THE DETERMINATION OF SUGAR CONTENT AND SWEETNESS INDEX OF NIPA PALM SUGAR (GULA APONG) OF SARAWAK

KUN AQILAH BINTI MARSET

BACHELOR OF SCIENCE (Hons.) CHEMISTRY WITH MANAGEMENT
FACULTY OF APPLIED SCIENCES
UNIVERSITI TEKNOLOGI MARA

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This Final Year Report Project entitled **"The Determination of the Sugar Content and Sweetness Index of Nipa Palm Sugar (Gula Apong) of Sarawak"** was submitted by Kun Aqilah binti Marset, in partial fulfilment of the requirement for Degree of Bachelor of Science (Hons.) Chemistry with Management, in the Faculty of Applied Science, and was approved by

Assoc. Prof. Ts. ChM. Dr. Mohammad Isa bin Mohamadin
Supervisor
Deputy Rector (Academic & International Affairs)
Universiti Teknologi MARA Cawangan Sarawak
94300 Kota Samarahan
Sarawak

Junaidah binti Mat Jusoh
Co-Supervisor
Center for Applied Sciences Studies
Universiti Teknologi MARA Cawangan Sarawak
94300 Kota Samarahan
Sarawak

Nurhafizah binti Mohd Selihin
Project Coordinator
B. Sc. (Hons.) Chemistry with Management
Center for Applied Sciences Studies
Universiti Teknologi MARA
Cawangan Sarawak
94300 Kota Samarahan
Sarawak

Ts. Dr. Siti Kartina binti Abdul Karim
Head
Center for Applied Sciences Studies
Universiti Teknologi MARA
Cawangan Sarawak
94300 Kota Samarahan
Sarawak

Date: 8th August 2023

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(Kun Aqilah binti Marset)

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LIST OF ABBREVIATIONS

BI	: Browning Intensity
CFU/g	: Colony Forming Unit per gram
CSCM	: Coco-Sap Chiller Method
DPPH	: 2, 2-diphenyl-1-picrylhydrazyl
EC_{50}	: Effective Concentration
EtOAc	: Ethyl Acetate
EtOH	: Ethanol
FW	: Firewood
GI	: Geographical Index
H_2O	: Water
HMF	: 5-hydroxymethyl-2-furfural
LC_{50}	: Lethal Concentration
LPG	: Liquified Pressure Gas
ME	: Microwave
MPN	: Most Probable Number
OHE	: Open-Heat Evaporation
RE	: Rotary Evaporation
TA	: Titratable Acidity

TSS	: Total Soluble Solid
TQP-MS/MS	: Tiple Quadrupole Mass Spectrometry/ Mass Spectrometry
SDGs	: Sustainable Goals

ABSTRACT

THE DETERMINATION OF SUGAR CONTENT AND SWEETNESS INDEX OF NIPA PALM SUGAR (GULA APONG) OF SARAWAK

Nipah (or *Nypa fruticans*) palm tree is one of the mangrove plants that grows wildly in coastal areas. Many products could be obtained from the tree, including nipa -sap (*nira*), -syrup and -sugar (*Gula Apong*), and thus has a vast economic potential for Sarawak. However, until now, these products still have low economic value probably due to lack of product characteristic and traditional processing techniques which could contribute to low yield and inconsistent quality of *Gula Apong*. This study aims to characterize the *Gula Apong* in terms of sugar content and sweetness index. In addition, the effect of white sugar/ table sugar addition and heating processes/ heat sources employed during traditional cooking process are also being investigated on these two characteristics. The traditional cooking process of Gula Apong employed in this study were based on two different heating processes/ heat sources, namely firewood (FW) and liquefied petroleum gas (LPG). Changes of the pH, temperature and Total Soluble Solid (TSS) during the traditional cooking process of *Gula Apong* were measured on-site at every 30 minutes interval. The sugar content was determined by using refractometric method while the sweetness index was obtained through titration method. The results revealed that sugar content increases along the cooking process using both firewood and LPG. For the sweetness index, the obtained results were LPG 15% (95.30), FW 15% (87.34), FW 0% (67.63), LPG 0% (53.81), GM (50.85) and GK (50.28). The sweetness index and sugar content of *Gula Apong* are found to be higher than *Gula Melaka* and *Gula Kabong*. It is hoped that this study will lead to new insights into exploring the *Gula Apong* potential as natural sweeteners as well as understanding the quality status of *Gula Apong* produced using traditional cooking techniques process.

ABSTRAK

PENENTUAN KANDUNGAN GULA DAN INDEKS KEMANISAN GULA NIPAH (GULA APONG) SARAWAK

Pokok palma Nipah (atau *Nypa fruticans*) merupakan salah satu tumbuhan bakau yang tumbuh secara meluas di kawasan pantai. Banyak produk yang dapat diperoleh daripada pokok palma Nipah, termasuk nipah -*sap* (nira), -sirap dan -gula (Gula Apong), oleh demikian, Gula Apong mempunyai potensi ekonomi yang luas untuk Sarawak. Namun, sehingga sekarang produk-produk tersebut masih mempunyai nilai ekonomi rendah disebabkan oleh kurangnya pengetahuan tentang teknik pemprosesan yang berkemungkinan menyumbang kepada penghasilan yang rendah kualiti Gula Apong yang tidak konsisten. Kajian ini bertujuan untuk mencirikan Gula Apong dari segi kandungan gula dan indeks kemanisan. Tambahan pula, kesan penambahan gula putih proses pemananasan/ sumber haba yang digunakan semasa proses memasak tradisional juga dikaji terhadap kedua ciri ini. Proses memasak Gula Apong secara tradisional yang digunakan di dalam kajian ini merupakan kayu api *(FW)* dan *liquified petroleum gas (LPG)*. Perubahan pH, suhu dan jumlah pepejal larut *(TSS)* semasa proses memasak Gula Apong secara tradisional telah diambil pada setiap selang 30 minit. Tambahan pula, kandungan gula ditentukan menggunakan kaedah refraktometri manakala indeks kemanisan Gula Apong juga telah diperolehi dari kaedah pentitratan. Keputusan kajian menunjukkan kandungan gula meningkat semasa proses masakan menggunakan kedua kaedah iaitu kayu api dan *LPG*. Bagi indeks kemanisan, keputusan yang didapati adalah seperti berikut: LPG 15% (95.30), FW 15% (87.34), FW 0% (67.63) dan LPG 0% (53.81), GK (50.28) dan Gula Melaka (50.28). Nilai indeks kemanisan dan kandungan gula dari Gula Apong didapati lebih tinggi daripada Gula Kabung dan Gula Melaka. Kajian ini diharapkan agar dapat membawa kepada pandangan baharu dalam penerokaan potensi Gula Apong sebagai pemanis semula jadi serta memahami status kualiti Gula Apong yang dihasilkan menggunakan proses teknik memasak tradisional.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Nipa palm (*Nypa fruticans*) is among the mangrove plant species, a type of estuarine and swamp environmentally plant which can be found in Pacific and Indian ocean (Ebana *et al.*, 2015 and Hossain *et al.*, 2015). It is also widely distributed in Thailand among mangrove forests, with Pak Panang River Basin, Nakhon Si Thammarat, Southern Thailand, having the biggest plantation area (around 41 km^2) (Saengkrajang *et al.*, 2021). It is the only palm tree that partially grows underwater (Saraiva *et al.*, 2023). It produces numerous propagules, which then will dispersed by the ocean currents (Widodo *et al.*, 2020). Nipa palms serve as the first line of defence while also lessening the effects of hurricanes, cyclones, and tsunamis (Widodo *et al.*, 2020).

Nipa palm sap is traditionally made by heating fresh sap in an open pan over a wood-fired stove (>100 ℃) while continuously hand-stirring to create a viscous, brown, concentrated liquid that is sweet and has a total soluble solids content of up to 48 brix% and nipa palm syrup > 65 brix% (Saengkrajang *et al.,* 2021).

In comparison to sugarcane, palm syrups often have better levels of minerals and antioxidants and a lower glycemic index (Saengkrajang *et al.,* 2021). Palm syrups from the following plants have long been used as natural sweeteners: *Arenga pinnata* (sugar palm), *Borassus flabellifer* (palmyra palm), *Cocos nucifera* (coconut palm), *Nypa fruticans* (nipa palm), and *Pheonix dactylifera* (date palm) (Saengkrajang *et al.,* 2021).

There were several studies related to nipa palm including the effect of the physical and chemical properties of syrup form nipa palm sap in Surat Thani, Thailand had been reported by (Apirattananusorn, 2021). The BI, HMF, sugar and salt content, odour, viscosity, taste, microbial count, and overall liking of the sap had been studied on. The browning intensity of the syrup was measured at 2.08 while the HMF was 16.28 mg/kg. The research revealed that the nipa palm syrup contained a high sugar (90.48%, db) and small amount of salt

(2.38%, db). The pH and acidity of the syrup were not noticeably change throughout the 12 weeks of storage time. The microbial analysis of the nipa syrup exposed that the total plate counts numbers in syrup, total yeast, and mold were less than 10 CFU/g. *E. coli* was reported having less than 3/g of MPN value until the final week of the storage period. The study suggested that the heating process of nipa palm at 80℃ was suitable for 12-week storage and genuinely harmless for consumption.

The physicochemical properties and nutritional composition of nipa palm syrup had been reported by Saengkrajang *et al.*, 2021. The variations in colour, clarity, pH, viscosity, TSS, total acidity, water activity, salinity, browning intensity and HMF were observed. The total phenolic acid and total flavonoid contents with varying concentration were determined. It was revealed that the major elements present in *Nypa fruticans* in Pak Panang District (site I), Nakhon Si Thammarat (site II), and Southern Thailand (site III) were Potassium and Sodium. Other than that, sugar derivatives, polyphenols, non-protein nitrogenous compounds, organic acids and several flavour elements were also identified. The browning intensity obtained were much higher for site I, site II and site III than reported by (Apirattananusorn, 2021). It was slightly higher for the HMF from site I while for site II and site III is lower as compared to reported by (Apirattananusorn, 2021). The total sugar of palm sugar from Pak Panang District, Nakhon Si Thammarat and Southern Thailand were higher than in Surat Thani, Thailand as reported by as Saengkrajang, (2021).

The study of sustainable nipa palm product utilization in Khanap Nak, Thailand was conducted (Cheablam and Chanklap, 2020). It focuses on the type of products made from nipa palms and the yields of nipa palm produced. The results of this study from interviewing the local farmers recommended that nipa palm in Khanap Nak could yield 5-100 years. However, the quantities of the nipa palm were observed varies in each season, leading to inconsistency of the nipa palm products prices.

The study on the distribution and characteristics of nipa palm (*Nypa fruticans*) in Southern part of Cilacap regency, Central Java, Indonesia was conducted by Widodo *et al.,* 2020. The factors such water pH, water salinity, soil pH and type of soil were determined. The study revealed that the nipa palm was primarily distributed along the river with Grey regosol and Alluvial Hydromorph soils.

Beside nipa palm, studies on other types of sugars from palm tree such *Cocos nucifera* (Coconut palm sugar), *Arenga Pinnata* (Aren palm sugar), and *Borassus flabellifer* (Siwalan palm sugar) were also being conducted. Prijono and Rachmatika (2020) had investigated a study on the effect of the sweetness level and amino acid composition of the four types of palm sugars mentioned earlier in the feed intake for Lorikeet bird (*Trichoglossus haematodus*). The major components of these palm sugar are sucrose which offered the Lorikeets high energy, low in protein and rich in amino acids as comparable to nectar. The study revealed that the feed intake of Siwalan sugar is significantly higher than the Coconut palm sugar, Aren palm sugar, and Nipa palm sugar. Thus, this study showed that Siwalan sugar has high sucrose content.

Next, the study conducted by Saraiva *et al.,* (2023) on the chemical analysis, nutritional profile, health impacts, safety and health control, and food industry applications. The study determined that the cost for coconut sugar production is higher than cane sugar. However, people are willing to pay the high prices due to its high nutritional values and low glycemic index (GI). The study revealed that a lower rate GI diets lower the probability of emerging certain chronic diseases such as type II diabetes. However, the health benefits also need to be focus on due to the lack of knowledge about this characteristic.

For *Cocos nucifera* (Coconut palm sugar), Asghar *et al.*, 2020 had reported the processing of coconut sap into sugar syrup using RE, ME, and OHE techniques. Coconut sugar was produced from the heating process of coconut sap using a traditional method at a high temperature (>100℃) in an open pan for several hours (3-5 hours). However, this study had revealed that the quality deterioration could occurred in terms of physical and chemical properties after conducting this traditional method. Thus, the study observed that coconut sugar produced by rotary evaporation at 60℃ and 250 mbar vacuum (RE-60) only take 12.2 min. The possible lowest temperature for this process is only 54.8℃ as compared to ME (13 min and a higher temperature at 103.2℃) and OHE (46.8 min at 101.6℃). This study suggests that using the rotary evaporation (RE-60) at 60℃ and 250 mbar vacuum is the most suitable method for producing a better physicochemical quality with minimum input energy and shorter processing time.

Lastly, Hebbar *et al.,* (2020) had reported a study on the inflorescence sap collected using novel coco-sap chiller method and its value-added products of *Cocos nucifera* (Coconut palm sugar). A new method which is 'coco-sap chiller' method (CSCM) instead of traditional method had been developed for collecting the coconut fresh sap. The study had identified the profiling of phenolic acids, flavonoids, amino acids, and vitamins using Ultra-Performance Liquid Chromatography (UPLC coupled with TQD-MS/MS). Different result in physical and biochemical properties had been observed between both collecting methods. A pH for sap collected by using CSCM was slightly alkaline (7-8) while below 6 by using traditional method. The study summarizes coconut sap collected by CSCM was fresh and containing a lot of health encouraging constituents such flavonoids, vitamins and phenolics.

To conclude, there were several studies had been conducted on *Nypa fruticans,* however it is still much more to discover on it especially on its characteristics. In Malaysia, nipa palm (*Nypa* fruticans) common and famous name is *Gula Apong* which will be further discussed in this chapter.

1.2 Problem statement

Gula Apong is one of products had been produced among local people in Sarawak and eventually become the source of their income. However, the market of *Gula Apong* is very limited to within Sarawak only. *Gula Apong* is correspondingly only used by small local based cottage industries despite having huge potential as another alternative to current table sugar, syrup, honey etc. It is postulated that such scenario is probably due to insufficient study on the characteristic and properties of *Gula Apong*, which then led to low marketability of the product and limited application in daily intake. To date, there are only a few studies can be seen on *Nypa fruticans* Sarawak in contrary to *Nypa fruticans* at other countries such as Indonesia, Nigeria, and Thailand by local researchers. To further explore the potential of local *Gula Apong* and to increase its economic value, the characteristic, and properties of nipa palm sugar from *Nypa fruticans* need to be done.

1.3 Research questions

1. What is the sugar content and sweetness index of processed *Gula Apong*?
2. How does the different heating process time and table sugar addition affect the sugar content of traditionally processed *Gula Apong*?
3. How does the different cooking techniques and table sugar addition affect sweetness index of traditionally processed *Gula Apong*?
4. What is the difference of sweetness index between traditionally processed *Gula Apong*, *Gula Melaka* and *Gula Enau (*or *Gula Kabong)*?

1.4 Objectives of study

The overall objective of the study is to characterize the processed *Gula Apong* in terms of sugar content and sweetness index.

The specific objectives are as below:

1. To determine the sugar content and sweetness index of *Gula Apong*.
2. To determine the effect of different heating process time and table sugar addition on sugar content of traditionally processed *Gula Apong.*
3. To determine the effect of different cooking techniques (LPG vs Firewood) and table sugar addition on sweetness index of traditionally processed *Gula Apong.*
4. To compare the sweetness index value between traditionally processed *Gula Apong*, *Gula Kabong* and *Gula Melaka.*

1.5 Significance of study

Gula Apong is a very significant product of local people of Sarawak and has become of well-known and signature local products. For certain areas, the production of *Gula Apong* has become their major economic activity and a source of their income. Looking at the vast potential of *Gula Apong,* initiatives have been taken by the authority to support this industry so that it can become a major part of Sarawak industry particularly in the food-based industry. The characterization particularly in term of sugar content and sweetness is very imperative especially toward contributing to the development of *Gula Apong* Sarawak's Quality Grading System and the filing of *Geographical Indication* (GI) of *Gula Apong*. Having these quality grading system and GI will certainly help to boost the economic and marketability value of *Gula Apong* which has the direct impact through elevating the economic status of the people. This is indeed in tandem with Sustainability Goals (SDGs) specifically for Area 1 (No Poverty) and Area 2 (Zero Hunger).

1.6 Expected Output/Outcomes/Implications

The expected outcomes from this study should be as following:

i. The sugar content is expected to increase throughout the heating process time due to table sugar addition of traditionally processed *Gula Apong*.
ii. The different cooking process techniques (LPG vs FW) as well as table sugar addition exhibit different values of sweetness index.
iii. It is expected that, there is a difference in the sweetness index (SI) between traditionally processed *Gula Apong*, *Gula Kabong* and *Gula Melaka*.

From this study, the finding can provide advantages and contribute to the food industry as an alternative natural sweetener in the global market. Furthermore, nipa palm is abundant and could make the Sarawak product as competent as other notable commercialized sweetener with an established Quality Grading System.

CHAPTER 2

LITERATURE REVIEW

2.1 Nipa Palm

The scientific name of Nipa palm (Figure 2.1) is *Nypa fruticans* Wurmb. The main product from nipa palm is the fresh sap. It is obtained by cutting the stalks of the inflorescences as well as tapping for approximately 12 hours, which is the same method to collect fresh sap from palmyra palm (*Borassus flabellifer* Linn.) (Apirattananusorn, 2021). Figure 2.2 shows the globular fruit of Nipa palm tree. Bamboo tubes (Figure 2.3) filled with some pieces of wood from Kiam (*Cotylelobium lanceolatum* Craib) is usually used to collect the fresh sap to avoid deterioration (Apirattananusorn, 2021). Natural microbes such as yeast and acid bacteria (for example, lactic acid bacteria in *Nypa fruticans*) fermented the fresh sap due to its high sugar content to produce local alcohol drink and vinegar (Apirattananusorn, 2021). Numerous chemical processes, in instance non-enzymatic browning processes like Maillard and caramelization, commonly occur during the prolonged heating and have an impact on the nutritional content and sensory properties of the syrups (Phetrit *et al.*, 2020). Naturally, there are no purifying steps or artificial chemicals used in the production of palm sugar (Victor and Orsat, 2018). As reported, the fundamental factors influencing the nutritional value as well as the sugar profile of palm syrup include species, harvesting period, plantation location, and processing (Francisco Ortega *et al.*, 2013).

Figure 2.1 The trunk of Nipa Palm (*Nypa fruticans*)

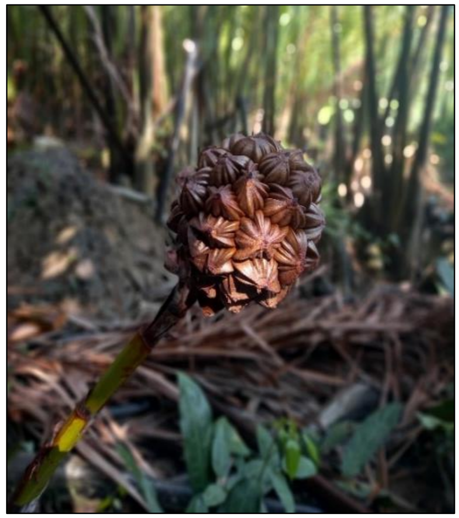

Figure 2.2 The Globular Fruit of Nipa Palm (*Nypa fruticans*)

Figure 2.3 Bamboo Tubes for Collecting Sap

2.1.1 Geographical distribution

Nipa palm can be found in a tropical as well as the coastal regions such as Southern Thailand, Pacific and Indian Oceans (Apirattananusorn, 2021 and Saraiva *et al.*, 2023). The major wild nipa palm plantation is originated in Indonesia (700,000 ha), followed by Papua New Guinea (500,000 ha) and the Philippines (8000 ha), respectively.

2.1.2 Utilization of Nipa Palm Based Product

Nypa fruticans is reported having diverse multipurpose tree among the other palm species due to its extensive range of utilization from most of the tree parts as shown in Table 2.1.

Table 2.1 Part of Nipa palm tree and its utilization

Part of the tree/ Product	Utilization
Inflorescences	Amorphous sugar, vinegar, palm sugar.
stalks (sap)	Fermented sap produces local alcohol, beer, and bioethanol. Treating diabetes
Young leaves	Wrap for smoking tobacco.
Midrib leaves	Brooms, basketry crafts, attract fish.
Mature leaves	Roofing for homes.
Stem	Tutor swimmers.
Endosperm of unripe fruits	Snack.
Syrup	Bread spread, topping for both modern and traditional foods.
Sprouted shoots	Vermicides.

Source: Chau Sum *et al.*, 2013, Hossain, 2015 and Apirattananusorn, 2021.

Inflorescences Stalks (Sap)

The mildly fermented sap known as "air nira" or "air sadap" in Indonesia and Malaysia and "tuba" in the Philippines is produced, distributed, and consumed as a local brew throughout South-East Asia. The sugary fluid from the flower stem is used to produce different compounds, including treacle (molasses), amorphous sugar, vinegar, and alcohol (Hossain, 2015). Lastly, according to Yusoff *et al.*, (2015), traditional Malay medicine uses vinegar from nipa palm tree to cure diabetes.

Young, Midribs and Mature Leaves

Nipa palm tree young leaves can be used to wrap tobacco for smoking. The midribs' leaves can also be made into brooms and other basketry crafts, and some of them can even be waved in the water to draw fish. The mature leaves of the nipa palm are highly valued by the locals for use in creating roofs for houses (Hossain, 2015).

Stems

The nipa palm plant's tall stem has a high buoyancy that is very suitable for Tutoring new swimmers (Hossain, 2015).

Endosperm (Fruits)

The fruits, which is the white endosperm of the immature nipa palm seeds are consumed as snack due to its sweet and jelly-like texture (Chau Sum *et al.*, 2013). The *Nypa fruticans* endosperm also produced as canned food (Nguyen Phuoc Minh, 2014).

Syrup

Syrup is the product from the nipa palm tree from the continuously heating process, can be eaten as bread spread as a natural food (Hossain, 2015). It can also be eaten as the topping for ice creams as a natural sweetener. In addition, in Thailand, nipa palm syrup is always eaten with traditional food, *Jung* (Surat Thani, Thailand local dessert) (Apirattananusorn, 2021).

2.1.3 Nipa Palm Sugar (*Gula Apong*)

Gula Apong which is also known as palm sugar, is derived from the Nipa Palm (*Nypa fruticans*). *Gula Apong* is one of the delicacies that can be the raw material in the making of cakes, desserts, and food coatings. It has a very high potential to be industrialized to become another alternative to commercial table sugar. Due to its abundance, the production of *Gula Apong* can become part of the economic activity for the suburban or villagers. With an extra proper planning and support, *Gula Apong* can also become a sought-after invention in the food industry.

Numerous investigations have been undertaken in relation to *Gula Apong.* First, according to (Abdullah *et al.*, 2022), a study was done to determine the effects of *Gula Apong's* use as a substitute sweetener in *kaya* on its physicochemical and sensory qualities. The results of this analysis showed that all *kaya* formulations had mildly acidic pH values between 5.81 and 5.84. The organic acids in the nipa palm sap may be present due to the lower pH. There were no discernible differences in the *kaya's* moisture content. Therefore, this investigation implies that the use of nipa palm sugar (*Gula Apong*) had no appreciable impact on its physicochemical qualities.

A study on phytochemical screening, determination of antioxidant activity and alpha-amylase inhibitory of nipa palm sugar was conducted by Sabri *et al.,* (2019). While EtOAc extract only revealed the presence of terpenoids, phenol, and tannins, phytochemical analysis of H_2O, MeOH, and EtOH extracts revealed the presence of saponin, terpenoids, phenol, flavonoids, and tannins. The inhibition of alpha amylase was used to assess the anti-diabetic effect of nipa palm sugar extracts. The outcomes showed that, when compared to other extracts, EtOH extract demonstrated the strongest inhibition.

A study of antioxidant and cytotoxicity of *Nypa fruticans* (Nipa palm sugar) extract had been conducted by Sabri *et al.,* (2018). The study revealed the cytotoxicity and 2, 2-diphenyl-1-picrylhydrazyl (DPPH) scavenging capacity of the methanol extract of Nipa palm sugar. Based on the extract's ability to scavenge DPPH, the antioxidant activity was assessed. The brine prawn Artemia salina was used in the cytotoxicity test, and the extract's LC_{50} value was determined. Nipa palm sugar had an EC_{50} of 1304 mg/mL according to the antioxidant activity, whereas ascorbic acid had an EC_{50} of 0.6112 mg/mL. The cytotoxicity test findings indicated that the methanol extract of nipa palm sugar was non-toxic because the LC_{50} value was 184.0 mg/mL.

2.2 Cooking Process of *Gula Apong*

2.2.1 Traditional Cooking Process using Firewood (FW)

The fresh nipa sap will be harvested from any wild grown nipa plant that are grown at. Then, the harvested sap will be cooked (above 100°C) in an open big wok by using firewood until it turns concentrated (Apirattananusorn, 2021). Along the cooking process, the colour changes are observed due to the non-enzymatic browning reactions (Maillard reaction and caramelization) (Apirattananusorn, 2021). It is not possible to control the temperature during this traditional process leading to a strong dark brown, which could lead to a low grade *Gula Apong* (Tai *et al.*, 2019).

2.2.1 Traditional Cooking Process using Liquified Petroleum Gas (LPG)

The nipa will be harvested from any wild grown nipa plant. Then, the harvested sap will be cooked (above 100℃) in an open big wok by using LPG until it turns into the desired product which is *Gula Apong*. This method usually takes more heating time as compared to traditional process for the nipa sap to fully became *Gula Apong.* This may be due to the full capacity of the heat that come from the firewood is higher than the LPG. Besides that, the uncontrollable temperature for traditional cooking process also helps the *Gula Apong* cooked at a shorter time.

2.2 Composition, Properties and Quality Characteristics

2.3.1 Sap Composition

Table 2.2 depicts the physical and chemical composition of *Nypa fruticans* sap as cited by Apirattananusorn (2021).

Table 2.2 Physical and chemical properties of Nipa sap

Physical and Chemical Properties	Values
Colour	
L*	52.29±6.40
a*	0.93±0.27
b*	5.21±0.14
T (%)	8.00±0.36
pH	5.35±0.00
TSS (Brix%)	14.53±0.05
Acidity (%, db)	2.76±0.03[l]
Reducing sugar (%, db)	5.15±0.05
Total sugar (%, db)	50.54±0.13

Moisture (%, wb)	86.21±0.13
Protein (%, db)	1.31±0.02
Salt (%, db)	2.47±0.13

[1]Acidity was calculated as lactic acid
db was based on dry weight basis
ws was based on wet weight basis

Source: Apirattananusorn, 2021

Nypa fruticans sap was reported to have the pH of 5.35, 14.53% of TSS, 50.54% of total sugar, 5.15% reducing sugar, 2.76% of acidity, moisture of 86.21%, protein with 1.31%, and salt with 2.47% (Apirattananusorn, 2021).

The browning reaction during the cooking process of palm sap might be cause by the Maillard reaction, caramelization, or ascorbic acid oxidation (Haryanti *et al.,* 2022). The transmittance (T) indicating the indistinct solution due to colloidal dispersions usually produced by acid bacteria and yeast (Hebbar *et al.,* 2018). The colour expressed according to CIELAB system will be determine by colorimeter: L* for lightness (blackness: 0; whiteness: 100), a* (greenness: negative; redness: positive) and b* (blueness: negative; yellowness: positive).

It has been reported that the total phenolic content of saline water of Nipa palm vinegar (NPV) was statistically knowingly lower than in both brackish water and fresh water where NPV ($p < 0.0001$) (Senghoi and Klangbud, 2021). Besides, the brackish water NPV for the percentage of acetic acid was significantly lower than saline water and fresh water with NPV ($p = 0.002$) (Senghoi and Klangbud, 2021). NPV also exhibited the highest anti-inflammatory activity IC_{50} 17.59±0.17 µL/mL followed by saline and brackish water with IC_{50} 18.12±0.47 µL/mL and 28.29±2.64 µL/mL, respectively.

2.3.2 Syrup Composition

A study by Apirattananusorn (2021) had reported that the content for fructose, glucose, sucrose, moisture, and protein as summarized in Table 2.3.

Table 2.3 Chemical properties of Nipa syrup

Chemical properties	T1	T2	T3	T4
HMF (mg/kg)	$13.94±0.46^{c}$	$44.40±0.71^{a}$	$14.53±0.60^{c}$	$16.28±0.46^{cb}$
Fructose (%, db)	$26.60±0.32^{c}$	$24.29±0.01^{d}$	$28.28±0.42^{ab}$	$27.02±010^{bc}$
Glucose (%, db)	$24.23±0.49^{b}$	$21.02±0.14^{c}$	$25.75±0.13^{a}$	$24.63±0.10^{b}$
Sucrose (%, db)	$46.97±0.12^{b}$	$41.24±0.20^{c}$	$49.35±0.33^{a}$	$46.54±0.42^{\mathbf{b}}$
Moisture (%, wb)	37.32±0.58	37.29±0.76	37.21±0.24	37.28±0.61
Protein (%, db)	$1.34±0.03^{a}$	$1.10±0.02^{b}$	$1.11±0.06^{b}$	$1.10±0.04^{b}$

^{a,b,c,d}The mean values in the same row are significantly different ($p < 0.05$)
^{ns}The mean values in the same row are not significantly different ($p \geq 0.05$)
db was based on dry weight basis
wb was based on wet weight basis

Source: Apirattananusorn, 2021

The results showed that the higher the HMF, the lower the value of the fructose, sucrose, and glucose. The increasing of processing temperature caused protein degradation due to Maillard reaction when the sap become more concentrated. The result trend was similarly to a study by Phetrit *et al.,* (2020).

Phetrit *et al.,* 2020 also reported that the element K was detected as the richest element in the nipa palm syrup along with other elements such as Mg, Ca, P, Na, Fe, Zn, Cu, Mn, and I. Si was also found in the syrup which possesses health benefits such as bone strengthening, reduction of the atherosclerosis risk, anti-inflammatory activity, and the improvement of collagen production.

2.3.3 Palm Sugar Composition

The ash content exhibited the inorganic compounds that possibly affect the colour and hygroscopic properties of palm sugar. Fat content will quantify the fat content that will have negative impact to the health (Yeyen Maryani *et al.,* 2021). Fructose and glucose are known as disaccharide while sucrose is monosaccharide. Disaccharides needs to undergo break down process by certain enzymes before being absorbed in the intestine while monosaccharides will be absorbed directly in the intestine (Yeyen Maryani *et al.*, 2021).

2.3 Sugar Content and Sweetness

Sugar is categorized under a class of food substance identified as carbohydrate which contains carbon, hydrogen, and oxygen (Wilberforce *et al.,* 2016). Sugar in the nipa sap has three types of structure known as mono, oligo or polysaccharides which contributing to the aroma and the intensity of its colour. The main function of sugar in food products is to provide the sweet taste and flavour while acting as preservative where the sugar prevents the growth of microorganisms. Note that table sugar does not contain any nutritional fact due to it is only full of calorie (Wilberforce *et al.,* 2016). For these past years, sugar is usually substituted with chemicals such saccharin and cyclamate.

According to a review paper by Magwaza and Opara (2015), a study on the analytical methods for determination of sugars and sweetness of horticultural products was conducted. In this review, the analytical techniques for determining the sugars and sweetness of fresh and processed fruits and vegetables are covered in this review, along with the use of instrumental destructive and non-destructive techniques to assess the sugar composition and describe the sweetness. Sugar content is determined by using refractometric method which include the use of refractometer. The TSS value is expressed by % Brix, which is automatically showed on the refractometer where it is based on ratio of the speed of light in vacuum as well as the speed of light through the sample. TSS values obtained must be adjusted using a factor, which is basically based on the percentage provided by sugars (Magwaza and Opara, 2015). For instance, the factor for lactic acid in determining *Gula Apong, Gula Enau (*or *Gula Kabong)* and *Gula Melaka* sweetness is 0.9. Table 2.4 summarized the application and models used in postharvest research of different fruit and vegetables.

Table 2.4 The application and models used in postharvest research of different fruit and vegetables.

Produce	Sugar Content expressed as	Type of Refractometer	Reference
Apple	TSS (%)	Auto digital	Nyasordzi *et al.*, (2013)
Blueberry	SSC (%)	Digital	Leiva-Valenzuela *et al.*, (2013)
Jaboticaba	SSC (%)	Digital hand-held	Torres Mariani *et al.*, (2014)
Orange	SSC (%)	Temperature-compensated	McDonald *et al.*, (2013)
Orange	SSC/TSS (˚Brix)	Digital	Wang *et al.*, (2014)
Pear	Sugar Content (˚Brix)	Digital	Wei and Wang (2013)
Plum	SSC (%)	Digital	Pereira *et al.*, (2013)
Pomegranate	SSC (˚Brix)	Benchtop temperature compensating	Zhang and McCarthy (2013)
Watermelon	SSC	Digital hand-held	Jie *et al.*, (2013)

Source: Magwaza and Opara (2015)

There are various types of methods to calculate the sugar content of a food. Amid the modern usage of instrumentation, High-Pressure Liquid

Chromatography (HPLC) is one of the main methods in determining the sugar content due to its accuracy and innovative method for carbohydrate analysis (Ma *et al.*, 2014). This summary had shown that HPLC method has been broadly chosen as the instrumentation used for determination of carbohydrates compound in foods. Table 2.5 depicts the overview of HPLC application to quantify sugar concentration of different horticultural products as cited by Magwaza and Opara (2015)

Table 2.5 The overview of HPLC application to quantify sugar concentration of different horticultural products.

Sample	NSCs analyte	Column	Mobile phase (eluent)	Detector	References
Fruit Vegetable Cereals	Fructose Glucose Sucrose	Prevail carbohydrate column	CH_3CN: H_2O (70:30 v/v)	ELSD	Shanmugavelan *et al.*, 2013
	Fructose Glucose Sucrose	CHO High Performance 4 µm (4.6mm x 250mm cartridge)	Acetonitrile :Distilled water (90:10 v/v)		Siti Roha *et al.*, 2013
Honey[a], Sugarcane jaggery[a], Sugarcane jaggery[b], Palm jaggery[b], Palm sap[b] Palm syrup[b]	Fructose Glucose Sucrose	Reverse phase Supelcosil LC-NH_2 (25 cm x 4.6 mm, 5µm)	a: CH_3CN: H_2O (85:15 v/v) b: CH_3CN: H_2O (65:35 v/v)	RID	Veena *et al.*, 2016

Source: Magwaza and Opara (2015) and Nipitpawn *et. al.*, 2022

For example, palm sugar can be obtained by treating and processing tree sap (nectar) from various types of palms such as aren (*Arenga pinnata (Wurmb) Merr*.), coconut (*Cocos nucifera Linn*), siwalan or palmyra (*Borassus flabellifer Linn*.), and nipah (*Nypa fruticans*) (Srikaeo and Thongta 2015). Palm sugar is always selected to become a substitute for table sugar as it can be naturally found without adding any preservative or chemical. According to Prijono and Rachmatika (2019), the nectar-based diets can be replaced with palm sugar solution-based diet. By doing this, the usage of brown sugar as the carbohydrate source for *T. haematodus* in captivity can be fully utilized. The sweetness of sugars is practically coming from the major components present in it, which are sucrose, fructose, glucose, and maltose (Sukoyo *et al.*, 2014).

The sweetness level of the palm sugar was analyzed by using hand-held refractometer (REF-113 ATC, 0-32% BRIX/ATC) in degree Brix (Prijono and Rachmatika, 2019). The result from brix% reading indicates total soluble solid (TSS) and the amount of sugar or the sweetness of the final product being analysed. A higher brix% gives higher nutrient density (assumption), has an improved in taste (widely known), and possesses a higher quality (Rane *et al.*, 2016).

Total soluble solid (TSS) and soluble solid content (SSC) are the crucial quality parameters used to indicate the sweetness of fresh and processed food products (Magwaza and Opara, 2015). These two terms are basically having the same meaning. The one that differentiate them is depending on the researchers report whether to use TSS term or vice versa. Soluble solids state the number of sugars, acids, along with minor amounts of dissolves proteins, vitamins, phenolics, pigments, and minerals in liquid samples.

Although the term brix% is commonly used interchangeably with TSS and SCC, brix% is theoretically referring only to the sugar content of the interest sample. Bearing in mind that sugars especially (glucose, sucrose, and fructose) and sugar alcohol (i.e, sorbitol and manitol) comprise approximately 85% of TSS in many fruits or other foods. This does not comply to fruit such limes that only have 25% of the TSS. The results of sugar content are always expressed in TSS or SSC.

The refractometer, which is a hand-held device generally measures the refractive index of juice. It is known as a standard method to measure the SSC or TSS of horticultural products such as fruits and vegetables. There are some types of refractometers that are in the marketplace, which are either based on the refraction or critical reflection of light that passes through the samples (Dongare *et al.,* 2014). The critical angle which is based on refractive index refractometer is more precise because it does not affect by the suspended solids and colour of the samples. Thus, refractive index is a very suitable and easy to implement for measuring brix percentage of turbid colloidal fluids (Dongare *et al.,* 2014). Brix refractometer is less effort, low-cost, readily available, less fragile, and less sensitive to environment such temperature and other factors. Refractometers can be found both digitally and analogue modes.

A sweetness index is the evaluation of sweetness as sucrose equivalent (Suceq). It is the calculation that based on the total suspended solid (TSS) or also known as brix% (or degree Brix) divided by titratable acidity. This is done because it is an estimation of the sweetness of fresh horticultural products where the sweetness index is based on the portion of the individual non-saturated sugar components (Magwaza and Opara 2015). As reported by Magwaza and Opara (2015), this sweetness index is the proportion of each carbohydrate that will be calculated which is according to the fructose and sucrose, 2.30 and 1.35 times correspondingly are sweeter than glucose. Thus, the level of sweetness is conveyed by using the molar concentration of each sugar component, namely glucose, sucrose, and fructose. Sweetness index can be calculated by using Eq (1) after conducting HPLC analysis of the individual sugars (Prijono and Rachmatika *et al.*, 2020).

SI = 1.00[glucose] + 2.30[fructose] + 1.35[sucrose] … (1)

The perception of taste in fresh horticultural products might be affected by other factors such as titratable acidity which was mentioned earlier in 2.3.2. A difference in SCC or TA alone does not implement applied importance concerning human perception of horticultural products sweetness (Magwaza and Opara, 2015).

SSC, TA, and the ratio which is SSC/TA features are usually used as laboratory and marketable indicators of maturity for many horticultural products. To conclude, SSC will increase because the fruits become sweeter when it started to ripe while TA decreases. The general sensory quality is highly associated with SSC and SSC/TA values in kiwi fruit (Tilahun *et al.*, 2020). The trend of TA value throughout the maturity of the fruits also differs depending on cultivars and harvest time of fruits (Park *et al.*, 2022). Although researcher is widely using SSC/TA ratio as an index of fruit maturity for several types of fruits, it has been reported that this measurement does not correspond to the perception of sweetness or tartness in others. Lactic acid and tartaric acids are the main organic acids which can be found in the palm sugar concentrate. It is found that the lactic acid is the main bacteria or microorganisms that produced organic acids (lactic acid). This condition has positively affected the decreased of palm sugar concentrate pH values. The pH of nipa palm sap is reported as 5.35 (Apirattananusorn, 2021). Thus, we can conclude that palm sugar concentrate including *Gula Apong* is slightly acidic in nature because of the presence of lactic acid in it.

CHAPTER 3

METHODOLOGY

3.1 Overview of Methodology

This chapter analyses on the experimental procedures that are implemented to achieve this research objectives. There are a few steps involves in this methodology. There will be a few flow charts provided for each methodology.

To achieve the first objective, sample preparation will be started in the first step. There will be two types of cooking techniques, two different types of samples collected, samples produced, and processing areas as showed in Table 3.1.

Table 3.1 Cooking techniques, types of samples and processing area

Cooking Techniques	Types of Samples	Processing Area
Firewood (FW)	0% sugar added. 15% sugar added.	Kampung Sri Tajo, Samarahan.
Liquified Petroleum Gas (LPG)	0% sugar added. 15% sugar added.	Kampung Pinggan Jaya, Kuching.

Source: Present study

Then, the samples will be taken at intervals of 30 minutes to perform the on-site measurements such pH, brix% and temperature (℃).

Next, the collected samples will be used to determine the sugar content by specific gravity bottle (pycnometer) bottle followed by inserting the values obtained into Eq (2) later.

For the second objective of this study, the sweetness index will be determined by conducting titratable acidity. The brix% values from the first method will be divided by the titratable acidity values to calculate the estimation of sweetness index for the *Gula Apong*. The same method will be applied for both *Gula Kabong* and *Gula Melaka*.

The last part in this study is to compare the sweetness index of the three types of palm sugar, namely *Gula Apong*, *Gula Kabong*, and *Gula Melaka*.

3.2 Experimental Flowchart

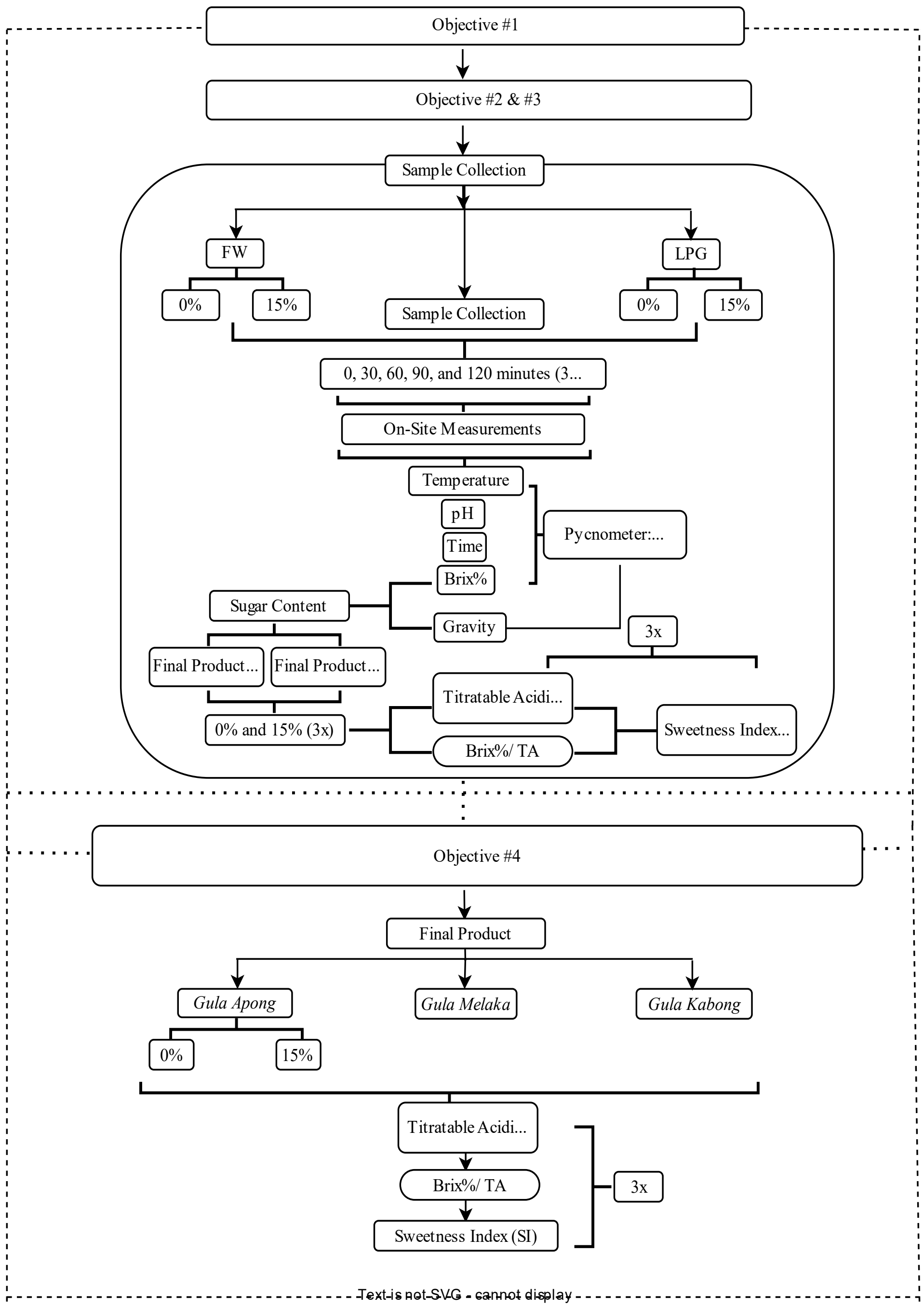

Figure 3.1 Experimental Methodology

3.3 Sample Collection

Materials:

Fresh nipa sap which was harvested from wild grown nipa plant in two different processing areas in Sarawak, namely Asajaya and Kuching were collected by the *Gula Apong* producers. Approximately 42L and 50L of the freshly harvested nipa sap for Asajaya and Kuching were collected respectively. The fresh sap was collected in a bamboo tube which the tubes were dried by heating it to avoid the sap deterioration. The sap was sieved and poured in a big wok with open-air style. The sap was heated with continuously hand-stirring to a temperature (>100°C) for both types of cooking techniques employed: firewood (FW) and liquified petroleum gas (LPG). The 15% sugar was added at 60 minutes for sample in Asajaya while 0 minutes for sample in Kuching. The triplicates of samples were taken at intervals of 30 minutes throughout the cooking process which took approximately 120 minutes (firewood) and 165 minutes (LPG).

Reagents:

Preparation of 0.25 N NaOH

A 2.5 g of Sodium Hydroxide (NaOH) was weighed and diluted to a 250 mL conical flask.

Preparation of 1% Phenolphthalein

1 g of Phenolphthalein powder was weighed and dissolved it in a 100 mL of 95% Ethanol.

Measurements:

pH Measurement

The pH of *Gula Apong* samples were measured by a portable pH meter.

Brix (%) Measurement

The brix% of *Gula Apong*, *Gula Kabong and Gula Melaka* sample were measured by using Atago Digital Hand-held "Pocket" Refractometer (PAL-3) which could detect 0-93% of brix value.

Figure 3.2 Atago digital hand-held "pocket" refractometer (PAL-3)

Temperature (℃) Measurement

The temperature of *Gula Apong* samples were taken by using a portable thermometer.

Figure 3.3 Portable pH meter

3.3.1 Traditional Cooking Process by Using Firewood (FW)

The nipa sap was cooked with 15% table sugar added and no sugar added until the viscosity increasing with time and *Gula Apong* was produced. Before the cooking process started to take place, the fresh nipa sap was harvested from any wild grown nipa plant in Asajaya. The nipa sap was collected in bamboo tubes (Figure 3.4) and was sieved to get a clean sap into a pail as shown in Figure 3.5.

Figure 3.4 Bamboo tubes

Figure 3.5 Sieving sap from bamboo tube

Then, the harvested sap was cooked by using firewood in an opened big wok in Figure 3.6 with continuously hand-stirring until it turns into the desired product which is *Gula Apong*.

Figure 3.6 Heating process by firewood

The 15% sugar was added at 60 minutes of heating process time. It took 120 minutes of time to fully became *Gula Apong* by using this method for both 0% and 15% sugar added. The mud was put on the outside surface of the wok to avoid the nipa sap's bubbles became vigorous as a safety precaution. The on-site measurements of pH, temperature (℃), and brix% were taken for 30 minutes intervals for all samples. All these measurements were taken as triplicates.

3.3.2 Traditional Cooking Process by Using Liquified Petroleum Gas (LPG)

The nipa sap was cooked with 15% table sugar added and no sugar added until the viscosity increasing with time and *Gula Apong* was produced. Before the cooking process started to take place, the fresh nipa sap was harvested from any wild grown nipa plant in Kuching. The sap was also sieved before poured into the wok. The sugar was added directly at 0 minute of heating process time (Figure 3.6).

Figure 3.7 Addition of sugar to nipa sap

Then, the harvested sap was cooked by using liquefied petroleum gas (LPG) also in an opened big wok until it turns into the desired product which is *Gula Apong*. This method had taken 165 minutes for the nipa sap to fully became

Gula Apong with 15% addition of sugar while 127 minutes without any addition of sugar. The on-site measurements of pH, temperature (℃), and brix% were taken for 30 minutes intervals for all samples. All these measurements were taken as triplicates.

Figure 3.8 Heating process by using liquified petroleum gas

3.4 Determination of Sugar Content

The values obtained from refractometer and densitometer where a 50 mL pycnometer or specific gravity bottle were used to measure the sugar content based on the following method:

The mass of sugar content in the *Gula Apong* sample were calculated as follow:

Volume of *Gula Apong* sample (from label and direct confirmatory measurement) = v (50 mL)

Density of *Gula Apong* sample (from densitometer) = y

% Sugar (brix value from refractometer) = z

Mass of *Gula Apong* sample (a) = y *x* v

% Sugar in *Gula Apong* sample (z) = $\frac{(Mass\ of\ Gula\ Apong\ sample\ (a)\ x\ 100)}{Mass\ of\ sugar}$ … (1)

All values in Eq. (1) were known except the mass of sugar.

∴ Mass of sugar = $\frac{(a\ x\ z)}{100}$

For example,

Mass of sugar = $\left(\frac{Mass\ of\ Gula\ Apong\ sample\ x\ \%\ of\ sugar\ in\ Gula\ Apong}{100}\right)$… (2)

Eq. (2) was used to obtain the mass of sugar in each sample of *Gula Apong*.

3.5 Determination of Sweetness Index

The sweetness index of *Gula Apong (Nypa fruticans), Gula Kabong (Arenga pinnata)* and *Gula Melaka (Cocos nucifera)* were determined by using the titratable acidity method.

A 5 g of each sample (FW 0% sugar added *Gula Apong (Nypa fruticans)*, FW 15% sugar added *Gula Apong (Nypa fruticans)*, LPG 0% sugar added *Gula Apong (Nypa fruticans)*, LPG 15% sugar added *Gula Apong (Nypa fruticans), Gula Kabong (Arenga pinnata)* and *Gula Melaka (Cocos nucifera)* were weighed into a 200 mL conical flask and 25 mL of distilled water was added. An aliquot of 2 mL of each sample were pipetted into a 50 mL of beaker. 10 drops of 1% phenolphthalein indicator were added into each beaker and was titrated against 0.25 N NaOH as described by AOAC, (2000). It was titrated until a pale pink persisted for 30 seconds occurred indicating the end point of the sample. The process for each sample was repeated as triplicate. The percentage acidity was expressed in lactic acid equivalence as referred to AOAC, (1997):

$$\% \text{ Titratable acidity} = \frac{n \ x \ N \ x \ Eq}{p} \ \dots \ (3)$$

Where:

n = Volume of NaOH used (mL)

N = Normality of NaOH used (0.25 N)

Eq = Lactic Acid (90.08)

P = Sample weight (5 g)

After the titratable acidity of each sample were determined, the sweetness index of the samples can be calculated as Equation (4) follow:

Sweetness Index = $\frac{Brix\,\%}{Titratable\ Acidity}$ … (4)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This study was able to determine the sugar content and the sweetness index of *Gula Apong* Sarawak, the effect of cooking techniques and table sugar addition on sugar content of traditionally processed *Gula Apong*, the effect of cooking techniques and table sugar addition on sweetness index of traditionally processed *Gula Apong,* as well as to compare the sweetness index of *Gula Apong*, *Gula Kabong*, and *Gula Melaka.* The details are as discussed in this chapter.

4.2 Effect of Heating Process and Sugar Addition on Sugar Content

Both the FW and LPG cooking methods began the heating of the nipa saps at room temperature (~24°C). The *Gula Apong* was made in 120 minutes, and the corresponding brix% for FW 0% sugar added, LPG 0% sugar added, FW 15% sugar added, and LPG 15% sugar added were, respectively, 91.30, 80.17, 90.83, and 85.77.

The obtained brix% values were corresponding to a study by Phaichamnan *et al.,* 2010 where the obtained results for brix were ranging from 59.01 to 73.05 for palm sugar concentrated (*Cocos nucifera* L. or *Borassus flabellifer* Linn.) based in Songkhla, Thailand. Apart from that, the brix% obtained in this paper is comparable to *Cocos nucifera (Gula Melaka*) brix% value which was detected at 87.30 according to Phang Chong *et al.*, 2019. Table 4.1 depicts the brix% for *Nypa fruticans* samples (FW 0% sugar added, LPG 0% sugar added, FW 15% sugar added, and LPG 15% sugar added FW 0% sugar added, LPG 0% sugar added, FW 15% sugar added, and LPG 15% sugar added) and brix% from other studies.

Table 4.1 Brix% of different palm sugars

Samples/ types of palm sugar	**Brix%**	**Reference**
FW 0% sugar added, *Nypa fruticans*	91.30	Present study
FW 15% sugar added, *Nypa fruticans*	90.83	Present study
LPG 0% sugar added, *Nypa fruticans*	80.17	Present study
LPG 15% sugar added, *Nypa fruticans*	85.77	Present study
Cocos nucifera L.	87.30	Phang Chong *et al.*, 2019
Cocos nucifera L. and *Borassus flabellifer* Linn.	59.01 – 73.05	Phaichamnan *et al.*, 2010

Source: Present study; Phang Chong *et al.*, 2019 and Phaichamnan *et al.*, 2010

Based on the Figure 4.1 to 4.6, the pH of the *Nypa fruticans* samples was constant in the range of 4.17 to 5.63. The temperature of the sap increased swiftly in the first 30 minutes from room temperature to the highest boiling obtained at this rate which was 99.00℃ for LPG 0% sugar added sugar added while the lowest was at 50.32℃ for FW 15% sugar added. During this heating time, the brix% of the samples did not show any significant changes for both cooking techniques, however it increased rapidly as it reached 60 minutes due to the addition of 15% sugar at 30 minutes. The highest boiling temperature of 101.10℃ for LPG 0% sugar added at 60 minutes heating process time was recorded while the lowest was recorded at 75.32℃ for FW 15% sugar added. At this rate of cooking time, the brix% of the samples started to double up for 15% sugar added for FW technique while slightly increased for LPG. Next, at 90 minutes to a maximum of 180 minutes of the heating process time for both cooking techniques, the temperature and brix% started to increase constantly where the temperature were in the variety of 87.83℃ to 111.40℃.

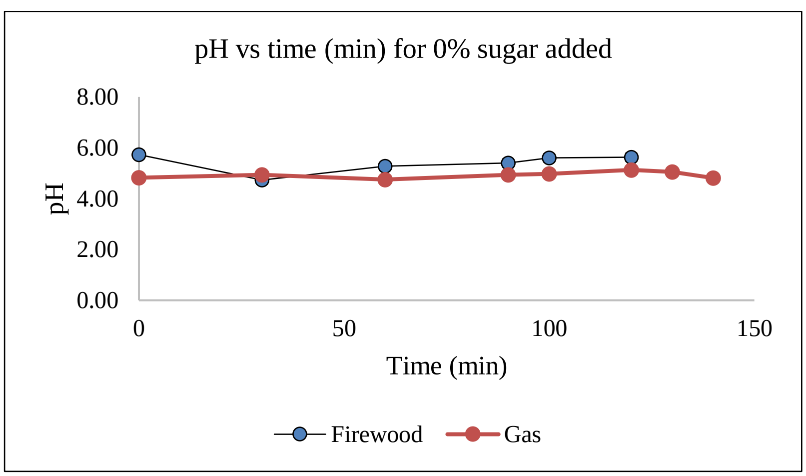

Figure 4.1 pH vs time (min) for 0% sugar added

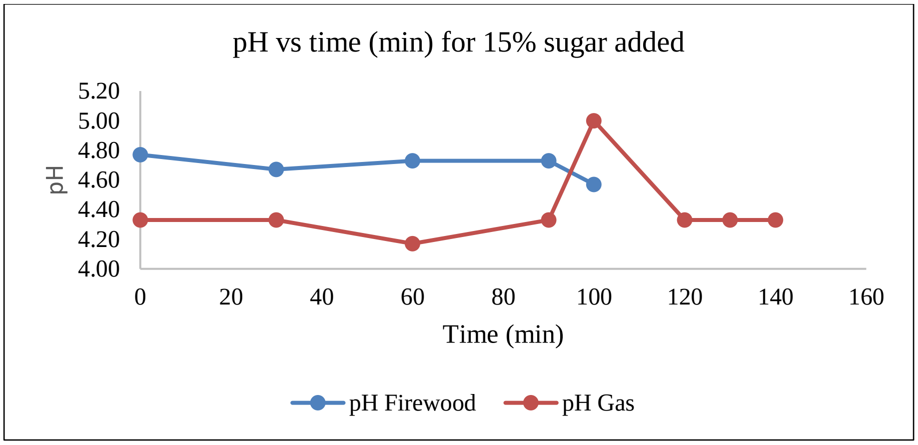

Figure 4.2 pH vs time (min) for 15% sugar added

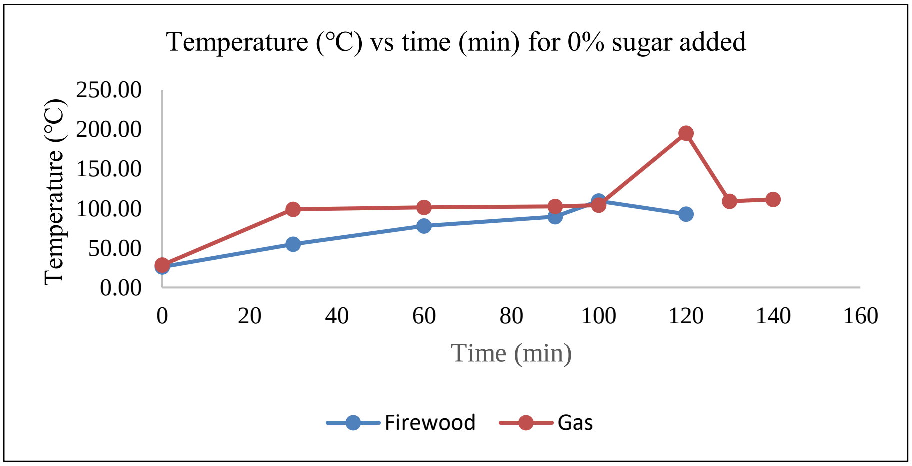

Figure 4.3 Temperature (℃) vs time (min) for 0% sugar added

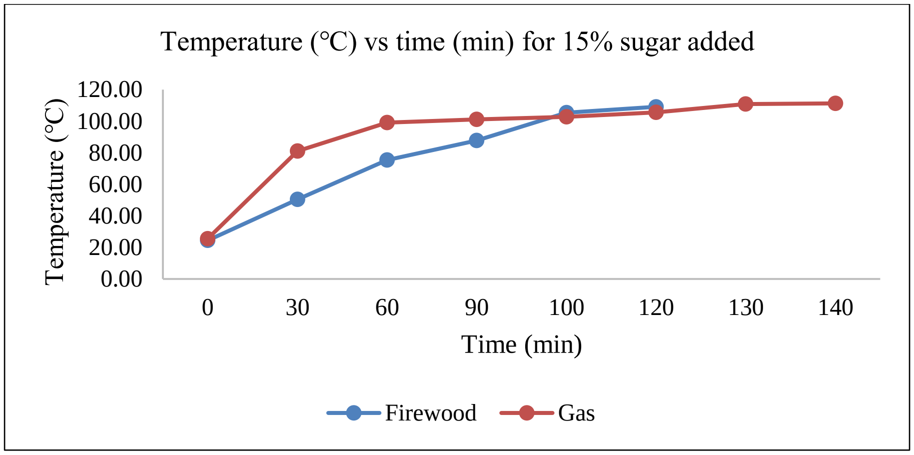

Figure 4.4 Temperature (℃) vs time (min) for 15% sugar added

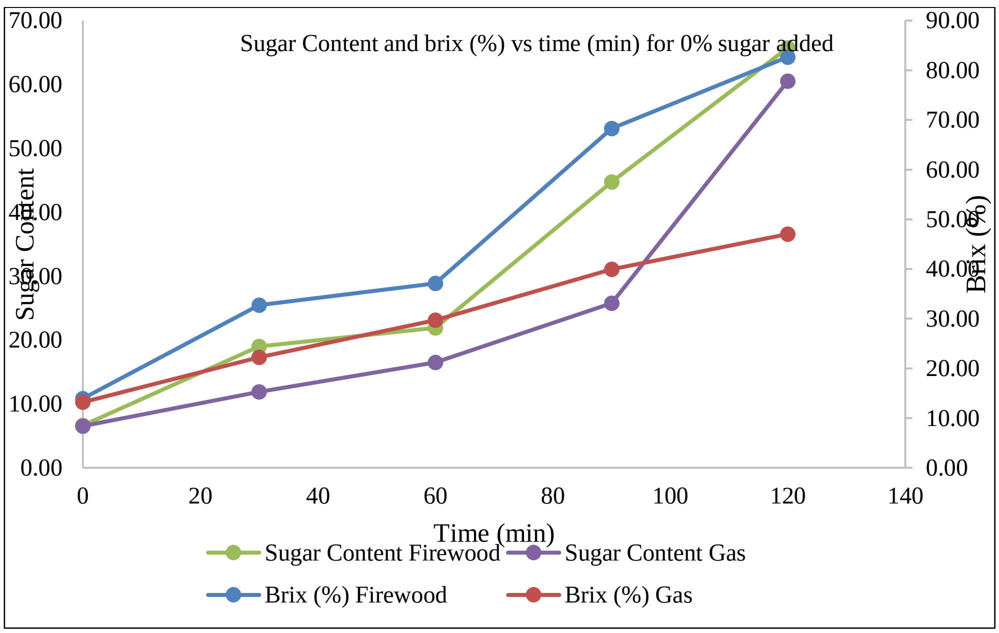

Figure 4.5 Sugar content and brix% vs time (min) for 0% sugar added

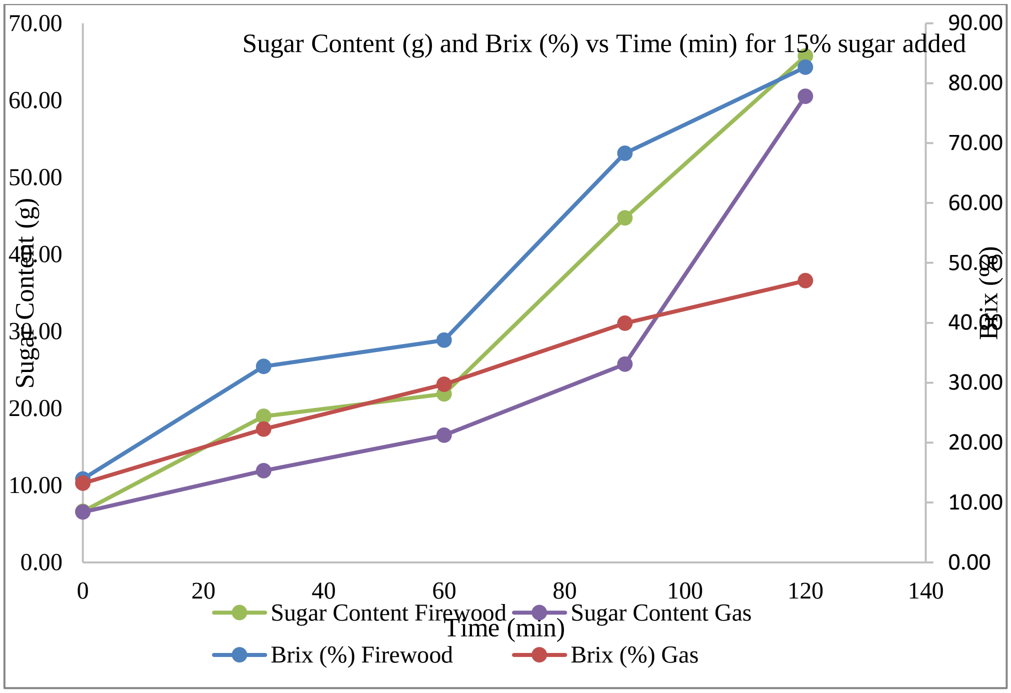

Figure 4.6 Sugar content (g) and brix% vs time (min) for 15% sugar added

Table 4.2 Sugar content calculation

Samples	**Heating time (min)**	**Triplicate density (g/mL)**	**Average density (g/mL)**	**Sugar content** $= \frac{a\ x\ \%\ z}{100}$
	0	0.96, 0.94, 0.94	0.95	6.62
	30	1.18, 1.16, 1.13	1.16	18.98
FW 0%	60	1.20, 1.18, 1.16	1.18	21.89
	90	1.35, 1.31, 1.27	1.31	44.74
	120	1.45, 1.43, 1.44	1.44	65.74
	0	1.29, 1.35, 1.35	0.87	5.72
	30	0.97, 0.93, 0.94	0.95	8.14
FW 15%	60	1.12, 1.17, 1.16	1.15	22.24
	90	1.29, 1.35, 1.35	1.33	48.35
	120	1.40, 1.44, 1.44	1.43	64.94
	0	1.02, 0.95, 1.01	0.99	6.53
	30	1.09, 1.03, 1.09	1.07	11.89
LPG 0%	60	1.13, 1.07, 1.13	1.11	16.50
	90	1.22, 1.15, 1.22	1.20	25.75
	120	1.27, 1.26, 1.28	1.27	60.53

	0	0.86, 0.88, 0.89	0.88	8.40
	30	0.95, 0.96, 0.94	0.95	14.43
LPG 15%	60	1.12, 1.17, 116	1.15	17.71
	90	1.29, 1.35, 1.35	1.33	23.24
	120	1.40, 1.44, 1.44	1.49	33.16

Source: Present study

Table 4.2 depicts the calculated sugar content for all samples during the heating process time in 30 minutes interval for each sample. The sugar content obtained for FW 0% sugar added, FW 15% sugar added, LPG 0% sugar added, and LPG 15% sugar added were not significantly different, 6.62, 5.72, 6.53 and 8.40 respectively for the fresh nipa sap at 0 minute. It was observed that during the heating process by using FW technique, the sugar content for 0% sugar added and 15% sugar added samples were drastically shoots to 21.89 and 22.24, respectively at 60 minutes. This was different from the samples that were heated by using LPG 0% sugar added was only having a sugar content of 16.5 and 17.71 for LPG 15% sugar added. At 90 minutes, the sugar content for samples heated by using FW technique increase double times with 44.74 (0% sugar added) and 48.35 (15% sugar added) while the LPG sample still increasing steadily but not as rapidly as FW with only 25.75 (0% sugar added) and 23.24 (15% sugar added) of sugar content. The sugar content for the final product for FW 0% sugar added, FW 15% sugar added, LPG 0% sugar added, and LPG 15% sugar added were consistent at 65.74, 64.94, 60.53, and 61.75, respectively. Thus, the sugar content of the *Nypa fruticans* during heating process increased along with time. This showed that the total sugar began to rise as the sample became concentrated.

It was also comparable to *Cocos nucifera* L. (Coconut palm) and *Borassus flabellifer* Linn. (Palmyra palm) where the sugar content for sugarcane jaggery from either two types of mentioned palms was 65.00 as found by Veena *et al.,* (2018). Phaichamnan *et al.,* 2010 revealed that the sugar content for 30 types of palm sugar concentrated (mostly palmyra and coconut palm) were having a range of 23.77 to 71.89.

4.3 Effect of Heating Process and Sugar Addition on Sweetness Index

Only the final product of *Gula Apong, Gula Kabong* and *Gula Melaka* were being tested in this part. The sweetness index was determined for all samples were calculated by using eq (3) from 3.5. Table 4.3 depicts the brix%, titratable acidity, and sweetness index of the samples. Titratable acidity for all samples were calculated by using Eq (3) while sweetness index for all samples were calculated by using Eq (4) from 3.5.

Table 4.3 Sweetness index

Samples	Brix%	Average brix%	Triplicate titration (mL)	Average titration (mL)	TA%	SI = Brix%/ TA%
FW 0%	91.30, 91.20, 91.40	91.30	0.3, 0.3, 0.3	0.30	1.35	67.63
FW 15%	92.5, 88.00, 92.00	90.83	0.2, 0.2, 0.3	0.23	1.04	87.34
LPG 0%	90.50, 85.90, 87.90	80.17	0.3, 0.2, 0.3	0.33	1.49	53.81
LPG 15%	87.80, 84.00, 85.50	85.77	0.2, 0.2, 02	0.20	0.90	95.30
GK	76.00, 76.50, 75.30	75.93	1.1, 1.1, 1.0	1.07	1.51	50.28
GM	76.8, 78.9, 77.7	77.80	0.6, 0.7, 06	0.63	1.53	50.85

Source: Present study

It was shown that the sweetness index of *Gula Apong* with no addition of sugar for both cooking techniques (FW 0% sugar added and LPG 0% sugar added) were 67.63 and 53.81, respectively while the sweetness index of *Gula Apong* with the addition of sugar for both cooking techniques (FW 15% sugar added and LPG 15% sugar added) were 87.34 and 95.30, respectively. Thus, the sweetness index of 15% added sugar were higher and showed a significant difference from the pure samples for both cooking techniques. The results for *Gula Kabong* and *Gula Melaka* showed that the sweetness index was both lower than *Gula Apong* which are 50.28 and 50.85, respectively.

These sweetness index values were comparable to a study by Prijono *et al.,* 2020 where they revealed the sweetness index for *Arenga pinnata*, *Cocos nucifera, Nypa fruticans* and *Borassus flabellifer* were 79.43, 78.05, 76.61 and 91.42, respectively.

The titratable acidity obtained for both cooking techniques (FW 0% sugar added and LPG 0% sugar added) were 1.35 and 1.41, respectively while the titratable acidity of *Gula Apong* (*Nypa fruticans*) with the addition of sugar for both cooking techniques (FW 15% sugar added and LPG 15% sugar added) were 1.04 and 0.90, respectively. The low values of titratable acidity led to the higher values in sweetness index of the samples. Microorganisms such lactic acid bacteria had increase the lactic acid in the sample leading to a higher value for titratable acidity, thus lower the pH (Karamoko *et al.,* 2016). *Gula Kabong* (*Arenga pinatta*) and *Gula Melaka* (*Cocos nucifera*) titratable acidity values were slightly higher at 1.51 and 1.53, respectively which led to a declining in sweetness index trend. The overall result for sweetness index is *Gula Apong* (*Nypa fruticans*) has higher sweetness index as compared to *Gula Kabong* (*Arenga pinatta*) and *Gula Melaka* (*Cocos nucifera*)

The titratable acidity values obtained in this study were slightly higher than values reported by Phaicamnan *et al.*, 2010 which only ranging from 0.24 to 0.86. Figure 4.2 portrayed the sweetness index and titratable acidity of all samples.

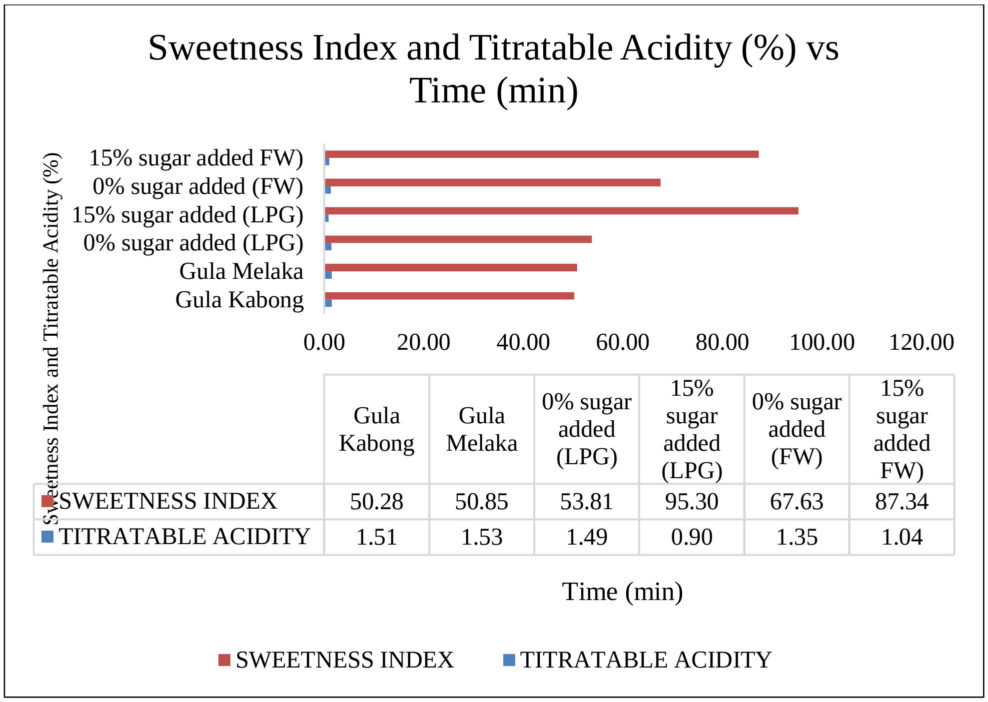

Figure 4.7 Sweetness index and sugar content vs time (min)

Figure 4.2 showed the higher the titratable acidity values, the lower the sweetness index values. The slightly higher titratable acidity indicated that the samples of *Gula Kabong*, *Gula Melaka* and LPG 0% sugar added were fermented earlier before being collected (Karamoko *et al.*, 2016).

4.4 Comparison of the Sweetness Index for *Gula Apong, Gula Kabong, and Gula Melaka*

The sweetness index is *Gula Apong* (*Nypa fruticans*), *Gula Kabong* (*Arenga pinatta*) and *Gula Melaka* (*Cocos nucifera*) were obtained from 4.2. The results obtained were tabulated as Table 4.4.

Table 4.4 Sweetness index of GA, GK and GM

Types of Palm Sugar	Sweetness Index
FW 0% sugar added *Gula Apong* (*Nypa fruticans*)	67.63
FW 15% sugar added *Gula Apong* (*Nypa fruticans*)	87.34
LPG 0% sugar added *Gula Apong* (*Nypa fruticans*)	53.81
LPG 15% sugar added *Gula Apong* (*Nypa fruticans*)	95.30
Gula Kabong (*Arenga pinatta*)	50.28
Gula Melaka (*Cocos nucifera*)	50.85

Source: Present study

Gula Apong (*Nypa fruticans*) for both FW and LPG cooking techniques were found higher in term of sweetness index as compared to *Gula Kabong* (*Arenga pinatta*) and *Gula Melaka* (*Cocos nucifera*). Prijono *et al.*, 2020 study revealed the sweetness index for *Arenga pinnata*, *Cocos nucifera*, *Nypa fruticans* and *Borassus flabellifer* were 79.43, 78.05, 76.61 and 91.42, respectively. Thus, the obtained values were lower for *Arenga pinnata* (50.28) as well as *Cocos nucifera* with only 50.85 as compared to Prijono *et al.*, 2020 results.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This study had acquired the sugar content and sweetness index of *Gula Apong* (*Nypa fruticans*) by using 3 methods which were refractometric method, specific gravity method (pycnometer), and titratable acidity method. In refractometric method, a brix refractometer was used to obtain the TSS or brix% of the samples. The specific gravity method (pycnometer) was used to determine the density of the sample to further calculate the sugar content.

5.2 Conclusion

The brix% obtained from brix refractometer for FW 0% sugar added *Gula Apong* (*Nypa fruticans*) palm sugar, FW 15% sugar added *Gula Apong* (*Nypa fruticans*) palm sugar, LPG 0% sugar added *Gula Apong* (*Nypa fruticans*) palm sugar, LPG 15% sugar added *Gula Apong* (*Nypa fruticans*) palm sugar, *Gula Kabong* (*Arenga pinatta*) palm sugar, and *Gula Melaka* (*Cocos nucifera*) palm sugar was summarized in Table 5.1.

Table 5.1 Brix%

Samples	Brix%	Average brix%
FW 0% sugar added *Gula Apong* (*Nypa fruticans*)	91.30, 91.20, 91.40	91.30
FW 15% sugar added *Gula Apong* (*Nypa fruticans*)	92.5, 88.00, 92.00	90.83
LPG 0% sugar added *Gula Apong* (*Nypa fruticans*)	90.50, 85.90, 87.90	80.17
LPG 15% sugar added *Gula Apong* (*Nypa fruticans*)	87.80, 84.00, 85.50	85.77
Gula Kabong (*Arenga pinatta*)	76.00, 76.50, 75.30	75.93
Gula Melaka (*Cocos nucifera*)	76.8, 78.9, 77.7	77.80

Source: Present study

The sugar content for FW 0% sugar added *Gula Apong* (*Nypa fruticans*), FW 15% sugar added *Gula Apong* (*Nypa fruticans*), LPG 0% sugar added *Gula Apong* (*Nypa fruticans*), and LPG 15% sugar added *Gula Apong* (*Nypa fruticans*) for 0, 30, 60, 90, and 120 minutes were obtained as showed in Table 5.2.

Table 5.2 Sugar content for *Nypa fruticans* during heating process at 0, 30, 60, 90, and 120 minutes

Samples	Heating time (min)	Sugar content = $\frac{a\, x\, \%\, z}{100}$
FW 0% sugar added	0	6.62
	30	18.98
	60	21.89
	90	44.74
	120	65.74
FW 15% sugar added	0	5.72
	30	8.14
	60	22.24
	90	48.35
	120	64.94

LPG 0% sugar added	0	6.53
	30	11.89
	60	16.50
	90	25.75
	120	60.53
LPG 15% sugar added	0	8.40
	30	14.43
	60	17.71
	90	23.24
	120	33.16

Source: Present study

The sweetness index of the samples was obtained after performing titratable acidity method. Titratable acidity of FW 0% sugar added *Gula Apong* (*Nypa fruticans*), FW 15% sugar added *Gula Apong* (*Nypa fruticans*), LPG 0% sugar added *Gula Apong* (*Nypa fruticans*), LPG 15% sugar added *Gula Apong* (*Nypa fruticans*), *Gula Kabong* (*Arenga pinatta*), and *Gula Melaka* (*Cocos nucifera*) were summarized in Table 5.3. All the calculations for brix% and titratable acidity were obtained by taking samples in triplicates manner.

Table 5.3 Brix%, titratable acidity and sweetness index

Samples	**Brix%**	**Average brix%**	**Triplicate titration (mL)**	**Average titration (mL)**	**TA%**	**SI = Brix%/ TA%**
FW 0%	91.30, 91.20, 91.40	91.30	0.3, 0.3, 0.3	0.30	1.35	67.63
FW 15%	92.5, 88.00, 92.00	90.83	0.2, 0.2, 0.3	0.23	1.04	87.34

LPG 0%	90.50, 85.90, 87.90	80.17	0.3, 0.2, 0.3	0.33	1.49	53.81
LPG 15%	87.80, 84.00, 85.50	85.77	0.2, 0.2, 02	0.20	0.90	95.30
GK	76.00, 76.50, 75.30	75.93	1.1, 1.1, 1.0	1.07	1.51	50.28
GM	76.8, 78.9, 77.7	77.80	0.6, 0.7, 06	0.63	1.53	50.85

Source: Present study

Besides the determination of sugar content and sweetness index, the effect of different heating process time and table sugar addition on sugar content of traditionally processed *Gula Apong* were studied. The sugar content was observed increasing along with the increasing heating time of the nipa sap. was also seen the rapidly uprising in the trend of the sugar content after the addition of table sugar during the cooking process of the sap. The sugar content obtained was summarized in Table 5.2. The sugar content rose quickly after the addition of table sugar in the nipa sap during the heating process while it was increasing slowly without addition of table sugar. This trend corresponds to the theory when the sap concentrated due to continuous heating, resulting in the increasing of sugar content in the samples.

The effect of different heating process time and table sugar addition on sweetness index of traditionally processed *Gula Apong* were also being studied.

The sweetness index was observed increasing along with the increasing heating time of the nipa sap especially after the addition of table sugar during the cooking process of the sap. The sweetness index obtained for LPG 15% sugar added *Gula Apong* (*Nypa fruticans*), FW 15% sugar added *Gula Apong* (*Nypa fruticans*), FW 0% sugar added *Gula Apong* (*Nypa fruticans*), LPG 0% sugar added *Gula Apong* (*Nypa fruticans*), *Gula Melaka* (*Cocos nucifera*) and *Gula Kabong* (*Arenga pinatta*) were 95.30, 87.34, 67.63, 53.81, 50.85, and 50.28, respectively.

Lastly, the sweetness index value between traditionally processed *Gula Apong*, *Gula Kabong* and *Gula Melaka* were obtained and compared in Table 4.3. It was observed that the sweetness index of *Gula Apong* (*Nypa fruticans*) for both cooking techniques (FW and LPG with or without sugar addition) with a value ranging from 53.81 to 95.30 was distinctively higher than *Gula Melaka* (*Cocos nucifera*) and *Gula Kabong* (*Arenga pinatta*) which was only 50.28 and 50.85, respectively.

5.3 Recommendations

This study helped to clarify how the sugar concentration, sweetness index, and other characteristics of *Nypa fruticans* sugar are impacted by heating as they transition from fresh sap to the finished product (palm sugar). Nonetheless, a lot of unanswered questions, as well as specific issues about the financial advantages of manufacturing high-quality sugar, have been revealed by this study. Therefore, some suggestions for additional investigation on the *Gula Apong* (*Nypa futicans*) Sarawak can be implemented for the sake of the Quality Grading.

The first study could be conducted is regarding to the effect of initial pH and final pH toward the sap during heating process. This study had shown the trend of pH on the fresh sap heating process. More investigation into the relationship between the starting pH (sap) and the final pH (palm sugar) during the heating process is possible. It is also possible to do additional research on the physicochemical characteristics of *Nypa fruticans* during the heating process, which may impact the product's quality. It might be worthwhile to conduct more research on the sugar's nutritional benefits. For the preparing more knowledge for local farmers, more research addressing the food safety standard during sap collection and handling might be conducted. To maintain the quality of *Gula Apong* Sarawak, this research may be able to reduce microbial development. To raise the quality standard of *Gula Apong* Sarawak, a sensory analysis study could be conducted. This will improve consumer acceptability, hence raising

Gula Apong Sarawak's economic value. A proximate study such ash, moisture, cellulose, hemi-cellulose, nitrogen, and lignin content also could be study for future research to enhance the quality grading of the *Gula Apong* Sarawak. A further study could be employed on *Nypa fruticans* to allow *Gula Apong's* identity known in the global market. Thus, a focus on geographical indication study of *Nypa fruticans* Sarawak need to further analyse so people will know the origin of it. As a conclusion, the recommendation studies are focusing on the enhancement and the establishment of Quality Grading System to achieve geographical indication (GI).

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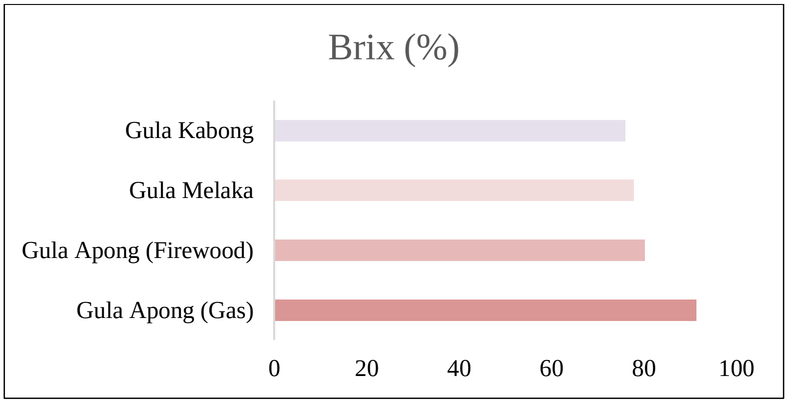
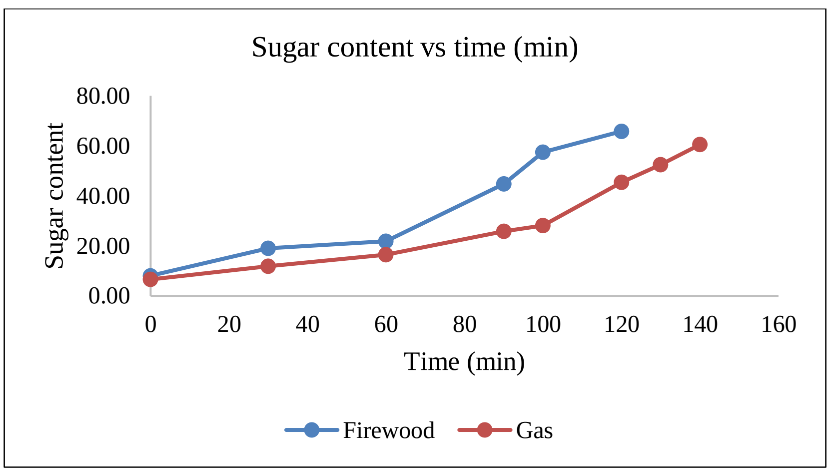
APPENDICES

APPENDIX A



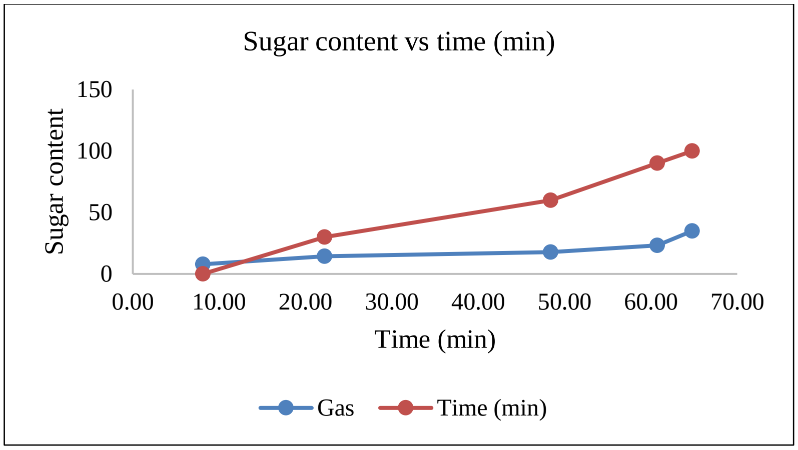
Brix% values for different palm sugars.

APPENDIX B



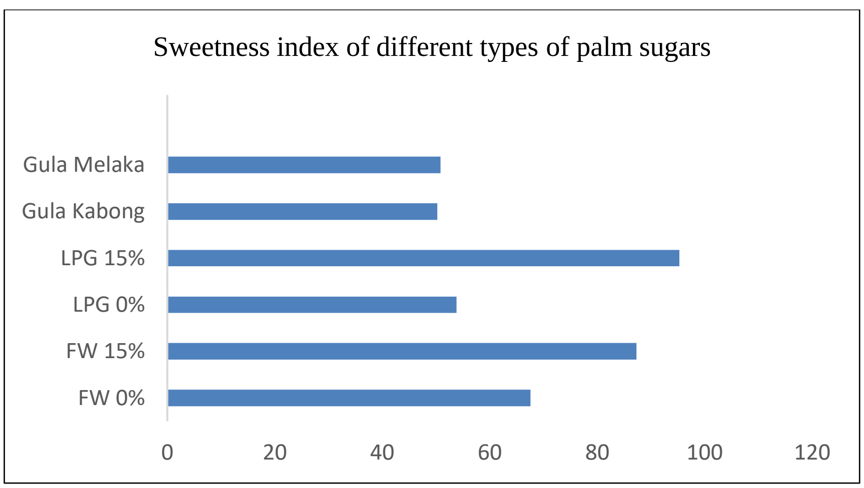
Sugar content vs time (min) for FW 0% sugar added.

APPENDIX C



Sugar content vs time (min) for FW 15% sugar added.

APPENDIX D



Sweetness index of different palm sugars.

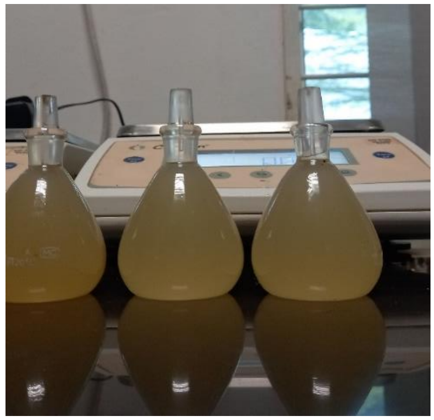
APPENDIX E

Nipa sap (*Nypa fruticans*).

APPENDIX F

Nipa palm sugar (*Nypa fruticans*).

APPENDIX G



Determination of sugar content by pycnometer.

APPENDIX H

Sodium Hydroxide for titratable acidity.

APPENDIX I

Palm sugar diluted with distilled water ready for titration.

APPENDIX J

	Phaichamnan, M. et al, (2010)	Present study
Sample	Borassus flabellifer Linn. (Palmyra palm)	Nypa Fruticans (Nipa palm), Cocos nucifera (Coconut palm), and Arenga pinnata (Aren palm)
Normality used	0.1 N	0.25 N
TA%	0.24-0.86	0.90-1.53
TSS (Brix%)	59.01-73.05	80.17-91.30
Sugar content	23.77-71.89	5.72-65.74
Sweetness index	N/A	50.28-95.30
Indicator	1% phenolphthalein	1% phenolphthalein

Raw data.

APPENDIX J

Site visit during sample collection.

APPENDIX J

A local Gula Apong producer, Mahli bin Ramli @ *Pak Mahli*.

CURRICULUM VITAE

A. Personal profile

Full name	Kun Aqilah binti Marset
National IC no	990116135472
Birth date	16th January 1999
Citizenship	MALAYSIA
Place of birth	Sarawak, MALAYSIA
Gender	Female
Correspondence address	No. 26, Lorong 22B1F, Taman Desa Ilmu, 94300, Kota Samarahan, Sarawak.
Telephone no. (H)	-
Telephone no. (HP)	+6011-7275 8921
Email address	2020898912@student.uitm.edu.my

B. Hobbies and interests

I enjoy singing, traditional dancing, and playing keyboard. I like to learn other cultures especially in Sarawak which have racial diversity.

C. Academic qualifications

Qualification	Area	Institution	Year Awarded
B. Sc (Hons.)	Chemistry with Management	Universiti Tekologi MARA, Malaysia	2023
Diploma	Industrial Chemistry	Universiti Tekologi MARA, Malaysia	2020
SPM	Pure Science	SMK Kota Samarahan	2016

D. Work Experience

Post	Place	Year
Internship student	Sarawak Tropical Peat Research Institute (TROPI)	2020
Self-business	Aiman Mall, Kota Samarahan.	2020

E. Related experience

Post	Place	Year
President	CHEMISTS Club, Universiti Teknologi MARA, Sarawak	2021-2022