DEVELOPMENT OF LOW GLYCAEMIC CARROT CAKE BY PARTIALLY SUBSTITUTING SUGAR WITH CONCENTRATED *Nypa fruticans* SAP

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by

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LIST OF SYMBOLS

m	Meter
cm	Centimetre
mm	Millimetre
µm	Micrometre
nm	Nanometre
>	Greater than
<	Lower than
≥	Greater than or equal to
≤	Lower than or equal to
v/v	Volume per volume
L	Litre
mL	Millilitre
µL	Microlitre
g	Gram
µg	Microgram
kg	Kilogram
mg	Milligram
M	Molar
mmol	Millimole
N	Normality
%	Percentage
°C	Degree Celsius
^{o}Brix	Degree Brix
g	Gravity force
N	Newton

kV	Kilovolt
C	Carbon
Cl	Confidence intervals
p	p-value

LIST OF ABBREVIATIONS

NFS	*Nypa fruticans* sap
CNFS	Concentrated *Nypa fruticans* sap
GI	Glycaemic index
GL	Glycaemic load
TPC	Total phenolic content
RP	Reducing power
DPPH	2,2-diphenyl-1-picrylhydrazyl
DM	*Diabetes mellitus*
HMF	Hydroxymethylfurfural
TSS	Total soluble solids
reg.	Regulation
HFCS	High fructose corn syrup
QC	Quality control
min	Minute(s)
SDF	Soluble dietary fiber
IDF	Insoluble dietary fiber
TDF	Total dietary fiber
DNA	Deoxyribonucleic acid
FC	Folin-Ciocalteu
TPA	Texture profile analysis
rpm	Revolutions per minute
CHO	Carbohydrate
FFA	Free fatty acids
HCl	Hydrochloric acid
H_3BO_3	Boric acid
NaCl	Sodium chloride
NaOH	Sodium hydroxide
SEM	Scanning electron microscopy
BMI	Body mass index
SBP	Systolic blood pressure
DBP	Diastolic blood pressure

iAUC	Incremental area under curve
SPSS	Statistical Package for Social Sciences
et al.	And others
SD	Standard deviation
SEM	Standard error of mean
ANOVA	Analysis of variance

PEMBANGUNAN KEK LOBAK MERAH GLISEMIK RENDAH DENGAN PEGGANTIAN GULA SECARA SEPARA DENGAN SAP *Nypa fruticans* PEKAT

ABSTRAK

Sap *Nypa fruticans* (NFS) atau air nira merupakan sejenis sap *nipah* yang kaya dengan gula dan menjadi minuman tradisional dalam kalangan komuniti Melayu di Malaysia. Disebabkan fungsinya sebagai pemanis semulajadi, NFS berpotensi menjadi salah satu sumber baharu bagi menggantikan gula tambahan dalam produk bakeri. Tujuan kajian ini adalah untuk menghasilkan kek lobak merah yang ditambah dengan sap *N. fruticans* pekat (CNFS) bagi menilai kesannya ke atas komposisi pemakanan, profil tekstur, penerimaan sensori dan nilai indeks glisemik (GI). NFS segar dinyahhidrat menjadi pekat dan ditambah ke dalam formulasi kek lobak merah sebagai pengganti separa kepada gula pada kadar 0, 5, 10, 15 dan 20%. Keputusan kajian menunjukkan penambahan CNFS ke dalam kek lobak merah pada kadar 20% meningkatkan komposisi pemakanan secara signifikan ($p<0.05$) yang merekodkan lembapan (33.31%), abu (1.47%) dan serat dietari (10.75%) tertinggi. Analisis profil tekstur menunjukkan penurunan yang sederhana pada kekerasan, kekenyalan dan kebingkasan apabila kadar penggantian CNFS semakin meningkat dalam kek lobak merah. Bagi aktiviti antioksida pula, ekstrak metanol kek lobak merah dengan penambahan 20% CNFS menunjukkan jumlah kandungan fenolik (TPC), kesan perencatan radikal bebas pada 2,2-difenil-1-pikrilhidrazil (DPPH) dan kuasa penurunan (RP) adalah yang paling tinggi berbanding dengan kawalan kek tanpa NFS dan ekstrak metanol kek lobak merah yang berlainan formulasi. Ujian penerimaan sensori menunjukkan markah purata untuk rupa, tekstur, rasa dan perisa kek lobak merah yang ditambah dengan 20% CNFS adalah lebih baik daripada kek lobak merah tanpa NFS. Berdasarkan keputusan yang diperoleh daripada ujian penerimaan sensori, dua formulasi (0 dan 20% CNFS) telah dipilih untuk ujian penentuan nilai GI. Nilai GI bagi kek lobak merah yang ditambah dengan 20% CNFS ialah 50 sementara 0% CNFS kek lobak merah ialah 55. Walaupun penambahan CNFS tidak signifikan dalam menurunkan puncak lengkung tindak balas glukosa plasma selepas makan, ia menurunkan nilai GI kek lobak merah secara signifikan. Keputusan kajian ini menunjukkan kek lobak merah yang ditambah dengan 20% CNFS adalah salah satu cara yang berkesan dalam menghasilkan kek GI rendah dan boleh diterima dari segi fizikal dan juga sensori.

DEVELOPMENT OF LOW GLYCAEMIC CARROT CAKE BY PARTIALLY SUBSTITUTING SUGAR WITH CONCENTRATED *Nypa fruticans* SAP

ABSTRACT

Nypa fruticans sap (NFS) or neera juice is a traditional sugar-rich palm sap beverage consumed among the Malay community in Malaysia. Being a natural sweetener, NFS could potentially be used as novel source to replace added sugar in bakery product. This study aimed to develop carrot cakes incorporated with concentrated *N. fruticans* sap (CNFS) and to determine the effects of nutritional compositions, textural profile, antioxidant capacity, sensorial acceptability and glycaemic index (GI) values. Fresh NFS was dehydrated into concentrated form and added in carrot cake formulations as partial replacement (0, 5, 10, 15 and 20%) for table sugar. Results indicated that incorporation of CNFS at 20% level significantly ($p<0.05$) increased the nutritional compositions of carrot cakes which recorded the highest moisture (33.31%), ash (1.47%) and dietary fiber (10.75%) content. In texture profile analysis, a slight decrease in hardness, springiness and resilience were reported with increasing levels of CNFS substitution in carrot cakes. For antioxidative activities, 20% CNFS-incorporated carrot cake methanol extract showed the highest total phenolic content (TPC), free radical scavenging effect on the 2,2-diphenyl-1-picrylhydrazyl (DPPH) and reducing power (RP) in comparison to control and other carrot cake methanol extract. Sensory acceptability test revealed that carrot cake formulated with 20% CNFS received better acceptability score for appearance, texture, taste and flavour compared to carrot cake without NFS. Based on sensorial acceptability results, two formulations of carrot cakes (0 and 20% CNFS) were selected for GI testing. It was found that the GI of carrot cake with 20% CNFS was 50 while the 0% CNFS carrot cake was 55. Although CNFS did not significantly lower the postprandial peak glucose responses, it can significantly lower the GI value of carrot cake. The results of this study showed that carrot cake incorporated with 20% CNFS could be an effective way to develop low GI cake with desirable physical and sensorial acceptability.

CHAPTER 1

INTRODUCTION

1.1 Background and problem statements

Diabetes mellitus (DM) is a chronic metabolic disorder commonly presenting with episodes of high blood glucose level (hyperglycaemia) and glucose intolerance, as a result of lack of insulin, defective insulin action, or both (Sicree *et al.*, 2006). The Malaysian National Health & Morbidity Survey (NHMS) reported the prevalence of diabetes increased from 14.9% in 2006 to 17.5% in 2015, respectively, and it was projected to rise to 21.6% by the year 2030 (Ministry of Health of Malaysia [MOH], 2015). The increasing trend of DM seems to have linked to the continued escalation of the availability of added sugar and sweeteners (kg per capita per year) in Malaysia which has risen from 28.8 kg to 48.7 kg, or almost 70% between 1967 and 2007, according to the data from the Malaysian Food Balance Sheet (Food and Agriculture Organization [FAO], 2017). The common added sugar which include table sugar, sweeteners and jam are widely used in food industry for the preparation of commercially processed products such as breads, biscuits, cakes, carbonated drinks, ice cream and local delicacies (*kuih)*. The main types of added sugar that are frequently used in processed foods are white refined sugars which are virtually 100 percent sucrose without additional nutrients (Insel *et al.*, 2018).

Consumption of artificial sweeteners such as aspartame, sucralose, saccharine and neotame on the other hand has been promoted as a prevention strategy to replace added sugar. However, the health risks of artificial sweeteners consumptions are still a highly controversial topic, which have allegedly been linked to adverse effects such as cancer, weight gain and metabolic disorders (Harpaz *et al.*, 2018; Marinovich *et al.*, 2013; Gupta *et al.*, 2012). Therefore, the discovery of novel alternative nutrient-rich natural sweetener to replace added sugar in processed foods is currently of major interest. An example of non-caloric natural sweetener is stevia which provides zero calories and functional in a wide array of beverages and foods. However, stevia is responsible for aftertaste bitterness as well as textural and colour differences, for example no browning development and no bulking characteristics in baking which could affect the desirability of the final product as reported in several studies (Luo *et al.*, 2019; Gao *et al.*, 2017) . Sweeteners that have the potential to replace sucrose must be water soluble, adequate in flavour, and cost-effective (Gómez, 2008).

In fact, there are very limited studies conducted on only reducing sucrose without any substitution in baked products due to the impact that has on physicochemical quality and acceptability. The nipa palm (*N. fruticans*) is a high sugar-yielding mangrove palm tree that produces palm sap from the cut stalks of infructescence after the removal of the floral or fruit heads (Päiväke, 1996; Fong, 1992; Hamilton & Murphy, 1988). *Nypa fruticans* sap (NFS) composed mainly of sucrose, glucose and fructose and it is also an abundant source of inorganic minerals, amino acids and vitamins (Nguyen *et al.*, 2016; Aimi *et al.*, 2013). The mixture of sugar content in nature for NFS might serve as a potential candidate for alternative sweetener in baking. Besides due to this high sugar content, the NFS has been utilised as a material of treacle, amorphous and for producing vinegar alcohol or fermented beverage called “tuba” or “soom” in the Philippines, “arak” or “tuak” in Indonesia, “toddy” in Malaysia, India and Bangladesh (Päiväke, 1996; Hamilton and Murphy, 1988).

Previous study by Sukairi *et al.* (2018) regarding NFS has reported that the nipa sap contains antioxidants and shows a great potential in the antidiabetic properties, suitable to be used as an alternative to produce natural sugar that gives a lot of benefits. These bioactive compounds present as food components have an influence on the body, specific tissues or cells. Bioactive compounds such as polyphenols, carotenoids, tocopherols and phytosterols are distinct from nutrients in which they are not essential and, currently, no daily intake value is recommended (Gibney *et al.*, 2009). However, they establish beneficial effects such as antioxidant activity, inhibition or induction of enzymes and gene expressions (Correia *et al.*, 2012). The majority of dietary antioxidant compound such as polyphenols potentially retard carbohydrate digestion by delaying the activities of the enzymes, α-amylase and α-glucosidase which are responsible for the digestion of carbohydrate and absorption of glucose in the digestive tract, respectively (Bhandari *et al.*, 2008; Ali *et al.*, 2006). The most common polyphenols that exhibit α-amylase inhibition characteristics are flavonoids. Flavonoids act as potent non-competitive inhibitors to the enzyme α-amylase by hydrophobic interactions (Yuan *et al.*, 2014). This inhibition causes the delaying digestion of the monosaccharides in the intestine, lowering blood glucose level and reducing the potential of DM. The presence of these bioactive compounds was reported to contribute to the overall low Glycaemic Index (GI) of a food as they effectively decrease the postprandial blood glucose level and insulin response (Kim *et al.*, 2016).

The GI is a classification of carbohydrate foods based on their acute blood glucose responses. GI is defined as the incremental area under the blood glucose response curve (AUC) after consumption of a 50 g available-carbohydrate portion of a test food expressed as a percentage of the response to the same amount of carbohydrate from a reference food, normally glucose or white bread, consumed by the same subject. It is a measure of how high and how fast the blood glucose rises, and how effective the body responds by bringing back to normal after ingestion of food (Whitney *et al.*, 1990). According to the Food and Agriculture Organization [FAO] (1998), GI can be determined by collecting blood samples over 2 hours and calculating incremental AUC (iUAC; Jenkins *et al.*, 1981). A diet with low GI is preferred in diabetic patients, as regulation of the glycaemia is primodal.

According to Malaysian Adult Nutrition Survey (MANS), consumption of bakery products such as biscuits, breads, *kuih* has appeared in the list of top ten daily consumed foods (Kasim *et al.*, 2018). Therefore, being a popular, easily available and convenient food, bakery products have a wide potential in developing functional foods by incorporation or partial replacement for sweetener to improve the overall nutritional quality of the bakery products. In this study, plain carrot cake was chosen as a baked-based product model for its healthier content, to partially substitute the table sugar for concentrated *Nypa fruticans* sap (CNFS) up to 20% as a reduction of 20% sugar is the most acceptable and could be achieved without difficulty as reported by Shukla (1995).

1.2 Objectives of the Study

1.2.1 General objective

To develop a low glycaemic carrot cake with desirable physico-chemical properties and sensory acceptability by partially substituting sugar with CNFS.

1.2.2 Specific objectives

1. To formulate carrot cakes by partially substituting sugar with CNFS.
2. To examine the nutritional compositions, antioxidant activities and textural properties of carrot cakes incorporated with CNFS.
3. To evaluate the sensory acceptibility of carrot cakes incorporated with CNFS.
4. To determine the GI of carrot cakes incorporated with CNFS.

CHAPTER 2

LITERATURE REVIEW

2.1 Nypa fruticans sap

The nipa palm (*Nypa fruticans*) is a mangrove palm tree that grows indigenously in many tropical countries in South East Asia. *N. fruticans* belongs to the family Arecaceae (Palmae) and it is the only member of the family which constitutes as a major element in the mangrove flora as it thrives in river sites and brackish water environment, contrast to usual palms like coconut and oil palm (Dransfield *et al.*, 2008). Currently, nipa palms are commonly distributed in Asian countries and stand of approximately 700,000 ha which could be found in Indonesia, Papua New Guinea (500,000 ha), Philippines (8000 ha) and Malaysia (20,000 ha) according to Jabatan Perhutanan Semenanjung Malaysia (2009). The widespread occurrence of nipa palms has made local communities to grow these palms for limited use to produce alcoholic beverage, vinegar or boiled down to sugar from the NFS produced after tapping. Fresh NFS quickly spoils without filtration and refrigeration. Therefore, maintaining fresh sap at the optimum temperature during marketing and transport is impractical. However, after the removal of water and processing, sugar, syrup and vinegar from NFS are more stable at ambient temperatures and could be supplied to local, regional, and sometimes international market (Francisco-Ortega and Zona, 2013).

The origin of palm sap is related to the transportation system in the palm trees. Many species of palm trees preserve their products of photosynthesis from leaves as starch inside the stems (Nguyen *et al.*, 2016). After fertilisation, starch in the stems is converted to sugars and enters the nutrient flow to be transported towards the growing parts of the plants through the phloem. The liquid that contains the nutrients and sugars constitutes the sap. Some species of the palm such as *N. fruticans* and *Cocos nucifera* contain little starch in their stems (Dalibard, 1999). One of the explanations of sugar source for this case does not involve starch accumulation, instead the soluble sugars from photosynthesis in the leaves are transported as the mobile phase of the sieve tube system throughout vegetative parts of the palms before they are used directly to form fruits or saps (Die and Tammes, 1975).

Unlike tapping coconut palms in which the stalk could be over 10 m in height, tapping NFS is relatively easy as saps are generally collected from stalks bearing young or mature globose infructescence developed from nipa palm at only about 1 m height. This has significantly reduced the challenges for tappers to climb up the trees to obtain the sap like in other palm species. The nipa palm lacks an upright stem, with leaves and inflorescence arising from a branch rootstock (Gibbs, 1911). During tapping, the infructescence is cut off and the stalk was tapped daily to obtain its sugary sap until the stalk shortens or no more sap is produced from the stalk (Tamunaida *et al.*, 2013). After tapping, the cut infructescence could be consumed as one of the ingredients in local dessert, commonly known as "attap chee". The full usage of products from tapping results in no biomass wastes and poses no deleterious effect on the palm growth. Hamilton and Murphy (1988) emphasised the interest of nipa in terms of yield and management whereby tapping is easy, producing no wastes and the environment protected, as it grows in brackish water environment where fresh and sea water mingle. Furthermore, the declaration of the nipa palm as a non-threatened and underutilised palm in South Asia by Food and Agricultural Organization of the United Nations [FAO], (1998) has made abundant nipa palms in this region available for sap collection.

2.1.1 Consumption of *Nypa fruticans* sap

Once NFS has been tapped and collected, the sap can have any of the five uses, which include fresh sap, locally knowned as "*air nira*" or neera juice that can be consumed readily, syrup or molasses, sugar, palm wine and also vinegar, depending on local needs, traditions and markets. Fresh, unfermented sap is boiled down to produce a syrup or molasses or further refined into sugar. Alternatively, fresh NFS, as known as, neera juice is also traditionally consumed by people in Malaysia as a sugary beverage or it can be fermented to become palm wine, usually known as toddy. Further, the toddy, through a process of acetic fermentation, yields vinegar containing acetic acid (Gupta *et al.*, 1980). This process is reported to be rapid under sunlight. Therefore, NFS is often collected before sunrise to prevent it from being fermented by fermenting organisms, mainly yeasts such as *Saccharomyces cerevisiae* (Okafor, 1975).

2.1.2 Preservation of *Nypa fruticans* sap

Preservation of foods is a method of maintaining foods at a desired level of properties or nature for their maximum benefits, minimising or preventing spoilage and to ensure their availability for as long as possible (Rahman, 2007). NFS is readily and spontaneously fermented, resulting in the development of alcoholic fermentation products. Therefore, to prevent this to occur, suitable conservation techniques need to be done after tapping to preserve the chemical composition and characteristics of fresh NFS. According to Minh (2014), unprocessed fresh NFS has an initial pH of 4.5–6.5; a pH at about 3.6 indicates palm sap is in the fermented stage.

After tapping, conversion of sweet sap into sugar and molasses is a common practice among the local communities. For traditional production of palm sugar, a large volume of filtered palm sap is poured into a big wok, where the filtered palm saps are heated on the wood fire stove for a few hours at temperature beyond 100 ^{o}C until it becomes concentrated to obtain a unique aroma (Ho *et al.*, 2007). This process can help to exterminate the microorganisms by heat and the high sugar concentration of the obtained product can also inhibit their growth (Naknean *et al.*, 2014). The resulting syrup which looks like honey is then sealed into bottles for sale. Besides, keeping the sap in a cooler box with dried ice or freezing (- 4 ^{o}C) can also help preserving the fresh NFS (Aimi *et al.*, 2013). The processed palm tree syrup does not contain any kind of additives or artificial colourings and can last for years by storing at a low temperature of -4 ^{o}C (Naknean *et al.*, 2013; Luis *et al.*, 2012).

2.1.2(a) Thermal deterioration of *Nypa fruticans* sap

Traditionally, palm sap syrup is produced by evaporating the palm sap in an open pan, and heated, using a wood fired stove, until it becomes concentrated. The producer will then determine the intensity of its brown colour, thickness and viscosity of the neera during the heating process. However, heat from the process may alter its unique flavour and colour. This heat causes the dark colour and affects the quality during storage. Since quality is vital in food production, thermal deterioration must be controlled during processing and storage. Maillard reaction and caramelisation may cause unacceptable nutritional and sensory effects in sugar-based food products and may be a limiting factor in the shelf life of products (Burdulu and Karadeniz, 2003).

The Maillard reaction is a complex network of various reactions involving reactants and products with high reactivity. The reaction impairs the content and bioavailability of amino acids and proteins (Morales *et al.*, 2007) and it is often related to the formation of harmful compounds such as acrylamide and hydroxymethylfurfural (HMF). According to Martins *et al.* (2001), this reaction is difficult to control and its mechanism is still a controversial issue. The reaction begins with condensation between a reducing sugar and a compound with free amino group or an amino acid or majority the ε-amino group of lysine in proteins. Under more severe heating, the product of condensation which is N-substituted glycosylamine is then rearranged to form the Amadori product (1-amino-1-deoxy-2-ketose) which is subsequently degraded into different compounds depending on the pH of the system. At low medium pH (4 – 7), HMF or furfural (when hexoses or pentoses are involved, respectively) are formed via enolisation, which are highly reactive compounds that take part in further reactions (i.e. condensation and polymerisation), leading to the formation of melanoidins and other brown polymers, and aromatic substances (Mauron, 1990). The condensation between reducing sugars and amino acids certainly destroys the amino acids and protein available leading to nutritional issues.

2.1.2(b) Low heat air dry technique and storage condition for *Nypa fruticans* sap

To produce good and constant quality of all the palm syrup sugar samples in accordance with national and international standards, suitable dehydration technique and storage condition are needed. Total soluble solids (TSS) is used to measure the sugar content of sugar solutions by the index of refraction using a refractometer and is referred to as the degrees Brix (^{o}Brix). According to reg. 132 of the Food Regulations 1985, molasses or syrup shall have TSS of not less than 85 ^{o}Brix at 20 ^{o}C.

Previous study was done by Naknean *et al.* (2013) to monitor the changes in properties of palm sugar syrup produced by an open pan and a vacuum evaporator during storage. Palm sap was concentrated using two methods: traditional open pan (at approximately 110 ^{o}C) and vacuum evaporator at 70 ^{o}C and 80 ^{o}C until its total soluble solids reached 70 ^{o}Brix to obtain palm syrup and each palm syrup sample was stored under 4 ^{o}C and 30 ^{o}C for 12 months. During storage, Maillard reaction took place in samples stored under 4 ^{o}C lower than those stored under 30 ^{o}C. Only the sample produced by an open pan and stored under 30 ^{o}C contained HMF content (50.58 mg/kg) higher than the permitted maximum limit (40 mg/kg) as recommended by the Codex Alimentarious. This study showed that heat treatment processing of palm sap at 70 ^{o}C to 80 ^{o}C using a vacuum evaporator is better in retaining desired quality attributes in syrup than palm sugar syrup produced by heating with an open pan. Non-enzymatic browning of palm sugar syrup during storage could also be reduced by storing at low temperature (-4 ^{o}C).

2.1.3 Nutritional values of *Nypa fruticans* sap

The freshly collected NFS has an oyster white colour, sweet in taste, and has opaque appearance with acidic pH about 4.4–6.9. It is an abundant source of inorganic minerals (5.2 g/L), 17 amino-acids, vitamin C and B vitamins. According to Aimi *et al.* (2013), a total of four volatile compounds were identified in fresh NFS which include ethanol (83.43%), diacetyl (0.04–0.06%), ethyl acetate (12.9%) and ethyl lactate (3.04%). After fermentation, four alcohols (ethanol and three higher alcohols) and three esters were detected. The volatile compounds in palm saps were responsible for the unique odour and characteristics of fresh and fermented NFS. According to Nguten *et al.* (2016), NFS contains 2.6 g/L potassium, 2.6 g/L chloride and 0.9 g/L sodium. The minerals in palm saps may be affected by the source of water and soil of the palm tree. For example, The inorganic content of NFS has particular high contents of Na and Cl, mostly because the nipa palm grows near the swampy seawater salt (Nguyen *et al.*, 2016). A study by Tamunaida *et al.* (2013) also showed that nipa palms that grow in brackish water environments where fresh water and seawater mingle produce saps which has more intense level of Na and Cl as their major inorganic element compared to palms that grow on higher lands.

NFS are known to continuously produce rich sugar sap from its infructescence. According to Nguyen *et al.* (2016), fresh NFS consists of 144.2 g/L of total sugars. Sucrose is the main sugar in the sap which constitutes about 51.9% of the total sugars, followed by 30.4% glucose and 17.8% fructose. Table 2.1 shows the chemical composition of NFS compared to sugarcane juice and several species of palm saps. The total sugar content of NFS (144.2 g/L) is comparable to that of the sugarcane saps which consist of 150.3 g/L of sugar. Furthermore, the sugar content of NFS is found to be as competitive as other sugar yielding palms such as coconut palm (*C. nucifera*) with 130.6 g/L total sugar and date palm (*Phoenix dactylifera*) with 124.8 g/L total sugar.

Table 2.1 Sap composition of various palm saps compared with sugarcane juice

Sap	**pH**	**Sap Composition (g/L)**						
		Total Sugar	**Sucrose**	**Glucose**	**Fructose**	**Ethanol**	**Organic Acids**	**Inorganics**
Oil palm (*Elaeis guineensis*)	6.6	116.1	105.9	4.9	5.3	-	-	-
Coyol palm (*Acrocomia aculeata*)	7.3	116.3	113.6	0.0	2.7	0.0	0.0	-
Coconut palm (*Cocos nucifera*)	6.4	130.6	77.3	36.6	16.7	-	-	2.6
Palmyra palm (*Borassus flabellifer*)	7.3	116.0	-	-	-	0.0	-	-
Date palm (*Phoenix dactylifera*)	6.8	124.8	99.3	8.0	9.4	-	-	3.5
Nipa palm (*Nypa fruticans*)	5.9	144.2	105.1	23.7	15.5	1.0	4.1	5.2
Sugarcane (*Saccharum officinarum*)	-	150.3	148.3	1.0	1.0	0.0	0.0	4.1

Source: Nguyen *et al.*, 2016

Previous study reported that aqueous extract of the vinegar possessed antihyperglycaemic activities comparable to the standard antidiabetic drug, metformin (Yusoff *et al.*, 2015). This finding is also in line with another study done by Sukairi *et al.* (2018) which showed that NFS samples have a great potential in the antidiabetics and antioxidant activity. This antidiabetic properties of NFS seemed to have linked to the presence of antioxidant compounds in NFS. The antioxidant compounds, such as phenolic acids and flavanoids delay carbohydrate absorption from the small intestine through selective inhibition of intestinal glucose transporters or enzyme, for example α-amylase and α-glucosidase, thereby suppressing postprandial hyperglycaemia.

2.2 Trend of sweetener intake

Since prehistoric time, man has sought for sweet tasting substances such as honey and fruits or berries for consumption. In the 16th century, sugarcane culture was spread across the world and sugar was prized as a luxury for beverages and confections for example coffee, tea and chocolate. In 1811, when France was cut off from sugar supplies by the British, researchers found out that starch could be hydrolysed with acid to give a sweet-tasting syrup. The starch sweetener industry continued using acid to hydrolyse starch until glucoamylase has proven to be an enzyme to catalyse this reaction (Inglett, 1976). The enzymatic isomerisation of glucose to fructose yields high fructose corn syrups (HFCS) which have excellent sensory properties and applicable to be used in soft drinks and other syrup-related markets. HFCS is easier to be transported and more economical in countries where the price of sugar is high. This leads to the wide application of this sweetener in industry. Two of the enzymes used to make the syrup, α-amylase and glucose isomerase are genetically modified to make them more stable at elevated temperature for industrial application (Varzakas *et al.*, 2016). In 1982, when the artificial sweetener was introduced, children began getting type 2 diabetes and the obesity rates soared. The syrup has been shown to interfere with people's metabolism by limiting the secretion of leptin, an enzyme which is responsible for signaling the brain to inhibit the feeling of hunger and helps in the limitation of food intake (Bray *et al.*, 2004). As a result with the lack of leptin enzymes, people tend to feel hungrier than usual and increase their intake of food consumption.

The accidental discovery of saccharin in 1879 began the non-nutritive sweetener era. Although saccharin appears ideally suited for diabetic patients, there has been controversy over the safety of saccharin. Rat feeding studies indicated that saccharin at high doses caused tumours in the bladder of male rats (Science Committee for Food [SCF], 1977). The same case was reported for the usage of cyclamate which was widely used in foods and beverages during the 1960s. Since then, cyclamate was prohibited in many countries. Other high intense sweeteners were also studied to determine whether these sweeteners would pose any appreciable risk to the health of the average consumers and of those whose pattern of food consumption and physiological or health status may make them vulnerable, for example cancer, weight gain, metabolic disorders and alteration of gut microbiota activity. The most recent carcinogenicity study in mice on high intense sweetener that caught the attention of public was published by Soffritti *et al.* (2010). Although the study did not specifically address aspartame, as intense sweeteners other than aspartame are also used in soft drinks, the authors speculated that exposure to aspartame or its metabolite methanol could be a causative factor for premature deliveries.

The 2013 World Health Statistics Report showed that in 2008, Malaysia had escalating obesity prevalence for adults aged above 20 years, above 30 years and children below 18 years among Southeast Asian countries. Increasing intake of sugar and sweeteners coupled with sedentary lifestyles are key factors to the rising problem of obesity and associated non-communicable diseases. According to the World Health Organisation (WHO) guidelines on sugar, a strong recommendation is given to reduce the intake of free sugars throughout the life course and to maintain intake of less than 10% of total energy. Added sugar is generally consumed as transformed sugar, composed almost extensively of carbohydrates, poor in vitamins, minerals, polyphenols and other biomolecules that could provide beneficial health effects. For these reasons, the trend of sweetener has now shifted from synthetic back to the natural and raw unprocessed sweeteners which have been proposed to provide health benefits owing to their rich polyphenol content and their antioxidant properties measured in vitro (Biesaga and Pyrzynska, 2013; Caderby *et al.*, 2013). Therefore, replacement of refined sugars by a natural sweetener could provide a healthier food choice for the industry to respond to the consumers' requests for improved food products.

2.2.1 Natural sweeteners

Unrefined sweeteners include all natural, raw sweeteners that are low processed. Natural sweeteners are usually made with the fruit or sap of plants. Generally, sugar alcohols like tagatose, sorbitol and xylitol are not included in this category, as well as other "natural" compounds derived from plant extracts that belong to the so-called "high intensity sweeteners". Natural sweeteners such as honey and maple syrup contain monosaccharides and disaccharides that give them the sweet taste (Varzakas *et al.*, 2016). Though not widely used as alternatives to sugar, natural non-refined sugar potentially contains beneficial bioactive compounds, especially polyphenolic acid and their antioxidant properties in nature. One of the benefits of using unrefined natural sweeteners as alternatives to sugar is due to their low GI as they provide a substantial content of other beneficial nutrients and bioactives (Phillips *et al.*, 2009). Interestingly, some of these compounds are found to exert beneficial health properties, particularly on glucose homeostasis. For example, polyphenolic compound found in some of the maple syrups were shown to have α-glucosidase inhibitory activity, suggesting that these molecules could slow down glucose absorption by the intestine in response to ingestion of sweetener (Li and Seeram, 2010).

2.2.1(a) Utilisation of palm saps in food products

For traditional purposes, palm sap is heated to obtain a palm sugar concentrate that can be kept longer. The unique flavour of palm sap concentrate has become a popular flavouring agent in confectionary, dairy and bakery products. The most widely used palm sap in wheat-based products is the coconut palm sugar which can directly be substituted for cane sugar in baking. The sweetness of coconut sugar is lesser than cane sugar but more flavourful, with a molasses-like flavour similar to brown sugar (McCaffrey, 2014).

In Malaysia, traditional Malay cakes and desserts known as *kuih* are usually fried, but sometimes grilled, or baked which can be found at hawker stalls, night market or *pasar malam* and restaurants. The basic ingredients used to produce sweet *kuih* are sugar, coconut milk, brown sugar and *gula melaka* (palm sugar). *Gula melaka* is extracted from the flower sap of a coconut palm and processed and sold in the form of hard cakes wrapped in dried brown coconut leaves (Ainuddin, 2013). Like normal sugar, they melt when boiled and taste bitter when burnt. *Gula melaka* is more natural and believed to be healthier and has long been used to make traditional Malay *kuih*. Examples of traditional sweet kuih are *kuih baulu*, *tapai*, *dodol*, *kuih bingka*, *kuih cek mek molek*, *kuih lapis pelangi* and *onde-onde*. Sometimes, this sweet Malay local *kuih* is served with other accompaniments such as *kuih lopes* eaten with caramelised palm sugar (Raji *et al.*, 2017). A study done by Azizah *et al.* (2015) showed that *kuih onde-onde* had the lowest sugar content compared to different type of traditional Malay *kuih.* According to Ang and Foo (2002), the filling of *kuih onde-onde* contains *gula melaka* instead of granulated sugar. Sucrose content in gula melaka (70%) is lower compared to granulated sugar (>99.5%) (Malaysia, 2012). This might be the reason for the lowest content of total sugar in *kuih onde-onde* compared to other *kuih* which were mostly made by granulated sugar.

Besides, unrefined palm sugar was utilised as a sweetener in probiotic ice cream. Low *et al.* (2015) formulated probiotic ice cream by comparing the effects of different levels of refined cane sugar and unrefined coconut palm sugar on the survivability of *Lactobacillus acidophilus* in probiotic ice cream and its sensory and antioxidant properties. There were no significant effects on the sensory score among the probiotic ice cream with different sugar levels. The replacement of refined coconut palm sugar developed the viability of probiotics, antioxidant capacity and total acceptability of probiotic ice cream. According to Oroian and Esriche (2015), the health benefits of antioxidants, which include reduction of risks developing cancer, high blood pressure, diabetes and other diseases make them ideal for the usage in functional foods.

Another study done by Saputro *et al.* (2017) on the quality attributes of dark chocolates formulated with palm sap-based sugar as natural alternative sweetener showed that the substitution of sucrose in dark chocolate with palm sap-based sugar not only developed a healthier chocolate that contained additional minerals, vitamins, antioxidative and anticarcinogenic compounds compared to standard dark chocolates, but also influenced the distinctive flavour/aroma of the chocolate products. The unique aroma was caused by the presence of 2,3-dihydro-3,5-dihydroxy-6-methyl-4(H)-pyran-4-one (DDMP), which has a caramel-like-flavour, is a Maillard reaction product which exhibits antioxidant activity (Zhou *et al.*, 2014; Yu *et al.*, 2013)

To sum up, palm sap-based sugar has the potential to be incorporated or substituted for sucrose in several food products to develop foods with nutritional values and well accepted by consumers. With that, palm sap-based sugar could be included into population's daily diets to benefit their general health.

2.3 Bakery products

Breads, cakes, pastries, cookies and crackers and many other products are examples of the common baked products in our daily life. Baking of bakery products can be defined as the process which transforms dough, basically made of flour and water with other ingredients such as sugars, fat, egg, leavening agent, and other additives (depend on each specific product) (Purlis, 2010). In bakery, the most important ingredient is wheat flour as it provides bulk structure to most of the bakery products. Wheat flour possesses the ability to form dough when mixed with water. It is unique among the cereals in that it contains protein composite known as gluten which has the ability to retain the gas produced during fermentation or by chemical leavening, thus yielding a leavened product. Normally, hard wheat which has high protein content is used primarily for yeast-leavened products such as breads, bagels, croissant and doughnuts. Another type of wheat which is the soft wheat has low protein content and it is suitable for making biscuits, muffins, pastries and cakes. Soft wheat flour has a protein content ranges from 8 to 10%. This results in producing a cell structure that provides good mouthfeel and a less chewy texture in chemically leavened baked goods (Hui, 2007).

As one of the most developing countries in Asia, demand for bakery products is remarkably high among Malaysian populations. Tey *et al.* (2008) reported that Malaysian's food consumption pattern has shifted from the traditional staple rice to a more Westernised diet such as wheat-based bakery products. Bakery products are widely consumed due to their affordable cost, convenient and wide variety of options. According to Malaysian Adult Nutrition Survey (MANS), consumption of bakery products such as biscuits, breads, local cakes (*kuih*) has appeared in the list of top ten daily consumed foods (Kasim *et al.*, 2018). Hence, studies on bakery products are a major concern as it could improve the eating habit and nutritional values of daily consumed foods among Malaysians.

2.3.1 Roles of sugar in bakery products

In bakery products, sugar plays many functional roles such as colour, flavour, texture, improving shelf-life and moisture retention. During dough mixing, Gluten strands are formed when flour proteins are hydrated. Gluten forms thousands of small, bubble-like holes that trap gases produced during leavening. These highly elastic gluten strands allow the dough to stretch under gas expansion. However, the dough may become rigid and tough if too much gluten is developed (McCann & Day, 2013). Sugar then competes with these gluten-forming proteins for water and prevents the full hydration of the proteins during mixing. If sugar is added correctly in the recipe, gluten maintains optimum elasticity, allowing for gases to be held within the dough. Sugar prevents gluten development and gives the final baked product good texture and volume (Pareyt *et al.*, 2009).

In cakes, sugar also plays a part in creaming and egg foams. Sugar and sweeteners give lightness to the cake by incorporating air in the form of small air cells into shortening during mixing. These air cells expand during baking when filled with gas from the leavening agent (McCann & Day, 2013). Sugar interacts with egg proteins to stabilise the whipped foam structure, contributing to elasticity, so air cells can expand (Pareyt *et al.*, 2009).

Gelatinisation in cakes occurs when the heat of baking causes the starch in flour to absorb liquid and swell. It is a physicochemical phenomenon involving the separation of starch granule within a moist environment at a certain temperature about 65 ^{o}C for most starches, when the granules begin to swell rapidly and take up a large amount of water. If too much gluten develops, the dough or batter will become rigid and tough. Sugar competes with starch for water and slows gelatinisation. As a result, less gluten is formed and allowing the dough or batter to become elastic instead of becoming rigid. By slowing down the gluten development, sugar helps giving the final baked product a tender crumb texture and good volume (The Sugar Association, 1992).

In bakery products, the surface colour is one of the important features, together with aroma, taste and appearance characteristics that will have direct impact from the consumers' viewpoint. Sugar in bakery products undergoes caramelisation and Maillard reaction, contributing to the development of appealing colour, flavour and aroma which is known as the browning effect (McCann & Day, 2013; Purlis, 2010;).

In general, a sugar reduction in sweetened bakery products by 15–20% has been reported as possible without radically changing formulations. A sugar reduction of more than 20%, however, is more challenging (Nip, 2006). Due to the numerous functions of sucrose in baked goods, the reduction sugar or sugarless baking causes several problems. A lower amount of dissolved solids in the batter or dough leads to a lower viscosity that hinders the incorporation of air and cell structure development. Both browning by Maillard reactions and caramelisation are less intense, and reduced sugar baking also influences flavour formation in the product and shelf life.

2.3.2 Alternatives to refined sugar in bakery products

The sweeteners that may be used to substitute sugar (mainly sucrose) in baked based products can be classified with respect to their origin (natural or artificial sweeteners) or with respect to their energy content (Patra *et al.*, 2009). Sweeteners that have the potential to replace sucrose must be water soluble, adequate in flavour, and cost-effective (Gómez, 2008). Besides, stability under elevated temperature must also be considered for the application in bakery products. The substituting sweeteners should also replace other functions of sucrose in bakery products, such as browning, crystallisation, viscosity, structure formation and moisture control (Alonso and Setser, 1994). Other features such as colourless, odourless, non-cariogenic, enhanced nutritional value and similar sweetness would be more feasible for fulfilling consumers' demand.

The ability of producing mixtures of sweeteners "designed" to confer the desired sweet taste with fewer calories and other functionalities to the final products is the latest trend in sweeteners. The desired sweet taste may be subjective and depend on or can be modified by many factors which include the chemical and physical composition of the medium, the concentration of the sweetener, the temperature at which the product is consumed, the pH and other ingredients in the product, and the sensitivity of the tasters (Nabors, 2016). In addition, when two sweeteners are blended, the perceived intensity of the mixture may be equal to (additivity), greater than (synergy) or less than (suppression) the total of the individual sweetness intensity (Zhou, 2014).

2.3.3 Bakery products as functional foods

The understanding of the importance of the relationship between nutrition and health has led to the concept of functional foods. Today's foods are designed not only to provide energy and satisfy hunger, but also to prevent nutrition-related diseases and improve the mental and physical well-being of the consumers (Mollet and Roland, 2002). Nutritious and functional ingredients have been incorporated into bakery products that confer health benefits for the consumers. Some of the functional ingredients investigated in the recent studies and incorporated in bakery industry include polysaccharides and fibers, prebiotics and probiotics, oils and lipids and antioxidant (Ubbink and Krűger, 2006; Kadam and Prabhasankar, 2010; Ng *et al.*, 2017).

In Malaysia, bakery product is listed as one of the five categories of functional foods, others include dairy products, beverages, bakery and snack bars. Functional foods are foods that may provide health benefits beyond basic nutrition (Bech-Larsen and Grunert, 2003). This simple definition is also in accordance with the major selling proposition for functional foods, where functional foods enable the consumer to lead a healthier life without changing eating habits (Lau *et al.*, 2012). The increase in healthcare awareness among Malaysians as well as the rising cost of medical treatment has led to an increase demand for production of healthy and functional foods. According to Lau *et al.* (2012), Malaysians prefer to consume less processed food products than consumers of developed countries. Therefore, being a popular, easily available and convenient food, bakery products have a wide potential in developing functional foods by incorporation or partial replacement for flour or sweetener to improve the overall nutritional quality of the foods.

Previous researches conducted on the incorporation of oyster mushroom powder as a source of dietary fiber and antioxidant in bakery products has shown that plant-based ingredients can potentially be used to enhance the nutritional values and exhibit low-GI properties (Ng *et al.*, 2017; Wan Rosli *et al.*, 2011). However, there is no study has been done lately on the development of functional foods by substituting refined sugar by using other local plant sources such as palm sap sugars.

2.3.4 Carrot cakes

Cake is baked batter which contains high level of sugar, fat, eggs, leavening agent and water. Each ingredient contributes to the main attributes of cake quality: tenderness, structure, moisture, colour (brown crust) or flavour. Most cakes are made using soft wheat flour with a low protein content of 7–9%. After pin-milled, a very fine particle size of soft wheat flour is produced and has more surface area to absorb more liquid to produce better quality cakes (Caballero *et al.*, 2016).

Carrot cakes are cakes that contain carrots mixed into the batter. Carrot cake may be eaten plain, but it is commonly glazed or topped with white icing or cream cheese icing and walnuts, often chopped. They are popular in loaf, sheet cake and cupcake form. Many carrot cake recipes include optional ingredients such as nut, raisins, pineapple or coconut.

One of the main ingredients in the carrot cakes, which is carrot, is one of the popular root vegetables rich in bioactive compounds like carotenoids and dietary fibers with several other health-promoting compounds (Sharma *et al.*, 2012). Carrots that are used in the cakes are significant source of phytonutrients including phenolics, polyacetylenes and carotenoids (Hansen *et al.*, 2003). Carotenoids, especially β-