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Effects of fermented red rice *(Oryza sativa)* and black rice *(Oryza sativa L. indica)* on blood pressure in pregnant women with preeclampsia

Efektivitas Pemberian Fermentasi Beras Merah (Oryza sativa) dan Beras Hitam (Oryza sativa L. indica) terhadap Tekanan Darah Ibu Hamil Preeklamsia

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ABSTRACT

Background: *Preeclampsia is a hypertensive disorder of pregnancy for approximately 75% of direct maternal deaths. Early detection and promoting healthier nutritional alternatives are strategies to mitigate its risks. Fermented red rice and black rice may serve as dietary interventions due to bioactive compounds such as lovastatin that may support maternal health in preeclampsia.*

Objective: *To compare and analyze the effect of fermented red rice and black rice on the blood pressure of pregnant women with preeclampsia. A true experimental research design with randomized pretest-posttest control-group design.*

Methods: *The study conducted from August-September 2025, involved 60 pregnant women with preeclampsia in the working area of Cikalongwetan Regional Hospital. Participants were randomly assigned to three groups, a fermented red rice, a fermented black rice, and a control receiving mineral water. Each group received 5mL of their intervention twice daily for four weeks. Data were analyzed using Paired Sample t-test and One Way ANOVA.*

Results: *The results after four-week intervention showed significant differences in blood pressure reduction among the groups. Fermented red rice showed the most decrease, with mean reduction of 22.5 mmHg in systolic blood pressure and 12.5 mmHg in diastolic blood pressure. Fermented black rice also showed reduction, averaging 14.5 mmHg (systolic) and 11.5 mmHg (diastolic). The One-Way ANOVA confirmed a statistically significant difference, the mean post intervention systolic (p=0.025) and diastolic (p=0.007) blood pressure among the groups.*

Conclusion: *The reduction in blood pressure was greater fermented red rice group compared to fermented black rice group.non- pharmacological pain management during labor.*

Keywords: *black rice, blood pressure, preeclampsia, red rice*

ABSTRAK

Latar Belakang: Preeklampsia merupakan gangguan hipertensi pada kehamilan yang berkontribusi terhadap sekitar 75% kematian maternal langsung. Deteksi dini dan pemanfaatan alternatif nutrisi yang lebih sehat merupakan strategi untuk mengurangi risiko preeklampsia. Beras merah fermentasi dan beras hitam fermentasi berpotensi menjadi intervensi diet karena mengandung senyawa bioaktif, seperti lovastatin, yang dapat mendukung kesehatan ibu dengan preeklampsia.

Tujuan: Menganalisis dan membandingkan pengaruh beras merah fermentasi dan beras hitam fermentasi terhadap tekanan darah ibu hamil dengan preeklampsia.

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Metode: Penelitian ini menggunakan desain true experimental dengan rancangan randomized pretest-posttest control-group. Penelitian dilakukan pada Agustus–September 2025 terhadap 60 ibu hamil dengan preeklampsia di wilayah kerja RSUD Cikalongwetan. Responden dibagi secara acak ke dalam tiga kelompok, yaitu kelompok beras merah fermentasi, beras hitam fermentasi, dan kontrol yang menerima air mineral. Setiap kelompok mendapatkan intervensi sebanyak 5 mL dua kali sehari selama empat minggu. Data dianalisis menggunakan uji Paired Sample t-test dan One-Way ANOVA.
Hasil: Setelah empat minggu intervensi, terdapat perbedaan penurunan tekanan darah yang signifikan antar kelompok. Kelompok beras merah fermentasi menunjukkan penurunan terbesar dengan rerata tekanan darah sistolik sebesar 22,5 mmHg dan diastolik 12,5 mmHg. Kelompok beras hitam fermentasi juga mengalami penurunan, yaitu rata-rata 14,5 mmHg (sistolik) dan 11,5 mmHg (diastolik). Hasil One-Way ANOVA menunjukkan perbedaan yang bermakna pada tekanan darah sistolik (p=0,025) dan diastolik (p=0,007) pascaintervensi antar kelompok.
Kesimpulan: Beras merah fermentasi lebih efektif dalam menurunkan tekanan darah pada ibu hamil dengan preeklampsia dibandingkan beras hitam fermentasi.

Kata kunci: beras hitam, beras merah, preeklamsia, tekanan darah

INTRODUCTION

Health development aims to improve access to and the quality of health services. One of the key strategies involves increasing the availability of human resources, infrastructure, medicines, and vaccines. Another important aspect focuses on enhancing maternal and child health through promotive, preventive, curative, and rehabilitative efforts. Maintaining maternal health is essential to ensure the birth of a healthy and high-quality infant while reducing maternal mortality. Preeclampsia remains one of the direct causes contributing to the high Maternal Mortality Rate (MMR). Indirect causal factors of maternal mortality include poverty, distance to health facilities, lack of information, inadequate services, and cultural beliefs and practices.[1]

Contributing factors to preeclampsia are multifactorial, involving a combination of genetic and environmental influences, as well as abnormal placental development. These conditions lead to an imbalance of angiogenic factors.[2] Improving the balance of angiogenic factors is a crucial step in mitigating and potentially treating preeclampsia.[3] Statins are effective in the prevention and treatment of preeclampsia.[4] Naturally occurring lovastatin (monacolin K), produced through food fermentation processes, has potential as a functional medicinal compound.[3 5 6 7 8] Fermented red and black rice are rich sources of antioxidants, particularly anthocyanins and flavonoids.[9 10 11] This may help reduce oxidative stress, a key contributor to the pathophysiology of preeclampsia. These bioactive compounds can enhance *nitric oxide* (NO) synthesis, thereby promoting vasodilation and lowering blood pressure. Furthermore, they help improve endothelial function, an essential mechanism for maintaining hemodynamic stability and preventing hypertension. Optimal endothelial function, in turn, can lower the risk of pregnancy complications such as preeclampsia.[12]

Preeclampsia is a serious obstetric complication that adversely affects the health of both the mother and the fetus. Fermented red and black rice have been reported to exert beneficial effects on health. Understanding how these fermented products influence blood pressure may lead to the development of safer and more natural alternatives to conventional therapies for pregnant women at risk of preeclampsia.

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Although both types of rice demonstrate potential health-promoting properties, comparative studies on the effects of fermented red and black rice in pregnant women with preeclampsia remain limited. In Indonesia, preeclampsia accounts for approximately 13% of maternal deaths.[13] The national target for reducing maternal mortality is 183 deaths per 100.000 live births by the year 2030. [14] In 2020, ten districts and cities in West Java recorded the highest maternal mortality rates, one of which was West Bandung Regency. Indicate that West Bandung Regency continued to report a disproportionately high incidence of preeclampsia-related maternal complications, underscoring the need for locally applicable, evidence-based dietary interventions. The implementation of preeclampsia screening is influenced by various factors, including health care providers, health facilities, environmental conditions, pregnant women, and family support.[15]

One potential approach to complement existing interventions is the use of traditional herbal therapy, such as fermented red rice and fermented black rice, which serve as natural sources of nutritional and bioactive compounds. Fermented rice has long been recognized in Asian culinary traditions as a functional food rich in nutrients and biologically active components. Red rice is particularly high in fiber and antioxidants, whereas black rice contains abundant anthocyanins that have been shown to exert beneficial effects on cardiovascular health. A systematic review and meta-analysis further confirmed that red yeast rice *(Monascus purpureus)* preparations are effective and well-tolerated in improving lipid profiles and reducing the risk of cardiovascular events, particularly in populations with statin intolerance or dyslipidemia, suggesting that the bioactive compounds in fermented red rice may exert clinically meaningful cardiovascular protective effects.[16]

Although both types of rice have demonstrated potential health benefits, the comparative effects of fermented red and black rice on preeclampsia in pregnant women have not been extensively investigated. A better understanding of the differential effects of these two fermented rice types may significantly contribute to the development of more effective nutritional interventions for the management of preeclampsia, thereby improving the quality of life of pregnant women and supporting optimal fetal health. To date no study has directly compared these two types of fermented rice within a single research design for blood pressure management in pregnancies complicated by preeclampsia. In view of the importance of preventive strategies, this study was conducted to compare the effects of fermented red rice *(Oryza sativa)* and fermented black rice *(Oryza sativa L. indica)* on blood pressure among pregnant women with preeclampsia. This study aimed to compare and analyze the effect of fermented red rice and black rice on the blood pressure of pregnant women with preeclampsia.

METHODS

Study design

This study employed a quantitative approach using a true experimental design with a randomized pretest–posttest control group design. This study compared the effects of fermented red rice (Oryza sativa) and fermented black rice (Oryza sativa L. indica) on blood pressure in pregnant women with preeclampsia. Data collection was conducted in the working area of Cikalongwetan Regional General Hospital over four weeks, from August 8 to September 4, 2025.

Data source and sampling procedure

The study subjects were pregnant women diagnosed with preeclampsia and hypertension who were treated at the Cikalongwetan Regional Hospital (RSUD Cikalongwetan). The target population consisted of all pregnant women with

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preeclampsia and high blood pressure within the hospital's service area in West Bandung Regency. The sample size of 60 participants (20 per group) was determined based on total population sampling, as the total number of pregnant women with preeclampsia who met the inclusion criteria and were accessible within the study period at RSUD Cikalongwetan was 60. Although a formal a priori power calculation was not performed, this sample size was considered sufficient for a pilot-scale randomized controlled trial and is consistent with similar studies examining dietary interventions in preeclampsia management. The absence of a formal power analysis is acknowledged as a limitation of this study.

The study sample was drawn from an accessible population that met the inclusion criteria, which included singleton intrauterine pregnancy, gestational age of ≥20 weeks based on the last menstrual period, systolic blood pressure ≥140 mmHg, diastolic blood pressure ≥90 mmHg, and the presence of proteinuria. The exclusion criteria were congenital heart defects; chronic diseases such as kidney disease, heart disease, hypothyroidism, and diabetes mellitus; as well as a history of smoking, alcohol consumption, or intrauterine growth restriction (IUGR).

The study sample was allocated into three groups using simple random sampling via a lottery method (cara undian): (1) an experimental group that received the fermented red rice intervention (Group A, n=20), (2) an experimental group that received the fermented black rice intervention (Group B, n=20), and (3) a control group that received mineral water (Group C, n=20). It is acknowledged that mineral water represents a low-fidelity placebo, as it does not replicate the sensory properties (taste, color, and aroma) of the fermented rice beverages. This constitutes a methodological limitation that may introduce performance bias, and is explicitly discussed in the limitations section of this paper.

The allocation sequence was generated by the principal investigator prior to participant recruitment. Sequentially numbered, sealed opaque envelopes were used to conceal the allocation from the recruiting midwives until the moment of assignment, thereby ensuring allocation concealment in accordance with CONSORT guidelines.

This study was conducted as an open-label trial; neither the participants nor the midwives administering the intervention were blinded to group allocation, given the distinct organoleptic characteristics (color, aroma, and taste) of the two fermented rice beverages compared to mineral water. The absence of blinding is acknowledged as a methodological limitation of this study and is discussed further in the limitations section.

Variables of the study

The independent variable in this study were fermented red rice and fermented black rice, while the dependent variables included blood pressure (systolic and diastolic).

Measurement and instruments

The nutritional composition of the fermented products was analyzed using the Luff Schoorl method for carbohydrate determination, the Soxhlet method for total fat analysis, and the Kjeldahl method for protein analysis. Blood pressure was measured using a manual sphygmomanometer and a stethoscope.

Data collection

Measurements were conducted twice prior to the intervention (day 0) and after the intervention (day 29) by trained midwives who had been instructed in standardized blood pressure measurement procedures. Each participant received 5 mL of the intervention twice daily for four weeks.

The intervention was conducted over four weeks within the same timeframe.

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Fermented red and black rice were prepared through a 44-hour fermentation process using baker's yeast *(Saccharomyces cerevisiae)*, boiled water, and granulated sugar. The fermented rice product used in this study was a beverage obtained from soaking the fermented rice.

This preparation was administered as an adjuvant therapy alongside the standard medical care received by all participants. Throughout the study period, all participants continued to receive standard antihypertensive pharmacological treatment as prescribed by their attending physicians at RSUD Cikalongwetan. The fermented rice beverages were therefore administered in addition to, and not as a replacement for, conventional medical therapy. Consequently, the observed reductions in blood pressure reflect the additive effect of the fermented rice intervention over and above standard pharmacological management.

Ethical considerations

This study obtained ethical approval from the Health Research Ethics Committee of Bhakti Kencana University (approval number: 244/09.KEPK/UBK/VII/2025).

Data analysis

Data analysis was carried out univariately using descriptive statistics and bivariately using normality tests, paired t-tests, and *one-way ANOVA* tests.

RESULTS

Table 1. Nutritional Profile and Bioactive Compound Characterization of Fermented Red Rice (per 100 g)

No.	Parameter	Unit	Results	%AKG/100g
1.	Total Fat	%	0.30	0.45
2.	Protein	%	1.02	1.71
3.	Carbohydrate	%	14.30	4.40
4.	Calories	kcal/100g	63.97	2.98
5.	Ash	%	0.99	-
6.	Vitamin C	mg/100g	7.28	8.09
7.	Antioxidant Activity (IC_{50})	µg/mL	333.51	-

Source: Research Data on Nutritional Profile and Bioactive Compound Characterization of Fermented Red Rice (per 100 g)

Based on Table 1, fermented red rice contained 14.30% carbohydrates, 1.02% protein, 0.30% fat, 7.28 mg/100 g vitamin C, and exhibited antioxidant activity with an IC_{50} value of 333.51 µg/mL. These findings indicate that fermented red rice contains nutritional and bioactive components that may contribute to health benefits.

Table 2. Nutritional Profile and Bioactive Compound Characterization of Fermented Black Rice (per 100 g)

No.	Parameter	Unit	Results	%AKG/100g
1.	Total Fat	%	0.16	0.24
2.	Protein	%	0.68	1.14
3.	Carbohydrate	%	13.97	4.30
4.	Calories	kcal/100g	60.05	2.79
5.	Ash	%	0.93	-
6.	Vitamin C	mg/100g	5.48	6.09
7.	Antioxidant Activity (IC_{50})	µg/mL	358.71	-

Source: Research Data on Nutritional Profile and Bioactive Compound Characterization of Fermented Black Rice (per 100 g)

Based on Table 2, fermented black rice contained 13.97% carbohydrates, 0.68% protein, 0.16% fat, 5.48 mg/100 g vitamin C, and an IC_{50} value of 358.71 µg/mL. Compared with fermented red rice, fermented black rice showed lower protein, vitamin C content, and antioxidant activity.

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Table 3. Characteristics of Research Subjects

Characteristics	Category	Experimental Group: Fermented Red Rice n=20	%	Experimental Group: Fermented Black Rice n=20	%	Control Group n=20	%
Age	At risk (<20, >35)	13	65	11	55	12	60
	No Risk	7	35	9	45	8	40
Education	Low (<SMA)	11	55	13	65	14	70
	High (≥high school)	9	45	7	35	6	30
Parity	At risk (>3)	12	60	10	50	9	45
	No Risk (<3)	8	40	10	50	11	55
Gestational Age	Second Trimester	6	30	7	35	4	20
	Third Trimester	14	70	13	65	16	80
History of Hypertension	Yes	5	25	7	35	3	15
	No	15	75	13	65	17	85

Based on Table 3**,** most participants in all groups were classified as being at-risk age, had a low educational level, and were in the third trimester of pregnancy. A history of hypertension was most frequently observed in the fermented black rice group (35%).

Table 4. Comparison of Systolic Blood Pressure Differences Before and After Fermented Red Rice (Oryza sativa) and Black Rice (Oryza sativa L. Indica) at Cikalongwetan Regional Hospital in 2025

Groups	Systole Before			Systole After			N	*Mean* Difference	*p-value Paired Sample T test*	*p-value One-Way ANOVA*
	Mean	SD	SE	*Mean*	SD	SE				
Fermented Red Rice	167.0	25.77	5.76	144.5	16.38	3.66	20	22.5	0.000	0.025
Fermented Black Rice	160.0	17.77	3.97	145.5	16.69	3.73	20	14.5	0.000	
Mineral Water	158.5	15.98	3.57	157.5	15.85	3.54	20	1.00	0.163	

Source: Primary Research Data 2025

Based on Table 4, the fermented red rice group showed the greatest reduction in systolic blood pressure (22.5 mmHg), followed by the fermented black rice group (14.5 mmHg). In contrast, the control group showed only a 1.0 mmHg reduction. Statistical analysis indicated a significant difference among the groups (p = 0.025).

Table 5. Comparison of Differences in Diastolic Blood Pressure Before and After Fermented Red Rice (Oryza sativa) and Black Rice (Oryza sativa L. Indica) at Cikalongwetan Regional Hospital in 2025

Groups	Diastole Before			Diastole After			N	*Mean* Difference	*p-value Paired Sample t-test*	*p-value One-Way ANOVA*
	Mean	SD	SE	*Mean*	SD	SE				
Fermented Red Rice	96.0	12.73	2,.5	83.5	8.13	1.82	20	12.5	0.000	0.007
Fermented Black Rice	93.5	5.87	1.30	82.0	8.30	1.80	20	11.5	0.000	
Mineral Water	92.0	6.15	1.38	90.0	7.95	1.78	20	2.00	0.104	

Source: Primary Research Data 2025

Based on Table 5, the fermented red rice group experienced a 12.5 mmHg reduction in diastolic blood pressure, while the fermented black rice group showed an

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11.5 mmHg reduction. The control group demonstrated only a 2.0 mmHg decrease. Statistical analysis revealed a significant difference among the groups (p = 0.007).

DISCUSSION

Based on Table 3, most pregnant women with preeclampsia were within the risk age category (<20 years and >35 years). The proportion of pregnant women in this category was 65% in the fermented red rice group, 55% in the fermented black rice group, and 60% in the control group. In addition, the majority of pregnant women with preeclampsia had a low level of education (<high school), accounting for 55% in the fermented red rice group, 65% in the fermented black rice group, and 70% in the control group. Regarding parity, most pregnant women with preeclampsia were classified as having a high-risk parity (>3), with proportions of 60% in the fermented brown rice group, 50% in the fermented black rice group, and 45% in the control group. The majority of pregnant women with preeclampsia were in the third trimester of pregnancy, accounting for 70% in the fermented brown rice group, 65% in the fermented black rice group, and 80% in the control group. Furthermore, most pregnant women with preeclampsia did not have a history of hypertension, with percentages of 75% in the fermented brown rice group, 65% in the fermented black rice group, and 85% in the control group.

In the intervention group, the mean systolic blood pressure of pregnant women with preeclampsia before receiving fermented red rice was 167.0±25.77 mmHg. After the administration of fermented red rice, the mean systolic blood pressure decreased to 144.5±16.38 mmHg, with a mean reduction of 22.5 mmHg. Similarly, the mean diastolic blood pressure before the intervention was 96.0±12.73 mmHg, and after receiving fermented red rice, it decreased to 83.5±8.13 mmHg, with a mean reduction of 12.5 mmHg.

In the black rice fermentation intervention group, the mean systolic blood pressure of pregnant women with preeclampsia before the intervention was 160.0±17.77 mmHg. After receiving fermented black rice, the mean systolic blood pressure decreased to 145.5±16.69 mmHg, with a mean reduction of 14.5 mmHg. Similarly, the mean diastolic blood pressure before the intervention was 93.5±5.87 mmHg, and after the administration of fermented black rice, it decreased to 82.0±8.30 mmHg, with a mean reduction of 11.5 mmHg.

In the control group of pregnant women with preeclampsia, the mean systolic blood pressure before receiving mineral water was 158.5±15.98 mmHg, while after the intervention it was 157.5±15.85 mmHg, with a mean difference of 1.0 mmHg. The mean diastolic blood pressure before administration was 92.0±6.15 mmHg, and after receiving mineral water, it decreased slightly to 90.0±7.95 mmHg, with a mean difference of 2.0 mmHg. The statistical analysis showed a p-value of 0.025 for systolic blood pressure and a p-value of 0.007 for diastolic blood pressure, indicating that there were statistically significant differences in the mean systolic and diastolic blood pressure after the intervention.

The Paired Sample t-test results demonstrated a statistically significant reduction in systolic blood pressure within the fermented red rice group [t(19) = 7.84; p < 0.001] and within the fermented black rice group [t(19) = 5.32; p < 0.001], whereas no significant change was observed in the control group [t(19) = 1.43; p = 0.163]. Similarly, diastolic blood pressure showed significant reductions in the fermented red rice group [t(19) = 6.71; p < 0.001] and the fermented black rice group [t(19) = 5.87; p < 0.001], but not in the control group [t(19) = 1.65; p = 0.104]. The One-Way ANOVA revealed a statistically significant difference in post-intervention systolic blood pressure across the three groups [F(2, 57) = 3.94; p = 0.025], as well as in post-intervention diastolic blood

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pressure [F(2, 57) = 5.47; p = 0.007].

The decrease in blood pressure seen from the results of the study in both intervention groups after administration of fermented red rice *(Oryza sativa)* and fermented black rice *(Oryza sativa L. indica)* showed a significant decrease, both in systolic blood pressure and diastolic blood pressure. However, when compared between the two intervention groups, the administration of fermented red rice *(Oryza sativa)* was more effective than the administration of fermented black rice *(Oryza sativa L. indica),* with a mean difference in systolic blood pressure of 22.5 mmHg and diastolic blood pressure of 12.5 mmHg. The mean difference in systolic blood pressure of 14.5 mmHg and in diastolic blood pressure of 11.5 mmHg in the black rice fermentation group. The decrease in blood pressure in the fermented red rice group indicates that the intervention is more effective in reducing blood pressure in pregnant women with preeclampsia. With this significant decrease, this intervention can be considered as one of the steps in the management of preeclampsia. This study proves that fermented red rice has been proven safe and effective. Fermented red rice preparations are safe and effective in improving lipid profiles and reducing the risk of cardiovascular events. The use of fermented red rice in specific situations (statin intolerance, patients with dyslipidemia who are ineligible for statin therapy) may be considered.[17]

The fermentation of red rice and black rice in this study is safe for consumption by pregnant women, because it uses a bacterial starter with yeast raw materials used in the production of industrial yeast extract, namely baker's yeast *(Saccharomyces cerevisiae).* This yeast extract is recognized as generally recognized as safe (GRAS) by most food safety certification bodies worldwide. The cell wall of baker's yeast contains a high proportion (15–30% of dry cell mass) of cross-linked polysaccharides, especially mannose oligosaccharides and β-glucans.[18] This yeast extract has a high content of nucleic acids, proteins, B vitamins, and fiber. The polysaccharide components (mannan and β-glucan) contribute significantly to the antioxidant properties of rice through their ability to capture hydroxyl free radicals and superoxide anions.[19] Yeast extract is also rich in amino acids, peptides, vitamins, minerals, nucleotides, and other nutrients that are widely used as food flavoring agents, food additives, and nutritional supplements.[20] Essential amino acids in yeast extract account for 40% of the total amino acids, meeting the standards of the United Nations Food and Agriculture Organization (UNFAO) and the World Health Organization (WHO) for essential amino acid content in healthy foods. Yeast extract has found applications in the medical and health fields due to its biological activity and high nutritional content. In addition to its anti-inflammatory and anti-cancer effects, oral β-glucan has other health benefits, such as lowering cholesterol and blood lipid levels without the side effects of synthetic drugs. Therefore, it has great potential for the development of treatments to manage conditions such as obesity, pneumonia, cardiovascular disease, and skin diseases.[21]

The control group experienced a decrease in blood pressure in pregnant women with preeclampsia. The mean difference between systolic blood pressure before and after mineral water administration was 1 mmHg, and the mean difference between diastolic blood pressure before and after mineral water administration was 2 mmHg. This indicates that this fermentation therapy is an adjuvant therapy. The decrease in systolic and diastolic blood pressure in the control group may be due to the consumption of synthetic drugs prescribed by the doctor.

The dosage of fermented rice in this study followed a procedure that is in accordance with the equivalent dose in humans (mg/kg), with a safe dose given up to 19 mL for adult humans. The dosage of fermented red rice and fermented black rice in

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this study was 2 × 5 mL per day. [22] Fermentation was carried out for 44 hours using boiled water, baker's yeast, and granulated sugar. [23] The fermented rice water in this study is a drink resulting from soaking fermented rice in boiled water, with the help of microorganisms in baker's yeast *(Saccharomyces cerevisiae).* From the results of this study, it is hoped that pregnant women with preeclampsia who have low knowledge and are at risk of parity can make this fermented water at home. Because the method of preparation is simple and economical. In addition to being easy, cheap, and economical, this drink is a source of synbiotics, namely a combination of probiotics (good microorganisms that live in drinks and are beneficial to the body) and prebiotics (substances that serve as food for these probiotics so they can grow). In addition to probiotics, the fermentation results also produce substances called secondary metabolites (postbiotics). Postbiotics are compounds produced by beneficial bacteria that help maintain the normal function of intestinal cells, such as strengthening the intestinal wall, fighting harmful bacteria, and improving digestive health.[24]

The results of the analysis of nutrients and bioactive compounds from fermented rice show that the vitamin C content in fermented red rice is 7.28 mg, and the vitamin C content in fermented black rice is 5.48 mg. The antioxidant activity (IC_{50}) in fermented red rice is 333.51 ppm, and in fermented black rice is 358.71 ppm. This shows that fermented red rice produces more vitamin C compared to fermented black rice. The IC50 for antioxidant activity (IC_{50}) is a number that indicates how strong a substance works as an antioxidant. The smaller the IC_{50} number, the stronger the antioxidant ability (less substance is needed to inhibit free radicals). The results of the analysis test show that the IC_{50} in fermented red rice is a stronger antioxidant compared to fermented black rice, which is slightly weaker in antioxidants. Fermented red rice demonstrated superior efficacy in reducing both systolic and diastolic blood pressure compared to fermented black rice, a finding that warrants careful mechanistic interpretation. The difference in antioxidant activity (IC_{50}) between the two fermented products was relatively modest, approximately 7% (333.51 vs. 358.71 µg/mL), which alone may be insufficient to fully account for the substantially larger reduction in systolic blood pressure observed in the red rice group (22.5 mmHg vs. 14.5 mmHg).

This discrepancy suggests that additional bioactive constituents beyond antioxidant capacity are likely contributing to the antihypertensive effect of fermented red rice. In particular, the higher protein content of fermented red rice (1.02%) compared to fermented black rice (0.68%) may have resulted in a greater yield of bioactive antihypertensive peptides, such as Leu-Arg-Ala (LRA), which exerts vasodilatory effects through Nitric Oxide (NO) mediation.[25] Furthermore, lovastatin (monacolin K), a naturally occurring statin produced during the fermentation of red rice, may have contributed synergistically to blood pressure reduction by improving endothelial function and modulating the renin-angiotensin system, mechanisms that are independent of antioxidant capacity.[4] Taken together, the antihypertensive superiority of fermented red rice over fermented black rice is most plausibly attributable to a multi-compound synergistic mechanism, encompassing higher vitamin C content, stronger antioxidant activity, greater antihypertensive peptide yield, and the potential involvement of lovastatin, rather than antioxidant activity alone.

Vitamin C can scavenge free radicals, and in people with hypertension, especially preeclampsia, oxidative stress (having a lot of free radicals) causes damage to the endothelium (the lining of blood vessels). This endothelial damage then causes blood vessels to stiffen, resulting in increased blood pressure. Vitamin C can protect the blood vessel endothelium from free radical damage and can increase the bioavailability of Nitric Oxide (NO), a substance that causes blood vessels to widen (vasodilation) and

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can reduce inflammation of the blood vessel walls. This makes blood vessels more relaxed and elastic, and blood pressure (systolic and diastolic) decreases. Furthermore, the strong antioxidant activity (IC_{50}) can also reduce oxidative stress, thereby reducing the production of Reactive Oxygen Species (ROS) that damage blood vessels. It can also reduce arterial stiffness, allowing blood to flow more smoothly and reducing the burden on the heart.

Antioxidants can also reduce the activation of the renin-angiotensin system so that the angiotensin II hormone that usually increases blood pressure can be suppressed by the antioxidant effect. Antioxidants can improve the oxidative balance in the body so that blood pressure decreases physiologically. The relationship with the decrease in systole and diastole is that systole (the pressure when the heart pumps blood) can decrease because blood vessels are more dilated and elastic, while diastole (the pressure when the heart is at rest) can decrease because peripheral vascular resistance is reduced due to improved endothelial function and reduced oxidative stress. Fermented rice drinks can reduce systolic blood pressure. [26] The results also showed that the protein produced from fermented red rice was 1.02% higher than that from fermented black rice, which was 0.68%. It is known that according to the 2020 study by Shobako and Ohinata, rice bran contains an antihypertensive peptide derived from protein, namely Leu-Arg-Ala (LRA).[25]

This protein is cleaved from a vicilin -like storage protein and belongs to the cupin superfamily of proteins, and is one of the major proteins in rice. Generally, protein-rich foods are digested by proteases or fermented by microorganisms.[25] This LRA is digested by thermolysin and its antihypertensive effect results in potent vasodilation, mediated by Nitric Oxide (NO), which is the main mechanism of LRA's antihypertensive activity. Therefore, exogenous bioactive peptides derived from fermented foods, including LRA and endogenous ligands, can help reveal changes in the cardiovascular system. [27] Fermented rice not only exhibits antihypertensive effects but also improves glucose metabolism and the levels of triglycerides and total cholesterol in the liver. [28]

The strength of this study lies in its direct comparison between two distinct types of rice, red rice and black rice, undergoing fermentation, and their respective effects on blood pressure among pregnant women with preeclampsia. While previous studies have examined each type of rice individually, few have directly compared the two within the same experimental framework. This innovative approach provides a valuable contribution to the existing body of knowledge by highlighting potential differences in their antihypertensive effects. Consequently, the findings of this study are expected to offer new insights into the development of healthier and more effective dietary interventions for managing blood pressure in pregnant women with preeclampsia.

The limitations of this study include the fact that several participants reported discomfort during the consumption of the fermented product due to its distinctive aroma. Therefore, a motivational approach was required to ensure compliance. However, no serious adverse effects were observed during the consumption period. Another limitation lies in the lack of control over the fermentation batches, as the fermentation process was conducted traditionally at home. This method increases the potential risk of pathogenic contamination, and thus, chemical and microbiological analyses are recommended. To minimize such risks, the researchers advised participants to store the fermented products in a refrigerator. Nevertheless, some participants kept their fermentation at room temperature due to the unavailability of refrigeration facilities. Furthermore, it was challenging to prepare a placebo with a similar taste, aroma, and color to the fermented samples. Blood pressure measurements were performed using a manual sphygmomanometer, which may have

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introduced variations in interpretation among different health workers.

The implications of this research contribute to the advancement of knowledge in the fields of clinical nutrition, obstetrics, and herbal pharmacology, particularly regarding the potential use of fermented food ingredients as adjuvant therapy for reducing blood pressure in pregnant women with preeclampsia. Moreover, the findings may support the development of functional food products derived from locally fermented rice that are safe for consumption during pregnancy. This study also aims to introduce such products to the general public as a traditional, health-promoting dietary alternative that can assist in maintaining optimal blood pressure throughout pregnancy.

CONCLUSION

Both fermented red rice (Oryza sativa) and fermented black rice (Oryza sativa L. indica) significantly reduced systolic and diastolic blood pressure in pregnant women with preeclampsia; however, fermented red rice demonstrated a markedly greater antihypertensive effect with mean systolic and diastolic reductions of 22.5 mmHg and 12.5 mmHg, respectively compared to fermented black rice (14.5 mmHg systolic and 11.5 mmHg diastolic), positioning fermented red rice as the more effective option for consideration as a supportive dietary adjuvant in the clinical management of preeclampsia. It is recommended that future researchers conduct studies with a larger sample size and include postpartum women, extending the observation period up to three months after delivery.

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