



Literature Review: Factors Affecting White Rice Glucose Levels

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Abstract

The high level of rice consumption in Indonesia is due to the belief that people have not eaten if they have not consumed white rice. Based on data from the BPS (2023), Indonesian people's rice consumption reached 31.54 million tons. The biggest content of white rice is carbohydrate content. Carbohydrates are broken down into glucose when they enter the body. White rice has higher glucose levels than brown rice, namely 25.40 per 100 grams (Diyah et al., 2018). According to Susanti & Bistara (2018), most diabetes mellitus sufferers experience hyperglycemia because they tend to consume foods with high glucose. Factors that influence white rice glucose levels are storage temperature, storage time, rice variety and cooking method. The aim of this research is to examine articles regarding factors that influence white rice glucose levels. The research method used is a literature review which examines articles from 2013-2023 of Google Scholar, Garuda, PubMed, Science Direct and Semantic Scholar with indexes Sinta 1-5 or Scopus Q1-Q4. Key words used are kadar glukosa, suhu penyimpanan, waktu penyimpanan, metode pemasakan, rice cooker, magicom, kukus, panggang, bakar, varietas beras putih, nasi putih, storage temperature, storage time, cooking method, steamed roasted, roasted grilled, white rice varieties, glucose content and white rice. Articles were selected using the PRISMA method. From the results of the literature review, it shows there is an influence of storage temperature (50%), storage time (25%), rice variety (50%) and cooking method (67%) on white rice glucose levels.

Introduction

Diabetes mellitus sufferers in Indonesia increased by 1.6% in 2018 from 6.9% to 8.5% or approximately 20.4 million people suffering from diabetes mellitus. In research conducted by International Diabetes Federation (2021), Indonesia ranks fifth among countries with the highest number of diabetes mellitus cases in the world. China holds the first position, followed by India, Pakistan, and the United States. The data shows that the prevalence of diabetes mellitus sufferers in Indonesia aged 20-79 years is 10.6%. Diabetes mellitus sufferers need to understand the factors that can affect blood glucose levels in the body (Mayawati & Isnaeni, 2017; Nababan et al., 2018; Kurniati & Abidin, 2023).

According to Perdana (2012) there is a relationship between the level of knowledge of diabetes mellitus patients and the control of blood glucose levels. A person can develop type 2 diabetes mellitus due to modifiable or non-modifiable factors (Govindarajan et al., 2017; Soviana & Maenasari, 2019). One of the modifiable factors is an unhealthy and unbalanced diet (Kemenkes, 2020). An unhealthy and unbalanced diet, such as consuming foods that contain high calories and glucose levels, can lead to hyperglycemia. This is proven by research by Susanti & Bistara (2018) which obtained results that the majority of diabetes mellitus sufferers experience hyperglycemia because they tend to consume foods with high glucose, which can cause diabetes and trigger insulin resistance.

According to Dwipajati & Hapsari (2024) type 2 diabetes mellitus sufferers are advised to consume carbohydrates amounting to 45-65% of total energy intake, preferably complex carbohydrates and those with low glucose levels such as brown rice. Brown rice has glucose levels of 23.03 per 100 grams, while white rice has a higher glucose level of 25.40 per 100 grams (Diyah et al., 2018; Prasetyaningsih et al., 2020; Hernawan & Meylani, 2016). In fact, almost all people in Indonesia like to eat white rice as their main meal (Kristianti et al., 2009; Pranata et al., 2022). According to data from Badan Pusat Statistika (2023), Indonesian people consume 31.54 million tons of rice. The largest component of white rice is carbohydrates.

Carbohydrates are broken down into glucose in the body. Thus, causing glucose levels in the body to increase. Many factors influence the glucose levels in white rice. These factors include storage temperature (Ishmah et al., 2019; Purbowati & Anugrah, 2020), storage time (Ishmah et al., 2019; Islamiyah et al., 2013; Juwita, 2020; Mukti et al., 2018; Novianti et al., 2017; Purbowati & Anugrah, 2020), white rice variety (Ishmah et al., 2019; Islamiyah et al., 2013; Juwita, 2020; Mukti et al., 2018; Novianti et al., 2017; Purbowati & Anugrah, 2020) and cooking methods (Juwita, 2019, 2020; Mukti et al., 2018).

Based on research conducted by Ishmah, et al (2019) regarding the difference in glucose content of white rice of the IR 64 variety at magicom and room temperature, the results showed that there was no difference in glucose content in rice stored at magicom and room temperature. On the other hand, research conducted by Purbowati & Anugrah (2020) shows that IR 64 variety rice in a rice cooker and stored at room temperature for 6 hours has an influence on the glucose levels of white rice. However, when stored for 12 hours, it does not affect the glucose levels in white rice (Mohan et al., 2014).

Research by Mukti, et al. (2018) regarding the analysis of the glucose content of rice for different cooking treatments such as cooking in a rice cooker, grilling, and roasting, found significant differences between these treatments on the glucose content of white rice. Juwita (2019) also conducted research on one of the ingredients in rice, namely the glucose content of rice stored in a rice cooker at 30oC and steamed at 30oC, finding no difference in glucose content between rice stored in a rice cooker and rice steamed. Based on this background, it is necessary to study the factors that influence the glucose levels of white rice, such as storage temperature, storage time, cooking methods and rice varieties in previous studies.

Methods

This research uses a literature review method, namely reviewing articles from 2013-2023 obtained from 5 databases, namely Google Scholar, Garuda, PubMed, Science Direct and Semantic Scholar with Sinta (S1-S5) or Scopus (Q1-Q4) indexes. The keywords for this research are kadar glukosa, suhu penyimpanan, waktu penyimpanan, metode pemasakan, rice cooker, magicom, kukus, panggang, bakar, varietas beras putih, nasi putih, storage temperature, storage time, cooking method, rice cooker, magicom steamed, roasted, grilled, white rice varieties, glucose levels, white rice. The article selection process flowchart uses the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) method, as shown in figure 1.

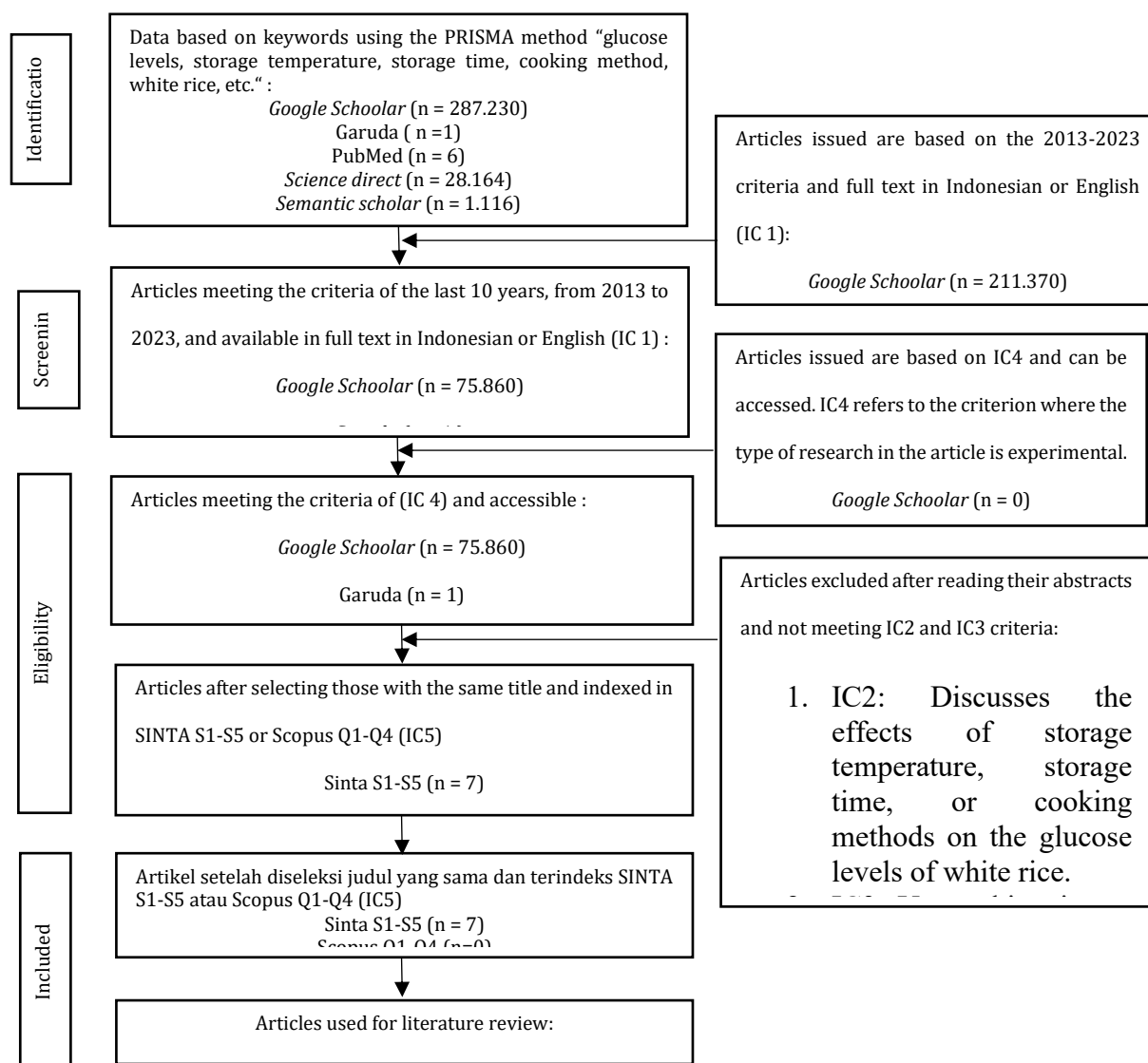


Figure 1. Flowchart of Research Article Selection Process using PRISMA Method

Article analysis using the descriptive analysis method involves describing the data from selected research articles, critiquing them carefully and thoroughly. Thus, summarizing the similarities, differences, strengths, or weaknesses of the selected articles. The selected articles that have been analyzed are presented in the form of a narrative description, by reviewing types of research, research methods, research samples and sampling techniques to be discussed in a general overview. The data is presented in tabular form regarding the effect of storage temperature, storage time, white rice varieties and cooking methods on white rice glucose levels. Then, the discussion is linked to several theories.

The systematic review used PRISMA approach to decide seven articles that met the prescribed inclusion and exclusion criteria: (1) indexed in SINTA 1-5, (2) related to the glucose concentration of white rice at the levels of storage temperature, storage time, cooking procedure, and rice species. After the texts were reviewed, a further review, using descriptive measures was made regarding the type of research, the nature of participants, the design of the study, and the measurement designs of the articles. The obtained results were narratively synthesised data in order to identify patterned or divergent effect on glucose level and hence

gain a coherent comparison of the findings across the studies and explain how each variable affects the glucose content of white rice.

Results and Discussion

Results of Research Article Extraction

The literature search used the Preferred Reporting Items for Systematic Reviews and Meta-analyses method (PRISMA) by entering keywords in Google Scholar to get 7 articles. Garuda 1 article, Semantic Scholar 1 article, PubMed and Science Direct no articles found. The obtained articles were sorted based on title, researcher names, and year of publication to observe similarities among them. Subsequently, 7 articles were identified that met the inclusion and exclusion criteria after sorting, as shown in Table 1.

Table 1. Research Article Data Extraction

Author, Title, Synta Index	Research Objects and Treatment	Research Method	Research Result
Purbowati & Anugrah (2020) The Effect of Temperature and Storage Time on Glucose Levels in White Rice Sinta 3 https://journal.walisongo.ac.id/index.php/Nutri-Sains/article/view/4565/pdf	1. Storage time: 0 hours, 6 hours and 12 hours 2. Storage temperature: Magicom (95,6°C, 81,3°C, 75,1°C) and room temperature (95,6°C; 25,0°C; 20,8o°C) 3. White rice variety: IR 64 4. Storage methods: Magicom and room temperature	1. Experimental research design using a Completely Randomized Design approach (RAL) 2. Data analysis: Kruskal-Wallis test. 3. Glucose level measurement: Spectrophotometry.	There was an effect of temperature and storage time of 6 hours on glucose levels in rice stored in magicom and at room temperature (p=0,046), but at temperature and storage time of 12 hours there was no effect of temperature and storage time on glucose levels (p=1,000).
Ishmah, et al (2019) Differences in Glucose Levels in Rice Stored at Magicom and at Room Temperature Sinta 5 https://jurnalgizi.unw.ac.id/index.php/JGK/article/view/62	1. Storage time: 0 hours, 2 hours, 4 hours, 6 hours, 8 hours 2. Storage temperature: <i>magicom</i> (95,6°C; 88,4°C; 85,8°C; 81,3°C; 77,1°C) and room temperature (95,6° C; 38°C;	1. Pre-experimental Posttest Only Design research design. 2. Data analysis: Kruskal-Wallis test. 3. Glucose level measurement: Luff Schoorl method.	There is no difference in glucose levels in rice stored in the Magicom and at room temperature (p=0,310)

	27,6°C; 25°C; 22,8°C) 3. White rice variety: IR 64 4. Storage method: magicom and room temperature		
Juwita (2020) Comparative Study of Glucose Levels in Rice Cooked Using the Rice Cooker Method and Traditional Methods at Various Temperatures Sinta 4 https://jnc.stikesmaharani.ac.id/index.php/JNC/article/view/159/163	1. Cooking temperature: 70°C; 42°C; 30°C 2. Storage time: - 3. White rice variety: C4 4. Cooking method: Teflon rice cooker, stainless steel rice cooker and traditional/steam er	1. Quantitative research methods and experimental research design with a randomized block design approach. 2. Data analysis: Tukey HSD test 3. Measurement of glucose levels: Dinitrosalicylic acid, Spectrophotometry- Colorimeter	The One-Way Anova test showed that there were real differences in the results, then a post hoc test was carried out with Tukey HSD, it was concluded that the glucose levels with each cooking method were the same and the difference in average glucose levels was descriptively not significant.
Juwita (2019) Differences in Glucose Levels of Rice Cooked in a Rice Cooker and Steamed Sinta 4 https://jurnal.poltekeshkupang.ac.id/index.php/jkp/article/view/348/223	1. Storage temperature: 30°C 2. Storage time: - 3. White rice varieties: - Cooking method: rice cooker and steamed	1. Quantitative research methods and experimental research design 2. Data analysis: Mann Whitney test 3. Measurement of glucose levels: Dinitrosalicylic Acid Method, Spectrophotometry- Colorimetry	There was no difference in rice glucose levels between rice cooked in a rice cooker and steamed ($p>0,05$).

Author, Title, Synta Index	Research Objects and Treatment	Research Method	Research Result
Mukti, et al. (2018) Analysis of Carbohydrate Content, Glucose, and Acceptance Test in Grilled Rice, Baked Rice, and Plain Rice Sinta 3 https://jurnal.unej.ac.id/index.php/JAGT/article/view/8333/5765	1. Cooking temperature: grilled and baked rice = 180°C, plain rice = - 2. Storage time: grilled rice = ± 10 minutes, baked rice = ± 25 minutes, plain rice = - 3. White rice variety: Du'Anak brand (CV. Dua Putra, Kalisat, Jember) Cooking methods: grilled, baked (oven), plain rice (rice cooker)	1. Type of study: Pre-experimental using One Group Pretest-Posttest design. 2. Data analysis: One-Way ANOVA and Post Hoc Tests (Tukey HSD) with a confidence level of 5%. Glucose level measurement: Direct Acid Hydrolysis Method: AOAC	The One-Way Anova test with a significance level (α) of 0.05 and obtained a p-value of 0.000 shows that there is a significant difference between the treatments in the form of burning and roasting on rice glucose levels. Subsequently, Post Hoc Tests (Tukey HSD) revealed significant differences with a p-value ≤ 0.05.
Novianti, et al. (2017) Analysis of Glucose Levels in White Rice and Corn Rice Using the Spectronic 20 Method Sinta 3 http://jurnal.untad.ac.id/jurnal/index.php/JAK/article/view/9241	1. Storage temperature: - 2. Storage time: 0 hours, 1 hour, 6 hours, 12 hours, 18 hours, 24 hours, 30 hours, and 36 hours 3. White rice variety: Santana 4. Cooking method: Rice cooker	1. Quantitative research method and experimental research design 2. Data analysis: - 3. Glucose level measurement: Spectrophotometry	The lowest glucose level in white rice at 0 hours is 10.761 ppm, and the highest glucose level at 18 hours is 56.488 ppm.
Islamiyah, et al. (2013) Kinetic Profile of Changes in Glucose Levels in Rice under Heating Sinta 3 http://jurnal.untad.ac.id/jurnal/index.php/JAK/article/view/9241	1. Storage temperature: - 2. Storage time: 0 hours, 4 hours, 8 hours, 12 hours, 16 hours, 20 hours, 24 hours, 28 hours, 32 hours, 36 hours and 40 hours	1. Quantitative research methods and 2. Experimental research design 3. Data Analysis: - 3. Measurement of glucose levels: Phenol	The decrease in white rice glucose levels from 0 hours to 40 hours is 32,265 ppm to 5,821 ppm.

	3. White rice variety: Mbramo 5. Cooking method: heating	Sulfuric Acid and method and UV-VIS Spectrophotometry	
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The selected research articles that used research objects such as white rice variety IR 64 were 2 articles (28,57%), 1 article about white rice variety C4 (14,28%), 1 article about Santana variety white rice (14,28%), 1 article about mbramo variety white rice (14,28%), 1 article about Du'Anak brand white rice (14,28%) and one of the other articles does not specify the variety of white rice used. The method for measuring glucose levels used by researchers includes 2 articles (28.57%) using Spectrophotometry, 1 article using Luff Schoorl (14.28%), 2 articles (28.57%) using Dinitrosalicylic Acid and Spectrophotometry, 1 article (14.28%) used Acid Hydrolysis Method: AOAC, and 1 article (14.28%) used Phenol Sulfuric Acid and UV-VIS Spectrophotometry. The selected articles discuss factors that influence white rice glucose levels such as storage temperature and time, white rice varieties and cooking methods. All selected articles used an experimental research design with data analysis using different methods.

Effect of Storage Temperature on White Rice Glucose Levels

Based on research results from 7 articles, there are 2 articles in Table 2 which examine the effect of storage temperature on white rice glucose levels. Purbowati & Anugrah (2020) explained that at a rice cooker storage temperature of 95,6oC – 81,3oC glucose levels decreased by 13,400 ppm, and from 81,3oC – 75,1oC they decreased by 11500 ppm. White rice stored at room temperature from 95,6oC – 25,0oC experienced a decrease in glucose levels by 20500 ppm, and at room temperature from 25,0oC – 20,8oC glucose levels decreased by 4400 ppm. In Table 2, the analysis from the research conducted by Purbowati & Anugrah (2020) indicates that storing white rice for 6 hours at 81,3oC in a rice cooker and at 25oC room temperature had a significant effect, with a p-value 0,046.

Table 2. Effect of Storage Temperature on White Rice Glucose Levels

No	Author	Variety of White Rice	Storage Temperature (°C)	Storage Time (Hours)	Glucose Levels (ppm)	p-value
1	Purbowati & Anugrah, et al. (2020)	Variety of IR 64	95.6 (Rice cooker)	0	46500	1.000
			95.6 (Room temperature)	0	46500	
			81.3 (Rice cooker)	6	33100	0.046a
			25.0 (Room temperature)	6	26000	
			75.1 (Rice cooker)	12	21600	1.000
			20.8 (Room temperature)	12	21600	
2	Ishmah, et al. (2019)	Variety of IR 64	95.6 (Magic com)	0	46500	0.310
			88.4 (Magic com)	2	43700	
			85.8 (Magic com)	4	23000	
			81.3 (Magic com)	6	33100	
			77.1 (Magic com)	8	17300	

			95.6 (Room temperature)	0	46500	
			38 (Room temperature)	2	29000	
			27.6 (Room temperature)	4	26000	
			25 (Room temperature)	6	21600	
			22.8 (Room temperature)	8	17300	

a) Kruskal-Wallis test significant ($p < 0,05$)

However, storing it for 12 hours at 75,1oC in a rice cooker and at 20,8oC room temperature showed no significant effect on glucose levels, with a p-value 1,000. According to Purbowati & Anugrah (2020) When stored for 6 hours at a storage temperature of 81,3oC in a rice cooker and at room temperature, there was a decrease in glucose levels in rice in both the rice cooker and room temperature. The rice is stored and heated in a heater, then taken out to check the glucose content. Where this check takes a long time for each repetition. Thus, the rice is exposed to room temperature which can cause the temperature and glucose levels in the rice to be unstable, namely a decrease and increase in glucose levels (Ishmah et al., 2019). This temperature difference produces different statistical test results.

According to Ishmah, et al (2019), at magicom storage temperatures of 95,6oC – 88,4oC the glucose levels of white rice decreased by 2800 ppm, at 88,4oC – 85,8oC decreased by 20700 ppm, at 85,8oC oC – 81,3oC white rice glucose levels increased by 10100 ppm, at 81,3oC – 77,1oC – 81,3oC white rice glucose levels decreased by 15800 ppm. At room temperature of 95,6oC – 38oC, there was a decrease in glucose levels of 17500 ppm. At room temperature of 38oC – 27,6oC, there was a further decrease of 3000 ppm in glucose levels. At 27,6oC – 25oC, there was a decrease in glucose levels of 4400 ppm. Therefore, at room temperature of 25oC – 22,8oC was a decrease in glucose levels of 4300 ppm.

These two studies prove that the decrease in temperature will be comparable to the decrease in glucose levels in white rice and the decrease in glucose levels at room temperature is faster than in heating. The decrease in glucose levels in rice in the rice cooker is in line with a previous study conducted by Islamiyah, et al (2013) which found that glucose levels in rice decreased with the length of time it was heated. Widhyasari (2017) also proves that the longer the cooking time in magicom, the carbohydrate content and water content of white rice can decrease. This causes the rice to have a dry and harder texture. Up to 12 hours the glucose content in room temperature rice also decreased.

According to Purbowati & Anugrah (2020), Changes in temperature affect the structure of starch in rice. Rice consists of long chains of glucose. In the process of cooking rice into rice, heating and cooling occur. When heated, starch granules gelatinize and lose their crystallinity. During cooling, the separated starch molecules form a gel and undergo gradual retrogradation. Thus, it becomes a semi-crystalline collection that is different from the original form of starch (Copeland et al., 2009). Haliza, et al. (2006) and Donmez et al. (2021), also explained that changes in structure and gelatinization were caused by heating starch with excessive water. Reheating and cooling starch that has undergone gelatinization also changes the starch structure. This leads to the formation of new insoluble crystals, in the form of retrograded starch. Retrograded starch is the most stable type of resistant starch and is difficult to digest because the straight chains of amylose are easily degraded, and when retrograded, they form a

compactpolymer that is difficult to hydrolyze by digestive enzymes (Hódsági, 2011). The structural change from starch to resistant starch causes a decrease in glucose levels.

Effect of Storage Time on White Rice Glucose Levels

Based on research results from 7 articles, there are 4 articles regarding the effect of storage time on white rice glucose levels in Table 3. In research by Ishmah, et al. (2019) at 0-2 hours of storage time in Magicom, white rice glucose levels decreased by 2800 ppm, 2-4 hours decreased by 20700 ppm, 4-6 hours increased by 10100 ppm, then at 6 storage times 6-8 hours, white rice glucose levels decreased by 15800 ppm. In room temperature storage with a storage time of 0-2 hours, glucose levels decreased by 17,500 ppm, 2-4 hours decreased by 3000 ppm, 4-6 hours decreased by 4400 ppm, then 6-8 hours decreased by 4300 ppm. The results obtained in research by Ishmah, et al. (2019) were that there was no difference in glucose levels in rice stored for 8 hours.

Research by shows that if the storage time in a rice cooker is 0-6 hours, white rice glucose levels will decrease by 13,400 ppm. Then, when the storage time for the rice cooker reaches 6-12 hours, it will also decrease by 11,500 ppm. The statistical analysis using the Kruskal-Wallis test in the study by Purbowati & Anugrah (2020) indicated a significant difference in glucose levels between Magic rice cooker treatment and room temperature after 6 hours. However, at 12 hours of treatment there was no difference. This is because there is repetition of treatment, causing glucose levels to decrease (Ishmah et al., 2019).

Table 3. Effect of Storage Time on White Rice Glucose Levels

No.	Author	Variety of White Rice	Storage	Storage Time (Hours)	Glucose Levels (ppm)	p-value
1.	Purbowati & Anugrah, et al. (2020)	Variety of IR 64	Rice cooker	0	46500	1,000
			Room temperature	0	46500	
			Rice cooker	6	33100	0,046 ^a
			Room temperature	6	26000	
			Rice cooker	12	21600	1,000
			Room temperature	12	21600	
2.	Ishmah, et al. (2019)	Variety of IR 64	Magic Com	0	46500	0,310
			Magic Com	2	43700	
			Magic Com	4	23000	
			Magic Com	6	33100	
			Magic Com	8	17300	
			Room temperature	0	46500	
			Room temperature	2	29000	
			Room temperature	4	26000	
			Room temperature	6	21600	
			Room temperature	8	17300	
3.		Variety of Santana	Heater	0	149535	-
			Heater	1	15055	

	Novianti, et al. (2017)		Heater	6	18651	
			Heater	12	40447	
			Heater	18	56488	
			Heater	24	36686	
			Heater	30	24045	
			Heater	36	22931	
4.	Islamiyah, et al. (2013)	Variety of Mbramo	Heater	0	32265	-
			Heater	4	28840	
			Heater	8	24831	
			Heater	12	20893	
			Heater	16	18967	
			Heater	20	14791	
			Heater	24	12023	
			Heater	28	10116	
			Heater	32	8414	
			Heater	36	6998	
			Heater	40	5821	

^{a)} Kruskal-Wallis Test Significant ($p < 0,05$)

In research by Islamiyah, et al. (2013), which examined the storage of white rice for 0-28 hours, it was found that the glucose levels in white rice had decreased, but at 32 hours it had increased and then decreased again at 36-40 hours. Likewise, in research by Novianti, et al. (2017), white rice glucose levels decreased for 1 hour, then increased at 6-18 hours and decreased at 24-36 hours. The increase in glucose levels occurs due to the process of breaking down starch into simple sugars, such as glucose, which occurs at high temperatures (Novianti et al., 2017; Purbowati & Anugrah, 2020).

Previous studies have shown that rice whose temperature decreases can experience retrogradation. Thus, it has higher starch resistance than parboiled rice. Resistant starch content in rice stored for 24 hours was $13,9 \pm 0,98$. Meanwhile, for freshly cooked rice is $9,1 \pm 1,02$ (Ha et al., 2012). Increasing the resistant starch content due to long-term storage can reduce the glucose content and digestibility of rice (Yu et al., 2017). Factors that influence glucose levels and digestibility of starch and rice include amylose content, amylopectin chain length, degree of amylose polymerization (DP) and amylopectin. The higher the amylose content, the easier it is for starch to experience retrogradation (Syahariza et al., 2013; Zhu et al., 2011). The amylose content has a significant effect on starch retrogradation. Rice with high amylose experiences rapid retrogradation. Meanwhile, low amylose experiences retrogradation slowly (Luna et al., 2015). Starch that easily becomes resistant starch causes glucose levels to decrease.

According to research, rice becomes soft and sticky if stored in magicom for too long. This is caused by continuous heating, where the energy released by the drying media becomes greater so that the water in the rice continues to evaporate. As a result, the white rice in magicom gets drier over time (Sutanto, 2015). Prolonged heating can affect the characteristics and nutritional content of white rice (Sutanto, 2015). Meanwhile, rice stored at room temperature will remain soft. However, over time the texture will become increasingly soft and watery. The longer rice is stored at room temperature, the greater the retrogradasi dengan mudah, sedangkan beras chance of bacteria developing, making the rice unsafe to consume. Research by Haryono (2011) shows that hot rice contains more glucose than cold rice, because the glycemic index of cold rice is lower than hot rice. As a result, cold rice does not quickly raise blood sugar levels. Mozaffarian (2016) emphasized that continuous high glucose consumption can be detrimental

to health, because excess glucose can increase the risk of obesity and is dangerous for diabetes sufferers. Reducing carbohydrate and glucose levels in food makes it safer to consume, especially for people with diabetes mellitus (Rafanani, 2013).

Effect of White Rice Varieties on White Rice Glucose Levels

Based on research results from 7 articles, there are 6 articles regarding the effect of white rice varieties on white rice glucose levels in Table 4. The study showed that rice varieties had a significant influence on the glucose levels of white rice. The IR 64 variety, studied by Purbowati & Anugrah, (2020) and Ishmah, et al (2019) showed a consistent reduction in glucose levels at various temperatures and storage methods. At an initial temperature of 95,6oC, the glucose level started at 46500 ppm. After 6 hours in a rice cooker at 81,3oC, the glucose level decreased to 33100 ppm. Meanwhile, at room temperature 25oC, it decreased to 26000 ppm. The same decrease was observed after 12 hours, with the glucose level reaching 21600 ppm at both temperatures. In contrast, the Santana variety, studied by Novianti, et al. (2017), showed a pattern of glucose levels increasing over 18 hours of storage before decreasing again. In this study, the initial glucose level measured quite low at 149535 ppm but gradually increased to peak at 56488 ppm after 18 hours of storage.

Table 4. Effect of White Rice Varieties on White Rice Glucose Levels

No	Author	Variety of White Rice	Storage Temperature (°C)	Storage Time (Hours)	Cooking Method	Glucose Levels (ppm)	p-value
1	Purbowati & Anugrah, et al. (2020)	Variety of IR 64	95.6	0	Rice cooker	46500	1.000a
			95.6	0	Room temperature	46500	
			81.3	6	Rice cooker	33100	0.046a*
			25.0	6	Room temperature	26000	
			75.1	12	Rice cooker	21600	1.000a
			20.8	12	Room temperature	21600	
2	Ishmah, et al. (2019)	Variety of IR 64	95.6	0	Magic Com	46500	0.310a
			88.4	2	Magic Com	43700	
			85.8	4	Magic Com	23000	
			81.3	6	Magic Com	33100	
			77.1	8	Magic Com	17300	
			95.6	0	Room temperature	46500	
			38	2	Room temperature	29000	
			27.6	4	Room temperature	26000	
			25	6	Room temperature	21600	
			22.8	8	Room temperature	17300	

3	Novianti, et al. (2017)	Variety of Santana	-	0	Heater	149535	-
			-	1	Heater	15055	
			-	6	Heater	18651	
			-	12	Heater	40447	
			-	18	Heater	56488	
			-	24	Heater	36686	
			-	30	Heater	24045	
			-	36	Heater	22931	
4	Islamiyah, dkk (2013)	Varietas Mbramo	-	0	Heater	32265	-
			-	4	Heater	28840	
			-	8	Heater	24831	
			-	12	Heater	20893	
			-	16	Heater	18967	
			-	20	Heater	14791	
			-	24	Heater	12023	
			-	28	Heater	10116	
			-	32	Heater	8414	
			-	36	Heater	6998	
			-	40	Heater	5821	
5	Juwita (2020)	Varietas C4	70	-	Stainless steel rice cooker	168339	0.000b*
			42	-	Stainless steel rice cooker	309842	
			30	-	Stainless steel rice cooker	333789	
			70	-	Rice cooker teflon	315421	
			42	-	Rice cooker teflon	229769	
			30	-	Rice cooker teflon	247253	
			70	-	Steam	321122	
			42	-	Steam	319935	
			30	-	Steam	194616	
6	Mukti, et al. (2018)	Variety of Du'Anakk brand (CV. Dua Putra, Kalisat, Jember)	±180	±10 menit	Roasted rice	28600	0.000c*
			±180	±25 menit	Baked rice	33800	
			-	-	Plain rice	20700	

Rice with high amylose content, such as IR 64, tends to retrograde faster. Where the straight amylose chains form bonds again after heating and produce a starch structure that is more

resistant to digestive enzymes. This retrogradation process reduces the availability of glucose. Therefore, the rice glucose levels decrease more quickly during storage (Darmawansyah, 2020; Setiawan, 2007). In contrast, the Santana variety may have a higher amylopectin content, which contributes to increased glucose levels during initial storage. Amylopectin has a more complex branched structure, which can result in slower starch breakdown and an increase in initial glucose levels before the degradation and retrogradation processes occur during longer storage times (Purbowati & Anugrah, 2020). Another factor that influences this difference is storage conditions, including temperature and humidity, which can speed up or slow down the starch degradation process. Storage at high temperatures in a rice cooker accelerates the retrogradation process, while storage at room temperature may slow it down, allowing for greater variations in glucose levels based on the type of starch in the rice (Habib & Aminudin, 2009).

The effect of Cooking Methods on Glucose Levels in White Rice

Based on the research findings from 7 articles, 3 articles specifically address the influence of storage time on the glucose levels of white rice, as shown in Table 5. In research conducted by different glucose levels were obtained from different cooking methods at different temperatures.

Tabel 5. Effect of Cooking Methods on Glucose Levels in White Rice

No.	Author	Variety of White Rice	Storage Temperature (°C)	Storage Time (Hours)	Cooking Method	Glucose Levels (ppm)	p-value
1	Juwita (2020)	Variety of C4	70	-	Stainless steel rice cooker	168339	0,000a*
			42	-	Stainless steel rice cooker	309842	
			30	-	Stainless steel rice cooker	333789	
			70	-	Teflon rice cooker	315421	
			42	-	Teflon rice cooker	229769	
			30	-	Teflon rice cooker	247253	
			70	-	Steam	321122	
			42	-	Steam	319935	
			30	-	Steam	194616	
2	Juwita (2019)	-	30	-	Teflon rice cooker	247253	0,127b
			30	-	Steam	194616	
3	Mukti, et al. (2018)	Variety of Du'Anakk brand (CV. Dua Putra, Kalisat, Jember)	±180	±10 minutes	Roasted rice	28600	0,000c*
			±180	±25 minutes	Baked rice	33800	
			-	-	Plain rice	20700	

a) Tukey HSD test; b) Mann Whitney test; c) Shapiro-Wilk test *influence

In the cooking method using a stainless-steel rice cooker at 70°C, the glucose level in white rice was 168339 ppm, at 42°C it was 309842 ppm, and at 70°C it was 333789 ppm. The results of the ANOVA statistical test were obtained in research conducted by Juwita (2020) with a p-value of 0.000, namely the effect of cooking methods on the glucose content of white rice, followed by Tukey's HSD test which resulted in non-significant findings. Mukti, et al. (2018) conducted a study on the effect of cooking methods on glucose levels in white rice using methods such as burning, baking, and using heaters (rice cooker or magicom). The One-Way ANOVA test resulted in a p-value of 0.000, indicating significant differences in treatments such as burning and baking on rice glucose levels.

On the other hand, in the study conducted by Juwita (2019) showed that the Man Whitney statistical test value with a p-value of 0.127, indicating no significant difference in glucose levels between rice cooked with a rice cooker and rice cooked by steaming at 30°C. According to Juwita (2019) this is due to the type of rice and the method of cooking the rice. Cooked rice samples were tested under the same temperature conditions, specifically at 30°C. Based on previous research, rice that has been kept in a rice cooker for a long time will have different glucose content compared to rice cooked traditionally or steamed and left unheated. The heating process during rice cooking reduces the glucose content in the rice. This process causes starch polymers to hydrolyze and break down, resulting in carbohydrate degradation. This degraded carbohydrate leads to a decrease in carbohydrate levels (Sutanto, 2015). Research by Mukti, et al. (2018) also indicates that heating rice reduces carbohydrate and glucose levels in rice.

Biochemical and Structural Mechanisms

The given literature review reveals retrogradation and starch modification as the major processes that lead to a resulting decrease in postprandial glucose levels in white rice samples, which underwent various temperature-related thermal exposure and maintained both after a certain length of time in storage. The section of results explains the temporal and quantitative changes in glucose levels according to the different experimental conditions, but what must here be pointed out, are those outlined in this discussion, which are outcomes of the molar adjustments of starch granules, specifically the amylose. On long-term storage, particularly at low temperature conditions (refrigerated or ambient), linear Amylose chains are then able to re-associate once more by dint of hydrogen bonding and, in the end, form semi-crystalline structures which are relatively resistant to the action of enzymes, i.e., a process known as type 3 resistant starch (RS3) and has been repeatedly linked to decreased digestibility and lower glucose levels released on exposure to enzyme activity (Zhang et al., 2006; Saj This must necessarily result in the finding of a decrease in circulatory glucose after extended storage at room temperature, or after cooking in rice cookers which are in fact the direct biochemical consequences of retrogradation processes.

The molecular structure of rice starch, the ratio of amylose to amylopectin and related chain flagitiousities, can also be regarded as a key factor which determines post-cooking glucose-dynamics in white rice. IR 64 and other cultivar types with high amylose are described by large amylose contents and linear, comparatively small-molecular chains of polysaccharides. These linear macromolecules readily aggregate into compact crystalline domains and therefore a faster rate of retrogradation in conditions of cooling or overlong storage (Wang et al., 2015). On the other hand, low-amylose type with high amylopectin content has much higher branched-chain densities which destabilize crystalline packing and slow down retrogradation (Tester et al., 2004; Syahariza et al., 2013). The following genetic-composition-based differences are the bases of expected changes in glucose release patterns among white rice genotypes, and over

storage. Complementary evidence suggests that, when given the right environment, very-long-chain amylopectin retrogrades, but at a significantly slower pace and degree as in the case with amylose, and this finding is confirmed by the disparate glucose behaviors recorded in the reviewed studies in the case of Santana and Mbramo (Zhu et al., 2011). The overall results highlight the subtle starch-based processes that underlie the post-cooking glucose kinetics variability of the various white rice cultivars and the importance of pre-storage, gastrointestinal model-based research.

Cooking alters the thermal setting of the starches-rich foods, hence changes digestibility and glucose release to be available as dietary material (Lehmann & Robin, 2007). Survey of the body of evidence shows that the first exposure to heat encourages starch gelatinization and increases short-term glucose potential, whereas extended heating beyond 612 hours (the usual period rice takes to cook) has the opposite side effect and reduces glucose content. The interaction of the temperature and time is due to retrogradation which occurs and promotes faster loss of water. When subjected to higher temperatures (being about 8095 C), the leaching of amylose raises the potential of extracting glucose, but exposure beyond water humidity the current absorption capacity can cause the replacement of bonds that were aqueous to bindings that are crystalline along with limiting the molecular mobility and promoting the recombining of amylose chains to crystalline formations (Hoover, 2010; Zhang et al., 2006). These conditions enable a post-gelatinization retrogradation to take place at a warm storage condition, which explains the non-linear tendencies noted in 6-hour and 12-hour storage periods.

There is an added layer of biochemical complexity of method-specific thermal regimens. Heat transfer methods vary in their principles of heat transfer, i.e. conduction, convection and moist heat, and have different impacts on the gelatinization of starch, leaching of amylose and accessibility of enzymes to food. Baking and roasting Dry-heat methods usually create solid textures and can form crusts on the surface that hinders the diffusion of the moisture, and also restricts starch expansion (Brouns et al., 2005; Jaisut et al., 2009). These physical obstacles limit the availability of glucose as it comes through with relatively less amount of glucose in roasted or baked rice Compared to boiled rice, steamed rice usually has high levels of internal moisture content, thus resulting in a greater degree of starch gelatinization apart. The enhancement in the susceptibility to enzyme hydrolysis also has an effect of increasing the likelihood of more complete starch gelatinization (Zhong et al., 2022; Bangar et al., 2022). The glycemic potential of these products is also increased unless they have been cooled and stored to allow retrogradation thereafter (Vatanasuchart et al., 2009). Available data suggests that the use of such different equipments as stainless steel and Teflon rice cookers show measurable differences in starch transformation thus suggesting that the thermal conductivity and heat retention properties of the equipment itself influences the rate and extent of starch alteration (Vatanasuchart et al., 2009).

Align with research from Finfer et al. (2013), The inconsistencies in the methodology of measuring glucose ought to be considered as it methodologically varies the reported data and as such might only be used as a correlation. The spectrophotometric, DNS colorimetric and Luff Schoorl titrative methods are differentiated to varying sensitivity, discreteness, and vulnerability to the interference of different reducing sugars or interfering components of the matrix (Brummer et al., 2012). As a result, the differences in fasted or post prandial glucose levels which are seen especially between different types of rice analyzed by different laboratories may not only indicate true difference in samples, but also variation in analysis. Perhaps though, trends of reported values are still strong, analysis of glucose magnitude should

include instrumental variance when concluding on the treatment effects, particularly where they are small.

The mechanistic conclusions resulted in these studies have significant food implications. The controlled-cooked white rice with subsequent retrograde cooling has a lower glycemic effect and comparatively higher content of resistant starch, a feature linked with the better-gut health, postprandial insulin, and metabolic control (Ha et al., 2012; Panlasigui et al., 1991; Yu et al., 2017). In the perspective of nutritional engineering, planned modifications to cooking and storage regimens can be viewed as a realistic intervention capable of suppressing the glycemic index of staple rice preparations, especially at the populations at risk of diabetes or metabolic syndrome. These actions are in line with the body of evidence showing the health promoting effect of RS3-enriched rice-based diets in both animal and human models (Englyst et al., 1992; Sajilata et al., 2006; Hoover, 2010).

The reported decrease of glucose in white rice under long-time storage or high-heat procedures is underpinned by a set of well elucidated biochemical processes, at best, and starch retrogradation, amylose crystallization, and digestive enzyme resistance within a long list. A chain of connected variables, rice variant, cooking conditions, temperature kinetics, and storage conditions after cooking govern the feasibility of rice-based glucose as dietary carbohydrate. Understanding the variables with vigor provides scientific basis to improve diet policies at par with prevention of chronic illness.

Conclusion

The results of the literature review show that there is an influence of storage temperature (50%), storage time (25%), rice variety (50%) and cooking method (67%) on white rice glucose levels. Different rice varieties show varying patterns of decreasing glucose levels, depending on temperature and storage time. Longer heating processes and higher temperatures tend to accelerate the reduction in glucose levels, while different cooking methods also affect the final results. Statistical analysis confirms that different storage methods and conditions significantly affect rice glucose levels. Based on the results, it shows that the lower the temperature of white rice, the lower the glucose content.

Suggestion

Therefore, diabetes mellitus sufferers are advised to consume rice cold.

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