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Optimizing healthy snacks for diabetics: Study of fiber and starch digestibility of glucomannan-modified Growol cookies

Optimasi snack sehat untuk diabetesi: Kajian serat dan daya cerna pati cookies Growol modifikasi glukomanan

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Abstract

Diabetes mellitus (DM) is an emergency health problem in the 21st century. High dietary fiber and resistant starch foods with low starch digestibility are solutions for DM. The addition of glucomannan to food can optimize the levels of dietary fiber, resistant starch, and starch digestibility. This study aimed to examine the optimization of dietary fiber, resistant starch, and starch digestibility in Growol cookies supplemented with glucomannan. Laboratory observations were conducted at the Universitas Respati Yogyakarta and Chemmix Pratama Yogyakarta Laboratory between July and September 2023. Cookies consisted of cookies A (negative control), B (positive control), C (modified 10-gram inulin), D (modified glucomannan 3%), and E (modified glucomannan 7%). Dietary fiber and resistant starch analyses were performed using the multi-enzyme method. Starch digestibility was determined by comparing the starch content obtained using the enzymatic method with that obtained using the acid hydrolysis method. Statistical analyses were performed using ANOVA and Kruskal-Wallis tests. There were differences in dietary fiber and resistant starch among the variants (p<0,001) with the highest being cookies E. There was no difference in starch digestibility between the variants (p=0,104) with the lowest being cookies E. In conclusion, glucomannan addition can optimize dietary fiber and resistant starch levels, as well as the starch digestibility of Growol cookies as a healthy snack for diabetics.

Keywords: Diabetes, dietary fiber, glucomannan, resistant starch

Abstrak

Diabetes mellitus (DM) merupakan darurat masalah kesehatan pada abad ke-21. Makanan tinggi serat pangan dan pati resisten serta rendah daya cerna pati merupakan solusi penanganan DM. Penambahan glukomanan pada produk makanan mampu mengoptimalkan kadar serat pangan, pati resisten, dan daya cerna pati. Penelitian bertujuan untuk mengkaji optimasi serat pangan, pati resisten, dan daya cerna pati pada *cookies* Growol dengan penambahan glukomanan. Penelitian berdesain observatori laboratorium dilakukan di Universitas Respati Yogyakarta dan Laboratorium Chemmix Pratama Yogyakarta pada Juli–September 2023. *Cookies* terdiri atas *cookies* A (kontrol negatif), *cookies* B (kontrol positif), *cookies* C (modifikasi inulin 10 gram), *cookies* D (modifikasi glukomanan 3%), dan *cookies* E (modifikasi glukomanan 7%). Analisis serat pangan dan pati resisten dilakukan dengan metode multienzim. Daya cerna pati diperoleh dari perbandingan kadar pati metode enzimatis dengan metode hidrolisis asam. Analisis statistik menggunakan *ANOVA* dan *Kruskal-Wallis*. Terdapat perbedaan kadar serat pangan dan pati resisten di antara varian *cookies* (p<0,001) dengan serat pangan dan pati resisten tertinggi adalah *cookies* E. Tidak terdapat perbedaan daya cerna pati di antara varian *cookies* (p=0,104) dengan daya cerna pati terendah adalah *cookies* E. Kesimpulan, penambahan glukomanan mampu mengoptimalkan kadar serat pangan dan pati resisten serta daya cerna pati *cookies* Growol sebagai *snack* sehat untuk diabetes.

Kata Kunci: Diabetes, glukomanan, pati resisten, serat pangan

Introduction

The International Diabetes Federation (IDF) emphasizes that diabetes mellitus (DM) is an emergency health problem of the 21st century, considering that more than half a billion people worldwide live with diabetes. The IDF estimates that there will be a global increase of 46 % %in diabetes cases from 2021 (around 537 million) to 2030 (643 million) and a sharp increase in 2024 (783 million). The largest increase occurred in Africa (134%), Southeast Asia (68%), and America (50%). The emergence of diabetes is evident in the increasing number of children and teenagers living with diabetes every year. More than 1,2 million children and adolescents have diabetes with 184 thousand new cases diagnosed each year (International Diabetes Federation, 2021b).

In fact, in 2021, as many as 537 million adults aged 20-79 years live with diabetes, and three of the four adults living with diabetes come from low-to middle-income countries. Moreover, diabetes contributes to 6,7 million deaths in 2021, namely one death every five seconds. Diabetes has also caused an increase in state spending on health by 966 million dollars, with an increase in spending of 316% over the last 15 years. Evidence of diabetes emergencies can also be seen from the increasing number of adults who experience impaired glucose tolerance (541 million), which places them at a high risk of developing type 2 diabetes mellitus (International Diabetes Federation, 2021c).

In Indonesia, the prevalence of DM in the population aged 20-79 years reached 6, 2% in 2020. Indonesia is predicted to become the 6th largest country in the world with a prevalence of DM aged 20-79 years of 14,1 million people in 2035 (Forouhi & Wareham, 2014). Periodic reports contained in Indonesia Diabetes Report from 2000 to 2021 shows that the incidence of diabetes in adults aged 20-79 years has increased from 5,7 million (2000) to 7,3 million (2011) and increased drastically to 19,5 million (2021) with the number of people with diabetes who do not diagnosed at 14,3 million and the death rate due to diabetes was 235.711 (6,5%). Moreover, 700 new cases of type 1 diabetes in children and adolescents aged 0-14 years were found, with a prevalence of 4.700 cases. The number of diabetic complications also tends to increase, including microvascular complications such as nephropathy (7,7%), neuropathy (17,6%), retinopathy (2,7%), and macrovascular complications such as cerebrovascular disease (5,4%), heart failure (5%), and coronary artery disease (5,4%) (International Diabetes Federation, 2021a). Ironically, the total medical costs incurred by Indonesia reached $576 million, with 56% spent on hospitalization, 38% on specialist visits, and 4% on other treatments (Hidayat et al., 2022). The Yogyakarta Special Region is one of the provinces with a higher diabetes prevalence (4,5%) than the national prevalence (2,4%) (Dinas Kesehatan DIY, 2021). The prevention and treatment of diabetes must be performed as early as possible. Optimal management of diabetes can prevent complications and reduce costs (Hidayat et al., 2022).

One solution for managing DM is to regulate simple sugar intake and increase the intake of dietary fiber and resistant starch (Abbas, 2021; Kosupa & Utama, 2020; Masrukan, 2020; Tuaño et al., 2021; Walsh et al., 2022). Consuming foods high in fiber and resistant starch can reduce postprandial glucose concentrations and increase insulin sensitivity (Pugh et al., 2023; Srimiati & Harsanti, 2023; Volpe, 2016). In addition, resistant starch has the potential to be used as a prebiotic, which is the main substrate for gastrointestinal microbiota (Bimo et al., 2015).

Furthermore, increasing the levels of dietary fiber and resistant starch in food products reduces the starch digestibility of a product. The lower the digestibility of food starch, the less glucose is produced, which causes a slight increase in the blood glucose levels. Foods with low starch digestibility are suitable for consumption by people with diabetes (Noviasari et al., 2015). A food product with good fiber and resistant starch contents was grown.

Growol is a traditional fermented food made from cassava from Yogyakarta. This fermentation occurs naturally and involves lactic acid bacteria, which are beneficial for health (Afrianto & Wariyah, 2020; Wicaksono et al., 2022). Growol can support the growth of bacteria such as *Lactobacillus*, which affects the balance of the gastrointestinal microbiota (Puspaningtyas et al., 2018; Sari & Puspaningtyas, 2019).

Growol has been developed in the form of Growol cookies, and then Growol cookies has been modified by adding inulin to increase the effectiveness of the fiber cookies. Growol cookies have a lower glycemic index (87) than glucose cookies (100). After the addition of inulin, the glycemic index of the Growol cookies decreased to 41 (low) (Puspaningtyas et al., 2020; Puspaningtyas et al., 2022). However, the addition of inulin has weaknesses in terms of texture, in which cookies tend to be more fragile and easy to break (Puspaningtyas, Sari, et al., 2022). Inulin can be substituted by glucomannan.

Glucomannan, a water-soluble fiber, has the potential to be used as a substitute for inulin in the development of growth cookies. Glucomannan can be used as an emulsifier, thickener, binder, and surfactant (Mura, 2021). In addition, in terms of physiological effects, glucomannan can improve lipid profiles and glycemic status (Keithley et al., 2013; Keithley & Swanson, 2005). Preclinical studies using glucomannan from konjac flour showed improvements in blood glucose control and insulin sensitivity in diabetic test groups (Susanti et al., 2015). A study in obese individuals showed that glucomannan has an inhibitory effect on glucose and increases insulin (Mashudi et al., 2022).

To date, studies related to the initial feasibility of glucomannan-modified Growol cookies as a healthy snack for diabetics have not been conducted, especially in terms of the levels of dietary fiber, resistant starch, and starch digestibility. This study supports the use of local food as a dietary solution in disease therapy, especially for diseases related to decreased body function, such as diabetes (Nakamura & Omaye, 2012). The use of cassava as a raw material for making Growols also supports Indonesia's food diversification and food security (Khoerunisa, 2020; Putri et al., 2022).

This study aimed to provide an overview of changes in the levels of dietary fiber, resistant starch, and starch digestibility in various modifications of Growol cookies. Ultimately, this research aimed to examine the optimization of dietary fiber, resistant starch, and starch digestibility of Growol cookies with the addition of glucomannan.

Methods

Research Design, Location, and Time

This was a laboratory observation of the differences in the levels of dietary fiber, resistant starch, and starch digestibility of glucomannan-modified Growol cookies compared to control Growol cookies and inulin-modified Growol cookies, which have been developed in previous research. This research consisted of several stages, starting from making Growol, producing Growol flour, manufacturing Growol cookies, and laboratory testing.

This research was conducted at Universitas Respati Yogyakarta, specifically in the Culinary and Dietetics Laboratory, as a place for making Growol, drying Growol, and making cookies. The Chemmix Pratama Yogyakarta Laboratory was used to analyze the food fiber content, resistant starch, and starch digestibility. This study was conducted from July to September 2023. This research has received a certificate of ethical suitability from the Health Research Ethics Commission, Faculty of Health Sciences, Universitas Respati Yogyakarta with number 0146.3/FIKES/PL/VII/2023.

Process of Making Growol, Growol Flour, and Growol Cookies

The cassava specifications used in making Growols refer to previous studies, namely Klentengan cassava (*Manihot esculente* or *Manihot utilisima*) with light green stems, five–nine finger leaves, 8-11 years old, long round tubers, thin brown outer skin, and slightly thick white or pink inner skin with white tubers inside (Helsius et al., 2023b, 2023a; Puspaningtyas et al., 2018).

Growol is made through a natural fermentation process according to previous studies (Puspaningtyas et al., 2018), starting from selecting cassava by peeling the cassava skin and removing the black or bluish parts. Next, the cassava was cut into smaller pieces of approximately 5 cm, followed by washing under flowing water two to three times. Next, cassava was soaked in water at a weight-to-volume ratio of 1:3. The cassava was soaked for four days until a distinctive aroma appeared, and the cassava became softer. The next step was washing and filtering the cassava using mori cloth seven times. The filtered cassava was then squeezed and molded into raw Growol. The final step was steaming the raw Growol into Growol.

The Growol-flouring process begins by slicing the Growol into thin pieces, followed by drying the Growol using a cabinet dryer at 80 °C for six hours. The next step was to flour the Growol using a grinder and sieve it with a 60-mesh sieve.

Cookies were made after Growol flour was available. Ingredients and the process of making Growol cookies are described in a previous study (Puspaningtyas et al., 2020; Puspaningtyas et al., 2022). The developed cookies consisted of negative control Growol cookies with granulated sugar as the sweetener (cookies A), positive control Growol cookies with non-calorie sugar as the sweetener (cookies B), Growol cookies with 10 g of inulin (cookies C), Growol cookies with 3% glucomannan (cookies D), and Growol cookies with 7% glucomannan (cookies E). The percentage of inulin used was based on previous studies (Puspaningtyas et al., 2022). The percentage of glucomannan use refers to the effective limit of glucomannan consumption of 1-4 grams per day (Keithley et al., 2013; Keithley & Swanson, 2005; Mohammadpour et al., 2020).

Dietary Fiber Testing

Dietary fiber analysis was performed using the multienzyme method (Nova et al., 2020; Tuwohingide et al., 2022). A total of 0,5 grams of sample (cookies) were weighed and then added 50 mL of pH 7 phosphate buffer and 0,1 mL of alpha-amylase enzyme. The mixture was then heated in a water bath at 100 °C for 30 min and stirred occasionally.

The samples were then removed and cooled. After cooling, 20 mL distilled water and 5 mL 1 N HCl were added. Then, 1 mL of 1% pepsin enzyme was added and heated in a water bath for 30 min.

After that, remove the sample and add 5 mL of 1 N NaOH and 0,1 mL of beta-amylase enzyme. The samples were incubated in a water bath for 1 h. The sample was then filtered through a filter paper of known weight.

Next, the sample was washed with 2 × 10 mL of ethanol and 2 × 10 mL of acetone. The sample was dried overnight in an oven at 105 °C. The sample was then cooled in a desiccator and the final weight of the sample was measured. The final weight of the sample is an illustration of the level of insoluble dietary fiber.

Meanwhile, 100 ml of the filtered filtrate was measured and 400 ml of 95% ethanol was added. The filtrate was allowed to settle for 1 h. The filtrate was then filtered using ash-free filter paper and washed with 2 × 10 ml ethanol and 2 × 10 ml acetone. The samples were then dried overnight in an oven at 105 °C. It was then placed in a desiccator, and the final sample was weighed. The final weight of the sample is an illustration of the water-soluble dietary fiber content.

The total dietary fiber content was the sum of the levels of insoluble and soluble dietary fiber. Dietary fiber testing was performed in triplicate for two units of each cookie variant.

Resistant Starch and Starch Digestibility Testing

Resistant starch analysis was performed using the multienzyme method (Anugrahati & Widjanarko, 2018). A total of 0,5 grams of sample (cookies) was weighed and then added 25 mL of 0,1 M phosphate buffer solution (pH 7) was added and stirred to form a suspension. Then, add 0,1 mL) was then added. Next, they were incubated in a water bath at 100 °C for 15 min and stirred occasionally.

The samples were then removed and cooled. After cooling, 20 mL distilled water, 5 mL 1 M HCl, and 1 mL 1% pepsin enzyme were added. The cells were then incubated again in a water bath for 30 min. Next, add 20 mL of distilled water, 5 mL of 1 N NaOH, and 0,1 mL of beta-amylase enzyme. The mixture was again incubated in a shaking water bath for 30 min. Filter paper was used to dissolve the residue, and the resistant starch content was analyzed through glucose weight conversion using the acid hydrolysis method with the following mathematical calculations (Polnaya et al., 2018). The G value is the weight of glucose in grams and the conversion of 0,9 comes from the free D-glucose conversion factor determined in the form of D-glucose in starch (162/180).

$$\% \text{ Resistant Starch} = \frac{1-Gx0{,}9}{sample\ weight} \text{ x } 100\%$$

Starch digestibility was determined by comparing the starch content of the enzymatic method with that of the acid hydrolysis method using the AOAC 2005 method (Anugrahati & Widjanarko, 2018). Testing for resistant starch and starch digestibility was performed in triplicate for two units of cookies for each cookie variant. The mathematical calculation for determining the starch digestibility is as follows:

Starch digestibility:

$$=\frac{strach\ content\ of\ enzymatic\ method}{strach\ content\ of\ acid\ hydrolysis\ method} \text{ x } 100\%$$

Statistical analysis

Data on dietary fiber (insoluble dietary fiber, water-soluble dietary fiber, and total dietary fiber), resistant starch, and starch digestibility were first analyzed for distribution using the Shapiro–Wilk test. The data on resistant starch and starch digestibility were not normally distributed ($p<0,05$). Meanwhile, the dietary fiber data were normally distributed ($p>0,05$). Next, for normally distributed data, a homogeneity of variance test was performed using the Levene Test. Only water-soluble dietary fiber data showed homogeneous variance ($p>0,05$).

Differences in water-soluble dietary fiber levels between the groups were tested using ANOVA. If the test results were significant, the Tukey's HSD test was continued. Differences in the levels of insoluble dietary fiber, total dietary fiber, resistant starch, and starch digestibility between the groups were tested using the Kruskal-Wallis test. If the test results were significant, the Mann-Whitney test was used.

Result and Discussion

Dietary Fiber Content

There were differences in the levels of insoluble dietary fiber, water-soluble dietary fiber, and total dietary fiber between cookies A, B, C, D, and E. Growol cookies with the addition of 7% glucomannan (cookies E) had the highest levels of insoluble dietary fiber, water-soluble dietary fiber, and total dietary fiber compared to other cookies (Table 1).

Table 1. Dietary fiber content of Growol cookies

Growol Cookies	% Insoluble Dietary Fiber			% Water-Soluble Dietary Fiber		% Total Dietary Fiber		
	Mean±SD	Mean Rank	p-value*	Mean±SD	p-value$^{\#}$	Mean±SD	Mean Rank	p-value*
Cookies A	3,16±0,07	3,50^{a}	<0,001	0,36±0,03^{a}	<0,001	3,52±0,10	3,50^{a}	<0,001
Cookies B	3,79±0,07	9,50^{b}		0,47±0,02^{b}		4,26±0,07	9,50^{b}	
Cookies C	5,26±0,38	15,50^{c}		0,57±0,02^{c}		5,83±0,38	15,50^{c}	
Cookies D	7,43±0,15	21,50^{d}		0,65±0,02^{d}		8,08±0,14	21,50^{d}	
Cookies E	8,55±0,20	27,50^{e}		0,74±0,01^{e}		9,29±0,20	27,50^{e}	

*Kruskal-Wallis; $^{\#}$ANOVA

^{abcde}Different letter notations indicate differences between groups

Resistant Starch Content and Starch Digestibility

The greater the addition of glucomannan to the Growol cookies, the higher the level of resistant starch in the cookies. There were significant differences in resistant starch levels between all variant cookies, with the highest resistant starch found in cookies E (Table 2). The greater the addition of glucomannan to cookies, the lower the starch digestibility. The lowest starch digestibility is found in cookies E followed by cookies D, cookies A, cookies C, and the highest starch digestibility at cookies B. There was no significant difference in starch digestibility among the cookies (Table 2).

Based on the results of statistical analysis, glucomannan-modified Growol cookies have higher levels of dietary fiber (both insoluble dietary fiber, water-soluble dietary fiber, and total dietary fiber) and resistant starch than control Growol cookies and inulin-modified Growol cookies. The starch digestibility of glucomannan-modified Growol cookies was lower than that of the control and inulin-modified Growol cookies. The addition of glucomannan to Growol cookies has been proven to increase the levels of dietary fiber and resistant starch. This is the basic reason for the development of modified glucomannan growth cookies as healthy snacks for diabetics.

Table 2. Resistant starch content and starch digestibility of Growol cookies

Growol Cookies	% Resistant Starch			% Starch Digestibility		
	Mean±SD	Mean Rank	p-value*	Mean±SD	Mean Rank	p-value*
Cookies A	2,78±0,04	3,50[a]	<0,001	51,36±6,53	17,50	0,104
Cookies B	4,10±0,08	9,50[b]		56,66±13,13	20,00	
Cookies C	6,29 (5,89-6,70)[#]	15,50[c]		52,66±6,53	19,33	
Cookies D	8,68 (8,59-8,75)[#]	21,50[d]		44,98 (44,62-56,51)[#]	12,17	
Cookies E	9,36±0,07	27,50[e]		42,88 (41,33-55,17)[#]	8,50	

*Kruskal-Wallis

[#]Median (Minimum-Maximum)

[abcde]Different letter notations indicate differences between groups

Dietary fiber is a carbohydrate that is difficult to process or break down by digestive enzymes. This property allows dietary fiber to provide good glycemic control. Dietary fiber, especially soluble dietary fiber, can increase the sensation of fullness owing to increased viscosity in the stomach. This increase in viscosity causes changes in the hormonal and enzymatic responses in the digestive tract. This affects the slow rate of glucose absorption (Giuntini et al., 2022; Noviasari et al., 2015).

Based on the results of the dietary fiber content tests, control Growol cookies and Growol cookies with the addition of inulin can be classified as a food source of fiber, considering that the total dietary fiber content in the cookies has reached the minimum standard, namely 3 g in 100 g of food (3%). Consuming 100 g of cookies can meet 10% of daily fiber needs. Furthermore, glucomannan-modified Growol cookies can be classified as a high-fiber food, considering that the amount of total dietary fiber in the cookies achieves the minimum standard for high-fiber foods, namely 6 g in 100 g (6%), which can meet 20% of the daily fiber needs (Codex Alimentarius Commission, 2009; Noviasari et al., 2015). The addition of glucomannan to Growol cookies can increase the levels of dietary fiber by two to three times compared with control cookies.

Insoluble dietary fiber plays a role in increasing fecal volume and making it easier to expel feces from the digestive tract. Soluble dietary fiber plays a role in controlling blood glucose and blood cholesterol levels. These two mechanisms help improve insulin sensitivity (Egayanti et al., 2019).

Consuming foods high in dietary fiber can reduce blood glucose levels by 9,97 to 15,3 mg/dL and also reduce HbA1c levels ranging from 0,26% to 0,55% (Asif, 2014; Post et al., 2012; Silva et al., 2013). Increasing fiber intake to 35 grams a day can reduce glycated hemoglobin (HbA1c) levels by up to 2,00 mmol/mol (2,3%), fasting plasma glucose by 0,56 mmol/L (10,09 mg/dL), and HOMA-IR by 1,24 mg/dL (Reynolds et al., 2020).

One type of soluble dietary fiber is glucomannan. Previous studies have applied glucomannan to instant noodle products. Daily consumption of 4 g of glucomannan in 400 g of instant noodles for 28 days can reduce HbA1c by 0,63%. This effect is caused by glucomannan, which plays a role in increasing the viscosity of the gastrointestinal tract, causing changes in hormonal responses and digestive tract enzymes, and reducing the rate of glucose absorption (Cheang et al., 2017; Giuntini et al., 2022).

In line with the results of dietary fiber, the addition of glucomannan to Growol cookies increased the levels of resistant starch by two to three times compared to control cookies. Similar to dietary fiber, resistant starch has slow digestibility, which can slow the increase in glucose levels in the body. In addition, resistant starch can also increase and maintain feelings of fullness. This is because the metabolism of resistant starch occurs from five to seven hours after food consumption (Egayanti et al., 2019; Noviasari et al., 2015).

Resistant starch is a food compound that escapes enzymatic digestion in the small intestine, is directly processed in the large intestine, and is fermented by gastrointestinal bacteria to produce short-chain fatty acids such as acetate, propionate, and butyrate. This plays a role in maintaining the balance of the gastrointestinal microbiota (Masrukan, 2020; Suloi, 2019; Tuaño et al., 2021; Walsh et al., 2022).

Several studies have shown other benefits of resistant starch in improving insulin sensitivity, reducing blood glucose levels to normal, reducing the sensation of hunger in line with weight loss therapy, treating obesity, and controlling the body's lipid profile (Masrukan, 2020; Suloi, 2019; Tuaño et al., 2021; Walsh et al., 2022)(Labatjo et al., 2023).

A negative correlation was observed between starch digestibility results. The addition of glucomannan to Growol cookies can reduce starch digestibility, although the difference in starch digestibility between the groups was not significant. Studies on modified cassava flour (mocaf) have shown that reducing the levels of resistant starch can increase starch digestibility. Conversely, the higher the level of resistant starch, the lower the digestibility of starch (Setiarto et al., 2018). In this study, cookies E (Growol cookies with the addition of 7% glucomannan) had the highest levels of dietary fiber and resistant starch with the lowest starch digestibility.

Other studies have also shown that starch digestibility is negatively correlated with the levels of compounds that are not digested by the small intestine, namely, levels of dietary fiber and resistant starch (Faridah et al., 2013).

The development of corn noodle products from corn flour shows that the control of corn noodles has a resistant starch content of 3,5%, dietary fiber of 6,87% and starch digestibility of 25,75%. Meanwhile, corn noodles processed with heat moisture treatment had higher levels of resistant starch and dietary fiber, namely 4,17% and 7,76% with a lower starch digestibility of 22,57% (Palupi et al., 2015).

The lower the digestibility of food starch, the less glucose is produced, which causes a slight increase in the blood glucose levels. Foods with low starch digestibility are beneficial for people with diabetes. The starch digestibility of food can be assessed using the food glycemic index approach (Noviasari et al., 2015).

A study on the development of analog rice using white corn flour as a base ingredient with the addition of soybean flour showed that analog rice has high levels of resistant starch and dietary fiber (3,28% and 5,84%). This analog rice also has a lower glycemic index (50) compared to the glycemic index of sosoh rice (69) (Noviasari et al., 2015). In other words, an increase in the levels of resistant starch and dietary fiber can reduce the glycemic index of analog rice in the food category with a low glycemic index (≤55) (Vega-López et al., 2018).

A similar study on various rice variants in the Philippines also showed that the higher the resistant starch content, the lower the estimated value of the glycemic index of rice. This is also related to the in vitro starch hydrolysis index. The lower the starch hydrolysis value, the lower is the estimated value of the rice glycemic index (Tuaño et al., 2021).

Another study related to the increase in resistant starch with a decrease in glycemic index was observed in the development of wheat substitute biscuits. The higher the wheat substitution, the higher the resistant starch content, which is indicated by an increase in resistant starch from 17,8% to 30,19% with 50% wheat substitution (Haryani et al., 2014). The higher the wheat substitution, the lower the glycemic index of the biscuit. Biscuits without wheat substitution had a resistant starch content of 17,8% with a glycemic index of 52,11. Biscuits with 20% wheat substitution have a resistant starch content of 21,23% with a glycemic index of 49,94 (Haryani et al., 2017).

It is known that the higher the level of resistant starch in a product, the lower the starch digestibility of the product, which can optimize the role of food as an alternative food for people with diabetes. A study conducted on 56 women with type 2 diabetes mellitus showed that the group that received a resistant starch intake of 10 g/day for eight weeks showed improvements in glycemic control. This is characterized by a decrease in glycosylated hemoglobin by 9,40%, insulin by 29,36%, and HOMA-IR by 32,85% (Karimi et al., 2016; Volpe, 2016). Another study also proved that administering 10 g of resistant starch a day can reduce fasting plasma glucose by 18,6 mg/dl and HbA1c by 0,2% (Gargari et al., 2015; Volpe, 2016).

The addition of glucomannan to growth cookies has been shown to increase the levels of resistant starch. These results show that glucomannan-modified Growol cookies have the potential to be developed as snacks for people with DM. However, this study has a weakness in that it did not study the types of resistant starch contained in Growol cookies, considering that there are five types of resistant starch: type 1, type 2, type 3, type 4, and type 5 resistant starch. Type 1 and type 2 resistant starches can influence glucose homeostasis through their mechanisms, and it is thought that there are differences in the mechanisms between resistant starch types 1 and 2. Type 1 and type 2 resistant starches can reduce postprandial blood glucose levels. Meanwhile, type 2 resistant starch can increase postprandial insulin response and improve fasting blood glucose levels. However, the role of type 3, type 4, and type 5 resistant starch has not been studied extensively (Pugh et al., 2023).

Furthermore, there are potential glucomannan-modified Growol cookies that need to be studied more deeply, especially regarding the effects of cookie consumption on changes in the metabolic profile in diabetes, such as changes in fasting blood glucose levels, postprandial blood glucose, HbA1c, insulin, and HOMA-IR.

Conclusion

The addition of glucomannan to Growol cookies can increase the levels of insoluble dietary fiber, water-soluble dietary fiber, total dietary fiber, and resistant starch compared to control cookies and Growol cookies with the addition of inulin. In addition, the addition of glucomannan can reduce the digestibility of starch in Growol cookies compared to that in control Growol cookies and Growol cookies with the addition of inulin. Growol cookies modified with glucomannan 7% (cooki*e*s E) are the best for diabetes sufferers in terms of levels of soluble dietary fiber, insoluble dietary fiber, total dietary fiber, resistant starch, and starch digestibility.

Glucomannan-modified Growol cookies have the potential to be used as a healthy snack for people with diabetes in terms of increasing levels of dietary fiber and resistant starch as well as decreasing starch digestibility in cookies. Further studies regarding the effectiveness of glucomannan-modified Growol cookies on changes in the metabolic profile of diabetes mellitus indicators, such as changes in blood glucose levels (temporary, fasting, and 2 h postprandial), changes in lipid profiles (triglycerides, HDL cholesterol, LDL cholesterol, and total cholesterol), and changes in HbA1c levels and insulin are needed. In addition, collaboration with the business industry is needed to commercialize and introduce cookies to the general public.

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