

# Investigating the Impact of Sugar-Free Gum on Blood Glucose Level: An Experiment Based on Diabetes Risk

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## Abstract:

This study aims to investigate the potential risks and benefits of non-sugar gums for diabetes patients by conducting literature reviews, Fehling's tests, and blood glucose examinations on healthy individuals to evaluate the metabolic effects of sugar-free gums from two well-known brands. The experiment data showed that the blood glucose levels of participants who ate sugary gum increased significantly during the first 40 minutes and then returned to a normal level at 80 minutes. In contrast, the blood glucose levels of sugar-free participants showed a slight decline or no signs of change. Results indicate that sugar-free gum contains no reducing sugar and shows little impact on short-term blood glucose levels. So, sugar-free products offer substitutions for sweet food for those people who need to control their blood glucose levels.

## Keywords:

Diabetes, Hyperglycemia, Sugar-free Gum, Blood Glucose, Fehling's Reagent

## 1. Introduction

### 1.1. Backgrounds

#### 1.1.1. Potential Risk of Diabetes

As of 2021, there were approximately 5366 million adults (aged 20-79) with diabetes worldwide, representing 10.5% of all active adults. It is projected that by 2045, this figure will increase to approximately 7832 (12.2%) [1]. Long-term high blood glucose can cause significant damage to the vascular system, possibly leading to retinopathy, end-stage renal disease, peripheral neuropathy, and diabetic ulcers. In severe cases, it can result in a series of health problems such as blindness or amputation. Meanwhile, major vascular complications of diabetes, such as myocardial infarction and stroke, have also become major causes of death, accompanied by an increased risk of cognitive dysfunction and other factors.

#### 1.1.2. Population with Diabetes

It is well known that people with diabetes cannot consume a large amount of sweet food, which makes them lose a lot of pleasure in their diet. However, the sudden popularity of sugar-free products nowadays has given these patients hope. According to market data, the penetration rate of artificial sweeteners in mainstream food and beverages has been continuously increasing in the United States. It has risen from 55% of market products in 2022 to over 60% in 2023, and by 2024, nearly 42% of adults have actively used low-calorie sweetener products.

### ***1.1.3. Effects of Gum on Blood Glucose Level***

Recent studies have shown that chewing sugar-free gum on an empty stomach may indirectly help regulate blood glucose levels by stimulating the secretion of incretin effect-stimulating hormones (such as GLP-1). LP-1 is a hormone secreted by intestinal L cells, which can delay gastric emptying, promote insulin release, and enhance the feeling of fullness. In a clinical trial conducted by Xu et al., healthy men on an empty stomach who continuously chewed sugar-free gum for 30 minutes had significantly higher plasma GLP-1 levels than those who did not chew ( $p = 0.031$ ) and reported higher subjective satiety at multiple time points [2]. That is to say, chewing sugar-free gum is not only harmless to diabetic patients but also has a certain alleviating effect on their condition [3].

## **2. Literature Reviews**

### ***2.1. Chewing Gum***

The history of chewing gum indicates that sugar was not an initial element but an additive that has progressively grown linked to it. While sugar, or more specifically, sweet taste, plays a more and more significant role in today's gum culture, it is crucial to comprehend its health implications. As chewing gum constitutes a daily snack for specific segments of the population, it is crucial to understand its ingredients, particularly the composition and effects of its sweeteners. The main sweeteners for sugar chewing gum are sucrose and glucose syrup. The sugar-free ones are xylitol and aspartame.

### ***2.2. Xylitol***

As one of the important sweeteners in sugar-free foods, Xylitol is widely used in chewing gum. Actually, Xylitol already exists in the human body - there are approximately 0.03-0.06 milligrams of xylitol per 100ml of blood. Xylitol has a low-calorie content, a Glycemic Index (GI) of only 7 (GI will be introduced later), and is slowly absorbed by the human body. Meanwhile, xylitol is easily soluble in water, and its absorption rate in the small intestine is less than 50%. The remaining 50% enters the large intestine and undergoes fermentation, producing beneficial butyric acid for the human body.

### ***2.2. Diabetes***

Diabetes is a disease caused by insufficient insulin secretion or utilization, which can be divided into type 1, type 2, and gestational (meaning pregnant) diabetes. Type 1 is caused by genetics and is common in adolescents; Type 2 is mainly caused by an unhealthy diet and lifestyle and is common in adults after the age of 40. Gestational diabetes denotes glucose tolerance irregularities or diabetes identified for the first time during pregnancy. Between diabetes and normal people, that is, prediabetes, there will

be Impaired Fasting Glucose (IFG) and Impaired Glucose Tolerance (IGT), and other symptoms. The following table shows the numerical values of these symptoms.

**Table 1.** Classification of sugar metabolism status (mmol/L).

| /                    | Types (mmol/L)        |                        |
|----------------------|-----------------------|------------------------|
|                      | Fasting blood glucose | Two hours after eating |
| Normal blood glucose | <6.1                  | <7.8                   |
| IFG                  | 6.1~7.0               | <7.8                   |
| IGT                  | <7.0                  | 7.8~11.1               |
| Diabetes             | ≥7.0                  | ≥11.1                  |

*Image credits: Adapted from World Health Organization (1999) [4]*

### 2.2.1. Causes of Type 2 Diabetes

The main inducements of type 2 diabetes are obesity and lack of exercise, and a long-term diet of high oil and sugar foods. Long-term high demand for sugar breakdown leads to insufficient insulin secretion. Gestational diabetes incidence is a complicated process involving genetic predisposition to diabetes, age, obesity, and alterations in endocrine hormones.

### 2.2.2. Evaluation Standard of Diabetes

Symptoms of diabetes: acute metabolic disorders such as polydipsia, polyuria, weight loss, skin itching, and blurred vision caused by hyperglycemia. The primary evaluation criteria are fasting blood glucose levels greater than or equal to 7.0 mmol/L, postprandial blood glucose levels greater than or equal to 11.1 mmol/L within two hours, and glycated hemoglobin levels greater than or equal to 6.5%.

## 2.3. Blood Glucose Level

All the rice, bread, noodles, steamed buns, and other grains we eat will eventually be converted into sugar and absorbed. Blood glucose levels refer to the concentration of sugar in the blood, which is a crucial indicator of the body's metabolic rate. Blood glucose levels can mainly be detected through a blood glucose metre, usually measured in mmol/L.

### 2.3.1. Glycemic Index (GI)

According to the International Tables of Glycemic Index and Glycemic Load Values [5], the Glycemic Index (GI) is the ratio of the glycemic effect of a 50g food to the glycemic effect of a 50g standard food (usually based on glucose), and the glycemic index of glucose is usually set at 100. If the GI of a food is 55 or below, it is considered a low sugar food. If the GI of a food is 55-70, it is estimated as a medium sugar food. If the GI of a food is 70 or above, it is regarded as a high sugar food.

This project identified through literature review that, while there exists a substantial academic materials regarding the GI of various foods, multi-time point blood glucose monitoring of sugar substitutes (such as xylitol), and the impact of chewing gum on oral health, there is a notable deficiency in research concerning the effects of sugar-free chewing gum on blood glucose levels, studies explicitly monitoring blood glucose after the consumption of both sugar-containing and sugar-free chewing gum. This project is an empirical data-driven report that addresses this deficiency.

### 3. Research Methods

This study reviewed prior research to assess the metabolic effects of xylitol, a prevalent sweetener used in sugar-free gum, and to elucidate the impact of sugar-free gum on blood glucose levels.

#### 3.1. *Fehling's Experiment*

The scheme conducted approximately two experiments to test blood glucose levels before and after chewing different gum samples under control conditions. Also, the Fehling's experiment showed whether the contents of the gum contained sugar. By placing the trial under basic conditions, the ketones were able to be transformed into aldehydes, the substance that reacts with  $\text{CuSO}_4$  to form reddish-brown precipitation, which clearly shows the presence of reducing sugar in gum.

#### 3.2. *Comparative Method*

The method, comparing how blood glucose responds between sugar-free and sugared gums, was applied in the experiments.

### 4. Research Analysis

#### 4.1. *Experimental Process and Data Analysis*

##### 4.1.2. *Blood Glucose Threshold*

The normal blood glucose level range of postprandial 3h should be 4.0-6.1 mmol/L. When the blood glucose level exceeds 7.8 mmol/L, a great amount of insulin will be released to lower the blood glucose. When it's lower than 3.9 mmol/L, the kidneys will release epinephrine to increase the blood glucose level.

##### 4.1.3. *Detection of Reducing Sugar in Gums by using Fehling's Reagent*

###### **Materials:**

Beakers  
Electronic balance  
Water bath heater  
Test tubes  
Glass rod  
Scissors  
Mortar and pestle  
Pipette  
Gum

###### **Reagents:**

Fehling's reagent (Solution A and Solution B,  $\text{CuSO}_4\text{:NaOH} = 50\text{:}10$ )  
Distilled water

###### **Procedures:**

a. Classify the gum samples into four groups based on brand and sugar content. The ingredient lists printed on the product packaging show that the sweetener of sugar-free gums is xylitol, and of the sugared ones is white sugar and glucose syrup:

Group A: Sugared Wrigley's Doublemint

Group B: Sugar-free Wrigley's Doublemint

Group C: Sugared Tata Bubble Gum

Group D: Sugar-free Tata Bubble Gum

b. Weigh 4.50 grams of each sample, cut the gum into small pieces using scissors to increase the contacting surface area, aiding dissolution. Dissolve each sample in 10.00 mL of distilled water in the beaker. Stir thoroughly to create a uniform gum solution.

c. Prepare Fehling's reagent by mixing the solution A ( $\text{CuSO}_4$ ) and the solution B ( $\text{NaOH}$ ) with a ratio of 5:1, with volumes of 50.00mL and 10mL, respectively.

d. Dispense properly equal volumes of Fehling's reagent into 4 clean labeled test tubes (from group A-D as mentioned above).

e. Add 1.00 mL of the corresponding gum solution into each test tube using a Pasteur pipette. Shake and swirl to mix the Fehling's reagent and gum solution completely.

f. Submerge the test tubes in a water bath heater maintained at  $70^\circ\text{C}$ . Start timing.

g. Observe and record the colour change every 30 seconds. Continue the recording until there's no colour change anymore. The reddish-brown precipitation indicates the presence of reducing sugar, while the blue colour indicates no or little reducing sugar

h. Leave the tubes undisturbed for 24 hours at room temperature.

#### ***4.1.4. Measuring the Effects of Gums from 2 Brands on Blood Glucose***

This section measures the blood glucose levels of three healthy teenage volunteers, aged 17, comprising one female and two males. The blood glucose levels of each participant were assessed daily, both before and after the mastication of gum in various groups. Blood glucose was checked at three intervals: t1, three hours post-lunch; t2, forty minutes after t1; and t3, eighty minutes after t1. The data were documented in a table later.

### ***4.2. Summarizations of Results***

#### ***4.2.1. The result of Fehling's Reagent Experiments***

In the experiments investigating the reducing sugar in gum by using Fehling's reagent, the observations were the following:

During the first 30 seconds, the substance colours in tubes A (Sugared Wrigley Doublemint) and C (Sugared Tata Bubble Gum) started turning red. Meanwhile, the colours of tubes B (Sugar-free Wrigley's Doublemint) and D (Sugar-free Tata Bubble Gum) did not change and remained blue.

In the 60s, the blueness in tubes A and C in these two tubes nearly disappeared and turned slightly yellowish-red, and precipitation began to occur. The colours of Tubes B and D did not change and remained blue.

In the 90s, part of the colour of the mixture in tubes A and C turned reddish-brown. The colours of Tubes B and D did not change and remained blue.

From the 120s on, a large amount of obvious reddish-brown was preserved in tubes A and C and did not change anymore. The colours of tubes B and D did not change and remained blue.

The colour indicates that the claimed “no sugar” chewing gum and bubble gum do not contain reducing sugar, while others do contain sugar, so that the colour of Fehling’s reagent changes.

#### 4.2.2. The Change in Mass of Gum after Drying

After conducting the Fehling’s experiments, the author used the oven to bake and dry the gums. Evaporating the water inside the gum, the author was able to estimate the weight of the gum after the sugar was dissolved in water.

Since the dissolution process extracted the sugar, the loss between the initial mass and the dried weight of the gum should be the approximate mass of sugar contained in the gum (The gum in group A was mashed, so no value was measured).

$$M_a = N/A$$

$$M_b = 4.50 - 1.38$$

$$M_c = 4.50 - 1.94$$

$$M_d = 4.50 - 2.47$$

**Table 2.** The blood glucose levels of three volunteer individuals at three time points.

|                      |   | Individual 1 |     |     | Individual 2 |     |     | Individual 3 |     |     |
|----------------------|---|--------------|-----|-----|--------------|-----|-----|--------------|-----|-----|
|                      |   | t1           | t2  | t3  | t4           | t5  | t6  | t7           | t8  | t9  |
| Wrigley’s Doublemint | X | 5.1          | 5.1 | 5.1 | 5.0          | 4.8 | 4.3 | 5.2          | 5.1 | 5.0 |
|                      | S | 5.2          | 5.5 | 6.0 | 4.8          | 5.4 | 5.2 | 5.1          | 5.5 | 5.0 |
| Tata Gum             | X | 4.8          | 4.4 | 4.2 | 5.1          | 4.8 | 4.5 | 5.9          | 5.1 | 5.0 |
|                      | S | 4.7          | 4.9 | 4.1 | 4.6          | 5.9 | 5.3 | 4.4          | 5.5 | 4.2 |

$$t1=16:20 \ t2=17:00 \ t3=17:40$$

Image credits: Yimo Liu

#### 4.2.3. Effects on Blood Glucose Level 3h after Meal

The author measured the three volunteer individuals’ blood glucose level 3h after a meal at three different time points (t1=16:20, t2=17:00, t3=17:40), where t1 is the blood glucose level 3h after lunch, then 40 and 80 minutes after chewing either sugared(S) or sugar-free(X) gum (table 2). Two brands were tested above: Wrigley’s Doublemint and Tata Bubble Gum. The blood glucose was measured by a portable glucometre.

## 5. Discussion and Conclusion

### 5.1. General Conclusion

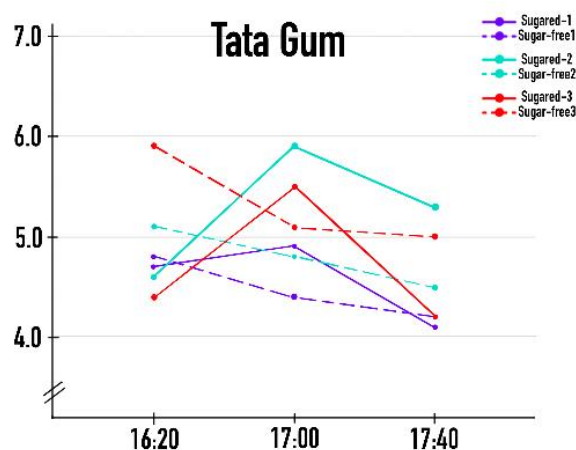
Table 2 shows that sugar-free chewing gums do not increase blood glucose levels, which further indicates that, from the standpoint of glycemic regulation, sugar-free gum is generally safe for individuals in good health.

### 5.1.1. Theoretic Level

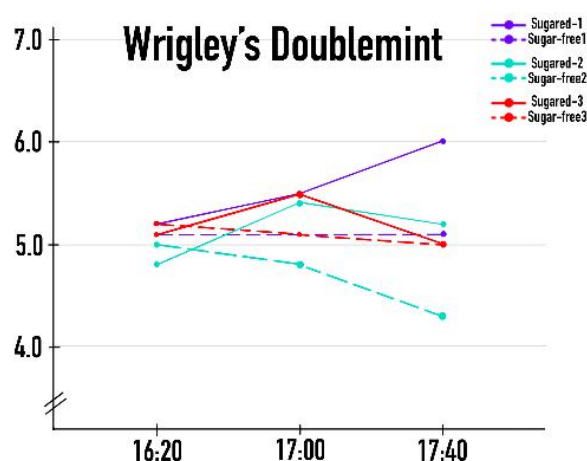
On the theoretical level, the author examined two companies' sugar-free and sugar-chewing gum using Fehling's reagent with four test tubes. For both companies, only the test tube containing a mixture of Fehling's reagent and sugar gum solution turns red after heating to 60 degrees Celsius, which indicates that only sugar-containing chewing gums contain reducing sugar, and indeed, sugar-free chewing gums do not. This result matches my previous conjectures, but the author was still uncertain if anything aside from sugar can elevate blood glucose levels.

### 5.1.2. Application Level

On the application level, the author tested the blood glucose level directly. The three volunteer individuals became the participants who took the blood glucose examination. The author used a glucose metre to test the level after they ate four different gums. The Figure 1 and Figure 2 below show my data on blood glucose tests, in which S indicates sugar, and X indicates sugar-free.



**Figure 1.** The blood glucose tests for the Tata gum for three experimental subjects. The solid lines represent sugared gum, the dashed lines represent sugar-free gum, and the different colours represent the three experimental subjects.



**Figure 2.** The blood glucose tests for Wrigley's Doublemint gum for three experimental subjects. The solid lines represent sugared gum, the dashed lines represent sugar-free gum, and the different colours represent the three experimental subjects.

For typical gum, the interval between each test is 40 minutes, since a human's blood glucose level reaches its highest approximately 30 minutes after eating. The

result also confirms my previous assumption: Sugar-free chewing gum does not increase blood glucose levels.

Both experiments suggest that sugar-free chewing gum is feasible for those who desire to control blood glucose. To be clear, here are two-line graphs obtained from the data in the table above. The lines show the trend of change in blood glucose clearly, as Figure 1 and Figure 2.

## 5.2. Limitations and Improvements

Since this investigation was limited to three people, there is insufficient testing on a broader population. Consequently, the conclusions derived from these experiments require additional validation through other investigations. Moreover, although blood glucose monitoring at various intervals serves as a crucial indicator of glycemic status, additional research is required to ascertain if the findings of this study apply to diabetic individuals, whether prolonged consumption of sugar-free gum influences blood glucose levels in this population, and if there are variations in the effects of sugar-free gum consumption among different age groups, genders, and occupational demographics. These areas necessitate more studies with an expanded sample size, which is a critical focus for future studies in this project. At the same time, alternative sugar substitutes like maltitol and erythritol's effects on blood glucose level control were not included in this study, which also needs to be explored subsequently.

## 6. Conclusions

In summary, this study systematically investigates the effects of sugar-free chewing gum on short-term blood glucose levels through chemical testing and human trials. The combination of Fehling's reagent experiments and real-time glucose monitoring offers clear evidence that sugar-free gum does not significantly alter blood glucose, supporting its potential as a safe alternative for individuals requiring glycemic control. While the sample size was limited and further research is needed—particularly among diabetic populations and with other sweeteners—this work contributes meaningful empirical data to an understudied area. It underscores the value of sugar-free products in dietary management and opens avenues for future research in public health nutrition.

## Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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