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Review Article

Production of Analog Rice from Mocaf and Soybean-Based Flours for Food Diversification: A Review

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Abstract

This systematic review examines the production of analog rice made from Modified Cassava Flour (Mocaf) and soybean flour as part of national food diversification efforts. Through a systematic literature search conducted across Google Scholar, ScienceDirect, and the SINTA database (2013–2025), this review identifies key findings on formulation strategies, extrusion processing, and nutritional characteristics. Previous studies indicate that mocaf–soy analog rice exhibits higher protein content (8–12%), improved fiber levels, and a lower glycemic index compared to white rice. The synergy between mocaf as a carbohydrate matrix and soybean flour as a protein fortifier produces analog rice with enhanced functional and nutritional value. These findings highlight the potential of mocaf–soy analog rice as a sustainable staple alternative supporting food diversification and national food security.

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1. Introduction

In Indonesia and much of Asia, rice dominates the staple diet, but this heavy reliance has raised significant health and food security concerns. Nadhifa et al. (2025) note that milled white rice is rich in carbohydrates but lacks protein, dietary fiber, and micronutrients, making populations dependent on it vulnerable to malnutrition and chronic diseases. Indonesian per capita rice consumption remains extremely high exceeding 110 kg per year and recent trends have shown increasing incidences of diabetes and cardiovascular diseases associated with rice's high glycemic index (Harlina et al., 2023). Budijanto and Yuliana (2015) similarly argue that Indonesia's endemic rice dependence undermines both food security and economic resilience, given its heavy reliance on imported rice. These nutritional limitations and supply vulnerabilities emphasize the urgent need to broaden staple consumption beyond conventional paddy rice.

Food diversification has long been a national strategy to address these challenges by promoting the use of various local carbohydrate sources. The Indonesian government initiated an official diversification program as early as 1974, yet rice remains dominant in household consumption patterns. The slow progress of this initiative is largely attributed to cultural preferences, limited consumer awareness, and a lack of appealing substitutes that mimic the sensory and cooking characteristics of rice (Rahmanto et al., 2021). Nevertheless, research consistently shows that expanding dietary variety through locally sourced staples can improve public health outcomes. Local tubers and legumes generally exhibit lower glycemic indices and higher fiber or protein content than polished rice, thus helping to reduce risks of obesity, diabetes, and protein-energy malnutrition (Faradilla et al., 2025). In practice, diversification efforts have increasingly focused on cassava, corn, sweet potato, and other starch-rich crops. Among these innovations, analog rice—rice-like granules produced from local flour sources—has emerged as a promising "vehicle" for diversification, as it allows consumers to maintain

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traditional cooking and eating habits while introducing more nutritious alternatives (Hizni et al., 2024).

Cassava and soybean play particularly complementary roles in analog rice formulations. Cassava, especially in its modified fermented form known as Modified Cassava Flour (Mocaf), serves as the main carbohydrate base due to its high amylopectin starch content and wide availability in Indonesia (Nadhifa et al., 2025). However, cassava flour alone provides limited protein content; therefore, analog rice formulations are often fortified with high-protein ingredients such as soybean flour. Soybeans contain approximately 35–40% protein and appreciable dietary fiber significantly higher than white rice's 6% making them an excellent fortifier. Several studies confirm that incorporating soy into cassava-based analog rice substantially increases protein content while lowering the overall glycemic index. For example, Mahendradatta et al. (2024) reported that analog rice made with legume flours, including soybean, achieved the highest protein concentration and a low GI (~40). Similarly, Bahlawan et al. (2023) optimized a mocaf–soy formulation (50:50) containing approximately 17% protein and 7% fiber, demonstrating its suitability as a nutritionally enhanced staple. In summary, Mocaf contributes the starch matrix, while soybean enhances protein and micronutrient composition, yielding analog rice with a more balanced nutritional profile compared to conventional rice.

Production of analog rice generally employs extrusion technology to form rice-like grains. Extrusion applies controlled heat, pressure, and shear to a starch–protein mixture, gelatinizing carbohydrates and shaping the material through a die. In analog rice production, an oval die is typically used to mimic the physical appearance of natural rice grains (Nadhifa et al., 2025). Compared to simple granulation methods, extrusion yields more uniform and stable products with better texture and sensory quality. Key parameters such as temperature, screw speed, and moisture level can be fine-tuned to optimize cooking quality and water absorption while minimizing nutrient degradation (Khoirunnisah et al., 2024). Hence, extrusion serves as a critical process that enables Mocaf–soy blends to be transformed into acceptable rice-like products that align with Indonesian culinary norms.

Overall, analog rice represents a promising innovation to support food diversification and nutrition improvement in rice-dependent societies. Budijanto and Yuliana (2015) emphasize the need for integrated research encompassing raw material selection, formulation, and process optimization to realize analog rice's potential as a functional staple. Therefore, this review focuses on the production of analog rice made from locally important ingredients—Modified Cassava Flour (Mocaf) and soybean flour—examining their functional synergy, extrusion processes, and reported nutritional and sensory characteristics. This discussion aims to inform scholars, practitioners, and policymakers about the role of Mocaf–soybean analog rice in achieving sustainable food diversification and national food security in Indonesia.

This review discusses (1) the potential of analog rice for food diversification, (2) raw materials and functional ingredients used in mocaf–soy analog rice, (3) the production process and extrusion parameters, and (4) the nutritional and physical characteristics of mocaf–soy analog rice reported in previous research.

2. Research Methods

This review was conducted using the Systematic Literature Review (SLR) method to collect, evaluate, and synthesize relevant studies on the production of analog rice from Modified Cassava Flour (Mocaf) and soybean flour. Literature searches were performed through Google Scholar, ScienceDirect, and the SINTA database using the keywords "Analog Rice", "Mocaf Flour", "Soybean Flour", "Extrusion Technology", and "Food Diversification". The search was limited to peer-reviewed national and international journal articles published between 2013 and 2025.

A total of approximately 100 studies were identified. After screening titles, abstracts, and full texts and applying selection criteria, 25 articles were included in the final analysis. Article selection was conducted using the following criteria:

Inclusion criteria:

1. Studies involving both Mocaf and soybean flour.
2. Studies discussing extrusion or related processing methods.
3. Primary empirical research or full review articles.
4. Full-text availability.

Exclusion criteria:

1. Opinion papers or conference abstracts without full texts.
2. Studies not involving Mocaf or soybean flour.
3. Duplicate or low-quality articles.

This systematic approach ensured that the collected studies were relevant, credible, and aligned with the aim of analyzing the potential of Mocaf–soybean analog rice for food diversification.

3. Discussion of Results

3.1 Potential of Analog Rice for Food Diversification

Indonesia's heavy dependence on white rice has generated nutritional and food security challenges. Polished rice contains mostly carbohydrates with minimal protein, fiber, and micronutrients, which contributes to malnutrition and increases risks of chronic diseases (Nadhifa et al., 2025). This dependency also places pressure on national food resilience, especially during periods of import instability (Budijanto & Yuliana, 2015). Although the government introduced food diversification programs in 1974, progress has been slow due to strong cultural preferences for rice.

Experts highlight the importance of utilizing local carbohydrate sources such as cassava, corn, banana, porang, gembili, and legumes to diversify consumption patterns and reduce glycemic load (Harlina et al., 2023). Analog rice, produced from local crops but shaped and cooked similarly to conventional rice, is considered a culturally acceptable alternative (Rozi et al., 2022). Evidence from community-scale programs shows that analog rice made from cassava or banana flour has been successfully adopted, improving household food security (Lalong et al., 2025).

Formulations combining Modified Cassava Flour (Mocaf) and soybean flour demonstrate strong nutritional potential. Mahendradatta et al. (2024) reported that the addition of soybean flour increases protein content while maintaining a low glycemic index (~40). A mocaf–soy blend of 50:50 was shown to contain approximately 17% protein and 7% fiber, substantially higher than white rice (Bahlawan et al., 2023). Handajani et al. (2020) also found that cassava–soy analog rice delivers around 9 g of protein per 100 g. Complementary findings by Azhari et al. (2025) showed that composite analog rice made from porang and gembili exhibits favorable proximate and physical characteristics, although sensory acceptance remains a challenge. Furthermore, Chaniago et al. (2025) demonstrated that incorporating antioxidant-rich ingredients such as Moringa leaves and purple sweet potato enhances functional value and color stability—indicating that similar fortification strategies can also be applied to Mocaf–soy formulations.

Overall, existing research consistently shows that Mocaf–soy analog rice is a nutrient-dense, functional, and culturally adaptable staple. Its favorable nutritional profile, lower glycemic index, and compatibility with local raw materials align strongly with Indonesia's food diversification goals and long-term food security initiatives.

3.2 *Nutritional and Physical Characteristics of Mocaf–Soy Analog Rice*

Previous studies have reported that analog rice formulated from Modified Cassava Flour (Mocaf) and soybean flour exhibits improved nutritional and physical characteristics compared to conventional white rice. Nutritionally, the incorporation of soybean flour significantly increases protein content due to its high protein concentration (35–40%). Bahlawan et al. (2023) reported that a 50:50 Mocaf–soy formulation contained approximately 17% protein and 7% dietary fiber, which is substantially higher than that of polished white rice. Similarly, Handajani et al. (2020) found that cassava–soy analog rice provides around 9 g protein per 100 g, supporting its potential as a protein-enriched staple food.

In addition to protein enhancement, Mocaf–soy analog rice has been reported to exhibit a lower glycemic index (GI) than conventional rice. Mahendradatta et al. (2024) observed that the inclusion of soybean flour contributed to a GI value of approximately 40, which is categorized as low and beneficial for controlling postprandial blood glucose levels. The presence of dietary fiber and protein in soybean flour is believed to slow starch digestibility, thereby reducing the glycemic response (Novikasari et al., 2023).

From a physical perspective, Mocaf–soy analog rice demonstrates favorable textural and functional properties. Fermented Mocaf improves water absorption capacity, swelling power, and gelatinization behavior, which are essential for forming cohesive rice-like granules during extrusion (Rozi et al., 2022; Nadhifa et al., 2025). The addition of soybean flour has been shown to enhance water absorption and produce a softer texture after cooking, which improves consumer acceptability (Khoirunnisah et al., 2024). However, higher soybean proportions may reduce grain hardness and structural integrity, indicating the importance of optimizing the Mocaf–soy ratio during formulation (Shaikh et al., 2025).

Color and appearance are also important physical attributes influencing consumer acceptance. Analog rice produced from Mocaf–soy blends typically exhibits a slightly yellowish or off-white color, depending on soybean concentration and processing conditions. Chaniago et al. (2025) demonstrated that the incorporation of functional ingredients such as Moringa leaves or purple sweet potato can enhance color stability and antioxidant properties, suggesting that similar strategies may be applied to Mocaf–soy analog rice to improve both functional value and visual appeal.

Overall, the nutritional and physical characteristics reported in previous studies indicate that Mocaf–soy analog rice is a nutritionally superior and functionally acceptable alternative to white rice. Its higher protein and fiber content, lower glycemic index, and favorable textural properties support its role as a functional staple food in food diversification programs.

3.3 *Ingredients Used for Analog Rice*

Analog rice is formulated to replicate the nutritional and functional characteristics of natural rice grains. Its nutritional value depends largely on the composition and quality of the ingredients used. Suitable raw materials should provide adequate carbohydrates, protein, fiber, and essential micronutrients comparable to natural rice (Mahender et al., 2016). To achieve this, proper selection of local ingredients especially those rich in starch and protein is essential. Table 1 shows the ingredients and composition of mocaf–soy analog rice based on previous studies.

The production of analog rice requires the right ratio of carbohydrate and protein sources so that compact, rice-like granules can form (Andarwulan, 2011). In mocaf–soy formulations, Modified Cassava Flour (Mocaf) serves as the main carbohydrate base, while soybean flour acts as a protein fortifier. Additional ingredients such as water, binding agents (e.g., palm oil), and emulsifiers (e.g., glycerol monostearate/GMS) help achieve the desired texture, stability, and uniformity of the grains during extrusion (Herawati et al., 2014). Below are the key components typically used in mocaf–soy analog rice production:

3.3.1 Primary Ingredients

1. *Modified Cassava Flour (Mocaf)*

Mocaf serves as the primary carbohydrate source and forms the structural base of analog rice. Its high amylopectin starch content supports gelatinization and cohesive granule formation during extrusion (Nadhifa et al., 2025). Fermentation during Mocaf processing enhances physicochemical qualities such as solubility, swelling power, and water absorption capacity (Rozi et al., 2022). Recent studies show that combining Mocaf with other local flours such as corn or porang further improves texture and sensory properties (Florie & Kusumayanti, 2024). Given its local availability and low cost, Mocaf remains a sustainable key material for national food diversification efforts (Faradilla et al., 2025).

2. *Soybean Flour*

Soybean flour provides 35–40% protein, 7–9% fiber, and essential fatty acids, making it an excellent supplement to mocaf (Bahlawan et al., 2023). Its inclusion improves the amino acid profile, digestibility, and overall protein content of analog rice (Mahendradatta et al., 2024). In addition, studies have shown that soy fortification significantly lowers the glycemic index (GI) and enhances the functional quality of analog rice (Novikasari et al., 2023). Furthermore, soybean-based analog rice demonstrates better water absorption and a softer texture after cooking, which contributes to higher consumer acceptability (Khoirunnisah et al., 2024).

3.3.2 Functional Ingredients / Additives

1. *Water*

Water functions as a plasticizer that reduces dough viscosity and allows proper shaping during extrusion (Ding et al., 2005). Adequate moisture levels, typically between 25–35%, also help achieve uniform gelatinization and prevent the formation of cracks or air bubbles in the grains, ensuring consistent texture and structural integrity of the analog rice (Nadhifa et al., 2025).

2. *Palm Oil*

Palm oil contains tocopherols and tocotrienols, which act as natural antioxidants and serve as a source of carotenoids. In analog rice production, palm oil functions primarily as a binder, helping to improve the texture and cohesiveness of the rice granules (Goufo & Trindade, 2015).

3. *Glycerol Monostearate (GMS)*

Glycerol monostearate (GMS) is a type of nonionic surfactant widely used in the pharmaceutical and food industries. In the production of analog rice, GMS functions as a lubricant within the extrusion barrel, helping to prevent the extrudate from sticking or clumping during the extrusion process (Yang et al., 2025). Although GMS is added in small quantities and does not contribute significant nutritional value, it is considered safe (GRAS) for food use. Its inclusion improves grain smoothness, surface uniformity, and overall processing efficiency (Yang et al., 2025).

3.4 *Analog Rice Production Process*

The production of analog rice made from Modified

Table 1. Ingredients and composition of mocaf–soy analog rice based on previous studies

Reference	Main ingredient composition (%)	Notes (binding agents/etc.)
Ningtyastuti et al. (2022)	Sago flour 45%; Mocaf 30%; Porang flour 5%; Soybean flour 20%	The best formulation (F5) based on hedonic organoleptic testing.
Jariyah & Vestra (2023)	Mocaf 70%; Sago flour 10%; Soybean flour 20%; Moringa leaves 3.5%	Addition of 3% carrageenan as a binding agent.
Anggraini & Jariyah (2025)	Mocaf 75%; Pedada fruit flour 5%; Soybean flour 20%	Addition of 1% glycerol monostearate (GMS).
Iklasanawan et al. (2023)	Gembili flour 50%; Mocaf 25%; Soybean flour 15%; Pea flour 10%	High-protein analog rice; added GMS and salt (NaCl).

Cassava Flour (Mocaf) and soybean flour aims to develop a nutrient-rich, rice-like product containing balanced levels of carbohydrates and proteins. The formulation of this analog rice can be improved by adding supplementary ingredients such as starch binders and emulsifiers (e.g., glycerol monostearate or GMS) to obtain optimal nutritional and physical properties (Mahendradatta et al., 2024).

The selection of raw materials, additives, and processing techniques—as well as the ratio between mocaf and soybean flour—greatly affects the quality, uniformity, and texture of the final analog rice grains. Therefore, these factors must be carefully controlled during production to ensure consistent results (Andarwulan, 2011). In general, the manufacturing process of mocaf–soy analog rice consists of several major stages, namely formulation, preconditioning, extrusion, drying, and product (Budi et al., 2013).

Various studies have reported different processing conditions for analog rice production depending on raw materials and processing equipment. Table 2 summarizes the main processing parameters for analog rice production reported in previous literatures.

3.4.1 Formulation

The formulation stage aims to produce an appropriate blend of ingredients based on predetermined ratios. Modified Cassava Flour (Mocaf) and soybean flour are used in powdered form to ensure even mixing and consistent nutrient distribution. Additional materials such as GMS, palm oil, and water are incorporated in specific proportions to enhance cohesion, emulsification, and lubrication during processing. Optimal Mocaf–soy ratios typically range from 70:30 to 50:50; higher soy content increases protein but may reduce granule hardness. Before extrusion, the mixture must reach uniform moisture and texture to ensure stable processing (Budi et al., 2013).

3.4.2 Preconditioning

The preconditioning phase ensures uniform hydration and plasticity of the dough. Controlled water addition—typically bringing moisture content to 25–35%—and mild heating promote partial starch gelatinization that enhances dough flowability and reduces mechanical resistance during extrusion. Proper preconditioning improves texture uniformity and minimizes defects such as cracks or uneven granule formation (Shaikh et al., 2025).

3.4.3 Extrusion

During extrusion, the preconditioned dough is subjected to heat, pressure, and shear forces that induce starch gelatinization and protein–starch interactions. Typical extrusion temperatures range from 70–120 °C, screw speeds from 80–150 rpm, and operating pressures from 3–6 MPa, depending on equipment specifications. The material is forced through a die to form rice-shaped granules with uniform size and density. Higher temperatures accelerate gelatinization and reduce cooking time, while higher screw speeds increase shear, improving expansion but potentially decreasing hardness. Thus, parameter optimization is essential to obtain desirable textural and structural characteristics of analog rice (Shaikh et al., 2025).

3.4.4 Drying

Freshly extruded analog rice has high moisture content and must be dried to ensure stability and shelf life. Drying can be done using sunlight or mechanical dryers. Mechanical drying at 50–60°C for 4–6 hours produces more consistent results, lowers the risk of contamination, and improves granule hardness and durability (Mishra et al., 2012). Proper drying also enhances rehydration properties during cooking.

3.4.5 Product

The final analog rice product is obtained after the drying stage, resulting in rice-shaped granules with stable moisture, proper hardness, and good rehydration properties. Quality evaluation at this stage

Table 2. Summary of process conditions for analog rice production based on previous studies

Reference	Raw Materials	Extrusion Temperature (°C)	Initial Moisture Content (%)	Screw Speed (rpm)	Drying Conditions
Budi et al. (2013)	Composite flour (cassava-based)	90–110	28–33	90–130	Sun drying or oven drying
Shaikh et al. (2025)	Mocaf-based composite flour	70–120	25–35	80–150	Hot air drying at 50–60 °C for 4–6 h
Mahendradatta et al. (2024)	Mocaf–soybean flour blends	80–115	25–30	-	Hot air drying at 50–60 °C
Khoirunnisah et al. (2024)	Mocaf and soybean flour	85–110	~30	100–120	Oven drying at 50 °C

focuses on physical characteristics (texture, density, color, and uniformity) as well as nutritional value and overall sensory acceptability. The finished product must meet quality and safety standards before being distributed (Mahendradatta et al., 2024).

4. Conclusion

The production of analog rice using Modified Cassava Flour (Mocaf) and soybean flour results in a product with high carbohydrate and protein content, offering a nutritional profile comparable to that of white rice. The combination of Mocaf as a carbohydrate source and soybean as a protein fortifier produces analog rice that is rich in fiber, has a lower glycemic index, and provides better nutritional balance. This Mocaf–soybean-based analog rice shows great potential to be developed as an alternative staple food to reduce dependency on conventional rice. Furthermore, its use of locally available ingredients supports food diversification efforts and contributes to sustainable food security in Indonesia

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