



Glycaemic Indices of the Traditional Sago-Based Snack and Staple Food in Sarawak, Malaysia

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Abstract

Sago (*Metroxylon sagu*) starch was the staple carbohydrate source in Sarawak, Malaysia. *Saguk* and *Linut* are two well-known traditional Sago foods. Like many traditional Sago foods, their glycaemic index (GI) has yet to be established. This study aimed to determine the GI for *Saguk* and *Linut*. Isoglucidic servings containing 50g available carbohydrate for both foods and glucose drink as reference, were consumed by 12 healthy subjects. Blood was drawn at predefined intervals for 2 hours to measure postprandial glycaemia and subsequently to determine the GIs. *Linut* and *Saguk* demonstrated "moderate to high GI" and "moderate to low GI" values of 69.8 ± 5.5 and 46.9 ± 5.1 . In addition, glycaemic load (GL) at various serving sizes was also evaluated. Serving sizes illustrated as one quarter, half and three quarters of a regular rice bowl, yielded "low to high" GLs values from 10.0 to 27.4 for *Linut*, while "low to moderate" GLs values from 5.9 to 17.6 for *Saguk*. Albeit its high GI, the GL for *Linut* at a serving size of up to half the volume of a regular rice bowl was moderate, thus suggesting a healthier serving *Linut* indulgence. This visualization is thought to be useful as portion control for *Linut*. This low GI characteristic of Sago is believed to be attributed to its resistant starch (RS) content. The marked GI difference between *Saguk* and *Linut* was the result of "wet" and "dry" heat treatments, which has profoundly affected the starch structure resulting in loss of RS, thus increasing starch digestibility. It is therefore noteworthy to exercise caution and refrain from any generalisation that meals composed predominantly from high RS sources such as Sago starch would elicit low glycaemic response. This can lead to erroneous deduction if factors such as food processing and glycaemic burden per serving are not judiciously considered.



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Introduction

Globally, the incidence of Type 2 diabetes mellitus (T2DM) continued to be on the rise. In Malaysia alone, the National Health and Morbidity Survey (NHMS) 2019 revealed that the prevalence rate of T2DM among Malaysian adults has grown from 13.4% in 2015, to 18.3% in 2019.¹ Additionally, of the nearly 1.7 million patients registered with the National Diabetes Registry in 2020, 10.07% of the cases were reported in Sarawak.² The projected rise in the incidence of T2DM could develop into a substantial health problem worldwide. This is further exacerbated in the light of the COVID-19 pandemic, as diabetes patients suffer disproportionately from acute COVID-19. The higher rates of serious complications and death had posed challenges to primary caregivers to appropriately manage glycaemia in COVID-19 patients with diabetes comorbidity.³

It is widely accepted that diet and nutrition play an important role in the prevention and management of diabetes. The wake of diabetes awareness has led to increasing interest in the role of low glycaemic index (GI) diet to reduce the risk of metabolic diseases including diabetes. GI is used to classify food based on their postprandial blood glucose raising potential. GI is defined as incremental area under blood glucose response curve (iAUC) expressed as a percent of the response, after consuming a test food that contains isoglucidic amount of either 25g or 50g of available carbohydrate to that of a standard food consumed by the same subject.⁴ In a low-GI food, longer time is required by the body to convert carbohydrate to glucose hence reducing both the postprandial glycaemic and insulinaemic response in our body. Thus, GI is widely used as a guide for food choices. In addition, a food GI is closely related to the digestibility of carbohydrate present in such food. Slower rate of digestion and absorption was identified as the factor to result in a gradual and controlled rise in postprandial glycaemia hence the food GI.^{5,6}

One of the main limitations in GI is, it does not take into consideration the amount of carbohydrate consumed even though this is a primary predictor of glycaemic response, and this has led to introduction of Glycaemic Load (GL).⁷ While GI tells us about the quality or type of carbohydrate

of a food, GL associates this information with its serving size. Up to this point, GI is established based on the portion of either 25g or 50g of available carbohydrate. However, almost always, this serving size is usually too big and does not represent the regular serving size of the food. A classic example is watermelon, which although the GI is high, it has a low GL because of the typically small serving size.⁸ Essentially, as the name implies, food with higher GL is expected to elevate postprandial blood glucose more than that of a lower GL. As a rule of thumb, foods that have low GL almost always have low GI, while those with an intermediate or high GL may have GI ranging from very low to very high.⁹

Before the introduction of rice, Sago starch was the staple carbohydrate source in Sarawak and some areas in Indonesia. Currently it is still widely used to make different types of food, such as Sago pearls, *tebaloi* (a popular biscuit), *keropok* (shrimp crackers), puddings and jellies.¹⁰

The Sago-based test foods tested in this study were *Saguk* and *Linut*. These two foods are indigenous to Sarawak, and largely consumed by the Melanau ethnic group, given the fact that Sago palm holdings are primarily located within their population locality. However, these foods can now be found widely throughout Sarawak.

Saguk is typically made by mixing Sago starch with ingredients among which includes desiccated coconut, coconut milk, rice husk, oil, water, and salt.¹¹ The composite is shaken horizontally on a traditional sieve. Continuous agitation will aggregate the composite into many small pearl-shaped *Saguk*. *Saguk* is then slowly roasted over wood fire which gives it the charred aroma. Traditionally *Saguk* is eaten on its own as snack, and can also be eaten with fish to replace rice in a main dish.

Linut has glue-like texture as it is in fact the gelatinized Sago starch and is typically eaten with sambal - a condiment made from shrimp paste, chillies, and lime. As a complete meal, *Linut* is also eaten with dishes such *asam pedas* (sour and spicy fish stew), to replace the carbohydrate component of rice.¹²

Like many traditional Sago meals, both *Saguk* and *Linut* have yet to have their GI determined. Therefore, the aim of this study was to measure the GI of two Sarawak's traditional carbohydrate-rich foods made from Sago starch. Subsequently the GL of these Sago foods at illustrative serving sizes were determined. This information will provide an idea of how these traditional foods should be consumed with a view to manage glucose intake. In addition, some insight on factors influencing starch digestibility which in turn affecting the GI of Sago food is also demonstrated.

Materials and Methods

Nutritional Analysis

Nutritional analysis for *Saguk* and *Linut* were conducted using proximate method stipulated in the Association of official Analytical Chemists (AOAC) standard methods, namely for protein, fat, ash, and moisture. Total carbohydrate was determined by calculation, while total dietary fibre was determined using method AOAC991.43. The available carbohydrate was then calculated by subtracting total dietary fibre (TDF) from the total carbohydrate obtained. Finally, the serving size that contained 50g available carbohydrate for both foods were determined accordingly. In this study, *Linut* was served with commercial ready-to-eat sambal (Adabi® *Sambal belacan pedas manis*), of which the nutritional information was obtained from the product label.

Preparation of Test Foods

Saguk used in this study was procured from a well-known *Saguk* entrepreneur from Kampung Medong, Dalat, Sarawak. Their product was synonymous with the brand of *Saguk* Medong as one of highly sought after *Saguk* in the state. Despite years of business, the production was still maintained at cottage industry level.

In this study, *Linut* was prepared fresh on test day. *Linut* with the right consistency was obtained by slowly adding 500ml of water to 88.5g of Sago starch, whilst heating over stove with rigorous stirring. *Linut* was ready when the starch had completely gelled and became translucent. The proper amount of *Linut* according to serving size determined was taken from this preparation. Likewise, an appropriate amount of sambal was served with

Linut. The available carbohydrate contributed per serving from both *Linut* and sambal were 47.5g and 2.5g respectively, which total to 50g as required by the study.

Glucose, D(+)-Glucose anhydrous (HmbG Chemicals) was the reference food chosen for this study. To prepare the glucose drink, 50g of D(+)-Glucose anhydrous was dissolved in 250mL water.

Glycaemic Index Study

The ethics and conduct of this GI study was reviewed and approved by Crop Research and Application Unit (CRAUN) Research Committee, Kuching, Sarawak (Approval number: CRAUNRC/20/01/IHGI20001) and carried out in accordance with Food and Agriculture Organisation (FAO) Food and Nutrition Paper on the Definition of Glycaemic Index. In line with the principle of good clinical practice, informed consent was obtained from all subjects prior to conducting the study.

This study targeted to recruit 12 subjects and inclusion criteria for these subjects include, healthy male or female subjects (not pregnant or lactating) aged between 18 – 55 years, who had body mass index (BMI) within 18 – 30 kg/m², who were not diabetic or prediabetic with fasting blood glucose (FBG) ≤ 5.6 mmol/L and 2-hour postprandial glucose level ≤ 7.8 mmol/L after an oral glucose tolerance test (OGTT). Prior to enrollment to the study, the OGTT screening was conducted by PathLab, an external medical pathology lab. Only subjects who fulfilled these inclusion criteria were recruited for the study. All subjects are required to complete five periods on separate days. This includes three periods for glucose drink and a period each for *Saguk* and *Linut*, of which sequence was in random order. Each food was served with 250 mL water, while the glucose drink was dissolved in an equal amount of water. The subjects were required to fast overnight for at least 10 hours prior to attending the study site in the morning. The study was held at Downstream Technology Division (DTD) food pilot plant, CRAUN Research Sdn. Bhd., Kuching, Sarawak.

Blood glucose samplings were done on -15 minute and 0 minute before food intake and the mean was regarded as the fasting or baseline glucose level. Minute zero was timed starting from the time

subject took the first bite of the foods or first sip of the glucose drink. Subsequently, blood glucose samplings were done on 15, 30, 45, 60, 90, and 120 minutes postprandial. Finger-prick capillary blood was sampled using sterile, single-use lancing device (Accucheck Safe-T-Pro Plus; Roche Diagnostics) and blood glucose was measured using glucometers (AccuChek Guide; Roche Diagnostics). Capillary blood sampling is the recommended blood glucose measurement method in a GI study by FAO guideline.⁴ In addition, capillary blood glucose was found to have smaller variability in determining GI value of food than venous blood glucose testing.¹³

Glucose response curve, GI and GL Evaluation

A glucose response curve was plotted and incremental area under the curve (iAUC) above the fasting glucose level were calculated according to the trapezoidal rule for each food.⁴ For each subject, iAUC of each test food ($iAUC_{test}$) was divided by mean iAUC of glucose drink from three repeated trials ($iAUC_{reference}$) and then expressed a percentage. The resulting values from all subjects were then averaged to calculate the GI for each test food.

$$GI = iAUC_{test} / iAUC_{reference} \times 100$$

The GI value of carbohydrate-rich foods can be classified as low (GI = <45), medium (GI = 46–69), and high (GI = >70).¹⁴ The GI values obtained for both *Saguk* and *Linut* were then compared using t-test assuming unequal variances, with significance level set as $p < 0.05$.

GL is determined using the GI value obtained. GL is defined as product of the available carbohydrates in grams in a serving of such food, and the food's GI and calculated as follows.⁸

$$GL = GI/100 \times \text{Available CHO in the serving (g)}$$

The GL value can be classified as low (GL = <10), medium (GL = 11 – 19), and high (GL = >20).⁹ Results were presented as mean \pm SEM. Computational for iAUCs were calculated using GraphPad Prism version 5.01 and other calculations and statistic were done in Microsoft® Excel® 2016 and SPSS 21.0.

Results

Nutritional Analysis and Available Carbohydrate Determination

Table 1 depicts the nutritional analysis results for both test foods and Sambal which was served with *Linut*. Both fat and protein were not detected in *Linut* samples as the ingredient was solely Sago starch which has low protein and fat content. A serving of 68g of *Saguk* was determined to provide 50g available carbohydrate. Meanwhile, the amount of available carbohydrate in a serving of 363.0g *Linut* was 47.5g. Small portion of Sambal contributed to the remaining available carbohydrate to make up to the serving size required by the study. As an illustrative the serving of 363g of *Linut* is equal to one heaped regular rice bowl. The volume of the bowl used in this study is approximately 280mL.

Table 1: Nutritional and available carbohydrate determination for test foods

	<i>Saguk</i>	<i>Linut</i>	<i>Sambal</i>
Total Energy (kcal/100g)	466	54	220
Carbohydrate (g/100g)			
Total (g/100g)	76.7	14.1	30.0
Total Dietary Fibre (g/100g)	3.7	1.0	4.4
Available (g/100g)	73.0	13.1	25.6
Fat (g/100g)	17.5	N.D	9.2
Protein (g/100g)	2.3	N.D	4.3
N.D – not detected.			

Baseline Characteristics of Subjects

The baseline characteristics of these subjects at screening, data are presented as mean ± standard deviation (Table 2). 12 subjects were successfully recruited and out of the 12 subjects, eight were males. All twelve subjects managed to finish the glucose drink and *Saguk* within time required. However, four subjects did not manage to finish even up to half the serving of *Linut* given to them. Therefore, their data were discarded in considering the GI value for *Linut*. The exclusion of these four subjects did not adversely affect the GI consideration as the FAO Food and Nutrition Paper recommended at least seven subjects for a GI study⁴ Therefore, for *Linut*, only data from the remaining eight subjects was considered. Their primary reason to reject *Linut* was due to its texture.

Given its glue-like nature, *Linut* is a type of food which may not have the sensory cues, but it can develop acquired preference over time. Although *Linut* is a traditional food in Sarawak, it is however has becoming a less common staple among the

younger generations. If future study were to be conducted, especially involving food atypical to normal liking, it would be wise to have the subject consuming and test the food as a practice prior to commencing the study, to mitigate risk of losing subjects due to protocol noncompliant.

Table 2: Baseline characteristics of study participants (N=12)

Parameter	N=12
Male	8
Age, year	31.2 ± 10.6
Body weight, kg	63.6 ± 11.1
BMI*, kg/m ²	22.8 ± 2.5
Fasting blood glucose, mmol/L	4.6 ± 0.4
OGTT post 2-hour glucose, mmol/L	5.5 ± 0.9
HbA1c	5.5 ± 0.2

*BMI, body mass index; OGTT, oral glucose tolerance test; Mean ± SEM (standard error of mean)

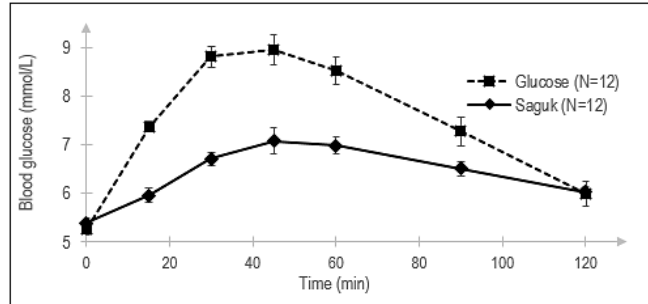


Fig. 1(a): Postprandial glucose response after consuming glucose (reference food) and *Saguk* (test food). Data collected from 12 study subjects. Data were presented as mean ± SEM.

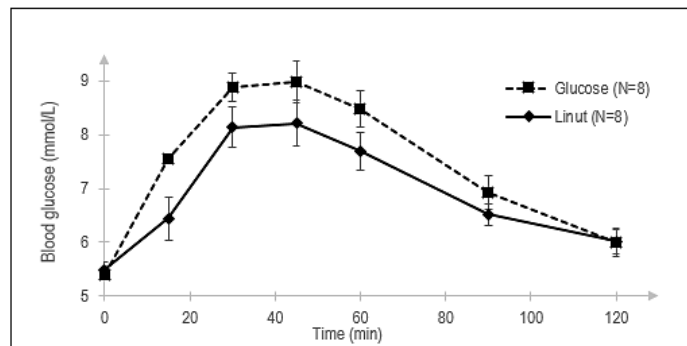


Fig. 1(b): Postprandial glucose response after consuming glucose (reference food) and *Linut* (test food). Data was only considered from the eight (8) subjects who managed to consume all the *Linut* served. Data were presented as mean ± SEM.

Glycaemic Index and Glycaemic Load Analysis

Postprandial blood glucose response after consumption of *Saguk* and *Linut* are presented in Figure 1(a) and Figure 1(b) respectively. The mean iAUCs and GIs for both *Saguk* and *Linut* as summarized in Table 3. From the analysis,

with the consideration of the standard error, it can be classified that *Saguk* has a moderate to low GI with GI value of 46.9 ± 5.1 . *Linut* on the other hand has a moderate to high GI value of 69.8 ± 5.5 . The difference in GIs between these sago foods is significant with $p = 0.009$ as in Figure 2.

Table 3: Mean iAUCs and GIs for *Saguk* and *Linut*.

	Saguk (N=12)		Linut (N=8)	
	Mean	SEM	Mean	SEM
iAUC _{test}	133.3	15.3	186.6	26.4
iAUC _{reference}	288.3	21.4	265.1	23.5
GI _{test}	46.9	5.1	69.8	5.5

iAUC, incremental area under the curve; GI, glycaemic index; SEM, standard error of mean.

‡ Only data from 8 subjects were considered in the evaluation of GI for *Linut*.

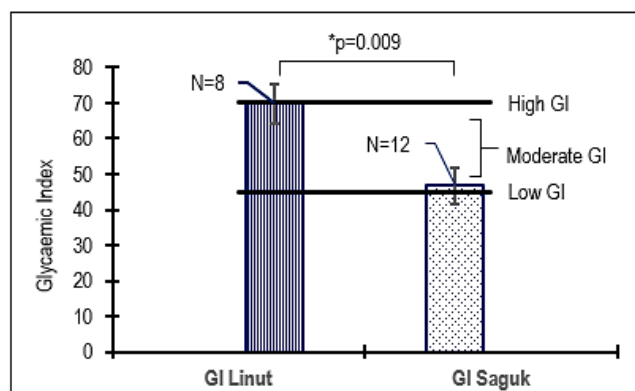
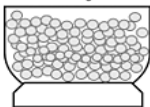
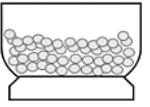
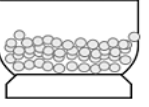
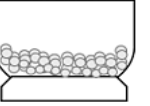

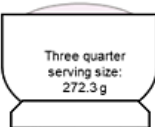

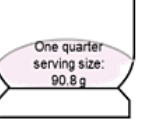


Fig. 2: Glycaemic indices (GI) values for *Saguk* (N=12) and *Linut* (N=8). The data represent mean \pm SEM from 12 subjects for *Saguk* and 8 subjects for *Linut*. Significant difference between the GIs of these two Sago foods, $p = 0.009$, t-test assuming non-equal variance

A further evaluation of the GL for these Sago foods is presented in Table 4. This GLs evaluation was attempted based on illustrative serving sizes relative to that of the serving sizes used in the GI study, which were 363g and 68g for *Linut* and *Saguk* respectively. Realistically the serving used in the GI study may be a bit too large than their regular serving sizes. In fact, the serving size for *Linut* in the GI study which can be visualised as heaped regular rice bowl, was deemed a lot by the study subjects.

GL evaluation revealed that if the size of serving for *Linut* is reduced to approximately a quarter of the amount that was served in GI serving, the GL is 10.0 which is still considered low. Half serving of *Linut* is reported to provide moderate GL of 18.3. Increasing the portion of *Linut* to approximately three-quarter of the GI study portion, will increase the GL further to 27.4 which is considered high. For *Saguk*, the GL ranges from 5.9 (low), 11.7 (moderate) and 17.6 (moderate) for serving of a quarter, half, and three-quarter of that served in GI study.

Table 4: Glycaemic load (GL) evaluation of Saguk and Linut at various serving sizes - illustrated as one-quarter, half and three-quarter of the size served for the GI evaluation.

Sago Food	Particulars	GI study serving	Illustrative Serving Sizes (Relative to that of the portion for GI study)		
			¾ Serving	½ Serving	¼ Serving
Saguk (GI = 46.80)	Illustrative sizes				
	Serving size (g)	68	51	34	17
	AVCHO (g)	50	37.5	25	12.5
	Glycaemic Load	-	17.6	11.7	5.9
	GL classification	-	Medium	Medium	Low
Linut (GI = 69.81)	Illustrative sizes				
	Serving size (g)	363	272.3	181.5	90.8
	AVCHO from Linut (g)	47.5	35.6	23.8	11.9
	AVCHO from sambal (g)	2.5	2.5	2.5	2.5
	Glycaemic Load	-	27.4	18.3	10.0
GL classification	-	High	Medium	Low	

‡ AVCHO – available carbohydrate

‡ GL for *Linut* is considered assuming the various serving sizes of *Linut* to be served with the equal amount of sambal as per GI study

Discussions

In this study, the GIs of *Linut* and *Saguk* were determined as 69.8 ± 5.5 and 46.9 ± 5.1 accordingly. Based on GI classification, these values are classified as being “moderate to high GI” and “moderate to low GI”. Traditionally, like rice, *Linut* is taken as main carbohydrate component in a complete dish. It is known that the GI for rice varies according to variety. The commonly eaten Jasmine white rice’s GI ranged from 80 – 92 which is categorized as high GI.^{15,16} Basmati rice which typically being labelled as “healthy rice” has a moderate GI of 55 – 62, and lastly Bario rice - a variety which is also indigenous to Sarawak demonstrated a moderate GI of 60 – 62.^{15,17} Thus, it is obvious that as main carbohydrate

component, when compared to Jasmine white rice, consuming *Linut* will have less effect on postprandial glycaemia.

A further evaluation of the GL revealed that, on regular-sized serving, the GL for *Linut* ranges from “low to high”, while *Saguk* reported GL from “low to moderate”. This GL evaluation should raise awareness regarding the appropriate portion control to consider for healthier indulgence of these Sago foods. As an example, despite *Linut* having moderate to high GI, it can still be enjoyed at a smaller portion. As shown in this study, even at a serving of up to 181.5g – which portion can be visualised as slightly more than half the volume

of a Regular rice bowl, the GL value was considered as moderate. This suggests that the serving size for a healthy *Linut* indulgence can be up to approximately half the volume of a Regular rice bowl. It should be interesting to learn the satiating effect afforded by these smaller servings of *Linut*, which evaluation was not covered in this study.

Unlike *Linut*, subjects considered the serving size for *Saguk* in this study was still appropriate. Its GL in regular-serving sizes ranged from low to moderate making *Saguk* a healthy snacking choice. The Sago characteristics for having low GI is believed to be attributed to the resistant starch (RS) content in Sago starch. RS is defined as the sum of starch and the product of starch digestion that resist digestion in small intestine of a normal human being.¹⁸ It acts more as dietary fibre for colonic fermentation by gut bacteria. From perspective of blood glucose control, food made from starch with high RS generally exhibit low GI value. It was reported that the RS content in native Sago starch ranged from 45.53 to 68.99%.^{19,20} Furthermore, analogue rice made from 100 percent Sago starch reported to exhibit low GI value of approximately 40.7.²¹

However, from this study it is evident that this is not necessarily true for *Linut*. Despite being made solely from high RS Sago starch, *Linut* has high GI, which was also significantly higher than GI for *Saguk* ($p=0.009$). This finding concurs to that of an earlier study which suggested various supplementation made from Sago such as porridge, paste and gel elicited high postprandial plasma glucose response.²² This finding thus suggested that for a starch-rich food, apart from RS content, there are additional factors that can affect digestibility and consequently the food's GI. Thermal treatment during food processing has been suggested as one of the factors to cause paramount effect on starch structure and consequently its digestibility.^{23,24} These thermal treatments may be divided into two types namely the "wet" methods such as boiling, steam cooking etc., and "dry" methods which include grilling, microwaving and roasting.

Of these methods, boiling in water has been suggested to result in rapid starch digestion. The crystalline structure of starch changes because of heating in a large volume of water, making it more

vulnerable to enzymatic hydrolysis.²⁵ In the similar manner to boiling, preparation of *Linut* requires Sago starch to be gelatinized, where starch and water are subjected to heat resulting in the starch granules absorbing water, swell and eventually burst to form gel. A gelatinized starch is more susceptible to enzyme hydrolysis and digestion. This is due to its amorphous nature which provides more binding sites for α -amylase and consequently will result in high GI food as was seen in *Linut*.²⁶

In contrast, when the "dry" heat treatment methods are used, less RS is affected thus, more native RS remain in product.²⁷ To date, *Saguk* production still uses the traditional method which involves roasting *Saguk* over wood fire in a specialized hut built with clay hearth.¹¹ This slow roasting may have managed to preserve the RS in *Saguk*, and it is evident in the value of GI obtained. The similar effect of "wet" and "dry" heat treatment was also demonstrated in baked potato which has higher RS content than that of the boiled ones.²⁷

Furthermore, incorporation of other ingredients in *Saguk* such as rice husk, desiccated coconut and coconut milk may also have some contributing factors in attenuating glycaemia. First, these ingredients can increase the amount of dietary fibres in *Saguk*. To date, the positive effect of high dietary fibre diet for glycaemic control has been widely established and accepted. Second is the possibility of interaction between Sago starch and fat, afforded by coconut milk and oil in *Saguk* which may have led to formation of amylose-lipid complex (ALC). This complex has recently been considered as a novel type of RS.²⁸ Depending upon digestive resistance mechanism RS may be classified into several types from type 1 (RS1) to type 4 (RS4).²⁹ Of the recent, several studies had suggested that ALC, either artificially created or formed during cooking, can be considered as type 5 resistant starch (RS5).²⁹ Meanwhile, native Sago starch is classified as RS2, which is the starch that is protected from digestion due to their crystalline structure.³⁰

The formation of ALC involved amylose morphing into a helix shape from its random coil structure in the presence of lipids, and therefore making alteration to its glycosidic bonds' torsion angles. This change in angle consequently result

in a structure less accessible to digestive enzymes, thus increased the resistance.²⁹ In preparation of *Saguk*, lipid from coconut milk and oil may have interacted with amylose from Sago starch to form ALC, this however requires further elucidation. Using the complexing index (CI), the extent of ALC formation can be determined with Iodine via colorimetry approach.³¹ This was not covered in this study and should warrant for future research.

Up to this point, it is clear that food processing profoundly affects a native starch's ordered structure which on its own, acts as natural physical barrier to enzyme digestion.³² In many foods, such structure is destroyed due to hydrothermal processes, which promotes partial or complete starch gelatinization.^{33,34} This implicates in loss of that resistive structure in native starch, and therefore increased enzyme digestibility. *Linut* and *Saguk* have demonstrated the impact of "wet" and "dry" thermal treatment, evident through the value of GI obtained. That being said, other food processing treatments regardless of "wet" or "dry" such as baking, frying and storage conditions were also found to have the potential to alter the RS content hence digestibility of foods.³⁵

To a certain extent, this study also suggested that incorporation of RS into food products may not always be straightforward and one that requires thoughtful considerations. Earlier studies suggested that 20 to 30g of RS can provide the physiological benefits to human.^{36,37} However, it is now understood that often the RS fraction of a food is compromised by conventional food processing.³⁸ As a result, method to increase the RS content either in raw starch as ingredient, or in processed foods, as well as overall strategies to slow the digestion of starchy food, are being studied extensively.^{24,39}

That being said, this study is not without any limitations. One of the limitations is the *Saguk* used in this study was obtained from only one *Saguk* supplier. As the recipe and processing can differ from one supplier to another, it would be of interest to examine the GI of *Saguk* from these various suppliers. Another limitation is the study was conducted with relatively small sample size

especially for *Linut*, which was almost close to the bare minimum size for GI evaluation according to the FAO guidelines.⁴

Conclusion

This study has managed to determine the GI of traditional Sarawak Sago foods namely *Linut* and *Saguk* which had never been established before. *Linut* and *Saguk* demonstrated "moderate to high GI" and "moderate to low GI" values of 69.8 ± 5.5 and 46.9 ± 5.1 respectively. Serving sizes illustrated as one quarter, half and three quarter of a regular rice bowl, yielded "low to high" GLs values from 10.0 to 27.4 for *Linut*, while "low to moderate" GLs values from 5.9 to 17.6 for *Saguk*.

Finally, this study has also managed to yield some insights to factors which may affect digestibility hence the GI of these Sago foods and starch-rich food in general. Despite earlier studies suggesting Sago starch as having low GI value, this however was not the case for *Linut*. It became evident that for *Linut*, hydrothermal cooking has gelatinized the Sago starch and altering its structure, resulting in loss of native RS thus increased starch digestibility and GI. Contradictorily, "dry" heat treatment for *Saguk* may have preserved its native RS.

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Conflict of Interest

All authors are the employee of CRAUN Research Sdn Bhd, where CRAUN Research is an agency entrusted by Sarawak State Government to spearhead Sago Research in Sarawak.

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