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Comparison of blood glucose responses by cane sugar (*Saccharum officinarum*) versus coconut jaggery (*Cocos nucifera*) in type 2 diabetes patients

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A B S T R A C T

Type 2 diabetic mellitus is a predominant metabolic disorder that has a direct impact on human health. Although scientific data are deficit, coconut jaggery has been suggested as a better alternative for cane sugar by some individuals. This study was conducted to assess the credibility of this claim. Coconut jaggery was prepared at Coconut Research Institute, Sri Lanka and nutritional composition of coconut jaggery was compared with cane sugar using standard methods. Significantly higher ($P < 0.05$) moisture (8.92 ± 0.22)%, ash (2.09 ± 0.33)%, protein (1.91 ± 0.28)%, fat (0.14 ± 0.02)% and fiber (0.05 ± 0.03)% contents were observed in coconut jaggery compared to cane sugar. The total starch and total sugar content of the coconut jaggery was significantly ($P < 0.05$) lower than that of the cane sugar. Forty-three patients (Male: 16, Female: 27) with type 2 diabetes from the Endocrinology unit, National Hospital Colombo, Sri Lanka were voluntarily engaged in the study, subjected to an initial health screening. Then, determination of postprandial blood glucose responses after intake of the standard (glucose), cane sugar and coconut jaggery. Average age of the selected group was (48.19 ± 7.95) years and they were all overweight (BMI > 23.0). The mean fasting blood glucose level and HbA_{1c} of the subjects were (149.05 ± 54.88) mg/dL and (9.170 ± 2.022)%, respectively. There was no significant difference ($P > 0.05$) in peak blood glucose concentrations or incremental area under the curve in blood glucose response of two test food. Therefore, coconut jaggery cannot be considered as a healthy substitute for cane sugar in type 2 diabetic patients.

1. Introduction

Consumption pattern of sugar rich food, beverages and confectionery directly affects on the blood glucose level, increasing threat of type 2 diabetes, obesity, hypertension and heart diseases [1].

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The American Diabetes Association [2] has revealed that 171 million characterized by hyperglycemia due to the deficiency of insulin secretion or seriously reduced action of insulin. Type 1 diabetes mellitus is caused due to destruction of β cells in the pancreas while type 2 diabetes mellitus is caused by the insulin deficiency and resistance, while gestational diabetes mellitus is recognized during the pregnancy [3]. Daily food intake of diabetic patients needs to be adjusted and it is very difficult to identify what type of food can be given to diabetic patients [4]. The failure of diet management by combining with physical fitness leads to damage of different body organs such as eyes, kidney, nerves, and cardiovascular system [5].

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Therefore, it is very essential to provide low glycemic healthy food and beverage options which have slow glucose releasing abilities for diabetic patients as well as for healthy individuals to maintain proper insulin regulation. Frequent consumption of high glycemic foods increases the risk of chronic diseases such as cardiovascular diseases and type 2 diabetes [6].

The glycemic index (GI) is measured by comparing hyperglycemic behavior of a particular food with a reference food; preferably glucose or white bread. It is defined as the incremental area under the β-glucose response curve of a tested meal containing 50 g of digestible carbohydrates and the incremental area under the β-glucose response curve of the standard food of 50 g of pure glucose [7].

Short-chain soluble carbohydrates such as granulated sugar are the frequently used sweeteners. These sugars are hydrolyzed into fructose and glucose to raise the blood glucose level immediately and results high GI values. Coconut jaggery is a traditional sweetener made from unfermented coconut sap and is believed to be a healthy substitute for cane sugar. It has been used as a medicinal sweetener in traditional medicine to purify blood, aids digestion and improves lungs health [8]. GI of coconut sap based sugar has been reported as 56.0 ± 3.6 and that of sucrose is 60 [9]. According to them coconut sugar and syrup made from coconut sap belongs to the low GI food category. Sagum and Arcot [10] have reported that processing condition and physiochemical properties of food have direct impacts on GI of the food. Therefore, the value reported for GI can change due to various technologies applied for manufacturing. There is a misconception that eating jaggery is healthier than eating table sugar (cane sugar) for diabetic patiens. However, it is not proven scientifically. Therefore, this study was designed to investigate glucose responses by coconut jaggery andcane sugar in poorly controlled diabetic patients, compared to the sugar standard, glucose.

2. Methodology

2.1 Test foods

The coconut jaggerywas prepared at Coconut Processing Research Division, Coconut Research Institute, Sri Lanka using pure unfermented coconut sap collected from Bandirippuwa Estate using novel sap collection device which is consisted a cooling compartment. Glucose and cane sugar were purchased from standard local suppliers.

2.2 Food composition analysis

The proximate composition of coconut jaggery and cane sugar (table sugar) was determined. The moisture content was determined using AOAC method 990.20 [11] and the results were expressed as fresh weight basis. Fat (Randle method: modification of AOAC method 920.39C), protein (Kjeldahl method: AOAC method 955.04), and ash (dry ash: AOAC method 900.02A) contents too were determined. The crude fiber content was determined by Fibertec method according to ISO 6865: 2000 method.

2.3 Total sugar content

Total sugar content was analyzed using phenol sulfuric method [12]. Known concentrations series of +D glucose were used to develop calibration curve. 1 mL of diluted 2 500 times sample was mixed with 1 mL of 5% phenolic solution and mixed well. Then 5 mL of concentrated sulfuric acid was added and the contents were kept 30 min for color development. One milliliter of water was used instead of sugar solution as a blank sample. Then the colors of the samples were measured at 490 nm using a spectrophotometer (UV 1800, Shimadzu, Japan) and concentration was determined using the calibration curve.

2.4 Total starch, resistant starch and digestible starch

Total starch and resistant starch of the coconut jaggery and table sugar were evaluated by incubating 100 mg of sample with the enzyme solution according to the method described by Goni et al. [13]. Glucose content generated by enzymes was determined using glucose oxidase-peroxidase enzyme kit (God Pap, France) using the procedure given by the supplier. Glucose concentration was converted into the starch percentage after multiplying by 0.9. The digestible starch fraction was determined by subtracting the content of resistant starch from total starch.

2.5 Selection of human subjects

Ethical clearance (ETH/COM/2017/03) was obtained from the Ethical Review Committee of the National Hospital Colombo, Sri Lanka (NHC-SL) and the permission was granted to carry out the clinical study at the Endocrinology unit, NHC-SL. Volunteers were recruited with their written consent at the Endocrine clinic, NHC-SL. Selected 43 human subjects of type 2 diabetes patients, who were 20−60 years of age and with no history of complications. They were subjected to measure height, weight, body mass index (BMI), pulse rate, blood pressure, fasting blood sugar (FBS) and HbA_{1c} for the purpose of screening.

The subjects who elicited HbA_{1c} less than 10% and prevalence of type 2 diabetes for 5−10 years were selected for the experiment. Patients having co-morbidities (ischemic heart disease, hypertension, renal disease) and recent diabetes related acute complications (hospital admission, blood sugar excursions needing adjustments in medications during the last 6 months) in the recent past were excluded. The 43 subjects were comprised of 27 females and 16 males.

2.6 Experimental design

The study was carried out as a randomized crossover design, following the international standard for GI test protocol recommended by the Food and Agriculture Organization (FAO) in 1998 [14]. Subjects were guided to fast 8−12 h before the experiment. Oral hypoglycemic was continued throughout the study, but the morning dose of insulin secretogogues was given after the test. 50 g of digestible carbohydrates containing glucose (50 g were dissolved in 250 mL water), coconut jaggery (50 g of solid jaggery with 250 mL water) and cane sugar (50 g were dissolved in 250 mL water)were given as serving portions and 3 different foods were provided in 3 separate days, keeping a 7 d gap. Glucose was used as the standard. The 3 types of foods were guided to consume within 10 min. Subjects were encouraged to keep physical activity to a minimum during the testing.

2.7 Blood sample collection

Before giving treatments, intravenous blood samples were collected at the antecubital fossa from the subjects who completed 12 h fasting period as a baseline. After serving food items, blood samples were collected at 30 min intervals for a period of 2 h (30, 60, 90, and 120 min). Blood samples were collected by well trained nurses at the Center for Diabetes, Endocrinology and Cardio Metabolism (Pvt) Ltd., Sri Lanka and separation of plasma was done by centrifugation (Avanti J-15R) at 2 500 r/min for 10 min. The glucose concentration of blood sample was analyzed by Randeximola fully automated glucose testing machine (RX 4900).

2.8 Blood glucose response curves

The glucose response curve for each subject were plotted and area under the β-glucose response curve for 2 h were calculated by the trapezoid rule using Microsoft Excel. The mean value of the area under the curve (AUC) was calculated on gender basis and as a whole group. The fasting blood glucose response of each subject was considered as the baseline for the area calculation.

2.9 Peak reduction and peak delay

The difference of peak blood glucose concentration (BGC) between the standard (glucose) and test foods was divided respectively by fasting blood glucose concentration (FBGC) of the standard, to calculate the peak reductionas following equation:

$$\text{Peak reduction (\%)} = \frac{\text{Peak BGC of standard} - \text{Peak BGC of test food}}{\text{Peak FBGC of the standard}} \times 100 \quad (1)$$

Peaking times were noted for each test food, to compare with that of the standard and time duration was recorded as peak delay.

2.10 Peak flattening rate

The peak flattening rate was calculated by blood glucose concentration reduction from peak level until 120 min, divided by time taken (t, min) as following equation:

$$\text{Peak flattening rate (\%)} = \frac{\text{Peak BGC of sample} - \text{Peak low level of BGC (120 min)}}{t} \times 100 \quad (2)$$

2.11 Data analysis

The area under the glucose response curves above the baseline were calculated for each patient for each sugar type using the trapezoid method using Microsoft Excel. The area under the glucose response, the dependent variable, was analyzed using ANOVA at the significance level of 0.05 while considering gender and the 3 sugar types as 2 classifying variables. Multiple post hoc comparisons were done with Tukey test. Minitab 16 software for the statistical analysis and Microsoft Excel for the exploratory data analysis were used in the study.

3. Results and discussion

3.1 Nutritional composition

Table 1 shows the nutritional composition of cane sugar and coconut jaggery. The moisture, ash and protein contents of jaggery were significantly (P < 0.05) higher than those of cane sugar. Moisture content is an important parameter to evaluate the quality and stability of the jaggery [15]. Moisture percentage of freshly prepared sugarcane jaggery is reported as 12.07%, which is higher than the moisture content of coconut jaggery [16]. The low moisture content of cane sugar is the reason for higher shelf life of that whereas coconut jaggery has a lesser shelf life. Ash percentage indicates that coconut jaggery contain a higher percentage of minerals than the cane sugar. Fat and fiber were not observed in table sugar, whereas they were observed in minor quantities in coconut jaggery ((0.14 ± 0.02)% and (0.05 ± 0.03)%, respectively). Therefore, the coconut jaggery has additional amounts of nutrients than cane sugar that could be beneficial for human health.

Presence of resistant starch and dietary fiber has an impact to reduce glycemic responses [17]. Variation of glycemic indices among rice varieties was observed mainly due to the different percentages of starch as amylase. Starch has the ability to decrease GI and insulin response [17]. Coconut jaggery has a significantly higher concentration of resistant starch of (0.28 ± 0.07)% compared to cane sugar ((0.13 ± 0.02)%). *In vitro* enzymatic digestion clearly revealed that the digestible starch content of coconut jaggery was significantly lower (P < 0.05). Therefore, it can be assumed that sucrose in cane sugar might get hydrolyzed into glucose and fructose rapidly than the coconut jaggery. Significantly higher concentration of total sugar in cane sugar ((96.75 ± 2.87)%) has a direct impact on blood glucose response compare to coconut jaggery ((82.71 ± 1.26)%). Therefore, sucrose or cane sugar should eventually raise the blood glucose response rapidly than the coconut jaggery does.

3.2 Screening of human subjects

The screening results of poorly controlled diabetic patients are shown in Table 2, with gender basis and as a whole group. Age was below 50 years and BMI of the majority was exceeding the overweight margin. Middle age and overweight are risk factors for type 2 diabetes.

Table 1
Nutritional composition of coconut jaggery and table sugar (%).

Treatment	Moisture	Ash	Protein	Fat	Fiber	TS	RS	DS	Total sugar
Table sugar	0.11 ± 0.07^b	0.11 ± 0.04^b	0.72 ± 0.06^b	0.00^b	0.00^b	95.86 ± 1.58^a	0.13 ± 0.02^b	95.73 ± 1.59^a	96.75 ± 2.87^a
Coconut jaggery	8.92 ± 0.22^a	2.09 ± 0.33^a	1.91 ± 0.28^a	0.14 ± 0.02^a	0.05 ± 0.03^a	85.69 ± 0.94^b	0.28 ± 0.07^a	85.42 ± 1.00^b	82.71 ± 1.26^b

Notes: Each value in table represents the results of mean value with ± SD of 5 replicates. Means with different superscripts are significantly different from each other's along each column (P < 0.05). TS, total starch; RS, resistant starch; DS, digestible starch.

The FBS level of 43 volunteers was significantly higher (150 mg/dL, $P < 0.05$) compared to the maximum healthy margin (100 mg/dL) of FBGC [18]. The fasting blood glucose values between 100 to 109 mg/dL are considered as the level of risk for type 2 diabetes or in other words, the pre-diabetes range [19]. HbA_{1c} of blood samples indicates average plasma glucose concentration over 8 to 12 weeks and higher than 6.5% of HbA_{1c} revealed the status of diabetic [20]. More than 9% ofaverage concentration of HbA_{1c} could be observed in selected subjects which declares that poorly controlled diabetic status of them. The level of HbA_{1c}should be maintained less than 6.5% to controlled the status of diabetic through the medicine and diet management. Most of the subjects were exceeding the high density lipoprotein and total cholesterol/high density lipoprotein values than the healthy limits of less than 40 mg/dL and less than 3.5, respectively.

3.3 Comparison of blood glucose response curves

Glucose responses of subjects over the 2 h period are shown in the Fig. 1. The fasting blood glucose was significantly higher in diabetic patents than the recommended maximum healthy level of 100 mg/dL ($P < 0.05$). Low insulin sensitivity makes diabetes patients incapable in proper blood glucose regulation.

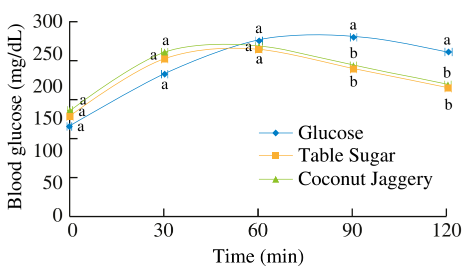

Fig. 1 Glucose response curve of coconut jaggery and table sugar. Different letters are significant different from each other's along the verticalaxis ($P < 0.05$).

Cane sugar and coconut jaggery elicited similar patterns, without significant differences at each measuring point ($P > 0.05$), even though coconut jaggery has significantlyhigher percentage of resistant starch ($P < 0.05$). Different types of resistant starch behave differently to lower the blood glucose levels. Haub et al. [21] identified that significantly different glycemic behaviorof 2 types of resistant starch having beverages. Matrix embedded starch (RS1), untreated resistant starch granules (RS2), de-branched and recrystalized resistant starch by cooking and cooling process (RS3) and structurally (chemically) modified resistant starch (RS4) have different glucose lowering potentials while RS4 has greater glucose lowering ability [21]. If the coconut jaggery has RS4 type of resistant starch it should have significant glucose lowering potential than the cane sugar. The concentration of type of resistant starch present in the coconut jaggery may not be enough to control the glucose releasing ability under the low insulin regulation machanizum in poorly controlled diabetes patients. Therefore, same pattern of glucose releasing could be observed in the cane sugar and coconut jaggery. Value addition of coconut jaggery with RS4 type of resistant starch may have high potential of reduction of glucose releasing ability of coconut jaggery than the pure coconut jaggery.

However, the glucose response of the standard (glucose) elicited a significant difference at 90 and 120 min compared to both table sugar and coconut jaggery ($P < 0.05$). Moreover, Trinidad et al. [22] have identified that GI of coconut sap sugar as 35 (low GI). Incorporation of 1% of inulin to the coconut syrup have resulted GI = 39. Coconut sugar incorporated bread has a significantly lower GI of 65.67 than the sugar cane incorporated bread (GI = 81.34). Preparation of four sweeteners mixed with wheat flour with sugarcane (GI = 75.44) and wheat flour with coconut sugar (GI = 60.72) has shown different glycemic indices [23]. Therefore, glucose response behavior in healthy persons and diabetes patients are grately varying and further research should be implemented to identifythe best for each category of people.

3.4 AUC, peak reduction and peak fattening rate

Mean value of the AUC of cane sugar, coconut jaggery and the reference food of glucose is shown in Table 3 as gender basis and as a whole group. Higher AUC was observed from the glucose (12 358 ± 3 302) followed second by cane sugar (8 478 ± 4 079). The lowest value of the area was shown in coconut jaggery (7 850 ± 3 936). Nevertheless, the difference of AUC between the 2 test foods was not significant ($P > 0.05$), but they were significantly lower than that of the glucose, the standard sugar.

Table 2
Characteristics of poorly controlled diabetes patients.

Parameters	Female	Male	Whole group	Reference	Gender analysis
Age (years)	47.96 ± 9.25	48.53 ± 5.65	48.19 ± 7.95	–	NSD
BMI (kg/m^2)	29.84 ± 4.93	26.047 ± 3.563	28.342 ± 4.775	< 23	$P < 0.05$
Pulse rate (min^{-1})	78.65 ± 7.04	80.53 ± 11.89	79.40 ± 9.17	60–100	NSD
Blood pressure (mmHg)	121 ± 17/76 ± 10	126 ± 20/ 79 ± 14	123 ± 18/77 ± 11	90–120/60–80	NSD
FBS (mg/dL)	145.7 ± 53.2	154.2 ± 58.7	149.05 ± 54.88	< 100	NSD
TC (mg/dL)	158.19 ± 37.38	173.0 ± 45.5	164.05 ± 40.91	< 200	NSD
LDL (mg/dL)	89.35 ± 34.24	103.24 ± 38.35	94.84 ± 36.13	< 100	NSD
Triglycerides (mg/dL)	108.12 ± 43.09	121.5 ± 47.8	113.42 ± 44.95	< 150	NSD
HDL (mg/dL)	47.88 ± 10.23	45.47 ± 9.92	46.93 ± 10.06	< 40	NSD
VLDL (mg/dL)	21.15 ± 8.66	23.88 ± 9.43	22.23 ± 8.97	10–30	NSD
Non HDL (mg/dL)	111.00 ± 36.19	127.53 ± 39.22	117.53 ± 37.85	< 130	NSD
Total CHOL/HDL	3.358 ± 0.770	3.782 ± 0.713	3.526 ± 0.768	< 3.5	NSD
HbA_{1c} (%)	9.288 ± 2.045	8.988 ± 2.034	9.170 ± 2.022	< 10	NSD

Notes: BMI, body mass index; FBS, fasting blood sugar; TC, total cholesterol; LDL, low density lipoprotein; HDL, high densitylipoprotein; VLDL, very low density lipoprotein; HbA_{1c}, amount of sugar attached to the hemoglobin. Each value in table represents the results of mean value with ± SD of 43 number of diabetes subjects. NSD, not significant difference.

Table 3
Area under the curve, peak reductions and peak flattening rates.

Parameters	Glucose	Cane sugar	Coconut jaggery
AUC (females)	12 481 ± 3 556[a]	8 282 ± 4 556[b]	7 848 ± 3 724[b]
AUC (males)	12 152 ± 2 922[a]	8 809 ± 3 228[ab]	7 854 ± 4 247[b]
AUC (whole)	12 358 ± 3 302[a]	8 478 ± 4 079[b]	7 850 ± 3 936[b]
Peak reduction rate (%)	–	14.37	10.69
Peak flattening rate (mg/(dL·min))	0.29	0.96	0.97

Notes: AUC, area under the curve; Means with ± SD value are presented. Different superscripts are significantly different from each other's along each row ($P < 0.05$).

The results of peak reduction clearly revealed that the cane sugar has 14.37% of peak reduction while coconut sugar has 10.69% peak reduction compared to the standard. However, the 2 test foods elicited no significant difference in peak reduction ($P > 0.05$).

After intake of reference food (glucose), glucose concentration of blood was increased to the peak level of 271.4 mg/dL and reduced to 253.93 mg/dL within the 2 h period that showed a slow rate of peak flattering. The peak fattening rate of glucose was 0.29 mg/(dL·min) while it for cane sugar and coconut jaggery were 0.96 and 0.97 mg/(dL·min), respectively. Evidently, peak flattening rates for both coconut, jaggery and cane sugar were more than 3 times higher compared to glucose. However, no significant difference in the peak flattening rate between the 2 test foods was observed ($P > 0.05$).

The higher standard division of FBS value of diabetes patients and AUC of different test food and glucose can be created some limitations of this study. The average concentration of HbA_{1c} (> 9%) in selected subjects declares that poorly controlled diabetic status of them and it can be affected negatively for the blood glucose response of diabetes patients. Moreover, the effect of jaggery and table sugar in diabetes patients should be studied as a more days experiment to identify the long term effect of coconut jaggey for the diabetes patients as a future direction of this study.

4. Conclusion

There were no significant differences in blood glucose responses with respect to ($P > 0.05$). AUC of blood glucose response curves, peak delaying rates and percentage peak reductions when table sugar and coconut jaggery were consumed by diabetic patients. Therefore, selection of coconut jaggery to replace table sugar cannot be recommended as a better alternative for diabetic patients.

Conflict of interest

We do not have conflicts of interest associated with this publication, and there has been no significant financial support for this work that could have influenced its outcome.

Ethical clearance

Ethical clearance was obtained from the Ethical Review Committee of the National Hospital Colombo, Sri Lanka : ETH/COM/2017/03

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