

Local Rice Consumption and the Risk of Developing Insulin Resistance in Wistar Albino Rats

Abdulrazak Mohammad Sani ¹ and Salisu Yusuf Yahaya ²

¹Department of Biochemistry, Zamfara State University Talata-Mafara

²Department of Biochemistry, College of Natural and Applied Science, Al-Qalam University, Katsina

*Correspondence Author's Email & Phone No.: auta091@gmail.com; +2347039887934

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ABSTRACT

Rice consumption, particularly of highly processed white rice (WR), has been associated with increased risk of insulin resistance (IR). This study aimed to compare the impact of consuming WR versus brown rice (BR) from five common local rice varieties in Nigeria on the development of IR using a Wistar albino rat model. Five local rice cultivars (Jamila, Kwandala, MBC, Yarkatabore, Farar jalof) were collected, with one set kept unpolished (BR) and the other polished (WR). Proximate analysis and quantification of bioactive compounds (total phenols, flavonoids) were performed. Wistar albino rats were fed either a normal diet, high-fat diet, or diets containing 100% BR or WR for 12 weeks. Body weight, fasting blood glucose, glycogen, triglycerides were assessed. BR varieties had higher protein, fiber, and carbohydrate content compared to WR. BR also exhibited significantly greater total phenolic and flavonoid contents. Rats fed BR showed no significant weight gain ($p < 0.05$), while some WR groups gained weight. Fasting blood glucose was elevated in WR groups versus control and BR groups. Blood glycogen was lower, and triglycerides higher, in certain WR groups. Consumption of BR varieties may confer protective effects against IR compared to WR in this rat model. These findings highlight the potential metabolic health benefits of incorporating local BR varieties into the diet to mitigate development of chronic disorders.

Keywords: brown rice, white rice, insulin resistance, diabetes mellitus, wistar albino rat

1.0 INTRODUCTION

The monocotyledonous plant known as *Oryza sativa*, or Asian rice, and *Oryza glaberrima*, or African rice, are the two cultivated species of the Poaceae (formerly Graminae) grass family, which comprises twenty wild species (Anindita *et al.*, 2019), it was found that *Oryza sativa* is currently the most extensively grown species globally (Saka *et al.*, 2023). Globally, rice is the most significant and extensively cultivated food crop. Almost half of the world's population relies on it as a staple food (Shehu *et al.*, 2023). For food security, it is both safe and essential (Flanary and Keane, 2020). A number of automated procedures, such as: hulling and milling, are used to produce polished rice, also known as white rice, which is mostly composed of starch (Saleh *et al.*, 2019). It is the type of rice that is consumed most frequently worldwide (Shehu *et al.*, 2023). Glycemic index values for white rice are generally higher than those of whole grains, even though they vary depending on the type of white rice, amount of processing, cooking time, and amylose content (Fiona *et al.*, 2021). About 67 % of the vitamin B3, 80 % of the vitamin B1, 90 % of the vitamin B6, 50 % of the manganese and phosphorus, 60 % of the iron, and all other nutrients are destroyed during the thorough milling and polishing process that transforms brown rice into white rice (Kalita *et al.*, 2021). Moreover, among populations for which rice is a staple food, white rice is the main source of dietary glycemic load (Ngo *et*

al., 2023). Notwithstanding the fact that polished white rice is frequently preferred by rice consumers, brown rice still has important nutrients that are not lost during polishing. This could be as a result of white rice's softness and more appealing appearance than brown rice (Saleh *et al.*, 2019). Different gastrointestinal enzymes are known to break down dietary carbohydrates into glucose (Christopher, 2019). For the majority of human cells, glucose serves as their main energy source. Insulin, a small peptide hormone, is necessary for the cells to absorb glucose. For these tissues, insulin signaling is therefore essential. But insulin resistance (IR) results from a reduction in insulin sensitivity brought on by a disruption of several molecular signaling pathways (li *et al.*, 2022).

In insulin-dependent cells like adipocytes and cardiomyocytes, IR is a complex pathological condition characterized by an inappropriate cellular response to the insulin hormone (Nolan and Prentki, 2019). Many metabolic diseases, including type 2 diabetes (T2D) and the metabolic syndrome, are caused by and accompanied by IR (Ekoru *et al.*, 2019).

Hyperglycemia, insulin resistance, and relative insulin deficiency are the hallmarks of type 2 diabetes, also referred to as non-insulin-dependent diabetes mellitus. It is the outcome of the interplay between behavioral,

environmental, and genetic risk factors (Yajuan *et al.*, 2020). Type 2 diabetes is associated with an increased risk of both short- and long-term complications, many of which are precipitous in nature.

Non-communicable chronic diseases (NCCDs) like type 2 diabetes and other metabolic disorders are becoming more prevalent worldwide. These diseases have historically been linked to the adoption of unhealthy Western lifestyle factors like the consumption of highly processed, high-energy foods (Imam and Ismail, 2017). NCCDs include diabetes and other metabolic diseases. As of right now, 463 million adults worldwide are estimated to have diabetes; by 2030, that figure is predicted to rise to 578 million, and by 2045, it is predicted to reach 700 million (IDF, 2019). According to IDF (2019), Nigeria has an estimated 20.7 million diabetics, making it the second-highest DM prevalence country in Africa. Imam *et al.* (2014) found that rats whose parents were fed WR as a staple diet had a higher chance of developing insulin resistance in their offspring. A different study showed that eating WR causes rats with type 2 diabetes to have worsening antioxidant status, but eating BR and germinated brown rice (GBR) helps to improve blood glucose levels and preserve antioxidant status to varying degrees in the rats (Saka *et al.*, 2023). To stop people from becoming even more affected by the pandemic, additional steps must be taken even though efforts have been made to prevent exposure to these NCCDs. Consequently, using the Wistar albino rat as a model organism, this study compares the risk of developing insulin resistance from consuming either white or brown rice in five commonly grown rice varieties that are grown locally.

2.0 METHODOLOGY

2.1 Sample Collection and Preparation

The various types of rice, which include: *Kwandala*, *Jamila*, *MBC*, *Yarkatabore*, and *Farar Jalof*, were acquired from various marketplaces within Zamfara State and its adjacent states. Seeds were split into two sets, peeled, and sun-dried. While one set (WR) was polished, the other set (BR) was left unpolished. To obtain rice flour suitable for analysis, portions of the BR and WR samples were then milled.

2.2 Study Design

2.2.1 Wistar Albino Rats: These rats were bought from the Nigerian Institute of Trypanosomiasis Research in Kaduna and kept in a room temperature range of 27 to 35 degrees Celsius. They were also provided with a regular diet and were exposed to a natural cycle of light and dark. The animals were kept on a regular rat diet for one week. Prior to experiments, a modified diet comprising 100%

BR or WR of rice varieties was used, with 10% HFD and ND serving as a control.

2.2 Experimental Design

Rats were divided into 12 groups of five rats each to assess the impact of local rice consumption on the risk of developing IR. While Groups 1 and 2 received normal ND and HFD diets, respectively, as control groups, each group was given a different type of rice. Over the course of 12 weeks, the rats were permitted to eat their prescribed diets. Then an analysis of their weight gain was done. Rats from each group were anaesthetized in chloroform, and sacrifice. Then, the blood was collected and used for biochemical analyses.

GROUP 1: Control rats given normal diet

GROUP 2: Control rats given HFD

GROUP 3: the rats in this group given WR of Jamila variety

GROUP 4: the rats in this group given with BR Jamila variety

GROUP 5: the rats in this group given with WR of Kwandala variety

GROUP 6: the rats in this group given with BR Kwandala variety

GROUP 7: the rats in this group given with WR of Yarkatabore variety

GROUP 8: the rats in this group given with BR of Yarkatabore variety

GROUP 9: the rats in this group given with WR of MBC variety

GROUP 10: the rats in this group given BR of MBC variety

GROUP 11: the rats in this group given WR of Farar jalof variety

GROUP 12: the rats in this group given BR of Farar jalof variety.

2.4 Proximate Analysis

The rice samples' proximate composition was determined as previously by Abubakar *et al.*, (2020) using the official procedures of the Association of Official Analytical Chemists (AOAC) (2023), albeit with some slight modifications. Consequently, the contents of ash, moisture, crude protein, fat, and fiber were measured, and the difference method was used to estimate the amount of carbohydrates. (I.e. calculating the total of each other %age composition and deducting it from 100).

2.5 Bioactive Compounds Analysis

2.5.1 Methanolic WR and BR Extract Preparation

Fifty grams (50 g) of powdered WR and BR were extracted separately using 500 mL of methanol by maceration for 72 hours. The residue was then filtered through a Whatman filter paper No 1. The extracts were then cleaned, sterile, with white muslin cloth. The

filtrate's total phenolic and flavonoid content was determined after it was concentrated under low pressure and turned into methanolic extracts.

2.5.2 Total Phenolic Content (TPC) Determination

The TPC was ascertained using a modified Folin-Ciocalteu colorimetric method (Sisco Research Laboratories, Mumbai, India) with a few minor modifications made in accordance with the manufacturer's instructions. In brief, 500 μ L of newly made 10 % Folin-Ciocalteu reagent was incubated for five minutes along with different concentrations of 150 μ L extracts or gallic acid (positive control). Saturated sodium carbonate (1 mL) was then added to neutralize the reaction. After 40 minutes of incubation, the absorbance was measured at 760 nm, and the results were expressed as milligrams of gallic acid equivalent per 100 g of extract weight (mg GAE/g DW).

2.5.3 Determination of Total Flavonoid Contents (TFC)

The Dowd method, which was reported by [Abubakar *et al.*, 2020, Silitonga *et al.*, 2023], and modified from Arvouet-Grand (1994), was used to determine the TFC. The procedure involved mixing an equal volume of the extract combined with two (2) milliliters of 2 % aluminum trichloride (AlCl₃) (Changzhou Baixing, Tianjin, China) in methanol. The mixture was then incubated for 10 minutes at room temperature. The absorbance reading at 415 nm was then compared to a blank sample that contained two (2) milliliters of methanol and two (2) milliliters of extract without AlCl₃. Using a standard curve and quercetin (Sisco Research Laboratories, Mumbai, India) as the standard, the TFC was ascertained. The quercetin equivalent per gram of extract weight (mg QE/gDW) was calculated by averaging three measurements.

2.6 Body Weight Measurements

The weight of the rats was measured before and after the intervention (12 weeks) using a Kern analytical balance (Kern & Sohn Ltd., Balingen, Germany). Five (5) rats per group were anesthetized with chloroform and then placed in a pre-weighed empty tube (Wuhan Servicebio Technology Co., Ltd., Wuhan, China) and weighed again. Weight differences were recorded in grams (g).

2.7 Biochemical Analysis

For each intervention diet, five rats were fasted and given a chloroform anesthesia. The rat's blood was drawn from the jugular vein and put in a blood sample container (Vacutainers) after they were placed in a bowl. The blood was centrifuged in a refrigerated floor centrifuge (MX-301 High Speed, Tomy Kogyo Co. Tagara, Japan) for three minutes at 14,000 \times g. Inc. at 4°C to extract serum.

For biochemical analysis, the serum that was extracted along with the blood was utilized.

2.7.1 Glucose Assay

Using the enzymatic glucose oxidase (GO) test kit (Spinreact, Girona, Spain) in accordance with the manufacturer's instructions, fasting blood glucose levels were measured; the results were expressed in mg/dL.

2.7.2 Glycogen Assay

In accordance with the manufacturer's instructions, the Anthrone colorimetric kit (Solarbio Life Science, Beijing, China) was also used to measure the blood glycogen level; the results were expressed in mg/g sample.

2.7.3 Triglyceride Assay

A colorimetric kit (Spinreact, Girona, Spain) was used to measure the blood triglyceride in accordance with the manufacturer's instructions.

2.8 Data Analysis

The analyses were performed using the group mean \pm SEM. IBM SPSS (version 16.0) was used to conduct a one-way analysis of variance (ANOVA) with a cutoff value of $p < 0.05$ in order to assess the significance level of mean differences.

3.0 RESULT

3.1 Proximate Analysis

Based on the proximate composition analysis, the protein content in the BR varieties varied between 4.8 ± 0.2 % and 6.8 ± 0.1 %. *Jamila_B* had the highest value and *Yarkatabore_B* had the lowest. While *Mai Bakin-Charki* (MBC), *Kwandala_W* (5.5 ± 0.1 %), and *Farar jalof* (4.2 ± 0.2 %) had the highest and lowest value in WR varieties. Likewise, the fiber content ranged from 8.1 ± 0.3 % for *Kwandala_B* to 9.4 ± 0.4 % for *Yarkatabore_B* for BR, and from 7.5 ± 0.3 % to $8, 5 \pm 0.2$ % for *Kwandala_W* and *Yarkatabore_W*. All five BR varieties' protein and fiber compositions did not differ significantly ($p > 0.05$), but there were significant differences ($p < 0.05$) between the protein content of the WR varieties. Carbohydrate content varied from 68.2 ± 0.1 % to 71.1 ± 0.2 % for the BR and from 70.9 ± 0.2 % to 73.3 ± 0.1 % for the WR. There were significant differences ($p < 0.05$) in the carbohydrate composition of both BR and WR varieties. Furthermore, there were no significant differences ($p > 0.05$) in the lipid content of all BR and WR varieties examined. Likewise, no significant differences ($p > 0.05$) in the moisture composition of every rice variety under investigation, with the exception of the WR and BR varieties *Yarkatabore_W* and *Jamila_B*, which both had ($p < 0.05$). In comparison to the BR, the WR had more ash. The variation in BR was between

2.4 ± 0.2 % and 3.2 ± 0.3 %, while in WR it was between 1.8 ± 0.1 % and 2.9 ± 0.3 %. Except for *Maibakincarki* cultivars ($p < 0.05$), there were no significant differences ($p > 0.05$) found between BR and WR varieties (Table 1).

Table1: Proximate composition of rice varieties (n=3)

S/NO	RICE CULTIVARS	% MOISTURE	% ASH	% PROTEIN	% FIBER	% LIPID	% CARBOHYDRATE
1	JAM B	11.3 ± 0.2b	2.4 ± 0.2b	6.8 ± 0.1c	8.6 ± 0.1b	2.7 ± 0.2c	68.2 ± 0.1a
2	JAM W	10.3 ± 0.1a	1.8 ± 0.1a	4.6 ± 0.1a	7.8 ± 0.1a	2.2 ± 0.1ab	73.3 ± 0.1c
3	MBC B	11.4 ± 0.2b	2.9 ± 0.2c	6.2 ± 0.1c	9.3 ± 0.1c	2.7 ± 0.1c	67.4 ± 0.5a
4	MBC W	10.7 ± 0.1ab	2.5 ± 0.2b	5.5 ± 0.1b	8.4 ± 0.2b	1.9 ± 0.2a	70.9 ± 0.2b
5	FRJ B	10.8 ± 0.2ab	2.8 ± 0.1c	4.8 ± 0.2a	8.2 ± 0.1ab	2.4 ± 0.1bc	71.1 ± 0.2b
6	FRJ W	10.4 ± 0.1a	2.4 ± 0.1b	4.2 ± 0.2a	7.8 ± 0.2a	2.2 ± 0.1ab	73.0 ± 0.2c
7	YKB B	12.6 ± 0.2c	2.7 ± 0.3bc	6.2 ± 0.2c	9.4 ± 0.4c	2.2 ± 0.2ab	69.2 ± 0.2a
8	YKB W	12.4 ± 0.2c	2.2 ± 0.2b	5.5 ± 0.2b	8.5 ± 0.2b	1.9 ± 0.2a	71.4 ± 0.2b
9	KDL B	11.5 ± 0.4b	3.2 ± 0.3c	5.2 ± 0.1b	8.1 ± 0.3ab	2.5 ± 0.2bc	68.4 ± 0.1a
10	KDL W	10.5 ± 0.2a	2.9 ± 0.3c	4.5 ± 0.2a	7.5 ± 0.3a	2.2 ± 0.1ab	71.8 ± 1.5bc

Means ± SD within a column marked with the same superscript letters are not significantly different ($p < 0.05$). B = brown rice, W = white rice. Jamila = JAM, Maibakincarki = MBC, Farar jalof = FRJ, Yarkatabore = YKB, Kwandala = KDL

3.2 Bioactive Compound Analyses

The result of the analysis demonstrated that BR and WR of the same variety differed significantly ($p < 0.05$). The phenolic content ranged from 0.7 ± 0.2 to 1.5 ± 0.1 mg GAE/g for BR and from 1.0 ± 0.0 to 1.8 ± 0.1 mg GAE/g for WR. The total flavonoid content varied from 4.3 ± 0.2 to 5.7 ± 0.2 GAE/g for BR and from 4.8 ± 0.3 to 6.5 ± 0.3 GAE/g for WR. There were significant differences ($p < 0.05$) between all the five BR and WR (see Table 2).

Table 2: Bioactive composition of rice varieties

S/NO	RICE CULTIVARS	TOTAL PHENOLIC (mg/TEA/g)	TOTAL FLAVONOID (mg/TEA/g)
1	JAM B	1.8 ± 0.1a	5.6 ± 0.2a
2	JAM W	1.5 ± 0.1b	4.7 ± 0.2b
3	MBC B	1.0 ± 0.0c	4.8 ± 0.3b
4	MBC W	0.9 ± 0.0c	4.3 ± 0.2b
5	FRJ B	1.2 ± 0.1c	6.4 ± 0.1a

6	FRJ W	0.8 ± 0.0c	5.7 ± 0.2a
7	YKB B	1.5 ± 0.3b	6.5 ± 0.3a
8	YKB W	0.8 ± 0.1c	5.4 ± 0.3a
9	KDL B	1.6 ± 0.2ab	5.6 ± 0.3a
10	KDL W	0.7 ± 0.2c	4.6 ± 0.3b

Means ± SD within a column marked with the same superscript letters are not significantly different ($p < 0.05$). B = brown rice, W = white rice. Jamila = JAM, Maibakincarki = MBC, Farar jalof = FRJ, Yarkatabore = YKB, Kwandala = KDL

3.3 Effects on Changes in Body Weight

A statistical analysis revealed significant differences ($p < 0.05$) between the BR, WR and HFD groups for both groups. The initial weight of rats on BR before intervention ranges from 177 ± 4.2 to 223 ± 9.5 , with *Yarkatabore* and *Farar Jalof* having the lowest and highest weights, respectively. For the WR at the start of the dietary intervention, the weight ranges from 180 ± 8.0 to 212 ± 6.4 , with rats *Jamila* variety having the lowest weight while *Farar Jalof* variety rats having the highest weight. However, there was a significant difference ($p > 0.05$) in weight differences between the groups and the control group in rats that consumed the intervention diets for a 12-week period, with the exception of the WR varieties of *Kwandala*, *Jamila*, and *MBC* (Table 3).

Table 3: Changes in body weight after 12 weeks of diet intervention.

S/NO	RICE CULTIVARS	INITIAL WEIGTH (g)	FINAL WEIGTH (g)	Change in weight
1	JAM B	213 ± 17.1a	220 ± 17.0a	7 ± 0.0a
2	JAM W	180 ± 8.0b	195 ± 7.4b	15 ± 0.6b
3	MBC B	201 ± 7.6a	206 ± 6.7ab	5 ± 0.9a
4	MBC W	182 ± 4.9b	190 ± 3.8b	8 ± 1.1a
5	FRJ B	223 ± 9.5a	228 ± 5.7a	5 ± 3.8a
6	FRJ W	212 ± 6.4a	216 ± 6.7a	4 ± 0.3a
7	YKB B	177 ± 4.2b	182 ± 4.4b	5 ± 0.2a
8	YKB W	195 ± 3.5ab	204 ± 8.2ab	9 ± 4.7a
9	KDL B	186 ± 3.8b	197 ± 7.8b	11 ± 4.0ab
10	KDL W	211 ± 4.2a	222 ± 4.6a	11 ± 4.0ab
11	ND	191 ± 9.0ab	209 ± 9.9ab	18 ± 0.9b
12	HFD	192 ± 5.7ab	216 ± 6.0a	24 ± 0.3b

Means ± SD within a column marked with the same superscript letters are not significantly different ($p < 0.05$). B = brown rice, W = white rice. Jamila = JAM, Maibakincarki = MBC, Farar jalof = FRJ, Yarkatabore = YKB, Kwandala = KDL

3.4 Impact on the Biochemical Variables

3.4.1 Impact of the consumption of rice varieties on fasting blood sugar level

After 12 weeks of intervention diets, Figure 1 depicts their fasting blood sugar levels; there were notable variations ($p < 0.05$) between BR and WR groups. The WR group showed higher values than the control groups

($p < 0.05$), WR's hyperglycemic effects are evident, as evidenced by the *Kwandala* variety's highest fasting blood glucose level of 186 ± 5.16 mg/dL. Conversely, there was no statistically significant difference between the BR varieties and the normal control group ($p > 0.05$).

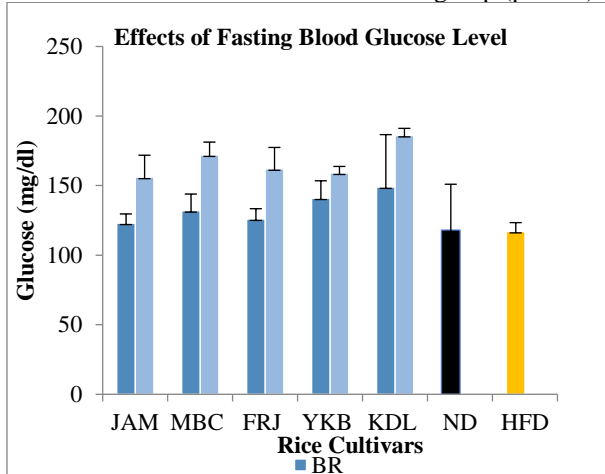


Figure 1 Effects of different rice varieties on fasting blood glucose in rats after 12 weeks of intervention diets. Bars represent mean \pm SD ($n = 3$). Black and yellow bars represent the groups fed normal diet and high fat diet respectively. ND = normal diet, HFD = high-fat diet Jamila = JAM, Maibakincarki = MBC, Kwandala = KDL, Yarkatabore = YRK, Farar jalof = FRJ,

3.4.2 Impact of the consumption of rice varieties on fasting blood glycogen

After consuming the intervention diets for 12 weeks, the blood glycogen levels of the rats are depicted in Figure 2. The range of glycogen levels in rats with BR strains was 4.1 ± 0.63 mg/100/mg to 4.7 ± 0.46 mg/100/mg. Rats on the other WR variants differ significantly ($p < 0.05$) from the control group, but rats on BR show no significant difference ($p < 0.05$) from the control group.

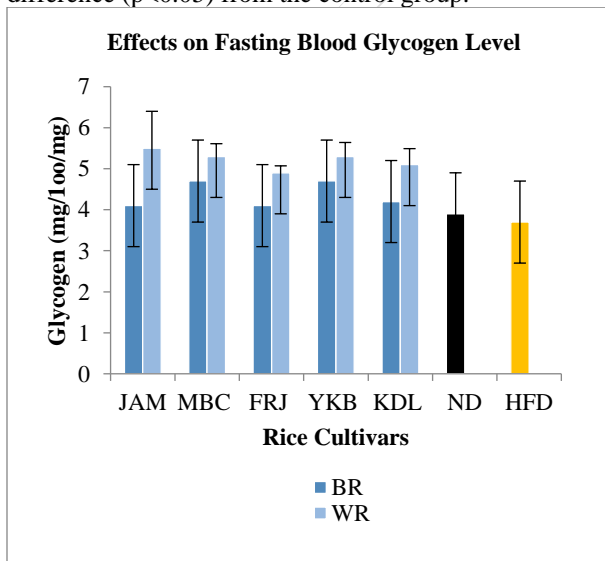


Figure 2. Effects of different types of rice on rats' fasting blood glycogen levels following a 12-week intervention diet. The bars show the mean \pm SD ($n = 3$). The groups fed the normal and high-fat diets are shown by black and yellow bars, respectively. ND stands for normal diet, HFD for high-fat diet, JAM for Jamila, MBC for Maibakincarki, KDL for Kwandala, YRK for Yarkatabore, and FRJ for Farar Jalof

3.4.3 Impact of the consumption of rice varieties on blood triglyceride Level

Figure 3 displays the differences in blood triglyceride levels after the intervention diet for 12 weeks. There was no significant difference ($p > 0.05$) between the triglyceride levels of the rats on the BR strains, which ranged from 48.3 ± 3.30 to 83.0 ± 5.16 mg/dl, and the control group's levels 39.5 ± 3.11 mg/dl". Comparing the WR groups to the HFD group, the triglyceride levels were not significantly different ($p > 0.05$), with the WR groups' levels ranging from 59.5 ± 10.47 mg/dL to 89.3 ± 2.22 mg/dL.

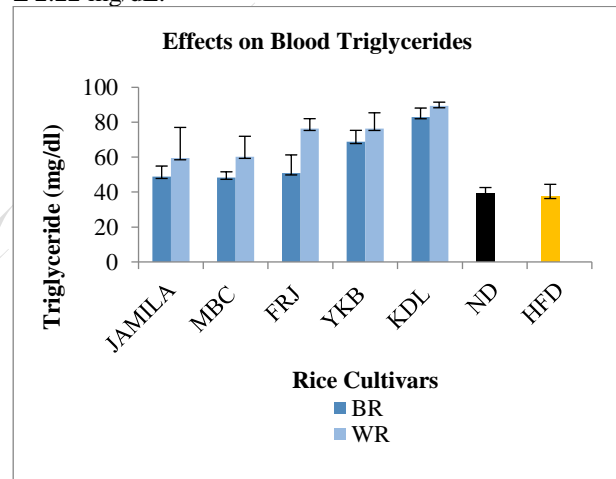


Figure 3: Effects of rice varieties on fasting blood triacylglyceride levels in rats after 12 weeks of intervention diet. Bars represent mean \pm SD ($n = 3$). Black and yellow bars represent the groups given normal diet and high-fat diet, respectively. ND = normal diet, HFD = high-fat diet Jamila = JAM, Maibakincarki = MBC, Kwandala = KDL, Yarkatabore = YRK, Farar jalof = FR

4.0 DISCUSSION

Nigeria's staple diet consists mainly of local rice varieties, which give the country's large population energy and nutrition. Protein makes up the fundamental building blocks of all body tissues and cells, and rice contains both starch and protein (Xinkang *et al.*, 2023). Rice is an important grain because it contains protein, which is essential to the grain's nutritional quality (FAO, 2020). As a wholesome, reasonably priced, and readily accessible protein source, rice protein has a lot of potential. It is regarded as a novel food ingredient that can successfully take the place of current grain and

animal protein sources (Jayaprakash *et al.*, 2022). The range of protein contents for the BR and WR varieties under study was 4.8% to 6% and 4.2% to 5.5%, respectively. These results indicate that the protein content of the WR forms is lower than that of the BR varieties. The current investigation revealed protein contents that were in line with those reported by Oko and Ugwu (2011) in their investigation of a number of local rice varieties and higher than previously documented values for a few local rice varieties (Shehu *et al.*, 2023). The presence of the bran layer accounts for the higher protein content in BR, whereas the milling process is responsible for the lower value of WR.

The relatively high carbohydrate content of all the rice varieties under investigation suggests that they are all suitable sources of energy. The results showed that the range of values for BR was 68.2 % to 71.1%, and for WR it was 70.9% to 73.3 %. These findings were consistent with Imam *et al.*, (2014), on their research in Nutrigenomic effects of brown and white rice on the pathogenesis of metabolic disorders using a fruit fly model in Sokoto (Northern Nigeria). This is understandable given that one of the most well-known dietary sources of carbohydrates is rice. WR and BR had comparable carbohydrate contents, most likely as a result of polishing having no effect on rice's carbohydrate makeup. Because polishing had little effect on the carbohydrate composition of rice, the carbohydrate content of white rice (WR) and brown rice (BR) was comparable. The primary component of rice's glycemic index which measures the quantity of glucose available for either immediate energy production or storage for later use is carbohydrates. Eating WR exclusively can result in persistent hyperglycemia, which can cause metabolic disorders like insulin resistance and obesity (Abubakar *et al.*, 2020).

Dietary fiber helps with digestion, improves glucose tolerance, and increases the volume of stool produced. In order to prevent postprandial hyperglycemia, a condition linked to high glycemic index diets like WR can lower the risk of metabolic diseases. Fiber can slow the breakdown of starch and the absorption of glucose into the bloodstream (Saka *et al.*, 2023). The study's fiber values demonstrated that, in comparison to their WR counterparts, all BR varieties had substantially higher fiber contents with values higher than those reported by Rathna *et al.*, (2019) but within the parameters established by Edeogu *et al.* 2007).

The ash content, which serves as a gauge for inorganic food components, varied depending on the variety under investigation. Despite the fact that polishing is known to eliminate mineral elements, no discernible variations

were found in the results, which could be explained by local mineral resources and environmental factors. The natural fertility of rice fields and the rate at which fertilizer is applied have been demonstrated to impact rice's mineral content (Tsujimoto *et al.*, 2019).

An essential factor in determining how long grain will last is its moisture content. Every type of rice had a moisture content that was suitable for long-term storage (Simonelli *et al.*, 2019). Among the studied varieties, the *Jamila* variety had the highest storage potential, as evidenced by its lowest moisture content (10.3 ± 0.1 %) in its WR. This result is in good agreement with Shehu *et al.*, (2023).

The percentage of lipid content found in each group is within a similar range and does not significantly differ ($p > 0.05$) from the other groups. The current outcome agrees with what Shehu *et al.*, (2023) previously reported. Since foods high in fat contain unsaturated fatty acids, which can cause oxidative rancidity, lipid content may also be significant for food shelf life (Iwe *et al.*, in 2016).

Because the bran layer is removed during polishing, white rice (WR) has less flavonoid than brown rice (BR). According to Liu *et al.*, (2020), flavonoids have hepatoprotective, anti-inflammatory, and antioxidant properties and prevent the absorption of glucose, lowering blood glucose levels and decreasing both gluconeogenesis and glycogenolysis. BR varieties have a higher total phenolic content than Shehu *et al.*, (2023) reported value (0.09 to 0.75), which is most likely because the bran layer contains phenolic compounds. These substances have anti-inflammatory and antioxidant properties. They also prevent the absorption of glucose, which lowers postprandial hyperglycemia and increases insulin release.

Research has connected WR consumption to diet-related metabolic disorders like obesity. This is because WR consumption increases oxidized LDL levels, weight gain, fat enlargement, and oxidative stress. BR consumption, on the other hand, is linked to better lipid profiles and a decrease in body weight. The BR varieties' higher fiber content lowers calorie density, slows down the digestion of nutrients, and increases satiety, which causes appetite differences between the WR and BR groups. The higher weight gain brought on by WR consumption is in line with a previous study by Shehu *et al.*, (2023), that found high-carb diets to be linked to higher fat content in middle age. The WR and high-fat diet (HFD) groups showed elevated triglyceride levels, which is in line with earlier research by Shehu *et al.*, (2023). Conversely, BR was associated with decreased triglyceride levels because it contained bioactive substances like oryzanol,

flavonoids, and phenols, which have effects on cholesterol and obesity that are consistent with Saka *et al.*, (2023). When rats were fed white rice (WR), their hyperglycemia worsened, resembling the hyper-fat diet (HFD) group a well-known model for inducing type 2 diabetes (Qi, 2023). On the other hand, the brown rice varieties (BR) displayed superior glucose levels. The BR types have high fiber content, which slows down sugar release and sustainably preserves sugar homeostasis (Liu *et al.*, 2020). WR, on the other hand, does not contain fiber, which causes quick absorption and circulation of glucose, raising postprandial glucose levels. Long-term hyperglycemia can even lead to the onset of diabetes by promoting diabetic complications like retinopathy, neuropathy, nephropathy, and oxidative stress (OS) (Saka *et al.*, 2023). Imam *et al.*, (2014) found that WR causes long-term hyperglycemia by making the glucose tolerance test worse. It has been demonstrated that hyperglycemia plays a crucial role in insulin signaling by upregulating serine/threonine kinase and GSK in muscle and liver and down-regulating INR, IRS-1, PI3K, GLUT-4, AMPK, and GCK (Shen *et al.*, 2015). Likewise, it has been demonstrated that WR influences MAPK1, MAFA1, and SLC2A2 (Abubakar *et al.*, 2020). Together, these alterations in gene expression caused IR. Rats belonging to the BR group had higher blood glycogen levels than those belonging to the WR group. There was a significant difference ($p < 0.05$) between the rats of the BR varieties and the control group.

Rats belonging to the BR group had higher blood glycogen levels than those belonging to the WR group. The BR varieties' rats showed a significant difference ($p < 0.05$) from the control group. The HFD group's glycogen levels and those of all the rats of the WR strains were noticeably similar. Depleted energy stores, a defining feature of insulin resistance (IR), are indicated by the low glycogen levels in the WR groups. Glycogen stores are depleted in insulin-resistant cells because they are unable to absorb glucose and must instead rely on glycogenolysis for energy (Carbo, 2023).

5.0 CONCLUSION

According to the study's overall findings, Wistar albino rats that consume specific white rice (WR) products develop hyperglycemia, dyslipidemia, lipogenesis, obesity, and excessive weight gain. On the other hand, consuming locally grown brown rice (BR) varieties, which exhibit anti-glycaemic, anti-lipogenesis, and anti-adiposity qualities, can lessen these negative effects, according to the study. The multitude of bioactive substances found in BR bran is probably what causes these advantageous effects. Thus, this research implies that substituting widely consumed WR with locally produced BR could potentially lower the incidence of

obesity, type 2 diabetes, and the complications linked to these conditions.

ETHICAL APPROVAL

Ethical approval for the study was obtained from the University Ethics Committee

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