



## The Effect of Okra Powder Fortification on the Proximate Composition and Glycemic Index of Rice as a Low-Sugar Staple Food for Individuals with Diabetes

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### ABSTRACT

The number of individuals with diabetes in Indonesia continues to rise, largely due to the habitual consumption of rice with a high glycemic index that triggers blood glucose spikes. Since rice is an essential part of the Indonesian diet, a practical solution is needed to lower its glycemic impact. This study aimed to analyze the effect of okra powder fortification on the proximate composition and glycemic index of rice as a low-sugar staple food for individuals with diabetes. The research was conducted experimentally using a Completely Randomized Design (CRD) with 50 respondents. Treatments included two controls (fasting and rice without okra) and three fortification levels: 5 g, 10 g, and 15 g of okra powder per 100 g of rice. Proximate analysis covered moisture, ash, protein, fat, and carbohydrate content, while sensory evaluation used a hedonic test. Blood glucose levels were measured at 0, 30, 60, 90, and 120 minutes after consumption, and data were analyzed using ANOVA and Duncan's Multiple Range Test (DMRT). Results showed that rice fortified with 15 g of okra powder had higher viscosity, reduced glucose absorption, and a lower glycemic index. The product was well accepted in taste, though texture refinement is still needed.

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### Introduction

Type 2 Diabetes Mellitus (T2DM) is a serious public health problem. Approximately 425 million people worldwide were diagnosed with T2DM in 2017, and this number is projected to increase to 629 million by 2045 (IDF, 2017). T2DM is also a major risk factor for cardiovascular disease, which remains a

leading cause of morbidity and mortality globally (Beckman et al., 2013). Moreover, the economic burden of T2DM contributes to about 12% of global health expenditures, primarily due to the costs of treatment and its complications (IDF, 2017). Therefore, there is an urgent need to reduce the global health and economic burden associated with T2DM.

Genetic and lifestyle factors—particularly dietary patterns—are significant determinants of T2DM. Since lifestyle factors are modifiable, lifestyle modification has become a key focus in efforts to reduce the risk of T2DM (Sembiring, 2022; Schellenberg et al., 2013). Several studies (Hemmingsen, 2017; Glechner et al., 2014; Merlotti et al., 2014) have shown that interventions aimed at improving diet quality (such as low-calorie and low-fat diets) and/or increasing physical activity levels can delay or prevent the onset of T2DM.

Various therapeutic approaches have been explored to reduce the global incidence of diabetes. Recently, there has been a paradigm shift from conventional therapies to herbal-based treatments, which are considered relatively safer. This shift is particularly significant for managing chronic diseases. Okra (*Abelmoschus esculentus* L.) is a popular vegetable plant known for its high nutritional value and therapeutic potential, making it a promising candidate for use in various nutraceutical formulations. Different parts of the okra fruit contain bioactive compounds that exhibit medicinal properties. The phytochemical components of okra have been studied for their potential therapeutic activities in several chronic diseases, including type 2 diabetes, cardiovascular disorders, and gastrointestinal diseases, as well as their antifatigue, hepatoprotective, antibacterial, and chemopreventive effects (Elkhalifa et al., 2021; Nasution et al., 2019; Putri et al., 2019).

Okra is a perennial plant primarily cultivated in tropical and subtropical regions worldwide and is an important agricultural commodity. The immature green pods are commonly consumed as

vegetables, while okra extract is often used as a thickening agent in various soups and sauces (Dhaliwal, 2010; Kumar et al., 2013). The polysaccharides found in okra are also used in sweet frozen foods such as ice cream and in bakery products due to their health benefits and longer shelf life (Archana, 2015; Costantino et al., 2004; Yuennan et al., 2014). Previous studies have reported that okra seeds are a rich source of oil, constituting about 20–40% of the total composition, depending on the extraction procedure (Savello et al., 1980). Linoleic acid, a representative polyunsaturated fatty acid (PUFA), is the dominant component of okra seed oil, accounting for approximately 47.4% of its fatty acid composition (Savello et al., 1980). Other essential dietary constituents, such as amino acids and their polymers (proteins), are also crucial for human growth and development (Cieślik et al., 2010; Alghamdi, 2018).

Okra seeds are reported to have a protein composition distinct from that of cereals and legumes, as their protein content provides a unique balance of essential amino acids, particularly lysine and tryptophan. Therefore, due to their richness in essential amino acids, okra seeds are considered an important component of the human diet (Gemedet et al., 2015). Okra is also rich in vitamins and carbohydrates, which are regarded as key nutritional components of food (Aykroyd et al., 1963). The fruit is widely recognized for its nutritional composition and is commonly consumed boiled, fried, or cooked in various dishes (Akintoye et al., 2011).

Many studies have reported that okra plant parts can lower hyperglycemic levels. The enzyme  $\alpha$ -amylase, which breaks down polysaccharides to release

glucose, plays an essential role in meeting the body's energy requirements. Water-soluble seed and peel extracts from okra have been shown to inhibit  $\alpha$ -glucosidase and  $\alpha$ -amylase activities (Sabitha et al., 2012). Furthermore, previous research reported that the inhibitory activity of  $\alpha$ -

glucosidase and  $\alpha$ -amylase in immature okra seeds is due to oligomeric proanthocyanidins (Lu et al., 2016). Further studies on the antidiabetic efficacy of okra have demonstrated that its rhamnogalacturonan content also mediates antidiabetic activity (Zhang et al., 2018).

## Materials and Methods

### Research Location and Duration

This research will be conducted at the Central Laboratory of STIKes Widya Husada Medan and the Chemistry Laboratory of the University of Sumatera Utara, from May to November 2025.

### Type of Research

This study employs a laboratory experimental design using a Completely Randomized Design (CRD).

### Research Design

The number of research samples was determined using the Federer formula. Both control and treatment groups consisted of six replications each, resulting in a minimum of 24 subjects. In this study, a total of 50 participants were included, selected based on specific criteria, including normal nutritional status determined by Body Mass Index (BMI) and waist circumference measurements, normal fasting blood glucose levels, no history of diabetes, and no allergies to the test foods.

### Preparation of Okra Powder

Ripe okra fruits were washed with clean water and dried until completely dehydrated. The dried okra was then ground into fine powder (80 mesh) to obtain okra flour.

### Rice Fortification

Rice was mixed with okra powder according to the specified doses (5g, 10g, and 15g per 100g of rice) and cooked with water in a 1:1.5 ratio (standardized).

The treatment groups were as follows:

- a. Control 1: Fasting subjects (baseline blood glucose).
- b. Control 2: Consumption of rice without okra powder (100g of rice).
- c. Treatment 1: Rice + 5g okra powder per 100g of rice.
- d. Treatment 2: Rice + 10g okra powder per 100g of rice.
- e. Treatment 3: Rice + 15g okra powder per 100g of rice.

### Proximate Analysis

- a. Moisture content (gravimetric method, 105°C).
- b. Ash content (incineration, 550°C).
- c. Protein content (Kjeldahl method).
- d. Fat content (Soxhlet extraction).
- e. Carbohydrate content (DNS method).

### Glycemic Index Test

The glycemic index was determined by measuring the blood glucose levels of 50 volunteer subjects who had signed informed consent forms after receiving Ethical Clearance. A portion of okra-fortified rice (50g) was administered to the volunteers after an overnight fast (water allowed) from approximately 8:00 p.m. to 8:00 a.m. Blood samples were collected at 0, 30, 60, 90, and 120 minutes after consumption to measure blood glucose levels. The same procedure was carried out for the control group, which consumed unfortified rice on the following day. The glycemic index was determined by comparing the area under the curve (AUC) between the test food and the reference food.

### Blood Glucose Measurement

Blood glucose levels were measured using a glucometer. Participants were selected based on normal nutritional status determined by BMI and waist circumference, normal fasting blood glucose levels, no history of diabetes, and no food allergies. Participant characteristics were obtained through questionnaires. Anthropometric measurements, including body weight and height, were used to determine BMI and waist circumference.

### Sensory Evaluation

The sensory quality of the samples was evaluated through a hedonic sensory

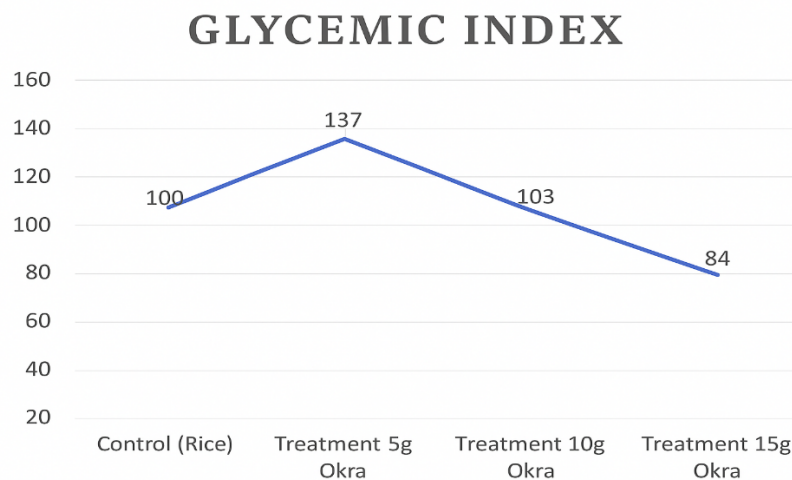
test conducted by panelists. Panelists assessed color, aroma, texture, and taste attributes. A 4-point hedonic scale was used (4 = like very much, 3 = like, 2 = Slightly like, 1 = dislike). Sensory testing was conducted indoors at room temperature under adequate lighting. Panelists were instructed to drink water between samples to cleanse their palate.

### Data Analysis

Data were analyzed using Analysis of Variance (ANOVA). Variables showing significant effects were further tested using Duncan's Multiple Range Test (DMRT) at a 95% confidence level ( $\alpha = 0.05$ ) with SPSS version 23.

## Results and Discussion

### Glycemix Index Result



- Control (100) → Pure white rice has a high glycemic index, consistent with findings in the literature.
- Treatment with 5 g Okra (137) → The addition of a low dose of okra was not effective and even increased the GI. This may have occurred because the amount of fiber/lectin was insufficient to reduce glucose absorption, while biological variation among subjects still influenced the results.
- Treatment with 10 g Okra (103) → A decrease in GI was observed, indicating that the soluble fiber and viscosity of okra began to slow glucose absorption. However, the GI remained in the high category.
- Treatment with 15 g Okra (84) → The most notable reduction was observed, with the GI decreasing to a moderate category. This suggests that a higher dose of okra fiber and phytochemicals

was effective in reducing postprandial blood glucose spikes after rice consumption.

Several recent studies support the finding that okra can lower glycemic parameters, both in the short and medium term. Research and systematic reviews have shown that okra consumption in various forms (powder, extract, or whole fruit) is associated with reductions in fasting blood glucose (FBG) and HbA1c levels in individuals with prediabetes and type 2 diabetes, indicating okra's potential to improve glycemic control clinically (Bahari et al., 2024; Zhang et al., 2024). These findings align with the present study, where administration of 15 g okra powder significantly reduced the glycemic index (GI) through a decrease in the incremental area under the curve (iAUC), demonstrating okra's role in mitigating postprandial glucose response.

The primary mechanism underlying this phenomenon is the presence of soluble fiber with high viscosity (mucilage) in okra. This fiber can slow gastric emptying and delay glucose absorption in the intestine, thereby reducing postprandial blood glucose peaks (Lu et al., 2023). This effect is consistent with the results of this study, in which the 15 g dose produced sufficient viscosity to suppress glucose absorption, resulting in a lower GI compared to the control group.

In addition, okra contains bioactive compounds such as flavonoids and carbohydrate-digesting enzyme inhibitors ( $\alpha$ -amylase and  $\alpha$ -glucosidase) that can reduce the breakdown of starch into

glucose, thus decreasing the amount of glucose available for absorption (Alblihd et al., 2023). These biochemical mechanisms complement the physical effects of soluble fiber, explaining why the reductions in iAUC and GI were greater than could be attributed to fiber alone.

The effects of okra also depend on dose, form, and duration of intervention. Several studies have reported that the hypoglycemic effect of okra is dose- and form-dependent, with variations observed depending on whether okra is consumed as powder, extract, or whole fruit, and on the length of consumption (Bahari et al., 2024; Nitzke et al., 2024). The results of this study, where the 15 g dose produced a more pronounced effect than 5 g and 10 g, are consistent with evidence showing that okra's effect becomes more evident at adequate doses.

Additional evidence from animal and in vitro studies also supports these mechanisms. In vivo studies have shown that okra extract or mucilage administration can reduce blood glucose, while in vitro studies demonstrated that okra fiber slows glucose release from the food matrix (Zhang et al., 2024; Nitzke et al., 2024). This reinforces the interpretation that the observed GI reduction is not only empirical but also mechanistically grounded. Therefore, the GI reduction observed in the 15 g treatment group is consistent with literature evidence showing that okra effectively lowers glycemic responses through a combination of physical (soluble fiber viscosity) and biochemical (enzyme inhibition) mechanisms.

## Proximate Test Results

Table 1. The proximate analysis

No.	Test Parameter	Result (%)
1	Moisture Content	11.25
2	Ash Content	7.80
3	Protein (Kjeldahl Method)	13.45
4	Fat (Soxhlet Method)	2.65
5	Carbohydrate (DNS Method)	64.85

The proximate analysis showed that okra contained 11.25% moisture, which is relatively low compared to most fresh food materials. This low moisture content may extend the shelf life by inhibiting microbial growth. The ash content of 7.80% reflects a high mineral level, indicating the presence of essential minerals such as calcium, magnesium, potassium, and iron, which are beneficial for bone health and overall metabolism. The protein content of 13.45% suggests that okra can serve as a potential source of plant-based protein, especially for individuals following vegetarian diets or reducing animal protein intake. The fat content, measured at 2.65%, is relatively low—consistent with the characteristics of vegetables—and is suitable for inclusion in a low-fat diet to reduce the risk of cardiovascular diseases.

Meanwhile, the carbohydrate content reached 64.85%, serving as the primary energy source. Most of these carbohydrates consist of dietary fiber, which plays an important role in maintaining digestive health, regulating blood glucose levels, and lowering cholesterol. Overall, this nutritional composition demonstrates that okra has potential as a functional food, providing not only energy but also supporting the prevention of metabolic diseases and the improvement of community nutritional status.

Previous studies have also reported the high nutritional potential of okra (*Abelmoschus esculentus*) based on proximate analysis. Liwanda et al. (2023) analyzed the nutrient composition of ten okra fruit genotypes and found significant variations in protein, fat, ash, and

carbohydrate levels, with certain genotypes showing higher mineral and macronutrient contents. These findings support the results of the present study, indicating that okra contains a relatively high protein content and ash level, which implies the presence of essential minerals.

Furthermore, Mahra et al. (2023) reinforced the potential of okra as a functional food. Their study on the substitution of agar flour with okra and cinnamon flour revealed significant levels of protein and carbohydrates, along with promising antioxidant activity. This indicates that okra functions not only as an energy source but also as a food ingredient with beneficial biological properties.

In addition, Obasi et al. (2024) evaluated the effects of different drying methods on the nutritional quality of okra. Their results showed variations in protein, fat, and moisture contents depending on the drying technique, with sun-drying producing the lowest moisture level (9.56%) while maintaining stable protein content (19.80–21.71%). These findings confirm that post-harvest processing influences the nutritional quality of okra but still retains its profile as a nutrient-dense plant-based food.

In summary, the findings of these studies are consistent with the present proximate test results, showing that okra has a relatively high protein content, low fat, and significant levels of carbohydrates and minerals. Therefore, okra has strong potential to be developed as a raw material for functional foods and nutrient-enriched processed products.

## Hedonic Test Result

Table 2. The Hedonic analysis

Evaluation Aspect	Average Score ( $\pm$ )	Dominant Category*
Color	5.2	Slightly Like – Like
Aroma	5.1	Slightly Like – Like
Taste	5.7	Like – Very Like

<b>Texture</b>	5.0	Neutral – Like
<b>Overall Appearance</b>	5.3	Slightly Like – Like
<b>Overall Acceptance</b>	5.6	Like – Very Like

#### Interpretation of Hedonic Test Data

- Taste and overall acceptance obtained the highest average scores (5.6–5.7), indicating that the rice fortified with okra powder was well-liked and generally accepted by consumers.
- Color and overall appearance also received positive scores (5.2–5.3), suggesting that the product was visually appealing.
- Aroma received an average score of 5.1, meaning that the product's aroma was fairly liked, although some respondents rated it as neutral.
- Texture showed the lowest relative score ( $\pm 5.0$ ), indicating that while it did not cause dislike, some respondents rated it between neutral and slightly like. This suggests room for improvement, such as enhancing the softness or chewiness of the rice.

Based on the hedonic test results from 50 respondents, the okra powder–fortified rice demonstrated good acceptance across nearly all evaluation aspects. The taste aspect obtained the highest mean score of approximately 5.7, categorized as “like – very like,” indicating that flavor was the main strength and most preferred feature of the product. Overall acceptance also showed a similar result with an average of 5.6, meaning that the fortified rice was generally well accepted by the respondents. The color and overall appearance aspects had average scores of 5.2–5.3, suggesting that the product was visually appealing though there is still room for improvement. The aroma received an average score of 5.1, showing that respondents found it fairly pleasant. Meanwhile, texture had the lowest mean score of around 5.0, categorized as “neutral – like,” implying that although it

did not cause aversion, some respondents perceived this aspect as needing refinement.

Overall, the okra powder–fortified rice shows promising potential as a low-sugar staple food alternative, with positive consumer acceptance—particularly in terms of taste—although improvements in texture are recommended to further enhance the overall product quality.

#### Conclusions

This study demonstrated that fortifying rice with okra powder, particularly at a 15 g dose, effectively reduced the glycemic index to a moderate category, indicating its potential as a low-sugar staple food alternative for individuals with diabetes. The proximate analysis showed that okra is rich in plant-based protein, minerals, and dietary fiber while being low in fat, supporting its role as a functional food. The hedonic test also indicated that okra powder–fortified rice was well accepted by consumers, especially in terms of taste and overall acceptance, although the texture aspect still requires improvement. Therefore, okra powder has strong potential to be developed as a fortification ingredient to enhance nutritional quality while reducing the risk of postprandial blood glucose spikes after rice consumption.

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