Available online: http://journal.ipb.ac.id/index.php/jgizipangan J. Gizi Pangan, March 2024, 19(1):21-30
Accredited based on DGHE, Republic of Indonesia No. 28/E/KPT/2019 DOI: https://doi.org/10.25182/jgp.2024.19.1.21-30
ISSN 1978-1059 EISSN 2407-0920

Physicochemical Properties, Glycaemic Index and Glycaemic Load of Chocolate Energy Bars Prepared with High Polyphenols Cocoa Powder and Guar Gum

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ABSTRACT

This study aimed to determine the physicochemical properties, Glycaemic Index (GI) and Glycaemic Load (GL) of chocolate energy bars prepared with different percentages of guar gum (0.5%, 1.0%, 1.5%) and high polyphenols cocoa powder. Proximate analysis was determined following the official methods Association of Official Analytical (AOAC). Ten eligible respondents who met the inclusion and exclusion criteria participated in the GI and GL determination. Test and reference food were given to the participants after overnight fasting. Blood capillary finger pricks were drawn for 7 interval time at 0 until 120 min. The blood glucose responses were calculated based on Incremental Area Under Curve (IAUC). The result revealed that the fat and calorie content were significantly lower in formulations with highest guar gum percentage ($p<0.05$). On the other hands the moisture, ash, carbohydrate contents, crude fibre, energy value, hardness, fracturability, pH value, and colour were all comparable to the control sample. The control and chocolate energy bars with 0.5% guar gum were in the category of high GI and GL. Whereas, the chocolate energy bars with 1.0% and 1.5% guar gum were in the medium category for both GI and GL. This study demonstrated that incorporating different percentages of guar gum in the high polyphenols chocolate energy bar changed some of the proximate compositions but not the physical properties. Furthermore, addition of guar gum affected the GI and GL as the values were reduced with the increased amount of guar gum.

Keywords: dark chocolate, guar gum, physicochemical properties, glycaemic index, glycaemic load

INTRODUCTION

Chocolate is a popular and enjoyable food item consumed by millions of people due to its distinct, rich, and sweet flavour. Malaysians consumed more chocolate than other region residents. The report stated that the average Malaysian consumed 0.5 kg of chocolate annually, whereas South-East Asian neighbours, such as the Philippines and Indonesia, consumed lesser with 0.3 kg, respectively (Durai 2022). The three most common commercial chocolate frequently seen in grocery shops are white, dark and milk chocolate. In comparison to milk and white chocolate, dark chocolate has the most considerable cocoa content. Most dark chocolate contains more cocoa and less sugar. Nutritionally, dark chocolate products have gained a positive reputation for their health benefits. Dark chocolate contains several health promoting elements such as bioactive components like polyphenols, flavonoids, procyanidins, theobromines, as well as vitamins and minerals that positively modulate the human immune system (Samanta *et al.* 2022). The high antioxidant contents in dark chocolate contributes to a prominent regulatory role such as lowering blood pressure, bolstering the blood flow and maintaining the immune system (Latif 2013).

High cocoa content in chocolate showed a strong correlation with content of dietary fibre and iron (Chen 2018). Hence, in addition to antioxidant, chocolate is rich in iron and dietary fibre. Iron is a vital nutrient that ensures proper growth development and functioning of the body and promotes the production of proteins that transport oxygen and regulate cell development. While, dietary fibre is known to have variety of health benefits, including treating colon disease, reducing the risk of heart disease, diabetes mellitus and colon cancer, improving blood sugar balance and digestive function.

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(Received 06-11-2023; Revised 12-01-2024; Accepted 01-02-2024; Published 30-03-2024)

(Barber *et al.* 2020). Dietary fibre from cocoa is derived from the cocoa bean seed coat or bran. (Sarriá *et al.* 2012). Soluble fibre also may help decrease cholesterol and assist control of blood sugar levels and the insoluble fibre is non-water soluble and bulks up the stool, hence reducing constipation (Newman 2020). In Europe, there is a special trend associated with consuming dark chocolate products with a high cocoa content, typically without the addition of milk (Alberts & Cidell 2006).

Food energy bars comprised mainly from cereals and other high-energy ingredients which are known as convenient snacks. The variable component in food energy bars are commonly carbohydrate, followed by protein, fat, and fibre (Gill & Singh 2020). Energy bars are now an acceptable option as a high-quality source of energy due to changes in dietary and lifestyle choices, increasing knowledge of nutrient-dense, healthy eating practices, and physical activity levels (Yadav & Bhatnagar 2015). Energy bars were initially advertised to athletes as a source of energy, but as the demand from luxury consumers increased and the number of customers who care about their health also increased, snack bar sales soared (Ho *et al.* 2016).

The energy bars may be a viable substitute for dietary supplements as it is further enriched with minerals, vitamins, phytochemicals, and other bioactive compounds. A higher Dietary Phytochemicals Index (DPI) is associated with decreased pre-diabetes (Davoudi-Kiakalayeh *et al.* 2017). Diets with a low Glycaemic Index (GI) are hypothesised to result in more stable blood sugar levels and weight loss by lowering postprandial glycemia (Ni *et al.* 2022). Low (GI) diets may also enhance endurance performance (Kaviani *et al.* 2019).

Polysaccharides could be used in place of cocoa butter to create low-fat chocolates (Amir *et al.* 2013). Pectin, xanthan gum, and guar gum were considered helpful in achieving the desired textural and organoleptic properties (Barman *et al.* 2021). Guar Gum contain high nutritious fiber content and excellent viscosity, that often used as an additive in food emulsifiers, as a thickener, and to solidify processed foods including breakfast cereal, dairy products, and baked goods (Aguilar *et al.* 2017). While it does not affect high-density lipoprotein or triglyceride levels, guar gum may lower total cholesterol and low-density lipoprotein levels. Therefore it may aid in maintaining healthy lipids and preventing Cardiovascular Disease (CVD) (Wang *et al.* 2021).

Hence, in this study aimed to develop chocolate bars prepared with different percentages of guar gum and high polyphenols cocoa powder to achieve better GI and GL index. In addition, the study also determined the proximate content, physical properties of chocolate energy bars prepared with different percentages of guar gum and high polyphenols cocoa powder to discover its potential as a functional food product.

METHODS

Design, location, and time

This descriptive study was conducted from 16th September 2022 until 10th February 2023. The chocolate energy bars were developed in the Food Preparation and Therapeutic Diet Lab and other analysis were carried in the respective lab of Universiti Sultan Zainal Abidin (UniSZA) campuses. This study was approved by the Universiti Sultan Zainal Abidin Human Research Ethics Committee (UniSZA/UHREC/2022/408).

Materials and tools

All raw materials and ingredients were purchased from the supplier (Callebaut Chocolate Finest Belgian Dark Chocolate) and other ingredients were purchased from the grocery market in Kuala Nerus, Terengganu, Malaysia. Glucometer Accu-Chek® Safe-T-Pro Uno (New South Wales, Australia) and glucose strips were used in collecting data for GI.

The chocolate energy bars were developed based on the formulation by Chandegara *et al.* (2018) with slight modification. It contains raw materials such nuts (almonds, cashew nut), dates (Phoenix dactylifera), raisin, rice crispies, oats (Avena sativa), honey (multiflora), seeds (sunflower and watermelon), cocoa powder. Three different percentages of guar gum at 0.5%, 1.0% and 1.5% were used to formulate the chocolate energy bars. All the ingredients were weighed according to the formulations (control) and were interchanged for other formulations of 0.5%, 1.0%, and 1.5% of guar gum respectively. Prior to the analysis, the energy bar was stored in the chiller with temperature of 4°C.

Procedures

Proximate analyses. The moisture, ash, crude protein, fat, and fibre content of the chocolate energy bars were determined based on standard procedures of AOAC International method. All analyses were conducted in triplicates.

Total carbohydrate and energy estimation. The total carbohydrate content was calculated by difference [Total Carbohydrate (% wet basis)=100% - % (moisture content + ash + crude protein + crude fat + crude fibre]. The energy content of the sample was estimated by multiplying by the factor values; [1 g of crude protein or carbohydrates provides 4 kcal and 1 g of crude fat provides 9 kcal of energy] (Said *et al.* 2019).

pH value measurement. The acidity and alkalinity were assessed using a pH meter (Mettler Toledo, Ohio, USA) from 5 g samples finely mixed and homogenized with 20 mL of distilled water.

Texture profile analysis (Hardness and fracturability). The hardness and fracturability of the energy bar according to mechanical characteristics was analyzed using a TA.XT.Plus texture analyzer (Stable Microsystems, UK). The 3-point bend rig probe was positioned centrally beneath the sample, and it was moved until the probe made contact with the sample before the deformation curves were captured (Mamat *et al.* 2018).

Colour profile analysis. The colour profile analysis was conducted using the Konica Minolta colorimeter (Konica Minolta, Tokyo, Japan) based on the L^* (lightness), a^* (redness), and b^* (yellowness) colour system. Colorimeter was calibrated prior to use with a white calibration plate. The instrument was positioned on top of the energy bar formulation, and each energy bar's L^* , a^*, and b^* values were recorded and analysed (Zainol *et al.* 2020).

Glycaemic index and glycaemic load determination. The value of GI for each sample was determined by the following protocol from the International Organisation of Standardisation ISO 26642:2010 (International Organisation for Standardisation 2010 Food products: Determination of the Glycaemic Index (GI) and recommendation for food classification). Ten eligible subjects with consent form that fulfilled the inclusion criteria, were selected to participate in this study. The screening procedures were followed to the standard guidelines for GI testing. All subjects underwent an Oral Glucose Tolerance Test (OGTT) before the GI test to certify their both inclusion and exclusion criteria.

The age of subjects ranged from 19–45 years old with normal Body Mass Index (BMI) and normal glucose tolerance. The inclusion criteria include healthy and not under any treatment or medications. Additionally, participants must be three months free from any clinical trial and were not allergic to the ingredients such as nuts, cereals, chocolates, and guar gum. The subjects were given 50 g of reference food and all three chocolate samples (0.5%, 1.0% and 1.5% of guar gum) within 3-days washing period for each food/bar. The blood glucose were taken for 2 h (0 min, 15 min, 30 min, 45 min, 60 min, 90 min and 120 min). The GI of chocolate energy bars was calculated by following the World Health Organization/ Food and Agriculture Organization (WHO/FAO1998) recommendation. GI and GL values were calculated as the following:

$$GI = \frac{\textit{Incremental Area Under Curve (IAUC) of each chocolate energy bar}}{\substack{\textit{Average IAUC of the reference food} \\ \textit{(white bread or glucose)}}} \times 100$$

$$GL = \frac{\textit{GI of carbohydrate x grams of carbohydate per serving food}}{100}$$

Data analysis

All data were analyses using the SPSS software, version 22 (IBM, Corp, Chicago, USA). The results of proximate analysis from the triplicate samples of each chocolate energy bar type were compared using the one-way of variance (ANOVA). The Tukey post hoc test was performed to determine the significance difference at $p<0.05$. Data regarding GI and GL were presented in descriptive statistics.

RESULTS AND DISCUSSION

Proximate composition

As shown in Table 1, the moisture content of chocolate energy bar prepared with different percentages of guar gum varying from 9.43% to 10.53%. Albeit, the highest moisture content was found in the 1.5% guar gum formulation, it was comparable to the control ($p>0.05$). The lowest moisture content was indicated at 9.43% for the 0.5% gur gum formulation. This was likely due to the hydrophilic polymers in guar gum that prevent moisture loss in the food products (Nehra

Table 1. Proximate composition of chocolate energy bars prepared with different % of guar gum

Components (%)	Chocolate energy bars with different % of guar gum			
	0	0.5	1.0	1.5
Ash	2.33±0.03^{a}	2.38±0.01^{b}	2.33±0.01^{a}	2.34±0.01^{a}
Moisture	10.12±0.13^{b}	9.43±0.09^{a}	9.92±0.14^{a}	10.53±0.11^{b}
Fat	15.05±0.20^{b}	14.72±0.38^{ab}	14.20±0.34^{ab}	13.91±0.67^{a}
Fibre	3.50±0.04^{a}	3.76±0.28^{a}	3.81±0.25^{a}	3.98±0.21^{a}
Protein	11.04±0.36^{a}	11.88±0.00^{a}	10.83±0.36^{a}	10.42±0.36^{a}
Carbohydrate	61.86±0.54^{a}	62.31±0.56^{a}	62.40±0.74^{a}	62.77±1.19^{a}
Energy (kcal)	427.05±1.41^{c}	429.24±3.11^{c}	420.72±0.51^{b}	417.92±5.72^{a}

^{abc} means in the same row with different lowercase letters are significantly different (p<0.05)

et al. 2022). Goswami *et al.* (2019) reported that moisture content had increased as the guar gum percentage in the product increased. This might happen due to the carbohydrate-based hydrocolloids properties, including guar gum possess higher water-holding capacity to retain the moisture in the food matrix (Colla *et al.* 2018).

The lowest fat content was found in chocolate energy bars with 1.5% guar gum (13.91 g/100 g) while the highest fat content was in the control (15.68 g/100 g). This because guar gum substitutes the fat content (Bavaro *et al.* 2021). Samakradhamrongthai *et al.* (2022) stated that substitution of guar gum and polydextrose, decreased fat content by 27.86% in comparison to the control formulation. Carbohydrate-based hydrocolloids is a potential fat replacements since they are water-soluble and hydrophilic by nature (Colla *et al.* 2018). The structure of Carbohydrate-based hydrocolloid can provide both full and partial functions of fat while offering lower fat calories (Kumar 2021).

In comparison, there was a decrease in protein content for control chocolate energy bars with 1.0 % and 1.5% guar gum formulation with no significant differences (p>0.05). The 0.5% guar gum formulation had the highest protein (1.88%) while 1.5% guar gum ranked the lowest (10.42%). Contradict to a study conducted by Goswami *et al.* (2019), the protein content increased when the guar gum percentage in the product increased. This can be due to the control chocolate and 0.5% guar gum had the highest amount of oats compared to other samples.

The highest fibre content was found in the 1.5% guar gum formulation (3.98%) and the lowest was found for the control (3.5%), but the difference was not statistically significant. On average, processed guar gum products contain a crude fibre content ranging from 1.61%–2.5% (Farah *et al.* 2016). The study was supported by Goswami *et al.* (2019) indicating that an increment in fibre content was related to an increased percentages of guar gum in the product. However, in our study the control chocolate energy bars had the highest amount of oats as compared to other samples. As reported by Munir *et al.* (2018), the addition of oat also increased the fibre constituents in snack bars. Hence, there result was not statistically significant.

The ash content of the chocolate energy bar was comparable in all formulations (ranging from 2.33%–2.48%), respectively. This is supported by a study by Farah *et al.* (2016) that reported the processed product of guar gum contains small amount of ash. Furthermore, several studies also reported that the ash content increased with the higher added guar gum incorporated in the composite flour and carabeef cookies (Immanuel & Singh 2022). However, according to the National Germplasm Resources Laboratory (USDA 2009), the other possible explanation for the comparable ash content in this study was likely due to the nuts that were used, as almonds have higher ash content (3.13%) and they were considered as the source of minerals including magnesium, calcium, and iron (Fernandes *et al.* 2013).

Carbohydrate content was also comparable with no significant difference (p>0.05) between all dark chocolate formulations. The range of carbohydrate content was from 61.86% to 62.77%, while in the control energy bar was 62.31%. The study conducted by Nazira and Azada (2016) reported that the carbohydrate content was increased when the guar gum percentage in the product increased. However, in this study, the carbohydrate content was not significantly varied because the major carbohydrate sources in this formulation are mainly nuts and honey.

Table 1 indicates that there was a significant difference in the amount of calories between the formulations. The energy value per 100 g ranged from 417.92 kcal to 429.24 kcal. The 0.5% formulation sample contained the highest calorie content (429.24 kcal) and the second was the control (427.05 kcal) with no significant difference. While the formulation of 1.5% guar gum exhibited the lowest calorie value (417.92 kcal). On average, these results were lower than the study by Tiwari *et al.* (2017), as a 100 g energy bar contained 440 kcal–500 kcal. The study by Sharma *et al.* (2021) produced multi-seed energy bars for sports persons with an energy value of 444.66 kcal per 100 g. In this study, the decrease in energy bar caloric value could be due to the lower amounts of cereals, nuts and fat used in the bars (Eke-Ejiofor & Okoye 2018) which were substituted with the guar gum.

The texture of chocolate energy bar (hardness and fracturability)

Table 2 presents the texture of chocolate energy bars incorporated with different percentages of guar gum. The addition of guar gum in a formulation is associated with lower hardness score. As shown in research by Amir *et al.* 2013, who reported that hardness decreased with the increasing level of guar gum. However, the result in this study showed inconsistencies in findings. The addition of 0.5% and 1.0% of guar gum resulted in lower hardness score. But there is an increase in hardness in the 1.5% guar gum formulation, which was higher than the control.

This was likely caused by other unbridled factors, such as the irregular arrangement of ingredients of energy bars, such as cashew nuts, almonds, pumpkin seeds, and sunflower seeds. There were sections of the chocolate energy bar that contained those hard ingredients and vice versa, which caused the cutting blade to cut irregularly. However, an alternative explanation can be associated with the characteristic of guar gum which absorb more water resulted in a harder gluten network and increase the hardness value (Goswami *et al.* 2019). This was consistent with the study of fat substitution (xanthan and guar gum) that increased the hardness of baked and pastry products (Aggarwal *et al.* 2018).

The fracturability of chocolate energy bars with various amounts of guar gum showed variations in fracturability. However, the difference between treatments (control, 0.5%, 1.0%, and 1.5%, respectively) was not statistically significant. The addition of more gums and carbohydrate-hydrocolloid-based ingredients increased the hardness of the cookies while decreasing their fracturability (Hussain *et al.* 2022). The study conducted by Singh *et al.* (2015) was also in accordance with this study, whereby the fracturability was decreased when the guar gum percentage in the product increased. However, the fact that there were sections of the chocolate energy bar that contained inconsistent ingredients might contribute to this variations in results.

Table 2. Physical properties of chocolate energy bars prepared with different % of guar gum

Formulation (%)	Texture value		pH	Colour value		
	Hardness	Fracturability		L^*	a^*	b^*
0	1.17±0.67[a]	1.19±0.31[a]	6.46±0.11[a]	36.25±1.75[a]	6.23±1.02[a]	10.38±1.56[a]
0.5	0.74±0.83[a]	1.00±0.3[a]	6.61±0.02[a]	31.06±5.73[a]	7.55±1.81[a]	9.93±1.38[a]
1.0	0.50±0.63[a]	0.84±0.31[a]	6.64±0.09[a]	33.16±2.70[a]	7.77±0.54[a]	10.89±0.87[a]
1.5	1.60±1.09[a]	1.19±0.62[a]	6.68±0.14[a]	30.74±2.18[a]	8.88±1.53[a]	11.41±1.52[a]

[abc] means in the same column with different lowercase letters are significant different (p<0.05)

pH value

The pH value of chocolate energy bars incorporated with different percentages of guar gum showed an ascending scale ranging from pH 6.46 (control), pH 6.61 (1.0% guar gum), pH 6.64 (1.5% guar gum) and pH 6.68 (2.0% guar gum), respectively. But the difference was not statistically significant. The pH value for all samples were found to near neutral with slight variation in the reading. The study by Nazira and Azada (2016) also showed similar outcomes, whereby the pH value increased when the guar gum percentage in the food products increased.

Colour profile

Colour attributes are one of the main factors that are perceived and impacted people's attitudes when choosing the food products. Chocolate composition, chocolate processing methods and roughness can affect the chocolate colour as the appearance of dark chocolate is regulated by its shape, shininess, surface appearance and smoothness or roughness (Saputro *et al.* 2017). In this study, all the colour values were observed and showed no significant differences amongst the treatments. The lightness (L^* value) for the chocolate energy bar (1.0%) was higher than the others (0.5% and 1.5% guar gum). Besides, there was an increment of the redness (a^* value) and yellowness (b^* value) from the control to the 1.5% guar gum chocolate energy bars. The lightness and yellowness results were in line with a study by Barman *et al.* (2021), whereas the redness was dissimilar. The addition of guar gum in the food products, including pastries affect the final colour because guar gum can react in partial hydrolysis of the mono- and disaccharides (Culetu *et al.* 2021). However, no significant differences were recorded between treatments for all the values (lightness, redness, and yellowness). Similar findings was reported by Goswami *et al.* (2019) that developed carabeef cookies with different percentages of guar gum, and it showed no significant differences in the values of redness, yellowness, chroma, and hue angle values between control and the formulated carabeef cookies. This condition might be caused by adding the guar gum in a very small amount and water is used to maintain the consistency of the formulation. Kamal (2015) developed low-calorie fibre-enriched biscuits supplemented with rice bran and guar gum and observed no significant colour differences.

Glycaemic index and glycaemic load evaluation

The meta-analysis study by Greenwood *et al.* (2013) reported that for every 50 g of carbohydrates consumed, the relative risk of Type 2 diabetes is 0.97. In this study, 50 g of carbohydrates was used as the dose-response curve of the IAUC glucose response has been shown to be in linear within the range of 25 g to 50 g of carbohydrates samples. Figure 1 illustrates the results of GI and GL of different percentages of guar gum incorporated in the chocolate energy bar. The chocolate energy bars with 0.5% guar

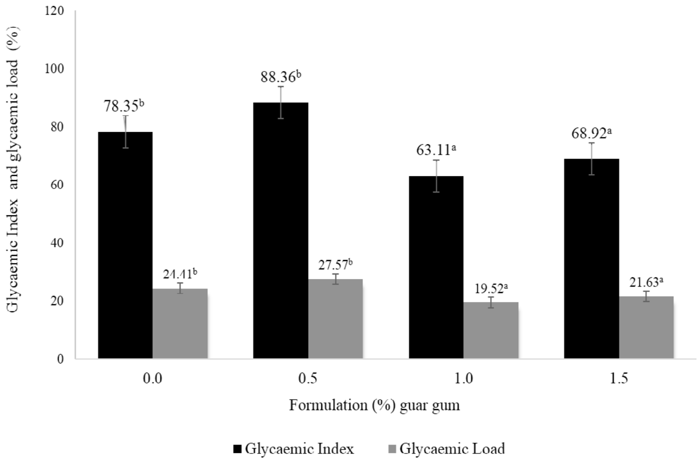

Figure 1. Glycaemic index and glycaemic load of chocolate energy bars prepared with different % of guar gum

gum had the highest GI value (88.35), value as compared to the control (78.35), 1.5% guar gum (68.92) and the lowest GI value was 1.0% guar gum (63.11) ($p<0.05$). Both control and 0.5% were in the high GI category, meanwhile, 1.0% and 1.5% guar gum formulations were in the medium. Theoretically, the GI value is decreased in parallel with the higher addition of guar gum as guar gum can reduce the absorption of sugar and lead to a decreased in blood sugar levels due to its characteristic as soluble fibre.

Functional components with a GI-lowering impact, including soluble dietary fibres and hydrocolloids like guar gum, aids in lowering the rate of carbohydrate hydrolysis and reduce the GI of diets (Santamaria *et al.* 2023). A study with 10% of guar gum in noodles demonstrated a low GI value (46.2) and possessed a high GL (Kumar & Prabhasankar 2016). Previous study on guar gum in the bread formulation has observed hypoglycaemic effect, effectively able to decrease in starch digestibility and reduce post-prandial glycaemic responses (Maehre *et al.* 2021).

Honey, such as added to this energy bar formulation, potentially containing additional sugar ingredients, that results in a higher GI value. Some honey in the market was incorporated with sugar as common ingredients including the sugar solutions from corn syrup and cane sugar syrup (Nik Husain & Ghazali 2021). Despite honey is mostly made up of different simple sugars, it has similar glycaemic response as glucose (Rajab *et al.* 2017).

The GL of food is an estimation of how much food will elevate a person's blood glucose level after consuming it. One gram of glucose consumption will increase the blood glucose to approximately one unit of GL (Kumar & Prabhasankar 2016). This decrease in GL associated with increasing guar gum percentage can be attributed to the reduction in the GI, as it follow a similar pattern. It was postulated that the reason of differences in GI for the formulations is the cocoa biochemical contents, which are a rich source of high-quality antioxidant polyphenols. They mainly comprise anthocyanins (4 % of total polyphenols), catechins (29%–38% of total polyphenols), and proanthocyanidins (58%–65% of total polyphenols) (Aprotosoaie *et al.* 2016). The dietary polyphenols including anthocyanins and catechins found could reduce starch digestion by the inhibition of α-amylase and α- glucosidase resulting in a lower GI of foodstuffs (Uğur *et al.* 2022). Another study by Kawakami *et al.* (2021) showed that consumption of chocolate containing cocoa polyphenols before a 50 g OGTT could improve early insulin and Glucagon-Like Peptide 1 (GLP-1) secretion in healthy participants, hence illustrating the potential of chocolate containing cocoa polyphenols to control postprandial glucose excursions.

CONCLUSION

The result revealed that the fat and calorie content were significantly lower in formulations with highest guar gum percentage ($p<0.05$). On the other hands the moisture, ash, carbohydrate contents, crude fibre, energy value, hardness, fracturability, pH value, and colour were all comparable to the control sample. The control and chocolate energy bars with 0.5% guar gum were in the category of high GI and GL. Whereas, the chocolate energy bars with 1.0% and 1.5% guar gum were in the medium category for both GI and GL. The values were lower than the control and 0.5% guar gum formulations, which had higher GI and GL.

ACKNOWLEDGEMENT

This research was supported by Ministry of Higher Education (MOHE), Malaysia through Fundamental Research Grant Scheme (FRGS/1/2021/SKK05/UNISZA/02/1). The authors also would like to thank the Faculty of Health Sciences and the Center for Research Excellence and Incubation Management (CREIM), UniSZA.

DECLARATION OF CONFLICT OF INTERESTS

The authors have no conflict of interest.

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