure 20: Texture Analysis graph

The Texture Profile Analysis (TPA) test, as already mentioned, consists of applying two cycles of deformation to a sample of the material to be studied. Between these two compression cycles, the sample rests for a certain time. The test speed is 5mm/sec with a target distance of 10mm and a strain of 75%.

Hardness is obtained by observing the maximum load reached during the first deformation cycle (F1). It is related to the stiffness of the material. It is found to be 7558.315g. The fracturability of this sample is 6564.982g.

Cohesiveness corresponds to the ratio between the area under the time/force curve during the second cycle (A5 + A6) divided by the area during the first cycle (A3 + A4). This parameter is related to the consistency of the material. If the material withstands the first cycle without disintegrating, the value will be close to 1, but if it disintegrates completely, it will be close to zero. The cohesiveness of the sample was found to be nil while adhesiveness was found to be -0.97g/sec.

Springiness corresponds to the ratio between the time needed for the material to reach the maximum load since it starts to deform in the second cycle (t2) and the time needed for the first cycle (t1). This parameter is related to the recovery of the material and its viscoelastic properties. 0.953 is the springiness of the sample as observed.

Chewiness is a parameter obtained by multiplying the hardness times by the cohesiveness time of the springiness. It is related to how easily a material can be bitten. It is -1.912 for the sample of Palm candy while gumminess is -2.006.

Resilience is calculated by dividing the upstroke area (A3) by the downstroke area (A4) of the first compression cycle. It is related to the plastic deformation of the material. If the material does not deform plastically its value will be one but if the material does not recover its shape after the first compression cycle its value will increase. Resilience of this sample is 0.001.

3.11 **COLOUR ANALYSIS**

To assess the quality of Palm candy, the colour analysis is a very important parameter.

TRIAL RUN	**L**	**a***	**b***
1	68.29	4.45	19.49
2	68.71	3.86	18.94
3	68.28	3.19	21.38
4	68.45	3.78	20.51
5	57.40	4.62	23.82
6	59.26	4.21	22.98
7	68.40	3.45	21.49
8	69.26	4.19	20.28
9	70.12	2.77	17.68
10	62.21	3.18	19.72
11	64.62	3.40	20.15
12	58.49	4.26	19.38
13	64.17	3.81	21.23
14	58.36	2.17	18.51
15	70.36	3.29	20.28
16	57.9	4.92	23.64
17	69.58	4.14	19.12
18	75.79	2.36	16.59
19	68.25	3.23	18.84
20	83.47	1.23	12.56
21	70.21	4.36	18.25
22	73.17	4.75	20.22

Table 9: Colour analysis of all the trials of Palm candy

Note: The parameters determined were L (lightness), a* (-a* to a* indicated green to red) and b* (-b* to b* indicated blue to yellow)

There might be several reasons for the colour of Palm candy such as non-enzymatic browning reactions (Maillard reaction) and oxidative rancidity. The reason behind the browning was the reaction between sugar syrup and organic acids (Mall et al., 2006). The rate of browning reaction increases with storage time. As crystallization period increased the CIE colour values (L*, a* and b*) increased, which indicated the brighter colour of mixture solution. These parameters gave the information on the reddish-brown colour of the crystallized sugar.

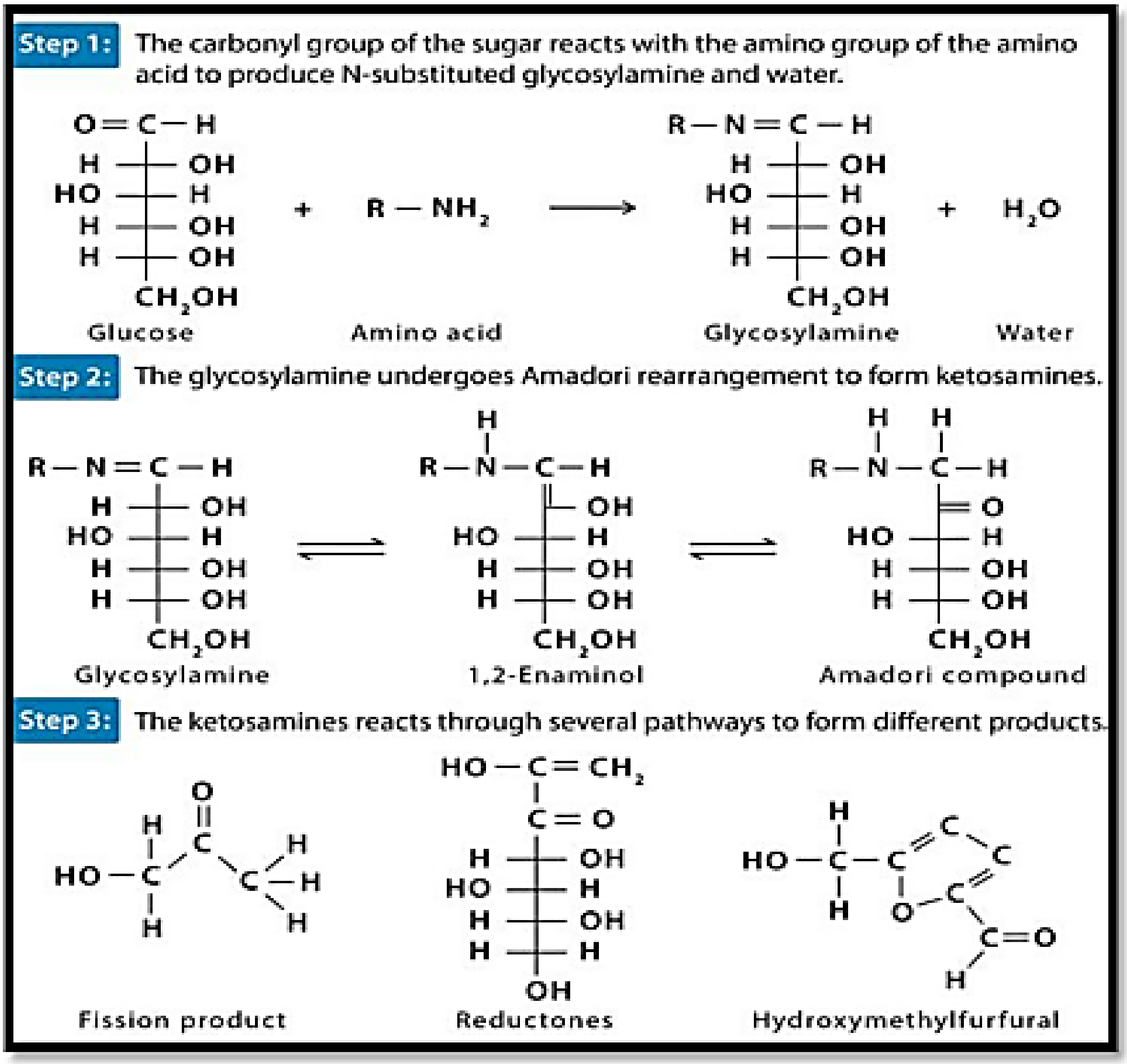


Figure 21: Mechanism of Maillard reaction (Upadhyaya et al., 2023)

3.12 **SENSORY ANALYSIS**

Sensory analysis integrates many different sciences to understand better the sensory properties of products and consumer response to these properties.

Quality Attributes					
SAMPLES	**COLOUR**	**TEXTURE**	**FLAVOUR**	**MOUTHFEEL**	**OVERALL ACCEPTABILITY**
1	8.45 ± 0.65	6.25 ± 1.02	7.26 ± 0.26	7.56 ± 0.64	7.98 ± 0.68
2	8.23 ± 0.26	7.26 ± 0.36	7.12 ± 0.45	6.98 ± 0.49	7.68 ± 0.13
3	7.98 ± 0.65	7.58 ± 0.65	7.36 ± 0.69	7.45 ± 0.13	7.78 ± 0.82
4	9.25 ± 0.48	7.12 ± 0.45	8.52 ± 0.12	8.45 ± 0.26	8.97 ± 1.05
5	8.96 ± 1.12	8.32 ± 0.28	8.16 ± 0.98	8.78 ± 0.97	8.86 ± 1.19
6	8.56 ± 0.22	6.96 ± 0.96	8.74 ± 1.09	8.12 ± 1.06	8.21 ± 0.98
7	9.10 ± 0.36	8.24 ± 0.78	8.03 ± 0.28	8.34 ± 0.58	8.85 ± 0.47
8	9.58 ± 0.56	7.56 ± 1.25	8.99 ± 0.36	9.01 ± 0.74	9.23 ± 0.85
9	9.45 ± 0.47	8.54 ± 1.09	9.15 ± 1.02	8.59 ± 0.14	9.05 ± 0.62
10	9.31 ± 1.10	8.98 ± 0.58	9.56 ± 1.31	9.58 ± 1.29	9.46 ± 0.12

Table 10: Sensory analysis data of 10 samples of palm candy

Note: Results were expressed as mean ± standard deviation.

CHAPTER 4

CONCLUSION

4. CONCLUSION

The study on Palmyrah palm Candy was extensive. Several attempts were carried out in order to improve the fundamental procedure utilised to manufacture this product. Palm candy manufacture now follows a consistent operating method. It was revealed that the quality and nutritional content of the palm candy produced is mostly determined by three parameters: the amount of palm candy syrup used, the heating temperature, and the heating duration. The result got darker, sweeter, and more flavourful as the temperature and cooking time rose. This climb was maintained until the ideal temperature and heating time were reached. Further increasing the temperature or cooking time made the product bitter and aesthetically unattractive. Furthermore, there appears to be a direct relationship between the mineral content and total phenolic content of the finished product, as well as the heating duration and temperature utilised during the manufacturing process. Following comprehensive sensory, colour, and mineral content analyses of all created samples, it was concluded that the optimal combination for the creation of palm candy was the addition of 750g palm candy syrup to 1500g sugar. Trial runs 18 and 22 had the best results of all the experiments, with yield percentages exceeding 80%.

Some potential future aspects of Palm candy are:

1. **Increased Demand for Natural Sweeteners:** With a growing emphasis on health and wellness, there is a rising demand for natural sweeteners like Palm Candy as an alternative to refined sugars and artificial sweeteners. Consumers are becoming more conscious of the health implications of their food choices, and Palm Candy fits into this trend as a natural and healthier option.
2. **Innovation in Palm Candy Products:** The food industry is known for innovation, and we may see new Palm Candy-based products emerging. This could include ready-to-use Palm Candy syrups, Palm Candy-infused snacks, or even Palm Candy sweetened beverages. These innovations would cater to consumer preferences for convenience and novel flavours.
3. **Sustainability and Ethical Sourcing:** Sustainable and ethical sourcing practices are becoming increasingly important for consumers. Companies that produce Palm Candy may need to focus on sustainable palm tree cultivation and ethical tapping practices to meet these demands. Certifications such as organic and fair trade could become more common in Palm Candy production.
4. **Health and Nutritional Research:** Ongoing research into the nutritional benefits of Palm Candy may uncover even more health advantages. As scientific knowledge evolves, we might discover new ways in which Palm Candy can positively impact health, leading to its increased popularity.
5. **Global Awareness and Availability:** While Palm Candy has deep roots in certain regions like South Asia and Southeast Asia, increased global awareness and availability could expand its market. As consumers worldwide become more interested in diverse and authentic flavours, Palm Candy might find its way into various international cuisines.
6. **Artisanal and Craft Production:** In some regions, there is a resurgence of interest in artisanal and craft food production. Palm Candy, with its traditional production methods and

cultural significance, fits well into this trend. Artisanal producers might focus on small-batch, high-quality Palm Candy production, appealing to discerning consumers.

7. **Health Food and Nutritional Supplements:** Palm Candy could also see use in the health food and nutritional supplement industries. As a natural sweetener with nutritional benefits, it might become an ingredient in products designed to boost overall health and well-being.

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