Malays. Appl. Biol. (2019) 48(4): 129–138

GLYCEMIC INDEX OF STARCH-BASED FOODS COMMONLY CONSUMED IN TERENGGANU, MALAYSIA

NUR AIN FATINAH ABU BAKAR[1], AINAA ALMARDHIYAH ABD RASHID[2], MOHD FATAHUDIN ISHAK[3] and ABBE MALEYKI MHD JALIL[1*]

[1]*School of Nutrition and Dietetics, Faculty of Health Sciences, Universiti Sultan Zainal Abidin (UniSZA), 21300 Kuala Nerus, Terengganu, Malaysia*
[2]*Nutrition and Dietetics Program, School of Health Sciences, Universiti Sains Malaysia Kelantan*
[3]*Women and Children Hospital, Kuala Lumpur*
[*]*E-mail: abbemaleyki@unisza.edu.my*

Accepted 14 October 2019, Published online 30 November 2019

ABSTRACT

This study was aimed to determine the GI of nine starch-based foods commonly consumed in Terengganu, Malaysia as follows: noodles (fried yellow *mi*, fried *mihun*, fried *kuay teow*), local *kuih* (*akok, apam ayu*, *mek comel*), and local fish snacks (boiled *keropok lekor*, fried *keropok lekor*, fried *keropok keping*). Glycemic index determination was done according to standard GI protocol. Ten healthy subjects completed each category of starch-based foods. i.e. three test foods and one reference food after an overnight fast (10-12 hr). Capillary blood samples were measured at baseline (fasting, 0 min) and at 15, 30, 45, 60, 90 and 120 min thereafter. Glycemic index was determined by expressing the percentage incremental area under the curve of the test food over reference food (glucose). Four foods were categorized as low GI as follows: fried *keropok keping*, GI = 29.00 (7.5); fried *mihun*, GI = 45.40 (7.43); *akok*, GI = 49.34 (5.11) and fried yellow *mi*, GI = 49.56 (6.77). These foods had significantly lower GI than reference food (glucose; GI = 100) ($p < 0.05$). The remaining five foods were categorized as high GI as follows: *apam ayu*, GI = 90.56 (12.0), *mek comel*; GI = 82.71 (9.42); fried *kuay teow*, GI = 79.50 (9.34); boiled *keropok lekor*, GI = 79.00 (9.50) and fried *keropok lekor*, GI = 70.00 (13.40). This study shows that starch-based foods raised glucose response differently and depends on the factors such as nutrient composition, food structure, processing techniques and cooking methods.

Key words: Glycemic Index (GI), fried yellow *mi*, fried *mihun*, fried *kuay teow*, *akok, apam ayu, mek comel*, boiled *keropok lekor*, fried *keropok lekor*, fried *keropok keping*

INTRODUCTION

Starch-based foods are being metabolised to monosaccharide (glucose) and will increase postprandial glucose response (FAO/WHO, 1998). The glycemic response after carbohydrate intake is the basis for the measurement of glycemic index (GI) (Jenkins *et al*., 1981). Glycemic index is defined as the incremental area under the curve elicited by a 50 g available carbohydrate portion of a food expressed as a percentage of the response after 50 g anhydrous glucose taken by the same subject (Wolever *et al*., 2006). The GI was originally meant to be an index of the blood glucose-raising potential of the available carbohydrate in foods (Wolever *et al*., 1991). The term 'glycemic index' is often used incorrectly to mean 'glycemic response'. These two terms are different by their definition and should not be confused because these entities have different mathematical and statistical properties (Wolever *et al*., 1991).

Recent studies have shown that high GI diet may increase the risk of cardiovascular diseases (CVD), breast cancer and T2DM (Frost *et al*., 1999). Low GI diet has been shown to reduce high-density lipoprotein cholesterol (HDL-C) and hence might play a role in reducing CHD risk (Frost *et al*., 1999). There was consensus that diets low in GI and GL were relevant to the prevention and management of diabetes and coronary heart disease, and probably obesity (Augustin *et al*., 2015). Glycemic index of a carbohydrate-rich food varies greatly depending on variety, origin, food processing, food preparation and nutrient composition within the food (Pi-Sunyer, 2002).

* To whom correspondence should be addressed.

Glycemic index of foods can be influenced by amount of carbohydrate within the foods. Foods with higher carbohydrate content are more likely to have higher glycemic index compare to foods with lower carbohydrate content. Besides amount of carbohydrate in the foods itself, type of sugar also can affect the GI value (Pi-Sunyer, 2002).

The nature of starch presents in the foods such amylose and amylopectin contents, starch-nutrient interactions, and resistant starch content could influence the GI (FAO/WHO, 1998). Type of starch within the foods can produce different GI due to difference in amylose and amylopectin ratios (Pi-Sunyer, 2002). The higher the proportion of amylopectin, the higher the GI, because amylopectin, which is made up of branched-starch molecules, is more easily hydrolyzed in the gut than the single strand amylose (Amelsvoort & Weststrate, 1992). Starch exists in carbohydrate foods in the form of large granules. These granules must be disrupted so that the amylose or amylopectin become available for hydrolysis. Grinding, rolling, pressing, mashing and thoroughly chewing a starch-rich carbohydrate will disrupt the amylose or amylopectin molecules, making them more available for hydrolysis thereby increasing the GI (Asp, 1987).

Cooking method has been shown to exert a differential effect in GI of a carbohydrate-rich food. For example, the starch in an uncooked potato is resistant to hydrolysis by digestive enzymes and thus, has a relatively low GI. However, when the potato is cooked, the starch molecules gelatinized and become readily digestible, thereby increasing the GI (Englyst & Cummings, 1987). According to Pi-Sunyer (2002), the addition of protein and/ or fat to carbohydrate-rich foods increases the insulin response while reducing the glycemic response (Pi-Sunyer, 2002).

Malaysia is very popular for its local foods and cuisine. There are variety of choices available in the local markets selling foods and delicacies such as *kuih* (sweet or savoury snacks), local traditional fish snacks and various types of noodles. However, currently, there is no evidence to suggest the GI of these foods. Therefore, this study was aimed to determine GI values for noodles (fried yellow *mi*, fried *mihun*, fried *kuay teow*), local kuih (*akok*, *apam ayu*, *mek comel*), and local fish snacks (boiled *keropok lekor*, fried *keropok lekor*, fried *keropok keping*).

MATERIALS AND METHODS

Subjects

Subjects were recruited at Medical Campus, Universiti Sultan Zainal Abidin (UniSZA), Kampus Kota, Kuala Terengganu. The study protocol was approved by UniSZA Research Ethics Committee (Ethical Approval No: UniSZA.N/1/628-1 (9)). Informed consent was obtained from each subject prior to study procedure. Subject's inclusion criteria are as follows: healthy, male or female and age between 18 to 75 years old. Exclusion criteria are as follows: pregnant, lactating mothers, smoking, diabetes mellitus type 1 or type 2, and those on medication affecting blood glucose and/or blood pressure (Wolever *et al.,* 1991). Subjects were advised to maintain their normal daily tasks and not to change their habitual physical activities.

Test and reference food

Three categories of carbohydrate-based test foods were selected for this study, namely noodles (fried yellow *mi*, fried *mihun*, fried *kuay teow*), local kuih (*akok, apam ayu* and *mek comel*), and local fish snacks (boiled *keropok lekor*, fried *keropok lekor* and fried *keropok keping*) available in Terengganu. These foods were purchased from local food sellers in Kuala Terengganu. All subjects were advised to consume the test food within 15 min. Glucose (Glucolin^{TM}) was used as the reference food. Table 1 shows the nutritional composition (g/serving portion) of ten different test foods. For noodles and local *kuih*, subjects were served with portion of test foods based on 50 g edible portion of carbohydrate. While for local fish snacks, as this study required the subjects to consume 50 g edible portion of carbohydrate, thus 40 g of carbohydrate were from test foods itself (boiled *keropok lekor*, fried *keropok lekor*, and fried *keropok keping*), while 10 g of carbohydrate was from the chili sauce (subjects served with 23 g of chili sauce containing 10 g of carbohydrate).

Nutritional composition for noodles and local *kuih* were calculated according to Macronutrients Composition of 100 Kelantanese Foods (Harith *et al.,* 2010), while for local fish snacks (fried *keropok lekor* and boiled *keropok lekor*) were based on study by Ibrahim *et al*. (2007). Nutritional composition for fried *keropok keping* was based on Nutrient Composition of Malaysian Food (Tee *et al.,* 1997). Nutritional composition of chili sauce served along with fish snacks was based on nutrition facts of the product (Kamariah Maju Enterprise, 2012).

Glycemic index (GI) determination

A total number of 30 subjects completed this study (Table 2). An equal number of subjects (n = 10) completed each food group, namely noodles, local *kuih* and fish snacks. Each of the subjects within the same food group went through four different occasions (three test foods and one reference food) after an overnight fast (10-12 hr). One portion of test food containing 50 g

Table 1. Nutritional composition of test foods

Test Foods	Ingredients	Serving Portion (g)	Nutritional value of food							Method of Preparation
			Energy (kcal)	*Protein (g)*	*Fat (g)*	*CHO (g)*	*Fiber (g)*	*Moisture (g)*	*Ash (g)*	
			Noodles							
*Fried yellow *mi*	Noodles, cooking oil, sliced chicken, egg, vegetables, sugar, seasonings	179	327	7.29	10.9	50	2.06	105	3.49	Stir frying
*Fried *mihun*	*Mihun,* cooking oil, sliced chicken, egg, vegetables, sugar, seasonings	149	267	3.84	5.72	50	0.29	88	1.12	Stir frying
*Fried *kuay teow*	Wheat flour, rice flour, tapioca flour, cooking oil, poultry, egg, sugar, seasonings	178	239	2.26	3.30	50	1.86	118	2.65	Stir frying
			Local *kuih*							
**Mek comel*	Sweet potatoes, wheat flour, margarine, sugar, cooking oil	92.1	269	4.9	5.51	50	1.43	NA	NA	Deep frying
**Apam ayu*	Wheat flour, egg, sugar, coconut milk, baking powder, screw pine leaves extract, green coloring, shredded coconut, corn flour	106.2	305	5.2	9.4	50	0.87	NA	NA	Steaming
**Akok*	Egg, wheat flour, coconut milk, sugar, water, salt, screw pine leave extract	112	241	7.2	1.38	50	0.44	NA	NA	Baking
			Local fish snacks							
**Boiled *keropok lekor*	Ground fish, sago starch, salts, sugar, monosodium glutamate	129	210	10.97	0.65	40	0.0	71	5.81	Boiling
**Fried *keropok lekor*	Ground fish, sago starch, salts, sugar, monosodium glutamate, oil	104	246	10.97	4.65	40	0.0	42.57	5.81	Deep frying
***Fried *keropok keping*	Ground fish, sago starch, salts, sugar, monosodium glutamate, oil	77	392	9.7	21.48	40	0.0	3.39	2.39	Deep frying
****Chili sauce	Vinegar, water, sugar, dried chili, onion, brown sugar	23	41	0.16	0.02	10	NA	NA	NA	Boiling

Nutritional composition of test foods was obtained from: Singles asterisk (*): Macronutrients Composition of 100 Kelantanese Food (Harith *et al.,* 2010). Double asterisks (**): based on proximate analysis done in study by Ibrahim *et al.* (2007), Triple asterisks (***): based on database in Nutrient Composition of Malaysian Food (Tee *et al.,* 1997). Four asterisks (****): based on nutritional facts of the product (Kamariah Maju Enterprise, Setiu, Terengganu, 2012).

Table 2. Characteristics of subjects

Category of local foods	Subjects characteristics	Subjects (n)	Mean (SEM)	Range
Noodles	Age (years)	10	19 (0)	19
	Body weight (kg)		60.26 (3.51)	50–79.3
	Height (cm)		157.74 (2.28)	144–169
	Body mass index (BMI, kg/m^2)		24.1 (1.28)	18.2–28.4
Local *kuih*	Age (years)	10	19.7 (0.47)	19–23
	Body weight (kg)		53.86 (3.83)	42–73
	Height (cm)		159.65 (3.75)	138–177
	Body mass index (BMI, kg/m^2)		20.95 (1.06)	16–26
Local fish snacks	Age (years)	10	19.9 (0.46)	19–22
	Body weight (kg)		50.2 (3.67)	40–80
	Height (cm)		153.6 (1.77)	144.5–162
	Body mass index (BMI, kg/m^2)		21.23 (1.37)	17.22–31.25

carbohydrate was given to the subjects with 250 mL water. Glucose (50 g) was given as reference food and dissolved in 400 mL water according to standard GI protocol (Wolever *et al.,* 1991). Capillary blood sample was obtained and glucose level determined using glucometer after an overnight fasting (10-12 hr). Fasting (baseline, 0 hr) and postprandial blood glucose were obtained at 15, 30, 45, 60, 90, and 120 min thereafter. The glucometer (ACCU-Chek) was calibrated and meet the ISO 15197 standard requirement for accuracy. Based on a study to determine the accuracy and precision performance of Accu-Chek Active System, the capillary data for Accu-Chek Active strip lot # 228835 was analyzed by regression analysis. The regression slope was 0.984 with a 95% confidence interval of 0.974 to 0.993. The intercept is -0.135 mmol/L (-2.4 mg/dL). The data presented demonstrate excellent correlation with a value of 0.998 with 1.000 as the optimum value (Roche Diagnostics, 2006).

Data analysis

Raw glucose data was manually entered in incremental Area Under the Curve (iAUC) data sheet (courtesy of Dr. Thomas Wolever, University of Toronto, Canada). Subject with value more than 2SD were excluded from the group (known as outliers) (Wolever *et al.,* 2006). Glycemic Index (GI) was calculated using the following formula:

Glycemic Index (GI) =
iAUC of test food (50 g carbohydrate)/
Mean iAUC of reference food (50 g glucose) × 100

Data were analysed using SPSS version 22.0 (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.). Results are expressed as mean (SEM). One-way analysis of variance (ANOVA) was used to analyze iAUC glucose and GI differences between foods. A repeated measure ANOVA was used to compare the difference of glucose response at different time points.

RESULTS

Characteristics of subjects

A total of 30 subjects comprised of five males and twenty-five females completed the trial. Overall, mean age and body mass index (BMI) of subjects recruited for each food category (noodles, local *kuih* and local fish snacks) were 19 (0) years and 24.1 (1.28) kg/m^2, 19.7 (0.47) years and 20.95 (1.06) kg/m^2 and 19.9 (0.46) years and 21.23 (1.37) kg/m^2, respectively (Table 2).

Blood Glucose Response and GI Value

Table 3 shows the mean blood glucose response at different time points after consuming test foods and reference food. There were significant differences between time 0 (fasting) and after 15 min for most test foods. The peak glucose response was attained between 30 to 45 min for most test foods. Figure 1–3 depicts blood glucose response for each test food. An inset in Figure 1–3 shows the iAUC for each test foods and reference foods.

Incremental area under the curve is crucial in determining GI value. The area under the curve was calculated as the incremental area under the curve (iAUC), ignoring the area beneath the fasting concentration. This can be calculated geometrically by using trapezoid rule (Brand-Miller *et al.,* 2009). This study showed that the mean iAUC after the consumption of test foods ranged between 73.9 (7.4) mmol.min/L and 303 (31.4) mmol.min/L. Reference glucose for noodle category showed the highest glucose response while *keropok keping* the lowest iAUC.

Table 3. Mean (SEM) blood glucose response of subjects at different time point for every test and reference foods

Type of test foods	N	0 (min)	15 (min)	30 (min)	45 (min)	60 (min)	90 (min)	120 (min)
				Noodles				
Fried yellow *mi*	9	4.80 (0.09)	5.43 (0.22)	6.42 (0.29)*	**6.91 (0.23)***	6.54 (0.28)*	5.88 (0.18)*	5.42 (0.18)
Fried *mihun*	10	4.67 (0.12)	5.49 (0.22)*	6.54 (0.19)*	**6.70 (0.21)***	6.09 (0.24)*	5.41 (0.17)	4.75 (0.14)
Fried *kuay teow*	10	4.37 (0.18)	4.99 (0.19)*	6.18 (0.25)*	6.95 (0.19)*	**7.17 (0.28)***	6.59 (0.40)*	5.62 (0.26)
Reference food (Glucose)	10	4.66 (0.11)	7.18 (0.37)*	8.36 (0.29)*	**8.23 (0.46)***	7.65 (0.42)*	6.91 (0.30)*	6.11 (0.29)*
				Local *kuih*				
Mek comel	9	4.51 (0.14)	5.38 (0.13)*	6.98 (0.35)*	**7.33 (0.24)***	6.93 (0.26)*	6.56 (0.31)*	6.13 (0.26)*
Apam ayu	10	4.66 (0.14)	6.19 (0.24)*	**7.96 (0.24)***	7.96 (0.40)*	7.70 (0.47)*	6.39 (0.41)	5.34 (0.22)
Akok	8	4.36 (0.08)	5.20 (0.29)	**6.84 (0.22)***	6.20 (0.29)*	5.59 (0.30)	5.25 (0.21)	4.84 (0.19)
Reference food (Glucose)	10	4.73 (0.14)	6.91 (0.28)*	**8.55 (0.29)***	8.04 (0.27)*	7.74 (0.30)*	6.84 (0.31)*	5.98 (0.38)
				Local fish snacks				
Keropok lekor (boiled)	10	4.65 (0.13)	6.11 (0.22)*	7.66 (0.20)*	**7.89 (0.20)***	6.85 (0.30)*	5.55 (0.26)	5.27 (0.16)*
Keropok lekor (fried)	9	4.69 (0.15)	5.66 (0.23)	**7.69 (0.22)***	7.46 (0.22)*	6.34 (0.15)*	5.61 (0.22)	5.46 (0.09)*
Keropok keping (fried)	9	4.84 (0.17)	5.49 (0.14)	**6.54 (0.21)***	6.11 (0.26)*	5.13 (0.21)	5.03 (0.21)	5.08 (0.14)
Reference food (Glucose)	10	5.03 (0.09)	7.33 (0.27)*	**8.61(0.18)***	8.60 (0.38)*	7.48 (0.49)*	6.53 (0.25)	5.79 (0.15)

*Significant increase in blood glucose response from fasting for test foods and reference foods ($p < 0.05$). Values in bold showed the peak blood glucose response that was achieved at after consumption of all test foods and the reference food.

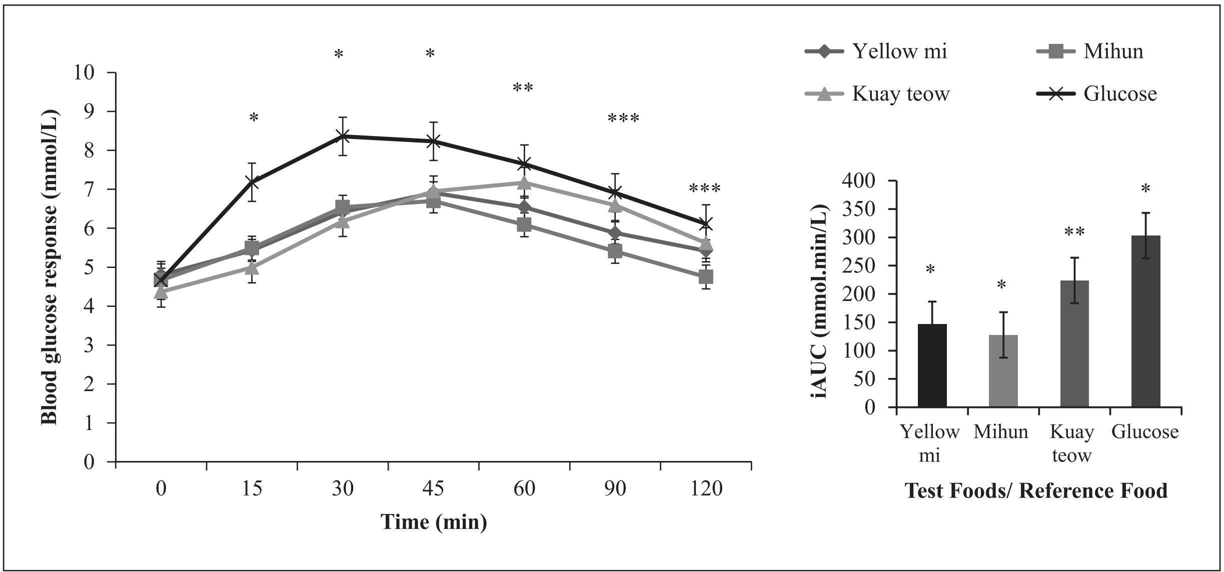

Fig. 1. Mean glucose response and iAUC of all test foods (noodles) and its reference food (glucose). Values are mean (SEM, as vertical bar) (n = 9-10). Single asterisk (*): Significant ($p < 0.05$) differences between Glucose vs all test foods. Double asterisks (**): Significant (p < 0.05) difference between Glucose and *Mihun*. Triple asterisks (***): Significant ($p < 0.05$) differences between *Mihun* vs *Kuay teow* and *Mihun* vs Glucose. **An inset figure**: Single asterisk (*): Significant ($p < 0.05$) differences between Glucose vs Yellow *mi* and *Mihun*. Double asterisks (**): Significant ($p < 0.05$) difference between *Kuay teow* and *Mihun*.

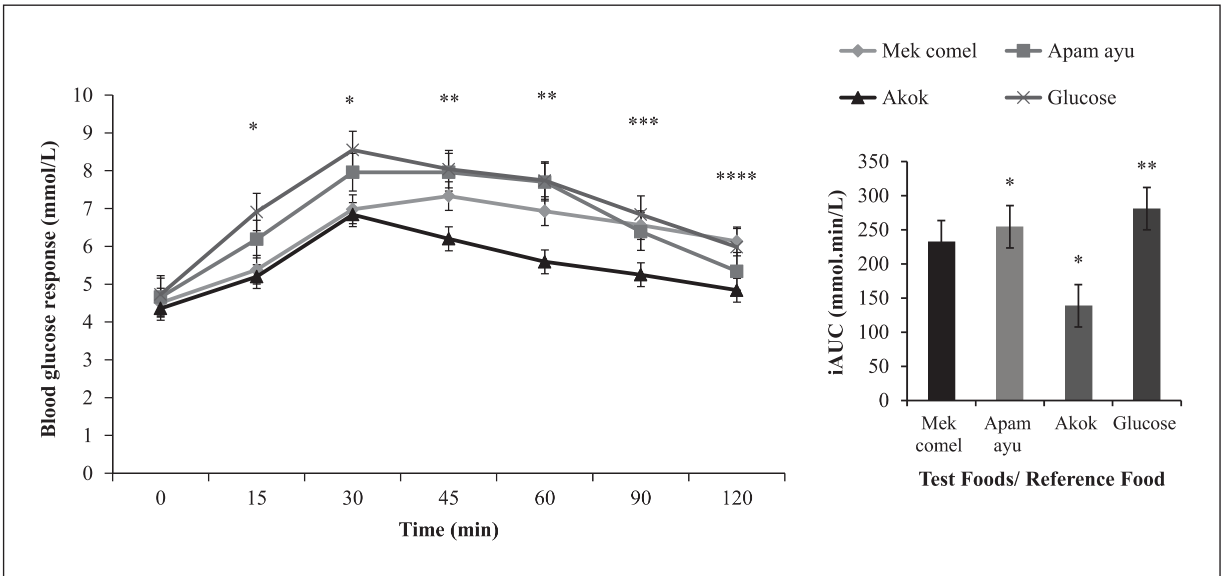

Fig. 2. Mean glucose response and iAUC of all test foods (local *kuih*) and its reference food (glucose). Values are mean (SEM, as vertical bar) (n = 8-10). Single asterisk (*): Significant ($p < 0.05$) differences between Glucose vs *Akok* and *Mek comel*, *Apam ayu* vs *Akok.* Double asterisks (**): Significant ($p < 0.05$) differences between *Akok* vs Glucose and *Apam Ayu*. Triple asterisks (***): Significant ($p < 0.05$) difference between Glucose vs *Akok.* Four asterisks (****): Significant ($p < 0.05$) differences between *Akok* vs glucose and *Mek Comel*. **An inset figure:** Single asterisk (*): Significant ($p < 0.05$) differences between *Apam ayu* vs *Akok*, Double asterisks (**): Significant ($p < 0.05$) difference between Glucose vs *Akok*.

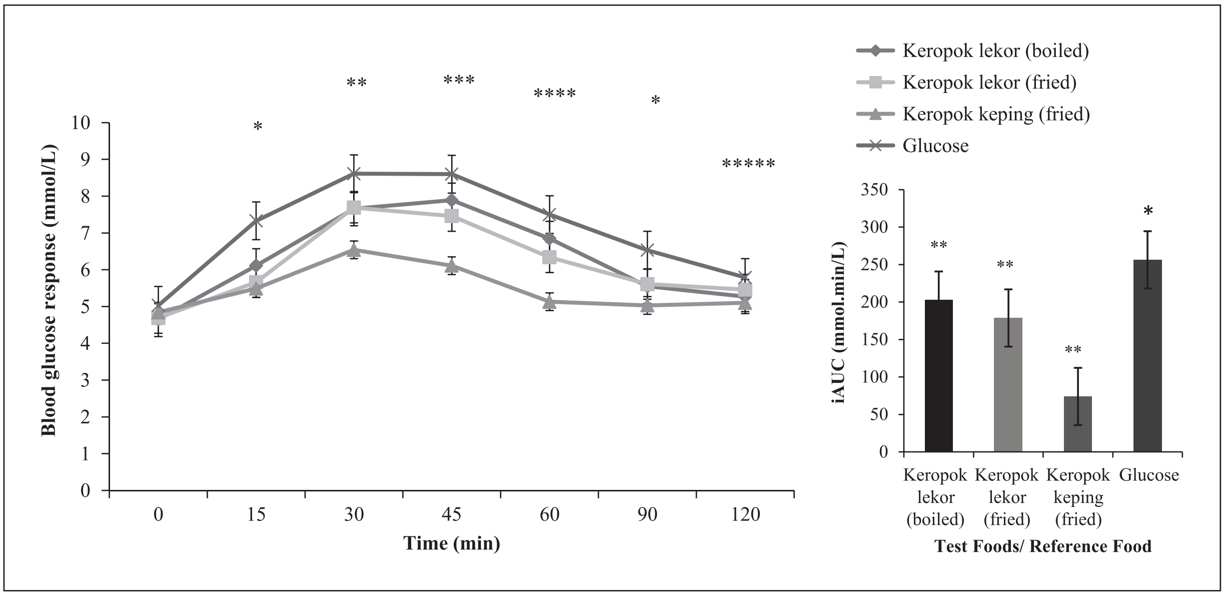

Fig. 3. Mean glucose response and iAUC of all test foods (fish snacks) and its reference food (glucose). Values are mean (SEM, as vertical bar) (n = 9-10). Single asterisk (*): Significant ($p < 0.05$) differences between Glucose vs Boiled *keropok lekor*, Fried *keropok lekor* and Fried *keropok keping*. Double asterisks (**): Significant ($p < 0.05$) differences between Glucose vs boiled *keropok lekor,* fried *keropok lekor* and fried *keropok keping;* and fried *keropok keping* vs boiled *keropok lekor* and fried *keropok lekor.* Triple asterisks (***): Significant ($p < 0.05$) differences between Glucose vs fried *keropok lekor* and fried *keropok keping; & keropok keping* vs boiled *keropok lekor* and fried *keropok lekor.* Four asterisks (****): Significant ($p < 0.05$) difference between Glucose vs *keropok keping;* and *keropok keping* vs boiled *keropok lekor* and fried *keropok lekor.* Five asterisks (*****): Significant (p <0.05) difference between Glucose vs boiled *keropok lekor* and fried *keropok keping.* **An inset figure:** Single asterisk (*): Significant ($p < 0.05$) differences between Glucose vs fried *keropok lekor* and fried *keropok keping*. Double asterisks (**): Significant ($p < 0.05$) differences between fried *keropok keping* vs boiled *keropok lekor* and fried *keropok lekor*.

Table 4. GI classifications of each test foods

Test foods	N	GI (SEM)	GI Classification	GI Ranking
Fried yellow *mi*	9[a]	*49.56 (6.77)	Low	4
Fried *mihun*	10	*45.40 (7.43)	Low	2
Fried *kuay teow*	10	79.50 (9.34)	High	7
Mek comel	9[a]	82.71 (9.42)	High	8
Apam ayu	10	90.56 (12.0)	High	9
Akok	8[a]	*49.34 (5.11)	Low	3
Boiled *keropok lekor*	10	79 (9.5)	High	6
Fried *keropok lekor*	9[a]	70 (13.4)	High	5
Fried k*eropok keping*	9[a]	*29 (7.45)	Low	1

[a]Subject exceeding 2SD were excluded from the group. *Asterisks (indicates) significantly ($p < 0.05$) lower compared with reference food (GI glucose = 100).

Glycemic index is classified into three categories as follow: less than 55 (low GI), 56-69 (intermediate GI) and more than 70 (high GI) (Brand-Miller *et al.,* 2006). Table 4 shows the mean GI and its classifications. Four foods showed low GI value namely fried *keropok keping* with GI of 29 (7.5), fried *mihun* with GI of 45.40 (7.43), *akok* with GI of 49.34 (5.11) and fried yellow *mi* with GI of 49.56 (6.77). These foods had significantly lower GI than reference food (glucose; GI = 100) ($p < 0.05$). The remaining five foods were categorized as high GI as follows: fried *keropok lekor* with GI of 70 (13.4), boiled *keropok lekor* with GI of 79 (9.5), fried *kuay teow* with GI of 79.50 (9.34), *mek comel* with GI of 82.71 (9.42) and *apam ayu* with GI of 90.56 (12.0).

DISCUSSION

Wheat noodles and rice-based noodles are two most starch-based foods consumed by Malaysian with mean intake frequency of 2.13 and 2.01 per week (one bowl per intake), respectively (Abdul Karim *et al*., 2008). Wheat noodle is known as yellow *mi* in Malaysia and it is made from wheat flour (Dewan Bahasa dan Pustaka, 2018). There are two types of rice-based noodles in Malaysia and are known as *mihun* (smaller than *mi*) and *kuay teow* (flat sheet) (Astawan, 2008; Chew *et al.,* 2012; Dewan Bahasa dan Pustaka, 2018). Fried *mihun* showed the lowest GI with 45.40 (7.43) (low GI) followed by fried yellow *mi* and fried *kuay teow* with 49.56 (6.77) (low GI) and 79.50 (9.34) (high GI) respectively. However, previous study showed that rice vermicelli (equivalent to *mihun*) had intermediate GI (Lok *et al.,* 2010). Different GI values between *mihun* and rice vermicelli might be due to lower carbohydrate content in *mihun* (50 g available carbohydrate) compared with rice vermicelli (53 g to 79 g available carbohydrate) (Lok *et al.,* 2010). A study showed that higher proportion of carbohydrate in a specific food lead to higher GI compared with fat and protein (Pi-Sunyer, 2002).

The differences in GI values between these foods could be explained based on how they are made. *Mihun* is prepared from rice paste extruded through steam and hot air dryer (Shelke, 2016). This process subsequently increased the resistant starch content in the final product (Sajilata *et al*., 2006). Previous study demonstrated that higher resistant starch content associated with lower GI value (Ranawana *et al.,* 2009). The starch granules in cooked starch-based food were in the form of large granules (Yeboah, 2018). The starch granules were disrupted during cooking process so that the amylose or amylopectin starch macromolecules become available for hydrolysis. Hence, by processing the food such as grinding, pressing, mashing which involve the change in particle size might disrupt the granules which can increase GI value of the food (Yeboah, 2018).

Akok, apam ayu and *mek comel* are three famous Terengganu traditional sweet delicacies. *Akok* showed the lowest GI followed by *mek comel* and *apam ayu* with 49.34 (5.11) (low GI), 82.71 (9.42) (high GI) and 90.56 (12.0) (high GI), respectively. *Akok* is made from eggs as the main ingredient and hence higher protein content compared with *apam ayu* and *mek comel* which mainly high in wheat flour. Several studies supported that protein addition in food had reduced glucose and increased insulin response (Frid *et al.,* 2005; Te Morenga *et al*., 2012; Wolever & Bolognesi, 1996). Fajans *et al*. (1967) suggested that amino acids in combination with leucine or not may stimulated insulin secretion after high-protein meals (cooked chicken liver or beef) consumption in healthy subjects (Fajans *et al*., 1967). Another study showed that proteins delayed gastric emptying and subsequently potentiates the effect of insulin on glucose removal from the circulation (Ranawana & Kaur, 2013). *Akok*, *apam ayu* and *mek comel* are cooked differently. *Akok* is baked in the oven while *mek comel* is deep fried in oil while *apam ayu* using steam method. Baking, steaming and frying might have different effects on starch gelatinization and retrogradation (Fernandes *et al*., 2005). Previous study showed that baked potatoes had a lower GI compared with boiled potatoes (Fernandes *et al.,* 2005). In our study, *akok* (prepared by baking) had the lowest GI compared with *apam ayu* and *mek comel*.

Apart from the sweet snacks, *keropok lekor* is a famous snack in Terengganu and it is available throughout the day. It is normally eaten as fried or boiled. *Keropok keping* (fish crackers) is also available throughout the day and normally eaten as a crisp or as a garnish with main dish such as *nasi kerabu* (traditional rice cooked with coconut milk and served with grated coconut and fish floss). Boiled and fried *keropok lekor* showed higher GI compared with *keropok keping*. *Keropok lekor* is prepared with sago flour which contains high proportion of amylopectin to amylose (Ahmad *et al.,* 1999). Branched amylopectin is more easily hydrolyzed in the gut than linear amylose and hence, higher glycemic response (Behall & Hallfrisch, 2002; Amelsyvoort & Weststrate, 1992). The ingredients, preparation and processing method of *keropok keping* and *keropok lekor* are similar except for the final production stage. *Keropok keping* is sliced into one to two mililitre thickness and then sun-dried for few days. Both fried *keropok lekor* and fried *keropok keping* are cooked by using deep frying technique. Several changes occurred during this process including heat and mass transfer, water evaporation and formation of the cellular porous structure, loss of moisture content, protein denaturation, starch gelatinization and color development (Bhat & Bhattacharya, 2001; Krokida *et al.,* 2000; Maneerote *et al*., 2009). Apart from cooking technique, cooking time will also affect GI. Longer cooking times may increase the glycemic impact of a food by breaking down the starch or carbohydrate and allowing it to pass through the body more quickly when consumed (Singh *et al.,* 2010). This study showed longer cooking time for fried and boiled *keropok lekor* had increased the GI values. The normal process of boiling the *keropok* dough itself require about an hour. This result was consistent with recent study exhibited that longer time cooked pasta had slightly higher GI than pasta cooked al dente 5 to 10 min (Kirpitch & Maryniuk, 2011). Fried *keropok keping* has low GI value and this could be due to higher fat contents compared to boiled and fried *keropok lekor*. Previous study showed that the addition of fat to carbohydrate-rich foods reduces glycemic responses by delaying gastric emptying, stimulating insulin secretion and subsequently reduce the GI value (Pi-Sunyer, 2002; Nuttall & Gannon, 1991). Hence, this result must be interpreted with caution. Low GI food may not be necessarily good for human health and must take into consideration the fat content.

This study suggests that that starch-based food affect glucose response differently. The GI of starch-starch based local Terengganu foods were in the order of fried *keropok keping* < fried *mihun* < *akok* < fried yellow *mi* < fried *keropok lekor* < boiled *keropok lekor* < fried *kuay teow* < *mek comel* < *apam ayu*. The GI index of foods depends on the factors such as cooking method, food processing, food structure and the macronutrient composition.

ACKNOWLEDGMENT

The authors would like to thank the subjects for their voluntary participation and Universiti Sultan Zainal Abidin (UniSZA) for the laboratory facilities.

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