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Effect of Steaming Time on Degradation of Sugar and Starch Content in Short, Medium and Long Grain Rice

Nur Sharmira Sahar[1], So'bah Ahmad[1,*], Syaiful Osman[2]

[1] School of Industrial Technology, Food Science and Technology Program, Faculty of Applied Sciences, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia
[2] School of Physics and Materials Studies, Materials Science and Technology Program, Faculty of Applied Sciences, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia

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ABSTRACT

Excessive consumption of sugar- and starch-rich foods poses health risks, necessitating strategies to reduce these components in staple foods like rice. This study evaluates the impact of steaming durations on sugar (glucose) and starch reduction in short-, medium- and long-grain rice. Using phenol-sulphuric and iodine techniques, the results indicate that steaming for 135 minutes achieves the greatest reduction, with short-grain rice showing the highest percentage decrease in glucose (26.75 %) and starch (37.75 %), followed by medium and long-grain rice. Extended steaming (180 minutes) led to a slight increase in sugar and starch levels due to saturation. The lowest final sugar and starch concentrations were observed in long-grain rice (2.324 g/L glucose and 2.200 mg/ml starch). These findings highlight steaming as an effective method to lower sugar and starch levels in rice, offering health benefits for individuals and potential applications in food processing industries.

1. Introduction

The high calorie and glycemic index of rice have been linked to numerous health problems, including an increased risk of type 2 diabetes, obesity and metabolic disorders such as hypertension, hyperlipidemia and cardiovascular disease [1-3]. Globally, type 2 diabetes affects 460 million people, while obesity rates have risen dramatically, with 13 % of adults worldwide classified as obese in 2016 [4]. In Malaysia, the prevalence of obesity among adults is even higher at 17.7 %, with older adults experiencing a steady increase in obesity rates over the years [5,6]. These alarming health statistics have driven interest in low-calorie, low-glycemic-index food alternatives, such as quinoa, oatmeal and brown rice [7]. However, these healthier options are often prohibitively expensive, making them inaccessible to lower-income groups, such as Malaysia's B40 households, whose income is below RM 4,850 per month [8].

* *Corresponding author.*
E-mail address: sobah@uitm.edu.my

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In response to this issue, commercial products like the Noxxa Low Sugar Rice Cooker claim to reduce starch in rice by 41 %, but their high cost makes them unaffordable for many [9]. Thus, there is a critical need for a simple, affordable and effective method to reduce starch and sugar content in rice. Steaming has been proposed as a cost-effective cooking technique, yet its effectiveness in reducing sugar and starch in various rice types remains underexplored.

This research aimed to investigate the impact of steaming duration on the sugar and starch content of three types of rice: short-grain, medium-grain and long-grain rice. Additionally, it seeks to utilize Ultraviolet-visible (UV-Vis) spectroscopy, a fast, simple and affordable detection method, to quantify sugar and starch levels before and after steaming. By addressing gaps in cooking methods and detection techniques, this study aspires to provide a practical solution for healthier rice consumption, particularly for populations with limited access to costly alternatives.

2. Methodology

2.1 Material

Three types of rice samples were obtained from a store called GIANT Hypermarket in Shah Alam, Selangor, Malaysia. The rice used was short, medium and long grain rice from the same brand called Jasmine. The short, medium and long grain rice used were the Jasmine Sumo Calrose sushi rice, Jasmine white rice and Jasmine Basmati rice respectively that manufacture by the same company which is Jasmine Food Corporation Sdn. Bhd.

2.2 Pre-steaming of Rice

a) Washing

600 g of each type of rice was washed with 800 ml of clean water four times until it was clean. Hence, 3.2 L water was needed to wash one type of rice and 9.6 L water in total used to wash each type of rice, namely, short, medium and long grain rice.

b) Soaking

600 g of washed rice were soaked in 600 ml of clean water for 30 minutes. The rice needs to be fully submerged in clean water.

2.3 Steaming Process

The rice was steamed in the electric steamer at medium heat to decrease the time taken for the steaming water to boil. The rice was put on top of cloth to prevent it from falling into the steaming water. The steamer was heated up to 100◦C before putting the rice on top of it. The rice was then steamed for 3 hours, and the rice samples were taken every 45 minutes for its sugar and starch content analysis.

2.4 Pre-treatment Rice for Determining Sugar and Starch Content

a) Cooling of rice

The steamed rice collected then was cooled at the room temperature, 27◦C for 1-hour prior further analysis.

b) Drying process

The rice samples were dried using the microwave drying to remove their water content. Each of the rice samples required a different drying time (minutes) due to their difference in moisture content and morphology, like short grain rice which behave sticky to each other and high in moisture. The moisture content of the rice samples was then measured by using the moisture analyzer where it was repeated twice. Table 1 shows the microwave drying time, heat intensity and moisture content of each of the rice samples.

Table 1
Microwave drying time, heat intensity and moisture content of rice samples

Types of rice	Steaming duration (Minutes)	Microwave drying time (Minutes)	Microwave heat intensity	Moisture content **(%)**
Short grain	0	-	-	11.265 + 0.015
	45	11	Medium	11.460 + 0.010
	90	15	Medium	11.585 + 0.015
	135	20	Medium	11.785 + 0.015
	180	23	Medium	11.790 + 0.040
Medium grain	0	-	-	10.030 + 0.020
	45	12	Medium	10.080 + 0.010
	90	15	Medium	10.460 + 0.060
	135	18	Medium	10.645 + 0.025
	180	22.5	Medium	10.830 + 0.000
Long grain	0	-	-	9.050 + 0.010
	45	13.5	Medium	9.280 + 0.001
	90	16.5	Medium	9.315 + 0.035
	135	19.5	Medium	9.380 + 0.010
	180	22.5	Medium	9.765 + 0.015

c) Extraction of sugar and starch from dried rice

In sugar extraction, 10 g of dried rice were hydrolyzed in 2 % sulfuric acid (H_2SO_4) at the temperature of 25◦C for 20 minutes to extract out the sugar (glucose) from the rice samples [10]. The hydrolyzed dried rice was then centrifuged at 3500 rpm for 15 minutes to collect the extracted sugar (upper layer) from the hydrolyzed dried rice for sugar concentration determination. Meanwhile, for starch extraction, 0.03 g of dried rice was diluted with 100 ml of distilled water and then boiled for 10 minutes. Then, 20 ml of the dried rice solution was hydrolyzed by 28 ml of hot distilled water, 6 ml of zinc acetate and 6 ml of potassium ferrocyanide to extract out the starch from the rice samples [11]. The hydrolyzed dried rice was then filtered out to collect the extracted starch from the hydrolyzed dried rice samples for starch concentration determination.

2.5 Standard Preparation for Sugar and Starch Concentration Determination
a) Preparation of sugar standard solution

Stock solution of glucose was prepared by diluting 180.16 g of D-glucose in 1000 ml of distilled water. Standard glucose solution with concentration of 0.5, 1.0, 1.5, 2.0, 3.0, 4.0, 5.0 and 6.0 g/L were prepared by pipetting the known volume of the glucose stock solution into a 100 ml volumetric flask. The volume was then marked up by using distilled water. The volume of stock glucose solution required to prepare the standard glucose solution was determined by using the equation of $C_1V_1 = C_2V_2$ where C_1 and C_2 are the concentration of the stock solution and standard solution respectively

while V_1 and V_2 are the volume of the stock solution required to prepare the standard solution, and the volume of the standard solution desired respectively. Next, 2 ml of each of the standard solutions was pipetted and transferred to the separate test tubes to determine the calibration curve of the standard glucose solution. 0.4 ml of a 5 % aqueous solution of phenol reagent and 2 ml of 96 % sulfuric acid were then added to each of the standard sugar solution [10]. After that, the mixture was left at room temperature for 10 minutes and then placed in the 25°C water bath for 20 minutes [10]. This is done to give time for the chemical to react with the solution. Lastly, the absorbance of each standard glucose solution was determined by UV-visible spectrophotometer at wavelength of 540 nm. This procedure was repeated twice.

b) Preparation of starch standard solution

Stock solution of starch was prepared by diluting 30 mg of potato starch in 100 ml of distilled water. Standard starch solution with concentration of 0.6, 1.8, 2.4, 3.6, 4.8 and 6.0 mg/ml were prepared by pipetting the known volume of the starch stock solution into a 100 ml of volumetric flask. The volume was then marked up by using distilled water. The volume of stock starch solution required to prepare the standard starch solution was determined using the equation of $C_1V_1 = C_2V_2$ where C_1 and C_2 are the concentration of the stock solution and standard solution respectively while V_1 and V_2 are the volume of the stock solution required to prepare the standard solution, and the volume of the standard solution desired respectively. Next, 0.05 ml of iodine and 15 % of trichloroacetic acid (TCA) were added to each of the standard starch solutions [11]. After that, the mixture was left at room temperature for about 10 minutes. Lastly, the absorbance of each standard starch solution was determined by UV-visible spectrophotometer at wavelength of 549 nm. This procedure was repeated twice.

2.6 Determination of Sugar and Starch Concentration
a) Determination of sugar (glucose) concentration in three types of rice

The determination of sugar (glucose) concentration in the rice samples was done using the phenol-sulphuric method. Firstly, 2 ml of sugar extracted out from the dried rice was mixed with 0.4 ml of 5 % aqueous phenol solution in the test tube using vortex for 3 minutes to homogenize the solution [10]. Then, 2 ml of 96 % sulfuric acid was quickly added to the mixture solution [10]. The test tube with the solution then was left at room temperature for 10 minutes then submerged in a 25◦C water bath for 20 minutes for it to react with each other and develop the colour [10]. The absorbance of the solution then was measured by the UV-visible spectrophotometer at the wavelength of 540 nm [10]. The quantification was then done by using the calibration curve of standard glucose solution while the calculation was done by using the equation of the linear regression from the calibration curve of standard glucose solution which is through the equation of $y = mx + c$. The *m* from the equation is the concentration of sugar (glucose) in the dried rice samples. The same steps were repeated twice for the three types of rice samples.

b) Determination of starch concentration in three types of rice

The determination of starch concentration in the rice samples was done using iodine test. Firstly, 5 ml of starch solution extracted out from the dried rice samples was mixed with 0.5 ml of iodine solution in the test tube to develop the colour to able the measurement of starch content by using UV-visible spectrophotometer [11]. Then, 1 ml of 15 % TCA was added to the solution [11]. This is

done to lower the pH of the solution as starch-iodine complex is more stable at the low pH [11]. Then, the absorbance of the solution was measured by the UV-visible spectrophotometer at the wavelength of 549 nm [11]. The quantification was then done by using the calibration curve of standard starch solution while the calculation was done by using the equation of the linear regression from the calibration curve of standard starch solution which is through the equation of y = mx + c. The *m* from the equation is the concentration of starch in the dried rice samples. The same steps were repeated twice for the three types of rice samples.

2.7 Statistical Analysis

The results were presented in means ± standard deviation in table and graph. The data were treated with one-way analysis of variance (ANOVA) with Duncan's post hoc test at 95 % confidence level. The statistical analysis was done using SPSS version 28.

3. Results and Discussion

3.1 Effective Steaming Time in Reducing Sugar (glucose) and Starch Concentration in Three Types of Rice

a) Sugar (glucose) concentration

Figure 1 shows the glucose concentration in three types of rice at different steaming times. Glucose concentration decreases from the raw rice (0 minutes) to 135 minutes, then increases at 180 minutes. The initial decrease is due to prolonged heating, which damages compounds in the rice, lowering glucose content [12]. Additionally, glucose leaching into the steaming water contributes to the reduction [13]. However, at 180 minutes, the rice becomes saturated and reabsorbs the glucose from the steaming water, leading to an increase in glucose concentration [13]. Notably, 135 minutes of steaming results in the lowest glucose concentration, as supported by the glucose reduction percentages in Table 2.

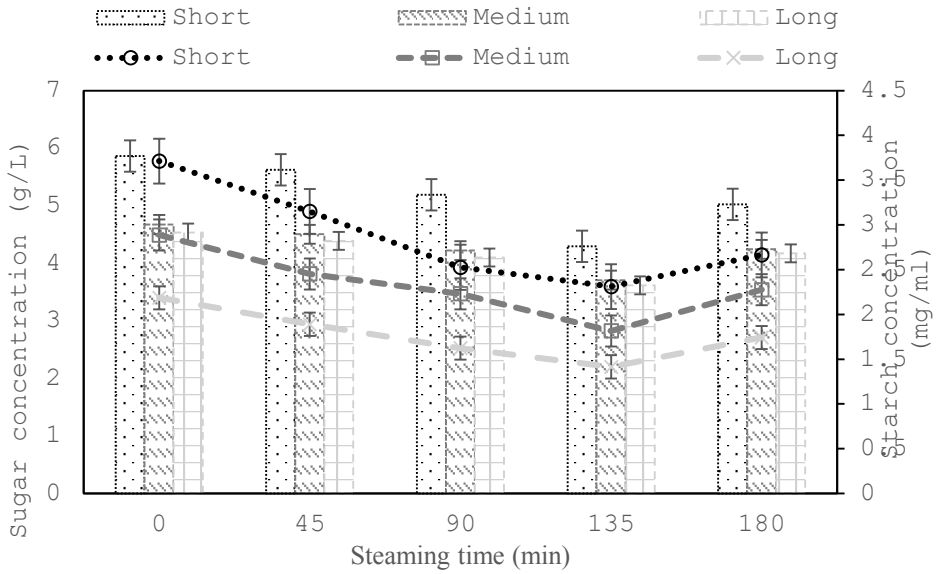

Fig. 1. Glucose and starch concentration of rice grains at different steaming times

Table 2
Sugar (glucose) reduction percentage in three types of rice at different steaming times

Types of rice (grain)	Reduction percentage (%)			
	45 minutes	90 minutes	135 minutes	180 minutes
Short grain	$4.05 + 0.05^{aD}$	$15.26 + 0.04^{aB}$	$26.75 + 0.04^{aA}$	$11.14 + 0.04^{aC}$
Medium grain	$3.60 + 0.08^{bD}$	$9.64 + 0.07^{bB}$	$20.69 + 0.00^{bA}$	$9.21 + 0.00^{bC}$
Long grain	$3.22 + 0.07^{cD}$	$9.62 + 0.04^{cB}$	$20.27 + 0.07^{cA}$	$9.21 + 0.00^{cC}$

Note: Results are expressed as glucose concentration. Values are expressed as mean ± standard deviation. Means within column (A,B,C,D,E) and within a row (a,b,c) marked with different letters were significantly different at the level of $p < 0.05$. The coefficient of variance was less than 10 %

Table 2 shows the glucose reduction percentages for three rice varieties at different steaming times. The highest glucose reduction occurred at 135 minutes, with 26.75, 20.69 and 20.27 % for short grain, medium grain and long grain rice, respectively, followed by 90, 180 and 45 minutes with the lowest reductions. Despite glucose concentration increasing at 180 minutes, its reduction remained lower than at 45 minutes, indicating that prolonged steaming times beyond 180 minutes could further elevate glucose levels. Therefore, 135 minutes is the most effective steaming duration for reducing glucose content in all three rice varieties, resulting in the lowest glucose concentrations. Low glucose concentration correlates with a lower glycaemic index [14], as less glucose is available for digestion and absorption into the bloodstream, reducing the glycaemic response. Consequently, 135 minutes of steaming may make rice a healthier option, potentially reducing the risk of health issues such as diabetes and obesity.

b) Starch concentration

Figure 1 shows the variations in starch concentration across three rice varieties at different steaming times. All three rice types exhibited a similar decline in starch concentration up to 135 minutes, followed by a rebound at 180 minutes. The analysis reveals that steaming reduces starch concentration, with the highest reduction occurring at 135 minutes. Prolonged heating leads to starch gelatinization, an endothermic process where starch loses its crystalline structure under specific heat and moisture conditions [15]. This results in the swelling and disintegration of starch granules, which are then hydrolysed and broken, reducing starch concentration [12]. Additionally, amylose and amylopectin leach out into the steaming water, further lowering starch content [13]. However, after 180 minutes, the starch concentration begins to rise due to saturation, with the rice reabsorbing the leached amylose and amylopectin [13]. Therefore, 135 minutes of steaming is the optimal duration for reducing starch content, as shown by the starch reduction percentages in Table 3.

Table 3
Starch reduction percentage in three types of rice at different steaming times

Types of rice (grain)	Reduction percentage (%)			
	45 minutes	90 minutes	135 minutes	180 minutes
Short grain	$15.15 + 0.00^{aD}$	$31.95 + 0.07^{aB}$	$37.75 + 0.08^{aA}$	$28.23 + 0.08^{aC}$
Medium grain	$15.05 + 0.08^{bD}$	$22.72 + 0.07^{bB}$	$37.08 + 0.08^{bA}$	$21.16 + 0.00^{bC}$
Long grain	$13.53 + 0.07^{cD}$	$25.74 + 0.08^{cB}$	$35.29 + 0.00^{cA}$	$20.29 + 0.07^{cC}$

Note: Results are glucose concentration and are expressed as mean ± standard deviation. Means within column (A,B,C,D,E) and within a row (a,b,c) with different letters were significantly different ($p < 0.05$). The coefficient of variance was less than 10 %

Table 3 shows that 135 minutes of steaming resulted in the highest starch reduction percentages—37.75, 37.08 and 35.29 % for short, medium and long-grain rice, respectively, followed by 90, 180 and 45 minutes. This suggests that while starch concentration begins to rise after 180 minutes, the increase is smaller compared to the 45-minute duration. Extending steaming beyond 180 minutes may increase starch concentration beyond that achieved at 45 minutes. Therefore, 135 minutes is the most effective steaming time for starch reduction across all rice types, yielding the lowest starch concentration. Lower starch content is linked to a lower glycaemic index [14], as slower digestion and absorption reduce glucose release and decrease glycaemic response. Thus, steaming rice for 135 minutes optimally reduces starch, making it a healthier option that may help mitigate health issues such as diabetes and obesity.

3.2 Comparison of sugar (glucose) and starch concentrations towards control in three types of rice
a) Sugar (glucose) contents

Table 4 shows the concentration of sugar (glucose) in the three types of rice at different steaming times.

Table 4
Glucose concentration of three types of rice at different steaming times

Types of rice (grain)	Glucose concentration (g/L)				
	0 minutes	45 minutes	90 minutes	135 minutes	180 minutes
Short grain	3.769 ± 0.006^{aA}	3.616 ± 0.002^{aB}	3.336 ± 0.002^{aD}	3.349 ± 0.002^{aC}	4.145 ± 0.005^{aC}
Medium grain	3.004 ± 0.004^{bA}	2.896 ± 0.006^{bB}	2.714 ± 0.002^{bD}	2.727 ± 0.000^{bC}	3.540 ± 0.000^{bC}
Long grain	2.915 ± 0.000^{cA}	2.821 ± 0.002^{cB}	2.635 ± 0.004^{cD}	2.683 ± 0.002^{cC}	2.710 ± 0.010^{cC}

Note: Results are expressed as glucose concentration. Values are expressed as mean ± standard deviation. Means within column (A,B,C,D,E) and within a row (a,b,c) marked with different letters were significantly different at the level of $p < 0.05$. The coefficient of variance was less than 10 %

ANOVA results show a significant difference in glucose concentration across steaming durations for all rice types at the 95 % confidence level. Raw rice exhibited the highest glucose concentration, followed by 45, 180, 90 and 135 minutes, which resulted in the lowest glucose concentration for all rice types. This indicates that steaming duration affects glucose content differently. Additionally, significant differences were observed between the three rice types at each steaming duration, with short-grain rice having the highest glucose concentration, followed by medium-grain and long-grain rice. Short-grain rice has the highest glucose content initially, which is why it retains the highest glucose concentration even after extended steaming [3]. Long-grain rice, which starts with the lowest glucose content, also has the lowest glucose concentration after steaming, as it initially has less glucose to be reduced. Thus, while each steaming duration similarly affects all rice types, the differences in initial glucose content determine the final glucose concentration.

a) Starch contents

In starch analysis, the three types of rice with different grain sizes, short, medium and long grain rice were steamed for 45, 90, 135 and 180 minutes with 0 minutes or the raw rice as the control in this study. Table 5 shows the concentration of starch in the three types of rice at different steaming times. The data was presented in mean ± standard deviation with statistical letters that show their significant differences.

Table 5
Starch concentration of three types of rice at different steaming times

Types of rice (grain)	Starch concentration (mg/ml)				
	0 minutes	45 minutes	90 minutes	135 minutes	180 minutes
Short grain	$5.775 + 0.005^{aA}$	$4.900 + 0.000^{aB}$	$3.930 + 0.010^{aD}$	$3.595 + 0.005^{aE}$	$4.145 + 0.005^{aC}$
Medium grain	$4.490 + 0.000^{bA}$	$3.815 + 0.005^{bB}$	$3.470 + 0.010^{bD}$	$2.825 + 0.005^{bE}$	$3.540 + 0.000^{bC}$
Long grain	$3.400 + 0.000^{cA}$	$2.940 + 0.010^{cB}$	$2.525 + 0.005^{cD}$	$2.200 + 0.000^{cE}$	$2.710 + 0.010^{cC}$

Note: Results are expressed as glucose concentration. Values are expressed as mean ± standard deviation. Means within column (A,B,C,D,E) and within a row (a,b,c) marked with different letters were significantly different at the level of $p < 0.05$. The coefficient of variance was less than 10 %

ANOVA results show a significant difference in starch concentration across steaming durations for all rice types at the 95 % confidence level. Raw rice had the highest starch concentration, followed by 45, 180, 90 and 135 minutes, which showed the lowest concentration for all rice types. This indicates that steaming duration affects starch content differently. Furthermore, significant differences in starch concentration were observed between the three rice types at each steaming duration, with short-grain rice having the highest starch concentration, followed by medium-grain and long-grain rice. This is due to short-grain rice's higher amylopectin content, which correlates with its greater starch content [3]. In contrast, long-grain rice, with its lower amylopectin and higher amylose content, exhibited the lowest starch concentration [3,16-18]. As amylopectin makes up approximately 70 % of starch [14], this explains the higher starch content in short-grain rice. Conversely, long-grain rice, which has lower amylopectin and higher amylose (20-30 % of starch) [16,19,20], has lower starch content. Therefore, short-grain rice maintains the highest starch concentration even after prolonged steaming compared to medium and long-grain rice, due to its initial higher starch content.

4. Conclusions

This study focused on the effect of steaming time on reducing the sugar (glucose) and starch content in three types of rice with different sizes of grain, short grain, medium grain and long grain rice. From the study, it was identified that the most effective steaming time in reducing the sugar (glucose) and starch content in rice is 135 minutes as it showed the highest reduction percentage in sugar (glucose) and starch in all three types of rice with the highest is in the short grain rice, followed by medium grain rice and lastly long grain rice. The glucose reduction percentage at 135 minutes of steaming in short, medium and long grain rice are 26.75, 20.69 and 20.27 % respectively. Meanwhile, the starch reduction percentage at 135 minutes of steaming in short, medium and long grain rice are 37.75, 37.08 and 35.29 % respectively. Furthermore, there are significant differences of sugar (glucose) and starch contents between the steaming time in three types of rice where the concentration of sugar (glucose) and starch content decrease from the control (0 minutes). The lowest sugar (glucose) concentration is in long grain rice with 2.324 ± 0.002 g/L, followed by medium grain rice with 2.382 ± 0.000 g/L and lastly short grain rice with 2.761 ± 0.002 g/L. Meanwhile, the lowest starch concentration is in long grain rice with 2.200 ± 0.000 mg/ml, followed by medium grain rice with 2.825 ± 0.005 mg/ml and lastly short grain rice with 3.595 ± 0.005 mg/ml.

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