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Potential of Analog Rice for Diabetes and Dyslipidemia: A Narrative Review of In Vivo Insight

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ABSTRACT

Analog rice is a potential alternative staple food for managing degenerative diseases, particularly type 2 diabetes mellitus (T2DM) and dyslipidemia. It can be formulated from various raw materials, including tubers, cereals, legumes, pulses, vegetables, and fruits, resulting in a product that resembles white rice. It contains bioactive compounds at levels comparable to or higher than that of white rice. The bioactive compounds, such as dietary fiber and resistant starch, function to slow glucose absorption and promote beneficial SCFA production, while the phenolic compounds act as potent antioxidants that may protect tissues from oxidative damage induced by hyperglycemia and dyslipidemia. This narrative review utilized PubMed, Scopus, ScienceDirect, and Google Scholar with keywords including "Analog rice","Diabetes Mellitus","Hyperglycemia","Dyslipidemia,","Lipid profiles,","Histopathology". The inclusion criteria comprised original English and Indonesian articles (2016-2026) evaluating in vivo analog rice interventions, selected through title, abstract, and full-text screening. The exclusion criteria were in vitro studies, human clinical trials, review articles, and non-peer-reviewed publications, resulting in 11 articles. The synthesized evidence suggests that analog rice consumption has potential benefits for reducing blood glucose levels, insulin levels, and the insulin resistance index (HOMA-IR), as well as improving pancreatic β-cell function (HOMA-β), increasing short-chain fatty acid (SCFA) production, and enhancing serum lipid profiles while reducing the atherogenic index (AI). Additionally, histopathological analysis showed tissue structure improvements, including in the β cells of the Langerhans islets, myocardial cells, and kidney cells. These findings suggest that analog rice has the potential to be effective in managing T2DM and dyslipidemia.

Key Messages:

- Analog rice has the potential to be an alternative staple food for individuals with diabetes mellitus and dyslipidemia.
- Specific formulations of analog rice have been associated with potential histopathological improvement in the pancreatic β cells of the Langerhans islets, myocardial tissue, and kidney cells caused by diabetes mellitus and dyslipidemia.
- While the current evidence from these studies is highly promising, further validation through advanced in vivo studies and human clinical trials is necessary to confirm long-term efficacy and determine the optimal dosage

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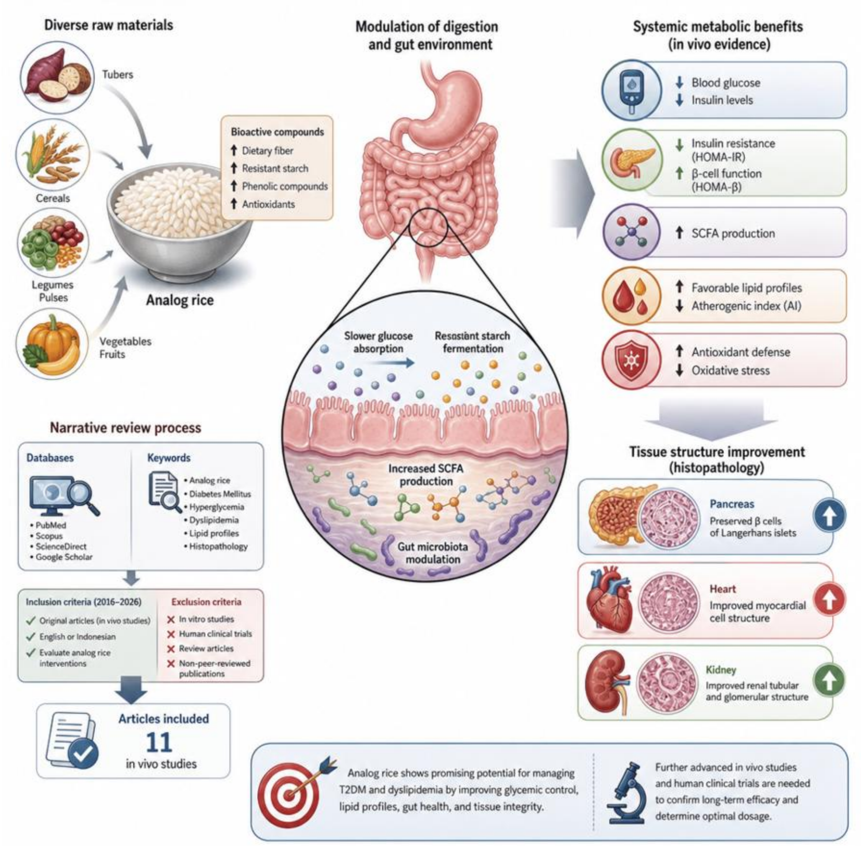
GRAPHICAL ABSTRACT



INTRODUCTION

Rice is a staple food that serves as the main source of calories, especially in most East Asian, Southeast Asian, and South Asian countries (1). Despite its central role in food security, the widespread consumption of white rice raises nutritional concerns. The urgency to address these nutritional concerns is underscored by the increasing global health crises of type 2 diabetes mellitus (T2DM) and dyslipidemia. The global prevalence of T2DM has significantly increased, with the number of affected individuals increasing from 529 million in 2021 to 589 million in 2025 (2, 3). Remarkably, around 60% of people worldwide who have T2DM are in Asia.(4), highlighting a critical regional burden that aligns with areas of high rice consumption. Concurrently, dyslipidemia remains a massive global health challenge. A comprehensive meta-analysis quantified this global burden in adults, revealing significant combined prevalences of 28.8% for hypertriglyceridemia, 24.1% for hypercholesterolemia, 38.4% for low HDL-C, and 18.93% for high LDL-C. Collectively, these findings confirm that dyslipidemia constitutes one of the most prevalent cardiovascular risk factors worldwide, further emphasizing the critical need for preventive dietary interventions (5).

White rice is composed predominantly of starch and contains low levels of protein, fiber, and bioactive compounds due to the removal of bran, aleurone layer, and germ during milling and polishing (6). As a result, white rice is digested more quickly in the human digestive tract and has a high glycemic index (GI), ranging from 73 to 93.5 (7). High consumption of white rice in high-GI diets, such as those relying heavily on white rice as a staple food, and poor overall dietary patterns, are associated with an increased risk of T2DM, dyslipidemia, and other metabolic syndrome-related diseases (8, 9). White rice consumption increased postprandial glucose and insulin levels (10). Another study demonstrated consistent findings, where a white rice-based diet is associated with increased fasting blood glucose, triglyceride, and insulin resistance (11). This nutritional limitation and effect of white rice has encouraged the development of alternative rice-based products with improved health-promoting properties.

Analog rice is an alternative staple food that can be developed by maintaining the habit of rice consumption, but with a better nutritional and functional profile. Analog rice is made to resemble paddy

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rice through extrusion or granulation process, starting with pregelatinization to increase starch (12). Analog rice can be formulated flexibly according to the desired nutritional profile and health targets adjusted to the characteristics of the raw materials used. The raw materials used to make analog rice were sourced from non-rice carbohydrate sources such as tubers and cereals (13). In addition, analog rice uses other ingredients to enhance the content of bioactive compounds, proteins, vitamins, minerals, or targeted nutrients. Analog rice is generally formulated with legumes, fruit, vegetables, and other ingredients that contain additional bioactive compounds (14, 15).

The effectiveness of analog rice can be evaluated using in vivo tests, allowing for the assessment of biological responses and underlying health mechanisms. To date, most in vivo studies have focused on metabolic disorders such as diabetes mellitus and dyslipidemia, which are related to the consumption patterns of white rice with a high glycemic index. An in vivo study shows that analog rice made from various mixtures of flour from tubers, germinated legumes, and cereals has shown potential effects as anti-diabetes and anti-dyslipidemia agents (16). This may be related to the high total phenol and dietary fiber content in the analog rice. Therefore, understanding the relationship between the profile of bioactive compounds and in vivo results becomes crucial to explain the potential of analog rice as a potential dietary strategy for metabolic syndrome.

Although in vivo studies have been widely conducted, a significant gap remains in the current literature. Findings regarding the metabolic benefits of analog rice are currently fragmented across various independent animal studies. There is a critical need to systematically synthesize these fragmented in vivo findings to establish a robust scientific foundation before designing targeted human clinical trials. Comprehensive syntheses linking specific bioactive compounds to biological mechanisms and in vivo outcomes remain limited. Therefore, the purpose of this review is to synthesize the findings of in vivo studies related to the impact of various analog rice formulations on biochemical and histopathological parameters in metabolic diseases. Additionally, this review aims to link the role of these bioactive compounds with the underlying mechanisms of metabolic disease management and prevention.

METHODS

This study employed a narrative review approach to synthesize existing evidence regarding the potential effects of analog rice based on in vivo studies. This review focused on the potential health benefits of analog rice, particularly in experimental models of diabetes mellitus and dyslipidemia, by evaluating biochemical and histopathological parameters. The literature search was conducted through the scientific databases PubMed, Scopus, ScienceDirect, and Google Scholar between November 1, 2025, and January 21, 2026. The keywords used included: “Analog rice” AND (“Diabetes Mellitus”, OR “Hyperglycemia”, OR “Dyslipidemia”, OR “Lipid profiles”, and OR “Histopathology”.

To capture recent developments in analog rice research, the selection process was guided by specific inclusion and exclusion criteria. The inclusion criteria comprised original research articles published in English and Indonesian between 2016 and 2026 that reported in vivo interventions of analog rice. Studies evaluating histopathological changes in target organs were also included. Conversely, the exclusion criteria were set to exclude studies that do not include an in vivo biological assessment (i.e., those only evaluating compositional or physicochemical material properties). Furthermore, in vitro studies, human clinical trials, review articles, and non-peer-reviewed publications were excluded. The complete study selection process, from initial identification to final inclusion, is visually represented in a flow diagram (Figure 1).

Articles were categorized according to thematic subtopics, including in vivo evaluation of analog rice in diabetic models, in vivo evaluation of analog rice in dyslipidemia models, and histopathological outcomes. Data were extracted manually using a table that included information on authors, study objective, research design, sample characteristics, variables assessed, main outcomes, and limitations. The synthesis process involved identifying current research trends, assessing consistency and discrepancies among findings, and highlighting gaps in the literature. This review aims to summarize the available evidence and provide scientific recommendations to inform future research direction and the potential clinical relevance of analog rice.

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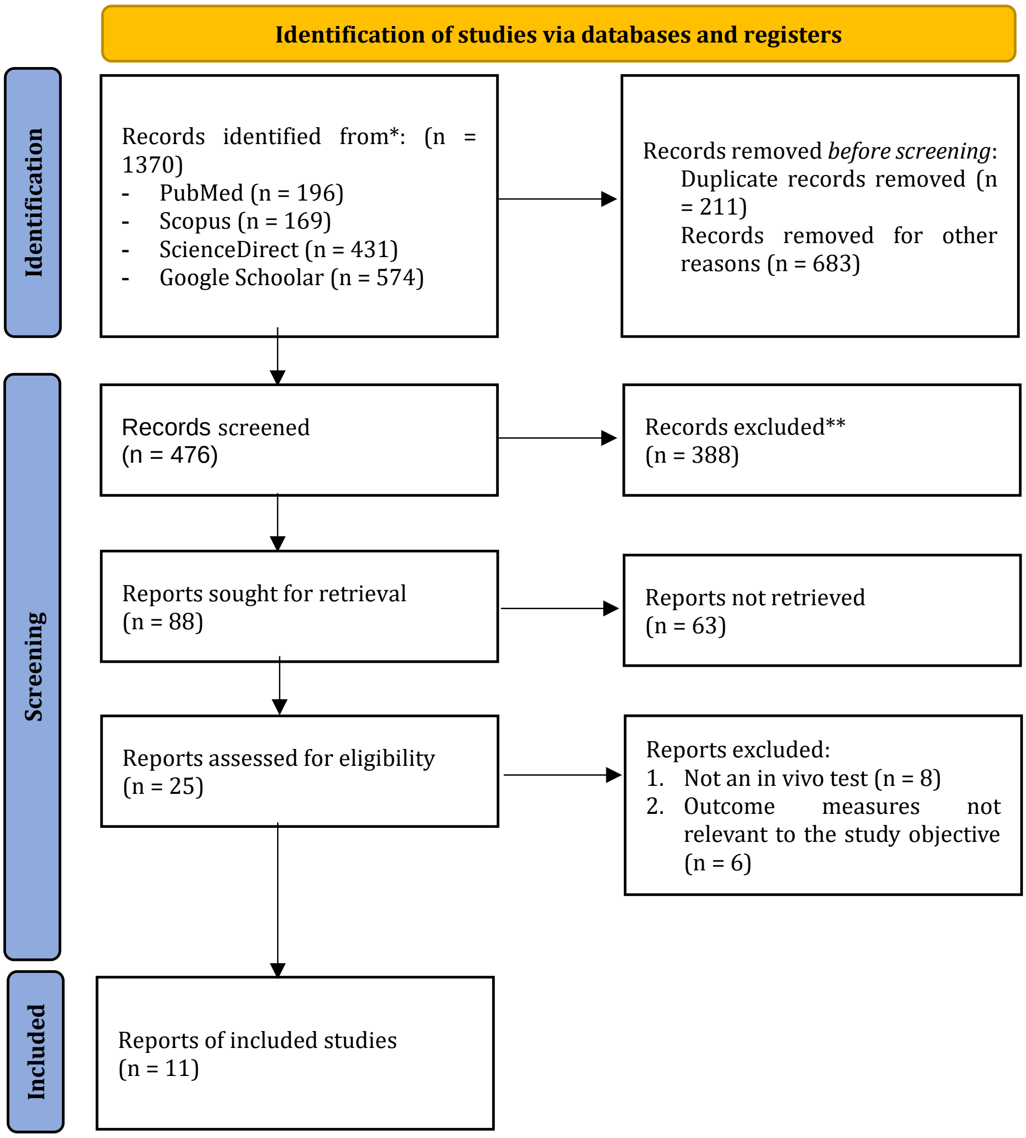

Figure 1. Prisma Flow Diagram

RESULTS

The comprehensive findings from the selected in vivo studies are summarized in Table 1. This table systematically details the experimental parameters of each study, including the specific analog rice formulations utilized, the characteristics of the animal models, the treatment group allocations, and the administered dosages. Furthermore, it outlines the primary outcomes of both biochemical and histopathological evaluations, alongside the key discoveries of each intervention.

The nutritional composition and subsequent metabolic effects of analog rice are fundamentally dependent on the raw ingredients used in its formulation. These ingredients are distinctly categorized into primary and secondary components. Primary ingredients serve as the foundational carbohydrate base and predominantly consist of roots, tubers, and cereals (17). In contrast, secondary ingredients—such as legumes, fruit derivatives, and functional spices—are incorporated to enrich the nutritional profile and provide targeted therapeutic benefits. Regarding the primary ingredients, formulations relying heavily on tubers such as Modified Cassava Flour (Mocaf), sago, arrowroot, and gembili, often combined with corn starch, consistently demonstrate strong anti-diabetic and anti-dyslipidemia properties. These base ingredients have the potential to lower fasting blood glucose (FBG) and improve lipid profiles by reducing total cholesterol, LDL, and triglycerides while elevating beneficial HDL.

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Table 1. Health Effects of Analog Rice Based on In Vivo Studies

Formulation of analog rice	Rat species (sex, age, weight), number of rats	Animal model/ Treatment duration	Group of rats (dosage)	Outcome measures	Key findings	Limitation	Ref
Anti-diabetic							
Mocaf, corn starch, and rice	*Rattus norvegicus* (male, 3 months old, 200-250 g), 24 (n=6)	Type 2 DM STZ (35 mg/kgBW, 3 days) and HFD (23% of fat, 3 weeks) / 28 days	**Healthy group** Standard feed (SF) (20 g) **Intervention group** - SF (20 g) - SF (20 g) + metformin (45 mg/kgBW) - Analog rice (20 g) + metformin (45 mg/kgBW)	**Biochemical** NR **Histopathological** Myocardial cell death	- Diabetes induces alterations in myocardial structure. - Analog rice with metformin → ↓ % myocardial cell death	The study design did not include an analog rice–only group, limiting causal interpretation of analog rice effects.	(22)
Gembili flour and turmeric	*Rattus norvegicus* (male, 2 months old, 150-200 g), 28 (n=7)	Type 2 DM STZ-NA (65 mg/kgBW – 230 mg/kgBW) / 14 days	**Healthy group** SF (NR) **Intervention group** - SF (NR) - Analog rice (4.16 g) - Analog rice (6.17 g)	**Biochemical** - Body weight - Fasting blood glucose (FBG) - Lactic acid bacteria profile - Short-chain fatty acid levels (SCFA) **Histopathological** NR	- A higher dosage of analog rice → ↑ significant effect - Analog rice → ↑ body weight, ↓ FBG, ↑ lactic acid bacteria, ↑ SCFA	The lack of detailed standard feed dosage limits direct comparison with the analog rice intervention.	(21)
Various tubers, cereals, and legumes	*Rattus norvegicus* (male, 10 weeks old, 150-200 g), 42 (n=6)	Type 2 DM Alloxan monohydrate (125 mg/kgBW) / 42 days	**Healthy group** SF (15 g) **Intervention group** - SF (15 g) - White rice C64 (15 g) - Analog rice 1 - Analog rice 2 - Analog rice 3 - Analog rice 4	**Biochemical** - Food efficiency ratio (FER) - FBG - Serum lipid profiles - Atherogenic index - Fasting insulin levels - HOMA-IR - HOMA- β	- All analog rice → ↑ FER - Analog rice 3 → ↓ total cholesterol - Analog rice 4 → ↑ HDL, ↑ plasma antioxidant activity, ↑ fasting insulin levels, ↑ HOMA- β, ↓ HOMA-IR, ↓ FBG, ↓ total glycerides, ↓ LDL, and ↓ AI	The use of four different analog rice formulations limits the ability to identify which specific ingredient contribute most to the observed effects	(16)

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Formulation of analog rice	Rat species (sex, age, weight), number of rats	Animal model/ Treatment duration	Group of rats (dosage)	Outcome measures	Key findings	Limitation	Ref
				- Plasma antioxidant activity **Histopathological** NR			
Mocaf, rice flour, cornstarch, soy protein, palm oil	*Rattus norvegicus* (male, 3 months old, 160-200 g), 55 (n=11)	Type 2 DM HFD (ad libitum) + STZ (35 mg/kgBW) / 6 weeks	**Healthy group** - SF (ad libitum) **Intervention group** - SF (ad libitum) - White rice (ad libitum) - Analog rice 1 (ad libitum) - Analog rice 2 (ad libitum)	**Biochemical** - FBG - Glucagon-like peptide-1 (GLP-1) - Insulin levels - Glucose transporter-2 (GLUT-2) **Histopathological** Pancreatic Langerhans beta cells	- Analog rice → ↓ FBG, ↑ GLP-1, ↑ insulin. - Diabetic groups → ↓ diameter of the Langerhans islet	The administration of HFD and STZ did not influence alterations in GLP-1 and GLUT-2. The duration of the intervention remains relatively brief.	(18)
Gembili flour	*Rattus norvegicus* (male, 2 months old, 150-200 g), 28 (n=7)	Type 2 DM STZ-NA (65 mg/kgBW – 230 mg/kgBW) / 14 days	**Healthy group** SF (ad libitum) **Intervention group** - SF (ad libitum) - Analog rice (4.16 g) - Analog rice (6.17 g)	**Biochemical** - HDL **Histopathological** NR	- A higher dosage of analog rice → ↑ HDL	Baseline lipid confirmation was not reported	(23)
Arrowroot flour and cowpea	*Sprague-Dawley* (male, 2 months old, 250-300), 25 (n=5)	Type 2 DM Alloxan monohydrate (120 mg/kgBW) / 21 days	**Healthy group** - **Intervention group** - SF (ad libitum) + glibencamide (0.45 mg/kgBW) - SF (ad libitum) - SF (ad libitum) + CMC-Na (0.5%/4 mL)	**Biochemical** - Glycemic Index (GI) - FBG **Histopathological** Necrosis and degeneration of pancreatic tissue	- Arrowroot-cowpea analog rice → ↓ GI than analog rice without cowpea - White rice → ↑ FBG - Analog rice → ↓ FBG approaches glibencamide - Histopathological improvement of the pancreas is characterized by the presence of beta cells and a reduction in Langerhans	The lack of healthy control group for the comparison of normal physiological conditions and short intervention duration.	(24)

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Formulation of analog rice	Rat species (sex, age, weight), number of rats	Animal model/ Treatment duration	Group of rats (dosage)	Outcome measures	Key findings	Limitation	Ref
			- Arrowroot analog rice (ad libitum) - Arrowroot-cowpea analog rice (ad libitum)		island damage in the analog rice group.		
Sago starch and red bean	*Rattus norvegicus* (male, 2-3 months old, 200-250), 35 (n=7)	Type 2 DM STZ-NA and glucose solution (60 mg/kgBW – 230 mg/kgBW and 5%) / 4 weeks	**Healthy group** SF (ad libitum) **Intervention group** - SF (ad libitum) - White rice C4 (ad libitum) - Sago analog rice (ad libitum) - Sago-red bean analog rice (ad libitum)	**Biochemical** - Glucose level changes - HOMA-β - HOMA-S - SCFA **Histopathological** Pancreatic Langerhans beta cells	- Sago analog rice → ↓ glucose levels, ↑ HOMA- β. - Analog rice → ↑ HOMA-S, ↑ insulin production and sensitivity, and ↑ SCFA.	Lack of food intake data, ad libitum feeding causes uncontrolled nutrient intake among groups, which can affect biochemical results.	(14)
Gembili flour	*Rattus norvegicus* (male, 2 months old, 150-200 g), 28 (n=7)	Type 2 DM STZ-NA (65 mg/kgBW – 230 mg/kgBW) / 14 days	**Healthy group** SF (ad libitum) **Intervention group** - SF (ad libitum) - Analog rice (4.16 g) - Analog rice (6.17 g)	**Biochemical** - Triglycerides (TG) **Histopathological** NR	- A higher dosage of analog rice → ↓ TG	Baseline lipid confirmation was not reported	(25)
Anti-dyslipidemia							
Banana flour, corn flour, and rice flour.	*Rattus norvegicus* (male, 2-3 months old, 150-250), 24 (n=6)	Dyslipidemia HFFD (4 mL/200 g) / 21 days	**Healthy group** SF (ad libitum) **Intervention group** - SF (ad libitum) - White rice IR64 (ad libitum) - Analog rice (ad libitum)	**Biochemical** NR **Histopathological** Kidney damage	- White rice → ↑ kidney damage score. - Banana analog rice → ↓ kidney damage scores compared to white rice.	Determination of dyslipidemia status based solely on body weight without supporting lipid profile data.	(19)
Cassava flour, sago starch, coconut dregs flour, and rice bran	*Sprague-Dawley* (male, NR, 40-60 g), 48 (n=8)	Hypercholesterolemia Cholesterol (0.50 g/day) + sodium cholate (0.125/day) / 28 days	**Healthy group** SF (20 g) **Intervention group** - SF (20 g)	**Biochemical** - Lipid profiles - AI	- Analog rice + 15% coconut dregs → ↓ TG - Analog rice + ciherang rice bran → ↓ TC, ↓ LDL, ↓ AI, ↓ total fat in liver	Baseline lipid confirmation was not reported	(20)

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Formulation of analog rice	Rat species (sex, age, weight), number of rats	Animal model/ Treatment duration	Group of rats (dosage)	Outcome measures	Key findings	Limitation	Ref
			- Analog rice + 15% coconut dregs (20 g) - Analog rice + ciherang rice bran (20 g) - Analog rice + cere rice bran (20 g) - Analog rice + campoireng rice bran (20 g)	- Weight of liver, kidney, and adipose - Liver total fat **Histopathological** NR	- Analog rice + cere rice bran → weight of kidney same like healthy group - Analog rice + campoireng → ↑ HDL, ↓ weight of liver and adipose.		
Mocaf, rice flour, corn flour, soy protein, palm oil	*Rattus norvegicus* (male, 3 months old, 150-200), 24 (n=6)	Hypercholesterolemia HFD (ad libitum) + STZ (35 mg/kgBW) / 21 days	**Healthy group** Standard feed (ad libitum) **Intervention group** - SF (ad libitum) - 60% SF + 40% white rice (ad libitum - 60% SF + 40% analog rice 1 (ad libitum) - 60% SF + 40% analog rice 2 (ad libitum	**Biochemical** - Body weight - Total cholesterol **Histopathological** NR	- Analog rice → ↓ body weight, and ↓ total cholesterol	The analog rice intervention was mixed with standard feed, so its effects could not be evaluated separately.	(26)

Note: NR (Not Reported); SF (Standard Feed).

Furthermore, tuber and cereal-based primary formulations show promising histopathological benefits, such as attenuating myocardial cell death and promoting the repair of pancreatic beta cells in diabetic rat models. Incorporating legumes and pulses—such as soy protein, cowpea, and red bean—as secondary ingredients into analog rice formulations synergistically enhances metabolic control, primarily through added protein and dietary fiber. The addition of these ingredients significantly lowers the overall glycemic index (GI) of the rice compared to non-legume-based mixtures. In in vivo studies, legume-enriched formulations notably improved pancreatic function by increasing insulin production, enhancing beta-cell function (HOMA-β), and elevating Glucagon-like peptide-1 (GLP-1) levels (18). This makes legume-based combinations particularly promising for hormonal regulation and improving insulin sensitivity in metabolic syndrome models.

While roots, tubers, and cereals are the most common primary bases, high-carbohydrate fruits can also serve as the primary carbohydrate source, offering unique physiological advantages. For example, analog rice formulated with banana flour as its primary base—potentially replacing cereal-based or tuber-based — exhibited distinct protective effects on renal tissues, successfully lowering kidney damage scores(19), while the addition of high-fiber coconut dregs has the potential to reduce triglycerides and improve atherogenic indices (20). Additionally, spice-enriched formulations, such as those incorporating turmeric into gembili-based rice, potential to affect gut metabolism by increasing beneficial lactic acid bacteria and short-chain fatty acids (SCFA), which play a crucial role in mediating systemic glucose homeostasis (21).

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DISCUSSION

Analog rice as an anti-diabetic

Analog rice has been widely developed as an alternative option to prevent diabetes mellitus. This is related to the fact that the staple food, white rice, has a high glycemic index (GI), which can cause a rapid increase in blood glucose levels and insulin response, thereby increasing the risk of T2DM (27). The potential benefits of analog rice are predominantly evaluated using in vivo tests with rats as the experimental models. Parameters commonly observed in the assessment of diabetes mellitus include blood glucose, insulin levels, HOMA-IR, HOMA-β, SCFA, serum lipid profiles, and atherogenic index (AI), with intervention durations ranging from at least 14 days to 42 days.

To evaluate the potential benefits of analog rice against T2DM, the rats were conditioned in a hyperglycemic state. The methods used included various approaches such as induction with streptozotocin-nicotinamide (STZ-NA) and alloxan monohydrate. STZ-NA is a diabetes agent known for its toxic effects on pancreatic β cells. This agent consists of Nicotinamide (NA), a derivative of vitamin B3 (niacin), which exhibits antioxidant properties that help reduce oxidative stress (28). Alloxan monohydrate is also toxic to pancreatic β cells through the formation of oxidative stress, which causes a decrease in insulin secretion and leads to hyperglycemia (29).

The intervention involved using analog rice made from sago starch and red beans. Rats were conditioned in a hyperglycemic state through STZ induction at 60 mg/kgBW and NA at 230 mg/kgBW, characterized by FBG levels exceeding 200 mg/dL. After four weeks of intervention, the sago analog rice without red beans addition showed a decrease in blood glucose levels and an increase in HOMA-β and HOMA-S. The increase in HOMA- β indicates an improvement or enhancement in pancreatic cell function in secreting insulin, and HOMA-S showed better insulin sensitivity. An increase in SCFA was also observed in the diabetic rat group given an intervention with analog rice made from sago flour, where the total SCFA (acetate, propionate, and butyrate) reached 237.89, higher than the healthy rat group fed a standard diet, which was only 77.01, and the diabetic rat group intervened with white rice, which was 89.58. The presence of SCFA can also be associated with increased insulin sensitivity, where acetate and propionate from resistant starch fermentation products can enhance buffering capacity, thereby reducing fatty acid levels in the muscles (30). This study lacked food intake data, so it cannot be confirmed whether each group received equal energy intake, which could potentially affect the results of blood parameter analysis in rats (14).

Research involving the induction of diabetes mellitus in rats with alloxan monohydrate was performed using a dose of 120 mg/kgBW. This study utilized rats with T2DM, which were divided into five experimental groups. The research aims to compare the group given arrowroot flour as an analog rice with the group given arrowroot flour with cowpea, with a diabetic rat group that was administered glybenclamide 0.45 mg/kgBW, and diabetic rats administered with 0.5% CMC solution/4 mL, and white rice. Glybenclamide is a medication typically used as a therapy to lower blood glucose levels, while CMC serves as a placebo that cannot affect blood glucose. These results indicate that white rice intervention significantly increased fasting blood glucose (FBG) over the 21-day intervention period, and the analog rice can reduce FBG, although the reduction was not significant compared to the group given medication. At the end of the intervention, the FBG graph for the analog rice group still falls into the high category, around 300 mg/dL. This may be due to the short duration of the intervention. The greatest decrease in FBG occurred in the arrowroot and cowpea analog rice groups, which could be attributed to their protein and fiber content. The presence of protein from cowpea beans in the intestine will enhance the response to incretin hormones, which are the main stimuli for insulin secretion

The lipid profile parameters in rats with T2DM have been assessed. The results showed that analog rice made from white Ipomea batatas, germinated *Vigna radiata*, germinated white *Zea mays*, and sago starch has been associated with improvements in lipid profile, characterized by decreases in LDL, total glycerides, and AI, and an increase in HDL. This improvement occurred because this analog rice contains the highest levels of total phenols (352.50 mg GAE), dietary fiber (22.11%), and starch (3.43%), according to the test results in this study. Insulin resistance in T2DM can disrupt lipolysis in adipose tissue, leading to the continued breakdown of stored triglycerides in adipocytes and the release of free fatty acids into the

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circulation. This results in increased production of VLDL and plasma triglycerides, which are main features of dyslipidemia in T2DM, so lipid profiles are often used as assessment parameters in diabetes mellitus conditions (16, 31).

A possible mechanism for the lipid profile improvement in analog rice is that the presence of total phenols interferes with cholesterol absorption in the intestine, thereby reducing the transport of cholesterol to the liver and its incorporation into VLDL particles, which are precursors to LDL (32). Dietary fiber also plays an important role in binding bile acids in the intestines, preventing their reabsorption. This forces the liver to use cholesterol to produce more bile acids, thereby reducing LDL cholesterol levels in the blood (33). The starch contained in analog rice also plays a role in improving blood lipid and glucose profiles. Indigestible fiber will ferment in the large intestine and produce SCFA, which plays an important role in lipid metabolism (34).

Analog rice as an anti-dyslipidemia

The use of analog rice interventions for dyslipidemia conditions is still underexplored. The induction of dyslipidemia in rats can be done in various ways. The research conducted used a high-fat diet (HFD) ad libitum and STZ induction administered at 35 mg/kgBW once on day 33. The induction of dyslipidemia in rats was performed over 40 days, until cholesterol levels exceeded 111 mg/dL, and was accompanied by overweight status when body weight exceeded the control group mean +2SD. The results of the study showed that analog rice intervention could reduce total cholesterol and promote weight loss in overweight rats (26). This indicates that analog rice made from Mocaf, rice flour, corn flour, soy protein, and palm oil may contribute to the management of dyslipidemia and overweight.

Interventions using analog rice made from cassava flour, sago starch, coconut dregs flour, and various rice brans showed that analog rice using Ciherang rice bran decreased total cholesterol, LDL, and AI. This may be attributed to Ciherang rice bran contains bioactive compounds such as γ-oryzanol, reaching 1602.51 μg/g, which is higher than other types of rice bran (20). γ-oryzanol plays a role in inhibiting cholesterol and increasing cholesterol excretion through feces. Additionally, γ-oryzanol is converted into ferulic acid, which acts as an antioxidant for plasma, and sterols inhibit cholesterol absorption (35). Furthermore, the dietary fiber content in the analog rice with Ciherang rice bran is higher, at 7.31%, compared to analog rice made with other types of rice bran. Dietary fiber can bind bile acids in small intestine, preventing reabsorption and promoting excretion and prompts the liver to convert more cholesterol into bile acids, lowering blood cholesterol levels (33).

The development of analog rice enriched with fiber, resistant starch, and bioactive compounds such as total phenols, flavonoids, and antioxidants not only has the potential as an alternative food in managing type 2 diabetes mellitus but also plays an important role in managing dyslipidemia, which is generally characterized by a poor lipid profile. Consuming analog rice has the potential to improve blood lipid profiles, indicated by reductions in LDL, total cholesterol, triglycerides, and atherogenic index, as well as an increase in HDL levels.

Histopathological effects of analog rice

Several studies on the potential benefit of analog rice also use histopathological analysis as an evaluation parameter, both in conditions of diabetes and dyslipidemia. The common histopathological parameters observed include myocardial cell death, the number and integrity of Langerhans islets, the degree of necrosis and degeneration of pancreatic tissue, as well as kidney damage, which reflect the systemic metabolic impact and the potential protective effects of analog rice on target organs. Rats conditioned in a diabetic state and intervened with analog rice made from Mocaf, arrowroot, and kidney beans for 28 days exhibit broader insulin expression in the β cells of the pancreatic islet Langerhans compared to the group intervened with white rice. The high insulin expression indicates good β cell function, thereby reducing blood glucose and increasing insulin levels (14).

Assessment of myocardial cell death in diabetic-induced rats shows that the administration of Mocaf-based analog rice, corn flour, and rice combined with metformin demonstrates improvement. The negative control group given standard feed without metformin combination experienced myocardial

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degeneration, cell vacuolization, and widening of inter-fiber spaces, reflecting tissue damage due to hyperglycemia and metabolic stress. The analog rice intervention may contribute to reduced myocardial damage and support the repair of heart tissue damage in T2DM conditions (22).

In dyslipidemia conditions, it can result in kidney tissue damage. Dyslipidemia induces oxidative stress and inflammation, which are critical factors in kidney damage. Lipid accumulation in the kidneys leads to the generation of reactive oxygen species (ROS) and inflammatory cytokines, contributing to glomerular and tubulointerstitial injury (36). Analog rice made from banana flour, corn, and rice flour shows improvement in kidney structure based on histopathological observations, characterized by reduced infiltration of inflammatory cells, edema, and necrosis, as well as glomeruli and tubules that resemble those of normal kidneys. This indicates that the analog rice intervention has the potential to provide a protective effect on the kidneys by suppressing inflammation, reducing cell damage, and maintaining the structural integrity of glomeruli and tubules in abnormal metabolic conditions (19). Overall, the histopathological findings support that analog rice can serve as an alternative staple food for managing metabolic disorders, not only through improving biochemical parameters but also through protecting and restoring tissue structures in pancreatic beta cells, heart cells, and kidney cells.

Translational and Practical Challenges

The research synthesized in this review presents several challenges. Primarily, the varying intervention durations across the included in vivo studies make direct comparisons and the evaluation of treatment effect consistency challenging. Additionally, some articles lack detailed data on the specific content of bioactive compounds, preventing a definitive explanation of the relationship between these components and the observed changes in biochemical parameters. To address these challenge future research must utilize longer, standardized intervention durations and more comprehensive molecular approaches to fully elucidate the mechanisms of histopathological improvement. Furthermore, expanded research specifically targeting the effects of analog rice on dyslipidemia is necessary, considering that diabetes mellitus is frequently accompanied by interconnected lipid metabolism disorders.

Beyond these methodological constraints, translating these preclinical in vivo findings into human applications presents significant challenges. While rodent models provide a robust fundamental understanding of underlying mechanisms—such as tissue repair, short-chain fatty acid (SCFA) production, and bile acid binding—inherent physiological, metabolic, and gut microbiota differences exist between rodents and humans. Consequently, the optimal intervention dosages and metabolic responses observed in animal models cannot be directly extrapolated to human diets. Therefore, well-designed human clinical trials are strictly required to validate these preclinical efficacies, establish standardized dosages, and confirm their true relevance to human clinical conditions.

Finally, the practical applicability of analog rice in managing metabolic syndrome hinges heavily on sensory acceptability. As a functional product intended to replace a daily staple food, sensory attributes—specifically texture, taste, and aroma—are critical determinants of consumer acceptance. The raw ingredients utilized significantly dictate these sensory profiles. For instance, while legumes provide excellent nutritional benefits, increasing the concentration of red bean flour beyond 10% can introduce a strong "beany" flavor and aroma, which subsequently reduces overall consumer preference for its taste and texture (37). Similarly, analog rice based on purple sweet potato tends to retain a strong, distinct sweet potato flavor that diverges from traditional white rice (38). Conversely, certain tubers and cereals, such as arrowroot and corn, exhibit a more neutral or bland taste, which can be strategically formulated to mask the overpowering flavors of other functional additives (39). Therefore, future development must prioritize balancing these functional health benefits with targeted sensory improvements, ensuring that analog rice is not only metabolically beneficial but also palatable and widely accepted for long-term dietary integration.

CONCLUSION

Analog rice has the potential to be used as an alternative staple food because it contains bioactive compounds with potential benefits in the context of diabetes mellitus and dyslipidemia. A review of various

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in vivo studies shows that intervention with analog rice has shown potential effects in lowering blood glucose levels, improving insulin sensitivity, increasing SCFA production, and improving lipid profiles and histopathological parameters in target organs. However, as mandatory steps prior to initiating human clinical trials, future research must prioritize formulation standardization and dosage optimization studies. These specific, forward-looking approaches are essential to confirm long-term efficacy and establish safe, precise guidelines for its dietary integration.

DECLARATION OF THE USE OF AI

The authors declare that no artificial intelligence (AI), AI-assisted technologies, or large language models (LLMs) were used in the conception of the study, data analysis, or the drafting, writing, and editing of this manuscript. The only exception is the graphical abstract, which was created using the design platform Illustrae (https://illustrae.co/). The authors take full responsibility for the content and accuracy of the graphical abstract and the entire manuscript.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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