

Glycemic responses by coconut (*Cocos nucifera*) jaggery and cane sugar (*Saccharum officinarum*): A comparative study

ABSTRACT

Aim: Cane sugar (*Saccharum officinarum*) and (*Cocos nucifera*) jaggery are prominent sweeteners. The aim of this study is to evaluate Glycemic Indices (GI) of cane sugar and coconut jaggery using healthy human subjects.

Place and Duration of Study: The research was conducted as a collaborative project with Coconut Research Institute Sri Lanka and National Hospital Colombo Sri Lanka, between 2019 to 2020.

Methodology: Starch fractions (Total starch - TS, Resistant starch – RS and Digestible starch – DS) and sugar profile of two test foods were analyzed. Thirty six (n=36) healthy volunteers were recruited and were subjected to health screening. Fifty grams of digestible carbohydrate containing test food portions were given for each subject who had been fasting for 8 - 12 hours. Intravenous blood samples were collected to analyze blood glucose concentration.

Results: Cane sugar contained high percentages of TS (95.86 ± 1.58 %), DS (95.73 ± 1.59 %) and RS was just 0.13 ± 0.02 %. Coconut jaggery contained a lower percentage of sucrose (76.12 ± 1.62 %) and glucose (5.22 ± 0.11 %). Healthy volunteers (25.95 ± 3.62 years) whom were having healthy fasting blood glucose concentrations (73.54 ± 8.89 mg/dl) and HbA1c (5.05 ± 0.35 %) were tested with glucose, and the two test foods.

Conclusions: There was no significant difference ($P > 0.05$) between blood glucose response curves and GI of coconut jaggery (65.19 ± 36.53) and cane sugar (60.76 ± 35.80), where both can be considered as moderate GI sweeteners.

Key words: cane sugar, glycemic Index, coconut jaggery, glucose response

Abbreviations:

Glycemic Indices – GI

Total starch - TS

Resistant starch – RS

Digestible starch – DS

1. Introduction

Sugar cane, sugar beet and palm trees are used for sugar production to accomplish the consumer demands. Asia is the world largest sugar consumer which includes 6.3 million tons of annual consumption of sugar with the 14.9 kg of per capita sugar intake [1]. Sweetness, texture and viscosity of food and beverages are enhanced with natural and synthetic sweeteners. Greater consumption of such food has impacted on the rise of non-communicable diseases such as diabetes, obesity, hypertension, heart diseases and many other related concerns [2]. Therefore, consumers prefer sweeteners such as jaggery which is a traditional sweetener, especially among rural communities, which is believed to be healthier.

Solid jaggery, liquid jaggery and powdered jaggery are the main three forms of jaggery sold in the world market. The solid jaggery is the concentrated sugar present in sugarcane juice or palm sap. Jaggery is unrefined whereas sugar is crystals of sucrose present in the respective juice [3]. India is the pioneer of sugar and jaggery producer in the world which accounted more than 70% of the total production. Sugarcane jaggery is more popular and it is about 65 % of world jaggery production [4]. The remaining 30% of the world jaggery requirement is fulfilled by the harvested palm sap. Palm jaggery is prepared from concentrating palm sap/nectar that is collected from tapping of immature inflorescence [5] with the help of fermentation inhibitors. Different types of palm tree such as Palmyra (*Borassus flabellifera*), wild date palm (*Phoenix sylvestris* L), kitul (*Caryota urenes*) and coconut (*Cocos nucifera* L.) are tapped for unfermented sap collection followed by preparation of jaggery [6] by concentrating it.

Jaggery is rich with Fe and it helps in reduction of anemia. It has the ability of cleaning the blood, lungs, stomach, intestine, respiratory track and curing ability against asthma, cough and congestion [7]. Digestibility of food depends on the physical and chemical characteristics; if rich in dietary fiber, lower rate of digestibility has been observed [8]. Food is categorized based on its glucose response behavior referred as the glycemic index (GI). GI is defined as the area under the β -glucose response curve (IAUC) after consuming 50g of digestible carbohydrate contain test meal to the blood glucose response of 50 g of pure glucose or white bread by the same healthy individual. Glucose or white bread is used as standard food with a GI value of 100 [9]. Then, food is ranked in three categories as a low glycemic food (<55), medium glycemic food (56-69) and high glycemic food (>70) [10].

The coconut sap collection method and processing methods may impact on physical and chemical nature of the food and eventually, to blood glucose responses. Therefore, this study aims to investigate glycemic responses by pure coconut jaggery prepared using a novel sap collection method that didn't use any fermentation inhibitors, and to compare that with cane sugar's GI using human subjects.

2. MATERIAL AND METHODS

2.1 Test foods

Unfermented coconut sap was collected from a novel sap collection device developed at the Coconut Research Institute - Sri Lanka, without adding any anti-fermenting agents. The device comprised with a cooling compartment with ice cubes to keep coconut sap sugar without getting fermented to alcohol. The sap collected as above was used for the preparation of coconut jaggery. The jaggery was stored in dried clean glass bottles until further analysis. The cane sugar and the reference (glucose) was purchased from the local market.

2.2 Total starch, Resistant starch and Digestible starch

Proportions of total starch (TS) and resistant starch (RS) of jaggery and cane sugar were analyzed by an in-vitro enzyme analysis method [11]. Glucose concentration of the sample was analyzed by the glucose determination kit (GOD PAP, France) and starch percentage were calculated by multiplying factor of 0.9. Digestible starch (DS) fraction of the sample was determined by subtracting the values of resistant starch from total starch.

2.3 Sugar profile

Sugar profiles of the samples were analyzed using High Performance Liquid Chromatography (HPLC-Agilent1100) using a Waters™ Sugar-Pak™ column at 90 °C. Coconut sap and cane sugar was diluted 200 times with MilliQ water and filtered through 0.45 µm nylon syringe filter. 20 µl was injected manually. The calibration curves for sucrose, glucose and fructose were constructed using a standard sugar solution from 0.05 % to 2%. The sample was eluted with Milli-Q water at 0.5 ml/min flow rate and detected through the RID detector (Agilent 1100). The concentration of each sugar type was determined using calibrated curves. The total sugar content of each sample was calculated by compiling value of each type of sugar concentration.

2.4 Selection of healthy volunteers

The ethics clearance was granted by the Ethical Review Committee of the National Hospital Colombo Sri Lanka (ETH/COM/2017/03). The subjects (n=36) were recruited by randomized method, keeping an equal gender balance. Healthy volunteers were recruited and the age of the participants were 20-40 years with body mass index 18-25. Initial health assessments of subjects were done through evaluating blood pressure, FBS, HbA1c and lipid profile to make sure they are not having any non communicable health disorders.

2.5 Experimental design

Written consent from the subjects was taken and they were educated with the protocol of the experiment. The subjects were advised to fast 8-12 hours overnight. Cane sugar, pure coconut jaggery and the standard (glucose) were served three days by keeping a weeks' gap. Fifty grams of digestible carbohydrate containing test food portion sizes were used in wet weight basis. Cane sugar and glucose were dissolved in 250 ml of water and coconut jaggery was served as a solid food with 250 ml of water. The subjects were requested to complete consumption within 10 minutes after ingestion.

2.6 Blood sample collection

After the fasting period, intravenous blood samples of subjects were collected from the antecubital fossa as baseline data. Blood samples were collected during a 2 hr period, keeping 30 min gaps (0 min, 30 min, 60 min, 90 min, and 120 min). The sample collection was done by a well trained nurse at *the Center for Diabetes, Endocrinology and Cardio Metabolism (Pvt) Ltd.*

2.7 Blood sample analysis

Blood glucose concentration was analyzed using Randex Imola (RX 4900) fully automated glucose testing machine after the separation of plasma using a centrifugal force (Avanti J -15R) at 2500 rpm for 10 min.

2.8 Area of glucose response curve of subjects and Glycemic Index

Mean blood glucose concentration (BGC) values were plotted against the time as described by FAO (1998) [9] to obtain β -glucose response curve. Mean value of glycemic index for both test foods was calculated, using glucose as the standard. Fasting blood glucose response of each subject was considered as the baseline for the area calculation. The area under the curve (AUC) of graphs were calculated by the trapezoid rule by dividing graph into trapeziums and triangles. Glycemic indices of the samples were determined by dividing AUC of the test food by the AUC of the standard [12].

2.9 Peak delay and percentage of peak reduction

Peak delay was evaluated as the time difference between the peak points of the standard (glucose) and test foods. The difference in BGC of the test food and the standard was calculated and it was divided by the fasting BGC of reference food to take a percentage of peak reduction of the test food sample.

$$\% \text{ Peak reduction} = \frac{\text{Peak BGC of standard} - \text{Peak BGC of test food}}{\text{FBGC of the standard}} \times 100 \%$$

2.10 Data analysis

AUCs were calculated using Microsoft excel. Minitab software was used to analyze the difference of BGC at each sampling point through ANOVA. There mean values were separated from Tukey's test at the significance level of 0.05.

3. Results and Discussion

3.1 Total starch, Resistant starch and Digestible starch

Table 1 shows the total starch (TS), resistant starch (RS), digestible starch (DS) and sugar profile of cane sugar and coconut jaggery.

Total starch and digestible starch content of cane sugar were higher in contrast to the comparatively high resistant starch content in the coconut jaggery. The glycemic index of a food depends on the proportions of resistant starch; amylose and amylopectin ratios and many other facts [13]. Minor differences in resistant starch quantities between coconut jaggery and cane sugar might not have a considerable role in the reduction of glycemic responses. Although resistant starch has an ability of escaping digestion in the small intestine [14].

Table 1. Starch fraction and sugar profile of cane sugar and coconut jaggery

Treatment	TS%	RS%	DS%	Total sugar %	Sucrose %	Glucose %	Fructose %
Cane Sugar	95.86 ± 1.58 ^a	0.13±0.02 ^b	95.73 ± 1.59 ^a	95.53±0.62 ^a	86.99±1.43a	8.57±0.93a	0.00b
Coconut Jaggery	85.69 ± 0.94 ^b	0.28± 0.07 ^a	85.42± 1.00 ^b	88.04±1.03b	76.12±1.62b	5.22±0.11b	6.69±0.47a

Means with different superscripts are significantly (p<0.05) different from each other's along each column. TS% - Total starch, RS% - Resistant starch, DS% - Digestible starch

According to the sugar profile of cane sugar and coconut jaggery, fructose is existing only in coconut jaggery. Significantly higher glucose (8.57±0.93%) and sucrose (86.99±1.43%) was in cane sugar. Glucose has ability to absorb into the blood directly without going through the hydrolysis process and eventually it can raise blood glucose response. The fructose is a simple sugar, that has a low glycemic index of 23 and it is suggested as a healthy sweetener for diabetic patients [15]. Therefore, the fructose quantity of coconut jaggery does not affect significantly to increase the blood glucose response.

3.2 Health characteristics of subjects

Results of initial health screening test of healthy volunteers are shown in Table 2.

Table 2. Characteristics of healthy volunteers

Gender	Female	Male	Whole group	Reference
Age (Years)	26.41±4.42	25.63±2.99	25.95±3.62	20-40
BMI(Kg/m ²)	20.88±2.43	22.86±2.36	22.04±2.56	18-24
Pulse rate (min ⁻¹)	77.59±9.10	70.67±7.68	73.54±8.89	60-100
Blood pressure (torr)	109.82±13/77.12±8	118.67±11/74.67±11	115.00±13/75.68±10	90-120/ 60-80
FBS mg/dl	83.53±6.45	90.33±7.41	87.51±7.73	<100
TC mg/dl	206.76±41.57	189.17±38.08	196.46±40.03	<200
TG mg/dl	113.65±29.03	119.25±32.05	125.22±31.29	<100
Triglycerides mg/dl	69.41±15.63	126.79±64.65	114.20±73.10	<150
VLDL mg/dl	53.88±15.41	44.63±9.57	48.46±13.00	<40
LDL mg/dl	19.00±10.21	24.96±16.86	22.49±14.63	10-30
Non HDL mg/dl	152.88±34.99	144.54±36.15	148.00±35.48	<130
Total CHOL/HDL	3.95±0.94	4.32±1.10	4.17±1.04	<3.5
HbA1c (%)	4.98±0.32	5.07±0.38	5.03±0.35	4.3-5.6

BMI; Body Mass Index, FBS; Fasting Blood Sugar, TC; Total Cholesterol, LDL; Low Density Lipoprotein, HDL; High Density Lipoprotein, VLDL; Very Low Density Lipoprotein, HbA1c – Amount of sugar attached to the hemoglobin

The study group consisted with 36 subjects with female (18) and male (18). Fasting blood glucose concentration of the study group is 87.51±7.73 mg/dl and they did not show pre-diabetic (100 to 109 mg/dl) or diabetic status [16]. Percentage of HbA1c further conformed their average plasma glucose during twelve weeks, which should be less than 5.03±0.35 % level to be a healthy person [17]. Therefore, screening results clearly confirms the health status of selected persons.

3.3 Glucose responses by subjects

Glucose responses of cane sugar and coconut jaggery are presented Figure 1 with respect to the standard (glucose).

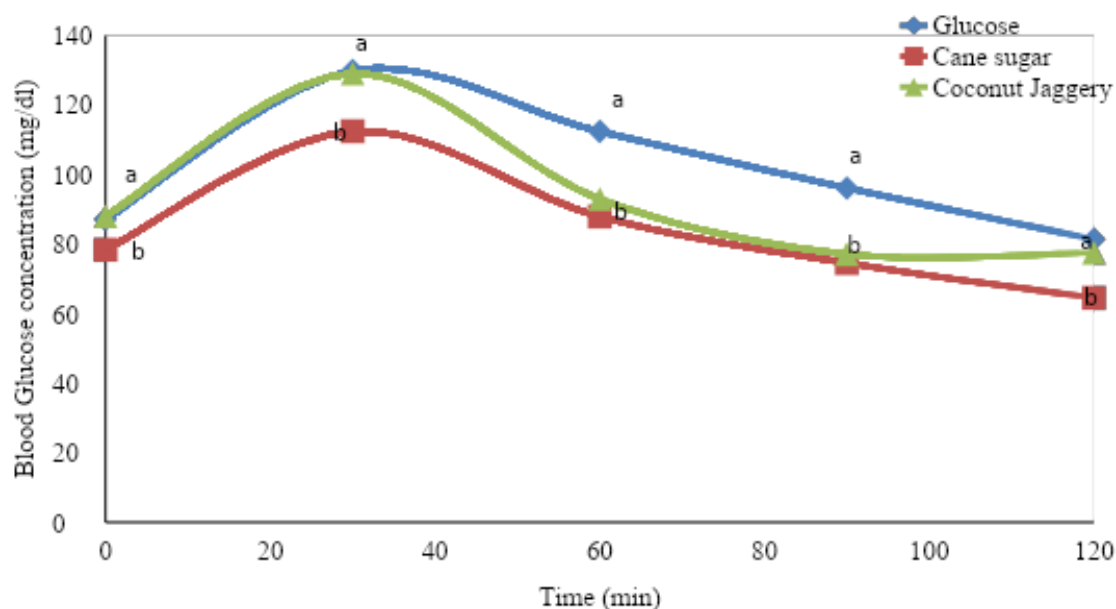


Figure 1: Glucose response curve of cane sugar and coconut jaggery

The peak glucose concentration of the standard and coconut jaggery were surging rapidly than the cane sugar, showing a significant ($p < 0.05$) difference at the 30 minute peak. The BGR curve of coconut jaggery has decreased rapidly to the 92.93 mg/dl, which is very similar to cane sugar at 90 minutes after food digestion. The blood glucose response of the standard was significantly greater at 60 and 90 min than both test foods. BGR curves prove that there was no significant different ($P > 0.05$) between cane sugar and coconut jaggery during in controlling glucose responses.

3.4 Peak delay and percentage of peak reduction

The blood glucose peak of the standard (glucose), cane sugar and coconut jaggery were in the similar position and it is 30 min after the food intake. Therefore, there is no peak delay for coconut jaggery and cane sugar.

The peak of glucose, cane sugar and coconut jaggery were 129.85 mg/dl, 112.45 mg/dl and 129.07 mg/dl respectively. Results of peak reduction evidently elicited that cane sugar has higher peak reduction of 19.98 % than the coconut jaggery (0.89 %). Thus, pure jaggery does not cause a significant peak blood glucose reduction.

3.5 Glycemic Indices

Glycemic indices of cane sugar and coconut jaggery are presented in Figure 2. There is no significant difference ($P>0.05$) between the glycemic index of cane sugar (60.76 ± 35.80) and pure coconut jaggery (65.19 ± 36.53). If the value of glycemic index of the test food is lower than 69 and can be considered as a medium GI food. The glycemic indices of coconut jaggery and cane sugar can be categorized as medium glycemic sweeteners.

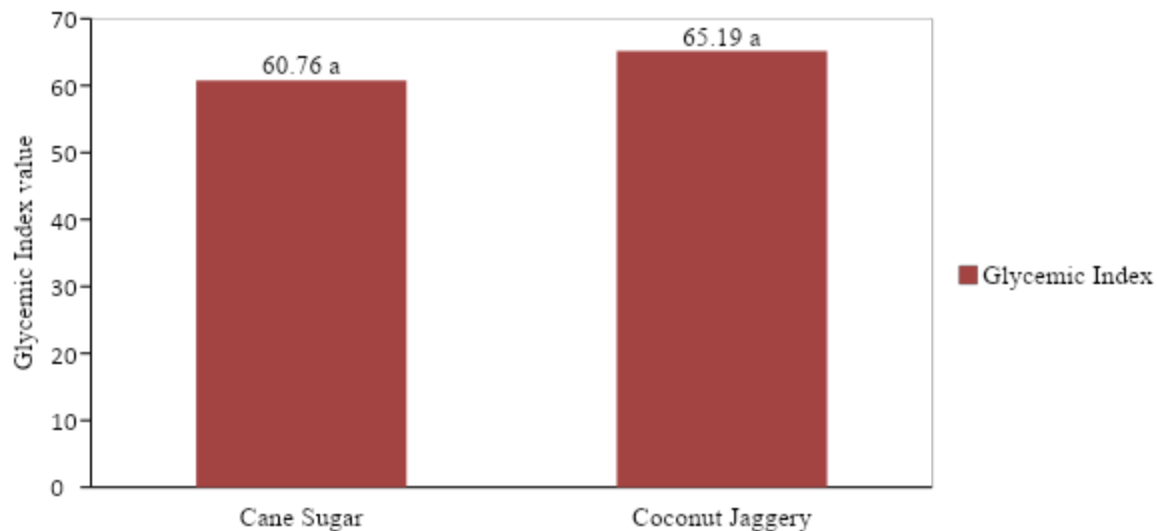


Figure 2: Glycemic Index of cane sugar and coconut jaggery

A previous study has proven that glycemic indices of Palmyra palm sugar, coconut sugar and cane sugar as 60 ± 4.2 , 56 ± 3.6 and 60 (medium GI food) respectively, and the results revealing that there was no significant difference ($P>0.05$) among three types of sweeteners [18]. Kalpana, 2014 [18] further said that, the slight reduction of GI of coconut sugar, might be due to the low concentration of fructose. Fructose is not absorbed directly and it's broken-down to glucose in the liver and a small concentration of glucose is released into blood circulation [19].

There is a negative relationship between resistant starch percentage and glycemic index of the food [20]. Different types of resistant starch such as matrix embedded starch (RS1), untreated resistant starch granules (RS2), debranched and recrystallized resistant starch by cooking and cooling processing (RS3) and structurally (chemically) modified resistant starch (RS4) have different glucose lowering potentials while RS4 has greater glucose lowering ability. Glycemic indices of beverages with two types of resistant starch of RS2 and RS4 were $34.9 \pm 11\%$ and $11.3 \pm 10\%$ respectively [21].

The largest discrepancy of glycemic indices of rice can be observed due to the processing methods, storage, cooking method [22]. The extrusion and parboiling process also increases the resistant starch content of the rice [23]. Moreover, the level of resistant starch and structure of resistant starch is affected for the variation of glycemic index of rice [24].

The glycemic indices of coconut jaggery and cane sugar in this study did not show significant differences ($P>0.05$) even though they had significantly different ($P<0.05$) level of resistant starch. It might be due to the variation of resistant starch structure of the coconut jaggery and cane sugar. The same results were resulted for edible film coated two types of rice varieties [25].

4. Conclusions

There were no significant ($P>0.05$) difference between glycemic indices of cane sugar (60.76 ± 35.80) and coconut jaggery (65.19 ± 36.53). Both cane sugar and coconut jaggery can be categorized as moderate GI foods.

Consent

All healthy volunteers gave their written consent for the sample collection. The form of written consent is attached herewith.

Ethical Approval

The ethics clearance was granted by the Ethical Review Committee of the National Hospital Colombo Sri Lanka (ETH/COM/2017/03).

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Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.