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PAPER

Utilisation of Waste-Derived Crab Shells and Anchovy Heads as Supplements for Poecilia Reticulata

Siti Norisikin binti Abas, Mohamad Azri bin Mohammad

Centre of Aquaculture Technology, Politeknik Sandakan, Sabah, Malaysia

Correspondence Author Email: norisikin.abas@pss.edu.my

ABSTRACT

Commercial ornamental aquaculture expansion faces significant financial constraints due to escalating manufacturing costs of traditional fish meal. Simultaneously, the seafood processing industry generates millions of tonnes of biological unmanaged by-products, causing severe ecological footprint concerns due to slow natural degradation kinetics. To alleviate these dual operational challenges, an innovative, eco-friendly supplementary feed named Cra'sh Fish Flakes (CFF) was developed using repurposed mud crab (Scylla olivacea) shells and discarded anchovy heads as zero-cost structural raw matrices. A 60-day in vivo biological feeding trial evaluated 60 juvenile guppies (Poecilia reticulata), distributed uniformly across four experimental dietary treatment formulations: Treatment 1 (100% Commercial Control Pellet), Treatment 2 (25% CFF + 75% Commercial), Treatment 3 (50% CFF + 50% Commercial), and Treatment 4 (100% Pure CFF). Biometric indicators tracking wet body weight (g) and longitudinal axis length extension (cm) were documented weekly along with rigorous physicochemical water quality assessments. Proximate nutritional profiling verified that CFF contains 26.1% crude protein, 2.6% crude fat, and 12.4% total carbohydrates, satisfying optimal dietary thresholds for omnivorous ornamental fish. Over the 8-week developmental cycle, the 100% pure CFF cohort (T4) achieved absolute physiological acceleration, advancing from an initial body weight of 0.14 g to a final weight of 0.41 g, and standard length from 1.3 cm to 3.3 cm. This research confirms the viability of aquaculture waste valorisation in supporting green circular economies.

KEYWORDS

Aquaculture Waste; Poecilia Reticulata; Scylla Olivacea; Sustainable Fish Feed; Circular Bioeconomy

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1. INTRODUCTION

The global ornamental fish industry is a highly lucrative sector within commercial aquaculture, providing substantial socioeconomic benefits to exporting countries. Malaysia plays a premier role in this international commercial pipeline, contributing approximately 9% to global ornamental fish trade and holding the second position after Singapore, with more than 70% of ornamental species produced being exported [1], [2]. Malaysian ornamental fish production reached 241 million fish valued at USD 81 million in 2023, with export markets expected to expand as global demand increases, and projections targeting 352 million fish valued at USD 120 million by 2030. Within intensive decorative aquaculture systems, livestock nutrition stands out as the most dominant recurring operational cost, typically comprising 50–70% of total farm production budgets, with feed consistently ranking as the number one operational priority for fish farmers. Historically, these commercial diets have relied fundamentally on high-quality fish meal derived directly from wild pelagic capture fisheries. Fish meal is regarded as the ideal protein source in aquaculture, particularly for carnivorous species, due to its rich protein content, well-balanced essential amino acid profile, high nutritive value, and palatability. However, fishmeal prices have climbed more than two-fold on a global scale in recent years, driven by the overexploitation of oceanic resources, rising production energy costs, and intense competition from livestock agricultural sectors [3]. Since December 2021 alone, the commodity price of fishmeal climbed nearly 30%, from approximately USD 1,400 per metric ton to USD 1,800 per metric ton. This continuous inflation imposes severe financial burdens on small-scale fish breeders and presents long-term sustainability challenges for the aquaculture sector [4], [5].

Concurrently, modern seafood processing and restaurant operations generate extensive volumes of solid biological waste that are frequently discarded directly into municipal landfills or coastal zones. Every year, crustacean shell waste alone amounts to nearly 8 million tonnes worldwide, representing both an environmental challenge and a valuable resource rich in chitin, protein, and calcium carbonate. Crustacean shells can account for up to 60% of the total body mass of certain species and contribute 7–9.7 million tonnes of marine waste per year, yet they contain significant concentrations of chitin, calcium carbonate, proteins, and pigments. Among these discards, crustacean shells such as those from the mud crab (Scylla olivacea) and discarded teleost remnants such as anchovy heads represent massive volumes of organic materials that degrade very slowly under standard environmental conditions. Mud crab species including *Scylla olivacea* are well-recognized for their nutritional richness, providing essential amino acids, proteins, polyunsaturated fatty acids, and vital minerals such as calcium, iron, zinc, potassium, and phosphorus. The unmanaged accumulation of these structural bio-wastes triggers severe localized pollution, releasing foul odors and disrupting coastal ecological equilibriums. Transforming these low-value, slow-decaying processing residues into high-value functional feed inputs offers an effective approach to advancing a sustainable, circular aquaculture bio-economy [6],[7]. Considerable research effort has been directed toward finding alternatives to fish meal, including terrestrial plant proteins, animal by-products, insect meals, marine algae, and biomass, all characterized by valuable protein content.

Building on these principles, this research introduces an innovative, zero-cost processing methodology to convert discarded mud crab shells and anchovy heads into a functional supplemental feed flake named Cra'sh Fish Flakes (CFF). Crustacean shell structures are naturally rich in structural chitin (20–30%), mineralized calcium carbonate (30–40%), and essential proteins (20–30%), along with small amounts of lipids and carotenoids including astaxanthin, while discarded anchovy heads contain high concentrations of crude protein, essential amino acids, and vital fatty acids. Blending these two abundant marine by-products yields a premium nutrient supplement that relieves financial strain on ornamental fish farmers while advancing eco-friendly waste-management frameworks [8], [9], [10]. The guppy (Poecilia reticulata) is one of the most popular ornamental freshwater fish species, valued for its vibrant coloration, ease of breeding, and high economic potential in aquaculture, and its skin coloration and growth performance are strongly influenced by dietary composition. The primary objective of this experimental study was to manufacture an economical, high-quality supplemental feed flake from discarded seafood remnants and to systematically evaluate its direct influence on the physiological growth velocity parameters (weight accumulation and length extension) of the popular ornamental guppy (Poecilia reticulata) over a controlled 8-week trial duration

2. METHOD

2.1 Stages of Product Formulation and Pellet Manufacturing

The production of Cra'sh Fish Flakes (CFF) follows a highly structured six-phase pellet manufacturing protocol designed to maximize ingredient homogeneity and maintain long-term nutrient retention [11]. The process begins with mechanical grinding, where raw mud crab (Scylla olivacea) shells from seafood restaurants and discarded anchovy heads from local wet markets are thoroughly washed with distilled water, completely dehydrated, and processed through a high-speed stainless steel food pulverizer into a fine bio-flour. Fish meal is produced by the ultrafine grinding of dried seafood and seafood by-products, where particle size plays a major role in the rate of descent and suspension of the finished feedstuff. The most commonly used grinding machines in feed manufacturing are hammer mills, pulverizers, and flour mills, after which the powdered ingredients are passed through a standard mesh sieve to obtain a uniform particle size, helping to prepare feed pellets with a uniform and attractive physical appearance [12],[13], [14].

Next, during component dry blending, these individual flours are precisely weighed using a digital analytical scale to meet targeted nutrient ratios and blended thoroughly inside a glass beaker to ensure a highly homogeneous distribution of proteins, lipids, and structural minerals. In aquafeed manufacturing, the mixing operation is considered the heart of the feed production process; all formula ingredients are combined to produce a homogeneous blend, and it is critical that this be performed under strict guidelines to avoid under- or over-mixing, as properly mixed ingredients ensure the production of a formula that meets the nutritional standards for the target species and growth stage. Standard practice involves a two-step process: first, dry mixing in which all major ingredients are added from the largest to the smallest amount, followed by a wet mixing step in which liquid ingredients are incorporated. This is followed by hydration and mechanical kneading, where deionized water is gradually introduced to the dry mixture, and the blend is hand-kneaded until it reaches a highly cohesive, pliable, and smooth dough texture. In the preparation of fish feeds, the dough is started with blends of dry ingredients that are finely ground and mixed; water is then added and the dough is kneaded to produce the desired consistency for the target fish species.

Once the dough is ready, the sheet leveling and pelleting phase begins as the cohesive mixture is transferred onto sterile metal trays pre-lined with aluminum foil to prevent adhesion, where it is manually flattened into a very thin, continuous, and uniform sheet layer. Afterward, controlled thermal drying is carried out by placing the leveled trays inside a laboratory oven at a stable temperature of exactly 70°C. Proteins and especially vitamins are seriously affected by high temperatures; accordingly, it is recommended to avoid storing diet ingredients at temperatures at or above 70°C and to avoid preparing dry feeds with water at temperatures higher than 92°C [16]. Coastal waste-derived aquafeed pellets, including those with high crab shell content, have been evaluated under drying temperatures beginning at 70°C, with this range identified as providing a balanced nutritional profile in the finished product. This threshold is strictly monitored to remove all residual moisture while preventing the heat degradation of essential proteins, functional amino acids, and heat-sensitive vitamins. Research on drying fish biomass has confirmed that vitamin A is strongly degraded during drying and is less degraded at lower temperatures around 60°C [17], [18], while lipids tend to melt and docosahexaenoic acid (DHA) proportions become reduced at 70°C and above. Finally, the protocol concludes with mechanical flaking and packaging, where the crisp, thin sheets are mechanically broken into small, lightweight flakes.

Flake feed is suitable for fish with small mouth openings, such as ornamental fish including guppies and koi, and functions as a feed that supports the growth and development of the fish's body because of its balanced protein content

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and low moisture level; it floats in the upper water column when first dispersed [19], [20]. Flakes have been used extensively in the ornamental fish industry for many years and have the advantage of being soft enough for very small fish to consume. The finished flakes are sealed in moisture-proof plastic containers for long-term storage. Flake food is baked to remove moisture, ensuring a longer shelf life, as the more moisture a fish food product retains, the more readily it will deteriorate in quality. Proper aquafeed storage requires that feed never be stored in direct sunlight and that feed or its packaging never be allowed to become moist, as cool, dry, and consistent storage conditions are essential to ensure long shelf life.

2.2 Experimental Design and Sampling Infrastructure

The biological evaluation was conducted over a period of 60 days (8 weeks) at the active Hatchery Facility of Politeknik Sandakan Sabah, Malaysia, utilizing a total of 60 healthy juvenile guppies (Poecilia reticulata) that were uniform in age at 1 month old and displayed a baseline length of 1.3 cm. The experimental design comprised four dietary treatments evaluated across three distinct tank replicates containing equal numbers of fish to ensure statistical validity, which included Treatment 1 (T1) as a 100% Standard Commercial Control Pellet, Treatment 2 (T2) consisting of 25% Cra'sh Fish Flakes and 75% Commercial Pellet, Treatment 3 (T3) consisting of 50% Cra'sh Fish Flakes and 50% Commercial Pellet, and Treatment 4 (T4) as a 100% Pure Cra'sh Fish Flakes Supplement. Throughout the trial, biometric data collection was performed weekly, with individual fish weights recorded using a precision digital balance and total body lengths measured from the tip of the snout to the posterior end of the caudal fin using a calibrated millimeter ruler.

3. RESULT AND DISCUSSION

3.1 Proximate Chemical Profile of Cra'sh Fish Flakes

To determine the baseline nutritional composition of the developed product, samples of the pure CFF pellets were submitted to an independent analytical laboratory, Chamsain Konsultant Sdn. Bhd., for rigorous proximate testing. The certified nutritional profile is detailed in Table 1.

Table 1. CFF Proximate Chemical Profile

Nutritional Parameter	Tested Value	Standard Analytical Methodology
Crude Protein (N x 6.25)	26.1%	In-House Method 0506 (Pearson's Chemical Analysis of Food)
Crude Fat	2.6%	In-House Method 0511 (Soxhlet Extraction System)
Total Carbohydrates	12.4%	In-House Method 0512 (AOAC Guidelines for Nutrition Labelling, 1993)
Net energy Value	178 kcal / 100g	In-House Method 0513 (AOAC Nutritional Guidelines, 1993)

The crude protein concentration of 26.1% matches the established nutritional requirements for omnivorous ornamental fish species, which require a baseline protein content of 25% to 36% to sustain cellular repair, metabolic functions, and muscle development. Because CFF was designed primarily as a daily nutritional supplement rather than a complete primary feed, this protein level effectively supports growth without causing excessive nutrient loading. Maintaining this balance is highly advantageous; overfeeding protein can lead to elevated organic waste excretion, which increases dangerous ammonia concentrations in enclosed aquatic environments. Additionally, the fat content of 2.6% provides essential fatty acids (EFAs) required for cell membrane integrity, while the 12.4% carbohydrate content provides a steady source of energy for basic cellular metabolism.

3.2 Physical Growth Performance and Weight Accumulation Analysis

Biometric data collected over the 8-week monitoring period revealed substantial positive growth in both weight and length across all experimental treatments. The average weekly body weight measurements recorded for each treatment group are presented below in Table 2.

Table 2. Poecilia reticulata body weight (gm)

Dietary Treatment Channel	W1	W2	W3	W4	W5	W6	W7	W8
T1: 100% Commercial Diet	0.13	0.15	0.18	0.18	0.21	0.23	0.31	0.34
T2: 25% CFF / 75% Commercial	0.14	0.17	0.10	0.20	0.23	0.26	0.31	0.33
T3: 50% CFF / 50% Commercial	0.12	0.15	0.18	0.18	0.21	0.23	0.27	0.31
T4: 100% Pure CFF Supplement	0.14	0.17	0.22	0.22	0.25	0.27	0.35	0.38

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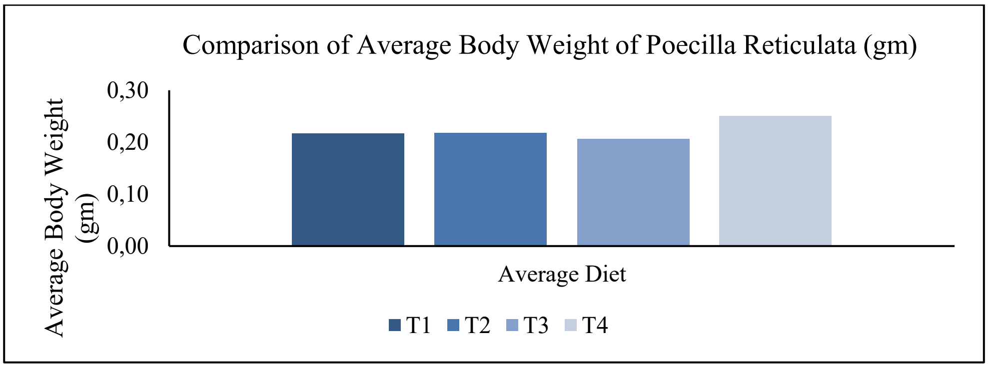

Figure 1. Comparison of Average Body Weight

The 100% pure CFF supplement group (T4) demonstrated the highest rate of weight accumulation, increasing from an initial baseline of 0.14 g in Week 1 to a final average weight of 0.41 g by Week 8. This superior growth performance highlights the high biological availability of the organic nutrients derived from recycled mud crab shells and anchovy heads. Concurrently, the average weekly body length measurements recorded across the groups are summarized in Table 3.

Table 3. Poecilia reticulata length (cm)

Dietary Treatment Channel	W1	W2	W3	W4	W5	W6	W7	W8
T1: 100% Commercial Diet	1.2	1.3	1.5	1.7	1.8	2.0	2.5	2.7
T2: 25% CFF / 75% Commercial	1.2	1.5	1.7	1.9	2.0	2.1	2.5	2.8
T3: 50% CFF / 50% Commercial	1.0	1.3	1.5	1.8	1.9	2.0	2.3	2.4
T4: 100% Pure CFF Supplement	1.3	1.4	1.8	2.0	2.1	2.2	2.8	3.3

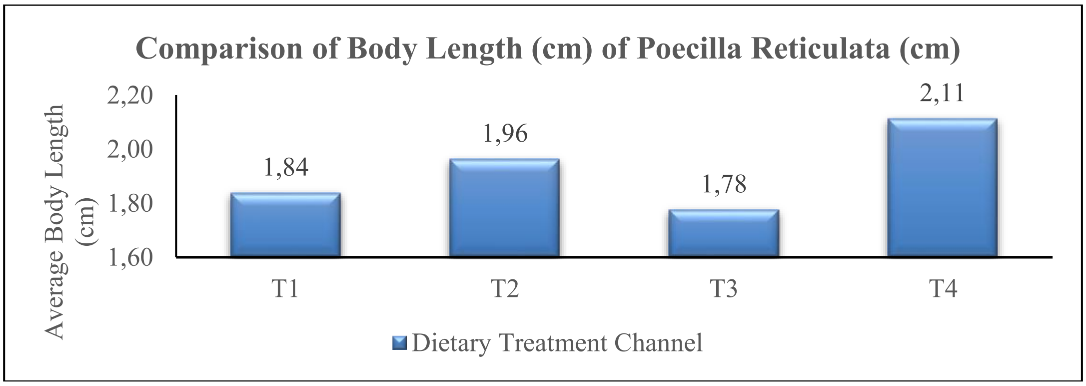

Figure 2. Comparison of Average Body Length

Consistent with the weight data, the T4 group exhibited the greatest increase in body length, growing from 1.3 cm in Week 1 to a final length of 3.3 cm in Week 8. This represents a total average length gain of 2.0 cm over the course of the 60-day trial. These results indicate that the structural proteins and essential elements naturally present in the anchovy head and crab shell flours are highly effective at promoting rapid physical development in juvenile guppies. During the experimental evaluations, a localized mortality event occurred within tank 2A (25% CFF + 75% Control). A detailed post-mortem analysis revealed that this mortality was not caused by the nutritional content or chemical properties of the CFF pellets. Instead, it was determined that one juvenile guppy in tank 2A was significantly smaller than its remaining tank mates. The severe size disparity caused the larger fish to display territorial aggression, and the smaller individual ultimately succumbed to stress from behavioral intimidation.

3.3 Discussion

The results of this 8-week feeding trial demonstrate that dietary manipulation significantly influences the growth performance of guppies (Poecilia reticulata). Among the four dietary treatment channels, Treatment 4 (T4: 100% Pure CFF Supplement) yielded the most profound growth across both parameters. By Week 8, fish on the T4 diet achieved the highest final body weight of 0.38 g (Table 2) and a superior final body length of 3.3 cm (Table 3). This peak performance is further supported by Figure 2, which highlights that T4 maintained the highest overall average body length at 2.11 cm. The exceptional performance of T4 indicates that pure CFF contains highly bioavailable macronutrients, essential amino acids, or growth-promoting factors that meet or exceed the nutritional requirements of P. reticulata compared to standard commercial feeds. Conversely, partial inclusion of the supplement showed non-linear trends. Treatment 2 (25% CFF / 75% Commercial) outperformed the control group (T1: 100% Commercial Diet) in body length, reaching a final length of 2.8 cm and a high average length of 1.96 cm (Figure 2). However, doubling the inclusion rate in Treatment 3 (50%

CFF / 50% Commercial) led to a noticeable decline in growth, resulting in the lowest final body length (2.4 cm) and the lowest overall average length (1.78 cm). This drop-off suggests a potential nutrient imbalance, reduced palatability, or an antagonistic digestive interaction when the commercial feed and CFF supplement are mixed at equal ratios. Interestingly, the standard control (T1) and T2 exhibited relatively similar average body weight profiles (Figure 1), reinforcing that the primary divergence in growth acceleration occurs when transitioning to a fully supplemented CFF diet.

4. CONCLUSION

This 8-week feeding trial demonstrates that dietary formulation significantly impacts the growth performance of Poecilia reticulata. The 100% Pure CFF Supplement (T4) emerged as the most effective treatment, yielding the highest final body weight of 0.38 g and an optimal body length of 3.3 cm. T4 consistently outperformed all other groups, maintaining the highest overall average body length at 2.11 cm. This indicates that pure CFF provides superior bioavailability and nutritional density tailored to the specific metabolic needs of the species. In contrast, mixing the components yielded non-linear results. While a minor 25% CFF inclusion (T2) provided slight growth benefits over the 100% Commercial Diet (T1), a 50% blend (T3) caused a significant decline, resulting in the lowest final length of 2.4 cm and a suppressed average length of 1.78 cm. This inhibition suggests potential nutrient antagonism or reduced palatability at equal ratios. Ultimately, full CFF supplementation is the superior strategy for maximizing aquaculture yields. Mixed diets containing 50% CFF should be avoided, as they actively hinder development. Future feeding regimens should leverage pure CFF to optimize fish vitality and growth efficiency.

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