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Predicted Glycaemic Index Values of Rice Prepared with Different Cooking Methods

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ABSTRACT

The current study investigated how the preparation methods impact the nutritional composition and estimated Glycaemic Index (eGI) of the white and brown rice samples. The analysis of proximate and eGI was conducted after the white and brown rice were prepared through these cooking methods: (1) cooking rice without additional coconut oil and not being refrigerated (control); (2) cooking rice without additional coconut oil and being refrigerated (XCOR); (3) cooking rice with additional coconut oil and not being refrigerated (COXR); and (4) cooking rice with additional coconut oil and being refrigerated (COR). The result showed that the COR method recorded the lowest calorie for both white and brown rice (223.93 kcal and 169.90 kcal per 100 g, respectively). Meanwhile, the COR method also recorded the lowest eGI for both white rice (2.31, 6.36, 6.07, 4.55, 3.02, 2.22 nm/min) and brown rice (1.44, 1.92, 1.92, 1.36, 0.66, 0.27 nm/min) at 20, 30, 60, 90, 120, and 180 min, respectively. In conclusion, consuming refrigerated rice that has been cooked with coconut oil can be used as an alternative preparation technique to lower both calorific value and glycaemic index for the preparation of healthier rice meals for health-conscious individuals.

Keywords: brown rice, coconut oil, eGI, refrigeration, white rice

INTRODUCTION

Changing dietary habits represents one of the most influential lifestyle factors. The fundamental reason for obesity and overweight is an energy imbalance between calories consumed and calories expended, which is a positive energy balance involving the total energy intake exceeding the total energy expenditure (World Health Organization (WHO) 2020). Besides, Diabetes Mellitus (DM) is a condition disease where the blood glucose level is surged irregularly due to the failure of the body to generate insulin or to use it to the fullest (Ganjifrockwala *et al.* 2017). It is linked with serious complications such as stroke, ischemic heart disease, cancer and possibly can lead to organ failure (Ng *et al.* 2020). Type 2 Diabetes (T2DM) is one of the common modern lifestyle-linked diseases associated with the high intake of refine carbohydrates and low consumption of Dietary Fibre (DF) (Helmyati *et al.* 2020). Positive energy balance may be due to unhealthy eating habits and an increased intake of energy-dense foods that are high in calories and sugars but low in DF content (Tanaka *et al.* 2020). This may have a significant adverse effect on nutritional status because of the exclusion of adequate quantities of fat, protein, and other essential nutrients.

Most Malaysians consume cooked rice daily as their staple food. White Rice (WR) and Brown Rice (BR) are commonly consumed in Malaysia. BR is a whole grain, containing all parts of the grain: bran, germ, and endosperm, whereas WR had the bran and germ removed (Santos & Timoteo 2016). Thus, BR contains more DF and provides several vitamins and minerals. A large serving of high-calorie dishes containing carbohydrates such as rice, bread, and pasta in the daily diet contributes to excess energy intake and subsequent weight gain. Consuming an excessive amount of carbohydrates, especially with a high glycaemic load, results in a large metabolic load on the body, resulting in an increase in the risk of developing several disorders, including T2DM (Joanne 2018). Due to the excess glucose in the blood, a quick elevation in blood glucose will put a high demand on the beta cells of the pancreas for insulin (Joanne 2018). This extra glucose will then be converted to glycogen, which will be

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deposited as fat in muscles and the liver (Tanaka *et al.* 2020). This condition can cause obesity if the person does not burn the excess calories (Tanaka *et al.* 2020).

Starches are one of the dietary carbohydrates that are made of two different polymers: amylose (essentially linear) and amylopectin (branched) (Arik Kibar *et al.* 2013). Starches can be divided into two types, which are Resistant Starch (RS) and Digestible Starch (DS) (Birt *et al.* 2013). An important fact is that the DS can be converted to the RS. This may be due to the interaction of amylose with other molecules when it is subjected to thermal treatments. The RS can be formed through the retrogradation process, which involves the process of cooling cooked starch after undergoing the cooking process beyond its gelatinisation temperature to form retrograded starch, RS3 (Wang *et al.* 2015). Another way to increase the resistance of starch is by developing RS5, self-assembled starch V-type complexes through the use of coconut oil as an acid combined with heat-moisture treatment during cooking (Arik Kibar *et al.* 2013). RS5 is formed when the hydrocarbon tail of the lipid and the helical cavity of amylose are joined together (Birt *et al.* 2013).

Dietary modifications, including fibre-rich food intake, decreased energy density, and high protein intake, aid in achieving an energy deficit to help weight loss and could be a primary solution to overcome obesity. Involving diet modification such as a low Glycaemic Index (GI) diet by choosing low-GI foods may be more effective than a high-GI diet at reducing body weight, especially in obese people, and controlling glucose and insulin metabolism in T2DM patients. Consuming a low-GI diet causes the glucose to be released slowly and steadily, reducing the high spike in blood sugar, which results in lowering the insulin response and then improving insulin sensitivity (Wang *et al.* 2015). The reduction in insulin secretion gives greater access to using the fat stores to generate energy (Birt *et al.* 2013).

The GI of food can be determined to assess the ability of the carbohydrates it contains to raise Blood Glucose Levels (BGL). Since in vivo GI determination heavily relies on the involvement of healthy human subjects through the consumption of the test food and requires the withdrawal of their blood, the in vitro estimated GI (eGI) assessment is advisable to be performed first. By performing the eGI through an enzymatic reaction approach, the nutritionist or analyst should be able to predict or estimate how fast the carbohydrate (digestibility rate of the starch of the test food in relation to the digestibility of starch in the reference material) raises the BGL. If the test food shows the potential to lower a GI, then the results obtained from eGI can be confirmed or validated further through an accurate in vivo GI study (Demirkesen-Bicak *et al.* 2021). In brief, the eGI is performed to extrapolate the percentage of starch hydrolysed at time t (min) and the equilibrium percentage of starch hydrolysed after 180 min (Eyinla *et al.* 2022).

In line with the fact that DF promotes satiety and satiation, an increase in DF intake was associated with better glycaemic control and more favourable CVD risk factors (Helmyati *et al.* 2021). As an alternative of starch replacement, DS in rice with a high concentration of RS by using coconut oil and refrigeration is proposed because it results in lowering the GI value and reducing energy density due to its lower calorie content, which is 2 kcal/g (Birt *et al.* 2013). Moreover, the presence of oleic acid (unsaturated fatty acid) in coconut oil (Santos *et al.* 2020) was found to be effective in decreasing starch digestibility by forming an amylose-lipid complex and making it resistant to enzymatic breakdown (Birt *et al.* 2013). Since the rate of starch digestibility of the test food is influenced by the presence of DF and RS, the current study emphasises how the preparation methods of rice impact the Estimated Glycaemic Index (eGI). The study aims to investigate the nutritional composition and predict the eGI values of white and brown rice treated with different preparation methods.

METHODS

Design, location, and time

The study was carried out in the Food Preparation, Nutrition, and Analytical Laboratory, Health Campus, Universiti Sains Malaysia (USM), Kelantan, Malaysia. The study was carried out from November 2022 to January 2023.

Material and tools

The main materials used for this study were WR, BR, and coconut oil. The most used WR rice (long-grain variety, 1 brand) and BR (long-grain variety, 1 brand) were purchased from a local hypermarket near to the Health Campus of Universiti Sains Malaysia which is located in the Kota Bharu district of Kelantan state, Malaysia. Two different types of rice are used: WR and BR, which are commonly consumed by Malaysians. Meanwhile, the coconut oil was purchased from a local hypermarket in Kubang Kerian, Kelantan. Chemicals and reagents used in this study were: hydrochloric acid, sulfuric acid, boric acid, red methyl, sodium hydroxide, sodium acetate, bromocrysol green, and methanol, from Merck, Germany. The selenium catalyst tablet, pancreatic enzyme, amyloglucosidase, and amylose were made by Thermofisher Scientific, United Kingdom. Acetic acid, ethanol, and potassium iodide were obtained from HmbG, Germany. Petroleum ether from JoChem Scientific & Instruments, Malaysia. The D-glucose assay kit was bought from Megazyme, Ireland. Iodine was purchased from Chemiz, Malaysia.

Procedures

Preparation of rice. Both WR and BR were then cooked with different cooking methods: (1) cooking rice without additional coconut oil and not being refrigerated (control); (2) cooking rice without additional coconut oil and being refrigerated (XCOR); (3) cooking rice with additional coconut oil and not being refrigerated (COXR); and (4) cooking rice with additional coconut oil and being refrigerated (COR) for 12 hours before performing further analyses. All cooking procedures and analyses are replicated twice.

One cup of rice (220 g) was rinsed and added to a predetermined quantity of water. For white rice, 1.5 cups of water are added, whereas for brown rice, 2 cups of water are added. In methods 3 and 4, 1 tablespoon of coconut oil was mixed with rice. Each type of rice was cooked and cooled. Rice in methods 1 and 3 was left at room temperature for 30 min, whereas rice in methods 2 and 4 was cooled for 30 min before being refrigerated (4−5°C) for 12 hours.

Analysis of proximate composition. Proximate parameters (composition of moisture, ash, protein, fat, and dietary fibre) were determined according to the AOAC methods (AOAC 2020). Meanwhile, the carbohydrate content was calculated as a hundred minus the total percentage of moisture, ash, crude protein, and fat (by-difference method). The carbohydrate content of samples was determined by calculating the percent remaining after all the other components have been measured:

$$\%\,Carbohydrates = 100 - (\%\,Moisture - \%\,Protein - \%\,Lipid - \%\,Ash)$$

Determination of amylose content. The amylose content of BR was determined by a colorimetric method with a blue amylose-iodine complex based on the method described by Jain *et al.* (2012).

Calorific value. The calorie content of the rice samples was calculated using a formula obtained from the U.S. Department of Agriculture (USDA) (2010):

$$Energy\,(kcal) = 4\,X\,Protein + 9\,X\,Fat + 4\,X\,Carbohydrate$$

In-vitro starch digestibility. eGI was determined using an assay kit GOPOD-format K-GLUC by spectrophotometry at a wavelength of 510 nm based on the method explained by Demirkesen-Bicak *et al.* (2021). One g of the sample was mixed with 5 ml of deionised water. After that, 10 ml of pepsin-guar gum solution was added, and the sample was incubated at 37°C at 175 strokes/min in a shaking water bath for 30 min. Then, 5 ml of 0.5 M sodium acetate was added, and the pH was adjusted to between 5 and 5.25. An enzyme solution of the mixture of pancreatin and amyloglucosidase (13.4 U/ml) was added, and the volume was adjusted to 50 ml using deionised water. After that, the sample was incubated for 180 min in a shaking water bath. Between the periods of incubation, 0.5 ml samples were taken at 20, 30, 60, 90, 120, and 180 min and placed in separate falcon tubes. Then the tubes were placed in a boiling water bath for 5 min to denature the enzyme. After that, the final volume of the samples was adjusted to 5 ml using deionised water and centrifuged for 5 min at 4,000X g. The eGI was calculated from the Hydrolysis Index (HI) value of each sample. The HI value was obtained through calculation by dividing the area under the hydrolysis curve with the white bread area. The eGI was then calculated using the formula below (Demirkesen-Bicak *et al.* 2021):

$$GI = 39.71 + 0.549\,X\,HI$$

Data analysis

The results were evaluated for statistical significance using the IBM Statistical Package for Social Sciences (SPSS) Statistics Data Editor Version 26. The results were conveyed as means±standard deviation. A p-value of less than 0.05 was deemed significant. The differences between the means were analysed for significance using a one-way analysis of variance (ANOVA) test by employing the post-hoc Tukey test.

RESULTS AND DISCUSSION

Moisture content. Moisture content in food can be defined as water left within the food, indicating an index of its nutrient content (Kim & Lee 2013). The moisture contents of the WR were 62.07, 62.74, 67.00, and 68.46%, respectively, whereas the moisture contents of the BR were 61.57, 63.54, 66.91, and 69.28% respectively (Table 1). These results showed that the WR had a relatively higher moisture content than the BR in preparation methods 1 and 3. Since the BR has a high-fibre bran, more water is needed to cook BR, and it is demonstrated that the bran layer inhibits moisture absorption (Chapagai *et al.* 2020). Plus, it may be due to the drying effects of the exothermic reaction of the dehusking procedure (Kim & Lee 2013). On the other hand, in preparation methods 2 and 4, BR shows that it has a relatively higher moisture content than WR. A previous study stated that the moisture content had little effect on the amylose recrystallisation (Ding *et al.* 2019). Thus, BR, which already contains more amylose concentration, has a higher moisture content to undergo amylose recrystallization during the retrogradation process.

For further analyses of ash, protein, and fat contents, each rice sample was ground first before being analysed; the results showed that there are

Table 1. The proximate composition of WR and BR prepared with different methods

Nutritional composition	Concentration (%)			
	Control	2 (XCOR)	3 (COXR)	4 (COR)
Moisture				
WR	62.07±0.11	62.74±0.13	67.00±0.10	68.46±0.08
BR	61.57±0.12	63.54±0.12	66.00±0.09	69.28±0.10
Ash				
WR	0.24±0.01[b]	0.28±0.02[b]	0.29±0.09[b]	0.24±0.04[b]
BR	1.17±0.02	1.13±0.01	1.17±0.07	1.08±0.06
Fat				
WR	0.50±0.02[b]	0.20±0.02[b]	4.10±0.09[b]	3.80±0.04[b]
BR	2.47±0.03	1.91±0.03	5.78±0.08	5.37±0.06
Protein				
WR	9.46±0.11	9.45±0.09	8.86±0.11	8.58±0.11
BR	8.91±1.12[b]	8.85±0.08[a]	8.63±0.10a	8.16±0.10[a]
Carbohydrate				
WR	27.73±0.18	27.33±0.11	19.73±0.14	18.88±0.12
BR	25.88±0.13[b]	24.58±0.13[a]	17.52±0.08[b]	16.10±0.11[b]
TDF				
WR	2.90±0.01[b]	2.93±0.02[b]	4.00±0.07[b]	6.20±0.05[b]
BR	4.90±0.02	4.82±0.03	5.60±0.05	8.01±0.09
Calorie (kcal/100 g)				
WR	344.72±1.10[b]	285.61±1.15[a]	248.00±1.10[a]	223.93±0.09[a]
BR	350.50±1.12[a]	267.85±1.13[b]	195.67±0.09[b]	169.91±0.15[b]

[a-b:] Mean±SD with different superscript letters within the same row indicate a significant difference ($p<0.05$)

WR: White Rice; BR: Brown Rice; TDF: Total Dietary Fibre

1 (Control): Rice cooked without additional of coconut oil and not being refrigerated

2 (XCOR): Rice cooked without additional of coconut oil and being refrigerated

3 (COXR): Rice cooked with additional of coconut oil and not being refrigerated

4 (COR): Rice cooked with additional of coconut oil and being refrigerated

different trends in analysing ash, protein, and fat content in the cooked rice.

Ash content. The ash content refers to the essential mineral residue remaining from burning organic matter at high temperatures. The higher the ash content of the food, the more mineral elements it contains. The ash content in the BR varied between 1.080–1.173% and the WR was between 0.239–0.290%. The result shows that the ash content was higher in the BR than in the WR. WR contains less ash content because the milling processes it undergoes, such as bran removal, have affected its mineral content (Helmyati *et al.* 2020). On the other hand, the result in Table 1 also shows that there is a decreasing pattern of ash content for both types of rice, WR and BR, that undergo refrigeration. According to the previous study by Helmyati *et al.* (2020), it demonstrated that a decrease in ash content in food may be due to the susceptibility of ash to storage conditions. It also might be caused by the physiological activities of the mineral, possibly due to the respiration process that subsequently decreases the mineral content in the rice samples (Nur Shafinaz *et al.* 2022). However, some minerals can be volatilized or reduced when heated at high temperatures during the drying process, particularly vitamins B and C (Chapagai *et al.* 2020). This study shows that the storage temperatures indirectly promote the physiological process and affect the ash content of rice samples.

Protein content. The protein content for the WR ranged from 8.58% to 9.46%, while the BR evaluated ranged from 8.16% to 8.91%. According to the Malaysian Food Composition Database (MyFCD 1997), domestic white rice contains a lower protein content with a value of 7.1 g/100 g while BR of Jasmine's production contains 8 g/100 g. Generally, WR has a higher protein concentration than BR in all preparation methods (Table 1). A previous study demonstrated that more pigmented rice tends to have reduced protein digestibility (Yuliana & Akhbar 2020). This supports our study's result which shows BR has a lower protein concentration than WR. Protein availability depends on several factors such as heat, the presence of moisture, reducing substances, and the duration of heating (Helmyati *et al.* 2021). The amino group of protein is attached to the carboxyl group through peptide bonds due to the loss of water molecules during the dehydration process (Schmeing 2013). However, this peptide bond can also be broken down to release the amino group through the hydrolysis process. This may happen during the cooking process of rice samples (Chapagai *et al.* 2020). The prolonged cooking may cause the physical structure of the protein to denature and no longer function (Sanfelice & Temussi 2016). Proteins are highly sensitive to temperature, both cold and hot, which may alter the structure of the protein, denature it, and make it non-functional (Sanfelice & Temussi 2016). Protein denaturation is not strong enough to disrupt the peptide bonds in the primary structure of the protein, but it can affect the secondary and tertiary structures of the protein (Amagliani *et al.* 2017). As the protein in rice samples is the secondary structure of the protein, the peptide bonds may easily be broken down.

It also shows that there is a decreasing trend in protein concentration with the preparation method. Protein unfolding may also be due to cold denaturation when proteins at room temperature are cooled to lower values (Sanfelice & Temussi 2016). Nonpolar groups of proteins tend to avoid contact with water to engage in hydrophobic interactions because, at low temperatures, the entropic advantage of the water molecule in folding non-polar groups of the protein inward is lessened (Taborsky 1979). This produces an endothermic reaction with low kinetic energy that may alter the protein concentration of refrigerated rice samples.

Fat content. All rice is made up primarily of carbohydrates, with small amounts of protein and practically low-fat content (Chapagai *et al.* 2020). Brown rice contains a good source of linoleic acid and essential fatty acids and does not contain cholesterol (Chapagai *et al.* 2020). Table 1 shows that the fat concentration of WR ranged between 0.20% and 4.12%, whereas that of BR ranged between 1.91% and 5.78%. Overall, low fat content was recorded in the WR variety (0.20%), significantly lower than the BR variety. As BR is categorised as a whole grain, the germ part contains fatty acids, making it contain more fat from the essential oil. It also shows that rice that was refrigerated had a lower fat concentration than rice that was not refrigerated. This result may be due to the formation of a starch-lipid complex in a starch-water system during the retrogradation process (Arik Kibar *et al.* 2013). A previous study stated that the more the amylose-fatty acid complex forms, the more unsaturated fatty acids are introduced to the amylose of starch (Arik Kibar *et al.* 2013). However, with the addition of the coconut oil during cooking (samples 3 and 4), the fat percentage in the rice samples increased by approximately 3 times that of the control sample. The crude fat content of coconut oil was higher in relation to the fat content of rice. However, even though coconut oil is highly saturated, its predominance of medium-chain fatty acids causes it to have a different metabolic behaviour (Santos *et al.* 2020).

Carbohydrate content. Carbohydrate content in food, including organic acids, polyols, and dietary fibre, contributes to the energy content, and it is important to provide the energy required by humans (Santos & Timoteo 2016). For carbohydrate content, the values shown in Table 1 were in the range of 18.88% to 27.73% for WR and in the range of 16.10% to 25.88% for BR. According to the MyFCD (1997), white rice contains a lower carbohydrate content with a value of 79 g/100 g, while brown rice from Jasmine's products contains 74 g/100 g. This result is consistent with the results obtained from our study, showing that BR has a lower carbohydrate concentration compared to WR. During the cooking process, the excess sugars from the starch may be separated from the rice and then converted into gelatinous liquid in the upper inner lid. This will produce rice with less carbohydrate content (Lauben 2022). Table 1 also shows that the carbohydrate content is decreasing with the refrigeration of rice samples for both rice types. Many factors influence carbohydrate digestion, including the type of starch and the type of preparation. During refrigeration, the retrogradation process occurs, and amylose is involved in this process. Amylose is a starch that accounts for approximately 20% of the dietary carbohydrate (Dworken *et al.* 2020). The high concentration of carbohydrates resulted in an increase in amylase activity to break down carbohydrates into simple sugar. This means that, in this study, carbohydrate, which is supposedly higher in amylopectin than amylose concentration, was rearranged to have more amylose concentration than amylopectin, thus having a lower carbohydrate content than usual (Ding *et al.* 2019). Low-carb foods tend to break down slowly during digestion. Thus, it is considered a low-GI food (Kaur *et al.* 2016). The addition of coconut oil during the cooking process showed that the use of coconut oil does not contribute to the carbohydrate concentration in the rice because it does not contain carbohydrates.

TDF content. There were significant differences ($p<0.05$) in the TDF content of WR and BR cooked with different methods. The presence of TDF in the diet is essential to increase the bulk of faeces because it has a laxative effect on the gut (Kaur *et al.* 2016). Generally, the BR samples have more TDF composition as compared to WR samples. The composition of TDF for WR treated with COXR and COR (4.0% and 6.2%) was significantly ($p<0.05$) lower than for BR treated with COXR and COR (5.6% and 8.0%), respectively. BR is known to be a good source of dietary fibre, and it was the highest in this study. The finding indicates that the BR has a higher TDF content than the WR. It is because BR is a whole-grain food containing bran and germ (Santos & Timoteo 2016). These parts specifically provide more fibre, vitamins, and minerals for those who consume BR. This also putatively elicits differential effects on satiety that are very advantageous in the regulation of energy intake as well as body weight (Sanfelice & Temussi 2016). In a comparison of methods 3 (COXR) and 4 (COR), there is an increasing pattern in the TDF concentration with the refrigeration method. During the refrigeration process, starch retrogradation occurs, resulting in an increase in TDF content. It happens when the available and digestible starches are converted into resistant starches, which are also considered dietary fibres because they are not broken down into glucose (Kaur *et al.* 2016). Refrigerated rice contains more Resistant Starch (RS) than unrefrigerated rice (Sanfelice & Temussi 2016). The use of coconut oil in this study also showed that coconut oil increases the TDF content of rice. It is because more amylose-lipid complexes are formed during the cooking process, producing RS type 5 (Birt *et al.* 2013).

In our present study, a positive correlation was observed in Table 2, wherein rice samples had a higher amylose content corresponding with the preparation methods. BR has a higher amylose concentration approximately 10 times (ranging between 91.39% and 113.3%) than WR (ranging between 3.94% and 9.43%). The higher the amylose content in the rice sample, the higher the starch retrogradation in the rice sample,

Table 2. The amylose concentration in WR and BR with different preparation methods

	Amylose concentration (%)			
	Control	2 (XCOR)	3 (COXR)	4 (COR)
Moisture				
WR	3.94±0.08	4.21±0.12	8.59±0.03	9.43±0.09
BR	91.39± 3.87	97.50±1.87	100.73±1.20	113.53±2.95

WR: White Rice; BR: Brown Rice

1 (Control): Rice cooked without additional of coconut oil and not being refrigerated

2 (XCOR): Rice cooked without additional of coconut oil and being refrigerated

3 (COXR): Rice cooked with additional of coconut oil and not being refrigerated

4 (COR): Rice cooked with additional of coconut oil and being refrigerated

which will subsequently increase the RS content (Helmyati *et al.* 2020). The increase in RS content in food lowers the eGI and calories of the food.

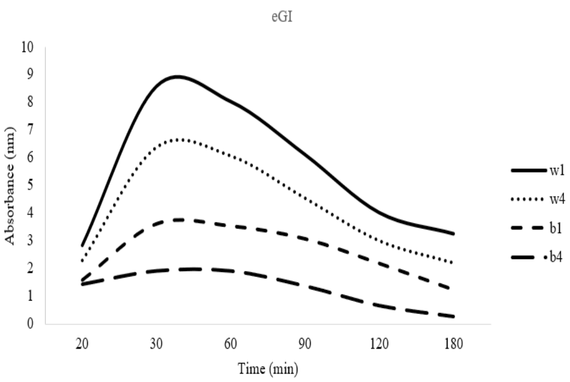
Energy value. Energy value measures the available amount of energy obtained from food via cellular respiration. In this study, Table 1 shows that BR with preparation method 1 (350.50 kcal) has the highest energy per 100 g among all samples analysed compared to the WR (344.71 kcal). According to the MyFCD (2003), medium-grain WR contains approximately 343 kcal, whereas the BR of Jasmine SunBrown's production contains 353 kcal. Even though BR is more nutritious, it contains more calories than WR. It is because the calorie content of food is determined by the fat, protein, and carbohydrate in the food (Rondanelli *et al.* 2019). As BR is wholegrain food, it has the germ and bran intact. Rice germ contains high levels of protein, fatty acids, and fibre, which are likely to contribute to the total calorie content of the food (Rondanelli *et al.* 2019). For this reason, the WR sample has fatty acid-rich germ removed during the milling process and contains fewer calories than the BR.

Above that, rice that has been refrigerated and rice with additional coconut oil have fewer calories because the DS is being converted into RS during starch retrogradation (Wang *et al.* 2015). RS contains fewer calories (2 kcal/g) than DS (4 kcal) (Maya *et al.* 2020). This can lower the calories consumed with the same food volume in each food intake. However, the rice sample of BR with preparation method 4 also has the lowest total energy per 100 g (169.91 kcal) than the WR (223.93 kcal).

Methods of food processing such as refrigeration affect the RS content of the food. According to the American Chemical Society (ACS 2015), the cooling process is essential because amylose from starch leaves the granules during gelatinisation to form hydrogen bonds between the amylose molecules outside the granule, so that it becomes resistant to the digestive enzyme (Wang *et al.* 2015). That is how RS is formed. WR, which is primarily known as a high-GI food, swaps to rice with a lower GI because of the starch retrogradation involving amylose reorganisation, which has changed the starch into RS or fibre (Ding *et al.* 2019).

The addition of coconut oil during the cooking process makes the oil enter the starch granules, and adding a layer to the starch makes it resistant to the digestive enzyme (Birt *et al.* 2013). The formation of amylose-lipid complexes restricts the swelling of the starch granules and the hydrolysis of the enzyme (Birt *et al.* 2013). Thus, in this situation, the starch granules have been converted into thermally stable RS type 5, which is formed through cross-linking of amylose-lipid.

The eGI. The GI of food is determined by its ability to raise blood glucose (Wang *et al.* 2015). The graph in Figure 1 shows that the eGI of BR is lower than the WR. This indicates the lower postprandial phase of hunger. It may be due to the lesser and slower breakdown of the BR than the WR. This difference appears to be influenced by the bran layer of the BR, which inhibits gastric acid absorption and slows gastric emptying, which manifests in the consequential state of satiety (Kaur *et al.* 2016). Besides, the higher the Resistant Starch (RS) contained in the rice sample, the lower the eGI it has. The higher RS content decreased its available carbohydrate content because RS is classified as an unavailable carbohydrate as it cannot be digested and



w1: White rice cooked without addition of coconut oil and not being refrigerated (control)
w4: White rice cooked without addition of coconut oil and being refrigerated
b1: Brown rice cooked with addition of coconut oil and not being refrigerated
b4: Brown rice cooked with addition of coconut oil and being refrigerated

Figure 1. The eGI of total starch in WR and BR cooked with different preparation methods

absorbed in the SI (Wang *et al.* 2015). Unlike the DS, RS is not broken down in the SI, where the carbohydrates are normally metabolised into glucose to be absorbed into the bloodstream. Thus, reducing the higher peak of blood glucose after a meal.

Since data is normally distributed, the Pearson correlation test was used to measure the strength and direction of the association between amylose concentration and eGI. The result showed a significant reduction in the eGI with the addition of amylose. Therefore, there is a significant relationship between amylose concentration and eGI. The result from simple linear regression analysis has shown that there is a significant, very strong, and negative linear relationship between amylose concentration and eGI (Table 3), tested using Pearson's correlation test ($p<0.001$, $r=-0.935$).

Since data is not normally distributed, Spearman's rank correlation test was used to measure the strength and direction of the association between amylose concentration and calories (Table 3). The result showed a significant reduction in calories with the addition of amylose concentration. Thus, there is a significant relationship between amylose concentration and

Table 3. The relationship between eGI and calories with different amylose concentrations

	eGI			Calories		
	n	r	*p*	n	r	*p*
Amylose concentration	4	-0.935	<0.001$^{\alpha}$	4	-0.634	<0.001$^{\alpha}$

α: Pearson Correlation; eGI: estimated Glycaemic Index

calories. The result from simple linear regression analysis has shown that there is a significant, strong, and negative linear relationship between amylose concentration and calories, tested using Spearman's rank correlation test ($p<0.001$, $r=-0.634$).

CONCLUSION

The methods of cooking rice with the addition of coconut oil and/or refrigerated rice were some of the alternative preparation techniques to lower both the calorific value and glycaemic index for the preparation of healthier rice meals. Additionally, the favourable effects on lowering calories and glycaemic index may be due to the increase in resistant starch (RS3 and RS5) contained in the cooked rice. Consuming refrigerated rice that has been cooked with coconut oil can be used as an alternative preparation technique to lower both the calorific value and the glycaemic index for the preparation of healthier rice meals for health-conscious individuals. In conclusion, the rice cooked with additional of coconut oil and being refrigerated (COR) method can be recommended to produce the lowest eGI for both WR and BR. Alternatively, the consumers may apply this COR method to cook BR to produce healthy rice not only with low in eGI and caloric value but also high in DF.

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DECLARATION OF INTERESTS

The authors have no conflicts of interest.

REFERENCES

[ACS] American Chemical Society. 2015. New low-calorie way to cook rice could help cut rising obesity rates -- ScienceDaily. https://www.sciencedaily.com/releases/2015/03/150323075233.htm?utm_medium=cpc&utm_campaign=ScienceDaily_TMD_1&utm_source=TMD [Accessed 25th January 2023].

[AOAC] Association of Official Analytical Chemists. 2020. Official Methods of Analysis of AOAC International - 20th Edition. Maryland (USA): AOAC International.

Amagliani L, O'Regan J, Kelly AL, O'Mahony. 2017. The composition, extraction, functionality and applications of rice proteins: A review. Trends Food Sci 64:1−12. https://doi.org/10.1016/j.tifs.2017.01.008

Arik Kibar EA, Gönenç İ, Us F. 2013. Effects of fatty acid additaon on the physicochemical properties of corn starch. Int J Food Prop 17(1):204−218. https://doi.org/10.1080/10942912.2011.619289

Birt DF, Boylston T, Hendrich S, Jane JL, Holis J, Li L, McClelland J, Moore S, Phillips GJ, Rowling M *et al.* 2013. Resistant starch: Promise for improving human health. Adv Nutr 4(6):587. https://doi.org/10.3945/an.113.004325

Chapagai MK, Wan Rosli WI, Karilla T, Pinkaew S. 2020. Variety difference of physicochemical and cooking properties of selected brown rice from Thailand and Malaysia. Food Res 4(3):630−635. https://doi.org/10.26656/fr.2017.4(3).305

Demirkesen-Bicak H, Arici M, Yaman M, Karasu S, Sagdic O. 2021. Effect of different fermentation condition on estimated glycemic index, in vitro starch digestibility, and textural and sensory properties of sourdough bread. Foods 10(3):514. https://doi.org/10.3390/foods10030514

Ding L, Zhang B, Tan CP, Fu X, Huang Q. 2019. Effects of limited moisture content and storing temperature on retrogradation of rice starch. Int J Biol Macromol 137:1068−1075. https://doi.org/10.1016/j.ijbiomac.2019.06.226

Dworken HJ, Keeton WT, Carr Hightower N, Sircus W, Hightower N, Sircus W. 2020. Human digestive system. Britannica. https://www.mendeley.com/catalogue/1133e640-da5a-3444-b264-c9f2f5e765e6/?utm_source=desktop&utm_medium=1.19.8&utm_campaign=open_catalog&userDocumentId=%7Ba5b3f265-7f42-3da5-b509-e344aaaf126b%7D [Accessed 29th January 2023].

Eyinla TE, Sanusi, RA, Maziya-Dixon B. 2022. Evaluation of in vitro and in vivo glycemic index of common staples made from varieties of white yam (*Dioscorea rotundata*). Front Nutr 9:983212. https://doi.org/10.3389/fnut.2022.983212

Ganjifrockwala FA, Joseph JT, George G. 2017. Decreased total antioxidant levels and increased oxidative stress in South African type 2 diabetes mellitus patients. Journal of Endocrinology, Metabolism and Diabetes of South Africa 22(2):21−25. https://doi.org/10.1080/16089677.2017.1324590

Helmyati S, Kiasaty S, Amalia AW, Sholihah H, Kurnia M, Wigati M, Rohana AJ, Ishak WRW, Hamid NA, Malik V *et al.* 2020. Substituting white rice with brown and black rice as an alternative to prevent diabetes mellitus type 2: A case-study among young adults in Yogyakarta, Indonesia. J Diabetes Metab Disorder 19(2):749−757. https://doi.org/10.1007/s40200-020-00555-8

Helmyati S, Amalia AW, Sholihah H, Kurnia M, Kiasaty S, Wigati M, Rohana AJ, Ishak WR, Hamid NA, Malik V *et al.* 2021. The pattern of carbohydrate intake among university students from Eastern Indonesia tends to be diverse. Curr Nutr Food Sci 17(8):867−875. https://doi.org/10.2174/1573401317666210224123425

Jain A, Rao SM, Sethi S, Ramesh A, Tiwari S, Mandal SK, Singh NK, Modi N, Bansal V, Kalaichelvani C. 2012. Effect of cooking on amylose content of rice. Eur J Exp Biol 2(2):385−388.

Joanne M. 2018. What are the dangers of excessive amounts of carbohydrates? https://healthyeating.sfgate.com/dangers-excessive-amounts-carbohydrates-4345.html [Accessed 22nd May 2022].

Kaur B, Ranawana V, Henry J. 2016. The glycemic index of rice and rice products: A review, and table of GI values. Crit Rev Food Sci Nutr 56(2):215−236. https://doi.org/10.1080/10408398.2012.717976

Kim YS, Lee H. 2013. Effect of quality characteristics on brown rice produced from paddy rice with different moisture contents. J Korean Soc Appl Biol Chem 56:289−293. https://doi.org/10.1007/s13765-012-3151-9

Lauben. 2022. Lauben low sugar rice cooker 1500at. https://www.lauben.com/en/electric-cookers/low-sugar-rice-cooker-1500at/ [Accessed 24th January 2023].

[MyFCD] Malaysian Food Composition Database 1997. Malaysian Food Composition Database. https://myfcd.moh.gov.my/ [Accessed 19th April 2023].

Maya S, Sulaeman A, Sinaga T. 2020. Alternative snack for diabetic patients from sago (*Metroxylon* sp.) starch and tempe. J Gizi Pangan 15(1):27−36. https://doi.org/10.25182/jgp.2020.15.1.27-36

Ng YV, Tengku Ismail TA, Wan Rosli, WI. 2020. Effect of overripe banana in developing high dietary fibre and low glycaemic index cookie. Br Food J 122(10):3165−3177. https://doi.org/10.1108/BFJ-12-2019-0934

Nur Shafinaz MS, Wan Mazlina MS, Hairil rashmizal AR, Fatimah S. 2022. Effect of storage temperatures on physico-chemicals, phytochemicals and antioxidant properties of watermelon juice (*Citrullus lanatus*). Metabolites 12(1):75. https://doi.org/10.3390/metabo12010075

Rondanelli M, Miccono A, Peroni G, Nichetti M, Infantino V, Spadaccini D, Alalwan TA, Faliva MA, Perna S. 2019. Rice germ macro- and micronutrients: A new opportunity for the nutraceutics. Nat Prod Res 35(9):1532−1536. https://doi.org/10.1080/14786419.2019.1660329

Sanfelice D, Temussi PA. 2016. Cold denaturation as a tool to measure protein stability. Biophys Chem 208:4−8. https://doi.org/10.1016/j.bpc.2015.05.007

Santos NLC, Timoteo VJA. 2016. Differences in satiating effects of white rice and brown rice in selected Filipino adults. Philipp J Crop Sci 41(2):55−60.

Santos JCO, Conceicao MM, Santos Martins J, Carlos J *et al.* 2020. Comparative study of physico-chemical properties of coconut oil (*Cocos nucifera* L.) obtained by industrial and artisanal processes. BioTechnology: An Indian Journal 16(3):1. https://doi.org/10.37532/tsbt.2020.16(3).210

Schmeing TM. 2013. Ribosome Structure. Encyclopedia of Biological Chemistry 1:128−135. https://doi.org/10.1016/B978-0-12-378630-2.00400-X

Taborsky G. 1979. Protein alterations at low temperatures: An overview. https://doi.org/10.1021/ba-1979-0180.ch001

Tanaka N, Okuda T, Shinohara H, Hirano N, Higashine Y, Hamaguchi I, Kang J, Asano Y, Umemoto M, Sakakihira *et al.* 2020. Prevalence of masked obesity associated with lifestyle-related habits, dietary habits, and energy metabolism in Japanese young women. J Gizi Pangan 15(2):81−90. https://doi.org/10.25182/jgp.2020.15.2.81-90

[USDA] U.S Department of Agriculture. 2020. Food and Nutrition Information Center (FNIC). https://www.nal.usda.gov/programs/fnic [Accessed 28th February 2023].

[WHO] World Health Organization. Obesity and overweight. 2020. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight [Accessed 25th May 2022].

Wang SS, Li C, Copeland L, Qing N, Wang S. 2015. Starch retrogradation: A comprehensive review. Compr Rev Food Sci Food Saf 14(5):568−585. https://doi.org/10.1111/1541-4337.12143

Yuliana ND, Akhbar MA. 2020. Chemical and physical evaluation, antioxidant and digestibility profiles of white and pigmented rice from different areas of Indonesia. Braz J Food Technol 23:e2018238. https://doi.org/10.1590/1981-6723.23818