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RESEARCH **Open Access**

The Glycemic Index of Gayam (*Inocarpus fagifer* Forst) Cookies as a High Dietary Fiber Food

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Abstract

The type 2 diabetes (T2D) is still one of the world's public health problems. It needs serious handling and prevention efforts in the nutritional aspect. The high prevalence of T2D is related to the low intake of dietary fiber. This type of food has a low glycemic index (GI). Gayam is a high-dietary fiber material that can be used for the manufacture of flour and as processed food material for the high-dietary fiber cookies. The objectives of this research were to study the GI evaluation of cookies from gayam flour. Cookies were tested for chemical composition, and glycemic index. The glycemic index evaluation test used 12 volunteers taken from the healthy group/nondiabetic, normal nutritional status (BMI: 18.5-22.9), and age 19-55 years. The results of this study indicate the dietary fiber content of gayam cookies was 4.57 g/100 g and included in the category of high dietary fiber food. The glycemic index of gayam cookies was 43 and the low glycemic index category. The obtained results show for the first time the potential of gayam cookies in hyperglycaemia management. The conclusion of this study was that gayam cookies has high dietary fiber content and low GI level. Gayam cookies can be used as an alternative snack to control blood glucose levels in the prevention of diabetes mellitus.

Keywords: Blood Glucose, Cookies, Dietary Fiber, Gayam, Glycemic Index.

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1. INTRODUCTION

Type 2 Diabetes Mellitus (T2DM) is a rapidly growing global health issue, largely due to lifestyle changes, urbanization, and demographic shift(Patil et al., 2023). In 2021, 537 million people worldwide had diabetes, with 90 per cent attributed to T2DM (Khan et al., 2019). The global prevalence rate is 6.1 per cent, with T2DM being the most common form. By 2045, the global diabetes population is projected to reach 783 million, primarily due to obesity, sedentary lifestyles, and population ageing (Lerman Ginzburg, 2023). Low- and middle-income countries are particularly affected, with 80 per cent of the global diabetes population residing in these regions (Ahmad et al., 2022). For this reason, it is very necessary to take this health problem seriously and or prevent it, among others, from the nutritional aspect.

Dietary fibre has a substantial impact on the management and potential reduction of the risk of diabetes mellitus, including type 2 diabetes mellitus (T2DM) and gestational diabetes mellitus (GDM) (Ding, 2024). Consuming dietary fibre has been linked to enhanced glycaemic management, decreased insulin resistance, and improved overall metabolic health(Gao et all., 2022). This response examines the mechanisms and impacts of dietary fibre on the management of diabetes, utilising insights from multiple studies (Fazal et al., 2024). Consumption of dietary fiber between 30-50g/day consistently helps lower blood glucose (Ding, 2024). The importance of dietary fibre in improving insulin sensitivity, a critical element in the management and prevention of metabolic disorders including type 2 diabetes, has been increasingly acknowledged. The research papers offered present a thorough perspective on the influence of dietary fibre on insulin sensitivity through many processes, such as the manipulation of gut microbiota, enhancement of body composition, and regulation of glucose metabolism (Ding, 2024; Gao et al., 2022; Hebbar et al., 2024). The presence of fibre in food has a considerable impact on the glycaemic index (GI), which quantifies the speed at which carbs in diet elevate blood glucose levels (Chiavaroli et al., 2021). Incorporating dietary fibre into carbohydrate-rich diets helps regulate the glycaemic response by retarding the processes of digestion and absorption (Mao et al., 2021). This impact is advantageous for regulating blood glucose levels and mitigating the likelihood of chronic conditions such as diabetes (Zhang et al., 2023). The subsequent sections go into the mechanisms and evidence that substantiate the influence of fibre on the glycaemic index (Ding, 2024). Foods that have a low GI also have the characteristics of causing the process to run slowly so that the rate of stomach emptying is slow (Hebbar et al., 2024; Muhammad Owais Fazal et al., 2024). Consumption of foods with a low glycemic index will result in a lower glycemic response and variability so that insulin response is also not as high as a high glycemic index (Demangeat et al., 2023).

The plant often referred to as "gayam" is formally classified as Inocarpus fagifer (Maulana et al., 2024). It is called by many names in different places and under different circumstances. Gayam (*Inocarfus fagifer* Forst.) is a local food spread throughout Indonesia. This plant holds great significance due to its ecological and therapeutic capabilities, as well as its cultural and economic importance in tropical regions (Wijanarka, Tifauzah, & Wijaningsih., 2020). The subsequent sections delve into the various appellations and circumstances in which gayam is recognised on a global scale (Hany Anastasia et al., 2016). It has a number of commonly used names, e.g. Tahitian chestnut, Polynesian chestnut, Otaheite chestnut, *aila* and *bosua* (Widayati & Umarudin, 2022). Wijanarka (2017) reported that the dietary fiber content of gayam was 21 per cent. However, currently processed gayam products are still limited to being made into boiled or chips even though they are made with flour. The material in the form of flour can be used as a basic ingredient for making cakes which are products that are liked by the public and are durable (Widayati & Umarudin, 2022).

Gayam has exhibited a functional food potential and represents an alternative source of the high dietary fiber (Wijanarka, Tifauzah, & Wijaningsih, 2020). Gayam seeds are rich in carbohydrates, with a content ranging from 76 per cent to 78 per cent, making them a potential energy source, the seeds also contain significant amounts of protein (11.7%), lipids (8.2%), and ash (3.4%) (Maulana et al., 2024). Consumption of gayam can provide a beneficial effect on human health, associated with indigestible components such as dietary fiber. The high carbohydrate content of gayam flour suggests its suitability for use in various food products, similar to how amaranth flour is utilized in bakery products, pasta, and other functional foods (Gebreil et al., 2020). All of which presented high dietary fiber content, but the glycemic index was not tested. This research was to evaluate the nutrient composition, dietary fiber and glycemic index of gayam cookies. This kind of product can be used as food to prevent diabetics.

2. RESEARCH METHOD

The main ingredient of this research was gayam fruit, which was obtained from Bantul Regency, Special Region of Yogyakarta, Indonesia. The gayam used is yellowish-brown in color, ripe on the tree, 3-4 months old and weighs 75-110 g/seed (medium-large size). The chemicals used for analysis are pro-analytical chemicals. Meanwhile, the enzymes include amylase, amyloglucosidase, and proteases made by SIGMA. Materials for the standard on measuring the blood glucose response of volunteers using pure glucose (glucose anhydrous). Accu-Chek glucometers are essential for diabetes treatment, providing convenience and precision in blood glucose levels testing. Their performance in home and clinical settings has been thoroughly assessed, ensuring accurate measurements for efficient diabetes control and surveillance (Zhao et al., 2024).

The main ingredient is Gayam flour which is pre-gelatinized (Wijanarka, 2017). Gayam fruit has not been peeled off at 100°C for 30 minutes. The Gayam was then peeled and sliced thinly (2-3 mm) and dried in a cabinet dryer at 50-60°C for 48 hours. The dried Gayam was blended and sifted to produce flour with a size of 60 mesh. Gayam cookies use a mixture of wheat flour and gayam flour, respectively, 65 per cent and 35 per cent, while all the main ingredients for control cookies use wheat flour. Additional ingredients for making cookies are butter, margarine, low-calorie sugar, egg yolks, powdered milk, and baking soda. Cookies are made by mixing the ingredients, kneading the dough, and baking at 160°C for 20 minutes.

The glycaemic index (GI) is determined by comparing blood glucose reactions in a test food to a reference food, typically consisting of pure glucose, with equal carbohydrate content. First, a sample (gayam flour) is prepared which will be tested and analyzed for the carbohydrate content and dietary fiber content and calculated total available carbohydrates. Carbohydrate content was calculated by the difference after the sample was analyzed proximately using the laboratory method for analyzing food fiber levels involves incubating samples with enzymes, filtering digestate for IDF determination, precipitating SDFP with alcohol, and quantifying SDFS using liquid chromatography, ensuring accurate measurement of total dietary fiber (McCleary & McLoughlin, 2022). A total of 10 volunteers selected had healthy criteria, had normal nutritional status (body mass index/normal BMI between 18.5-22.9 kg/m2), aged 21-23 years, either male or female, normal blood sugar levels, willing to follow the specified research protocol and have signed informed consent. This study was approved by Politeknik Kesehatan Kementerian Kesehatan Yogyakarta Research Ethics Boards reviewed and approved the study protocol. All volunteers received adequate information about the study and had the opportunity to ask questions.

The volunteers were asked to fast for 10 hours (overnight fasting), except for water, in the morning a 50L blood sample was taken using the finger-prick capillary blood samples method to measure fasting blood glucose levels. Furthermore, volunteers were given the sample food that was tested (steamed gayam flour) and had to be eaten until it was finished. The number of samples was determined based on the carbohydrate content and dietary fiber content so that the sample ate contained total available carbohydrates equivalent to 50 grams of sugar. Half an hour after the meal was finished, a blood sample was taken again, and the glucose level was measured. Blood samples were taken every half hour until the second hour. The previous activity (point) was carried out on different types of samples on the same volunteers on different days (done every day). From fasting blood glucose levels and after eating (30, 60, 90, and 120 minutes) a glucose response curve was made. The glucose response was also made for the control food i.e., glucose solution. The glucose response curve is made by filling in the results of glucose measurements based on time on the X-axis (measurement time) and Y-axis (blood glucose level). The glycemic index is determined by comparing the area of the sample glucose response curve with the standard glucose response, multiplied by 100.

The composition of the chemical data was analyzed using analysis of variance (one-way ANOVA) with SPSS software for windows. Blood glucose response data were processed to obtain GI values using Microsoft Excel and analyzed descriptively.

3. RESULTS AND DISCUSSION

The results of the analysis of the chemical composition of the Gayam and Control Cookies are presented in Table 1. The moisture, ash, fat, protein, and carbohydrate content of the two cookies did not have a big difference. However, for food content, there is a relatively large difference in the amount. The dietary fiber content in Gayam cookies has a higher dietary fiber content than control cookies. Dietary fibre is crucial for a nutritious diet, categorizing foods into low, medium, and high levels which each contains 2, 4, and 6 grams of dietary fiber per serving, thus Gayam cookies are classified as high in dietary fiber. This helps in understanding and strategizing food consumption for nutritional needs and health goals (El-Habashy, 2017; K et al., 2017).

Table 1. The Chemical Composition of The Gayam Cookies and Wheat Cookies

Samples	**Chemical Composition (%wet basis)**					
	Moisture	**Ash**	**Fat**	**Protein**	**Carbohydrates**	**Total fiber**
Wheat cookies	5.39	1.77	24.62	8.46	59.74	2.38
Gayam cookies	4.69	2.44	25.58	7.88	59.62	4.57

The number of test samples in the form of style cookies given to volunteers is determined based on the total content of available carbohydrates which describes the total carbohydrate content available for the body that is easily digested. The determination of accessible carbs in meals necessitates comprehension of the function of dietary fibre and its influence on the overall carbohydrate content. Available carbohydrates refer to the types of carbohydrates that can be broken down and taken in by the human body, ultimately supplying energy. The computation frequently entails deducting the fibre content from the overall carbs, as fibre is indigestible non the small intestine. This procedure is essential for precise nutritional labelling and dietary planning, particularly for persons with specific dietary requirements like diabetics (Alharbi et al., 2015). In Table 2, the content of KH by difference, total dietary fiber content, and total available carbohydrates (AC), as well as the weight of the cookies samples tested are presented.

Table 2. Carbohydrate Content, Total Dietary Fiber, Available Carbohydrates, and Weight of The Gayam Cookies Consumed Equivalent to 50 Grams of Available Carbohydrates

Samples	**Carbohydrates by difference (%wb)**	**Total fiber (%wb)**	**Available carbohydrates (%wb)**	**Weight of sample equivalent to 50 g glucose (g)**	**Number of cookies (pieces)**
Wheat cookies	59.74	2.38	57.36	87.17	9-10
Gayam cookies	59.62	4.57	55.05	90.83	10-11

Notes: **available carbohidrates = carbohydrate by difference – total fiber, wb= wet basis*

In this study, the number of gayam cookies given to volunteers was equivalent to 50 grams of AC in one consumption. The number of samples of Gayam cookies equivalent to 50 grams of AC ranged from 87.83-9.83 grams. The number of samples of cookies given to volunteers weighed between 87 and 91 grams. Samples with these weights were relatively realistic amounts for consumption.

The blood glucose response shown by the volunteers after consuming the food and the standard glucose as presented in Table 3. The glucose response is the blood glucose after we start the meal. In this study, the standard food used a pure glucose solution. The practice of using "pure glucose" as a standard or reference in establishing the GI is widely accepted in the field of nutritional science (Flavel et al., 2021). This technique is essential for establishing a uniform standard against which the glycaemic response of different diets can be evaluated. The utilisation of glucose as a benchmark is endorsed by global protocols and is essential to the methodology of GI testing (Wolever et al., 2019). Nevertheless, there exist discrepancies and obstacles in its implementation that must be resolved in order to achieve more precise and dependable outcomes.

Table 3. Fasting and Postprandial Blood Glucose Concentration (mg/dl) After Consuming Glucose (Reference Food), Wheat Cookies and Gayam Cookies.

Samples	**Time (min)**				
	0	**30**	**60**	**90**	**120**
Glucose	85.25	145.75	124.83	120.50	104.17
Wheat cookies	82.17	100.08	105.08	102.00	96.67
Gayam cookies	80.17	106.17	97.08	93.33	92.67

The glucose response is the blood glucose level after the volunteers studied the test food. In this study, the standard food used a pure glucose solution In Table 3, it can be seen that style cookies and control cookies have a glucose response below the standard glucose. In Figure 1, the blood glucose levels of volunteers are presented after standard glucose, style cookies, and control cookies. The glucose response curve is made by filling in the results of glucose measurements based on time on the X-axis (measurement time) and Y-axis (blood glucose level). The GI is a metric employed to assess the impact of various diets on post-consumption blood glucose levels (On-Nom et al., 2022). Glycaemic index is determined by measuring the rise in blood glucose levels after consuming a test food, in comparison to a standard reference, usually glucose. Understanding this notion is essential for effectively controlling dietary decisions, particularly for persons with diabetes or those who are susceptible to non-communicable diseases. The subsequent sections explore the methods of determining GI, the variability in GI values, and the ramifications of these metrics (Chiavaroli et al., 2021; Flavel et al., 2021). As in the glucose response, it was seen that both cookies had an increase in blood glucose levels below the standard glucose.

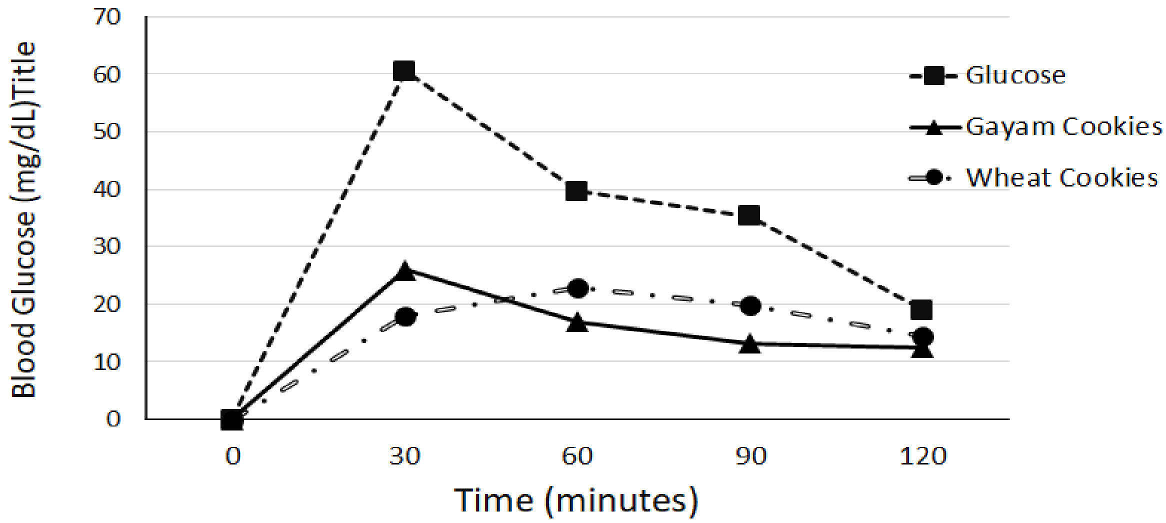

Figure 1. Changes of The Blood Glucose Level of The Volunteers After Consuming Glucose (Reference Food), Wheat Cookies, and Gayam Cookies

The area under the standard glycaemic response curve for glucose or test food is calculated by using blood glucose data obtained from measuring the blood glucose response of volunteers for each food. The data is then plotted on a coordinate axis, with the X-axis representing time (in minutes) and the Y-axis representing blood glucose levels. The GI was determined by measuring the area under the curve for the rise in blood glucose levels following consumption of the glucose-standard food (A) and the tested food (B). The glycaemic index of the food is determined by multiplying the result of the calculation of B/A by 100. Based on Figure 1, it can be calculated the area of the curve for the increase in blood glucose levels after consuming standard glucose foods, style cookies, and control cookies so that the glycemic index can be calculated. The GI is a metric employed to categorize carbohydrates in meals according to their influence on blood glucose levels(Simões et al., 2021). The glycaemic index calculation, invented by Wolever et al, (2019) involves measuring the incremental area under the blood glucose response curve (iAUC) after taking a test item and comparing it to a reference food, usually glucose. This method offers a uniform methodology to evaluate the glycaemic impact of different foods, which is essential for dietary control, particularly for those with diabetes (Meng et al., 2017). Using the formula developed by Wolever et al, (2019) curve area (minutes x mg/dL) for standard glucose, cookie style, and control cookies was 4,343.7; 1,870.2, and 2,037.6. The data are presented in Table 4. These figures were used to calculate the GI values.

Table 4. Incremental Area Under Curve (iAUC) and Glycaemic Index (GI) of Glucose (Reference Food), Wheat Cookies, and Gayam Cookies

Samples	**Area under curve (AUC) (mg/dl × min)**	**Glycemic index (GI)**
Glucose	4,343.7	100
Wheat cookies	2,037.6	47
Gayam cookies	1,870.2	43

The results of determining the glycemic index showed that the style of cookies was 43 and the control cookies were 47. According to Wolever, the classification of the glycemic index value of food using pure glucose as a standard food is low GI (< 56), medium GI (55-69), and High GI (>69) (Meng et al., 2017). This shows that Gayam cookies made from Gayam flour have a low GI. This is thought to be due to cookies using pre-gelatinized Gayam flour which has a low glycemic index. GI values are categorized using pure glucose as a reference food in nutritional research. This method compares a test food's blood glucose reaction with pure glucose, which has a GI value of 100 (Li et al., 2021). Understanding the impact of different foods on blood sugar levels is crucial, especially for managing diseases like diabetes (Wang et al., 2021). However, GI values should consider eating patterns and personal health circumstances when used in practical situations. Combining GI with other nutritional data and personalized dietary guidance can maximize health results (Kalra & Gupta, 2015).

Gayam flour prepared by pre-gelatinization treatment causes the starch in the heat-treated material by boiling to gelatinize. Further treatment with drying in starch will be retrograded. The retrograded starch causes an increase in the content of resistant starch in the Gayam flour so that it has a low GI impact (Wijanarka, Tifauzah, & Wijaningsih., 2020). Several aspects, such as the kind and solubility of dietary fibre, its physiological effects, and its involvement in metabolic health, determine the value of dietary fibre in food, notably its impact on the GI. Dietary fibre, encompassing both soluble and insoluble forms, plays a vital function in regulating the GI of foods, which quantifies the speed at which carbohydrates in diet elevate blood glucose levels. This response is crucial for the management of diseases such as diabetes and obesity (Chiavaroli et al., 2021; Hebbar et al., 2024; Mao et al., 2021). In this study, the possibility that affects the GI value is the content of dietary fiber. This is supported by data on food fiber content in Gayam cookies, including the high category.

Until now, there is no research on the GI of gayam cookies, so the results of this study cannot be compared with the same type of food. Flakes produced by combining mangrove fruit flour, porang, and mocaf flour have demonstrated low GI values (Jariyah et al., 2022). Adding pulse components such as pea and lentil flour to cereal-based products can reduce their GI. For example, pasta and bread made with pulse components had lower GI values compared to their counterparts made with wheat flour, rendering them healthier choices for managing glycaemic control. Roti produced with Caryota urens and Cycas circinalis flours are classified as low GI foods, having GI values of 57 and 66, respectively. These conventional flours have the potential to be used as alternatives to wheat and rice flours with higher GI (RamyaBai et al., 2019). Although low-GI foods are advantageous for regulating blood glucose levels, it is crucial to take into account the complete nutritional composition and dietary circumstances. For example, foods that have a low GI may yet have a high calorie or fat content, which can affect both weight control and overall well-being. Furthermore, the GI of a dish can differ depending on how it is prepared and how an individual's metabolism responds to it. This indicates that while GI is important, it should be considered alongside other aspects when planning a diet. Moreover, whereas in vitro techniques offer preliminary understanding, in vivo experimentation is essential for precise gastrointestinal (GI) assessment, as evidenced by inconsistencies between projected and observed GI values in certain investigations (Augustin et al., 2020). However, the GI of the two foods used the standard food of white bread, so to compare the GI of gayam cookies in this study had to be multiplied by 0.7 because the standard food used is glucose. On the other hand, if the glucose standard is used, it must be multiplied by 1.4 when compared with the standard white bread.

This condition is thought to be due to the higher dietary fiber content of gayam cookies than control cookies. The same thing was also reported by Wijanarka (2017) who reported that the content of dietary fiber in Gayam was 21 per cent. Consuming foods that are rich in fibre can effectively regulate appetite and enhance the feeling of fullness, so facilitating the control of food consumption and potentially assisting in weight management (Patil et al., 2023). The cause of this action can be traced to a variety of physiological pathways that are triggered in the body by dietary fibres (Zhang et al., 2023; Akhlaghi, 2024). Research has demonstrated that consuming diets rich in fibre can result in decreased energy consumption and body weight, along with enhanced feelings of fullness and decreased appetite. Nevertheless, the degree of weight reduction varies, and several studies indicate just minimal alteration (Borkoles et al., 2022). Dietary fibres can impact hunger by exerting an effect on the gastrointestinal tract. They induce stomach distention and hinder gastric emptying, hence extending the sensation of satiety (Ehret et al., 2023). In addition, dietary fibres enhance the quantity of undigested nutrients that reach the ileum, thereby prompting enteroendocrine cells to release hormones such as cholecystokinin, glucagon-like peptide-1 (GLP-1), and peptide YY. These hormones are recognised for their ability to decrease appetite and extend the feeling of fullness. The gut ferments fibres to generate short-chain fatty acids (SCFAs), including acetate, butyrate, and propionate. The short-chain fatty acids (SCFAs) are assimilated and have the ability to stimulate the brain to produce satiety signals, resulting in decreased appetite and a diminished need for high-calorie foods (Eley, 2022). Cookies made from Gayam flour make the product high in dietary fiber, glycemic index, and high satiety. Cookies are also cookies which are popular and durable products. Gayam cookies can be used as food to prevent type 2 diabetes (Wijanarka, Tifauzah, & Wijaningsih, 2020).

4. CONCLUSION

The Gayam cookies have a glycaemic index of 43, placing them in the low glycaemic index category. Gayam cookies are a suitable snack option for managing blood glucose levels and reducing the risk of diabetes due to their high dietary fibre content and low glycaemic index. Further clinical research on patients with type 2 prediabetes is necessary to investigate the hypoglycemic effect of gayam cookies.

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