World Nutrition Journal |eISSN 2580-7013

ORIGINAL PAPER

Changes in postprandial plasma malondialdehyde levels between consumption of brown rice compared to white rice in sedentary workers

Received 9 July 2025
Accepted 11 October 2025
Published 28 February 2026

Link to DOI:
10.25220/WNJ.V09.i2.0003

Citation: Taradita W, Hardiany NS, Wardhani WI. Changes in postprandial plasma malondialdehyde levels between consumption of brown rice compared to white rice in sedentary workers. World Nutrition Journal.2026 February 28,9(i2): 25-36

Wulandari Taradita[1], Novi Silvia Hardiany[2], Wahyu Ika Wardhani[1]

1. *Department of Nutrition, Faculty of Medicine, Universitas Indonesia, Jakarta, Indonesia*
2. *Department of Biochemistry and Molecular Biology, Faculty of Medicine, Universitas Indonesia Jakarta, Indonesia*

Abstract

Background: Office workers are prone to sedentary behavior and low physical activity, which can increased oxidative stress. The effect of dietary carbohydrates on oxidative stress can be assessed through changes in Malondialdehyde (MDA) levels, typically observed 2-4 hours of postprandially. In Indonesia, white rice remains the dominant carbohydrate source, whereas brown rice is known to contain antioxidants and dietary fiber that help counteract free radicals.

Objective: The study aimed to compare the effect of brown rice and white rice consumption on postprandial plasma MDA levels.

Methods: A total 28 sedentary workers subjects from FKUI Salemba participated in this open label, randomized, parallel clinical trial using consecutive sampling. Subjects were allocated to consume either 150 g of white rice (IR-64/*Setra Ramos* variety) or 150 g of brown rice (*Aek Sibundong* variety). Each meal was given once accompanied by 60 g of omelette, 70 g of tofu stew, and 220 ml of water. The participants were aged 23-48 years, with 80% being female, and all had normal BMI.

Results and Conclusion: Significant differences in energy intake (p=0.026) and protein intake (p=0,014) were observed between the groups. Postprandial plasma MDA levels in the brown rice group tended to decrease, though not -significantly. (p=0.0649), whereas the white rice group showed a significant increase (p=0.01). No significant difference was found between the two groups (p=0.065). Nevertheless, brown rice can still be considered a better alternative staple food than white rice, as its antioxidants and higher fiber content can protect the body's cells from diet-induced oxidative stress.

Keywords: brown rice, oxidative stress, postprandial MDA, sedentary workers, white rice

Corresponding author:
Name : Novi Silvia Hardiany
Institutions : Department of Biochemistry and Molecular Biology, Faculty of Medicine, Universitas Indonesia, Jakarta, Indonesia
Email : novi.silvia@ui.ac.id

Introduction

Office workers frequently engage in sedentary behaviors—characterized as waking activities performed while seated or reclined with an energy expenditure of ≤ 1.5 METs—mainly due to extended periods of sitting.[1,2] In Southeast Asia, approximately 35% of women and 18% of men aged 18–44 exhibit such inactivity, accounting for an estimated 500 million non-communicable disease events projected between 2020 and 2030.[3] The high rate of sedentary behavior in the office, coupled with low levels of daily physical activity, is currently considered a risk factor for chronic diseases. This is partly due to the dysregulation of cellular redox homeostasis, decreased mitochondrial function, and increased activity of Nicotinamide Adenine Dinucleotide Phosphate (NADPH) oxidase, which leads to increased oxidative stress. Oxidative stress is known to have a linear relationship with the incidence of metabolic and chronic diseases. It is generally defined as an imbalance between pro-oxidants and antioxidants that causes disruption of reduction-oxidation (redox) signaling and control. This imbalance produces unstable molecules or Reactive Oxygen Species (ROS) that can cause molecular damage in the body. Increased generation of ROS can have detrimental effects on vital cellular components, including proteins, lipids, and DNA as a result of oxidative stress. This can induce tissue damage in the body's cells, which can result in a number of chronic diseases.[4-6] Over time, persistent sedentarism exerts sustained pressure on mitochondrial systems and diminishes the effectiveness of enzymatic antioxidants, thereby weakening the primary cellular defense mechanism against ROS and further exacerbating oxidative damage.[7] In contrast, Perez et al. reported a significant negative correlation between levels of moderate-to-vigorous physical activity and plasma malondialdehyde (MDA)—a biomarker of lipid peroxidation—particularly among men.[8]

As mentioned before, one important process that reduces enzyme function and molecular signaling pathways, ultimately leading to tissue damage, is oxidative stress.[9] Reactive Oxygen Species-induced lipid membrane degradation can increase the fluidity and permeability of the membrane, allowing water and Na to enter and causing cell enlargement and ultimately lysis. Protein damage, on the other hand, includes enzyme inactivation, peptide chain breakage, aggregation of cross-linked reaction products, changes in electrical charge, modifications to specific amino acid positions, and vulnerability to proteolysis. Finally, ROS can break DNA strands, remove nucleotides, alter bases, cause DNA-protein crosslinking and cause damage to DNA by deoxyribose oxidation.[10]

One of the byproducts of polyunsaturated fatty acid peroxidation, malondialdehyde (MDA) is well known for being one of the most sensitive indicators of lipid oxidative damage.[11] The body reacts to oxidative stress circumstances in two stages. Within minutes after eating (postprandial), the first phase starts, and it often peaks two to four hours later. The immune system stabilizes or homeostatic metabolism returns to normal, during the second phase, which is known as the adaptation phase. The stress reaction will last for a long time and progress to a condition of dysmetabolism or failure to balance the redox system if both phases are disturbed, either because the first phase's effect is too great or the adaptation phase does not proceed smoothly.[12,13]

In reaction to oxidative stress, body cells employ an antioxidant defense system that is primarily an endogenous antioxidant and consists of a number of enzyme components, including glutathione peroxidase (GPx), catalase (CAT), and superoxide dismutase

(SOD).[6] Superoxide anion is broken down by SOD into oxygen (O_2) and hydrogen peroxide (H_2O_2), which is subsequently transformed back into water (H_2O) and oxygen by CAT and GPx.[14,15] The three endogenous antioxidants can cooperate to defend against ROS-induced cell damage thanks to this mechanism.[16] One dietary element that has an impact on oxidative stress is carbohydrates. In general, excessive intake of glucose and fatty acids causes an increase in the production of acetyl coenzyme A (acetyl CoA), an enzyme that plays a role in cellular metabolism. Increased acetyl CoA levels result in increased NADH formation in the tricarboxylic acid (TCA) cycle. As a result, mitochondria are stimulated to produce excess superoxide in the electron transport chain, thereby increasing superoxide levels in the mitochondria. This leads to excessive production of ROS, damaging mitochondrial proteins, deoxyribonucleic acid (DNA), and lipids. It then activates redox-sensitive transcription factors and triggers an inflammatory cascade.[17]

In Indonesia, white rice, a refined grain, serves as the primary energy source. Rice consumption is dominated by household consumption, followed by consumption in industry, hotels, and restaurants. Data shows that consumption of white rice processed into white rice reaches 80 kilograms per person per year.[18] As public awareness of health issues increases, the cultivation of other types of rice, such as brown rice, has also begun to increase. However, its cultivation has not yet received as much attention as white rice.[19] Because it contains phenolic compounds, flavonoids, anthocyanins, proanthocyanidins, tocopherols, tocotrienols, and phytic acid, brown rice, a type of whole grain, has a high degree of antioxidant activity in addition to white rice, which is a refined grain. Proanthocyanidin is the primary secondary metabolite found in brown rice, while genes that create anthocyanins—natural pigment compounds that combat free radicals—are found in the aleurone portion of the grain.[20] Brown rice can avoid an excessive rise in blood glucose because of its low glycemic index and rich nutritious content, including fiber, vitamins, and minerals.[21] Postprandial oxidative stress can be prevented by combining physical activity with the consumption of foods that possess antioxidant properties. In this context, the researcher aims to investigate the effect of dietary choices by comparing brown rice and white rice consumption, specifically examining their impact on postprandial plasma MDA levels in healthy adult sedentary worker volunteers.

Methods

Subjects and research location

This clinical trial research has been ethically approved by the Research Ethics Committee of the Faculty of Medicine, Universitas Indonesia (FMUI) with the letter KET-1779/UN2.F1/ETIK/PPM.00.02/2024. The sample size was 24 people (intervention group 12, control 12) with an estimated dropout of 20%, so the total minimum sample size was 30 people. During the intervention period, two subjects from the intervention group dropped out, one because they did not consume the intervention food (brown rice) and the other because of difficulties in taking blood samples, so that the subjects could not continue to the next stage of the study. The total number of subjects analyzed was 28 subjects, which 15 subjects were in the control group, and 13 subjects were in the intervention group. The sample was collected using a consecutive sampling technique from administrative workers of FKUI Salemba. Inclusion criteria included healthy administrative employees, age 21-59 years, normal body mass index (18.5-22.9 kg/m^2),

low physical activity (≤600 METs minutes/week), and informed consent. Exclusion criteria included pregnancy/breastfeeding/menopause, consumption of herbal medicines and/or vitamin supplements within 24 hours before data collection, history of diabetes mellitus (DM), cardiovascular disease (CVD), cancer, hypertension, hypercholesterolemia, vegan, smoker/alcohol drinker, allergy to intervention food ingredients. Informed consent was signed after a full explanation of the purpose, methods, and risks of the study. This study was a clinical or experimental open-label trial, parallel, with random allocation using the randomlist.com application.

Feeding modifications and procedures

Two types of rice were used in this study: control, 150 g white rice of the IR-64/*setra ramos* variety and intervention, 150 g brown rice of the *aek sibundong* variety. Each rice was given a combination of 60 g of omelet and 70 g of tofu stew, and 220 ml of water. The white rice was cooked using a rice cooker until the marker changed from "cook" to "warm" after washing twice, with the ratio of white rice and water when cooking as much as 150 g: 246 mL. After that, the rice was left in the rice cooker for 15 minutes before stirring and serving.[21] Meanwhile, brown rice was cooked by soaking brown rice first for 2 hours after washing twice so that the development of rice is better so that the texture of the rice is more like white rice and acceptable to the subject.[22] Then brown rice was cooked according to the same processing method as white rice using a rice cooker, but with a ratio of rice to water, namely 1: 2.[21-23] The results of the 2007 NutriSurvey in the control group included energy 403 kcal, carbohydrates 51 g, protein 20.9 g, fat 12.3 g, and fiber 2.8 g. While the intervention group has nutritional values based on NutriSurvey 2007, including energy 376 kcal, carbohydrates 43.4 g, protein 19.9 g, fat 13.2 g, and fiber 2.8 g.

The research subjects fasted from 9.30 pm to 07.30 a.m (10 hours) the next day before being given the research food once during breakfast. Then the subject was given a breakfast according to the modified food made by the researcher and asked to finish the food within 15 to 20 minutes. During the observation period, no additional calories or excessive activity beyond daily work habits were allowed. Observation was conducted for 4 hours after consumption of the study meal. At 12:00 p.m. (4 hours later), the subjects were recollected for blood collection as a measure of postprandial plasma MDA, which was then taken to the Biochemistry and Molecular Biology laboratory of FKUI.

Data collection

Sociodemographic data collection in the form of gender and age, anthropometric measurements, physical activity assessment, calorie needs, along with macronutrients and fiber, as well as basal plasma MDA levels was carried out before the intervention (baseline), while postprandial plasma MDA levels were taken 4 hours after the intervention (endline). Anthropometric measurements were carried out to obtain body mass index (BMI) data by measuring height using a shorrboard with an accuracy of 0.1 cm and weight using a SECA scale with an accuracy of 0.1 kg.

Physical activity assessment using the international physical activity questionnaire short-form version (IPAQ-SF) questionnaire was carried out to equalize the subject's physical activity level, which was sedentary. This questionnaire consists of 7 questions based on the physical activity performed by the subject during the last 7 days. Then food

intake was assessed using a 1 x 24-hour food recall sheet which was interviewed directly by the researcher on 1 working day without comparing it with holidays to describe a diet similar to the real situation in the daily work of the subjects.

Blood sample collection and examination

Venous blood of 5 ml was collected into two different heparin tubes, before and 4 hours after dieting. Blood storage was placed in a refrigerator at 4^0C and transportation was performed using a cool box with ice blocks by maintaining the same temperature as storage. Malondialdehyde levels were then measured with TBARS assay or Will's method, using a spectrophotometer in the biochemistry and molecular biology laboratory of FKUI.[24]

Statistical analysis

Data were analyzed using SPSS (version 26). Univariate tests assessed the characteristics of age, gender, BMI, caloric intake, macronutrients (carbohydrate, protein, and fat), and fiber intake, as well as basal MDA levels. Results with normal distribution were written as mean±SD, while results with abnormal distribution were written as median (minimum-maximum). Bivariate tests were conducted to assess changes in MDA levels of each group before and after the intervention using paired T test if the distribution was normal/Wilcoxon if the distribution was not normal, while the final result to see the difference in changes in MDA levels between groups using unpaired T statistical test if the distribution was normal/Mann-Whitney if the distribution was not normal. Significant is set for $p < 0.05$.

Results

Selection of research subject

There were 28 subjects who participated in this study until the end. All subjects signed informed consent at the beginning of the study and continued with a characteristic interview, screening criteria for research subjects, anthropometric assessment, physical activity assessment, and food intake assessment. The researcher then conducted group matching by equalizing the gender distribution in each group and using simple randomization techniques on eligible subjects for the division of control and intervention groups. Subject scheduling was carried out to proceed to the dietary intervention stage and blood sampling for plasma MDA examination. The stages of selection of research subjects can be seen in **Figure 1**.

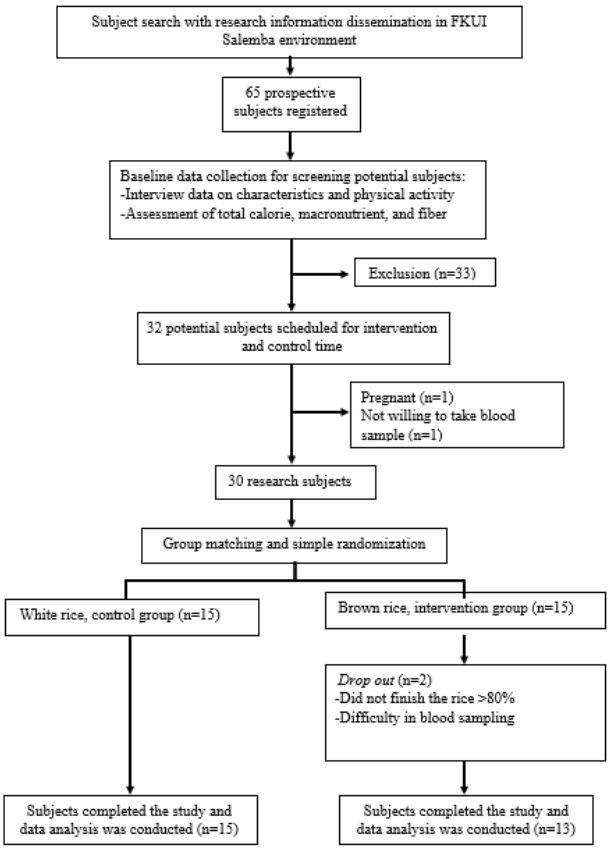

Figure 1. Research subject selection chart

Characteristics of the study subjects

Based on the results of univariate analysis, the age of the subjects in this study had a median of 27 years (23-48 years) for the whole subject, and so did the control group, while the average age of the subjects in the intervention group was 30 ± 6.7 years. There were 6 male subjects, with each group having the same proportion of 3 subjects each, fewer than females in both the control group (80%) and intervention group (76.9%). The body mass index (BMI) of the subjects in this study has been selected with normal BMI inclusion criteria (18.5-22.9 kg/m2), so the results of BMI distribution are not much different. There was no significant difference between the two groups in terms of characteristics tested by bivariate analysis ($p>0.05$) in **Table 1**.

Table 1. Characteristics of study subjects

	Total subjects (n=28)	White rice group (n=15)	Brown rice group (n=13)	P value
Age (years)	27 (23-48)	27 (23-48)	30±6.7	0.711[a]
Gender, n (%)				
Male	6 (20)	3 (20)	3 (23.1)	0.84[b]
Female	24 (80)3	12 (80)	10 (76.9)	
Body mass index (kg/m^2)	20.97±1.24	20.94±1.20	21±1.34	0.87[c]

[a]*Mann-Whitney test*
[b]*Chi-square test*
[c]*Unpaired T-test*

Energy, carbohydrate, protein, fat, and fiber intake

The energy and macronutrient intake of the study subjects assessed using 24h food recall according to **Table 2**, had a normal distribution, with significant differences between the two groups in total energy intake (p=0.02) and protein intake (p=0.014), while other intakes, such as carbohydrates and fats did not have significant differences between groups. Total energy intake in the control group had an average of 1,709 ± 341.5 kcal, while the intervention group tended to be lower at an average of 1346 ± 467.7 kcal. Likewise, the average protein intake in the control group was higher (63 ± 11.1 kcal) compared to the intervention group (47.9 ± 18.6 kcal). In contrast to the normal distribution of energy and macronutrient intake, fiber intake assessed by a similar method resulted in data with abnormal distribution in all subjects, with a median value of 7.1 g/day (2.3-20.4 g/day) but was normally distributed in each group.

Table 2. Energy, macronutrient, and fiber intake of study subjects

	Total subjects (n=28)	White rice group (n=15)	Brown rice group (n=13)	P value
Energy intake (kcal)	1540±437.9	1709±341.5	1346±467.7	0.026*
Carbohydrate intake (g/day)	168.8±52.8	182.7±52.9	152.8±49.9	0.138
Protein intake (g/day)	56.0±16.6	63±11.1	47.9±18.6	0.014*
Fat intake (g/day)	72.3±30.9	81.7±28.8	61.4±30.7	0.083
Fiber intake (g/day)	71 (2.3-20.4)	8.8±4.9	7.5±4.3	0.472

**Unpaired T-test*

Plasma MDA levels

In **Table 3**, it can be seen that the basal MDA assessment in all subjects was normally distributed (p>0.05), which means that the subjects' baseline values were the same. Basal MDA and postprandial MDA levels in both groups did not have significant differences. The brown rice group showed a non-significant change in plasma MDA levels (p=0.0649), whereas the white rice group exhibited a significant increase in plasma MDA levels (p=0.01). There was no significant difference in plasma MDA levels between the consumption of brown rice compared to white rice (p=0.065).

Table 3. Changes in plasma MDA levels

	Total subjects (n=28)	White rice group (n=15)	Brown rice group (n=13)	P value*
Basal plasma MDA levels (nmol/mL)	0.75±0.17	0.68 (0.41-0.82)	0.83±0.18	0.051[a]
Postprandial plasma MDA level (nmol/mL)		0.84 (0.28-1.01)	0.85 (0.31-1.05)	1.00
Difference (nmol/mL)		0.14±0.2	-0.006±0.21	0.065[b]
P value[c]		0.01	0.649	

[a]*Mann-Whitney test*
[b]*Unpaired T-test*
[c]*Wilcoxon test*

Discussion

The age of the subjects who participated until data analysis in this study ranged from 23 years to 48 years, with a median of 27 years in the control group, while the average age of subjects in the intervention group was 30 years. The age range obtained in the subjects of this study is by data from the Central Statistics Agency in 2024 regarding the Labor Force in Indonesia, where the age group of 25-44 years is the largest age group of workers in Indonesia.[25] Likewise, the prevalence of employees with low physical activity according to Adawiyah, et al.[26] research was found to be more at the age of 19-44 years compared to the older group, namely 45-65 years. Male subjects in both groups amounted to 3 subjects or less than 25%, less than women, both in the control group which dominated up to 80% and the intervention group with the distribution of women reaching 76.9%. The gender distribution of subjects in this study has gone through a matching process to equalize the characteristics between groups for a more normal distribution. Research by Khakim, et al[27] and Abadini, et al[28] found that sedentary behavior was more prevalent in female office employees. In addition, global data conducted by the Lancet 2024 study stated that from 2000 to 2022, women were physically inactive with an average percentage of 5% higher than men.[29]

The subjects in this study were limited to the normal BMI category. This IMT restriction was carried out because of the possibility of increased oxidative stress in overweight and obese subjects (IMT> 22.9 kg/m2), which could affect the results of the MDA examination. Excessive fat accumulation in obesity can cause a pathological increase in serum free fatty acid (FFA) concentration, which can interfere with glucose metabolism, stimulate the accumulation of energy substrates (glucose and fat) into the liver, muscle, and fat tissues, and trigger mitochondrial and peroxisomal oxidation. Increased oxidative damage leads to higher cytokine production, ROS synthesis, and an increased rate of lipid peroxidation.[30]

All intake data in this study were obtained using the 24-hour food recall method on weekdays. Food intake can be influenced by various factors, such as age, gender, weight and height, environmental temperature, hormonal status, and dietary patterns.[31] The work environment, such as interaction and support among coworkers, working time, and eating habits inside and outside the office are also taken into consideration in assessing the subject's food intake.[32] Research conducted on office workers in Japan showed that office workers who ate lunch in the office canteen had a Healthy Eating Index value in 2015 (HEI-2015) followed by workers who brought home-made food. This is in contrast to

workers who choose to eat lunch from fast food restaurants or takeaways due to overwork and therefore shorter mealtimes.[33]

The statistically similar basal MDA levels in this study indicate that both groups had similar levels of oxidative stress before treatment, so basal plasma MDA levels are not expected to affect the results after treatment. The increase in oxidative stress that occurred after consumption of the study food would be biased due to uneven basal oxidative stress levels in the subjects. The tendency to decrease postprandial oxidative stress in the brown rice group proves that the consumption of brown rice has an effect in reducing oxidative stress that occurs after consuming daily food when compared to white rice which actually increases postprandial plasma MDA levels.

The decrease in postprandial MDA levels in the brown rice group can occur one of them because of the anthocyanin content in brown rice which has antioxidant effects and is not owned by white rice. Anthocyanins and anthocyanidins, like other polyphenols and flavonoids, have the ability to bind and eliminate free radicals such as reactive oxygen and nitrogen species (ROS and RNS) thus preventing oxidative stress.[34,35] Anthocyanin levels in the aek sibundong brown rice variety are 10.87 mg/100g, and in addition to the high antioxidant activity found, these levels also act as high anti-diabetic by preventing stress on the endoplasmic reticulum and inhibiting pancreatic lipase activity, resulting in improved glycemic control and lipidemia, and protecting the liver from insulin resistance caused by a high-fat diet.[36-38] Flavonoids in brown rice can also inhibit glucose uptake and prevent glucose-induced lipid peroxidation.[38]

Research from Wiedani, et al.[38] who examined bioactive activities such as anthocyanins in dragon fruit, which has an anthocyanin content of 8.8 mg/100g, found that there was a decrease in plasma MDA levels in experimental mice despite being given a high-fat diet. Another study that shows the effectiveness of anthocyanins against MDA is research with the herbal plant *Clitoria ternatea* (butterfly pea), which every gram can reduce postprandial MDA levels up to 2 hours after consumption of sucrose carbohydrates.[39] The high dietary fiber in *aek sibundong* brown rice, which is around 3.3 g/100 g, can also affect MDA inhibition. Compared to the white rice variety IR 64 / *setra ramos* which was the control food given in this study, it only contains 0.5 to 1 g/100 g of dietary fiber. Dietary fiber content has a negative relationship with the glycemic index value of food. The glycemic index value of white rice from the IR64 variety is 79, which is in the high category.[40] Meanwhile, brown rice from the *aek sibundong* variety has a glycemic index in the medium category, at 59.[41] Fiber functions to slow down the rate of food in the digestive tract and inhibit enzyme activity so that the digestive process, especially starch, is slowed down and the blood glucose response will be lower, thus the glycemic index value tends to be lower. If there is an increase in glucose in the blood, NADPH oxidase activity will increase and produce superoxide, which can eventually trigger lipid peroxidation. Lipids found in plasma, mitochondria, and endoplasmic reticulum membranes are the main targets of ROS attacks and peroxidation in most macromolecules. The end products of lipid peroxidation, known as lipid peroxides, can be toxic to any cell and require destruction by antioxidants such as glutathione.[42] This is reinforced by a study in Las Vegas that proved a decrease in MDA as well as an increase in serum antioxidant capacity in pregnant women who were given a blueberry diet supplemented with 12 g of soluble fiber for 8 weeks.[43]

This study has limitations in assessing healthy clinical status, which is the inclusion criterion of the subject, where only subjective anamnesis is carried out for the history of the subject's disease. At the very least, after history taking, simple laboratory tests such

as lipid and glucose profiles should be performed to more objectively assess current metabolic disease status related to oxidative stress. In addition, the use of the food recall method to assess daily intake in this study risks recall bias even though the researcher has minimized the bias by modelling various food menus using a food photo book. A single intervention may not produce significant results in this study, although postprandial plasma MDA changes can occur within 2-4 hours after eating. The author suggesting that repeated interventions should be considered in future studies or adding more research samples.

Conclusion

The change in postprandial plasma MDA levels between the consumption of brown rice compared to white rice in sedentary workers was not significant. However, plasma MDA levels in the brown rice group tend to decrease, while MDA levels in the white rice group significantly increased. Therefore, brown rice can be considered a better alternative staple food option compared to white rice, because it contains antioxidants and higher fiber to protect the body's cells from diet-induced oxidative stress. This must be accompanied by a balanced diet and sufficient physical activity.

Conflict of interest

There was no conflict of interest related to this research. The authors have no personal or financial relationship that could influence the judgment or action.

Acknowledgements

This study was fully supported by the Department of Nutrition, Faculty of Medicine, Universitas Indonesia.

Author's contribution

All authors contributed equally to the conception and design of the study, data acquisition, analysis and interpretation of data, drafting and critical revision of the manuscript, and final approval of the version to be published. All authors have read and approved the final manuscript.

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