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GLYCAEMIC INDEX, PALATABILITY, ACCEPTABILITY AND PERCEIVED SATIETY OF COOKIES PREPARED WITH DURIAN (*Durio Zibethinus* Murr.) AND β-GLUCAN

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ABSTRACT

Durian is rich in macronutrients and bioactive compounds. β-glucan is a soluble fibre and has the ability to increase perceived satiety and reduce glycaemic response. Hence, durian and β-glucan can be used for the development of functional foods. The aim of this study was to determine the effects of cookies prepared with durian and β-glucan on glycaemic index, acceptability, palatability and perceived satiety. Ten healthy participants with normal BMI completed four trials with a 3-day washout period. Foods were given to the subject after an overnight fast. Blood was sampled at fasting (0 min, baseline) and 120 min after food consumption and assayed for glucose concentration. Acceptability, perceived satiety and palatability were assessed using visual analogue scale. There were no significant differences for acceptability and palatability between control and test cookies. Cookies prepared with durian and/or β-glucan significantly ($p < 0.05$) increased perceived satiety except for thirstiness and pleasantness compared with control cookies. Durian and β-glucan cookies showed lower glycaemic index compared with other biscuits with 59.4 (14.63). This study suggests that cookies prepared with durian and β-glucan is acceptable and has the potential to reduce GI compared with control. A combination of durian and β-glucan in cookies shows promising health benefits and could be used for the development of functional foods.

Key words: Glycaemic index, acceptability, palatability, satiety, durian, β-glucan

INTRODUCTION

Glycaemic index (GI) is defined as the incremental area under the blood glucose response curve (AUC) after a portion of food containing 50 g available carbohydrate over reference foods (white bread or glucose) taken by the same subject (Wolever *et al*., 1991). Food is categorised as high GI when the value is more or equal to 70 (Vega-López, Venn & Slavin 2018). Value between 56 to 69 is considered as intermediate GI and low GI when the value is less or equal to 55 (Augustin *et al*., 2015). The medium and low GI foods are better option than high GI because it blunted postprandial glucose response (ADA, 2014). Increasing soluble dietary fibre content is one of the options to lower glycaemic response of starch-based food such as breads and cookies (Tosh, 2013). Our previous study showed the addition of 5 g of β-glucan prepared in white bread reduced short-term (30 min) starch hydrolysis compared with control wheat bread (Jalil *et al*., 2015).

β-glucan is naturally occurring non-starch polysaccharides from barley and oats (Barsanti *et al.,* 2011; Zeković *et al.,* 2005). Previous studies have shown that β-glucan be able to reduce glycaemic responses after meals (Kwong *et al.,* 2013). EFSA has approved 4 g of β-glucan per 30 g of available carbohydrate to beneficially reduce postprandial blood glucose (EFSA, 2011). A randomized crossover study showed that snack bars containing 1.5, 3, and 6 g of a β-glucan from oat and barley lowered postprandial blood glucose AUC (0–120 min), with an average of 25% ($p < 0.05$) compared with white bread controls (Panahi *et al*., 2014). A recent research showed that β-glucan can regulate appetite and reduced energy intake when prepared with white rice (Aoe *et al*., 2014). The evidence has shown that β-glucan has a potential to reduced blood glucose and increased perceived satiety when prepared with foods. However, it is not known whether a combination with other component

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such as durian will synergistically reduce blood glucose response and increase perceived satiety.

Durian (*Durio zibethinus* Murr.) is a native fruit in South East Asian countries such as Malaysia, Indonesia and Thailand (Bai-Ngew *et al*., 2014). Fully ripe fruit are usually has a pale to bright yellow. It has a sweet taste and strong smell resembling a rotten onion. Durian is also rich in macronutrients (fat and protein), minerals, flavonoids and vitamins such as vitamin C, B complex and β-carotene (Ariffin *et al*., 2015). Durian showed low GI (GI = 49) compared with other tropical fruits such as papaya, pineapple and watermelon (Robert *et al*., 2008). Durian is rich in macronutrients and bioactive compounds and hence can be used in combination with other food component such as β-glucan for the development of functional foods. Hence, this study was aimed to determine the combined effects of durian and β-glucan in cookies on postprandial glycaemic response, glycaemic index, acceptability and perceived satiety.

MATERIALS AND METHODS

Study design and recruitments

This study is a non-randomised controlled trial based on Latin Square design. This study was approved by the Universiti Sultan Zainal Abidin Ethics Committee with the referral code of (UniSZA/UHREC/2018/63). Participants were selected based on the inclusion and exclusion criteria according to the standard glycaemic index study protocol (Wolever *et al.*, 1991). The exclusion criteria were diabetic individual or with clinical signs or symptoms of chronic disease and taking any medications known to affect glucose or lipid metabolism. Ten healthy adult aged between 18–60 years with BMI between 18.5 and 24.9 kg/m^2 and non-smoker were conveniently recruited from Faculty of Health Sciences, Universiti Sultan Zainal Abidin. The sample size were based on the standard GI protocol and the number of participant needed is ten, which have to be studied on multiple occasions (Wolever *et al*., 1991). Ten participants completed four trials in a random order as follow: i) β-Glucan cookies ii) Durian cookies iii) β-glucan + durian cookies iv) control cookies. Participants were blinded in which they do not know which product they were getting in each intervention trial. Durian flavour was added in control cookies and in β-glucan + cookies to mimics the real durian taste and smell.

Anthropometric measurements

Bodyweight and height were measured using SECA Clara 803 (SECA, Hamburg, Germany) and stadiometer SECA Model 217 (SECA, Hamburg, Germany), respectively. Weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively. Body mass index was calculated by dividing body weight (kg) with height (m) × height (m).

Cookies preparation

Table 1 shows the formulation of four types of cookies and their nutrition facts. The nutrition value was calculated in Nutritionist Pro software. The β-glucan was added based on the 4 g per 30 g of available carbohydrate based on the EFSA recommendation. Based on Table 2, the 50 g of available carbohydrate represents isoenergy in every type of cookies. The cookies were prepared by adding the dry ingredients first (wheat flour, sugar, salt, β-glucan cookies for β-glucan cookies), then were continued by adding other remaining ingredients. The cookie dough then shaped into cookies shape and baked at 130°C for 10-15 min in an oven.

Blood sampling

Participants were instructed to eat their dinner no later than 10:00 pm and fast for 10 hr before the laboratory visit. Plain water was allowed during this

Table 1. Ingredients for cookies preparation

Ingredients (g)	Control	Durian	β-Glucan	Durian and β-Glucan
Durian flesh	–	150	–	150
β-Glucan	–	–	62.93	69.67
Wheat flour	375	375	375	375
Butter	50	50	50	50
Sugar	125	125	125	125
Egg	100	100	100	100
Vanilla extract	5	5	5	5
Salt	0.36	0.36	0.36	0.36
Durian flavour	10	–	10	–
Total weight (g)	664.55	804.55	727.49	874.22

Table 2. Nutritional value for one serving of cookie containing 50 g of available carbohydrate

Type of cookies	Control	Durian	β-Glucan	Durian and β-Glucan
Serving portion (g)	5.50	6.00	5.50	6.00
Energy (kcal)	295.6	293.44	308.92	306.75
Carbohydrate (g)	50.00	50.00	50.00	50.00
Protein (g)	7.97	7.67	7.97	7.67
Fat (g)	7.08	6.99	7.08	6.99
β-Glucan	–	–	6.69	6.68

fasting period. Participants attended the lab at 8:00 am and advised to rest for 10 min upon arriving in the laboratory. The blood sample was obtained by finger-prick. Fasting blood samples (t = 0 min, baseline) was immediately obtained. Breakfast test meal was given and participants were advised to consume the food at their own pace within 10 to 12 min. This time was based on the pilot study conducted in healthy subject. Postprandial blood were obtained at 15, 30, 60, and 120 min after breakfast. Capillary blood was obtained using finger-prick sampling according to standard operating procedure (Coopey, 2018). Blood glucose was assayed using glucometer (Accu Chek Performa, New South Wales, Australia). Glucometer is a rapid and reliable method to measure blood glucose concentration (Rebel *et al.,* 2012). Calibration was done using a standard glucose strip provided by the manufacturer. Glycaemic index was calculated according to Wolever *et al*. (2008) as follow:

$$\frac{iAUC\ test\ cookies}{iAUC\ control\ cookies} \times 71$$

The GI value was multiplied by 71 instead of 100 to standardize the glucose scale (Wolever *et al*., 2008).

Palatability and acceptability test

Palatability and sensory test were conducted according to the method described by Lawless and Heymann (1999). Test foods were presented to the participants. Participants were advised to consume the food at their own pace between 10-12 min. This time range was based on pilot study conducted in healthy volunteers. There were seven attributes of palatability and acceptability as follow: colour, texture, aroma, taste, flavour, appearance and overall acceptance. A likert-like scale was used as follow: (10-like extremely, 9-like very much, 8-moderately like, 7-slightly like, 6-dislike, 5- like, 4-dislike slightly, 3-dislike moderately, 2-dislike very much and 1-dislike extremely). A cup of plain water was given to the participants to rinse their mouth before the trial (Ariffin *et al*., 2015).

Perceived satiety

Perceived satiety ratings were determined using a 10-cm visual analogue scale (VAS) during the same session as palatability and acceptability scoring. Perceived satiety was measured at fasting (0 min, baseline) and 30, 60, 90 and 120 min after food intake. Perceived satiety ratings consist of hunger (How full are you?), fullness (How hungry are you?), satiety (How satiated are you?), desire to eat (How strong is your desire to eat?) and prospective food consumption (How much would you be able to eat right now?), thirstiness (How thirsty are you?), pleasantness (How pleasant is the product to you?) (Blundell *et al*., 2010). The VAS scores were collected and evaluated. Eating time was measured by giving the participants timers and asking them to mark down the time spent on eating (Pentikainen *et al*., 2014).

Statistical analysis

All data were analysed using IBM SPSS (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY). Data was presented as the mean (standard deviation). The *p*-value less than 0.05 was considered as significant. Normality test was performed on continuous data before statistical analysis. One-way ANOVA was used to determine mean differences of GI, acceptability, palatability and perceived satiety. Repeated measures ANOVA were used to determine mean differences between time points.

RESULTS

Baseline characteristics

Table 3 shows the baseline characteristics of the participants. Ten participants completed four trials with 3-day washout period. No side effects were reported during the trials. The mean age of the participants were 21.9 (0.74) with a range between 21 to 23 years old. Body mass index was 21.92 (1.36) with a range of 20 and 24.1 kg/m^2. In UniSZA the ratio of female is more than male, so the participants selected were all female.

Table 3. Subjects' characteristics (n = 10 females)

Variable	Mean (SD)
Age, years	21.9 (0.74)
Weight, kg	54.23 (6.09)
BMI, kg/m^2	21.92 (1.36)
Ethnicity (n)	Malay (8)
	Indian (2)

Blood glucose response and glycaemic index (GI)

Figure 1 shows blood glucose response from 0 to 120 min for different cookies. There were significant differences at 15 min ($F_{(3,36)} = 4.706$, $p = 0.007$) based on one-way ANOVA. Repeated measures ANOVA with Greenhouse-Geisser correction showed significant time interactions with $F_{(2.698, 105.208)} = 91.625$ ($p < 0.05$) for all the cookies except 15 min vs 120 min and 30 min vs 60 min. Incremental area under the curve (iAUC) of the control cookies was significantly higher ($p < 0.05$) compared with durian, β-glucan and durian plus β-glucan cookies. Figure 2 shows the glycaemic of different cookies. The GI of durian, β-glucan and durian plus β-glucan cookies were 63.8, 71.8 and 59.4 respectively. One-way ANOVA showed there were no significant ($p > 0.05$) differences between groups. Durian and durian plus β-glucan cookies were categorized as medium GI while β-glucan as high GI.

Acceptability and palatability

Figure 3 shows the mean acceptability and palatability score for the control, durian, β-glucan and durian with β-glucan cookies. The mean colour score for all cookies was in the range from 7.30 (1.25) to 7.90 (0.57) and the whole texture mean score was from 5.90 (1.85) to 6.30 (2.63). The mean aroma and taste score for all cookies was in the range 7.2 (1.14) to 8.2 (1.03) and in the range 6.90 (1.66) to 7.70 (1.34) respectively. The mean flavour score for all cookies was in the range from 7.30 (1.49) to 8.0 (0.94). The mean score for entire cookies was in the range of 6.4 (2.22) to 7.5 (1.08). The overall appearance scored mean was in the range from 6.90 (1.79) to 7.9 (1.37). There were no significant differences between groups for acceptability and palatability between cookies based on one-way ANOVA analysis.

Perceived satiety

Figure 4 to 10 shows the perceived satiety namely, fullness, hunger, satiety, desire to eat, prospective food consumption, pleasantness and thirstiness from 0 to 120 min. There were no significant differences for fullness, hunger, satiety, desire to eat, prospective food consumption, pleasantness and thirstiness after consumption of durian, β-glucan and durian plus β-glucan cookies compared with control. However, with exception of pleasantness and thirstiness, there was significant

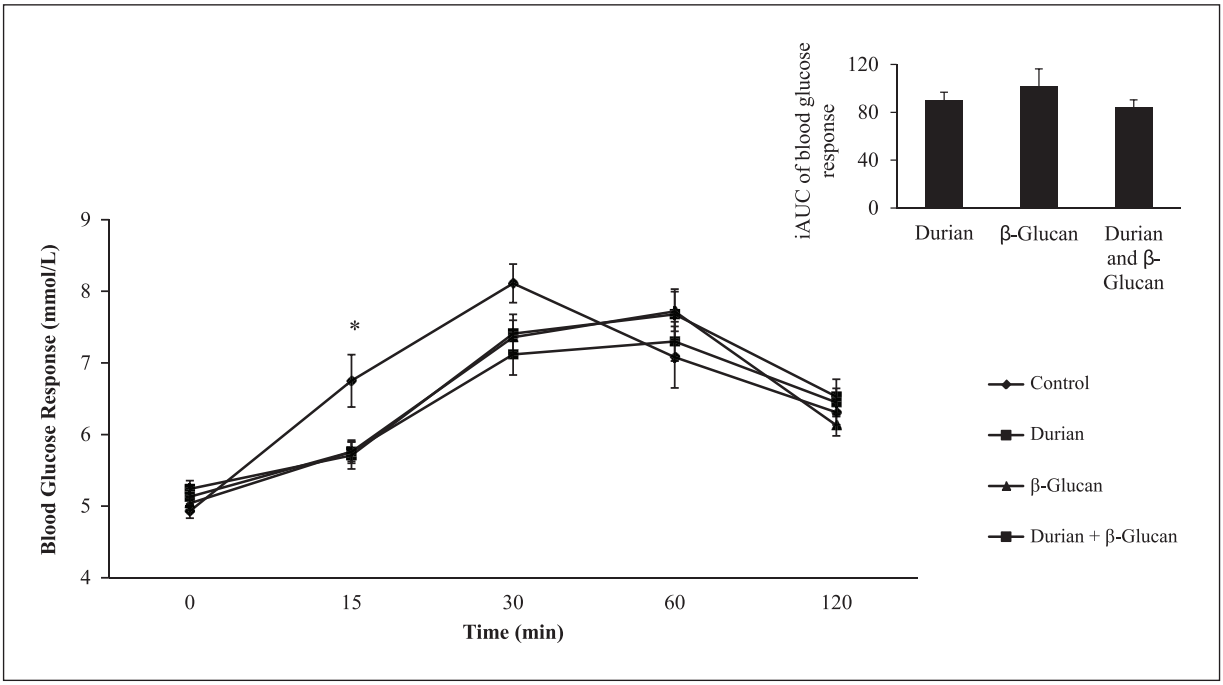

Fig. 1. The mean blood glucose response of test food and reference food. Presented values are as means (SEM) (n=10). Comparison of glucose concentration ($p < 0.05$): Asterisk (*) indicates significant ($p < 0.05$) differences between control vs durian, and durian + β-glucan. Inset figure: The incremental area under the curve of the blood glucose response.

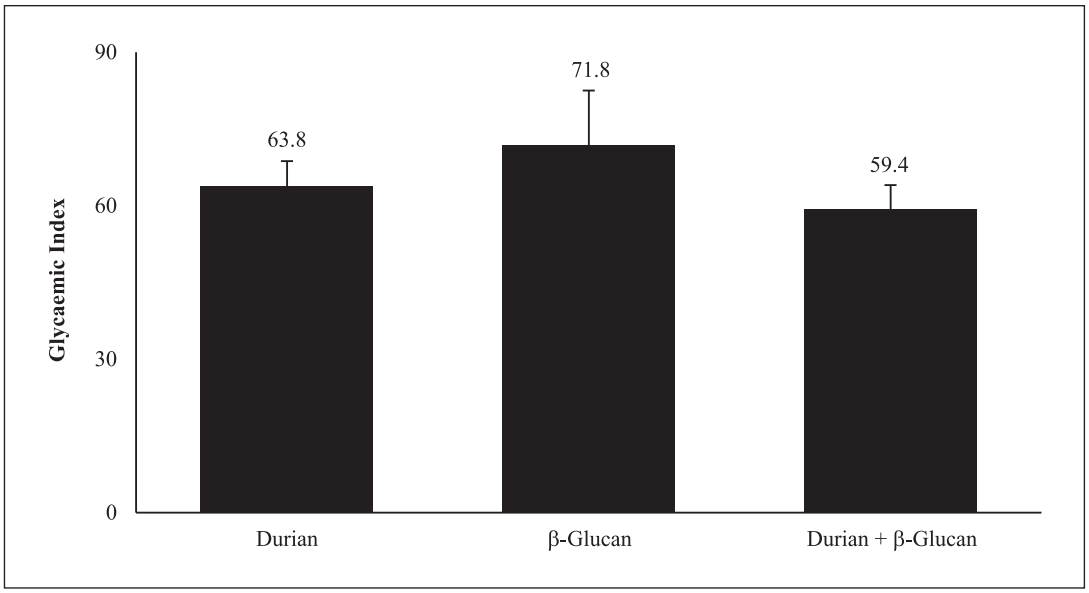

Fig. 2. The glycaemic index of durian, β-glucan and durian + β-glucan cookies. The GI calculated as the area under the curve of the test food divided by the area under the curve of the reference food multiplied by 71.

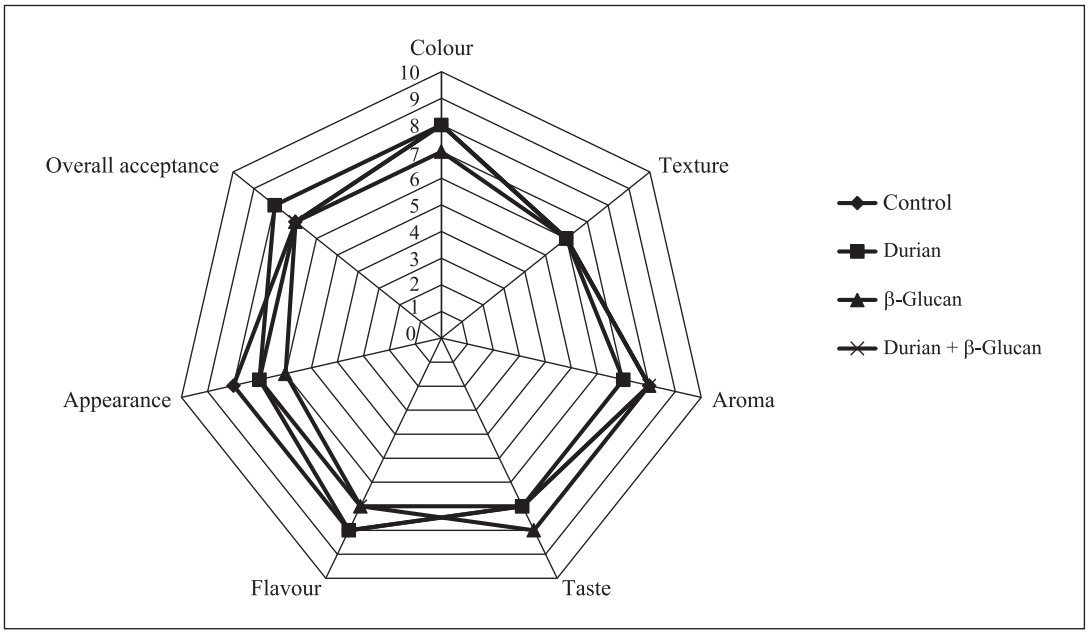

Fig. 3. The mean acceptability score of the cookies (n = 10). Acceptability and palatability preference consists of seven sensory variables as follow: colour, texture, aroma, taste, flavour, appearance, and overall acceptance.

time by treatment interactions as determined using repeated measures ANOVA. There were no significant differences for iAUC perceived satiety between cookies (an inset figure).

DISCUSSION

Durian is a well-known fruit native to southeast Asian country like Malaysia, Thailand and Indonesia. It has sweet taste and a good source of macronutrient as well as micronutrient antioxidant (polyphenols) (A Aziz & Mhd Jalil, 2019). However, the study on the health benefits of durian is still limited. β-Glucan is a well-established soluble dietary fibre and positively regulates postprandial glucose response (Panahi *et al*., 2014). However, β-glucan-based products are not always palatable and acceptable. Hence, the objectives of this study were to determine the acceptability and palatability, perceived satiety and glycaemic index of cookies prepared with these two functional ingredients.

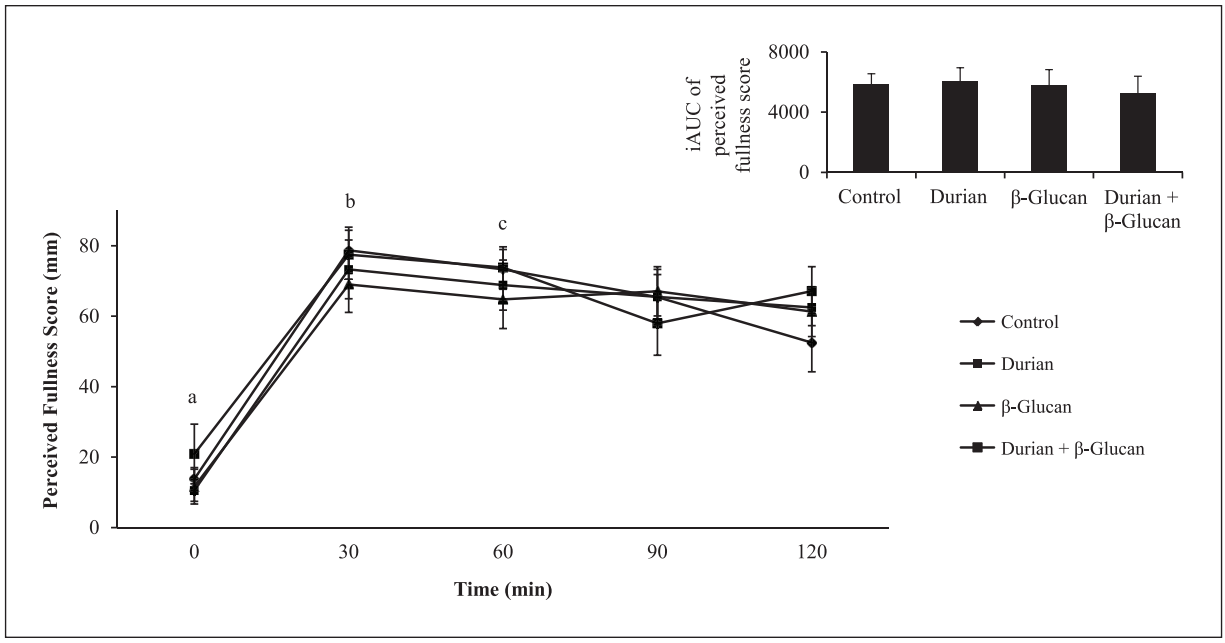

Fig. 4. Perceived fullness score (mm) after consumption of four different cookies. There were no significant differences between cookies (one-way ANOVA). Inset figure: iAUC of fullness at 0 to 120 min. The alphabet represents significant time by treatment interaction ($p < 0.05$) a: 0 min vs 30, 60, 90 and 120 min, b: 30 min vs 120 min, c: 60 min vs 120 min.

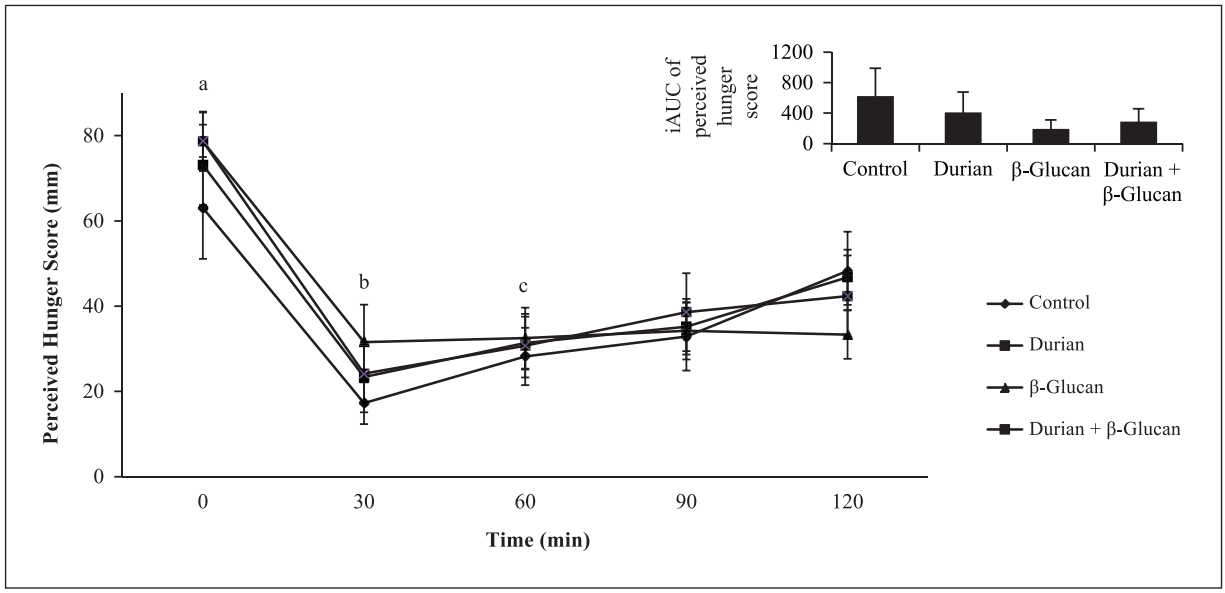

Fig. 5. Perceived hunger score (mm) after consumption of four different cookies. There were no significant differences between cookies (one-way ANOVA). Inset figure: iAUC of hunger at 0 to 120 min. The alphabet represents significant difference time by treatment interaction ($p < 0.05$), a: 0 min vs 30, 60, 90 and 120 min, b: 30 min vs 120 min, c: 60 min vs 120 min.

This study showed that there were no significant differences in acceptability and palatability of cookies prepared with durian and β-glucan compared with control cookies. The cookies prepared with either β-glucan, durian or combination of both were acceptable as control cookies prepared only with wheat flour. All four types of the cookies showed similar colour, texture, aroma, taste, flavour, appearance, and overall acceptance. This was in line with previous studies which showed that products prepared with β-glucan such tortillas and snack bars increased perceived satiety compared with control (Ames *et al.,* 2015; Panahi *et al*., 2014). In the present study, all cookies were formulated to contain 50 g of available carbohydrates. Fat and sugar content were similar between cookies. Fat and sugar

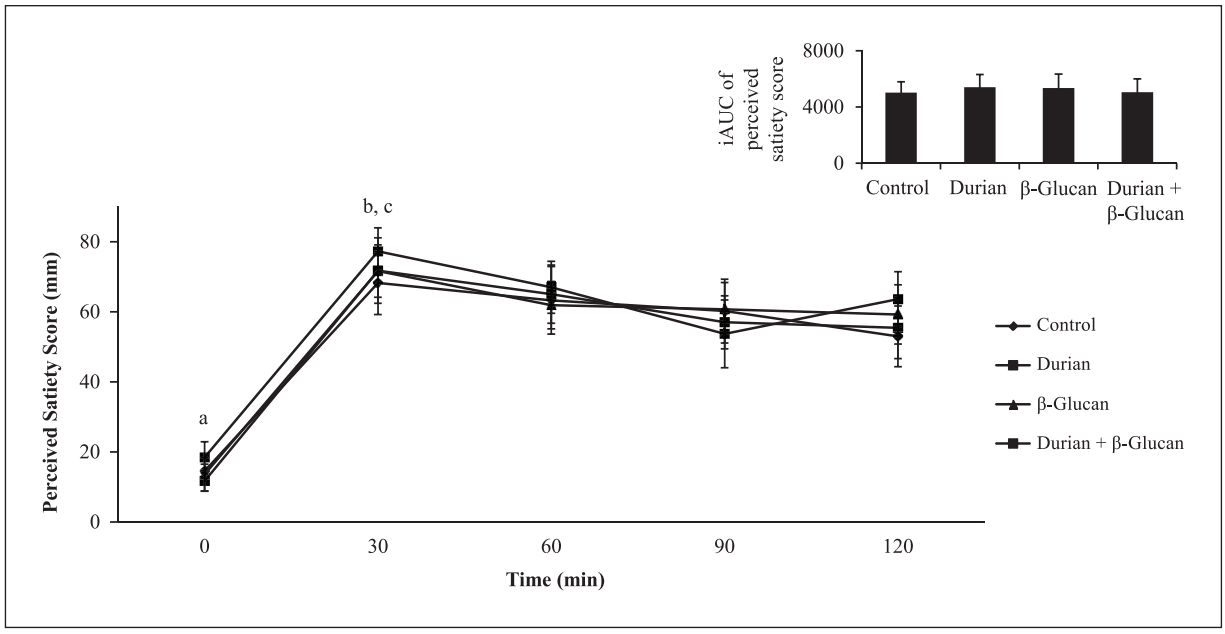

Fig. 6. Perceived satiety score (mm) after consumption of four different cookies. There were no significant differences between cookies (one-way ANOVA). Inset figure: iAUC of satiety at 0 to 120 min. The alphabet represents significant difference time by treatment interaction ($p < 0.05$), a: 0 min vs 30, 60, 90 and 120 min, b: 30 min vs 60 min, c: 30 min vs 120 min.

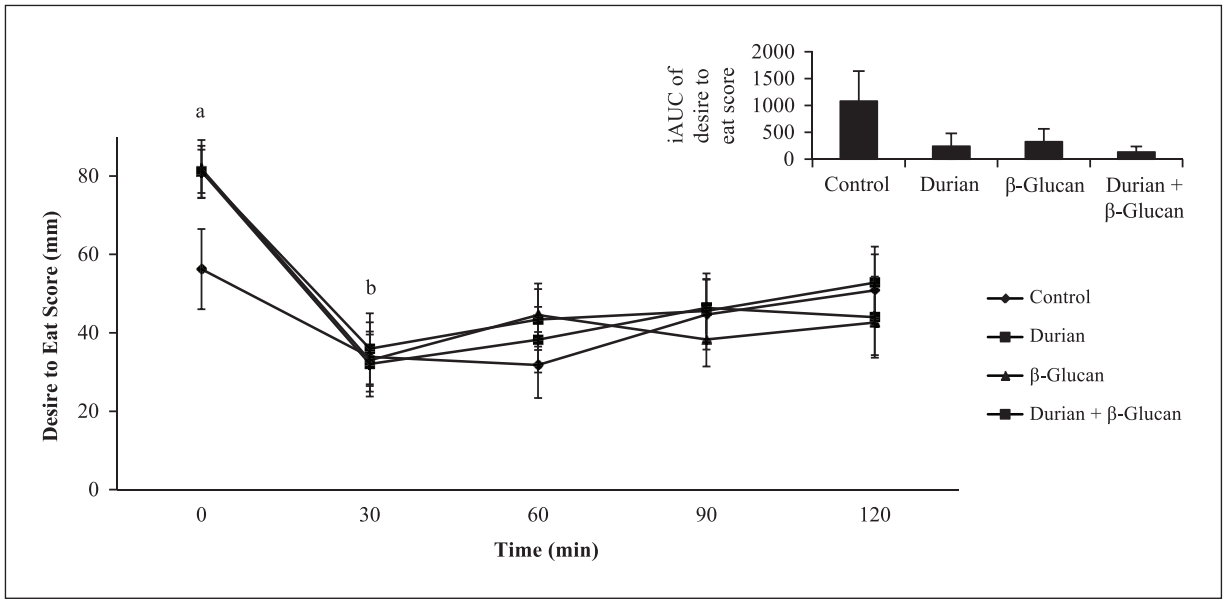

Fig. 7. Perceived desire to eat score (mm) after consumption of four different cookies. There were no significant differences between cookies (one-way ANOVA. Inset figure: iAUC of desire to eat score at 0 to 120 min The alphabet represents significant time by treatment interaction ($p < 0.05$) a: 0 min vs 30, 60, 90 and 120 min, b: 30 min vs 120 min.

has contributed to the taste and mouthfeel of the foods (Krebs, 2009). Hence, this could explain why the tastes of all cookies were similar. The other reason could be due to the addition of durian flavour in the control cookies. The subjects were blinded against the real durian with the addition of durian flavour. The addition of flavour is essential to ensure the subjects will not be able to differentiate the type of cookies, which possibly cause to be bias. This could partially explain why the palatability and acceptability were similar between control and experimental cookies. However, there were other factors affecting the acceptability and palatability such as personal preference for food (Ruijschop *et al.,* 2009).

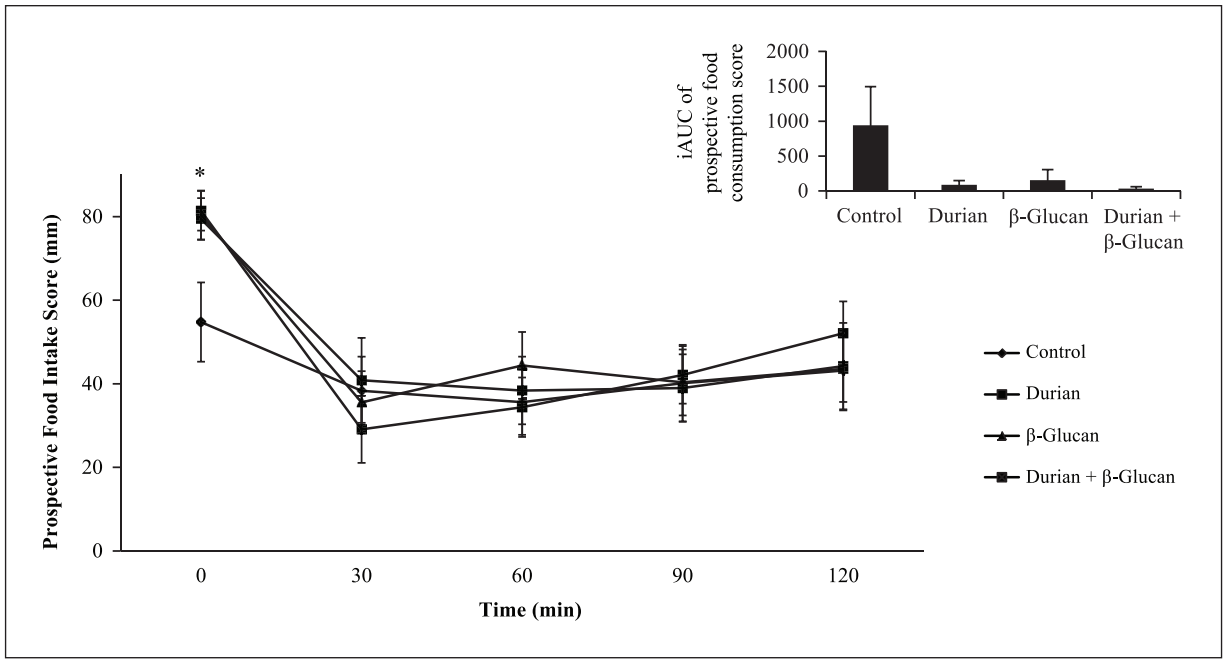

Fig. 8. Perceived prospective food consumption score (mm) after consumption of four different cookies. There were no significant differences between cookies (one-way ANOVA). Asterisks (*) indicate significant differences ($p < 0.05$) between control vs durian, β-glucan and durian + β-glucan cookies. Inset figure: iAUC of prospective food consumption from 0 to 120 min.

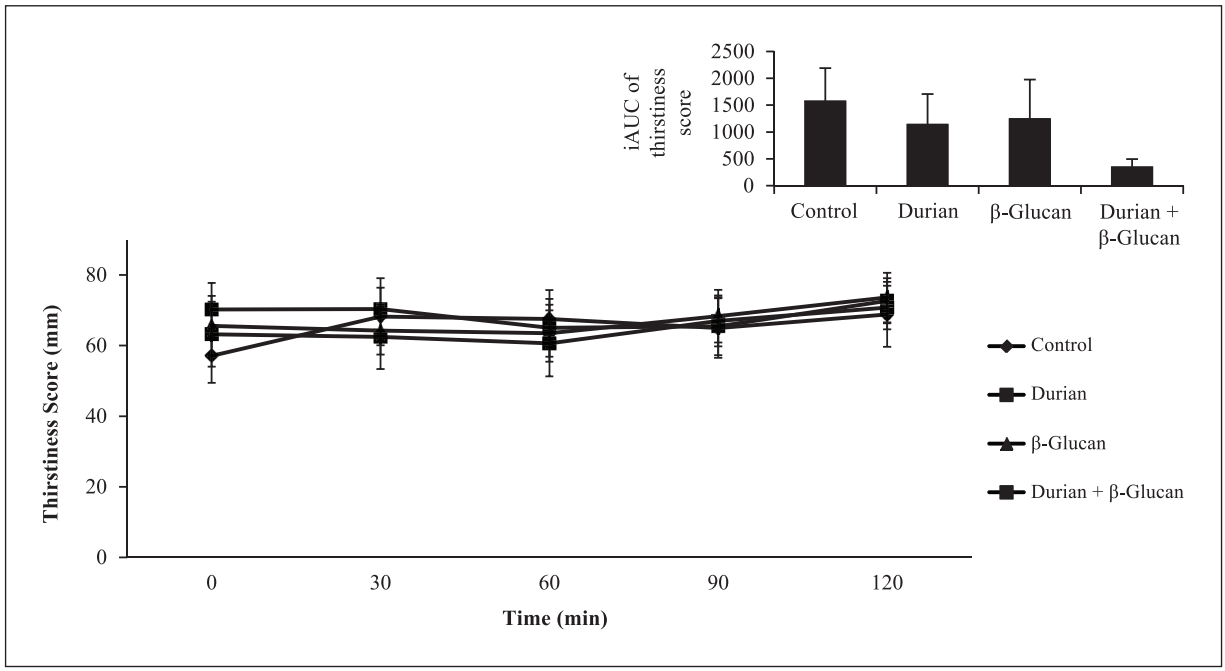

Fig. 9. Perceived thirstiness score (mm) after consumption of four different cookies. There were no significant differences between cookies (one-way ANOVA). Inset figure: iAUC of thirstiness from 0 to 120 min.

A review by Salleh *et al*. (2009) showed that soluble fibres increased perceived satiety (Salleh *et al*., 2019). In this study, perceived satiety was assessed using a 100-mm visual analogue scale (VAS) on perceived fullness, hunger, satiety, desire to eat, prospective food consumption, pleasantness and thirstiness. This study showed that perceived fullness, hunger, satiety, desire to eat and prospective food consumption were higher in the cookies prepared with durian and β-glucan compared with control cookies. Juvonen *et al*. (2001) showed that 10 g of soluble dietary fibre

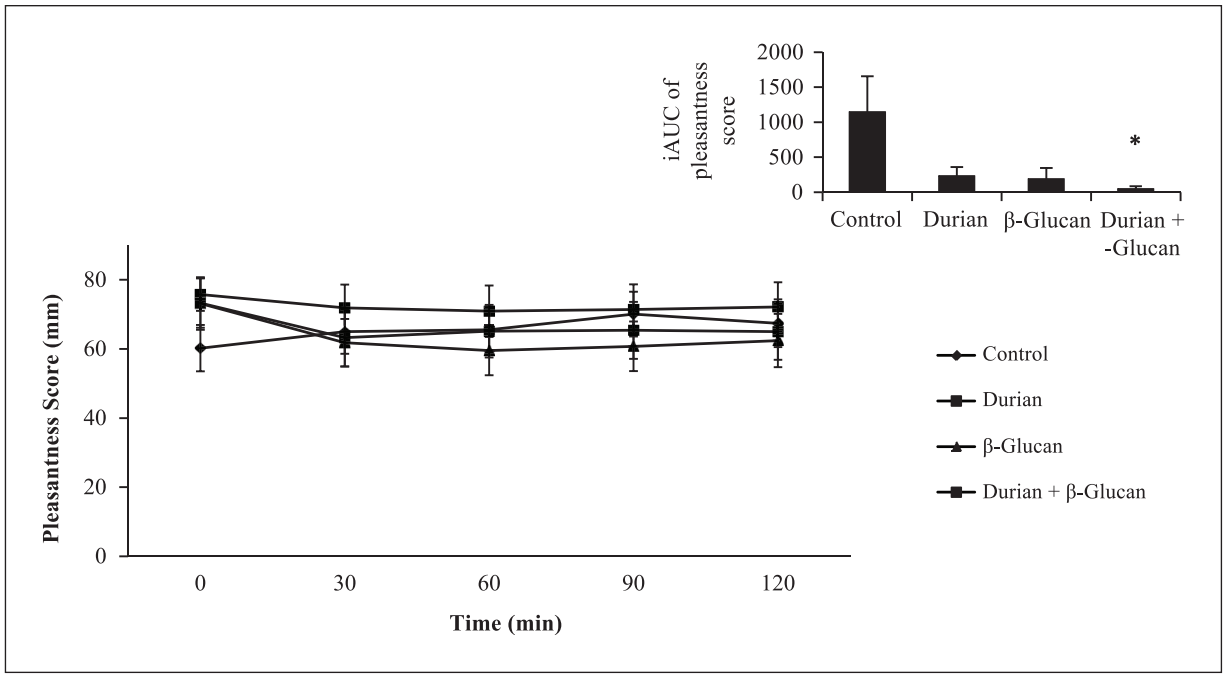

Fig. 10. Perceived pleasantness score (mm) after consumption of four different cookies. There were no significant differences between cookies (one-way ANOVA). Asterisks (*) in an inset figure indicates significant difference ($p < 0.05$) between durian + β-glucan vs other cookies. Inset figure: iAUC of pleasantness from 0 to 120 min.

either from wheat or oat bran in semisolid food matrix (pudding) increased the perceived satiety (Juvonen *et al*., 2011). This showed that β-glucan can increase the prospective satiety. Furthermore, a study that used 8 g of β-glucan increased perceived satiety compared with 4 g of β-glucan (Pentikainen *et al*., 2014). Another study prepared soup with different doses of β-glucan, i.e. high molecular weight β-glucan (HBG) and low molecular weight β-glucan (LBG). The results showed that different doses of β-glucan did not affect perceived hunger, fullness, desire to eat and prospective food consumption between test meals (Clegg & Thondre, 2014). Paquin *et al*. (2013) showed juices enriched with either xanthan gum (0.18 g), β-glucan (0.38 g), or a mix of xanthan gum (0.09 g) and β-glucan (0.23 g) significantly increased perceived satiety (Paquin *et al.,* 2013). The studies mentioned above demonstrated that higher dose of β-glucan (8 g) increased perceived satiety compared with low dose (0.23 g). Hence, the dose use is important when considering the effect of β-glucan on perceived satiety. Previous studies showed that soluble fibre increased perceived satiety due to its ability to delay gastric emptying (Pentikainen, 2014; Wanders, 2011). Delay gastric emptying might have increased perceived satiety and also might beneficially reduce postprandial glycaemic response.

This study showed that glycaemic index of durian plus β-glucan cookies was lower with 59.4 (4.63) compared with durian or β-glucan cookies with 63.8 (4.89) and 71.8 (10.7), respectively. Durian is rich in macronutrients (protein, fat), soluble fibre and polyphenols compounds (A Aziz & Mhd Jalil, 2019). A study showed durian was ranked the lowest glycaemic index (GI) with GI of 49 (5) compared with other tropical fruits such pineapple, papaya and watermelon with GI of 82 (4), 58 (6) and 55 (3), respectively (Robert *et al*., 2008). Previous study showed that soluble fibre and polyphenols could reduce the glycaemic index (Bahadoran *et al.,* 2013; Kwong *et al.,* 2013). The effects of β-glucan in reducing blood glucose is well established (Tosh, 2013; Panahi *et al*., 2014). Many studies suggested that β-glucan can reduce the postprandial blood glucose level (Hlebowicz *et al.,* 2013; Juvonen *et al*., 2011), however in this is study the β-glucan containing cookies revealed the high GI and in classification of high GI. Soluble fibres behave differently when prepared in liquid, semisolid or solid foods. Soluble fibre absorbs more water and increase stomach distention when prepared in liquid meals (De Graaf *et al*., 2004). Previous studies showed that high-viscosity β-glucan decreased glucose and insulin responses compared with control (Juvonen *et al*., 2009; Panahi *et al*., 2007). However, this is not the case for solid foods. The effects of β-glucan prepared in solid foods on glucose response are still inconclusive. Panahi *et al*. (2014) showed that different doses of β-glucan (1.5, 3 and 6 g) reduced glucose response when prepared in snack bars (Panahi *et al*., 2014).

Panahi *et al*. (2014) hypothesize that solubility decreases with increasing β-glucan content due to 'intra' (between β-glucan molecules) and 'inter' (with other molecules present in bar matrix) interactions in the solid bar matrix.

CONCLUSIONS

This study shows that cookies prepared with a combination of durian and β-glucan was acceptable and palatable compared with control cookies. Durian and β-glucan increased perceived satiety and was classified as medium GI. This study suggests that a combination of soluble β-glucan and durian in cookies potentially reduced the glycaemic and could be further study in different food matrices (liquid and semisolid).

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