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The Potential for Producing Aquaculture Feed Mixed with Rice Bran Available in Rural Tanzania

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Abstract Despite the high number of primary industry workers in many developing countries, the sector's share of gross domestic product remains low. To eliminate economic disparities in developing countries, it is crucial to promote primary industries in rural areas. Diversifying agriculture through integration with fisheries could be one solution. This study focused on feed production utilizing rice bran, a byproduct of rice cultivation, to enable small-scale tilapia farming as a side business for farmers in Tanzania's rice-growing regions. The results confirm the possibility of manufacturing feed consisting of 50% rice bran and indicate that the supplementation of this feed with local protein sources can satisfy the nutrient requirements of tilapia. Rice bran is prone to spoilage but this preservation issue has been resolved by using fermented rice bran. The use of rice bran, an agricultural residue is expected to increase, not only in tilapia feed, but also in livestock feed.
Keywords: Agricultural residue, Feed supplementation, Nutritional requirements, Tilapia, Rural area

Introduction

African nations are attracting global attention as potential markets. However, the gap between urban and rural areas in African countries is substantial and acts as a hindrance to economic development in each nation. Tanzania, located in East Africa is one of the most poverty-stricken nations; although the urban poverty rate is only 16%, the rural poverty rate remains high at 31.3% (JICA, 2022). Agriculture, forestry, and fisheries (i.e., primary industries) are major local industries that play important roles in Tanzania's economy. Although the number of primary industry workers is high (~65%), the sector's share of gross domestic product remains at 26.9% (MAFF, 2020), indicating the poverty of primary industry workers in rural areas. Economic growth and poverty reduction are Tanzania's national strategies, and increasing the growth and productivity of the primary sector is essential for achieving these goals.

Increasing the value of agricultural residues in rural Tanzania is an important part of the Japan International Cooperation Program, the Science and Technology Research Partnership for Sustainable Development (SATREPS). In particular, oil has been extracted from rice bran, which is considered a waste by rice farmers, and the oil is being used as a fuel. This project also includes the development of a manufacturing method for fish feed using rice bran as the main ingredient and the assembly of a simple manufacturing device.

Fish farming is one of the fastest-growing production sectors worldwide (FAO, 2016). Aquaculture has been popular in Zanzibar, which is surrounded by the sea, since 1960; it is also becoming increasingly popular on the Tanzanian mainland (Global Note, 2025). Farmed tilapia production has been growing steadily over the past 20 years (Fig. 1). FAO (2025) reported that approximately 14,100 fishponds were scattered all over the country, mostly in the regions of Ruvuma (4,842), Iringa (3,137), Mbeya (1,176), and Kilimanjaro (1,660). Furthermore, as observed in the Sokoine University graduate entrepreneur cooperative support program, Tanzania is promoting an integrated approach that combines agriculture, fisheries, and livestock production. Recently, cage aquaculture has been rapidly expanding on Lake Victoria suggesting a potential increase in demand for fish feed. Since feed and fertiliser costs are critical factors for farmers, the effective utilization of agricultural residues could yield substantial benefits for them. A successful integration of agriculture and fisheries could lead to stable incomes and increased profits for farmers.

Tanzania relies on imports for most of its fish feed (Adéyèmi, 2020), which is a major economic burden.

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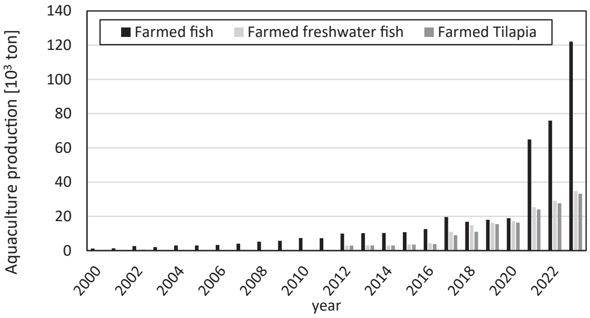

Fig. 1. Aquaculture production in Tanzania.

According to the Tanzanian national budget speech for 2025/2026 by the Ministry of Livestock and fisheries (MLF), a total of 9,347 tons of fish feeds were imported during 2024, whereas only 5,879 tons were domestically produced (URT, 2025). Feed costs account for 60–75% of the total costs associated with aquaculture (Ramirez *et al*., 2022), with fish meal—the raw material—being the main factor increasing feed costs (Ye *et al*., 2011). If feed for aquaculture that can replace fishmeal and does not rely on imports can be produced, it is expected to contribute substantially to the development of Tanzania's aquaculture industry by reducing the economic burden on producers. Attempts to utilise locally produced agricultural waste may be beneficial. In this regard, Adéyèmi *et al*. (2020) conducted an extensive survey of fish feed used locally in Benin to investigate economically viable feeds for fish farming. Locally available raw materials include cereal bran, soybean meal, cottonseed meal, cassava chips, palm kernel cake, soybeans, and maize. Rapeseed (Maritin *et al*., 2019) and soybean meal (Hardy, 1996; Ye *et al*., 2011) have been evaluated as supplementary sources of nutritional protein. Spirulina (Ramirez *et al*., 2022; Rosenau *et al*., 2021), insects (Gasco *et al*., 2020), and microorganisms (Patsios *et al*., 2020) have also attracted attention as raw materials with nutritional benefits; however, they are expensive to cultivate.

This study examined the production of tilapia feed using locally available agricultural residues with a view to expanding into aquaculture operations for economic development in rural Tanzania. According to a 2025 FAO report, the majority of small-scale fish farmers use household food waste, corn bran, wheat bran, vegetables, and wild grasses as fish feed (FAO, 2025). To ensure feasibility and sustainability, feed was manufactured using rice bran—a readily available local agricultural residue for rice farmers—as the main raw material. Rice bran contains beneficial substances and is sometimes used in functional foods and cosmetics (Cheong *et al*., 2019; Taniguchi *et al*., 2012; Tsuchiya *et al*., 2022). In Tanzania, some is used as animal feed, but most is treated as agricultural waste. Tanzania produces 3.44 million tons of rice per year, with an estimated 344,000 tons of rice bran (The United Republic of Tanzania, 2021). According to the US Department of Agriculture (USDA, 2025), rice cultivation accounted for the largest production area in Tanzania during 2021/2022, accounting for 1,351,000 ha. The highest milled rice production in the 2024/2025 cropping season was 2,515,000tons. More than 70% of rice production in the country comes from the leading regions of Shinyanga, Tabora, Mwanza, Mbeya, Rukwa, and Morogoro (URT, 2025). In Tanzania, two rice varieties are primarily preferred to in domestic and regional markets: SUPA and TWD 306 (SARO 5). This study focused on feasibility in rural areas, examining the use of agricultural residues readily available to local farmers as a protein sources.

Materials and Methods

Materials

Procurement of rice bran

Assuming that Tanzanian rice farmers would use locally produced resources to produce aquaculture feed, NERICA—widely used in Africa—was preferred as the main source of bran. NERICA-L-15 (WAS 122-IDSA-1-WAS-2) was purchased from seed bran harvested in Burkina Faso in 2020. Due to the need to procure large quantities of bran for the experiment, the variety was determined by sowing several seed rice varieties in Saga Prefecture, Japan. NERICA-10 (WAB 450-11-1-1-P41-HB) was harvested to obtain the bran. NERICA was milled using rice hulling (THU35B, Satake, Hiroshima, Japan) and milling machines (TM05C, Satake), with a milling yield of 90%, as is usual for milling conditions in Japan. In addition, bran from Japanese rice grown in Chiba Prefecture, Japan, was used to compensate for the intermittent nature of the yield and harvest time. The milling conditions for Japanese rice were the same as those used for NERICA.

Procurement of protein sources

Commercial corn gluten meal (Kogostarch Co., Ltd, Chiba Prefecture), fish meal (Suzuei Shoji Co., Ltd, Chiba Prefecture), and soybean meal (Showa Sangyo Co., Ltd, Tokyo) were added to aquaculture feed as protein sources. Rapeseed meal (Showa Sangyo Co., Ltd) and Nile tilapia (*Oreochromis niloticus*) were also used to provide protein as sources accessible in rural Tanzanian areas. From local interviews, it was confirmed that soybean meal and rapeseed meal were easily available to farmers. Tilapia were procured from frozen edible fish that had been gutted in Vietnam. The following procedure described by Tozawa and Kawabata (1987) was used to produce fish meal from the tilapia. The tilapia (1.347 kg) was cut into several pieces and placed in 2 L of boiling distilled water. After boiling for approximately 10 min, the tilapia was pressed by hand to remove moisture and then deveined. The water removed from the tilapia was collected, combined with the boiling water, and allowed to stand, after which the oil that had solidified at the top was removed. The cut fish meat was mixed with boiling water, then dried in a constant-temperature drying chamber at 40 °C until the moisture content reached 20%. The dehydrated contents were then pulverized for 60 s in a pulveriser (Wonder Crusher WB-1, Osaka Chemical Co., Ltd., Osaka Prefecture) yielding 304 g of fish meal.

Feed preparation

The raw materials for fish feed were first thoroughly ground using a stand mixer (KSM150, KitchenAid, Michigan, USA). Each ingredient was mixed at the specified ratio and extruded into pellets with a diameter of 1 mm using a food grinder (CKT5601; KitchenAid). The extruded pellets were dried in a constant-temperature dryer at 50 °C for 6–8 h, then cut into a few mm lengths.

Fermented soybeans (10 g) produced by natto bacteria (*Bacillus subtilis natto*) were added to 500 mL of distilled water. The mixture was homogenized using a homogenizer to prepare the culture medium. The culture solution was added to 2 kg of rice bran, thoroughly mixed, and cultured at 30 °C for 48 h in a constant-temperature incubator. Fermentation was conducted under aerobic conditions, with the internal temperature of the rice bran monitored by thermometer and maintained above 40 °C. Subsequently, 300–400 mL of distilled water was added every 2 d, and the mixture was thoroughly stirred to maintain fermentation. After approximately 2 w, fermentation was deemed complete when the temperature dropped to 30 °C. The fermented rice bran was dried at approximately 25 °C for 24 h and then pelleted using the same procedure described earlier.

Analysis

The nutritional components were analysed in accordance with the official method based on the Japanese Food Sanitation Inspection Guidelines, and the contents of protein, fat, and ash soluble nitrogen—specified as nutritional requirements for tilapia—were determined. The analysis was conducted by an accredited laboratory (Japan Food Research Laboratories, Tokyo) in compliance with the Japan's Food Sanitation Act.

Results and Discussion

Differences in the proximate composition of rice bran

Table 1 shows the proximate component analysis results for the bran used in the experiment. The analysed items included moisture, crude protein, crude fat, crude fibre, crude ash, and soluble non-nitrogenous substances. The general components were specified by the Japanese feed analysis standards. Sample moisture content varied during measurement due to transport and storage conditions, but other component concentrations were considered to change proportionally with moisture content. Therefore, in this study, values were calculated on a dry matter basis. Similarly, the analysis results below were also expressed as dry weight.

The nutritional requirements for tilapia are shown in Table 1 (Ng *et al*., 2013). Although composition varies by strain and production region, rice bran in tilapia feed is deficient in protein while tending to contain excessive soluble non-nitrogenous substances. Saga Prefecture-produced NERICA rice exhibited particularly high levels of these substances, necessitating reduction. Lipid and fibre content generally met tilapia nutritional requirements, though Japanese rice tended to have a

Table 1. Proximate composition of rice bran on a dry matter basis.

	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Crude ash (%)	N-free extract (%)	Sodium (mg)	Energy (kcal)
Rice bran							
NERICA (Saga)	14.7	12.5	10.0	11.8	51.0	12	390
NERICA (Burkina Faso)	18.9	17.5	8.0	13.3	42.3	0.02	424
JAPONICA (Chiba)	16.1	21.6	8.7	9.2	44.5	6	426
Tilapia nutritional requirements	35–40	10–15	8–10	Ca: 0.4 P: 0.6	≤40	-	-

NERICA (Saga): NERICA-10 (WAB 450-11-1-1-P41-HB), NERICA (Burkina Faso): NERICA L-15 (WAS 122-IDSA-1-WAS-2), JAPONICA (Chiba): Milky Queen.

higher lipid content.

Design of compound feed and its formability

Soybean meal available in rural Tanzania was selected to supplement the protein deficiency in rice bran-based feed. Of the commercially available ingredients, fish meal was selected as the animal protein source and corn gluten meal as the plant protein source. Subsequently, compound feed was designed to meet the nutritional requirements of tilapia. The component analysis results for each ingredient are presented in Table 2. The nutritional composition of locally available rapeseed meal, as an alternative to corn gluten meal, is also included.

Based on the nutritional composition of the raw materials, the compound feed was prepared by mixing 25% or 50% rice bran with 15% soybean meal and supplementing the remaining 35% with fish meal or corn gluten meal. The deficiency in the 25% rice bran formulation was compensated for by the use of wheat. Additionally, a test feed substituting rice bran for wheat was prepared, and its formability was comparatively evaluated. Table 3 shows the nutritional composition and feed appearance after forming.

This design confirmed high-protein nutrition and improved issues with rice bran. Increasing rice bran content also reduced excessive soluble nitrate levels. Lipid content depended on the raw materials, with ideal results obtained in feeds containing large amounts of rice bran. Ideal feed formability was achieved at a high rice bran inclusion, suggesting that the oil content in rice bran enhanced formability.

As evident from the sieve yield, feed pelletability tended to decrease with increasing wheat bran inclusion (Table 3). Even at 50% rice bran, pellet formation remained satisfactory, and feed meeting protein requirements was successfully formulated.

Rice bran fermentation for improving preservability

Supplemental protein was added to prevent nutritional deficiencies in feed with a high rice bran content, but this accelerated feed spoilage, indicating that protein supplementation was unsuitable for long-term storage. Fish feed made from plant-based waste materials, such as rice bran and corn brans is susceptible to mould growth during long-term storage under high humidity conditions, and the mycotoxins produced by mould may affect fish growth (Marijani *et al.*, 2019). Under Japanese climatic conditions (25°C, humidity 60–80%), mould growth was observed in fish feed samples after approximately one month of storage. Therefore, feed degradation may progress even more rapidly in Tanzania and tropical regions.

The inclusion of fermented rice bran improved the shelf life of feed. The fermenting of rice bran increased various nutritional components, thereby improving the quality of rice bran as a feed ingredient (Tosti *et al.*, 2021). The fermentation of rice bran was promoted using natto bacteria (*Bacillus subtilis natto*), a fermenting microorganism derived from rice straw that is readily available to Tanzanian farmers.

The experimental feed was prepared by mixing 50%

Table 2. Proximate composition of raw materials on a dry matter basis.

	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Crude ash (%)	N-free extract (%)
Soybean meal	51.0	2.2	6.0	7.3	33.4
Rapeseed meal	44.5	2.5	10.0	7.0	36.4
Corn gluten meal	70.8	2.8	0.9	2.3	22.1
Fish meal	73.3	9.2	0.2	17.9	0.4
Tilapia fish meal	70.9	14.2	<0.1	17.8	<0

Table 3. Nutritional composition of compound feed prepared with different raw material ratios on a dry matter basis.

Raw materials (Ratio)			Nutritional composition (%)				
			Crude protein	Crude fat	Crude fibre	Crude ash	N-free extract
Soybean meal (15%)	Corn gluten meal (35%)	Rice bran (25%)	36.9	6.1	3.1	4.4	49.4
		Rica bran (50%)	39.0	10.0	5.0	6.7	39.5
		Wheat bran (25%)	39.1	3.2	3.4	2.8	51.4
		Wheat bran (50%)	40.5	4.4	5.3	4.1	46.2
	Fish meal (35%)	Rica bran (25%)	40.8	7.8	2.9	8.9	39.4
		Rica bran (50%)	42.5	11.3	5.4	11.0	29.7
		Wheat bran (25%)	41.1	4.7	3.2	8.0	42.9
		Wheat bran (50%)	43.2	5.4	5.4	9.1	36.9

Table 4. Proximate composition of fermented rice bran feed using corn gluten meal or fish meal as protein sources in raw materials on a dry matter basis.

	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Crude ash (%)	N-free extract (%)
Corn gluten meal	49.4	3.9	10.1	12.9	23.8
Fish meal	50.2	5.6	9.7	16.7	17.8

Table 5. Proximate composition of feed prototypes using tilapia or rapeseed meal as protein sources on a dry matter basis.

Raw materials			Crude protein (%)	Crude fat (%)	Crude fibre (%)	Crude ash (%)	N-free extract (%)
Fermented rice bran	Soybean meal	Tilapia fish meal	48.2	7.1	8.9	18.2	17.5
Fermented rice bran	Soybean meal	Rape seed meal	38.6	2.4	13.0	14.1	31.9

fermented bran, 15% soybean meal, and 35% corn gluten or fish meal (Table 4). Using fermented rice bran did not affect pellet formability. Furthermore, no mould or other spoilage was observed in the feed even after four months of storage. However, fermentation of rice bran substantially reduced lipid content.

Preparation of prototype feed

Based on the experimental results of the prototype feed, a feed formulation was prepared using ingredients available in rural areas of Tanzania. Instead of fish meal, tilapia, an easily obtainable farmed fish, was used as the animal protein source. For the plant-based protein source, rapeseed meal was chosen instead of corn gluten meal; excessive use of soybean meal has been reported to be harmful to farmed fish (Ye *et al.*, 2011). The nutritional composition of the feed (a mixture of 50% fermented rice bran, 15% soybean meal, and 35% each of the protein sources) is shown in Table 5.

During the trial production of feed primarily using fermented rice bran, mould was not evident even when using locally available natural resources (Fig. 2). In typical aquaculture, the feed conversion ratio (FCR) for tilapia is 1.5–2.0 (Watanabe *et al.*, 2022). Therefore, it was estimated that 435–580 g of feed would be required to grow 10 g of fry to the shipping size of 300 g. If the feed consisted of 35% protein, 150–200 g of protein would be needed. If all protein was sourced from tilapia-derived fishmeal, approximately 760–1000 g of tilapia would be required, which was considered impractical. Analysis indicated the presence of excess protein, making this amount of fishmeal unnecessary. Herath *et al.* (2016) demonstrated the feasibility of Nile tilapia production using fishmeal-free feed (Herath *et al.*, 2016). Since crop yields fluctuate seasonally, locally available protein sources can be selected based on their availability.

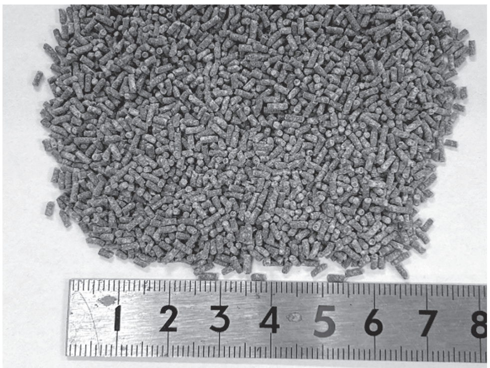

Fig. 2. Fish feed made from rapeseed meal.

Conclusions

Even at a rice bran content of 50%, adding protein sources enabled the production of feed suitable for tilapia. Producing fish feed with a high concentration of rice bran, an agricultural residue, facilitated the use of rice bran as a resource and contributed to the manufacture of inexpensive feed. As complementary protein sources, soybean meal, rapeseed meal, and tilapia carcasses generated during aquaculture are feasible options available in rural Tanzania. This approach required no additional raw material purchases; however, the ease of procuring protein sources in rural Tanzania warrants further verification. Rice bran possesses excellent moulding properties due to its oil content. However, storage stability is a concern. This issue can be resolved through fermentation of the rice bran.

This study designed tilapia feed with a focus on protein, the most critical nutrient. Future work should explore other ingredients based on palatability to the fish. The prototype feed lacked sufficient fat, and depending on the selected ingredients, fat supplementation may be necessary. The sinking or floating properties of feed are important for effective feeding (Yamada *et al.*, 2009) and should be considered in future work. Trials using prototype feed should be conducted in small-scale ponds for tilapia farming. The challenge is to ensure feeding is both effective and economical, while assessing the impact of the feed on water quality and soil. Feed design and manufacturing methods need to be adjusted according to the availability of local agricultural residues. Making the process more versatile and economically feasible is a future research challenge. The effective utilization of rice bran, a local waste product, holds potential not only as tilapia feed but also as feed for livestock.

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