Resistant Starch, Amylose, and Amylopectin, Content in Breadfruit Cookies as an Alternative Snack for Individuals with Diabetes Mellitus

by Ani Margawati

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FULL PAPER

Resistant starch, amylose, and amylopectin content in breadfruit cookies as an alternative snack for individuals with diabetes mellitus

Fitriani, Z.A., *Dieny, F.F., Margawati, A. and Jauharany, F.F.

Department of Nutrition Science, Faculty of Medicine, Universitas Diponegoro, Indonesia

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Abstract

Uncontrolled hyperglycaemia in individuals with diabetes mellitus can increase the risk factors for disease complications. Therefore, lifestyle management becomes a vital measure for those individuals, especially in diet management, to control their blood sugar level. Breadfruit starch-based cookies contain resistant starch, amylose, and amylopectin that can inhibit the increment of blood sugar levels. Hence, these cookies can be used as an alternative snack for those individuals. This study was aimed to analyse the content of resistant starch, amylose, and amylopectin, as well as the acceptability level of breadfruit starch-based cookies. We used a completely randomised experiment using four formulations with various breadfruit flour content: 25%, 50%, 75% and 100%. The breadfruit formulation containing breadfruit flour (BF) and wheat flour (WF). Formula 25% (25% BF 75% WF, 50% (50% BF and WF), 75% (75% BF 25% WF), and 100% BF. The one-way ANOVA was used to compare the content of resistant starch, amylose, and amylopectin among the cookies. Furthermore, the Friedman test was used to analyse the acceptance level of the cookies, which includes colour, odour, texture, and flavour. The cookies contain 19.38-20.51% of resistant starch, 13.55-16.60% of amylose, and 83.39-86.44% of amylopectin. The highest resistant starch and amylose contents were found in cookies with 100% breadfruit flour content, while the highest amylopectin content was found in the 25% formulation. The acceptability level of the cookies included colour, odour, texture, and flavour. Cookies made with 100% breadfruit flour contained the highest resistant starch and amylose, but the lowest amylopectin. It also received the highest acceptability among the panellists.

1. Introduction

Diabetes mellitus (DM) is a metabolic disease indicated by high blood sugar level due to impaired insulin secretion, the disruption of insulin action, or both. DM is closely related to tissue impairments such as impairments in kidneys, eyes, neural system, heart, and blood vessels if the disease remains untreated for a long time (American Diabetes Association, 2011). Nowadays, the prevalence of DM is relatively increasing. Based on Data Riset Kesehatan Dasar (Riskesdas) Indonesia 2018, The national prevalence of DM cases as specified by the symptoms and diagnoses in the population of age ≥15 years old, increased from 6.9% in 2013 to 8.5% in 2018 (Kementerian Kesehatan RI, 2013; Kementerian Kesehatan RI, 2018). The World Health Organization (WHO) even predicts that diabetes mellitus will afflict more than 21 million Indonesians in 2030 (World Health Organization, 2016).

According to the International Diabetes Federation, 382 million of adults around the world (8.3%) had diabetes and 80% of them residing in low and middle-income countries. If the trend continues, 592 million or a tenth of the adult population will suffer from DM (International Diabetes Federation, 2012). Indonesia is ranked one of the top ten countries with DM worldwide, after the European countries, the United States, and China. Individuals with DM in Indonesia are increasing; 90-95% of them is type 2 DM. The World Health Organization has predicted that the number of diabetics in Indonesia will continue to grow and reach about 21.3 million in 2030 (Wild *et al*., 2004).

Lifestyle modifications take a crucial part for diabetics, especially to help them control their blood sugar level and to lower the risk of further complications. Dietary management is one of the modifications that can affect the blood sugar level, which can be achieved by

*Corresponding author.
Email: *fillahdieny@gmail.com*

choosing the correct amount and type of carbohydrates consumed. Selecting the right food ingredients has become the scientific basis for determining the glycaemic response in a person. Carbohydrates that are recommended for individuals with DM are complex carbohydrates or polysaccharides, especially resistant starch.

Resistant starch is a form of starch that resists digestion due to its compact molecules preventing its breakdown by the digestive enzymes, thus avoiding blood sugar spikes (Fuentes-Zaragoza *et al*., 2010; Herawati, 2011). One food ingredient that contains high resistant starch, amylose, and amylopectin is breadfruit. It is widely available in Indonesia and has a unique taste. Per 100 g of breadfruit contains 100 kcal of energy, 1.3 g of protein, 0.3 g of fat, and 2.2 g of fibres (Adinugraha and Kartikawati, 2012). Moreover, breadfruit contains low-digestible starch compared to the starch in rice, corns, and other tubers which is advantageous to lower blood sugar and blood insulin level (Landon *et al*., 2012).

Breadfruit is one of the local staple foods that contains lower calories compared to rice, potatoes, and sweet potatoes. It has approximately 3.25% higher of resistant starch content compared to sweet potatoes, potatoes, and wheat (Rosida and Yulistyani, 2013). In flour form, the resistant starch in breadfruit is 23.6% more than rice, 24.2% more than corn, 20.6% more than cassava, 31.5% more than potatoes, and 26.5% more than wheat (Septianingrum *et al*., 2016).

However, despite the benefits it offers, the fruit has not been put to good use due to its poor shelf life. Therefore, to manage this problem, the fruit is often converted into flour. This flour form is expected to have a longer shelf life as well as to increase its possibility to be processed into other foods. Breadfruit flour has a low glycaemic index (GI) which is favourable to be an alternative food source for diabetics.

There is a growing interest in the utilisation of breadfruit in a wide range of products since breadfruit contains an appreciable amount of resistant starch that could lower the glycaemic and insulin responses. A study by Noor et al. showed that breadfruit flour had higher crude fibre of 4.85% than commercial wheat flour, which contained 0.23% crude fibre (Siti Nuriah *et al*., 2018). Another study by Zakaria found that the 5% substitution of breadfruit resistant starch in bread formulation gave a lower GI value of 76 than GI value of 97 showed by control bread (Zarinah *et al*., 2018). Turi *et al*. (2015) conducted a study to review the nutritional profile of breadfruit and found that cooked breadfruit has low to moderate GI which is a potential to be used in controlling diabetes.

As breadfruit flour is easier to process, a variety of foods has been produced. One of them is breadfruit cookies. The cookies are expected to have a longer shelf life due to its low water content (4%) compared to other processed foods such as brownies, cakes, sponge cakes, or compared to deep-fried and steamed breadfruit. Other than that, the cookies are easier to make and to carry around (Dewi *et al*., 2010). The breadfruit cookies are also expected to have high public acceptability, hopefully among individuals with DM, thus increasing its economic value.

According to the abovementioned background, this study aims to investigate the content of resistant starch, amylose, and amylopectin in breadfruit cookies as an alternative snack for individuals with DM.

2. Materials and methods

2.1 Study design, location, and time

This research falls into food production category. It was conducted from August to September 2017. The analyses of resistant starch, amylose, and amylopectin were performed in the Centre for Food and Nutrition Studies, Universitas Gadjah Mada, Yogyakarta. Furthermore, the acceptability test of the cookies was carried out in the Department of Nutrition Science office, Universitas Diponegoro, Semarang.

2.2. Materials

The breadfruit flour used in the recipe is made of the white breadfruit type that is widely available in the market. The white breadfruit was selected because it produced flour with the same colour as wheat flour. We obtained the other ingredients such as eggs, vanilla, salt, baking powder, margarine, and stevia at Toko Semarang. The utensils used were a mixer, a blender, a sieve, spatulas, bowls, a scale, knives, an oven, and spoons. The process includes breadfruit flour production, ingredient mixing, and dough cutting.

2.3. Methods

This research is a completely randomized experiment using four formulations with various breadfruit content: 25%, 50%, 75%, and 100%. The percentage of formulation of breadfruit flour and wheat flour is determined based on optimization of nutritional content of breadfruit flour cookies that are eligible for biscuits according to SNI (Standard Nasional Indonesia). F100 is a formulation of breadfruit flour 100% (100 g), F75 consists of breadfruit flour 75% (75 g) and wheat

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flour 25% (25 g), F50 is a formulation breadfruit flour and wheat flour, each equal to 50% (50 g) and F25 consist of 25% (25 g) breadfruit flour and 75% (75 g) wheat flour. A preliminary experiment was carried out to produce the four variants of the cookies. To make the cookies, eggs and margarine were mixed followed by vanilla, salt, baking powder, sugar and the breadfruit formulation containing breadfruit flour and wheat flour. All the ingredients were blended and homogenized using a mixer for about 5-10 mins. After a homogenous dough had formed, the dough was shaped by a cookie-cutter. The last step was baking the cookies in an oven at approximately 150°C for 25-30 mins. The sugar type used in the cookies was stevia, a special type of sugar for people with DM. The nutrient content of snacks per portion usually covers 10% of the daily energy requirement. Snacks are usually consumed 2-3 times per day, and therefore provide 200 kcal of energy, 25 g of carbohydrate, 6.7 g of fat, and 10 g of protein.

The method used for the determination of resistant starch was done using the method proposed by Goñi *et al.* (1992). The amylose content was determined using the colorimetric iodine method, while the amylopectin content was estimated by different calculation 14. All the content analyses were run three times.

2.4. Organoleptic testing

The acceptability of the breadfruit cookies was examined by the hedonic test using four rating scales: 1 = Dislike a lot, 2 = Dislike a little, 3 = Like a little, and 4 = Like a lot. We selected twenty-five slightly trained panellists from the Department of Nutrition Science Universitas Diponegoro. These panellists were students who were in their 5th or 7th semester and had completed their course on food acceptability. We chose slightly trained panellists because they were more approachable and more efficient in terms of cost and time compared to trained panellists. The trained panellists have to complete a series of training and pass the examination, which may require more time and cost allocation.

The selection of panellists was started with an interview. The interview aimed to identify candidates' background, health status, and their willingness to participate as a panellist. We then performed a screening test to examine their commitment, openness, honesty, and general knowledge on the sensory panellists. The organoleptic analysis was carried out in Room 304, located on the third floor of the Department of Nutrition Science, Universitas Diponegoro, Semarang. The organoleptic test was carried out in a room far from the food storage area, in order not to disturb the panelists' sensory. Every panellist received 5 g of cookies from each formulation: F25, F75, F50 and F100. All cookies given had the same size. Moreover, the ID assigned to each cookie had been made unique to prevent the panellists from guessing the cookie's contents. We avoided using a subsequent coding method such as A, B, C or 1, 2, 3 that might lead the panellist to give a high rating based on the code order15. In this research, we used three digits random codes: 283, 125, 608, and 479.

3. Results and discussion

The breadfruit cookies contained 19.38-20.51% of resistant starch, 13.55-16.60% of amylose, and 83.39-86.44% of amylopectin. The analysis results show that there are significant differences in the contents of resistant starch, amylose, and amylopectin among the four cookie formulations.

Table 1 shows the significant differences of resistant starch, amylose and amylopectin contents among the formulations. The resistant starch was found the highest in the 100% formulation, while the lowest in the 25%. Similar results were also observed in the amylose contents. However, the amylopectin content was quite the opposite. The 25% formulation contained the highest amylopectin, while 100% contained the least.

Table 1. The contents of resistant starch, amylose, and amylopectin per 100 g of breadfruit cookies

Formulation	Resistant starch (%)	Amylose (%)	Amylopectin (%)
F25	19.38±0.15	13.55±0.03	86.44±0.03
F50	19.57±0.17	14.26±0.01	85.73±0.01
F75	20.03±0.03	15.88±0.02	84.11±0.02
F100	20.51±0.09	16.60±0.04	83.39±0.04
	p = 0.001	p = 0.000	p = 0.000

The acceptability of the breadfruit cookies was examined by the hedonic test or the preference test with panellists. The test results are shown in Table 2 and Figure 1.

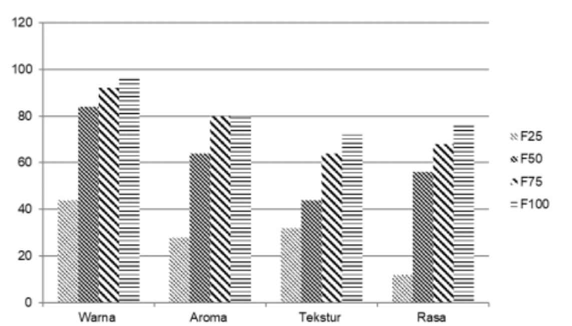

Figure 1. The illustration of percentage of panellists that gives the acceptance rate of breadfruit cookies based on colour, odour, texture, and flavour with likes category

Table 2 describes the average rating of the cookie

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acceptability among the panellists. The 100% formulation received the highest rating of all. We found that the rating was directly proportional to the breadfruit content. The Friedman test analysed preference categories: Extremely dislike, dislike, like, and extremely like. The panellists had also put the 100% formulation into the extremely like category.

Table 2. The average rating of the breadfruit cookies acceptability

Cookies	F25	F50	F75	F100
Colour	2.56±0.14	3.20±0.15	3.36±0.16	3.36±0.16
Odour	2.20±0.18	2.96±0.16	3.36±0.16	3.36±0.16
Texture	2.08±0.16	3.36±0.16	2.52±0.17	2.08±0.15
Flavour	1.76±0.15	2.56±0.16	2.96±0.19	3.20±0.18

Figure 1 illustrates the acceptability of the breadfruit cookies according to the panellists. The number of panelists who like the taste, color, aroma and texture of cookies with 100% formula is more than other formulas.

Breadfruit cookies contained of 19.38-20.51% resistant starch, 13.55-16.60% amylose, an 83.39-86.44% amylopectin. The analyses in this study showed significant differences between resistant starch, amylose, and amylopectin content on the four breadfruit cookies formulations. The highest resistant starch content was found in the 100% breadfruit flour, while the lowest one was in the 25% breadfruit flour. The low content of amylose in the cookies can influence the low content of resistant starch in breadfruit. Amylose content which is relatively low in the cookies with 25% of breadfruit flour caused no increase in resistant starch in cookies.

The production of resistant starch through retrogradation is more natural to occur in foods containing high amylose (Herawati, 2011). It is because amylose has a straight-chain structure, quickly graded, and when amylose chain rejoin to form a polymer compact and difficult to be hydrolysed by the digestive enzymes (Dewi and Isnawati, 2013). The retrogradation of amylose produces type 3 resistant starch (Fuentes-Zaragoza *et al*., 2010). It is one of resistant starch formed from starch retrogradation, for example, due to processing and cooling (Herawati, 2011). The retrogradation is also desirable in terms of nutritional significance, due to the slower enzymatic digestion of retrograded starch and moderated release of glucose into the bloodstream (Wang and Copeland, 2013).

Amylose content on the cookies with 25% breadfruit flour was in a low category, according to amylose classification in which 10-15% is low, >15% is moderate, and >20% is high (Indrasari *et al*., 2008). According to the result from the by-difference calculation, the amylopectin content in the cookies varied, ranging from 83.39 to 86.44%.

Factors that affect resistant starch content in the breadfruit cookies are the ratio of amylose and amylopectin content and the cookie preparation process. In general, cookies will go through a heating (roasting) process before consumption. The heating process can cause the starch to gelatinise, and if it continues throughout the cooling process, it will cause retrogradation. Retrogradation is a change in gelatinised starch during the cooling process. Gelatinisation and retrogradation will affect the digestibility of the starch in the intestine. The affected starch cannot be digested completely in the human intestine, causing the formation of digestive-resistant starch or resistant starch (Septianingrum *et al*., 2016).

Resistant starch is a form of starch that is unable to be digested by the digestive enzymes and resistant to gastric acid, and therefore it can reach colon to be fermented by probiotics. Resistant starch may also act as prebiotics in comparison to FOS and inulin. It has the ability to bind and maintain the water level in faeces, so it can prevent constipation when consumed in a large amount (Septianingrum et al., 2016). Furthermore, it also has other psychological effects such as maintaining intestinal and colon health, controlling GI in the blood and insulin response, providing satiety and decreasing energy intake, and improve lipid profiles in the blood (Lapu and Telussa, 2013). The process of resistant starch metabolism occurs within 5-7 hours after consumption; thus, it can lower postprandial blood sugar and insulinaemia (Ajani *et al*., 2012).

Retrogradation process of amylose can increase the content of resistant starch in food. Other than that, amylose is also beneficial for individuals with DM. Studies show that high amylose diet can reduce blood sugar level and insulin response curve due to its unbranched and compact structure compared to amylopectin (Behall and Howe, 1995). Therefore, it needs a longer time to digest, resulting in a lower blood sugar level compared to consuming food with high amylopectin content (Siagian, 2004; Gropper *et al*., 2009).

A previous study showed that breadfruit flour has a GI of 59, which is lower than the GI of rice (Fkr *et al*., 2011). This is beneficial to control blood sugar level as GI is a food indicator based on its effect on blood sugar level. The GI refers to a term that describes how fast the food affects blood sugar level after consumption. This study reveals that the cookies made from breadfruit flour had high resistant starch content that is resistant to hydrolysis of digestive enzymes due to its structure and granules. Increasing blood glucose level can interfere accordingly. Therefore, the higher resistant starch the food contains the lower its GI.

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Consuming 20 g of resistant starch per day can improve insulin sensitivity in male diabetics (S Landon *et al*., 2012). Food Agriculture Organization (FAO) recommends the consumption of 15-20 g of resistant starch per day to feel the benefits. This study shows that 100 g cookies with 100% breadfruit flour contain 20.51 g of resistant starch. Therefore, consuming 100 g of the cookies can be recommended to individuals with DM. However, this is not the upper limit of consumption. The consumption limit of resistant starch for them is not yet found. A study shows that higher consumption of resistant starch leads to a better improvement of insulin sensitivity in diabetics (Rosida and Yulistyani, 2013). Thus, breadfruit cookies consumption can be increased. However, we should also take the amount of staple food consumed into account. Another research analysing resistant starch in snack bars from various sorghum showed that it only contained 7.88-8.44% of resistant starch (Fathurrizqiah and Panunggal, 2015). The breadfruit cookies in this study had higher resistant starch content (19.38-20.51%) compared to the sorghum snack bar.

Based on the odour, cookies with 100% breadfruit flour content are more preferred than other cookies. This could be due to its high amylose content compared to the other cookies. Amylose has high water absorption. As a result, the higher its ability to absorb water, the ability of flour to absorb fat will be lower. If less fat absorbed, the peroxide formation during roasting at high temperatures will be prevented, thus reducing rancidity (Simamora *et al.,* 2014). Similarly, 100% breadfruit flour cookies received the highest rating on the texture acceptability level. The density of breadfruit flour cookies is believed to play a part to make the cookies crunchier.

In terms of taste acceptability, the 100% formulation received the highest rating compared to the others. Breadfruit flour has a typical flavour compared to other flour commonly used in cookies making. Tastes perceived by the gustatory system are divided into four categories: salty, sweet, bitter and sour. The substances in food dissolved and captured by the taste buds before sending a signal to the brain to recognise each taste. Although the cookies with 100% breadfruit flour got the highest rating among the other cookies, many panellists commented that the cookies were not sweet enough, this is due to the small amount of sweetener added to the cookies.

This study shows that cookies with 100% breadfruit flour content are the best one. Based on the data analysis from the colour acceptability test, the cookies with 75% and 100% breadfruit flour are more attractive and less pale compared to the others. The cookies with 75% breadfruit flour had a similar colour with the 100% ones. Breadfruit flour cannot precisely resemble wheat flour in terms of the final product colour. However, since the breadfruit flour has a slightly brown colour, it makes the colour of the cookies more attractive and less pale.

Breadfruit flour can be processed into a variety of products, including cakes, cookies, tart, bread and other products. Breadfruit flour can also replace wheat flour up to 100% (Fkr *et al*., 2011). Chiffon cake made from 100% breadfruit flour has excellent acceptability in terms of texture, aroma and taste because the breadfruit has a unique taste and aroma compared to wheat flour (Sari *et al*., 2015). This study also confirms this finding, showing that the acceptability of the cookies with 100% breadfruit flour content got the highest rating and preferred by panellists in terms of odour, taste, texture and colour. The cookies made from the breadfruit flour has indeed a slightly more brownish colour compared to cookies made with wheat flour. However, this actually what makes the cookies distinctive and more attractive for the consumers to try.

4. Conclusion

Breadfruit cookies made from 100% breadfruit flour can be an alternative snack for individuals with DM. Based on our experiments, the four breadfruit cookie formulations have different resistant starch, amylose and amylopectin contents. The highest content of resistant starch and amylose was found in cookies with 100% breadfruit flour, while the lowest is in the 25% composition. The highest amylopectin content was found in the 25% formulation, and the lowest was in the 100% formulation. In contrast, the results of the hedonic test indicated that the cookies made from 100% breadfruit flour were the most accepted cookies by panellists in terms of odour, colour, texture and taste.

Conflict of interest

The authors declare no conflict of interest.

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