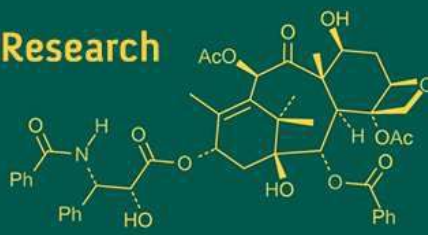


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Effect of partial replacement of fishmeal with roasted guar korma on growth performance and survival of pacific white shrimp, *Penaeus vannamei* Boone, 1931

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Abstract

The efficacy of partially replacing fish meal (FM) with roasted guar korma meal (RGKM) in the diet of *Penaeus vannamei* post-larvae (initial weight 0.035 g) was investigated over a 60-day feeding trial, maintaining a 35% crude protein level across all five experimental diets. Five diets were formulated, comprising a control diet (0% RGKM replacement) and four treatment diets where FM protein was substituted with RGKM protein at 25%, 50%, 75%, and 100%. Juvenile shrimp, stocked at 20 individuals per tank, were fed 5% of their body weight twice daily. Analysis of growth performance, feed efficiency, and survival rate indicated that the 25% RGKM replacement diet (T₂) yielded the most favorable results, demonstrating the highest mean weight gain, Specific Growth Rate (SGR), and Protein Efficiency Ratio (PER), alongside the lowest Feed Conversion Ratio (FCR), suggesting optimal nutrient utilization at this substitution level. Conversely, the highest survival rate (100%) was observed in both the control diet and the 75% RGKM replacement diet. Overall, the findings conclusively reveal that the partial substitution of FM with RGKM significantly influenced the weight gain, SGR, FCR, and PER of *P. vannamei*, highlighting the potential of RGKM as a viable, protein-rich alternative in shrimp aquaculture feed.

Keywords: *Penaeus vannamei*, roasted guar korma, growth and survival

1. Introduction

Aquaculture, defined as the husbandry of aquatic organisms, has emerged as the fastest-growing food production sector globally (Little *et al.*, 2016) ^[15], providing income and livelihoods for millions and serving as the primary strategy to meet the burgeoning worldwide demand for aquatic food that conventional catch fisheries cannot sustain (Subasinghe *et al.*, 2009; FAO, 2018) ^[22, 10]. This sector delivers substantial economic, social, and environmental benefits, including enhanced food security, poverty reduction, improved human nutrition, increased employment, and foreign exchange earnings. Fish remains a vital and often the least expensive source of animal protein, feeding over half of the world's population (FAO, 2016) ^[9]. In 2018, global total fish production reached 179 million tonnes (valued at US\$401 billion), with aquaculture contributing 82 million tonnes (46% of the total) and an estimated value of US\$250 billion (FAO, 2020) ^[11]. Crustaceans accounted for approximately 9.3 million tonnes of this production, with *Penaeus vannamei* (Pacific white shrimp) alone representing 53% (4.9 million tonnes) of the total crustacean output (FAO, 2020) ^[11]. The commercial success of *P. vannamei*, the most productive penaeid species globally, is evident in its dominance in tropical aquaculture, representing over 90% of Western Hemisphere shrimp culture and driving significant foreign exchange earnings for countries like India. India's shrimp sector, a crucial contributor to coastal socio-economic well-being, has successfully shifted from culturing the native *Penaeus monodon* to the exotic *P. vannamei* following the introduction of Specific Pathogen-Free (SPF) strains in 2009, a move that revitalized the industry due to inherent difficulties in *P. monodon* breeding for disease resistance (Babu *et al.*, 2014; Srinivas *et al.*, 2016; Amaya *et al.*, 2007; Ravuru and Mude, 2014) ^[4, 21, 2, 19].

Guar, also known as cluster bean, is a deep-rooted summer annual legume of considerable social and economic importance that can withstand drought and high temperatures (Mishra *et al.*, 2013) ^[17].

Guar has become one of the most important crops for farmers in arid areas of India due to its great adaptability to unpredictable rainfall, many industrial uses, and importance in cropping systems for characteristics such as soil enrichment properties, minimal input requirements, etc. A Guar is the Indian subcontinent native. The crop is primarily grown in Rajasthan, Haryana, Gujarat, and Punjab, with a little amount of cultivation in Uttar Pradesh and Madhya Pradesh. The crop is also produced in various countries of the world, like Australia, Brazil, and South Africa. India is the leading producer of guar and contributes 80 percent of total guar production in the world (Antil and Chhikara, 2019) [3].

Roasted guar (*Cyamopsis tetragonoloba*) korma is a by-product of the guar gum industry left after removal of gum, containing high protein and low gum (Ramteke *et al.*, 2014). The seed coat is removed first, then the dehulled seed, which is then processed to make guar korma. Guar korma is less expensive and high in crucial amino acids (Tyagi *et al.*, 2011) [23]. The protein content of guar meal ranges between 30-55% depending on fraction type (Biel and Jaroszevska, 2017) [5]. It is used as feed for livestock, including the fisheries sector, after processing, since it is a rich source of proteins, minerals, and fiber with a high digestibility (Janampet *et al.*, 2016) [12]. The roasted guar korma contained 50.27% protein (Tyagi *et al.*, 2011) [23].

2. Materials and Methods

2.1 Experimental Animals

The post larvae of *P. vannamei* were brought from commercial shrimp hatchery and transported in polythene bags by road to Veraval. Post larvae were brought to Wet Laboratory and acclimatized in the FRP tank (500 L) with continuous aeration and feeding for 5 days. Post larvae with a total weight of approximately 0.035 g were selected for the experiment.

2.1 Experimental Diet Preparation

Five distinct experimental diets were meticulously formulated to evaluate the effect of partially replacing fish meal (FM) with roasted guar korma meal (RGKM) on *P. vannamei*. The diets were defined as T₁ (Control, 100% FM protein), T₂ (75% FM protein, 25% RGKM protein), T₃ (50% FM protein, 50%RGKM protein), T₄ (25% FM protein, 75% RGKM protein), and T₅ (100% RGKM protein), with the protein content of all diets consistently maintained at 35%. Ingredients, including sterile A-grade FM, procured RGKM (cleaned and powdered), wheat flour, tapioca powder, sunflower oil, and fish oil, were characterized by their proximate composition before diet preparation (Table 1). Diets were formulated using the Pearson Square method (Table 2). Initially, feeding was conducted at a rate of 5% of the shrimp body weight; however, after the first 10 days, the daily ration was adjusted and fed to apparent satiation until the experiment's conclusion, aligning with protocols like those described by Catarino *et al.* (2019) [7]. The total daily ration was manually distributed in three equal parts at 08:00, 14:00, and 20:00 hours.

2.3 Growth parameter

Growth performance, feed efficiency, and survival of *P. vannamei* were meticulously assessed throughout the 60-day experimental period. To determine body weight, a

subsample of 20 shrimp from each tank was collected at 15-day intervals after an overnight starvation period. Individual weights were recorded using an electronic balance and a water-filled glass beaker to minimize handling stress. Growth parameters were subsequently calculated using established formulas: Mean weight increment was determined by subtracting the initial average body weight from the final average body weight. The specific growth rate (SGR), expressed as a percentage per day, was calculated according to El-Sayed (1999) [8] using the formula:

Mean weight increment = Final average body weight-Initial average body weight

2.3.1. Specific Growth Rate (SGR)

Specific growth rate (specific growth rate) is a way of measuring how fast the cells of the body of *P. vannamei* were dividing during a culture period. SGR as a percentage was calculated according to El-Sayed (1999) [8] by using the formula given below.

$$\text{SGR (\%/day)} = \frac{\text{Loge } W_2 - \text{Loge } W_1}{T} \times 100$$

Where, T = experiment period, W₂ = final weight, W₁ = initial weight.

2.3.2. Feed Conversion Ratio (FCR)

Feed conversion ratio is the mass of the food eaten divided by the body mass gain, all over a specified period of time. The FCR (Food Conversion Ratio) was calculated according to El-Sayed (1999) [8] using following formula:

$$\text{FCR} = \frac{\text{Feed intake (g)}}{\text{Weight gain (g)}}$$

2.3.3. Protein efficiency ratio (PER)

Protein efficiency ratio is way to a measure how much of protein utilized for converted into the body of experimental shrimp during culture period. PER (Protein efficiency ratio) was calculated according to El-Sayed (1999) [8] using the formula given below.

$$\text{PER} = \frac{\text{Weight gain (g)}}{\text{Protein intake (g)}}$$

2.4 Survival

To determine the survival of *P. vannamei* in each aquarium, daily observation was made and dead animals were removed from each aquarium and their number were recorded. The Survival of *P. vannamei* as percentage was calculated using the formula given below.

$$\text{Survival rate (\%)} = \frac{\text{No. of shrimp survived after rearing}}{\text{No. of shrimp stocked}} \times 100$$

2.4 Analysis of Water Quality Parameters

Water quality parameter such as temperature, pH, dissolved oxygen, and alkalinity was checked at a weekly interval

throughout the experimental period. The pH and temperature were measured by a pH meter, pH indicator solution (universal indicator), and mercury thermometer, respectively. Dissolved oxygen and alkalinity were measured using Wrinkles' method and the EDTA method, respectively.

2.6 Proximate Analysis of Shrimp Carcass

The proximate composition of shrimp was estimated just after completion of the experiment. The whole meat of the shrimp was taken for proximate analysis. The shrimp meat was minced properly. The samples were analyzed for crude protein, crude fat, ash, and moisture employing standard methods.

2.7 Statistical analysis

Statistical analysis was carried out by using two factor CRD (Completely Randomized Design) experimental designs with five treatments and four replications (Snedecor and Cochran, 1967) [20].

3. Results

3.1 Growth parameters

The evaluation of the effect of partial fish meal (FM) replacement with roasted guar korma meal (RGKM) on the Specific Growth Rate (SGR) of *P. vannamei* revealed a significant impact of dietary substitution (Figure 2). Overall, the study demonstrated an inverse relationship between the level of RGKM protein incorporation and SGR, where increasing replacement generally led to a reduction in SGR. However, the treatment incorporating 75% FM protein and 25% RGKM protein (T₂) unexpectedly yielded the highest SGR (2.46%/day), surpassing even the control diet (T₁, 2.41%/day). Following the T₂ treatment, the descending order of SGR was T₃ (50% RGKM, 2.42%/day), T₁ (Control, 0% RGKM, 2.41%/day), T₄ (75% RGKM, 2.38%/day), and the lowest SGR was observed in the 100% RGKM replacement diet (T₅, 2.36%/day) (Table 3). Statistical analysis confirmed a significant difference ($p < 0.05$) among the dietary treatments. The superior SGR observed in the 25% RGKM replacement diet suggests that this specific level of substitution has a beneficial, enhancing effect on the growth performance of *P. vannamei* relative to the un-substituted control, while higher inclusion levels beyond 25% consistently depressed growth metrics.

3.2 Survival rate and feed conversion ratio (FCR) analysis

The assessment of survival rate in *P. vannamei* across the 60-day trial indicated robust conditions and dietary compatibility, as evidenced by high survival across all groups. The highest Survival Rate (100%) was achieved in both the control diet (T₁) and the 75% roasted guar korma meal (RGKM) replacement diet (T₄), with no mortality recorded. Treatments T₂ (25% RGKM) and T₃ (50% RGKM) maintained a high survival rate of 98.75%, while the 100% RGKM replacement diet (T₅) recorded the lowest, though still high, survival rate of 96.25%. These results strongly suggest that the environmental parameters were well-suited and that none of the experimental diets induced serious nutritional deficiencies or toxicities (Table 3 and Figure 2).

Concurrently, the feed conversion ratio (FCR) demonstrated significant variation among treatments. The lowest FCR,

indicating the most efficient feed utilization, was recorded in the 25% RGKM replacement diet (T₂) at 1.32. This efficiency was statistically superior to all other groups. Following T₂, the FCR values for the remaining treatments were: T₃ (50% RGKM) at 1.44, T₁ (Control) at 1.44, T₄ (75% RGKM) at 1.48 and the highest FCR was observed in the 100% RGKM replacement diet (T₅) at 1.62. Statistical analysis confirmed significant differences ($p < 0.05$) in FCR among treatments, with the optimal feed efficiency observed at the 25% RGKM inclusion level (Table 3).

3.3 Protein efficiency ratio (PER)

The Protein Efficiency Ratio (PER) of *P. vannamei* in different treatments is presented in Table 3. Higher PER was observed in Treatment T₂ (2.17 ± 0.075^a), followed by treatment T₃ (2.06 ± 0.044^{ab}), T₁ (1.99 ± 0.077^b), T₄ (1.92 ± 0.026^{bc}), and T₅ (1.76 ± 0.043^c). Statistical analysis showed that there is a significant difference ($p < 0.05$) among treatments.

3.4 Water quality parameters

Throughout the experimental period, the physico-chemical parameters of the culture water were consistently maintained within the ideal ranges required for the optimal health and growth of *P. vannamei*. Specifically, the temperature ranged from 20.5 to 26.8 °C, and the pH was stable between 7.9 and 8.2. Dissolved Oxygen (DO) levels were maintained between 6.79 and 6.90 ppm. Critical nitrogenous compounds were kept at low, non-toxic concentrations, with ammonia ranging from 0.064 to 0.075 ppm, nitrite from 0.13 to 0.15 ppm, and nitrate from 1.74 to 1.95 ppm. Furthermore, the alkalinity was recorded between 141.76 and 158.76 ppm. These consistent values confirm that water quality was not a limiting factor and ensured a stable environment, allowing for a reliable assessment of the experimental diets.

3.5 Proximate analysis of the shrimp carcass

The data for proximate analysis of biochemical composition after the experiment (dry weight basis) are given in Table 4. The protein content was significantly highest (19.21%) in T₂ compared to other treatments. The fat content was significantly highest (2.08%) in T₃. The ash content was significantly highest (1.4%) in T₁. The moisture content was found to be the highest (73%) in T₂ compared to the other treatments.

4. Discussion

The present study investigated the effects of replacing fish meal (FM) protein with roasted guar korma meal (RGKM) on growth performance, survival, feed utilization, protein efficiency, and carcass composition of *Penaeus vannamei*. The results show that RGKM can be effectively included at moderate levels, while excessive amounts negatively impact shrimp performance.

Specific growth rate (SGR) was significantly affected by dietary treatment, with an overall decline as RGKM inclusion increased. Similar reductions in growth with higher plant protein replacement levels have been reported by Kalanjiam *et al.* (2014) [13], Yadollahi *et al.* (2018) [24], Ahmed (2018) [1], and Khava (2020) [14]. Notably, the diet containing 25% RGKM protein (T₂) yielded the highest SGR, surpassing the control diet. This suggests that partial FM replacement at an optimal level may enhance growth,

possibly due to improved protein utilization or dietary balance. Yang *et al.* (2015) [25] also reported decreased growth in *P. vannamei* when FM replacement exceeded 30%, supporting the observed threshold effect.

Survival rates remained high (>96%) across all treatments, indicating that RGKM inclusion did not cause adverse physiological effects or nutritional deficiencies. The lack of significant mortality suggests that the experimental diets and culture conditions were appropriate, consistent with the findings of Khava (2020) [14].

Feed conversion ratio (FCR) varied significantly among treatments and followed growth trends. The lowest FCR was observed in T₂, indicating better feed efficiency at 25% RGKM inclusion. Conversely, FCR increased with higher RGKM levels, with the poorest feed efficiency recorded in the 100% replacement diet. This decline may be due to reduced digestibility, amino acid imbalance, or residual anti-nutritional factors in RGKM, as previously reported by Yadollahi *et al.* (2018) [24] and Ahmed (2018) [11].

Protein efficiency ratio (PER) was highest in T₂ and decreased progressively with greater RGKM inclusion, reflecting reduced protein utilization efficiency at higher levels of substitution. Similar patterns have been observed in crustaceans and finfish fed high levels of plant protein (Capuzzo, 1983; Mazid *et al.*, 1997; Khava, 2020) [6, 16, 14], emphasizing the importance of protein quality and digestibility.

Overall, this study indicates that RGKM can replace up to 25% of FM protein in *P. vannamei* diets without affecting

growth, survival, or feed efficiency. However, higher inclusion levels negatively impact growth performance and protein utilization, underscoring the need to optimize inclusion levels when developing sustainable shrimp feeds. Throughout the study, all measured physicochemical water quality parameters remained within the optimal ranges recommended for *P. vannamei*, indicating that culture conditions were well maintained.

Table 1: Proximate composition of ingredients

Ingredients (%)	Crude Protein (%)	Crude Fat (%)	Ash (%)	Moisture (%)
Fishmeal	69	11.30	19.51	6.5
Roasted guar korma meal	53	6.65	5.22	5.3
Wheat flour	8.4	2.14	1.5	11.32

Table 2: Composition of experimental diets

Ingredient (%)	Diets (35% Protein)				
	T ₁ (Control)	T ₂ (25%)	T ₃ (50%)	T ₄ (75%)	T ₅ (100%)
Sterilized Fishmeal	65	48	32	17	0
Roasted guar korma meal	0	18	34	51	69
Wheat flour	12	12	12	11	11
Tapioca powder	17	16	16	15	14
Fish oil	2	2	2	2	2
Plant oil	2	2	2	2	2
Vitamin and minerals	2	2	2	2	2
Total	100	100	100	100	100

Table 3: Growth parameters and Survival rate of various treatments at the end of the experiment

Parameters	Treatments				
	T ₁ (C)	T ₂	T ₃	T ₄	T ₅
Mean weight gain (gm.)	0.857±0.060 ^{bc}	0.993±0.027 ^a	0.880±0.026 ^{ab}	0.787±0.049 ^{bc}	0.739±0.022 ^c
Specific growth rate (%)	2.41±0.023 ^{abc}	2.46±0.010 ^a	2.42±0.011 ^{ab}	2.38±0.020 ^{bc}	2.36±0.010 ^c
Feed conversion ratio	1.44±0.059 ^{bc}	1.32±0.046 ^c	1.44±0.027 ^{bc}	1.48±0.019 ^b	1.62±0.041 ^a
Protein efficiency ratio	1.99±0.077 ^b	2.17±0.075 ^a	2.06±0.044 ^{ab}	1.92±0.026 ^{bc}	1.76±0.043 ^c
Survival rate (%)	100±0.00 ^a	98.75±1.25 ^{ab}	98.75±1.25 ^{ab}	100±0.00 ^a	96.25±1.25 ^b

Table 4: Proximate analysis of body composition of shrimp (Wet weight basis)

Treatments	Protein %	Fat %	Ash %	Moisture %
T ₁ (Control)	18.82	1.95	1.4	70.0
T ₂	19.21	2.01	1.1	73.0
T ₃	19.01	2.08	1.2	71.3
T ₄	18.43	1.50	1.3	71.1
T ₅	17.81	1.75	1.2	69.2

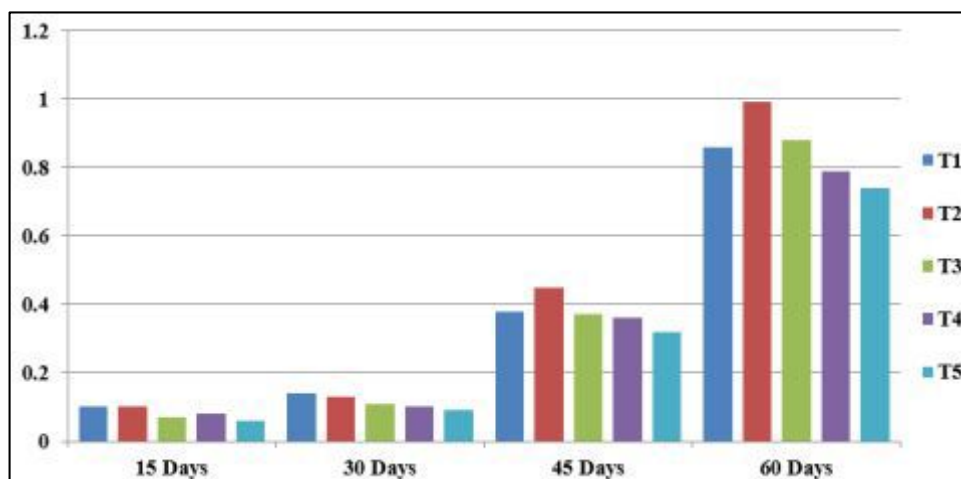


Fig 1: Mean weight gain (g) of *P. vannamei* recorded in various treatments during the culture period

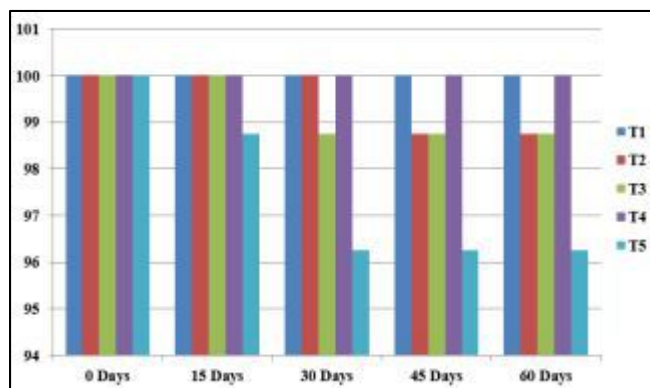


Fig 2: Survival (%) of *P. vannamei* recorded in various treatments during the culture period

5. Conclusion

The 60-day feeding trial clearly demonstrated that the partial substitution of fish meal (FM) with roasted guar korma meal (RGKM) significantly influences the growth performance and feed efficiency of *Penaeus vannamei*. Based on the comprehensive analysis of the results, it is concluded that Treatment T₂, formulated with a 25% replacement of FM protein by RGKM protein (i.e., 75% FM protein and 25% RGKM protein), was superior across key performance indicators, recording the significantly highest weight gain, Specific Growth Rate (SGR), and Protein Efficiency Ratio (PER), alongside the significantly lowest Feed Conversion Ratio (FCR). Although the highest survival rate (100%) was achieved in the control (T₁) and 75% RGKM replacement (T₄) diets, the overall growth and feed utilization benefits of T₂ establish it as the optimal dietary formulation evaluated in this study for enhancing the production efficiency of *P. vannamei*.

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