



The New Sugar to Suppress Postprandial Hyperglycemia: Improvement of Refined White Sugar by Mixing Specially Grown Brown Cane Extract

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Abstract

The minimal refining process of sugarcane extract retained some of its phytochemicals, vitamins, and minerals. The addition of this extract to the refined brown sugar lowered glycemic index (GI) and suppress postprandial hyperglycemia. A quick squeeze of sugar cane and quick processing caused a considerable amount of antioxidants (polyphenols). Overall, low postrandial (LP) sugar had a better nutritional quality in terms of physicochemical characteristics and health benefits.

Keywords: New Sugar; LP Sugar; GI; Brown Sugar; Postprandial Hyperglycemia

Introduction

Adverse effects of refined white sugar have been well recognized, and WHO recommends not to take more than 10g a day [1,2]. However, its consumption remains high because of its gustative, nutritional, and preservative properties that make it an essential nutrient.

Tissues, such as the brain, nervous tissue, red blood cells, and skeletal muscle, can only use glucose as an energy source. Among them, the brain is thought to consume about 20% of the basal metabolic rate. If the basal metabolism is 1500 kcal/day, it is equivalent to 300 kcal/day (glucose 75 g/day). In addition of brain, many other tissues also use glucose as energy source, therefore, at least 100g/day of sugar is required for people to live.

Refined sugar is made by sequential process: washing, extraction, purification, crystallization, drying, and packaging [3]. The

high purity of refined sugar, however, its nutritional value is low, and it provides empty calories. Unrefined brown sugar has a low glycemic index (GI) which may prevent hyperglycemia. Recent studies reveal the risk of postprandial hyperglycemia is more critical by a human study and predictive factor of cardiovascular diseases [4].

Brown sugar comprises 88% to 93% of sucrose, but it has a unique flavor and smell due to predominant phytochemicals [5,6]. Sugar cane juice contains rich flavonoids (apigenin, luteolin, and triclin derivatives) and many phenolic acids, such as hydroxycinnamic acid, caffeic acid, and sinapic acid [7,8]. These are considered to be functional ingredients [9,10].

Usually, brown sugar has higher amounts of phenolics than refined sugar. For instance, the total phenolic content of brown sugar ranges from 108.1 µg to 259.6 µg gallic acid equivalent (GAE)/g

sample [5]. Phytochemicals may play an essential role in maintaining physical health.

We developed a mixture of refined brown sugar and flesh sugar cane extract, which lowered GI and prevented postprandial hyperglycemia. We named this new sugar as LP (low postprandial) sugar.

Health professionals recommend increasing the intake of foods rich in antioxidants. Raw brown sugar extract may offer a potential extra health benefit source in this regard. We succeeded to improve the nutritional properties of refined brown sugar by adding the specially grown brown cane extract and confirmed the suppressive effects on postprandial hyperglycemia.

Materials and Methods

Our sugar cane farm on Tanegashima island grows species of sugar cane, Kurokaido and Norin 22, which fit the Japanese soil and climate. According to WHO standards, raw sugar extract is directly produced from food-grade sugar mills aside from our sugar cane farm by a sequential process involving washing raw materials, extraction, and minimal refining. These processed in one day to keep flesh and preserve functional factors.

The quick and fewer processes involved in producing raw sugar cane extract retained some naturally occurring trace minerals (such as calcium, magnesium, and potassium), vitamins, amino acids, antioxidants, and phytochemicals.

We used partially refined brown sugar from Australian refined brown sugar.

Then, concentrated raw sugar cane extract was added at a rate of 2% to the refined sugar after detecting metal contamination. Addition of 1% was less effective, and 2% or more did not cause additional benefit and the taste of brown sugar remained.

Determination of nutrients

Nutrients and functional ingredients were measured at the Japan Food Chemicals Analyzing Center and SUNTEC, Japan.

Determination of glycemic index

Ten normal, healthy subjects were recruited voluntarily to participate in the study. Before the tolerance test, all subjects received a health check-up. The Minamimachi Clinic obtained the study's ethical approval, and all subjects gave the written informed consent to participate.

Three separate tolerance tests were performed in the morning after a 10 - 12 h overnight fasting. After a fasting blood sampling, subjects drank a test glucose 50g in 200 ml water at a comfortable pace within 5 min and had further blood samples at 15, 30, 45, 60, 90, and 120 min after the start. Test drink of LP sugar contained same amount of glucose, and was served with water as well.

Blood could be obtained by finger-prick and whole blood glucose measured by the Abbott glucose sensor. The blood sampling method and glucose measurement remained standard for the duration of the study plasma glucose measured by a hexokinase method.

Statistical analysis

All analyses were conducted double for each sugar sample. IBM-SPSS version 24 was used for statistical analysis. Significant differences between the mean values of the pieces were statistically analyzed using paired analysis. Mean and s.d. of biochemical and other physical data by sex were calculated. The significance level was set at $p < 0.05$.

Results and Discussion

Determination of Nutrients, vitamins, and minerals

The nutrient contents of refined brown sugar, sugar cane extract and LP sugar are shown in table 1. Carbohydrate content was 98.4, 70.4, and 98.2, respectively. Most of them were sucrose (96.6%), but a small amount of glucose and fructose were present. High protein content (0.9%) and ash (2.1%) were characteristic of sugar cane extract.

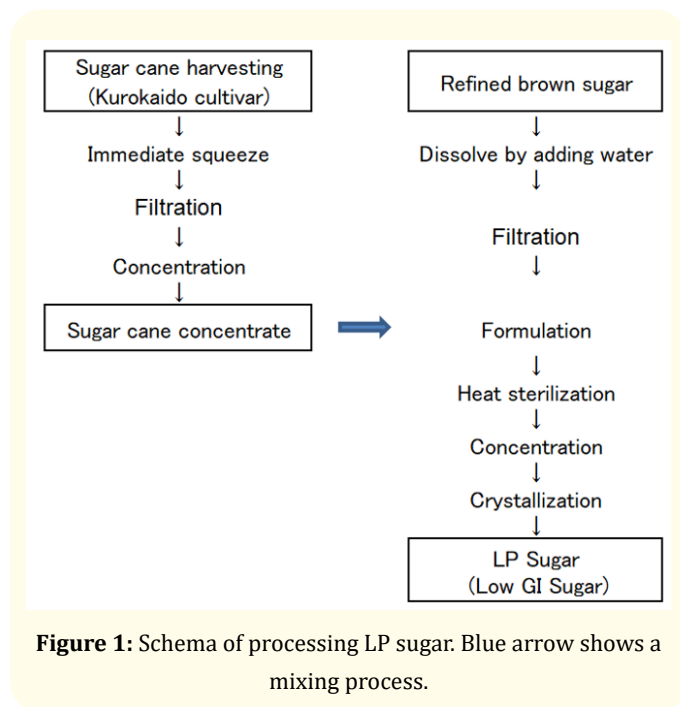


Figure 1: Schema of processing LP sugar. Blue arrow shows a mixing process.

Name	/100g	Brown sugar	Sugar Cane Extract	LP Sugar
Energy	kcal	398	276	383
water	g	0.2	26.6	1.4
Carbohydrate	g	99.6	70.4	98.2
sucrose	g	96.6	52.7	96.6
glucose	g	na	na	0.5
fructose	g	na	na	0.4
Protein	g	<0.01	0.9	0.1
Lipid	g	<0.01	<0.01	<0.01
Ash	g	0.5	2.1	0.3
Polyphenol	g	—	—	0.09
ORAC total	umole TE/g	14	55	16
ORAC hydrophilic	umole TE/g	14	55	16
ORAC lipophilic	umole TE/g	nd	nd	nd
Na	mg	30.8	9.0	18.3
NaCl eq	g	0.0780	0.023	0.0470
K	mg	162	914	100
Ca	mg	41.4	32.1	28.9
Mg	mg	13.7	45.9	11.4
Fe	mg	0.62	0.40	0.41
Cu	mg	0.02	0.04	0.02
Zn	mg	nd	nd	nd
Mn	mg	0.22	0.23	0.24
Mo	µg	nd	nd	nd
Se	µg	nd	nd	nd
P	mg	4.2	30.7	3.8
I	µg	nd	nd	nd
Cr	µg	nd	nd	nd
As ₂ O ₃	ppm	nd	nd	nd
Pb	ppm	nd	nd	0.02
Cd	ppm	nd	nd	—
Hg	ppm	nd	nd	—
Bacilli	n/g	<300	<300	<300
Coli		negative/2.22g	negative/0.1g	negative/0.1g
O157		—	—	negative
Fungus	/0.1g	negative	negative	negative
Yeast	/0.1g	negative	negative	negative
Spore	n/g	<300	<300	<300
Staphylococcus	/0.01g	negative	negative	negative
Salmonella	/25g	negative	negative	negative
Bacillus cereus	/0.01g	negative	negative	negative
Clostridia	n/g	—	negative	negative

Table 1: Ingredients of raw sugar, sugar cane extract, and new sugar.

Mineral contents were correlated with ash content. LP sugar had a rich ash content (0.3g/100 g). Potassium, calcium, and magnesium were high in sugar cane extract, as well as brown sugar. Other minerals, such as Zn, Se, Cr, Mo, and I, were not detected. Toxic As, Cd, Pb, and Hg were not present. Bacilli, fungus, and yeast were not present.

The polyphenol contents of LP sugar were determined following the Folin-Ciocalteu method. Results showed that sugar cane extract (240 mg GAE/100 g sample) had the highest, and LP sugar followed (90 mg GAE/100 g sample).

Amino acids were not remarkable except for aspartic acid (28 mg/100g) (Table 2).

Glucose intolerent test

The average age of the participants was 35.8 ± 10.5 years in males and 39.1 ± 10.1 years in females (Table 3). Systolic and diastolic blood pressure were within a standard range, and pulse and body temperature were also in the normal range.

Laboratory data of participants were shown in table 4.

Aminoacid contents in LP sugar		
Arginine	mg	nd
Lysin	mg	nd
Histidine	mg	nd
Phenylalanine	mg	1
Tyrosin	mg	nd
Lysin	mg	2
Isoleucine	mg	1
Methionine	mg	nd
Valine	mg	3
Proline	mg	2
Glutaminic acid	mg	9
Seline	mg	2
Threonine	mg	2
Asparatic acid	mg	28
Tryptophan	mg	nd
Cystine	mg	nd
Hydroxyproline	mg	nd

Table 2: Amino acids content in LT sugar.

	Male n = 4		Female n = 6		Total n = 10	
	Mean	SD	Mean	SD	Mean	SD
Age	35.8	10.5	39.1	10.1	37.8	9.9
Sys BP	120.7	12.5	109.5	13.2	114.0	13.9
Dia BP	82.3	13.7	69.1	9.2	74.4	12.8
Pulse	77.3	15.3	74.1	8.8	75.4	11.7
Temp	33.3	0.8	33.3	0.8	33.3	0.8

Table 3: Anthropometric data of participants.

		Male n = 4		Female n = 6		Total n = 10	
	Unit	Mean	SD	Mean	SD	Mean	SD
Age	Year	35.8	10.8	39.2	10.1	37.8	9.9
BMI	kg/m ²	21.9	2.5	21.9	3.5	21.9	3.0
WBC	/mm ³	5200.0	1134.3	6000.0	2773.4	5680.0	2207.5
RBS	104/mm ³	507.5	7.0	440.7	44.3	467.4	47.9
HB	g/dl	15.4	1.0	12.7	0.9	13.8	1.7
HT	%	47.1	2.5	40.8	3.2	43.3	4.3
PL	104/dl	25.5	3.5	25.3	9.1	25.4	7.0
PMN	%	60.8	3.4	59.9	10.0	60.3	7.8
Lymph	%	31.2	4.2	33.0	8.6	32.3	6.9
Mono	%	5.1	1.8	5.3	1.8	5.3	1.7
Eosino	%	2.4	1.7	1.3	0.7	1.7	1.2
Baso	%	0.6	0.4	0.5	0.2	0.5	0.3
Amylase	Unit	76.3	11.5	74.5	25.9	75.2	20.5
Glucose	mg/dl	82.0	5.0	86.0	10.5	84.4	8.6
HbA1c	%	5.4	0.1	5.4	0.2	5.4	0.2
glu_alb	%	13.1	1.3	15.4	1.2	14.5	1.7
protein	g/dl	7.3	0.3	7.0	0.2	7.2	0.3
BUN	mg/dl	12.6	1.3	10.0	3.0	11.0	2.7
tot_chol	mg/dl	218.8	10.8	191.3	34.4	202.3	29.9
HDL	mg/dl	46.3	6.7	66.0	13.5	58.1	14.8
LDL	mg/dl	143.0	6.8	108.7	22.0	122.4	24.5
TG	md/dl	147.8	87.6	81.3	55.0	107.9	73.6
AST	Unit	20.8	5.4	16.0	1.4	17.9	4.1
ALT	Unit	23.0	15.4	10.7	2.3	15.6	11.1
γ-GT	Unit	31.5	19.6	15.7	8.4	22.0	15.3
ALP		257.5	62.3	147.0	39.7	191.2	73.7
LD		174.5	35.7	162.0	8.4	167.0	22.5

LAP		53.5	6.0	48.8	5.0	50.7	5.6
tot_bil		1.0	0.2	0.8	0.2	0.9	0.2
dir_bil		0.1	0.0	0.1	0.1	0.1	0.0
Indirect bil		0.9	0.2	0.7	0.2	0.8	0.2
Cr	mg/dl	0.9	0.1	0.6	0.1	0.7	0.2
UA	mg/dl	5.9	0.3	4.1	1.2	4.8	1.3
CK	mg/dl	122.8	22.0	76.0	23.3	94.7	32.3
Na	mg/dl	140.3	1.3	138.7	1.2	139.3	1.4
K	mg/dl	4.0	0.3	4.1	0.2	4.0	0.2
Cl	mg/dl	99.8	0.5	101.0	1.1	100.5	1.1
Ca	mg/dl	9.4	0.3	9.0	0.3	9.2	0.3
P	mg/dl	3.1	0.3	3.3	0.4	3.2	0.4
Fe	ug/dl	121.3	27.3	91.2	28.2	103.2	30.5

Table 4: Laboratory data of participants by sex.

In both males and females, the subjects were middle-aged healthy subjects with BMI 21.9 kg/m². Hematological tests were all within normal range with adequate hemogram.

Their fasting glucose level was 82 ± 5 in males and 86 ± 10.5 mg/dl in females.

HbA1c was 5.4 ± 0.1% in males and 5.4 ± 0.2% in females. Glu-coalbumin was 13.1 ± 1.3% in males and 15.4 ± 1.2% in females. TG, LDL, and total cholesterol were slightly high among males. Gamma GTP and ALP were also high among males.

Postprandial glucose level

In this study, post-challenge glucose spikes were defined as the difference between the maximal post-challenge glucose level during OGTT, irrespective of the time after glucose challenge and the level of fasting plasma glucose [9].

Measured GTT and LP sugar level by time are shown in table 5. GI of LP sugar was 52.9 ± 12.7. Changes in glucose level by time are shown in figure 2. LP sugar suppressed the glucose level, especially after 60 min.

	1 st OGTT		2 nd OGTT		LP sugar	
	Mean	SD	Mean	SD	Mean	SD
glu0	93.6	6.5	100.3	7.7	103.3	7.8
glu15	139.0	14.7	133.2	18.4	145.8	19.1
glu30	155.9	24.1	175.3	25.0	155.5	27.9
glu45	162.2	43.4	181.6	33.7	152.8	40.2
glu60	163.9	47.2	177.8	45.7	144.2	31.3
glu90	141.2	28.7	152.0	36.2	121.8	10.7
glu120	132.7	22.4	137.8	29.6	101.4	17.7
IAUCg1	104.0	38.6	111.6	37.9	61.6	20.6
GI					52.9	12.7

Table 5: Blood glucose level after 50g glucose tolerance test and that of LP sugar.

Discussion

Preference for sweet is the essential desire of obese and diabetic people. Importance is the prevention of complications, like cardiovascular events.

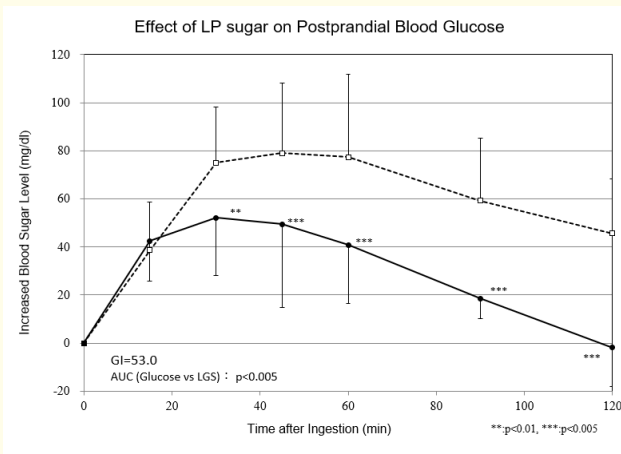


Figure 2: Comparison of new sugar vs. glucose on postprandial glucose level. Dot line; glucose, solid line; LP sugar.

ID	Glucose	LP sugar
53731	74	44
53732	135	73
53735	73	48
53736	91	69
53737	90	62
53740	83	44
53741	154	108
53743	113	76
53744	58	67
53758	100	74
Average	97.1	66.5

Table 6: Individual difference of postprandial glycemia (mg/dl) by glucose or LP sugar.

Many studies [11-13] have clearly shown that the glucose serum level 2h after an oral challenge with glucose is a powerful predictor of cardiovascular risk. Two important meta-analyses also confirm this evidence. The first, by Coutinho, *et al.* [11], examined studies on 95,783 subjects. The second, which involved 20,000 subjects, pooled the Whitehall Study, Paris Prospective Study, and Helsinki

Policemen Study [12]. A 33-yr follow-up of the Whitehall study in which a 50g OGTT was performed at baseline in 1967-1969 in 17869 male civil servants aged 40 - 64 years reported a threshold model with a linear slope as best describing the relationship between 2-h post-load blood glucose and mortality risk.

The possible role of postprandial hyperglycemia as an independent risk factor has also been supported by the Diabetes Intervention Study, which showed how postprandial hyperglycemia predicts infarction in type 2 diabetic subjects [13].

In diabetes, the postprandial phase is characterized by a rapid increase in blood glucose levels. The postprandial state is a contributing factor to the development of atherosclerosis. The postprandial "hyperglycemic spikes" may be relevant to the onset of cardiovascular complications. Cardiovascular events appeared to increase linearly with 2-h post-challenge plasma glucose without a threshold. In contrast, there was a possible threshold for fasting plasma glucose at 5.5 mmol/l (100 mg/dl).

For ischaemic heart disease death for fasting glucose, the hazards ratio was best modeled by a positive linear relationship. Still, for 2-h glucose, it was modeled by a J-shaped curve, and the lowest observed death rate was in the interval centered on 6.0 mmol/l (108 mg/dl).

Epidemiological and intervention studies have shown that postprandial hyperglycemia is a direct and independent risk factor for cardiovascular disease (CVD). The STOP-NIDDM trial has presented data indicating that treatment of subjects with impaired glucose tolerance with the α -glucosidase inhibitor acarbose, a compound that specifically reduces postprandial hyperglycemia, was associated with risk reduction in the development of new cases of hypertension and a 49% risk reduction in cardiovascular events [14].

To decrease the postprandial hyperglycemia, the glycemic index (GI) could alternatively be employed, but GI has a significant within-subject variation of blood glucose responses [15]. Besides, GI was determined by individual food, so its health effects are still in debate.

LP sugar is a good choice of sweetener for prediabetic and diabetic patients. Previous studies suggested that a high ash content is attributed to a high potassium content, which may impart an un-

pleasant taste and hinder sugar crystallization [16]. In the present study, the sugar ash contents were relatively high, but it did not impair the tasteful sweetness.

LP sugar is also rich in potassium, which has antihypertensive effects. Unrefined sugars retain large amounts of phenolic and flavonoid compounds from sugarcane juice. The contents of phenolics, flavonoids, and other compounds are usually responsible for the dark coloration of brown sugars [7,8].

The mechanisms through which acute hyperglycemia exerts its effects may be identified in the production of free radicals. The harmful impact of postprandial hyperglycemia on diabetes complications has been sufficient to influence key professional guidelines. Correcting postprandial hyperglycemia may form part of the strategy for preventing and managing CVDs in diabetes. The antioxidant activity of LP sugar is helpful for this purpose [17,18].

Our LP sugar showed the characteristic suppression of postprandial glycemia compared to glucose or ordinary brown sugar. The suppression of late absorption at 90 min to 120 min suggested the inhibitory action of acarbose. It may need further study to confirm this.

Conclusion

The quick and minimal refining process of sugarcane extract retained some of its phytochemicals, vitamins, and minerals. An immediate squeeze of sugar cane and quick processing caused a considerable amount of antioxidants (polyphenols). The addition of this extract to the refined brown sugar lowered GI and suppress postprandial hyperglycemia. Overall, LP sugar had a better nutritional quality in terms of physicochemical characteristics and satisfy people who are difficult to restrict sugar intake.

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Conflict of Interest

Arimura and Kimura are working in the Daito-seito Co. Ltd. Watanabe and Sakakibara had no conflict of interest to declare.

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