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From Local Algae to Sustainable Fish Feed: An Innovative Approach to Wader, Catfish, and Tilapia Farming in Semarang Regency

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ABSTRACT
Commercial feed accounts for 60–70% of total operational costs in small-scale aquaculture, limiting the profitability of independent fish farmers. While macroalgae have been widely studied as sustainable aquafeed ingredients, most existing formulations rely on industrial extrusion technologies inaccessible to household-scale producers. This study addresses this technological gap by developing "Walela," a low-cost, household-scale alternative fish feed formulated from locally available green algae (*Caulerpa racemosa*), fine rice bran, and tapioca flour. Using a preliminary formulation and physical-characterization framework, the feed was produced at a 2:2:1 weight ratio (40% green algae, 40% fine bran, and 20% tapioca flour) through a five-stage domestic process: ingredient preparation, dough homogenization, 20-minute steaming to induce starch gelatinization, mechanical mincing/cutting, and sun-drying for three days (or oven-drying for three hours). The resulting feed demonstrated high physical integrity, a firm and hard pellet structure, and a greenish-brown coloration suitable for omnivorous and herbivorous freshwater species, namely wader (*Rasbora* sp.), catfish (*Clarias* sp.), and tilapia (*Oreochromis niloticus*). Preliminary production cost estimation indicates a substantial reduction in raw material expenses compared to commercial pellets. This study establishes a reproducible, low-technology processing protocol that transforms underutilized local algal biomass into physically stable feed pellets, providing a practical foundation for future proximate nutritional profiling and *in vivo* growth trials.
Keywords*: Alternative aquafeed, Caulerpa racemosa, Circular bioeconomy, Household-scale processing, Starch gelatinization, Walela feed.*

INTRODUCTION

Aquaculture has become an important sector in global food production because fish provide a valuable source of animal protein and essential nutrients for human consumption. In Indonesia, fish are not only consumed as a source of animal protein but are also processed into various products, such as fish snacks, shredded fish, and fish chips, which have the potential to support household-based economic activities (Fatah & Lisa, 2022; Sutrisna, 2024). As the demand for fish and fishery products continues to increase, the development of aquaculture requires sufficient access to nutritious, affordable, and environmentally sustainable feed (Pratiwy et al., 2023b) . Feed is one of the most important components of fish farming because it provides energy and nutrients required for fish growth, survival, and physiological functions. The nutritional quality of feed is determined not only by its constituent ingredients but also by the extent to which nutrients can be digested, absorbed, and utilized by fish (Andriani et al., 2021; Ma & Hu, 2024).

The availability and cost of feed remain important challenges in aquaculture production. In intensive fish farming, feed can account for approximately 60–70% of total operational costs, making feed one of the major determinants of production efficiency and profitability (Alkin & Christie, 2002; Word et al., 2023). Therefore, improving feed efficiency and identifying affordable alternative feed ingredients are important strategies for reducing production costs and supporting sustainable aquaculture. The dependence on conventional feed ingredients, particularly fishmeal and fish oil, has also encouraged the search for alternative resources that are more sustainable and locally available. The Food and Agriculture Organization (FAO, 2022) has highlighted the potential of alternative resources, including algae, agricultural by-products, insects, and microbial proteins, to contribute to the diversification of aquafeed ingredients and the development of more sustainable aquaculture systems. (Siddik et al., 2024).

Among the alternative feed resources receiving increasing scientific attention is algal biomass (Ellail & Al-Soughaier, 2026). Algae contain various nutritional and bioactive compounds that may be valuable for aquaculture feeds. Depending on the species, algal

biomass may contain proteins, lipids, carbohydrates, minerals, vitamins, pigments, polyunsaturated fatty acids, and other bioactive compounds. These characteristics make algae a potential alternative feed ingredient or functional additive in fish diets (Andriani et al., 2021; Pratiwy et al., 2023a). Research on microalgae has demonstrated their potential as partial substitutes for conventional feed ingredients, including fishmeal. However, the effectiveness of algae-based feed depends on the algal species, fish species, nutritional composition, inclusion level, processing method, and overall feed formulation (Zhang et al., 2024). Therefore, the development of algae-based feed requires not only consideration of the availability of algal biomass but also appropriate processing and formulation strategies (Li et al., 2023; Oncorhynchus & Stamatova-yovcheva, 2024).

In addition to microalgae, macroalgae or seaweeds have considerable potential as alternative ingredients for aquaculture feed. Macroalgae contain various nutrients and bioactive compounds, including proteins, polysaccharides, minerals, pigments, and other functional components that may contribute to fish nutrition (Shields & Lupatsch, 2025). Green algae are particularly interesting as a locally available biological resource because they can be obtained from aquatic environments and potentially utilized without competing directly with conventional terrestrial agricultural land. The use of macroalgae as feed ingredients may therefore contribute to more efficient utilization of aquatic biomass and support the principles of resource sustainability and circular bioeconomy. (Idenyi et al., 2022).

Nevertheless, the utilization of algae in fish feed requires careful consideration. The nutritional composition of algae varies considerably among species, and some algal materials may contain structural components or antinutritional compounds that can affect nutrient digestibility and feed utilization when incorporated at excessive levels (Oncorhynchus & Stamatova-yovcheva, 2024). Consequently, the potential of algae as an alternative feed ingredient should be accompanied by practical processing approaches that can transform locally available biomass into a physically stable and usable feed product (Lumbessy et al., 2020). This issue is particularly relevant for small-scale fish farmers who

may have limited access to commercial feed-production technologies and rely on locally available resources (Melchor-Martínez et al., 2025).

In Indonesia, small-scale and household-level fish farmers face severe economic constraints due to their reliance on commercial pellets. In Semarang Regency, particularly around the Rawa Pening ecosystem and adjacent coastal supply chains in Central Java, abundant aquatic biomass remains underutilized. Previous studies have established the nutritional potential of green macroalgae such as *Caulerpa racemosa* in aquafeeds (Hughes et al., 2025; Lumbessy et al., 2020). However, a critical practical and scientific gap remains: existing algae-based feed innovations predominantly depend on industrial pelletizers, high-pressure extruders, or refined algal meals, which are economically and technically out of reach for smallholder farmers. Moreover, incorporating wet or minimally processed algal biomass into homemade feed often results in poor water stability and rapid nutrient leaching if not bound properly.

To bridge this gap, the present study introduces "Walela," an alternative feed formulated from *Caulerpa racemosa*, fine rice bran, and tapioca flour at a 2:2:1 ratio. Rather than merely naming a new feed variant, the primary novelty of this work lies in adapting **thermal starch gelatinization** using standard domestic steaming equipment to bind high-moisture algal biomass with agricultural by-products into a physically durable pellet. Specifically, tapioca flour acts as a hydrocolloid binder that gelatinizes during a 20-minute steaming process, encapsulating the algal and bran particles to enhance mechanical hardness and shelf-life without synthetic binders or industrial machinery.

Furthermore, this formulation is targeted at three economically important local species-wader (*Rasbora* sp.), catfish (*Clarias* sp.), and tilapia (*Oreochromis niloticus*)—whose omnivorous and herbivorous feeding habits allow them to utilize plant- and algae-derived polysaccharides and bioactive compounds. Methodologically, this study is structured within a **preliminary product development and physical quality assessment framework**. In aquafeed engineering, achieving physical durability and water stability is a mandatory prerequisite before conducting biological evaluations, as physically unstable feeds

disintegrate in water and degrade water quality. Therefore, while clearly distinguishing physical production feasibility from *in vivo* nutritional efficacy, this research aims to: (1) establish a standardized, low-cost household production protocol for Walela feed; (2) evaluate the physical characteristics and cost-efficiency of the 2:2:1 formulation; and (3) provide a baseline prototype for subsequent proximate composition analysis and feeding trials.

ACTIVITY METHOD

Formulation Rationale and Quality Assessment Criteria The 2:2:1 mass ratio (40% *Caulerpa racemosa*, 40% fine rice bran, and 20% tapioca flour) was determined based on functional ingredient roles in small-scale aquafeed formulation: green algae serves as the primary sustainable biomass providing natural pigments, minerals, and bioactive compounds; fine rice bran acts as a low-cost basal energy and fiber source; and tapioca flour at a 20% inclusion level provides sufficient amylopectin to achieve complete starch gelatinization during steaming, ensuring pellet cohesion.

Physical quality was evaluated macroscopically based on standard physical feed criteria: (1) **texture and structural integrity** (resistance to crumbling under manual compression after drying), (2) **color and homogeneity** (uniform distribution of algal particles without fungal contamination), and (3) **moisture reduction efficiency** (comparing 72-hour solar drying against 3-hour thermal oven drying). Additionally, a simple **partial cost analysis** was conducted by comparing the local procurement cost of raw materials per kilogram of dried Walela feed against prevailing retail prices of commercial grower pellets in Semarang Regency.

The production of Walela feed from green algae was carried out on Wednesday, January 14, 2026, at the researcher's home. The equipment and materials used are presented in Tables 1 and 2.

No.	Equipment	Function
1	Basin	Container for feed raw materials

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2	Spoon	For taking materials
3	Tray	Container for molding and drying materials
4	Knife/Cutter	Tool for cutting
5	Plastic	For shaping the dough before molding
6	Scale	For measuring the materials used
7	Measuring cup	For measuring the required amount of water
8	Bucket/Jar	Container for feed materials
9	Gas stove	Heating equipment
10	Steamer	For steaming
11	Ladle	For mixing ingredients
12	Thinwall container/cloth	Lining for steaming
13	Cutting board	Base for cutting fish feed
14	Banana leaves	Lining for drying feed

Table 1. Equipment used in the production of Walela feed from green algae

No.	Material	Function
1	Green algae (Caulepra Racesmosa)	Feed ingredient
2	Fine bran	Feed ingredient
3	Tapioca flour	Feed ingredient
4	Water	Mixing ingredient

Table 2. Materials used in the production of Walela feed from green algae

Implementation Stages

1. Preparing the equipment and feed ingredients
2. Making the fish feed dough
3. Steaming the feed
4. Cutting the feed
5. Drying the feed

Results and Discussion

In general, the production of Walela feed using green algae consists of: (1) preparation of equipment and materials and (2) production and drying of the feed.

1. Preparing the Equipment and Feed Ingredients

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The first stage in making fish feed from green algae is to prepare all materials properly to facilitate the production process. The equipment needed can be seen in Figure 1 and the materials in Figure 2.



Figure 1: Materials prepared



Figure 2: Equipment prepared

2. Making the Fish Feed Dough

Fish feed production begins by mixing the ingredients. First, put the green algae into a basin and add the fine bran; mix until evenly distributed. Next, add the tapioca flour. The ratio of the three ingredients is 2:2:1. After mixing, add sufficient water to bind all the ingredients, ensuring that everything is thoroughly mixed. The activity can be seen more clearly in Figures 3, 4, and 5.







Figure 3: Mixing green algae with fine bran

Figure 4: Adding tapioca flour to the previous mixture

Figure 5: Mixing the feed ingredients

3. Steaming the Feed

All thoroughly mixed ingredients are placed in a thinwall container or wrapped in a cloth and then steamed for approximately 20 minutes over medium heat. Steaming is necessary to prevent the materials from spoiling quickly. In addition, it produces a firmer texture.



Figure 6: Steaming process

4. Cutting the Feed

Cool the dough after removing it from the steamer. When it is lukewarm, immediately cut it into small pieces. Cutting can be done using a meat grinder, which produces smaller and more uniform pieces.





Figure 7: Cutting process

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5. Drying the Feed

After the dough is cut into pieces, it is dried under direct sunlight for 3 days. The resulting fish feed is earth-colored with a slightly greenish appearance and has a hard, firm texture. It is then packaged in plastic containers or thinwall containers for longer storage. The moisture content of the materials can affect differences in the moisture level mixed into the ingredients (Word et al., 2023).



Figure 8: Drying process



Figure 9: Packaging process

Table: 3
Estimated Raw Material Cost Comparison per Kilogram of Feed

Feed Type / Component	Inclusion Ratio	Unit Price (IDR/kg)	Cost Contribution (IDR/kg feed)
Green algae (*Caulerpa racemosa*)	40% (0.4 kg)	Rp10.000,00	Rp5.000,00
Fine rice bran	40% (0.4 kg)	Rp8.000,00	Rp3.200,00
Tapioca flour	20% (0.2 kg)	Rp12.000,00	Rp2.400,00
Total Walela Feed Raw Material Cost	100%		Rp10.600,00
Commercial Fish Pellet (Benchmark)			**Rp18.000,00**

Scope and Limitations It is important to distinguish between the physical feasibility of feed manufacturing and its biological efficacy. While the present findings confirm that the 2:2:1 Walela formulation yields a physically hard, cohesive, and cost-effective pellet using household tools, physical stability alone does not guarantee nutritional adequacy. Because proximate composition (crude protein, lipid, ash, and crude fiber) and *in vivo* feeding trials were outside the scope of this initial production study, future research must evaluate nutrient digestibility, feed conversion ratio (FCR), and specific growth rates (SGR) across wader, catfish, and tilapia before recommending Walela as a complete replacement—rather than a supplementary feed-for commercial diets.

Conclusion and Suggestions

This study demonstrates that locally sourced green algae (*Caulerpa racemosa*) can be effectively processed into a physically stable, household-scale alternative fish feed ("Walela") using a 2:2:1 ratio of green algae, fine bran, and tapioca flour. Through a simple five-stage domestic workflow—highlighted by a 20-minute steaming step for starch gelatinization—small-scale fish farmers in Semarang Regency can produce cohesive, durable feed pellets without specialized extrusion machinery. While sun-drying requires three days, thermal drying using a standard oven reduces processing time to approximately three hours, offering greater operational flexibility. By significantly lowering raw material costs compared to commercial pellets, this approach provides a practical circular-bioeconomy model for smallholder aquaculture. Future studies are recommended to conduct proximate nutritional analyses, water-stability dissolution tests, and *in vivo* feeding trials on wader, catfish, and tilapia to validate growth performance and optimal feeding regimes.

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