

Antihyperglycemic effect of cookies with coffee parchment extract flour in wistar rats

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Editor: Samuel Pereira de Carvalho

Received in May 13, 2025 and approved in January 9, 2025

ABSTRACT

Obesity is the most important risk factor for type 2 DM, which can affect disease progression and insulin resistance. Coffee skin has not been utilized optimally, but it has high antioxidants and dietary fiber, which could be used as a food product. Coffee parchment is obtained through wet and semi-wet coffee processing, which is produced from the dehulling process. This study evaluated the antihyperglycemic potential of functional cookies enriched with coffee parchment extract flour, a by-product rich in antioxidants and dietary fiber. Three cookie formulations are cookies without the addition of coffee parchment extract flour (F0), cookies with the addition of 10% coffee parchment extract flour (F1), and cookies with the addition of 15% coffee parchment extract flour (F2). They will analyze sensory evaluation, dietary fiber, and antioxidants, and determine the glycaemic index in vivo using Wistar rats. The analysis results show that the three formulations can control blood glucose levels to remain within the normal range. It is caused by the antioxidants and dietary fiber of coffee parchment that have a role in controlling blood glucose levels. The cookie formulation intervention with coffee parchment extract flour has a lower GI, 21.98 (F1) and 22.15 (F2). Cookies with coffee parchment extract flour showed significantly higher antioxidant (41.82% and 50.31%, for F1 and F2) and dietary fiber content (4.71% and 5.79%, for F1 and F2) and resulted in lower postprandial glycaemic responses. These results suggest that parchment coffee parchment extract flour may be a promising functional ingredient for developing low-GI snacks for diabetes prevention.

Key words: Coffee by-products; dietary fiber; glycemic index; animal model; functional food.

1 INTRODUCTION

Diabetes mellitus (DM) is a chronic disease characterized by the pancreas's inability to produce sufficient insulin or the body's inability to utilize the insulin produced effectively. According to the 2023 Indonesian Health Survey (SKI), the prevalence of Type 2 Diabetes Mellitus (T2DM) in Indonesia has increased from 10.9% to 11.7%. The International Diabetes Federation (IDF) estimated that Indonesia ranked sixth globally in the number of individuals with diabetes aged 20–79 years, with approximately 20.4 million cases in 2025 (International Diabetes Federation, 2025). This increasing trend is strongly associated with unhealthy dietary habits and lifestyle patterns (Murtiningsih et al., 2021). The consumption of foods high in sugar, salt, and fat contributes significantly to obesity and diabetes, as obesity is a major risk factor for the development of T2DM, which can exacerbate insulin resistance and disease progression (Wu et al., 2014; Zheng et al., 2018).

Indonesia is recognized as one of the world's leading coffee producers and exporters. The commodity ranks as the country's fourth-largest source of foreign exchange earnings, following palm oil, rubber, and cocoa. Coffee consumption has been steadily increasing, driven by the growing integration of coffee drinking into daily lifestyles and the proliferation of coffee shops in rural and urban areas. Various by-products such as pulp, husk, parchment, and silver skin are generated during coffee processing, whether wet, semi-wet, or dry. Coffee skin

is frequently discarded or underutilized, despite its potential nutritional and functional value. Coffee skin components are notably high in dietary fiber: husk contains 26–32 g/100 g, pulp 16–24 g/100 g, parchment 89–92.6 g/100 g, and silver skin 55–74 g/100 g (de Santos et al., 2021). Additionally, these by-products are rich in bioactive compounds, particularly antioxidants. For instance, the husk exhibits total phenolic content of 384–455 mg GAE/100 g and total flavonoid content of 7–8.47 mg QE/100 g; pulp contains 255–453 mg GAE/100 g of phenolics; parchment 228–284 mg GAE/100 g; and silver skin 10.75–17.3 mg GAE/100 g with 2.73 mg QE/g of flavonoids (Gemechu, 2020). So, it is promising for food product development. The rise in coffee consumption in Indonesia has led to a proportional increase in coffee skin waste. If properly utilized, this by-product may contribute to value-added opportunities and improved income for coffee farmers in Indonesia.

Among the various coffee by-products, coffee parchment is located in the endocarp layer of the coffee cherry. It contains high levels of antioxidants and dietary fiber. It is produced during wet and semi-wet coffee processing due to the dehulling stage. According to Gemechu (2020), coffee parchment contains approximately 232.6 µg/g of chlorogenic acid and a total phenolic content ranging from 228 to 284 mg GAE/100 g. It also contains 89–92.6 g/100 g of total dietary fiber, making it a promising candidate for functional food applications. Due to its high antioxidant and fiber content, coffee parchment is considered beneficial in the dietary

management of type 2 diabetes. These compounds may reduce blood glucose levels by inhibiting glucose absorption and slowing starch digestion (Silva et al., 2024). Accordingly, foods rich in antioxidants and dietary fiber are often recommended for individuals with type 2 diabetes, as they can help improve glycaemic control. Previous studies have successfully incorporated coffee parchment extract flour into baked goods. For example, Lanywati et al. (2023) reported that adding 2.5% parchment coffee skin to cookies increased their antioxidant and dietary fiber content to 43.86% and 13.67%, respectively. Silva et al. (2024) further demonstrated the hypoglycaemic potential of parchment coffee skin extract, noting its high α -amylase inhibitory activity, which delays starch digestion and glucose absorption in the digestive tract. Dietary fiber from this by-product has also been identified as a therapeutic strategy for managing glycaemic response, preventing weight gain, regulating lipid metabolism, and reducing the risk of cardiovascular disease (Ting et al., 2021). Cookies are a snack that both young and older adults widely like. Cookies are often used as a snack to accompany coffee or tea. However, making cookies using high glycaemic index ingredients can increase the risk of causing diabetes and obesity. Cookies with the addition of coffee parchment extract flour can be a healthy snack to avoid diabetes and obesity. In this study, we analysed the effects of incorporating coffee parchment into cookie formulations, specifically focusing on its impact on antioxidant content and dietary fiber levels, and its potential role in providing antihyperglycemic benefits.

2 MATERIAL AND METHODS

2.1 Materials

The main ingredient was parchment Arabica coffee parchment obtained from coffee farmers in Temanggung, Central Java, Indonesia. The ingredients used in the cookie formulation were modified cassava flour (Ladang Lima, Indonesia), corn starch (Maizenaku, Indonesia), palm sugar (Nutrifarm, Indonesia), egg yolks, margarine (Royal Palmia, Indonesia), baking powder (Koepoe Kopepoe, Indonesia), vanilla (Koepoe Kopepoe, Indonesia), and salt (Refina, Indonesia) obtained from the market in Surakarta, Indonesia. The chemicals used for analysis were DPPH (Sigma-Aldrich Ireland Ltd), buffer pH 8.2, 50 Alpha-Amylase (Sigma-Aldrich Ireland Ltd), distilled water, protease (Sigma-Aldrich Ireland Ltd), HCl (Merck, Jerman), amyl glucosidase (Sigma-Aldrich Ireland Ltd), ethanol (Merck, Jerman), acetone (Merck, Jerman), and methanol (Merck, Jerman). The tools used are basins, whisk, pots, stoves, sieve, pans, analytical scales, pH meters, desiccators, ovens (Mito Fantasy Mo-888, Indonesia), grinding machine, spectrophotometers (Genesys 150 UV-Vis, USA).

2.2 Methods

2.2.1 Making of Coffee Parchment Extract Flour

Coffee parchment skin extraction was performed according to the patent WO 2013/004873 (del Castillo, 2013). A total of 50 g of coffee parchment was extracted with 1 L of distilled water for 10 minutes. The extract was filtered and dried using an oven at 50 °C to a constant weight. The dried extract was ground using a grinding machine to flour form Figure 1.



Figure 1: Making of Coffee Parchment Extract Flour.

2.2.2 Making of Cookies with The Addition of Coffee Parchment Extract Flour

The making of cookies consists of 3 formulations, F0 (without the addition of coffee parchment extract flour), F1 (the addition of 10% coffee parchment extract flour), and F2 (the addition of 15% coffee parchment extract flour). The cookies-making methods are based on Lanywati's research (2023), which consists of three stages: making dough, moulding, and baking. All ingredients were weighed according to Table 1. Margarine, palm sugar, egg yolks, salt, and vanilla were mixed, then shaken until homogenized using a whisk for 3 mins. After that, modified cassava flour, coffee parchment extract flour, cornstarch, and baking powder were added, then stirred again until homogenized. After all ingredients were smooth, the dough was weighed per 50 g and baked in an oven at a temperature of 170°C for 20 minutes.

Table 1: Cookies Formulation Composition.

Materials	F0	F1	F2
Coffee parchment extract flour (g)	-	10	15
Modified Cassava Flour (g)	100	100	100
Corn Starch (g)	10	10	10
Margarine (g)	100	100	100
Egg Yolk	1	1	1
Palm Sugar (g)	75	75	75
Salt (g)	2	2	2
Baking Powder (g)	2.5	2.5	2.5
Vanilla (g)	2.5	2.5	2.5

This research has received ethical clearance from the Research Ethics Committee, Faculty of Medicine, Sebelas Maret University, Indonesia, with Number 38/UN27.06.11/KEP/EC/2025 on March 21, 2025.

2.2.3 Analysis of Cookies with The Addition of Coffee Parchment Extract Flour

2.2.3.1 Sensory Evaluation of Cookies with The Addition of Coffee Parchment Extract Flour

Sensory analysis determined the acceptability of the three cookies: F0, F1, and F2 formulations. A total of 20 untrained panellists were randomly recruited to assess the acceptability of the cookie's formulation using a structured quantitative acceptance assessment test. The parameters assessed were texture, taste, aroma, and preference level. The 5-point rating scale used is (1) Like very much, (2) Like, (3) Netral, (4) Dislike, and (5) Dislike very much.

2.2.3.2 Dietary Fiber of Cookies with The Addition of Coffee Parchment Extract Flour

Insoluble dietary fiber (IDF), soluble dietary fiber (SDF), and total dietary fiber (TDF) were determined using a gravimetric test based on the AOAC-991.43 and AACC-32.07.01 methods (Lee et al., 1992). The analysis was repeated twice for each sample. Yields are expressed as a percentage by weight (%).

2.2.3.3 Antioxidant Activity of Cookies with The Addition of Coffee Parchment Extract Flour

Antioxidant activity was determined using the DPPH method (Molyneux, 2004). Cookie samples were added to the methanol solution and filtered. Samples were prepared at a concentration of 1.000 ppm in methanol solution. The sample solution was diluted to obtain 200, 400, 600, 800, and 1.000 ppm concentrations. Each concentration of sample solution was taken as much as 4 mL and reacted with 1 mL of 0.2 mM DPPH solution. Sample absorbance was measured using a spectrophotometer (Genesys 150 UV-Vis, USA), at a wavelength of 517 nm. The analysis was repeated three times for each sample. Inhibition (%) can be calculated using the formulation below:

$$\%Inhibition = \frac{Blank \ Absorbance - Sample \ Absorbance}{Blank \ Absorbance} \times 100\% \quad (1)$$

2.2.3.4 Determination of Glycaemic Index of Cookies with The Addition of Coffee Parchment Extract Flour In Vivo

Determination of the glycaemic index of cookies with addition of coffee parchment extract flour in vivo follows Fibrianto's research with some modification. The animals used in this study were male Wistar rats (*Rattus norvegicus*) with the inclusion criteria of 8-10 weeks of age, 150-250 grams of body weight, and active and non-disabled rats. These criteria are

considered the criteria for healthy rats that can be used as samples in glycaemic index testing. The rats were obtained from the Food and Nutrition Centre Laboratory of PAU, Gajah Mada University, Yogyakarta. The number of rats used was 20, that there were three groups with five rats per group with different treatments, such as intervention of glucose (standard food), cookies without the addition of coffee parchment extract flour (F0), cookies with the addition of 10% coffee parchment extract flour (F1), and cookies with the addition of 15% coffee parchment extract flour (F2). Before treatment, they were allowed to adapt to the new environment for 7 days and were kept with standard animal feed and unlimited water. Before blood sampling and test food administration, the subjects were required to fast for 10 h (only allowed to consume water). The glycaemic index measurement was done by taking blood from the subjects to determine fasting blood glucose levels (minute 0). After that, the subjects were given standard or test food (2g) to be consumed within 25 minutes. After the consumption, the rat's serum glucose levels were measured using Glucose Oxidase - Peroxidase-Amino antipyrine (GOD-PAP) methods at 0, 30, 60, 90, and 120-min intervals. The serum glucose levels obtained from each measurement time point were plotted as a curve. The measurement time (minutes) is on the X axis, and the blood glucose level (mg/dl) is on the Y axis. The glycaemic index of each subject was determined by comparing the area under the curve of the food whose glycaemic index would be measured with the standard food.

2.2.3.5 Statistical analysis

The cookie formula was made once and the analysis was repeated 3 times sensory evaluation, dietary fiber, antioxidant activity, and determination of glycaemic index in vivo using Wistar rats). Data were expressed in terms of mean $\pm$ standard deviation. The normality of data distribution was verified using ANOVA (analysis of variance). The Duncan post-hoc test, or Duncan Multiple Range Test (DMRT), is a follow-up test used in analysis of variance (ANOVA) to compare means between treatment groups after the ANOVA results indicate a significant difference between the groups. This test helps determine which groups are statistically different from each other. Averages indicated by different letters (a, b, c) are significantly different ($P < 0.05$). Statistical tests were performed using the Statistical Package for Social Science (SPSS) version 23 with test statistics.

3 RESULTS

3.1 Appearance and Sensory Evaluation of Cookies with The Addition of Coffee Parchment Extract Flour

Coffee parchment extract flour has a light brown color and a soft texture like wheat flour (Figure 1). This flour is

used to add to cookie dough. The appearance of cookies with the addition of coffee parchment extract flour is shown in Figure 2. The F2 cookies formulation (the addition of 15% coffee parchment extract flour) has a darker color than F0 (no addition of coffee parchment extract flour) and F1 (the addition of 10% coffee parchment extract flour). This indicates that adding more coffee parchment extract flour will produce darker cookies.

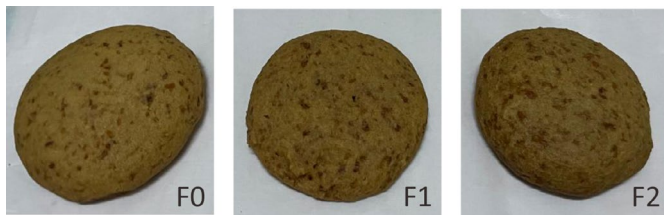


Figure 2: F0, F1, and F2 Cookies Formulation Appearance.

Sensory evaluation aims to determine the panellist's assessment of cookies with the addition of coffee parchment extract flour. The panellist's assessment of cookies with the addition of coffee parchment extract flour is shown in Table 2.

Table 2: Sensory Evaluation of Cookies Formulation with The Addition of Coffee Parchment Extract Flour.

Cookies Formulation	Parameters			
	Flavor	Texture	Taste	Level of Preference
F0	3.55±0.76 ^a	3.75±0.91 ^a	3.95±0.82 ^a	3.40±1.14 ^a
F1	3.60±0.82 ^a	3.55±0.94 ^a	4.05±0.99 ^a	4.00±0.56 ^a
F2	3.50±1.00 ^a	3.35±0.81 ^a	3.65±1.13 ^a	3.84±0.89 ^a

The 5-point rating scale used is (1) Like very much; (2) Like; 3 Netral; 4 Dislike; and 5 Dislike very much). All data is the average of 3 repetitions. The mean followed by different letters in the same column shows a significant difference ($p<0.05$).

The F0, F1, and F2 cookie formulations were not significantly different based on flavour, texture, taste, and level preference. This shows that the similar acceptance among the formulations of the addition of coffee parchment extract flour as a food additive.

Table 3: Total Dietary Fiber and Antioxidant Activity Content of Cookies Formulation with The Addition of Coffee Parchment Extract Flour (%).

Cookies Formulation	Insoluble Dietary Fiber (IDF)	Soluble Dietary Fiber (SDF)	Total Dietary Fiber (TDF)	Antioxidants Activity
F0	3.56 ± 0.07 ^a	0.29 ± 0.01 ^a	3.85 ± 0.04 ^a	37.71 ± 0.07 ^a
F1	4.37 ± 0.09 ^b	0.37 ± 0.01 ^b	4.73 ± 0.03 ^b	41.82 ± 0.06 ^b
F2	5.35 ± 0.01 ^c	0.45 ± 0.21 ^c	5.79 ± 0.03 ^c	50.31 ± 0.12 ^c

All data is the average of 3 repetitions. The mean followed by different letters in the same column shows a significant difference ($p<0.05$).

3.2 The Total Dietary Fiber and Antioxidants Activity of Cookies with The Addition of Coffee Parchment Extract Flour

Table 3 shows the total dietary fiber and antioxidant activity of cookies with the addition of coffee parchment extract flour. An increasing concentration of coffee parchment extract flour added to a cookie formulation can produce higher antioxidant and dietary fiber content. So, the F2 formulation has the highest antioxidants and dietary fiber.

3.3 Glycaemic Index of Cookies with The Addition of Coffee parchment Extract Flour in Vivo using Wistar Rats

The average blood glucose levels of rats after food intervention of glucose (Standard food) and F0, F1, and F2 cookies formulation with the addition of coffee parchment extract flour (Test food) are presented in Figure 3.

The glycaemic index is an indicator that measures how quickly foods containing carbohydrates trigger an increase in blood glucose response. The glycaemic index of each subject was determined by comparing the area under the curve between the food whose glycaemic index would be measured with the standard food shown in Table 4.

All data is the average of 3 repetitions. The mean followed by different letters in the same column shows a significant difference ($p<0.05$)

4 DISCUSSIONS

After fermentation and removing the mucilage layer during coffee bean processing, the coffee parchment remains a layer that covers the coffee beans. It is located in the endocarp layer, the coffee bean's outer skin. This coffee skin will be dried so that it loses moisture, becomes dry and brittle, so that the color changes from pale to dark yellow or light brown. The Arabica skin coffee bean has a brighter color than the robusta coffee bean (Butar-butur et al., 2024). Adding coffee parchment extract flour resulted in a darker cookie color (F2) than F0 and F1. Adding coffee parchment extract flour to cookie dough can reduce the brightness of cookies, so increase the brown level.

The increasing concentration of coffee parchment extract flour also increases the browning level of the dough, so F2 becomes darker. In the research results, Rizkaprilisa et al. (2023) showed that adding coffee parchment extract flour to bread dough causes a decrease in the brightness of the bread and an increase in the level of redness in the bread, but no change in the yellowness level. Based on the panellist assessment, they still accept the cookie formulation's texture, flavour, and taste by adding 10% (F1) or 15% (F2) coffee parchment flour. It is shown that coffee parchment is potentially acceptable to the public as a food additive.

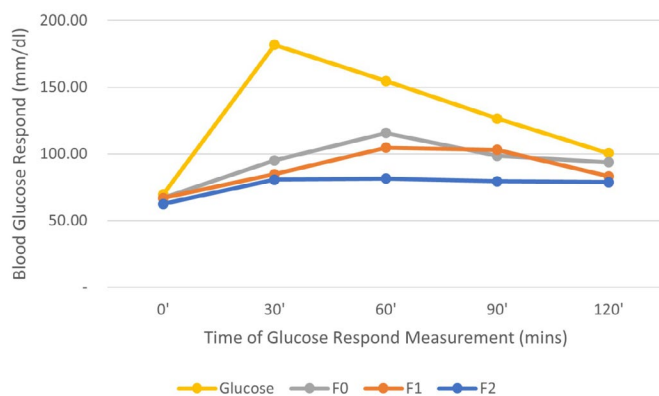


Figure 3: Blood Glucose Response Curve Wistar Rats After Food Intervention of Glucose (Standard Food) and Cookies with The Addition of Coffee parchment extract flour (Test Foods).

The increasing concentration of coffee parchment extract flour can increase dietary fiber and antioxidants. The highest dietary fiber and antioxidant is F2 with $5.79 \pm 0.03\%$ and $50.31 \pm 0.12\%$, respectively. Coffee parchment extract flour has high levels of dietary fiber and antioxidants. They have 89–92.6 g/100 g dietary fiber and antioxidants, including chlorogenic acid 232.6 $\mu\text{g/g}$ and total phenolic content 228–284 mg GAE/100 g. Coffee parchment has a total dietary fiber content of 89–92.6 g/100g (de Santos et al., 2021; Gemechu, 2020). It happens in Lanywati et al. (2023) and Rizkaprilisa et al. (2023) research that the increasing concentration of coffee parchment can increase their antioxidant and dietary fiber content in cookies (43.86% and 13.67%, respectively) and bread (30.65% and 7.93%, respectively). Intervention of glucose provides an increase in blood glucose levels with a peak glycaemic response at the 30th mins with a blood glucose level of 181.80 mm/dl, then begins to decrease gradually to 154.60 mm/dl at the 60th mins, 126.40 mm/dl at the 90th mins, and 100.60 mm/dl at the 120th mins. Changes in blood glucose levels show a very high increase in glucose intervention, and it takes 90th minutes for glucose levels to return to normal. This indicates that glucose is directly digested and absorbed by the body.

Table 4: Glycaemic Index of Cookies Formulation with The Addition of Coffee Parchment Extract Flour.

Food Intervention	Measurement Time (minutes)	Blood Glucose Response Measurement (mm/dl)	Glycaemic Index
Glucose	0'	69.50±0.65 ^c	100.00±1.89 ^c
	30'	181.80±0.76 ^d	
	60'	154.60±0.04 ^d	
	90'	126.40±0.33 ^c	
	120'	100.60±1.22 ^c	
F0	0'	66.91±1.11 ^b	31.26±0.49 ^b
	30'	95.06±2.21 ^c	
	60'	115.64±2.56 ^c	
	90'	98.55±2.53 ^b	
	120'	93.68±4.81 ^b	
F1	0'	66.91 ± 1.82 ^b	21.98±0.49 ^a
	30'	84.72±0.91 ^b	
	60'	104.69±1.81 ^b	
	90'	103.12±2.12 ^b	
	120'	83.15±1.45 ^a	
F2	0'	62.45±0.37 ^a	22.15±1.72 ^a
	30'	80.75±0.75 ^a	
	60'	81.47±0.75 ^a	
	90'	79.42±1.09 ^a	
	120'	78.82±0.91 ^a	

The intervention of cookie formulation experienced a gradual increase in blood glucose levels with a peak glycaemic response at the 60th minute, then decreasing at the 90th and 120th minutes. Blood glucose levels are still within the normal range (70–100 mg/dl). The cookies formulation used low glycaemic index ingredients such as modified cassava flour, corn starch, and palm sugar. Low GI foods (≤ 55) are characterised by a smaller incremental rise and fall in blood glucose (Barclay et al., 2021). Intervention of F0 cookies formulation provides an increase in blood glucose levels with a peak glycaemic response at the 60th minute with a blood glucose level of 115.64 mg/dl, then begins to decrease gradually to 98.55 mg/dl at the 90th minute and 93.68 mg/dl at the 120th minute. But, the peak glycaemic response of F0 (115.64 mm/dl) was greater than F1 and F2. Intervention of F1 cookies formulation provides an increase in blood glucose with a peak glycaemic response at the 60th mins with a blood glucose level of 104.69 mm/dl, then begins to decrease gradually to 103.12

mm/dl at the 90th mins and 83.15 mm/dl at the 120th mins. While the intervention of F2 cookies formulation provides an increase in blood glucose with a peak glycaemic response at the 60th mins with a blood glucose level of 81.47 mm/dl, then begins to decrease gradually to 79.42 mm/dl at the 90th mins and 78.82 mm/dl at the 120th mins. Adding coffee parchment in F1 and F2 cookie formulations can keep blood glucose levels within the normal range. This decrease of blood glucose levels is caused by the presence of bioactive compounds such as phenolics, tannins, and flavonoids which can act as antioxidants and fight free radicals by preventing the chain reaction of converting superoxide into hydrogen superoxide by donating hydrogen atoms from aromatic hydroxyl groups (-OH) to bind free radicals, thus providing a protective and repair effect on damaged pancreatic beta cells (Monteiro, et al., 2020). Phenolic flavonoids also stimulate insulin secretion. Tannins and flavonoids can block the action of α -glucosidase, which lowers the amount of glucose absorbed and increases the amount in the digestive system (Fibrianto et al., 2023). Dietary fiber can block the fat absorption and reduce energy intake by regulating food intake, digestion, absorption, and metabolism (He et al., 2022). Higher dietary fiber intake has been associated with a decreased risk of T2D and flattened glycemic and insulinemic responses consistent with our results (Mao et al., 2021).

The glycaemic index is an indicator that measures how quickly foods containing carbohydrates trigger an increase in blood sugar levels. The glycaemic index (GI) reflects a food's carbohydrates (glycaemic) and the rate at which these carbohydrates are digested, absorbed, and metabolized, thus appearing as glucose in the blood. GI has a scale of 1 to 100, where low GI foods (≤ 55) are characterized by smaller increases and decreases in blood glucose, while high GI foods (≥ 70) are characterized by faster and higher peaks and troughs in blood glucose levels (Barclay et al., 2021). The cookie formulation used modified cassava flour, corn starch, and palm sugar, which have low GI. Modified cassava flour has a glycaemic index of <55 , so it is often used to make healthy snacks such as cookies, producing cookies with a low glycaemic index (25.77-31.24) (Utami & Eko, 2023). Low GI foods can improve insulin sensitivity, fasting triglyceride levels, maintain a healthy body weight, and significantly improve health risk markers (Liaquat et al., 2022). So, the intervention of F0 cookies formulations without adding coffee parchment extract flour has a low GI (31.26), lower than the intervention of glucose (100.00). At the same time, the intervention of cookies formulation with the addition of coffee parchment extract flour has lower GI, 21.98 (F1) and 22.15 (F2). It shows that the antioxidant and dietary fiber of coffee parchment can affect the control of blood glucose levels and keep them within the normal range. Although cookie formulation F2 had higher antioxidant and dietary fiber content compared to

F1, GI of the intervention cookie formulas F1 and F2 did not differ significantly. Although the addition of dietary fiber and antioxidant compounds is often reported to reduce glycemic response, recent evidence suggests that this relationship is not always linear. Effectiveness is strongly influenced by fiber type (viscous vs. non-viscous), molecular weight/viscosity formed in vivo, interactions within the food matrix, and changes that occur during food processing (e.g., depolymerization, viscosity loss) (Giuntini et al., 2022; Munteanu & Schwartz, 2024). Therefore, the addition of greater quantities of fiber or antioxidants does not always result in a proportional or additional reduction in glycemic index.

The antioxidants and dietary fibers of coffee parchment can lower the glycaemic index by controlling blood glucose levels. It can be seen in Table 3 that the F1 and F2 cookie formulations have a higher antioxidant and dietary fiber content compared to F0. So, the intervention of F1 and F2 cookies formulation shows smaller blood glucose increases, keeping them within the normal range. In the research results, Do Reis Gallo et al. (2021) showed that brown sorghum bread has higher fiber and antioxidant activity, presenting the lowest GI. Dietary fiber may play an essential role in treating obesity with increased satiety, delayed nutrient absorption, reduced blood pressure, reduced blood lipid concentrations and body fat, reduced triglyceride and low-density lipoprotein (LDL) cholesterol, and improved glycaemic response (Rakmai et al., 2021). Coffee parchment has phenolic compounds that have the potential for LDL oxidation inhibition, oxidative stress reduction, blood pressure modulation, plasma cholesterol and triglycerides reduction, as well as type 2 diabetes development (Jimenez-Pulido et al., 2022). So, coffee parchment extract flour may be a promising functional ingredient for developing low-GI snacks for diabetes prevention.

5 CONCLUSIONS

The addition of coffee parchment extract flour to cookie dough produced a darker color that remained acceptable to panellists and contributed to improved functional properties. Cookies formulated with this flour (F1 and F2) demonstrated low glycaemic index values (21.98 and 22.15), helped maintain normal blood glucose levels, and showed higher antioxidant activity and dietary fiber content, resulting in reduced postprandial glycaemic responses and potential benefits for diabetes prevention.

6 AUTHOR CONTRIBUTIONS

Conceptual Idea: Windy, R.; Methodology design: Windy, R.; Salsabila, A.P.B.; Data collection: Windy, R.; Linda, F.S.; Data analysis and interpretation: Windy, R.; and Writing and editing: Windy, R.; Salsabila, A.P.B.; Linda, F.S.

7 DATA AVAILABILITY STATEMENT

Data available upon request to authors.

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