

Potential of Cersenlau Sugar as a Therapeutic Sugar Agent: Evidence from Rat Models and Healthy Adults

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Diabetes mellitus is a rising global health concern. This study aimed to determine the effect of Cersenlau sugar on fasting blood glucose, 2-hour postprandial blood glucose, and HbA1c levels in type 2 diabetes mellitus (DM) rats and healthy adults. The research involved two phases: the first phase utilized a true experimental pretest-posttest control group design with 27 alloxan-induced Wistar rats, while the second phase employed a quasi-experimental nonequivalent control group design with 44 healthy adults. The intervention lasted two weeks, during which blood glucose and HbA1c levels were measured before and after. Statistical analysis included ANOVA and MANOVA. Results showed that in the first phase, fasting glucose, postprandial glucose, and HbA1c significantly decreased in the intervention group. In the second phase, Cersenlau sugar reduced body weight but did not significantly affect glucose or HbA1c levels, whereas commercial sugar increased 2-hour postprandial glucose levels. The findings suggest that Cersenlau sugar has potential as a therapeutic agent for type 2 diabetes mellitus and could serve as a health-promoting sweetener for healthy individuals. However, this study is limited by the small sample size and gender imbalance in Phase II, warranting cautious interpretation and the need for a larger, balanced study. This preliminary finding requires confirmation in longer-term studies with diabetic or prediabetic patients.

Keywords: Antioxidants; Blood Glucose Control; Cersenlau Sugar; Therapeutic Sweetener; Type 2 Diabetes Mellitus.

Diabetes mellitus (DM) is a degenerative disease that is common in society and is a health problem in developing countries, even throughout the world. In developing countries entering the industrialization era, the incidence and prevalence of this disease continue to increase.¹ Diabetes mellitus describes a group of metabolic disorders characterized by increased blood glucose levels. People with diabetes have a higher risk of morbidity and mortality than the general population.² Type 2 diabetes mellitus is a long-lasting condition marked

by high blood sugar levels, which occur mainly due to the body's resistance to the action of insulin produced by the beta cells of the pancreas.^{3,4}

As reported by the International Diabetes Federation (IDF), diabetes mellitus impacts 1.9% of the world's population, ranking it the seventh leading cause of death globally. Given this prevalence, an estimated 463 million people were living with diabetes in 2019. By 2030, this number is expected to rise to 578 million, and by 2045, it is projected to exceed 700 million. [5,6]. In Indonesia,

IDF recorded 10.7 million people with diabetes in 2019, ranking seventh in the world for the highest number of diabetes cases.⁵

According to the 2018 Riskesdas, the prevalence of diabetes mellitus based on a doctor's diagnosis was 2.0% for individuals 15 years or older, and 1.5% for the general population across all ages.⁶ According to the WHO, no more than 10% of total daily calories should be consumed in the form of sugar (about 200 Kcal, or 50 g, which is equivalent to 12 teaspoons). Even the UK's Scientific Advisory Committee on Nutrition (SACN) advises a maximum of 5% of daily calories, or 30 g, which is equivalent to 7 teaspoons.⁷⁻¹¹ Commercial sugar production for diabetics only offers sugar that contains zero calories without containing phytochemical compounds useful as antidiabetics. This study aims to develop a sugar product that has dual benefits: it is a sweetener and has therapeutic benefits.

Exogenous antioxidants come from outside the body. Phenolic compounds can help reduce oxidative stress through various mechanisms that depend on their chemical structure. For example, they can chelate iron ions, which play a crucial role in producing harmful oxygen species. According to Shin *et al.*, the boiled water extract of leaves showed the highest chelation activity at 76.9%, followed by fruits at 68.9%, flowers at 62.9%, and flower stalks at 38.5%.¹² Flavonoids derived from red grapes have been shown to inhibit the oxidation of low-density lipoprotein (LDL), alkoxy, and hydroxyl through hydrogen atom donation.¹³ Because of its capacity to chelate metal ions such as iron and copper. Flavonoids are also able to inhibit the formation of free radicals.¹⁴

Cersenlau sugar is made from Kersen cherries and purple butterfly pea flowers. Flavonoids, flavones, and anthocyanins are antioxidant compounds found in purple butterfly pea flowers and kersen cherry fruits.¹⁵⁻¹⁷ Jumain *et al.* found that kersen fruit juice with a concentration of 15% v/v, 30% v/v and 60% v/v can significantly reduce blood glucose levels in male mice after being induced with 20% b/v glucose solution.¹⁸ In line with the results of this study, Agustina *et al.* found that giving kersen fruit juice (*Muntingia calabura* L) to type 2 DM patients can significantly reduce blood glucose levels.¹⁹ Oral administration

of butterfly pea flower water extract (*Clitoria Ternatea* L) to experimental mice reduced serum glucose and Hb glycosylation, increased serum insulin, liver, and muscle glycogen in bones, and prevented hypoglycemia in albino mice. It was more effective than the diabetes drug glibenclamide (10 mg/kg).¹⁷

Added sugars are those added during food preparation or manufacturing, including glucose, fructose, sucrose (a sugar made from a mix of glucose and fructose), and hydrogenated starch hydrolysate (also known as high-fructose corn syrup). The World Health Organization (WHO) and the Scientific Advisory Committee on Nutrition (SACN) use the term "free sugar" to include all sugars naturally found in honey, fruit juices, and syrups.^{7,8,11}

Purple butterfly pea flowers (*Clitoria Ternatea* L) contain phenolic compounds, flavonoids, anthocyanins, and flavonol glycosides which have the potential as antioxidants. Ethanol extract of butterfly pea flowers lowers blood sugar in the serum of diabetic rats by inhibiting the activity of the α -galactosidase and α -glucosidase enzymes but there is no inhibition of the activity of the α -d-fructosidase enzyme.¹⁵

Commercial sugar products for diabetics on the market mainly highlight their very low-calorie content but lack phytochemical compounds that are beneficial as antidiabetics. Due to its high levels of flavonoids, anthocyanins, and dietary fiber, Cersenlau sugar may provide hypoglycemic effects by protecting pancreatic β -cells with antioxidants, inhibiting carbohydrate-digesting enzymes, and slowing glucose absorption, making it a promising dual-action sweetener. This study aims to evaluate the effects of Cersenlau sugar on fasting blood glucose, 2-hour postprandial glucose, and HbA1c in rats with type 2 diabetes and healthy adults.

MATERIALS AND METHODS

The study was conducted in two phases. Phase I employed a true experimental pretest–posttest control group design using 27 alloxan-induced Wistar rats, divided into three groups (negative control, positive control, and intervention). The intervention group received Cersenlau Sugar at a dose of 400 mg/kg BW/day

administered orally for 14 days, based on previous studies demonstrating its safety and potential efficacy in animal models. Phase II research uses a quasi-experimental design with a nonequivalent pretest-posttest control group, involving two groups: Control and Intervention, involving 44 healthy adults (22 per group). Participants were randomly assigned to receive either Cersenlau Sugar (0.4 g/kg BW/day, one package consumed each morning for 14 consecutive days) or commercial sugar (5 g/day). The 14-day duration was chosen to allow observation of short-term metabolic and glycemic effects. Measurements included fasting blood glucose, 2-hour postprandial glucose, and HbA1c at baseline and post-intervention, as well as body weight and dietary intake using a semi-quantitative food frequency questionnaire.

Phase I research uses a true experiment with a pretest-posttest control group design. The sample is split into three groups: Group I is the Negative Control, Group II is the Positive Control, and Group III is the Intervention. Phase II research uses a quasi-experimental design with a nonequivalent pretest-posttest control group, involving two groups: Control and Intervention.

The subjects of the phase I study were white Wistar rats (*Rattus norvegicus*), aged 2 to 3 months, with an average body weight between 150 and 200 grams. Acclimatization lasted for 1 week. The rats were provided with food and water according to standards.

The accessible population in the phase 2 study were healthy adults, with a sample size of 44 people (22 people per group). Subject inclusion criteria: women: 1) Healthy; 2) Not pregnant; 3) Not using hormonal contraception; 4) Reproductive age. Male: 1) healthy; 2) age: 25-45 years.

Determination of sample size in phase I research refers to the Frederer formula

$(r - 1) (t - 1) e^{15}$. The sample size is 27, divided into 3 groups, namely Positive Control, Negative Control, Intervention. The sample size of each group is 9 rats. The sample size in phase 2 research refers to Referring to clinical research guidelines, the sample size in phase 1 clinical research is 20-100 people²⁰. The sample size in this study was 44 people (22 people per group). Sample selection using simple random sampling technique.

To make Cersenlau sugar, 200 g of Cherry

kersen simplisia is mixed with 10 g of purple butterfly pea flower simplicia until the mixture is homogenized. Phase I research: Cersenlau sugar is boiled with 100 mL of boiling water for 10 minutes over low heat. After cooling, the mixture is filtered, resulting in 100 mL of Cersenlau sugar solution. Phase II research: The Cersenlau sugar is packaged according to the needs of the research subjects (400 mg / kg BW / day) into 14 packs. How to serve: Boil Cersenlau sugar in 100 mL of water for 10 minutes from the moment the water boils, using low heat.

After getting used to the environment, White Wistar Rats were given alloxan to induce type 2 diabetes mellitus. The intervention was done once a day through a gastric tube. The negative control group was given 0.5 mL of distilled water, the positive control group received 32.5 mg/kg BW of sweetener, and the intervention group was given 400 mg/kg BW of Cersenlau sugar. The treatment lasted for two weeks.

In phase 2 of the study, Cersenlau sugar was prepared at a dose of 0.4 g/kg BW/day, and each subject consumed one package every morning for 14 days. Control group received 5 g of commercial sugar per day for 14 days. The 14-day interval was selected as it provides sufficient time to detect short-term metabolic and glycemic changes following a dietary intervention. Although HbA1c reflects average glucose levels over 8–12 weeks, previous studies have shown that significant glycemic shifts may influence HbA1c in shorter durations, especially under controlled interventions. In contrast, fasting and 2-hour postprandial blood glucose are well-established short-term indicators responsive to changes in carbohydrate intake and glucose handling within days. Nutritionists educated respondents about carbohydrate intake, physical activity, and preparation of Cersenlau Sugar during the intervention. During the intervention period, each respondent was monitored by field researchers every day, including: carbohydrate consumption, respondent activity, and consumption of intervention materials.

Measurements

In Phase 1, blood samples for blood sugar were taken 3 times, namely after acclimatization, one day after alloxone induction (pretest data), and after 2 weeks of intervention (posttest data). HbA1c

levels were examined after 2 weeks of intervention. Measurements in the phase 2 study were taken 2 times, namely pretest (before treatment) and posttest (after intervention 2 weeks). Examination of fasting blood sugar levels, 2-hour PP blood sugar, and HbA1c. In addition, measurements were made of carbohydrate consumption consisting of Semi Quantitative Food Frequency Questionnaire (SQ FFQ) forms and recording guidelines and respondents' BMI.

Laboratory

Fasting blood sugar level examination, 2-hour PP blood sugar, HbA1c using blood taken from blood vessels through the retroorbital plexus in the eyes of mice. In healthy people, it is examined using peripheral blood from the respondent's finger.

Statistical analysis

Data analysis with computer assistance, including descriptive analysis and ANOVA test for the phase I study. For phase 2 study, including descriptive, comparative, and MANOVA.

Ethical clearance

Researchers apply aspects of respect for human, justice, and beneficence. Phase 1 study, Ethical feasibility certificate from the Veterinary and Biomedical Research Ethics Commission of IPB University, number KE/SKHB/147/EC. Phase 2, submission of ethical approval to the Ethics Commission of the Denpasar Ministry of Health Polytechnic. Ethical approval no. DP.04.02/F. XXXII.25/0503/2024, May 7, 2024.

RESULTS

Plant determination test was conducted in the biology laboratory of the Mahasaraswati

Faculty of Pharmacy, Denpasar. Plant determination test based on the Flora of Java (Spermatophyta) book guidelines, according to its morphological properties and characteristics, it shows that this plant family is Muntingiaceae (cherry) and Fabaceae (purple pea), members of the Muntingia (Kersen) and Clitoria (purple pea). According to its type, this plant is Muntingia Calabura L (Kersen) and Clitoria Ternatea L (purple pea).

A hedonic quality test was conducted with three formulations. Formula 1 (002), Formula 2 (107), and Formula 3 (292) had significant differences. Sample 002 obtained a score of 3.1353b, sample 107 with a score of 2.2323a, and sample 292 with a score of 2.0767a. Overall, the Cersenlau sugar most preferred by consumers is sample 002, namely Cersenlau without additional ingredients.

Cersenlau sugar is a mixture of cherry fruit simplicia and purple butterfly pea flower simplicia with a ratio of 20:1, containing a total of 35.95% sugar, antioxidant capacity of 1208.09 mg GAE/L, Flavonoid 155.59 mg/100 g, vitamin C 5889.4 mg/100g, crude fiber 25.124%, betacarotene 2.671 mg/100g, FE 8.098 ppm, anthocyanin 1.64 mg/100g. These bioactive components indicate that Cersenlau sugar, in addition to being a sweetener, is also capable of being an antioxidant, antianemia, beneficial for eye health, digestion and liver, and kidneys.

Phase I research is preclinical research conducted on experimental animals as shown in Table 1. Sugar from a mixture of cersen cherry and purple butterfly pea flowers was tested on mice suffering from diabetes mellitus. Pretest blood sugar levels were not different in the third group (p.0.05). Giving Cersenlau sugar was able to reduce

Table 1. Blood sugar levels and HbA1c in Diabetes Mellitus Rats in Phase I

Variables		Groups			<i>p</i>
		I	II	III	
Level of Blood Sugar	Before intervention	321.67 ± 522	323.22 ± 7.60	325.11 ± 5.73	0.515
	1 week intervention	377.78 ± 16.38	346.56 ± 9.06	119.22 ± 4.3	0.000
	2 weeks intervention	433.11 ± 3.89	395.78 ± 15.39	82.00 ± 194	0.000
	(Posttest)				
Posttest Level of HbA1c		11.49 ± 0.18	10.99 ± 0.21	6.13 ± 0.46	0.000

Group I: Negative Control given 0.5 ml of distilled water

Group II: Positive Control given 32.5 mg/kg BW/day of commercial sugar

Group III: Intervention, given 400 mg/kg BW/day of Cersenlau sugar

Table 2. Characteristics of Research Subjects in Phase II

Characteristic	Intervention Group		Control Group		Total		p
	f	%	f	%	f	%	
Sex							
Male	2	9.09	2	9.09	4	9.09	
Female	20	90.91	20	90.91	40	90.91	
Total	22	100	22	100	44	100	
Body Mass Index							0.408
normal	20	90.91	20	90.91	40	90.91	
overweight	2	9.09	2	9.09	4	9.09	
Total	22	100	22	100	44	100	
Percentage of carbohydrate consumption to total calories							0.933
< 45%	1	4.55	2	9.09	3	6.82	
45 - 65%	19	86.36	18	81.82	37	84.09	
> 65%	2	9.09	2	9.09	4	9.09	
Total	22	100	22	100	44	100	

blood sugar levels in mice suffering from type 2 DM. Blood sugar levels in both control groups showed an increase, while in the intervention group decreased ($p < 0.01$). HbA1c levels after 2 weeks of intervention in the intervention group were lower than the control group. There was a significant difference in the third group ($p < 0.01$). The results of this study indicate that Cerselau sugar as a therapeutic sugar agent is able to improve the blood sugar and HbA1c profiles of mice suffering from DM.

Phase II research is a continuation of clinical research I which was tested on healthy people. The research subjects obtained were 44 people as shown on table 2. Respondents in each group were mostly women (91%), most had normal BMI (91%) and carbohydrate consumption according to recommendations (45-65%) of 84%. There was no difference in body mass index and percentage of carbohydrate consumption in both groups ($p > 0.05$).

Table 3 indicates that body weight, HbA1c levels, fasting blood sugar levels, and 2-hour postprandial blood sugar levels in both study groups were similar before the intervention ($p > 0.05$). The Independent T Test analysis results after 2 weeks of intervention also showed no difference between the groups ($p > 0.05$), except for 2-hour postprandial blood sugar levels. After 2 weeks, the average body weight was 2.59 kg higher and 2-hour postprandial

blood sugar levels were 8.73 mg/dL higher in the control group (commercial sugar) compared to the Intervention group. This study suggests that consuming commercial sugar may increase 2-hour postprandial blood sugar levels.

The difference in the pretest and posttest averages is proven by the results of the Paired T test described in table 4. There was a significant difference in pretest and posttest weight in the Intervention group ($p < 0.05$). The average weight after 2 weeks of intervention decreased by 1.29 kg. In contrast, the control group (commercial sugar) experienced an increase in weight of 0.273 kg. HbA1c levels, fasting blood sugar, and 2-hour postprandial blood sugar did not differ in the two groups ($p > 0.05$). These data indicate that there is an effect of Cerselau sugar on the weight loss of respondents.

Effect of Cerselau Sugar on body weight, HbA1c levels, and blood sugar levels

The results of the Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root tests obtained $p = 0.255$. These results suggest that there is no difference in the average between groups. Cerselau Sugar has an effect on weight loss. Cerselau Sugar has no effect on HbA1c levels $p 0.836$, fasting blood sugar levels $p 0.730$, and 2-hour postprandial blood sugar levels $p 0.784$. Giving commercial sugar has an effect on increasing 2-hour postprandial sugar levels $p 0.046$.

Table 3. Phase 2: Differences in HbA1c Levels, Fasting Blood Sugar, Sugar Levels 2-Hour Postprandial, Before and After Treatment Between the Control Group and the Intervention Group

Variables	Pretest		p	Posttest		p
	Intervention Group (Cersenlau sugar)	Control Group (commercial sugar)		Intervention Group (Cersenlau sugar)	Control Group (commercial sugar)	
Body Weight (kg)	60.7 ± 11.56	61.73 ± 10.83	0.762	59.41 ± 11.13	62.0 ± 11.98	0.461
HbA1c (%)	5.49 ± 0.30	5.53 ± 0.24	0.629	5.46 ± 0.28	5.45 ± 0.29	0.836
Fasting Glucose level (mg/dL)	93.36 ± 4.18	93.09 ± 10.42	0.934	94.45 ± 11.55	93.22 ± 4.87	0.730
2-Hour postprandial glucose (mg/dL)	103.86 ± 16.95	109.72 ± 25.83	0.379	105.0 ± 12.39	113.73 ± 13.75	0.046

Table 4. Body Weight, HbA1c Levels, Fasting Blood Sugar Levels, and 2-Hour Postprandial Blood Sugar Before and After Treatment in the Control Group and the Intervention Group

Variables	Intervention Group		p	Control Group		p
	Pretest	Posttest		Pretest	Posttest	
Body Weight	60.7 ± 11.56	59.41 ± 11.13	0.000	61.73 ± 10.83	62.00 ± 11.98	0.572
HbA1c level (%)	5.49 ± 0.30	5.46 ± 0.28	0.675	5.53 ± 0.24	5.45 ± 0.29	0.057
Fasting blood sugar levels (mg/dL)	93.36 ± 4.18	94.45 ± 11.55	0.608	93.09 ± 10.42	93.22 ± 4.87	0.969
Blood sugar 2-hour postprandial level (mg/dL)	103.86 ± 16.95	105.00 ± 12.39	0.784	109.72 ± 25.83	113.73 ± 13.75	0.455

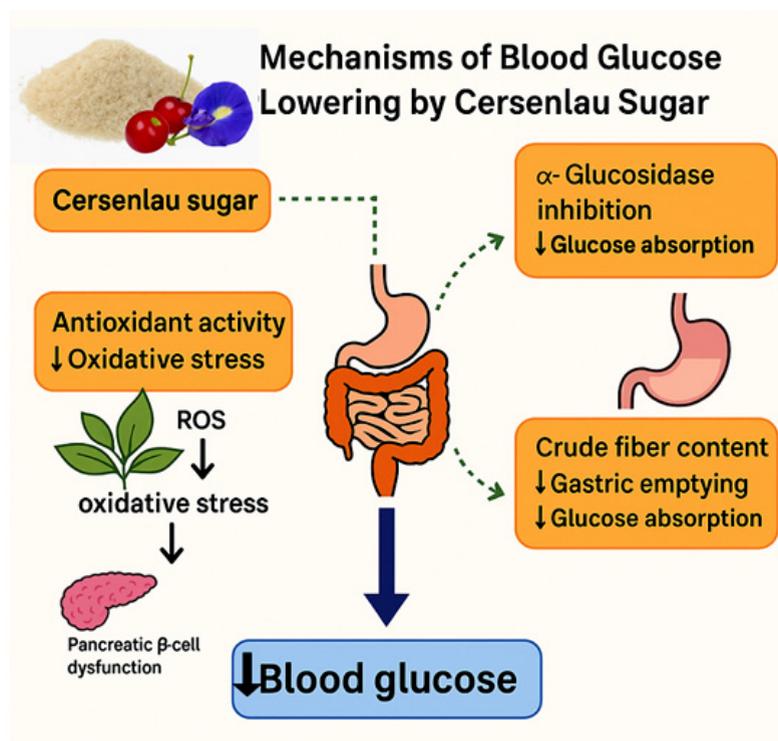


Fig. 1. Mechanism of blood glucose lowering by cersenlau sugar

DISCUSSION

Phase I research indicates that Cersenlau Sugar has potential as a therapeutic agent for people with type 2 diabetes. Administering Cersenlau Sugar can decrease fasting blood sugar, 2-hour postprandial levels, and lower posttest HbA1c levels in the intervention group. This effect is due to the high bioactive content of Cersenlau Sugar, which includes antioxidants, flavonoids, vitamin C, beta-carotene, sugar, iron, anthocyanins, and crude fiber.

When the body's production of reactive oxygen species (ROS) gets out of balance with its antioxidant defense, it causes damage to and dysfunction in pancreatic beta cells. In people with diabetes, chronic high blood sugar and mitochondrial problems lead to more ROS being produced, which worsens oxidative stress. This, in turn, causes damage to blood vessels and hinders endothelial function, playing a role in the development of complications like retinopathy, nephropathy, and cardiovascular disease.^{2,4,21,22} Ways to lower oxidative stress in diabetes include

antioxidant therapy, using sugar substitutes as sweeteners, and taking vitamins C and iron to prevent anemia caused by kidney problems (erythropoiesis). Other helpful strategies include taking beta-carotene, vitamin C, flavonoids, and anthocyanins, which have antioxidant properties. Eating crude fiber can also provide a feeling of fullness for longer, bind sugar and fat, and help control blood sugar and body weight.^{21,22} Our study's findings support Cintari's 2023 research, which showed that SGOT, SGPT, and creatinine levels dropped and pancreatic tissue in mice with type 2 diabetes improved after four weeks of Cersenlau Sugar treatment.^{23,24}

Phase II research with healthy subjects showed that Cersenlau Sugar affected respondents' weight loss but had no effect on fasting blood sugar levels, 2-hour PP blood sugar, and HbA1c. It was found that fasting blood sugar levels, 2-hour PP blood sugar, and HbA1c in the intervention group with Cersenlau Sugar before and after treatment showed no difference ($p > 0.05$).

Under normal conditions, interactions in cells demonstrate a synergy mechanism that

enables physiological processes to function properly, signaling that the body is in good health. Beta Langerhans cells in the pancreas secrete insulin, which helps absorb blood sugar and convert glucose into energy. Glucagon, cortisol, and insulin work together to maintain the body's metabolic balance. The average carbohydrate intake of the study participants was 220 g per day for women (52.16%), with an average BMI of 25.69 kg/m² and an average HbA1c level of 5.53%. This carbohydrate intake aligns with WHO recommendations, which suggest 45-65% of total calories. Consuming carbohydrates according to needs supports normal glucose metabolism and helps the body use them to sustain organ function. This intake level is similar to the average intake in well-controlled type 2 diabetes patients in Japan, which is 226 g per day with an HbA1c level of 7.6%.²⁵

In simple form, carbohydrates produce calories the fastest²⁶ Glucose is needed for brain activity, red blood cell formation, and skeletal muscle activity to move. Glucose is also used for the formation of amino acids. Therefore, the recommended daily carbohydrate consumption in healthy adults is 45-65% of total calories. The remaining carbohydrates that are not needed are stored in the liver and muscle tissue in the form of glycogen and fat. When glucose intake is low, the body will degrade glycogen into glucose through the mechanisms of glycogenesis and gluconeogenesis.^{27,28}

Insulin regulates glucose balance through insulin-sensitive organs, such as the liver, muscles, and kidneys.²⁹ When blood glucose increases, insulin binds to its receptors on liver, fat, and muscle cells, then triggers intracellular translocation of glucose, and increases glucose uptake by peripheral tissues. Insulin triggers glycolysis reactions and inhibits glucagon secretion by stopping glycogenesis and gluconeogenesis so that blood glucose levels decrease.^{30,31}

Two-hour PP blood sugar levels increased after the intervention in the commercial sugar group (the average posttest was higher than the pretest) and there was a difference between the two groups. This condition is likely because commercial sugar does not contain dietary fiber, so there is nothing to bind sugar and inhibit its absorption. In the intervention group, there was no

increase in blood sugar levels. 2-hour PP, because the high fiber content in cersenlau sugar provides a feeling of fullness for longer.

Dietary fiber is difficult to digest along the digestive tract. This creates a feeling of fullness. The fiber undergoes hydrolysis in the small intestine so that it can pass through it to the large intestine. Furthermore, in the large intestine, fermentation occurs to provide food needed by the intestinal microbiota to live and grow. This condition plays an important role in the process of microbiota diversification in the formation of feces in the large intestine which is followed by water absorption, so that feces are easier to pass.³²⁻³⁵

Insulin secretion in research subjects who received Cersenlau sugar intervention is likely related to normal pancreatic function, especially pancreatic Beta cells that secrete insulin. Purple pea flowers have strong antioxidant properties. Research by Cahyaningsih, et al. in 2019, found that 80% ethanol extract of Telang flowers had strong antioxidant activity with an IC50 value of 87.86 ppm.^{16,23,24,36} Cintari research in 2023 also found that administering Cersenlau sugar to Wistar rats could enhance pancreatic beta cells.²³

The glucose-lowering potential of Cersenlau sugar is likely attributable to its synergistic bioactive profile, primarily driven by antioxidant flavonoids, anthocyanins, and crude dietary fiber. The anthocyanins and flavonoids from *Clitoria ternatea L.* and *Muntingia calabura L.* exhibit strong radical scavenging effects that reduce oxidative stress, a key contributor to pancreatic β -cell dysfunction in diabetes mellitus.^{27,28} Additionally, Cersenlau sugar may inhibit intestinal α -glucosidase enzymes, thus slowing carbohydrate digestion and reducing postprandial glucose excursions.^{17,19} Its high fiber content also delays gastric emptying and glucose absorption, promoting better glycemic control. These mechanisms, summarized in Figure 1, provide a plausible biochemical basis for the hypoglycemic effects observed in the present study.

Flavonoids and anthocyanins contained in Cersenlau sugar may exert glucose-lowering effects through several biochemical pathways. These compounds are known to inhibit intestinal α -glucosidase and α -amylase enzymes, thereby delaying carbohydrate digestion and reducing postprandial glucose excursions. In addition,

they scavenge reactive oxygen species (ROS), protecting pancreatic β -cells from oxidative stress-induced apoptosis, which is a major contributor to the progression of type 2 diabetes. Dietary fiber further supports glycemic control by slowing gastric emptying and enhancing satiety, which can indirectly reduce caloric intake and body weight. Together, these synergistic effects provide a mechanistic basis for the hypoglycemic and weight-modulating potential of Cersenlau sugar.

The discrepancy between the significant results in Phase I (animal model) and the nonsignificant findings in Phase II (healthy adults) may be explained by several factors. First, the baseline glucose and HbA1c levels of healthy adults were already within normal ranges, making it less likely to observe measurable reductions. Second, the short duration of intervention (14 days) may not have been sufficient to capture the full effect on HbA1c, which typically reflects glycemic control over 8–12 weeks. Third, the relatively small sample size and gender imbalance may have limited the statistical power of Phase II. Despite these limitations, the observed reduction in body weight and prevention of postprandial glucose rise in the intervention group suggest that Cersenlau Sugar may have a protective role in early metabolic regulation. Future trials should involve participants with prediabetes or type 2 diabetes, longer intervention periods, and larger, more balanced cohorts to better evaluate its clinical efficacy. The absence of significant changes in glucose and HbA1c among healthy adults suggests that the therapeutic effect of Cersenlau Sugar may be more pronounced in individuals with impaired glucose tolerance or diabetes, where oxidative stress and insulin resistance are more evident. This highlights the importance of conducting future clinical trials in such populations to better assess translational impact.

The findings of this study led to the development of a sugar prototype derived from plants native to Indonesia. Cersenlau sugar serves as a safe sweetener for individuals with diabetes mellitus. Additionally, this sugar benefits healthy people by helping prevent anemia and supporting overall health due to its high antioxidant content, which aids the digestive tract, pancreas, blood vessels, heart, liver, and kidneys.

CONCLUSION

Cersenlau sugar shows potential as a supportive dietary sweetener with possible therapeutic benefits in type 2 diabetes mellitus. Nevertheless, larger and more rigorously designed studies are warranted to confirm its efficacy and long-term safety in human populations. Future studies should be conducted with longer intervention periods, larger and more gender-balanced samples, and participants with prediabetes or type 2 diabetes, to further validate the clinical utility of Cersenlau Sugar.

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Conflict of Interest

The author declares no conflict of interest.

Data Availability Statement

This statement does not apply to this article.

Ethics Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval

Informed Consent Statement

All participants involved in Phase II of this study provided written informed consent after receiving detailed information about the study objectives, procedures, potential risks, and benefits. Participation was voluntary, and subjects were assured of confidentiality and the right to withdraw at any time without consequences.

Clinical Trial Registration

This research does not involve any clinical trials.

Permission to reproduce material from other sources

Not applicable.

Author Contributions

Ni Nyoman Budiani: Writing, Data

collection, Funding Acquisition, Supervision; Ni Komang Wiardani, Listina Ade Widya Ningtyas, Gusti Ayu Tirtawati: Data Collection, Analysis, Writing, Review and editing.

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