



Blood Glucose Fasting Increasing Levels Comparison After Consumption of Stevia and Granulated Sugar in Healthy Individuals

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Abstract

Introduction: Increased blood glucose levels are caused by a lifestyle that involves excessive consumption of foods and drinks containing sweeteners. *Stevia Rebaudiana Bertoni* leaves are a natural ingredient that can be used as a natural sweetener because they contain stevioside and rebaudioside A, with a sweet taste effect that is 200 to 300 times higher than the sucrose found in granulated sugar. However, few studies still report comparative data on fasting blood glucose levels after consuming natural *Stevia* and granulated sugar as a sweetener in healthy individuals. **Purpose:** To compare the increase in fasting blood glucose levels after consuming *Stevia* and granulated sugar as sweeteners in healthy individuals. **Methods:** Experimental research with a pretest-posttest with control group design was carried out using purposive sampling. The research subjects were 40 people aged 17-23 years who were asked to fast for 8-10 hours. Fasting blood glucose levels were measured before consuming powdered and liquid *Stevia*, granulated sugar, and mineral water as a control, and further measurements were carried out 45 minutes after treatment. **Results:** The highest increase in fasting blood glucose levels occurred in subjects who consumed granulated sugar solution, namely 15.8 mg/dL, followed by subjects who consumed liquid *Stevia* solution at 6.6 mg/dL, and the lowest in subjects who consumed powdered *Stevia* solution. Powdered *Stevia* increased blood glucose by 5.6 mg/dL. **Conclusion:** There is a significant difference in blood glucose levels before and after the treatment of consuming powdered *Stevia*, liquid *Stevia*, and granulated sugar sweetener. The increase in fasting blood glucose levels after consuming powdered or liquid *Stevia* sweetener was significantly lower than that of the granulated sugar sweetener.

Keywords: Blood sugar levels; *Stevia*; granulated sugar

Introduction

Diabetes mellitus is a metabolic disease characterized by an imbalance in blood sugar levels resulting from impaired insulin secretion. Chronic hyperglycemia in diabetes mellitus is associated with long-term microvascular complications affecting the eyes, kidneys, and nerves, as well as an increased risk of cardiovascular disease (CVD).^{1,2} The impact of increased blood sugar levels in diabetes mellitus cases in dentistry, one of which can be a predisposing factor for the occurrence of periodontitis due to the thickening of blood vessels, which causes a slowing of blood flow carrying nutrients from the body. This slowing of blood flow also reduces the body's ability to fight infection, triggering plaque and calculus accumulation, which can aggravate infection and cause periodontitis in the oral cavity.³

One of the triggers for increased blood sugar levels is an excessive lifestyle of consuming sweetened foods and beverages. Excessive intake of sugar-sweetened drinks is



commonly associated with the development of metabolic syndrome and type 2 diabetes as well as increased body weight (obesity).⁴ Sugar, also known as sucrose, is the most widely used sweetener today. One tablespoon of sugar contains 60 kilocalories, and 1 gram of sugar equals 4Kcal, so it significantly contributes to overall energy intake when consumed in large amounts.⁵ Lifestyle patterns that consume excessive sugar can also lead to weight gain, which can then trigger type 2 diabetes. Increased body weight also poses a risk of obesity as the excess energy is stored as fat in the body tissues. Excessive fat accumulation in the body can lead to insulin resistance, which in turn affects blood glucose levels and may eventually result in diabetes mellitus.^{5,6}

Considering the impact of sugar consumption on health, it is necessary to limit daily sugar intake and look for alternative sweetener substitutes that are safer and have minimal side effects on body health. Sugar substitutes derived from synthetic (artificial) ingredients include aspartame and saccharin. Aspartame, however, has been reported to give side effects in the form of headaches and some neuropsychiatric symptoms, while consumption of saccharin can cause dermatological reactions, including pruritus and eczema.^{5,6}

Another alternative sugar substitute sweetener that is currently receiving a lot of attention because it offers numerous health benefits with minimal side effects is the natural sweetener *Stevia*. According to Goyal SK et al. and Pol J et al., as cited by Deviyanti S. (2021), *Stevia* sweeteners are known to contain various phytochemical components with antibacterial, antifungal, anti-inflammatory, antineoplastic, anti-obesity, antidiabetic, and anticariogenic activities.⁹⁻¹⁴ According to Pol J et al., cited by Deviyanti S. (2021), *Stevia* sweetener has also been shown to have no mutagenic, teratogenic, or carcinogenic effects and does not cause allergies. *Stevia* sweetener is extracted from the leaves of the *Stevia rebaudiana* Bertoni plant, which belongs to the taxonomic sunflower family (*Asteraceae*) and originates from Paraguay.^{9,15} According to Geuns J., cited by Khiraoui A et al. (2017),¹⁶ the sweetness-carrying component isolated from *Stevia* leaf extract is known to be a diterpene glycoside known as steviol glycoside, including stevioside, steviolbioside, various rebaudioside (A through F), and dulcoside components. According to Lemus-Mondaca R. et al. cited by Jan SA et al. (2021),¹⁷ stevioside and rebaudioside A are the two main components of the natural sweetener *Stevia*, which is thermostable for use in cooking food. According to Gasmalla MAA. cited by Jan SA et al. (2021),¹⁷ stevioside has a sweetness level 300 times sweeter than sucrose. Furthermore, Flavi VS., cited by Jan SA et al. (2021), states that rebaudioside A has a sweetness level 250-



400 times greater than sucrose.¹⁷ *Stevia* sweetener, as a natural sweetener to replace sugar, is classified as a non-nutritive sweetener.^{18,19} Although commercial products of *Stevia* sweetener are widely available in both powder and liquid forms, research data on the effect of consuming various types of *Stevia* compared to sugar on blood glucose levels in healthy individuals remains limited. This information is important for the public and serves as the basis for our research in this study.

Methods

This research is an experimental study with a pretest-posttest research design with a control group. The research on "Comparison of Increased Blood Glucose Levels After Consumption of Various *Stevia* Natural Sweetener Preparations and Granulated Sugar in Healthy Individuals" was carried out after obtaining approval from the Research Committee of the Faculty of Medicine, Prof. Dr. Moestopo University.

The research was conducted from June to December 2024. The study involved 40 subjects, consisting of 10 men and 30 women. The inclusion criteria were: willingness to participate and signing informed consent, age between 17 and 23 years, good general health without systemic disease, normal fasting blood glucose levels ranging from 70 to 99 mg/dL, no smoking within 1 hour prior to examination, no alcohol consumption, and not taking certain medications. Subjects also had a normal Body Mass Index (BMI) ranging from 18.5 to 24.9 kg/m². Capillary blood glucose levels were measured using a digital glucometer (Accu-Chek Active, Figure 1) equipped with glucose strips (Figure 2), after a fasting period of at least 8 to 10 hours. Subjects were instructed to consume 100 mL of water solution with various types and dosage forms of sweeteners within 5 minutes. After 45 minutes, a second blood glucose level check was conducted. The research subjects were divided into 4 groups. Group 1: 10 subjects who consumed a mineral water solution with powdered *Stevia* sweetener—½ sachet (1.3 grams) dissolved in 100 mL of mineral water. Group 2: 10 subjects who consumed a mineral water solution with liquid *Stevia* sweetener—2–3 drops dissolved in 100 mL of mineral water. Group 3: 10 subjects who consumed a mineral water solution sweetened with granulated sugar—1 teaspoon (5 grams) dissolved in 100 mL of mineral water. Group 4: 10 subjects as a negative control, who consumed 100 mL of unsweetened mineral water.

All data from the study were analyzed using the SPSS software program. The normality distribution of data was analyzed using the *Shapiro-Wilk Test* with a significance value

($p > 0.05$), followed by the *Paired T-test* to determine whether there was a significant difference in the mean value of fasting blood glucose levels before and after treatment. A one-way ANOVA test was conducted to see significant differences in the mean value of fasting blood glucose levels after treatment between all groups. *Games-Howell post hoc test* was conducted to determine significant differences in fasting blood glucose levels after treatment between groups.²⁰



Figure 1. Glucometer “AccucheK”



Figure 2. “AccucheK” Strip Glucose

Results

Based on Table 1, the majority of research subjects were female, totaling 30 individuals (75%), while 10 were male (25%) out of a total of 40 participants. The most common age among the subjects was 19 years (40%), while the least represented were those aged 21 years, with only 2 participants (5%) out of 40 research subjects. The average *Body Mass Index* (BMI) of the research subjects was in the normal category, at 21.06 kg/m² with a standard deviation of 1.39.

Table 1. Frequency Distribution of Research Subject Characteristics Based on Gender, Age, and BMI

Category	Frequency (n)	Percentage (%)
Gender	10	25%
Man	30	75%
Woman	40	100%
Total		
Age (years)	5	12.5%
17	3	7.5%
18	16	40%



19	7	17.5%		
20	2	5%		
21	4	10%		
22	3	7.5%		
23	40	100%		
Total				
Category	Frequency (n)	Mean (kg/m ²)	Standard Deviation (SD)	
BMI*	40	21,06	1.39	

* *Body Mass Index (BMI)*

The results of the Shapiro-Wilk normality test in Table 2 show that the p-values for blood glucose measurements before and after treatment in each group were greater than 0.05 ($p > 0.05$). This indicates that the data were normally distributed.

Table 2. Results of the *Shapiro-Wilk Normality Test*

Treatment	Statistics	Sig	Df.
Consuming Powdered <i>Stevia</i> Solution			
Blood Glucose Levels Before	0.968	0.876	10
Blood Glucose Levels After	0.928	0.429	10
Consuming Liquid <i>Stevia</i> Solution			
Blood Glucose Levels Before	0.961	0.795	10
Blood Glucose Levels After	0.931	0.459	10
Consuming Granulated Sugar Solution			
Blood Glucose Levels Before			
Blood Glucose Levels After	0.905	0.251	10
	0.924	0.392	10
Consuming Mineral Water Solution (Control)			
Blood Glucose Levels Before	0.978	0.952	10
Blood Glucose Levels After	0.911	0.285	10

According to the results of the paired t-test in Table 3, there was a significant difference ($p = 0.000$) in the average fasting blood glucose levels in each group before and after treatment.



Table 3. Average Value of Fasting Blood Glucose Level Measurement Results Before and After Treatment in Each Group

Treatment	Number of Samples	Mean (mg/dL)	Std. Deviation	Std. Error Mean	Sig.
Powdered Stevia Solution					
Blood Glucose Levels Before	10	67.00	5.47	1.73	0.000*
Blood Glucose Levels After	10	72.60	4.59	1.45	
Blood Glucose Levels changes		5.60			
Liquid Stevia Solution					
Blood Glucose Levels Before	10	62.90	4.93	1.55	0.000*
Blood Glucose Levels After	10	69.50	7.59	2.40	
Blood Glucose Levels changes		6.60			
Granulated Sugar Solution					
Blood Glucose Levels Before	10	72.70	6.86	2.17	0.000*
Blood Glucose Levels After	10	88.50	7.79	2.46	
Blood Glucose Levels changes		15.80			
Mineral Water Solution (Control)					
Blood Glucose Levels Before	10	69.70	5.43	1.71	0.000*
Blood Glucose Levels After	10	61.50	6.90	2.18	
Blood Glucose Levels changes		-8.20			

*significant $P < 0.05$ using *Paired t-test*

A diagram illustrating the average fasting blood glucose levels before and after treatment, as well as the changes in average fasting blood glucose levels for each group, is presented in Figure 3.

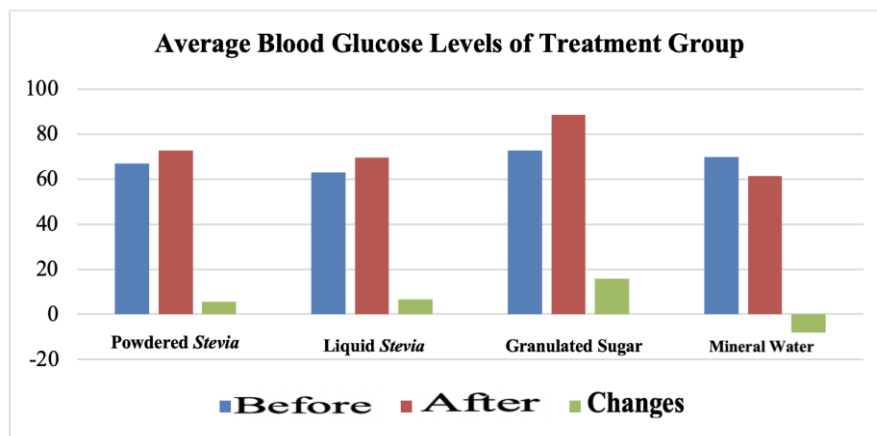


Figure 3. Diagram of Average Values of Fasting Blood Glucose Level Measurement Results Before and After Treatment

According to Table 3, the highest increase in average fasting blood glucose levels before and after treatment was observed in the group of subjects who consumed a mineral water



sweetened with granulated sugar, with an increase of 15.8 mg/dL, from 72.70 mg/dL to 88.50 mg/dL. The second highest increase was found in the group that consumed mineral water with liquid *Stevia*, showing an increase of 6.6 mg/dL, from 62.90 mg/dL to 69.50 mg/dL. The smallest increase occurred in the group that consumed mineral water sweetened with powdered *Stevia*, with an increase of 5.6 mg/dL, from 67.00 mg/dL to 72.60 mg/dL. Meanwhile, decrease in the average blood glucose levels was observed in the control group, who consumed unsweetened mineral water with a reduction of 8.2 mg/dL from 69.70 mg/dL to 61.50 mg/dL. Based on the results of the one-way ANOVA comparing the average blood glucose levels among all groups before and after treatment, a statistically significant difference was found ($p = 0.000$; $p < 0.05$) (Table 4).

Table 4. Significant Differences in Mean Fasting Blood Glucose Levels Among Study Groups Based on One-Way ANOVA Test Results

	Sum of squares	df	Mean square	F	Sig.
Between groups	3849.075	3	1283.025	27.430	.000*
Within groups	1683.900	36	46.775		
Total	5532.975	39			

* significant $P < 0.05$ with the one-way ANOVA test

Based on the Games-Howell post hoc test results shown in Table 5, a significant difference in mean fasting blood glucose levels was observed between the group that consumed unsweetened mineral water and the group that consumed mineral water sweetened with granulated sugar ($p = 0.000$), as well as the group that consumed powdered *Stevia* ($p = 0.003$). However, there was no significant difference compared to the group that consumed liquid *Stevia* ($p = 0.100$).

The granulated sugar group showed significantly higher mean blood glucose levels compared to all other groups: the unsweetened group ($p = 0.000$), the powdered *Stevia* group ($p = 0.000$), and the liquid *Stevia* group ($p = 0.000$). The powdered *Stevia* group differed significantly from the unsweetened group ($p = 0.003$) and the granulated sugar group ($p = 0.000$), but not from the liquid *Stevia* group ($p = 0.692$). Lastly, there was no significant difference between the liquid *Stevia* group and either the powdered *Stevia* group ($p = 0.692$) or the unsweetened group ($p = 0.100$), but it did differ significantly from the granulated sugar group ($p = 0.000$).



Table 5. Average Value of Fasting Blood Glucose Levels After Treatment Between Group Pairs.

	Mineral Water	Granulated Sugar Solution	Powdered Stevia Solution	Liquid Stevia Solution
Mineral Water	-	0.000*	0.003*	0.100
Granulated Sugar Solution	0.000*	-	0.000*	0.000*
Powdered Stevia Solution	0.003*	0.000*	-	0.692
Liquid Stevia Solution	0.100	0.000*	0.692	-

*Significant $P < 0.05$ with *Games-Howell Post Hoc*

Discussion

Excessive consumption of sugary drinks and foods is one of the contributing factors to metabolic disorders, which can lead to obesity and trigger diabetes mellitus. High sugar consumption can have bad effects on health if not managed properly. Excessive sugar consumption will increase plasma blood sugar levels which can trigger type II DM. This happens because too much energy enters and is stored in the body's tissues until insulin resistance occurs. Therefore, we need alternative sweeteners to replace sugar from natural ingredients that are low in calories and have safety aspects for body health as one of the prevention efforts.²¹

Our current research was conducted to compare the increase in blood glucose levels after consuming mineral water with various types of natural sweetener, *Stevia*, and mineral water sweetened with granulated sugar, with a negative control in the form of a group of subjects who consumed unsweetened mineral water solutions. This research involved a total of 40 subjects. There were 10 male subjects and 30 female subjects, with an age range of 17-23 years as healthy individuals with an average BMI of 21.06 kg/m². All subjects met the predetermined inclusion criteria. After the subjects had fasted for 8-10 hours, blood glucose was measured before and 45 minutes after consuming a mineral water solution with the natural sweetener *Stevia* in powder or liquid form, and a mineral water solution sweetened with granulated sugar and an unsweetened mineral water solution (control group).

According to Marks et al., as cited by Kasengke et al. (2015), a person's postprandial blood glucose level will differ from their fasting blood glucose level or the level measured before eating.²² After consuming food or beverages containing carbohydrates, blood glucose



levels will increase. Some of the glucose contained in food will undergo metabolism to be converted into glycogen in the liver. After 2 or 3 hours of fasting, glycogen will be broken down by the glycogenolysis process, and the glucose formed is released into the blood. As glycogen stores diminish, triacylglycerol in adipose tissue is broken down to provide fatty acids for energy and glycerol for gluconeogenesis. Amino acids are also released from muscles to function as precursors of gluconeogenesis. After an overnight fast, blood glucose levels are maintained by both glycogenolysis and gluconeogenesis, but after 30 hours, liver glycogen stores are depleted and gluconeogenesis becomes the sole source of glucose in the blood.

Normal post-absorptive blood glucose ranges from 4.5–5.5 mM, may rise to 6.5–7.2 mM after carbohydrate intake, and drops to 3.3–3.9 mM during fasting.²² This seems to be in line with the results of our current research, which showed an increase in average blood glucose levels 45 minutes after consuming Stevia- or sugar-sweetened mineral water. Although the increase was slightly higher in the liquid Stevia group than the powdered Stevia group, the difference was not statistically significant ($p > 0.05$) when compared to both the powdered Stevia group and the control group (unsweetened mineral water). In contrast, the increase in the sugar group was significantly higher ($p < 0.05$), with a rise of 15.8 mg/dL, compared to the liquid Stevia group (6.6 mg/dL), powdered Stevia (5.6 mg/dL), and the control group, which showed a decrease of –8.2 mg/dL.

The increase in the average value of blood glucose levels in the group that consumed mineral water with powdered Stevia sweetener, as well as the control group, was significantly lower than in the group that consumed mineral water sweetened with granulated sugar. This can be explained by the fact that Stevia contains sweetening components in the form of Diterpene glycosides or Steviol glycosides, which consist of various mixtures of different metabolites, primarily stevioside and rebaudioside.²³ According to Chauhan N et al., quoted by Kazmi A et al. (2019), the steviol glycoside component of *Stevia* sweetener has zero calorific value (zero calories).²³ It is also known to stimulate insulin secretion through a direct action on β cells in the pancreas without altering K^+ -ATP channel activity and cAMP levels in the islets (a group of cells in the pancreas that produce hormones), allowing it to act as an antihyperglycemic agent. Insulin, a hormone produced by the β cells of the pancreas plays a major role in regulating glucose, protein, and fat in the body by promoting the uptake of glucose from the bloodstream for storage in the liver, fat, and skeletal muscle cells.²⁴



Aranda-Gonzales I et al., quoted by Kazmi A et al. (2019), stated that the application of stevioside as a component of *Stevia* sweetener in experimental mice with diabetes, has also shown a direct link to increased insulin production which suppresses the gluconeogenesis process.²³ Momtazi-Borojeni AA et al. (2017) also explained that the natural sweetener *Stevia* does not contribute to increasing blood glucose levels because the steviol component it contains has the effect of opening the blood vessels. Pancreatic β -cells stimulate insulin secretion in response to glucose in the blood. The use of the natural sweetener *Stevia* is therefore recommended for managing cases of type 2 diabetes mellitus.²⁵

According to research by Chan TH et al., as cited by Jan SA et al. (2021), stevioside as the main component of the *Stevia* sweetener, not only increases insulin production, but has also been shown to reduce the gluconeogenesis by suppressing the expression of the phosphoenolpyruvate carboxykinase gene in the liver of experimental rats, thereby helping to maintain optimal blood glucose levels.¹⁷ According to Koyama E et al., as cited by Singh G et al. (2024), steviol glycosides, the sweetening components of *Stevia*, are not degraded in the upper digestive tract, but instead reach the large intestine (colon) where they are degraded into glucose and *steviol* by bacteria in the intestine. *Steviol* is then absorbed into the bloodstream, reaches the liver, and is conjugated with glucuronic acid, facilitating the excretion process.^{26,27,28} These findings may explain why, in our current study, the group of subjects who consumed mineral water sweetened with liquid *Stevia* showed only a modest increase in average blood glucose levels compared to the group that consumed mineral water sweetened with granulated sugar. Additionally, there was no significant difference in blood glucose level increases between the group that consumed *Stevia* powder and the control group.

In our study, participants who consumed the mineral water solution, used as both the control treatment and solvent, also showed a reduction in blood glucose levels. Consumption of mineral water solutions as a control group and solvent in our current study was proven to reduce blood glucose levels significantly lower than other groups. The significantly lower fasting blood sugar levels compared to all other groups can be explained by the consumption of water (without sweeteners), which does not contain calories that will be broken down into sugar in the body and can help remove chemicals or toxins, including excess sugar, which will be excreted by the kidneys through urine, thereby lowering blood glucose levels.²⁹

Driposwana Putra et al. (2022) reported a decrease in blood glucose levels after drinking water regularly for 14 days in individuals with type 2 diabetes mellitus.²⁹ Similarly, a study by



Kurniasari et al. (2023) found that the intervention group receiving hydrotherapy experienced an average reduction in blood glucose levels of 52.5 mg/dL, while the control group showed an average reduction in blood glucose levels of 33.56 mg/dL. Hydrotherapy, by consuming 8 glasses of water per day (approximately 1.5 liters), is thought to assist in the elimination of toxins from the body, including excess glucose through urine and sweat.^{29,30}

Almost 60% of our body consists of water, and it plays a vital role in various physiological functions. Inadequate hydration can damage organs and disrupt body systems. Apart from absorption, circulation, transportation of nutrients, production of saliva, and maintaining body temperature, water plays an important role in the digestive process of removing metabolic waste.³⁰ The choice of time for measuring blood glucose levels at 45 minutes in our current study was based on literature indicating that plasma glucose levels typically rise between 30 and 60 minutes after food consumption, then decrease rapidly within 2 hours, returning to normal levels around 120 mg/dL. Foods or drinks with a low glycemic index are digested more slowly, leading to a slower storage process and gradual availability of glucose, as glycogen storage occurs progressively. In contrast, granulated sugar—a disaccharide carbohydrate with a high glycemic index—is rapidly digested, causing a quick spike in blood glucose levels.³¹ These mechanisms help explain the significant increase in average blood glucose levels observed in the group that consumed mineral water sweetened with granulated sugar, compared to the groups that consumed Stevia-sweetened mineral water (both powder and liquid forms), as well as the control group in our current study.

The results of our current study appear to be in line with research by Al-Sultan RM et al. (2021), which examined the effect on fasting blood glucose levels after consuming 100 ml of a drink containing 0.2 mg/ml sucrose on the first day, 5 mg/ml *Stevia* sweetener on the second day, and 10 mg/ml *Stevia* sweetener on the third day, measured at 0, 30, 60, 90 and 120 minutes in 33 healthy research subjects with an average age of 24 years. The study explained that the highest significant glycemic response (average blood glucose value), namely 5.23 mmol/L, occurred 30 minutes after consumption of 0.2mg/ml sucrose solution, accompanied by an increase in insulin levels. In contrast, after 30 minutes of consuming the *Stevia* sweetener solution, blood glucose levels decreased and reached their highest levels 60 minutes after consumption. However, there was no significant difference ($p < 0.001$) in the blood glucose response between the different *Stevia* doses (5 mg/mL and 10 mg/mL). Insulin levels also remained relatively stable within 60 minutes after consuming the *Stevia* sweetener solution.⁴



This research also suggests that replacing sugar (sucrose) with the Stevia sweetener can be a viable alternative to reduce health risks associated with sugar, particularly for individuals suffering from diabetes. The study concluded that short-term consumption of the Stevia sweetener did not significantly raise blood glucose levels in healthy individuals.^{4,32}

Various studies also show that Stevia is safe for consumption by both healthy individuals and those with diabetes mellitus or obesity.^{13,33} However, researchers still recommend consuming Stevia within safe limits and according to the recommended intake, which is around 0.1 – 4 mg/kg body weight/day.^{34,35}

Conclusion

There was a significant difference in blood glucose levels before and after consuming sucrose or Stevia sweeteners. The increase in fasting blood glucose was significantly lower after consuming mineral water sweetened with Stevia (either powder or liquid) compared to granulated sugar. No significant difference was observed between the powdered Stevia group and the unsweetened (negative control) group. These findings suggest that Stevia may serve as a suitable alternative to sugar for maintaining blood glucose homeostasis and may help prevent obesity and type 2 diabetes in healthy individuals.

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