Effect of overripe banana in developing high dietary fibre and low glycaemic index cookie

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Abstract
Purpose – Demand for dietary fibre-enriched and low sugar bakery products is increasing rapidly due to current high incidence of type 2 diabetes mellitus. Overripe banana has been discarded due to its low quality and appearance. However, overripe banana exhibits rich sources of natural sweetener and dietary fibre which could potentially be used as a novel food ingredient in bakery product. Thus, the study aims to determine the nutritional properties, sensory acceptability and glycaemic index (GI) value of chocolate cookies formulated with overripe banana sweetener (OBS) as partial replacement (10, 15 and 20%) for table sugar and utilization of overripe banana residue (OBR) as partial replacement (8%) for wheat flour.
Design/methodology/approach – Nutritional composition was analysed using AOAC methods and sensory acceptability using 7-point hedonic scaling method. *In Vivo* GI determination was continued according to FAO/WHO method.
Findings – Incorporation of OBR and OBS significantly ($p < 0.05$) increased nutritional values of chocolate cookies. Chocolate cookies formulated with 8% OBR +20% OBS recorded the highest TDF (7.80%) and ash (1.47%) content. Sucrose content of chocolate cookies was reduced significantly with increasing level of OBS. Sensory scores for control and 8% OBR-incorporated cookie were not significant difference for all the sensory attributes. Moreover, incorporation of OBS up to 15% produced higher scores in term of aroma, flavour and overall acceptance. Three formulations of chocolate cookies (control, 8% OBR and 8% OBR +15% OBS) were selected for GI testing and recorded GI values of 63, 56 and 50, respectively.
Originality/value – Overripe banana can be used as a food ingredient in developing high fibre and low-GI cookie.

Keywords Chocolate cookies, Overripe banana, Nutritional values, Sensory acceptability, Glycaemic index
Paper type Research paper

Introduction
Diabetes mellitus (DM) is a debilitating chronic metabolic disorder identified by high blood glucose level (hyperglycaemia) mainly due to insulin insensitivity. It is associated with some

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serious complications such as cancer, ischemic heart disease, stroke and various organs failure (ADA, 2013). The prevalence of DM has doubled in the past three decades and becoming global public health concern, ranging from 4.7% in 1980 to 8.8% in 2017, and it is expected to increase to almost 10% by the year 2045 (Cho *et al.*, 2018). The incidence of DM is due to many factors, for example rapid urbanization, eating habit and increasing rates of obesity and sedentary lifestyle (Hu, 2011). Even there are plenty of efforts and antidiabetic agents provided, DM still a major cause of morbidity and mortality worldwide (Erejuwa *et al.*, 2012).

The increasing trend of DM has led to more emphasis on diabetes-related functional food with the view of improving their blood glucose control. One of the approaches is by assessing the physiological effects of food by the concept of glycaemic index (GI) which is a value given to carbohydrate-rich foods based on their effect on postmeal glycaemia (Esfahani *et al.*, 2009). GI of a food is depended on the rate of digestion and absorption of carbohydrates in small intestine (Arvidsson-Lenner *et al.*, 2004). As a result, low-GI foods are able to produce gradual rise in blood glucose level and therefore are favourable in terms of health, especially for the management of diabetes. There are several food components that can be used to reduce GI of a food. These include the presence of dietary fibre (DF) and types of sugar added in the food.

DF is the edible part of the plant which is resistant to enzymatic digestion and absorption in human small intestine with complete or partial fermentation in the large intestine (Dhingra *et al.*, 2012). DF, particularly soluble fibre mostly found in fruits and vegetables has been shown to have a direct effect on the GI of a food (Weickert and Pfeiffer, 2018). The viscous, gel-forming and more readily fermented properties of these fibres increase viscosity of food which lead to prolonged carbohydrate digestion and absorption as well as improved satiety and thus lowering postprandial blood glucose level (Abutair *et al.*, 2016). The recommended DF intakes for adults are 20–30 g/day. Nevertheless, the intake for DF among populations is low, ranging from only 3–16 g/day (Lee and Wan Muda, 2019).

Sugars are one of the major components in our diet and normally added into foods and beverages to enhance the colour, texture and flavour development. The most common of which is sucrose or table sugar which is widely used in food industry for the production of commercialized food products such as bakery products, ice cream and carbonated beverages (Zargaraan *et al.*, 2016). However, overconsumption of sucrose-rich product may lead to weight gain, cardiovascular diseases and type 2 diabetes (Goldfein and Slavin, 2015). In consequence, artificial sweeteners (non-nutritive sweetener) such as aspartame, sucralose, neotame and saccharin have received great attention to replace added sugar as these sugars generally have little to no calories and provide low glycaemic response (Mattes and Popkin, 2008). Nevertheless, the effect of artificial sweeteners on human health is still a controversial topic. There are previous studies that found the link between artificial sweeteners and adverse health effects, for example weight gain, cancer, nausea, diarrhoea and metabolic disorder (Harpaz *et al.*, 2018). Moreover, there was a report mentioning that artificial sweeteners induce glucose intolerance by altering the gut microbiota (Suez *et al.*, 2014). Hence, there is an increasing interest in searching for a more natural and nutrient-rich sweetener. Alternative sweeteners that are believed to be healthier are natural sweeteners from high sugar tropical fruits such as banana, pineapple, mangoes, pomegranate, etc.

Banana *(Musa sp.)* is one of the most widely consumed fruit and has an annual production of approximately 70*m* tonnes all over the world (Darvari *et al.*, 2010). Banana fruit has been long recognised as a great source of nutrients and has beneficial effects on human health (Sidhu and Zafar, 2018). However, banana is a perishable fruit that has a short lifespan from harvest until the onset of deterioration (Karim *et al.*, 2018). Previous studies have claimed that the purchase intention for overripe banana was significantly lower due to low quality, brown spots appearance as well as decrease in firmness of the pulp (Symmank *et al.*, 2018). As a result, banana has been shown as one of the most-wasted product as most retailers ask for fruit in yellow colour (Mattsson *et al.*, 2018). Despite that, overripe banana consists of an excellent source of vitamins, minerals, DF and natural sweetener (Kumar *et al.*, 2012). The sugar content mainly composed of sucrose, fructose and glucose increased tenfold from unripe banana to overripe banana, raising from 1.26% to 12.28% (Yap *et al.*, 2017). Previous study by Chaipai *et al.* (2018) revealed that the DF in banana pulp did not vary with maturity although most of the starch has been converted into sugar in overripe banana. There have been a few studies that utilized overripe banana or second grade banana to produce banana puree films (Martelli *et al.*, 2013) and biodegradable starch laminates (Alanís-López *et al.*, 2011). However, overripe banana is still underutilized, and very little effort has been put to identify its functionality in terms of application to food. Hence, the utilization of overripe banana will not only help in increasing value of food product but also indirectly reduce food waste.

According to the Malaysian Adult Nutrition Survey (MANS), cookies are among the top 10 food items consumed by Malaysians (Kasim *et al.*, 2018). Thus, cookies could be an effective carrier of nutrients. Besides, most of the commercialized cookies are low in DF and high in sugar. In this context, the objective of this study was to determine the nutritional properties, sensory acceptability and glycaemic index (GI) value of chocolate cookies formulated with overripe banana sweetener (OBS) as partial replacement for table sugar and utilization of overripe banana residue (OBR) as partial replacement for wheat flour.

Materials and methods

Experimental design

There were control sample and four experimental samples. The control sample was the chocolate cookie without substitution of both OBR and OBS, while the experimental samples consist of chocolate cookies formulated with 8% OBR to partially replace wheat flour and with 10%, 15% and 20% OBS to partially replace table sugar. The study compared the control chocolate cookie and formulated chocolate cookies in terms of the proximate composition, total dietary fibre (TDF), sugar profile, sensory acceptability and GI value.

Preparation of raw material

Fully ripened *Musa Acuminata cv.* Berangan banana (stage 4) was purchased from local fruit store in Kota Bharu, Kelantan and kept in room temperature at 25 °C, relative humidity of 80–85% until the fruit reached the desired ripeness (overripe, stage 5) without any ripening agent. The stage of ripening was determined according to Karim *et al.* (2018) using colour chart and physical observation. Extraction of banana was done by using method established by Albuquerque *et al.* (2005) with modification. The banana pulps were homogenised with water in the ratio of 1:3 and centrifuged at 15000g for 25 mins at 4 °C. Filtration was done with filter paper Whatman No. 4 to extract out the residue from the liquefied banana pulp.

Preparation of OBS

The clear banana liquid was dehydrated using technique described by Tadakittisarn *et al.* (2007) with slight modifications. 50g of banana liquid were dehydrated in a thermal dehydrator (Anywin FD770, China) at 60 °C overnight (16 h) to remove the moisture content. The concentrated syrup was then kept in screw cap bottle at 4 °C prior to analysis and further use. Both pH and total soluble solids (TSS) Brix of the syrup were measured using Hanna pH 211 microprocessor pH meter (USA) and hand refractometer (Atago 3851 PAL-BX/RI, Japan), respectively.

Preparation of OBR

The residue (w/v) obtained after filtration were dried in the conventional oven (Memmert, Germany) at 55 °C for 24 h followed by milling into powder using electrical blender and then sieved into fine powder (125µm diameter) using a sieve. The residue powder obtained was kept in screw cap bottle at 4 °C until further use.

Development of chocolate cookies

Incorporation of 8% overripe banana pulp powder to replace wheat flour has been identified as the best formulation in previous study by Ng *et al.* (2020). Hence, the chocolate cookie formulated with 8% OBR was used in this study.

The chocolate cookies were formulated by using commercially available raw ingredients such as butter, margarine, castor sugar, egg, baking powder, cocoa powder, wheat flour and corn flour. OBS was used to partially substitute castor sugar at the percentage of 10, 15 and 20% as listed in Table 1. In a mixing bowl, butter and castor sugar were beaten by using an electric hand mixer followed by adding egg into the mixture slowly until a creamy texture was achieved. After addition of all dry ingredients, the mixture was beaten again for 5 mins and kept in the fridge for 2 h. The refrigerated dough was manually shaped into 3 mm thick using a 5 cm diameter mould. After that, they were put on a baking sheet and baked at 170 °C for 12 mins. The cookies were then cooled at room temperature for 1 h before grinded into powder form and kept in screw cap bottle at 4 °C until further analyses.

Nutritional analyses

Proximate analyses for OBR, control and formulated chocolate cookies were conducted using AOAC (1996a) for moisture (air-oven method), total ash (dry-ashing method), protein (Kjeldahl method) and fat (Soxhlet method). Carbohydrate was calculated by the difference: Total CHO = 100 – (g of moisture + ash + protein + fat). Total dietary fibre (TDF) was determined by using enzymatic-gravimetric method based on AOAC (1996b). Sugar profile was determined using the Boehringer Mannhein/ R Biopharm sugar analysis kit for enzymatic analysis of sucrose, glucose and fructose according to the manufacturer's instructions.

Sensory evaluation

Sensory evaluation of chocolate cookies was carried out by 60 untrained panels consisting staffs and students of the School of Health Sciences, Universiti Sains Malaysia Health Campus. The samples were coded with 3-digit permuted number and evaluated according to the 7-point hedonic scale method by Sharif *et al.* (2017). Sensory attributes included aroma, colour, appearance, crispiness, flavour and overall acceptability (1 = dislike the most and 7 = like the most).

In vivo GI determination

The study was conducted according to WHO/FAO (1998). After given written informed consent, 13 healthy subjects (four males and nine females with no histories of chronic diseases and smoking; ages ranged from 18 to 60; body mass index of 18.5–24.9 kg/m^2) were randomly assigned to take glucose drink (reference food) and three different test foods containing 25g of available carbohydrate at different occasion after overnight fasting. Glucose drink was repeated for three times to improve the precision of measurement, hence reduce variation of GI mean

Table 1.
Incorporation levels of OBS and OBR in chocolate cookie

		Quantities (g)				
Items	Ingredients	*Control (0% OBR and OBS)	0% OBS + 8% OBR	10% OBS + 8% OBR	15% OBS + 8% OBR	20% OBS + 8% OBR
1.	Castor sugar	41	41	36.9	34.8	32.8
2.	OBS	0	0	4.1	6.2	8.2
3.	Wheat flour	76	69.9	69.9	69.9	69.9
4.	OBR	0	6.1	6.1	6.1	6.1

values (Brouns *et al.*, 2005). A standard 250ml of water was given with each meal, and the subjects were encouraged to consume the food within 10–15 minutes. A minimum of 3-day gap was maintained as the washout period between the test meals to minimise any carryover effect.

During each session, blood samples were collected at fasting, then further at 15, 30, 45, 60, 90 and 120 minutes after consuming the food. Approximately 4µl of blood were drawn from capillary finger prick into cavity of disposable plastic microcuvette (HemoCue Glucose 201 RT Microcuvette, Sweden) then analysed for blood glucose concentration by using glucometer (HemoCue Glucose 201 RT, Sweden).

The calculation of incremental area under curve (iAUC) was done using Microsoft Excel (version, 2007; USA), in which the trapezoid rule was used. The blood glucose response value will be excluded if falls below the baseline. The iAUC for each test food was expressed as a percentage of the mean of iAUC for glucose consumed by the same subject. The resulting values for all subjects were averaged to calculate the GI for each test food.

$$\mathrm{GI} = \frac{\text{Area under curve of test food}}{\text{Area under curve of reference food}} \times 100$$

Ethics

The study was reviewed and approved for implementation by the Human Research Ethnics Committee USM (HREC) with study protocol code of USM/JEPeM/19030180.

Data analyses

All data were tested for significance by using one-way repeated measure analysis of variance (ANOVA) followed by Tukey's post hoc test to compare the mean differences among the samples. Data analysis was performed using SPSS, version 24.0. (SPSS Inc, Chicago, Illinois). Three batches of OBS, OBR and chocolate cookies were produced in this study for all measurements. Results were expressed as mean of three replicate ± standard deviation (SD) except for TDF ($n = 2$) and sensory evaluation ($n = 60$). The GI values were expressed in mean ± SEM. Significance level was established at $p < 0.05$.

Results and discussion

Chemical characteristics of OBS

The chemical characteristics of OBS after processing was presented in Table 2. The concentrated OBS obtained was found to have a pH value of 4.74. Similar trend were found in banana syrup (4.9) (Tadakittisarn *et al.*, 2007) and dates syrup (4.6–5.3) (Al-Mutairi and Al-Jasser, 2012). According to Kumar *et al.* (2009), the reduction in pH value upon dehydration was a concentration effect due to large amount of water was removed from the tissues. Besides, Zulkifli *et al.* (2016) found pH of banana as shown to decrease as banana ripens.

Parameters*	Concentration (%)
Moisture	16.54 ± 0.04
pH	4.74 ± 0.03
TSS (°Brix)	81.54 ± 0.09
Ash	3.05 ± 0.02
Sucrose	50.39 ± 0.10
Fructose	16.33 ± 0.08
Glucose	13.65 ± 0.08

Note(s): *The analysis was replicated thrice ($n = 3$) and expressed in mean ± SD

Table 2. Chemical characteristics of OBS

The changes in acidity are most probably caused by the biochemical changes (malic acid, citric acid, oxalic acid and potassium) during ripening of banana fruit (Etienne *et al.*, 2013). From the acidity value of OBS, it can be suggested that OBS is not purely a sugar solution but also contains minerals and organic acids which are also supported by the high ash content (3.05%) of OBS obtained in this study. This result is slightly lower than plum syrup with ash content 3.8% (Abu, 2002). This is mainly because mineral content varies in different types of fruit. The moisture content of OBS was 16.54%, indicating that most of the moisture content in OBS has been removed through dehydration at 60 °C. Benhura *et al.* (2016) recommemded drying temperature between 40 °C and 80 °C for syrup to obtain the highest concentration of reducing sugars. The high TSS of OBS (81.54°Brix) obtained was attributed by high amount of sugar and low moisture content. The major carbohydrates found in OBS were sucrose (50.39%) followed by fructose (16.33%) and glucose (13.65%) which is in contrast with study by Tadakittisarn *et al.* (2007) where content of sucrose (35.99%) followed by glucose (16.94%) and fructose (14.75%) were observed in banana syrup. The differences were probably due to the different ripening stages and types of banana used and also growing conditions of the plant. According to Yap *et al.* (2017), the total sugar content increased drastically from unripe to overripe banana. Furthermore, fructose content was reported to be the lowest in unripe banana but appeared to be the dominant sugar in overripe banana. This is consistent with the higher sucrose and fructose content in OBS. The high sugar content (above 68% sugar level) can prevent the growth of microorganism (Rawat, 2015). Based on the lower moisture content and shelf stable potentials, OBS could be used as a nutritive sweetener in bakery products.

Nutritional compositions of chocolate cookie

The nutritional analyses indicated that the OBR, by-product of OBS contained low level of moisture (4.19%) and fat (0.17%) but high amount of ash (2.76%), protein (5.21%) and carbohydrate (87.74%). Surprisingly, high quantity of TDF (33.61%) was also found in OBR that may be due to increase of water-soluble fibre (pectin) when banana ripen. Hence, firmness of banana pulp decreases as ripening progress (Duan *et al.*, 2008). The nutritional values of chocolate cookies formulated with OBS and OBR at different levels are shown in Table 3. In general, incorporation of OBS and OBR in chocolate cookie resulted in significantly differences in all nutritional compositions except fat content. There were no significant differences ($p > 0.01$) in fat content in OBS and OBR formulated chocolate cookies as compared to control chocolate cookie.

Incorporation of 8% OBR showed a significant ($p < 0.05$) increment in TDF content and ash content as compared to control chocolate cookie, raising from 3.18 to 7.77% and 0.72–1.47%. Similar trend was observed in bakery product formulated with different fruits

Table 3. Nutritional composition of chocolate cookie incorporated with OBS and OBR

Nutritional compositions	Concentration (%) *Control (0% OBR and OBS)	0% OBS + 8% OBR	10% OBS + 8% OBR	15% OBS + 8% OBR	20% OBS + 8% OBR
Moisture	2.58 ± 0.07^{b}	2.44 ± 0.04^{c}	2.55 ± 0.01^{b}	2.63 ± 0.02^{b}	2.75 ± 0.02^{a}
Ash	0.72 ± 0.02^{e}	1.12 ± 0.02^{d}	1.30 ± 0.01^{c}	1.39 ± 0.02^{b}	1.47 ± 0.02^{a}
Protein	7.41 ± 0.04^{a}	7.20 ± 0.02^{b}	7.21 ± 0.03^{b}	7.25 ± 0.04^{b}	7.24 ± 0.03^{b}
Fat	21.15 ± 0.03^{a}	21.28 ± 0.07^{a}	21.28 ± 0.01^{a}	21.24 ± 0.04^{a}	21.27 ± 0.07^{a}
Carbohydrate	68.14 ± 0.11^{a}	67.95 ± 0.06^{a}	67.64 ± 0.03^{b}	67.47 ± 0.07^{c}	67.19 ± 0.08^{d}
TDF	3.18 ± 0.53^{b}	7.77 ± 0.13^{a}	7.74 ± 0.18^{a}	7.74 ± 0.32^{a}	7.80 ± 0.15^{a}
Sucrose	25.12 ± 0.10^{a}	24.95 ± 0.04^{a}	21.65 ± 0.06^{c}	19.42 ± 0.11^{d}	17.67 ± 0.06^{e}

Note(s): Mean ± SD values bearing different subscript letter within the same row indicate significant differences ($p < 0.05$)

(orange, passion fruit and watermelon) and vegetables residue (Ferreira *et al.*, 2015) and pineapple residue powder (Singh, 2016). There is a solid health claim that increase of DF intake is associated with better diet quality, decreases incidence of chronic diseases and improves overall body function (Walia *et al.*, 2009). A study was done by Brauchla *et al.* (2013) revealing that addition of high fibre snack significantly improves diet quality in children. In addition, the children accepted the snacks easily; hence high fibre snack could be an alternative source of fibre. With that, OBR could be used as a potential source of DF in food product especially for those who do not favour taking fruits and vegetables in their daily diet. In contrast, both protein and moisture content of 8% OBR-chocolate cookies decrease significantly ($p < 0.05$), from 7.41 to 7.20% and 2.58 to 2.44%, respectively. The results were in line with Ng *et al.* (2017) who replaced wheat flour with oyster mushroom powder in cinnamon biscuit. Reduction in protein content is due to the lower protein content in OBR as compared to wheat flour. Cookies are dry product with very low moisture content as thermal processing reduces the final moisture content in the product. Moreover, the high fibre content in OBR might absorb large amount of water which results in further decline of moisture content during baking. A reduction in water activity with high levels of fibre content could lead to a microbial-free and shelf-stable cookie.

While OBR was being utilised as fibre-enriched ingredient in the chocolate cookie, OBS was partially substituted with table sugar at 10, 15 and 20% with the purpose of reducing the sucrose content and improving the nutritional quality in the chocolate cookie. There were no significantly difference ($p > 0.05$) observed in protein and TDF content when levels of OBS increases as compared to 0% OBS chocolate cookie. There was significantly increase ($p > 0.05$) of moisture content in 10 and 15% OBS-chocolate cookie as compared to 0% OBS-chocolate cookie (2.44–2.63%), but no significant difference was observed when compared with control chocolate cookie. Meanwhile, a sharp increment in moisture content was shown when levels of OBS increase up to 20%, significantly ($p < 0.05$) increase to 2.75%. Similar result was reported by Tai *et al.* (2019) to partially replace sugar with concentrated *Nypa fruticans Sap* in carrot cake. The increment in moisture content is influenced by the different solubility rate of sugar during mixing. The crystalline form of sucrose having fewer interactions with water leads to more water easily evaporated to make drier cookie during baking. Meanwhile, high moisture absorption of glucose and fructose in OBS has more interactions with water by hydrogen bonding and prevents it from evaporation during baking, thus producing chocolate cookie with higher moisture content. Due to high amount of ash content in OBS (3.05%), increasing levels of OBS from 10% to 20% in chocolate cookie significantly increase ($p < 0.05$) the ash content, varying from 1.12% to 1.47% when compared with 0% OBS-chocolate cookie. Majzoobi *et al.* (2018) reported a similar result in biscuit formulated by replacing sucrose with date syrup. In contrast, there is a significantly reduction ($p < 0.05$) in carbohydrate (67.95–67.19%) and sucrose content (25.12–17.67%) with increasing percentage of OBS incorporated in chocolate cookie compared to 0% OBS chocolate cookie. The finding is in agreement with Mehrabi *et al.* (2017) on grape syrup as sucrose replacer in sponge cake. The trend is attributed to proportion of sucrose, fructose and glucose in OBS. According to Amarra *et al.* (2016), Malaysia is one of the countries with the highest consumption of sugar, approximately 96–118 g/day which is way above the recommended intake (roughly 50 g/day). One of the major sources of contributing sugar comes from commercial biscuit in Malaysia (Norhayati *et al.*, 2015). Hence, it is important to reduce sugar content in bakery product to improve carbohydrate metabolism in the body.

Sensory acceptability

Table 4 shows the sensory acceptability of chocolate cookies incorporated with OBS and OBR. The result showed that the scores for all the attributes in all formulations ranged from 4.52 to 5.42. Apparently, the scores for all the attributes increased with increasing levels of OBS added into the chocolate cookie. Among all the formulations, 15% OBS-chocolate cookie recorded the highest score for all attributes but no significant difference ($p > 0.05$) in comparison with other formulations (control, 0 and 10% OBS). However, incorporation of OBS up to 20% showed a decline in scores for all attributes, with significantly decrease ($p < 0.05$) in flavour (4.52) and overall acceptance (4.62). The addition of higher amounts of OBS led to lower scores in sensory attributes is possibly due to the high flavour of banana. This may be because of consumers' previous expectations and perception of chocolate cookie as well as individual's preferences on banana flavour intensity. A research by Piqueras-Fiszman and Spence (2015) suggested that taste and flavour are mostly determined by the expectations generated prior to tasting. Hence, enhancing banana flavour in the chocolate cookie may have influenced negatively on consumers rating. The data obtained suggested that consumers generally prefer chocolate cookie with 8% OBR +15% OBS as it has a more balanced flavour.

In vivo GI determination

In order to provide a comprehensive evaluation of the effect of OBS and OBR incorporation in chocolate cookie, the blood glucose response after consuming the OBS and OBR formulated chocolate cookie was investigated and presented in Figure 1. At 15 and 30 mins, the blood glucose level for three test foods (ranged from 5.87 to 6.27 mmol/L) and (6.73–7.50 mmol/L), respectively were significantly lower ($p < 0.05$) compared to reference food (6.99 and 8.63 mmol/L). The peak time of all test foods was at 45 mins. The highest blood glucose response at 45 mins recorded was reference food (8.84 mmol/L), followed by control chocolate cookie (7.83 mmol/L), 0% OBS chocolate cookie (7.59 mmol/L) and lastly 15% OBS chocolate cookie (7.06 mmol/L). The blood glucose responses for all test foods at 45 mins were significant decrease ($p < 0.05$) in comparison with reference food. Moreover, the blood glucose response of 15% OBS chocolate cookie showed a significantly lower ($p < 0.05$) as compared to other test foods.

The iAUC for each subjects and GI value of the test food were calculated and shown in Table 5. Glucose has the highest iAUC (199.60 ± 12.75), followed by control chocolate cookie (125.32 ± 7.27), 0% OBS chocolate cookie (104.63 ± 8.43) and 15% OBS chocolate cookie (101.16 ± 6.41). All the test foods had significant difference ($p < 0.05$) in mean of iAUC when compared with reference, but no significant differences ($p > 0.05$) were detected among all the test foods.

GI is the ranking (on a scale of 0–100) given to different carbohydrate-rich foods, depending on how the food affect the blood glucose response (Jenkins *et al.*, 2008). The ranking for food with moderate GI is between 56 and 69, while low GI food is 55 or less (Schuchardt *et al.*, 2016). The GI for the control chocolate cookie (63 ± 5) and 0% OBS chocolate cookie (56 ± 3) were classified as moderate-GI food, whereas 15% OBS chocolate cookie recorded GI (50 ± 3) fall in category of low-GI food. There were significant differences ($p < 0.05$) in GI among all the test foods.

Table 4.
Sensory acceptability of chocolate cookies incorporated with OBS and OBR

Properties	*Control (0% OBR and OBS)	0% OBS + 8% OBR	10% OBS + 8% OBR	15% OBS + 8% OBR	20% OBS + 8% OBR
Colour	5.02 ± 1.02^a	5.22 ± 1.16^a	5.15 ± 1.17^a	5.23 ± 1.20^a	4.88 ± 1.26^a
Appearance	4.73 ± 1.23^a	4.87 ± 1.30^a	4.92 ± 1.31^a	4.92 ± 1.15^a	4.62 ± 1.16^a
Aroma	4.75 ± 1.26^a	4.70 ± 1.24^a	4.77 ± 1.31^a	4.83 ± 1.40^a	4.55 ± 1.31^a
Crispiness	5.38 ± 1.26^a	5.33 ± 1.21^a	5.32 ± 1.12^a	5.42 ± 1.15^a	5.03 ± 1.30^a
Flavour	4.95 ± 1.06^a	4.97 ± 1.47^a	4.92 ± 1.36^a	5.07 ± 1.08^a	4.52 ± 1.32^b
Overall Acceptance	4.98 ± 1.28^a	5.07 ± 1.26^a	5.10 ± 1.23^a	5.12 ± 1.12^a	4.62 ± 1.13^b

Note(s): Mean ± SD values bearing different subscript letter within the same row indicate significant differences ($p < 0.05$)

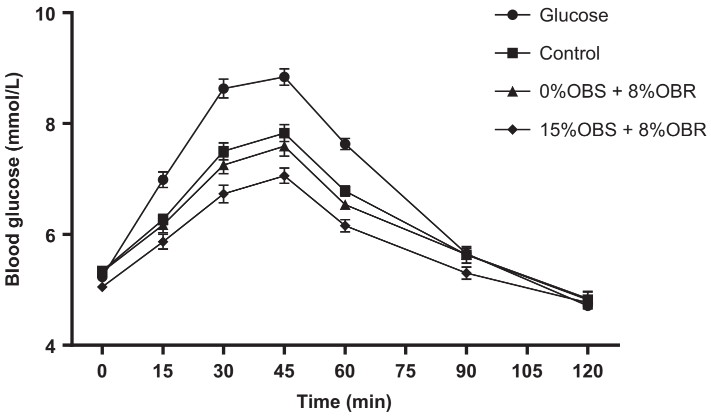

Figure 1. Mean blood glucose responses of glucose and three formulations of chocolate cookie formulated with OBS and OBR

Table 5. Mean of iAUC and GI values of glucose and three formulations of chocolate cookie formulated with OBS and OBR

Test food	iAUC (mmol x min/l)	GI value
Glucose	199.60 ± 12.75[a]	100[a]
Control (0% OBS and OBR)	125.32 ± 7.27[b]	63 ± 5[b]
0% OBS + 8% OBR chocolate cookie	104.63 ± 8.43[b]	56 ± 3[c]
15% OBS + 8% OBR chocolate cookie	101.16 ± 6.41[b]	50 ± 3[d]

Note(s): Mean ± SEM values bearing different subscript letter within the same row column significant differences ($p < 0.05$)

DF plays an important role in developing a low-GI food. DF is made up of highly complex subtances that do not degrade in the gut which also can be defined as nondigestible carbohydrate. Different types of DF are distinguished by their water solubility which has different effects in lowering glycaemic response (Weickert and Pfeiffer, 2018). The lower GI of 0% OBS chocolate cookie is due to the substitution of 8% OBR in the formulation which consists mainly soluble fibre pectin. Soluble fibre is well known for its gel-forming properties leading to the increase in viscosity of food which slow down digestion and prolong the feeling of fullness; hence sharp increase of blood glucose can be prevented (Abutair *et al.*, 2016). In addition, the soluble fibre in OBR can inhibit starch gelatinization in chocolate cookie by acting as a barrier to protect starch granule against water penetration leading to the formation of smaller starch granules. As a result, enzymatic hydrolysis of the starch is limited causing slower conversion rate of starch to glucose (Weickert and Pfeiffer, 2018). Therefore, delay in entry of glucose into the bloodstream and lower the postprandial glucose level. Similar trends were reported by Abutair *et al.* (2016) who showed improvement in glycaemic response among type 2 patients using soluble fibres from psyllium.

The nature of sugar components is another factor influencing glycaemic glucose response. Incroporation of 15% OBS was shown to further lower the GI of the chocolate cookie as compared to 0% OBS chocolate cookie which indicated substitution of table sugar with OBS can reduce the postprandial glucose level. This is possibly due to higher fructose content and lower sucrose content in OBS as compared to table sugar which is 100% sucrose without any additional nutrients (Insel *et al.*, 2018). According to Bantle (2009), fructose is one of the sweetest naturally occurring sugar with lower GI (19) in comparison with sucrose (68) and glucose (100). There were few studies that demonstrated the effect of fructose in lowering blood glucose in diabetes rats (Kwon *et al.*, 2008), healthy subjects (Heacock *et al.*, 2002) and type 2 diabetes subjects (Vaisman *et al.*, 2006). One of the reason is the different metabolism of fructose and glucose. Fructose is primarily delivered and metabolized in the liver, whereas glucose is readily absorbed in the bloodstream (Sun and Empie, 2012). Second, the hepatic glucose uptake is stimulated by fructose. Conversion of fructose to fructose-1-phosphate in liver stimulates glucokinase in hepatocytes, which is responsible for the uptake and storage of glucose as glycogen. The activation of glucokinase causes the uptake of unmetabolized glucose in the bloodstream into the liver (Erejuwa *et al.*, 2012). A study by Shiota *et al.* (2002) revealed small amount of fructose with glucose load increased hepatic glucose uptake and reduced postprandial hyperglycemia.

Low GI foods have been closely associated with control of body weight, improving glucose tolerance and reducing risk of type 2 diabetes. Thus, development of low GI chocolate cookie by using OBS and OBR could be useful in providing health benefits to consumers.

Conclusion

Incorporation of OBS and OBR positively influenced nutritional aspects of the chocolate cookie, especially TDF content and GI value. In summary, this study demonstrated that overripe banana can be an alternative novel DF-rich and low-GI food ingredient, which could widely be utilised in developing various overripe banana–based functional foods. Thus, further highlight to the possibility to produce bakery products utilizing agro-industrial co-products to prevent unnecessary food waste. For further studies, especially clinical trials for diabetes patients are needed to be considered to confirm the health benefits of overripe banana–enriched food products.

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