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ORIGINAL ARTICLE

Paradoxical rise in interleukin-6 following brown rice intake: A postprandial study in sedentary workers

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Abstract

Background: Brown rice is thought to have anti-inflammatory effects due to its high dietary fiber and phenolic content; however, evidence in sedentary populations is limited. IL-6 is a key pleiotropic cytokine responsive to postprandial inflammation.

Objective: This study compared postprandial IL-6 levels after brown vs. white rice consumption in sedentary workers.

Methods: In this open-label, parallel-group trial, 28 normoweight participants (22 women, 6 men) consumed 150 g of rice, 60 g of fried eggs, and 70 g of tofu stew. Nutritional composition was determined from available sources, with fat content of brown rice (2.4 g/100 g) obtained from the manufacturer's laboratory report and that of white rice (0.5 g/100 g) from published data. Participants were randomized by gender into brown rice (n=13, age 30.15 ± 6.71) and a white rice groups (n=15, age 27 [23-48]). IL-6 levels were measured at baseline (10-hour fast) and 4 hours post-meal. Previous-day intake (24-hour food recall) and physical activity (IPAQ-SF) were recorded. Non-parametric tests were applied.

Results: Participants averaged 321.5 ± 181.2 METs. Despite higher fat content in brown rice, intake did not differ significantly between groups. IL-6 changes were not statistically significant (p=0.069). However, the brown rice group showed a numerically higher postprandial IL-6 level, while the control group remained relatively stable.

Conclusions: No significant IL-6 differences were observed, however the paradoxical elevation following brown rice consumption is probably due to subtle influences of nutrient composition or participant characteristics. Further studies with stricter dietary control and biomarkers are warranted.

Keywords: inflammation, interleukin-6, sedentary behavior, whole grains

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Introduction

Rice is a staple food that dominates the global caloric supply, contributing to over 50% of daily energy intake in many populations, including Indonesia.[1,2] Its consumption level in Indonesia reaches 13 – 46 times higher than that of other carbohydrate sources, with an average of 6.7 kg per capita per month in 2021. However, the majority of rice consumed is refined grain, specifically white rice.[3] The milling and polishing processes remove the bran and germ layers, which are rich in fiber and bioactive compounds, resulting in lower fiber content and a higher glycemic index (GI).[4] These characteristics have been associated with increased inflammatory responses.

Several studies have reported that high GI-foods are associated with adverse metabolic and inflammatory responses.[4–6] Such foods can increase postprandial glucose excursions, promote oxidative stress and activate inflammatory signaling. Experimental evidence further suggests that high-GI meals may enhance pro-inflammatory signaling, including NF-kB signaling in mononuclear cells.[5] In this context, white rice, particularly high-GI varieties such as IR-64 (GI = 79)[7], may contribute to an increased risk of inflammation due to its combination of high GI and low fiber content.

Therefore, this situation opens up opportunity for exploring alternative carbohydrate sources that are more beneficial from a health perspective. Brown rice emerges as a promising functional food commodity because it its a whole grain rich in fiber and phenolic compounds.[8] This content contributes to a lower glycemic index and has the potential to reduce the risk of inflammation.[4] As research on brown rice continues to grow, its popularity in society is also steadily increasing, prompting the government to strive to enhance its availability.[3,9]

Despite its huge potential, research on the effects of brown rice consumption in population with sedentary lifestyle remains very limited. Yet, this population is increasingly growing in the modernized era. Based on WHO report, approximately 27.5% of adults over 18 years old globally have sedentary behavior and low physical activity.[10] This phenomenon is becoming more prominent due to the lack of public open spaces, the penetration of television, mobile devices, video players, and the increase in occupational sedentary behaviors, such as office work.[11] This condition is highly relevant in Indonesia, considering 36.3% of the population aged fifteen and over, equivalent to nearly 50 million of people, work as office employees or staff, a group highly vulnerable to a sedentary lifestyle.[12]

This study was conducted to examine the effect of brown rice intake on differences in postprandial inflammatory responses compared to white rice in those population. The postprandial inflammatory response is of particular concern as it is a factor that can underlie the development of insulin resistance and atherosclerosis.[12,13] This response is assessed using the inflammatory marker IL-6, whose levels can increase by 30 - 40% starting from 3 hours after a meal and peak at 6 hours after a meal.[12,14] Abnormal, persistent activation of this response – which can last for more than 16 hours per day – can lead to persistent activation of the immune system and result in chronic low-grade inflammation, thereby increasing the risk of metabolic and cardiovascular diseases.[12,13] Specifically, this study aims to measure the effect of consuming 150 g of rice – either whole grains (brown rice) or refine grains (white rice) - on changes in IL-6 levels among sedentary workers. This portion size was selected to reflect a commonly consumed daily serving.

Methods

Study design and settings

This experimental study employed a parallel, randomized, open-label design. It was conducted from August 2024 to May 2025 in the administrative work environment of the Faculty of Medicine, Universitas Indonesia. Interleukin-6 (IL-6) levels were measured at the Biochemistry Laboratory of the Faculty of Medicine, Universitas Indonesia, Jakarta. Ethical approval was obtained from the Health Research Ethics Committee of the Faculty of Medicine, Universitas Indonesia (No: KET-1779/UN2.F1/ETIK/PPM.00.02/2024).

Participants

The subjects were sedentary administrative staff aged 21–59 years with normal body mass index (BMI: 18.5–22.9 kg/m²) and low physical activity (≤600 MET-min/week) who provided written informed consent. A total of 30 subjects were recruited and randomly allocated into two parallel groups: 15 in the intervention group (brown rice) and 15 in the control group (white rice). Exclusion criteria included pregnancy, breastfeeding, menopause, smoking, alcohol consumption, vegetarian diet, food allergies, chronic diseases (diabetes, cardiovascular disease, cancer), immunosuppressant use, and antioxidant supplement intake within 24 hours.

Procedures

Subjects received meals containing carbohydrates, fats, and proteins. Each meal consisted of 150 g of rice (white or brown), 60 g of omelette, 70 g of tofu stew, and 250 ml of water. The nutritional composition of the meals was calculated using NutriSurvey 2007 software based on the predefined meal design. The nutritional values of the rice used in the analysis were inputted into the software based on available compositional data sources as shown in Table. 1, the control group meal provided 515.2 kcal, 128.8 g carbohydrates, 27.1 g protein, and 12.8 g fat, while the intervention meal provided 473.6 kcal, 118.4 g carbohydrates, 33.2 g protein, and 15.6 g fat.

The nutritional composition of rice was determined from available data sources. The fat content of brown rice (2.4 g/100 g) was obtained from the manufacturer's laboratory analysis report, while that of white rice (0.5 g/100 g) was derived from previously published compositional data.[15]

The white rice used was IR-64 variety, and the brown rice was Aek Sibundong variety, known for its high nutritional and antioxidant/anti-inflammatory properties.

Pre-intervention

After detailed explanations, subjects were randomized into groups. They fasted for 10 hours (21:30–07:30) before intervention, consuming only water. Strenuous exercise was prohibited 48–60 hours prior, and caffeine intake was restricted 24 hours before. Subjects maintained their usual sedentary activities (e.g., sitting, watching TV, computer use) and were provided with an instruction sheet outlining what to do and what to avoid prior to the intervention.

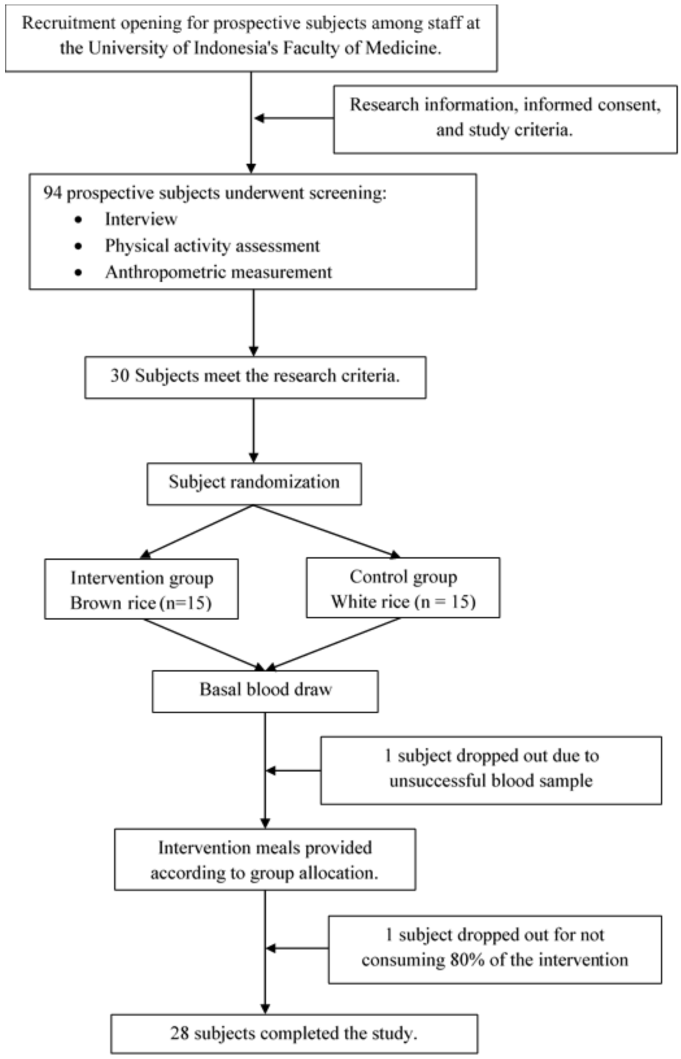

Figure 1. Research flow

Table 1. Macronutrient composition in intervention and control group food

	Carbohydrate (g)	Protein (g)	Fat (g)	Fiber (g)
Intervention group				
Brown rice (150 g)	110.3	16.7	3.6	6.4
Fried egg (60 g)	0.7	6.9	8.8	-
Tofu stew (70 g)	7.4	9.6	3.2	0.3
Total (g)	118.4	33.2	15.6	6.7
Energy (kcal)	473.6	132.8	140.4	
Percentage (%)	63.4	17.7	18.8	

	Carbohydrate (g)	Protein (g)	Fat (g)	Fiber (g)
Control group				
White rice (150 g)	120.7	10.6	0.8	0.6
Omelette (60 g)	0.7	6.9	8.8	-
Tofu stew (70 g)	7.4	9.6	3.2	0.3
Total (g)	128.8	27.1	12.8	0.9
energy (kcal)	515.2	108.4	115.2	
Percentage (%)	69.7	14.7	15.6	

Nutritional values were calculated by the authors using NutriSurvey 2007.

During Intervention

On the study day, fasting blood was drawn at 07:30–08:00 for baseline IL-6 measurement. Subjects then consumed their allocated meal within 15–20 minutes. They remained sedentary (≤1.5 METs) until the 4-hour postprandial blood draw at 12:00, permitted only water intake during this period.

Post-intervention

Postprandial blood samples were collected at 12:00 (4 hours after intervention). Subject observation forms and complaint logs were collected for documentation.

Sociodemographic Data

Subject characteristics (age, sex, BMI, physical activity, calorie and fiber intake) were collected via interviews and questionnaires. BMI was calculated as weight/height^2 (kg/m^2). Physical activity was assessed using the validated International Physical Activity Questionnaire-Short Form (IPAQ-SF), which consists of seven items evaluating vigorous, moderate, and light activities, including walking and sitting time over the past 7 days; results were converted into metabolic equivalents (METs) based on the IPAQ scoring protocol. Dietary intake was assessed using a 24-hour food recall conducted on a weekday and analyzed using NutriSurvey 2007. Pre-study briefings covered research objectives, procedures, and questionnaire completion.

Analysis of IL-6 level

Venous blood (5 mL) was drawn from the cubital fossa at baseline and 4 hours post-intervention. Samples were centrifuged at 3000 rpm for 10 minutes to separate plasma, which was then aliquoted and stored at -20^{o}C until analysis. IL-6 levels were quantified using sandwich ELISA (FineTest® Human IL-6 Kit) at the Biochemistry Laboratory. The assay involved incubation, washing, enzymatic reactions, and optical density measurement at 450 nm. The change (Δ) in IL-6 levels were calculated by subtracting baseline IL-6 levels from postprandial levels measured 4 hours after meal consumption.

Statistical analysis

Data were analyzed using SPSS v27. Univariable analysis included baseline IL-6 levels and sociodemographic data. Normality was assessed with Shapiro-Wilk test. Within-group differences were analyzed with non parametric test Wilcoxon, and between-group differences with Mann-Whitney. A p-value <0.05 was considered significant.

Results

Baseline characteristics

Data were analyzed per protocol, including all 28 subjects who completed the study. Baseline characteristics are shown in **Table 2**. The overall median age was 27 years (range: 23-48). The mean age was higher in the intervention group (30.1 ± 6.7 years) than the control group (28.6 years). The cohort consisted of 6 males and 24 females, with a balanced sex distribution (20% male, 80% female) across both groups.

The mean body mass index (BMI) for all subjects was 20.9 ± 1.2 kg/m², with similar values in each group. The mean physical activity level, measured in metabolic equivalent minutes/week (IPAQ-SF), was 321.5 ± 181.2. The median baseline IL-6 concentration was 0.82 pg/dL (range: 0.06–17.73). As indicated by p-values in **Table 2**, all baseline characteristics were homogeneous between the control and intervention groups.

Table 2. Baseline Characteristics of Subjects

Characteristics[1]	Both groups (N = 28)	Control group[2] (n = 15)	Intervention group[3] (n = 13)	p value
Age (year)	27 (23 – 48)*	27 (23 – 48)*	30.1 ± 6.7	0.711
Gender[4]				
Male (20%)	6	3	3	0.843
Female (80%)	24	12	10	
BMI (kg/m²)	20.9 ± 1.2	20.9 ± 1.2	21.0 ± 1.3	0.873
METs[5] (minutes/week)	321.5 ± 181.2	327.6 ± 179.5	314.5 ± 190.1	0.853
Baseline IL-6 level (pg/dL)	0.82 (0.06-17.73)	0.9 (0.06-4.60)	0.82 (0.24-17.73)	0.950

[1] All data are presented as mean ± standard deviation, except * median (min – max)
[2] The control group is the group that received white rice
[3] The intervention group is the group that received brown rice
[4] Data are presented as n (number)
BMI: Body Mass Index; METs: Metabolic Equivalent of Task; IL-6: Interleukin-6

Energy, macronutrients, and fiber intake

Dietary intake was assessed via a 24-hour food recall from the day before the intervention. Complete data were available for 23 subjects. The mean energy intake was 1482.6 kcal/day. The control group had a slightly higher mean intake (1369.8 kcal/day for intervention vs. control). Mean carbohydrate intake was lower in the intervention group (152.2 g/day) compared to the control. Protein intake was higher in the control group (59.6 g vs. 50.9 g), as was fat intake (40.9% of energy). Mean fiber intake was similar between groups (control: 7.5 g/day; intervention: 8.1 g/day; overall: 7.8 g/day).

Table 3. Characteristics of subjects' intake with 1x24-h food recall prior to the study day

Intake	Both groups (N = 23)	Control group (n = 12)	Intervention group (n = 11)	p value
Energy (kcal/day)	1482.6 ± 435.3	1586.0 ± 398.8	1369.8 ± 463.9	0.242
Carbohydrate (g/day)	161.9 ± 56.7	170.9 ± 62.2	152.2 ± 51.2	0.442
Protein (g/day)	55.4 ±16.2	59.6 ± 12.9	50.9 ± 18.8	0.206
Fat (%)	39.8 ± 8.3	40.9 ± 8.2	38.6 ± 8.6	0.518
Fiber (g/day)	7.8 ± 4.0	7.5 ± 3.7	8.1 ± 4.4	0.726

IL-6 levels

IL-6 levels were analyzed per protocol (**Table 4**). In the brown rice group, post-intervention IL-6 was non-significantly higher than baseline (p=0.087). The white rice group showed a non-significant decrease (p=0.910). The between-group difference in IL-6 change was not statistically significant (p=0.069), although the intervention group had a numerically higher postprandial median IL-6 level (**Table 5**).

Table 4. Changes in IL-6 levels in each group pre- and post-intervention

	Pre-intervention IL-6 Level (pg/mL)	Post-intervention IL-6 Level (pg/mL)	p value*
Control group[1] (n=15)	0.94 (0.06 – 4.60)	0.90 (0.05 – 4.30)	0.910
Intervention group[2] (n=13)	0.82 (0.24 – 17.73)	1.34 (0.29 – 13.50)	0.087

*Wilcoxon

Table 5. Changes in IL-6 levels in the control and intervention groups

	Control group[1] (n= 15)	Intervention group[2] (n= 13)	p value*
Changes in IL-6 levels (pg/mL)	0.02 (-2.69 – 1.14)	0.52 (-6.14 – 11.46)	0.069

*Mann-Whitney

A boxplot illustrates the distribution of IL-6 changes. Visually, the change appears larger in the intervention group, but statistical tests confirmed this difference was not significant (p>0.05, 95% CI), indicating no meaningful difference between groups.

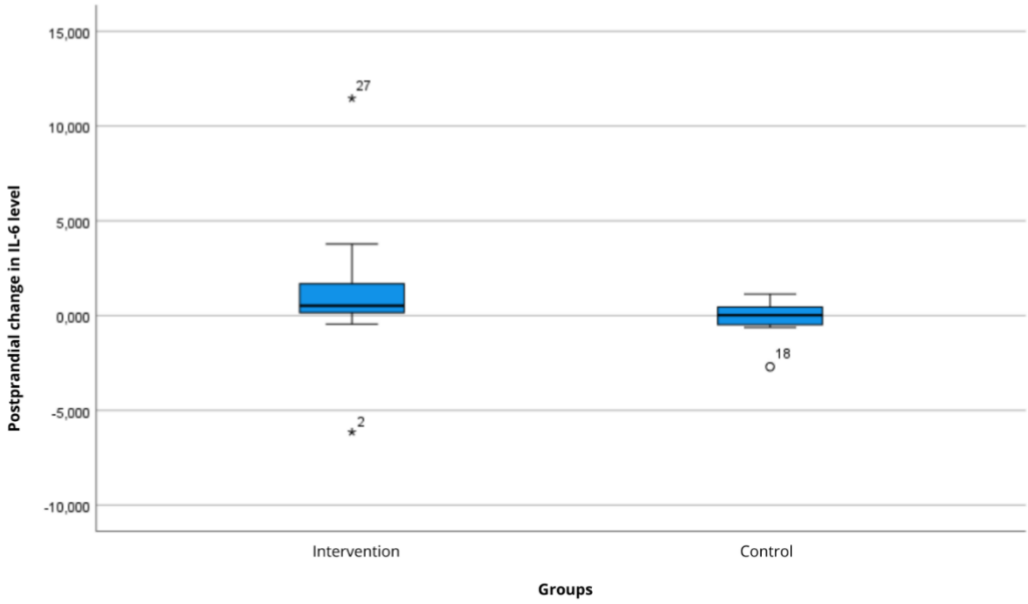

Figure 2. Boxplot of the difference in interleukin-6 level changes between the control and intervention groups.

Discussion

Based on author's knowledge, this study is the first postprandial study in healthy sedentary individuals comparing the effects of brown and white rice on inflammatory marker interleukin-6. This study involved healthy adults (21 – 59 years old, median of age is 27 years old) with low physical activity (IPAQ ≤600 METs/minutes/week). Subjects were given test meals consisting of 150 g of rice (white rice for the control group and brown rice for the intervention group), 70 g of tofu stew, and 60 g of an omelette. IL-6 level were measured at baseline (after a 10 hours fast) and 4 hours after eating.

Subjects were recruited from both sexes, but the proportion of female (80%) was more dominant than male due to a larger number of female prospective subjects meeting the inclusion criteria, primarily because active male smokers were excluded. Active smokers were excluded because smoking significantly increases inflammatory status and IL-6 levels, which could interfere with the study results.[16–18] Subjects were selected from office workers, who are known to be at risk of having low physical activity patterns. In this study, subjects had an average MET of 321.58/week. Although sedentary behavior is associated with the risk of future increases in BMI[19], all subjects in this study had a BMI within the normal range.

The subjects' calorie and macronutrient intake before the intervention did not differ significantly, with an average intake of 1482.65 kcal per day. Sedentary dietary patterns are often associated with unhealthy diet preferences[20–22], but efforts were made to minimize intake variation before the intervention by instructing subjects not to change their diet and to discontinue supplements. The macronutrient composition of rice is influenced by the degree of milling. Unsorted brown rice (Aek Sibundong variety) has higher fat, protein, and fiber content, but was found to have lower carbohydrates compared to white rice (IR-64).[23–25] The test meal in the control group had a composition of 69.7% carbohydrates, 14.7% protein, and 15.6% fat (12.8g). Meanwhile, the intervention group's meal consisted of 63.4% carbohydrates, 17.7% protein, and 18.8% fat (15.6g). The energy content of both groups was approximately 700 kcal. The percentage of fat in the intervention meal was relatively lower compared to previous studies which reached 60-70% fat.[6,14,26]

IL-6 is a pleiotropic cytokine with a dual role: it acts as a pro-inflammatory adipokine from adipose tissue and as an anti-inflammatory myokine secreted by muscles during physical activity.[27,28] IL-6 is also involved in the regulation of energy metabolism, particularly by promoting lipolysis and fatty acid mobilization from adipose tissue and enhancing fatty acid uptake in skeletal muscle under basal conditions.[29] In addition, IL-6 has been proposed to act as an energy allocator that facilitates glucose uptake in metabolically active tissues, although its effects on glucose metabolism vary depending on physiological conditions.[30] In the postprandial state, IL-6 concentration typically peaks around 6 hours after a meal, increasing up to two-fold from the baseline value.[31–33] Therefore, the measurement taken at the 4th hour in this study may not have captured the peak concentration, but rather reflects the early phase of postprandial inflammatory dynamics.

The results showed no statistically significant difference ($p>0.05$) in the change of IL-6 levels between the brown rice and white rice groups.Although IL-6 levels were numerically higher in the intervention group, this difference did not reach statistical significance. This observation may be related to differences in meal composition, such as fat content; however, this interpretation remains speculative and should be interpreted with caution. Previous evidence suggests that dietary fat may influence postprandial IL-6 responses through several interconnected mechanisms, including the translocation of lipopolysaccharides (LPS) via chylomicrons, stimulation of adipose tissue-derived cytokine release, and the induction of oxidative stress through lipoprotein oxidation.[26,34–37] Nevertheless, these mechanisms are proposed based on prior studies and cannot be directly inferred from the present findings.

This finding aligns with several previous studies which also found no postprandial increase in IL-6 when the fat content in the test meal was not excessively high (around 10-40g)[34] or in subjects with a healthy metabolic status.[26,35,36] A systematic review indicated that out of 45 studies, 10 studies found no significant changes in IL-6 following the consumption of high-fat meals.[37] The study by Callcott et al.,[38,39] on pigmented rice showed a significant decrease in IL-6 at 1 and 2 hours after consumption in healthy subjects, indicating that the measurement at the 4th hour might have missed the initial decrease dynamics influenced by the antioxidants in brown rice. Other studies show that the type of fatty acid (saturated vs. unsaturated) or the type of carbohydrate (high vs. low glycemic index) does not always consistently produce different IL-6 responses, highlighting the complexity of the postprandial inflammatory response.[40] Food matrix, nutrient bioaccessibility, and interactions with metabolic factors such as insulin and triglycerides play important roles.[41]

From a clinical perspective, these finding suggest that substituting white rice with brown rice in a single meal may not produce immediate differences in postprandial IL-6 levels in healthy sedentary individuals. Therefore, dietary recommendations aimed at reducing inflammation should consider overall dietary patterns, total fat intake, and metabolic status rather than focusing solely on the type of staple carbohydrate. Brown rice may still offer long-term health benefits due to its higher fiber and bioactive compound, but its acute anti-inflammatory effect may be limited.

This study has several limitations, such as the use of a 1x24 hour food recall and the IPAQ questionnaire, which carry a risk of recall bias; an open-label design that potentially introduces a placebo effect; and the estimation of the test meals' nutritional composition from secondary data rather than direct analysis.

For future research, it is recommended that similar studies be conducted by combining brown rice with other anti-inflammatory foods and measuring additional parameters such as blood glucose levels, triglycerides, and body composition (body fat percentage, muscle mass) to understand their relationship with the inflammatory response. Furthermore, serial blood sampling should be performed until at least 6 hours postprandial to capture the peak IL-6 concentration.

Conclusions

In conclusion, the acute consumption of either brown rice or white rice within the context of a daily meal with low total fat content did not significantly affect IL-6 levels at the 4-hour after eating in healthy, sedentary individuals. The postprandial IL-6 response is a complex process influenced by the interaction of various factors beyond the type of rice, including the total fat amount, food matrix, and the individual's metabolic status.

Conflict of interest

There is no conflict of interest

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Ethic Statement

This study was approved by the Health Research Ethics Committee of the Faculty of Medicine, Universitas Indonesia (Approval No: KET-1779/UN2.F1/ETIK/PPM.00.02/2024). The study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from the participant prior to data collection.

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Author Contributions

RFP: Conceptualization, data acquisition, formal analysis, interpretation of results, drafting the manuscript, and final approval of the version to be published.
SWJ: Supervision, interpretation of the data, critical revision of the manuscript for important intellectual content, and final approval of the version to be published.
WL: Conceptualization, study design supervision and consultation, critical revision of the manuscript for important intellectual content, and final approval of the version to be published.

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