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Replacement of fish meal with co-extruded wet tuna viscera and corn meal in diets for white shrimp (*Litopenaeus vannamei* Boone)

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Abstract

A feeding trial was conducted to evaluate the potential of replacing fish meal with co-extruded wet tuna viscera and corn meal in diets for juvenile white shrimp *Litopenaeus vannamei*. Five practical diets were formulated to contain 30% crude protein and 16.6 kJ g^{-1}. The feeding experiment was carried out in a recirculating seawater system with fifteen 25-L tanks with 15 shrimp per tank. Each dietary treatment was fed in triplicate in a completely randomized design for 41 days. Percent weight gain (WG%), survival (S%) and feed conversion ratio (FCR) were calculated, comparisons of these parameters showed no statistical differences ($P > 0.05$) among treatments. The shrimp almost tripled their weight during the feeding trial. Under the experimental conditions S%, WG% and FCR were either improved or were not significantly influenced by the replacement of fish meal with double co-extruded viscera+corn, except for a slight increase in feed consumption without affecting FCR. Hence, this product can be included by up to 40% in practical shrimp diets without any detrimental effects.

Keywords: *Litopenaeus vannamei*, extrusion processing, fish meal, marine by-products

Introduction

Fish meals are important in animal husbandry, including aquaculture, providing dietary protein with desirable essential amino acid profiles. The industry is looking to reduce the use of fish meal in aquaculture diets by partial substitution with alternative animal and vegetable proteins (Kaushik 1989; Cruz-Suarez, Ricque-Marie, Martinez-Vega & Wesche-Ebeling 1993; Higgs, Dosanjg, Prendergast, Beames, Hardy, Riley & Deacon 1995). Technological advances have made it possible to recycle fisheries waste products into acceptable protein supplements for the animal feed industry. Annual Mexican tuna landings are approximately 130 000 MT, 52–54% of which is discarded as waste or by-products including heads, fins, skin, black meat and viscera. These by-products are often processed into low-quality fish meal. According to data from the tuna canning industry, 5–6% of its wastes are viscera (Moroyoqui-Buitimea 1998). These wastes can be recycled into valuable protein through the extrusion process that makes the utilization of raw material more efficient (Dominy & Lim 1991). Further, wet marine by-products can also be used to enhance the quality of plant protein as a feed ingredient for diet of aquatic animals. Therefore, these by-products should be considered valuable commodities that processing turns into high-quality animal feed ingredients. This would reduce the cost of animal feeds and at the same time alleviate environmental concerns relative to the disposal of this waste product (Robinson, Miller & Vergara 1985; Botting 1991; Dominy & Lim 1991; Kiang 1994). Corn is a low-cost grain and a rich source of sulphur containing amino acids (NRC (National Research Council) 1993), which may complement the amino acid profile of tuna viscera. This combination may be a good option for partial or possibly complete substitution of fish meal. Starches are low-cost sources of dietary energy, generally well utilized by shrimp (Cruz-Suárez, Ricque-Marie, Pinal-Mansilla & Wesche-Ebeling 1994), and thermal processing to gelatinize starch increases its digestibility in diets fed to *Litopenaeus vannamei* (Davis & Arnold 1993). However, the conditions of dry extrusion have been shown to affect the energy digestibility coefficients of cereal grains, especially of whole corn flour (Davis & Arnold 1995). The purposes of the present study were to compare the weight gain (WG), feed conversion ratio (FCR) and survival of shrimp fed diets in which fish meal was partially replaced by a mixture of extrusion-cooked plant and animal proteins and to evaluate the feasibility of the use of by-products prepared by extrusion for aquaculture feeds.

Materials and methods

Experimental ingredients and diet

The co-extruded meals and diets were prepared and analysed in the facilities of the Aquaculture and Environmental Unit of the Food and Development Research Center, Mazatlán, Sinaloa, México. The single co-extrude (SCVC) obtained from a 35:65 (wet basis weight) mixture of tuna viscera and whole corn flour was ground and used to obtain the double co-extrude (DCVC), consisting of a 35:65 (wet basis) mixture of the single co-extrude and tuna viscera respectively. Both mixtures were blended to obtain a pre-extrusion moisture content between 28% and 30%. The moisture content of 28.3 $\pm$ 0.5 gave adequate processing temperatures. The data obtained on the chemical composition of the original components and on the two extrudes are given in Table 1 and those of the double co-extrude were used as a basis for the formulation of the five experimental practical diets containing increasing levels of double extrude. Fish meal and soybean meal were the main protein sources of the control diet (D1), and the other four diets (D2, D3, D4 and D5) contained 10%, 20%, 30% and 40% protein from DCVC. Fat and carbohydrate contents of the diets were manipulated so that all were approximately isocaloric (16.6 kJ g^{-1}) and isonitrogenous, and formulated to provide 30% crude protein, reported to be the optimal level for *L. vannamei* shrimp postlarvae (Colvin & Brand 1977). The ingredients and the composition of the experimental diets are summarized in Table 2. The diets were prepared by thoroughly mixing the ingredients with cold water and a cold binder, and the resulting paste was pelletized in a meat grinder Tor-rey (Mod 22, Monterrey, México)

Table 1 Composition of basal ingredients and single and double processed co-extrudes*

Nutrient	Corn flour†	Tuna viscera‡	SCVC	DCVC
Moisture	12.73	77.61	11.29	12.23
Crude protein	7.17	70.57	15.82	23.33
Ether extract	5.49	5.84	1.28	1.80
Crude fiber	3.55	0.49	2.58	2.51
Ash	1.46	8.78	2.01	2.83

*Result are percentages, expressed on a dry matter basis.
†Made from whole grain.
‡Tuna viscera, Pinsa S.A de C.V., Mazatlán, México.
SCVC, single co-extruded viscera+corn; DCVC, double co-extruded viscera+corn.

Table 2 Formulation and proximate composition of experimental diets* (%)

Ingredients	D1	D2	D3	D4	D5
Fishmeal†	38.16	33.39	28.62	23.85	19.08
DCVC‡	0.00	12.83	25.65	38.48	51.30
Soybean meal§	12.66	12.66	12.66	12.66	12.66
Fish oil¶	1.91	2.52	3.08	3.69	4.30
Soybean oil	1.91	2.52	3.08	3.69	4.30
Starch	37.17	27.89	18.71	9.44	0.16
Binder (Na alginate)¶	2.00	2.00	2.00	2.00	2.00
Lecithin¶	0.50	0.50	0.50	0.50	0.50
Vitamin premix‖	2.00	2.00	2.00	2.00	2.00
Mineral premix‖	3.00	3.00	3.00	3.00	3.00
Vitamin C‖	0.20	0.20	0.20	0.20	0.20
Cholesterol**	0.50	0.50	0.50	0.50	0.50
Percent fishmeal replaced by DCVC	0	10	20	30	40
Nutrients	Proximate composition (% basis dry)				
Moisture (%)	7.2	7.65	7.73	7.58	6.49
Crude protein (%)	33.41	32.75	31.45	30.7	30.74
GE (kJ g^{-1})††	17.37	18.54	18.66	18.73	19.17
Ether extract	6.93	9.46	10.12	11.30	12.08
NFE‡‡	50.24	48.81	49.87	51.57	48.08
Ash	9.42	8.98	8.56	9.57	9.09

*D1, control diet.
†Harinas y Aceites de Occidente, S.A., Mazatlán, México.
‡Double coextrude made with tuna viscera, and corn meal obtained from the local Mexican supplier.
§Solvent extracted, commercially available.
¶Drogueria Cosmopolita, S.A de C.V., México, D. F.
‖MaltaCleyton Cía, Culiacán, Sinaloa, Mexico.
**Sigma Chemicals, St Louis, MO, USA.
††Gross energy calculate based on 23.67, 17.77 and 39.79 kJ g^{-1} protein, carbohydrate and fat respectively (Aksnes, Hjetnes & Opstvedt 1996).
‡‡Nitrogen-free extract (calculated by difference).

equipped with a 1.6-mm diameter die. The pellets were dried in a forced air oven for 24 h at 40 °C, ground manually in a mortar, sieved to a particle size of 700–1000 μm and stored at − 4 °C until use.

Extrusion process

The extrusion-cooked mixture of whole corn flour plus wet tuna viscera was carried out using a single screw extruder, Model 600 JR, INSTA-PRO® (Insta Pro, Des Moines, IA, USA), set up with a steam lock configuration of 600–10, 600–08, 600–08, 600–08, single flight screws and a 0.79-cm nose cone. The extruder was heated with whole soybeans to obtain a starting temperature of 110–120 °C prior to running the co-extrusion mixes.

Analytical methods

The ingredients and diets were analysed for N content using Kjeldhal analysis with a Kjeltec 1030 analyser (Foss Tecator AB, Höganäs, Sweden), an automatic distillation/titration unit, and their crude protein content was calculated as N × 6.25. The total lipid content was determined using soxhlet extraction with petroleum ether for 6 h following the procedure of Association of Official Analytical Chemist (AOAC) (1984). Ash was obtained by incinerating the samples in a muffle furnace at 550 °C for 12 h, and dry matter was determined by drying the sample in an oven at 105 °C for 16 h and weighing it to the nearest 0.1 mg. In each case, determinations were done in triplicate.

Experimental design

The feeding experiment was carried out in a recirculating seawater system with fifteen 25-L circular plastic tanks containing 15 shrimp each with an initial mean weight of 148–162 mg. A similar weight distribution pattern in each tank was achieved by allocating the shrimp according to their individual weight. Each rearing tank was supplied with aerated seawater, flowing at a rate of 1.5 L min^{-1}, and the shrimp were subjected to continuous artificial lighting. Water temperature was 28 ± 0.5 °C, dissolved oxygen ranged between 7.0 and 8.0 mg L^{-1} and salinity was 34 ± 1 mg L^{-1}. Each of the five test diets was randomly assigned to triplicate groups of shrimp and all groups were fed their respective diet to visual satiety five times daily at 2-h intervals, during 41 days. The shrimp were weighed at 14, 28 and 41 days to obtain mean body weights for each tank. The response variables were determined following the methods described by Cruz-Suárez, Ricque-Marie, Tapia-Salazar, McCallum and Hickling (2001) for each experimental tank: mean body weight; WG% = 100 × (final weight − initial weight)/(initial weight); dry food intake (DFI) for shrimp was estimated from the sum average daily food intake for each tank using DFI = $\sum_i^{41}$[(intake on *i*th day)/(number of shrimp on *i*th day)]; FCR = (food intake per shrimp)/(average WG per shrimp); survival (S%) = 100 × (final count)/(initial count).

Statistical methods

All data were subjected to one-way analysis of variance to test the effect of experimental diets (Steel & Torrie 1960). Before conducting ANOVA all of the data were tested for normality and heterogeneity of variances (Cochrans test). Data were considered significant at the 0.05 level. Statistical analyses were performed using the STATISTICA (1996) software.

Results

Proximate analysis of experimental ingredients and co-extrudes are given in Table 1. Values for ether extract, crude fibre and ash were similar in both co-extrudes, SCVC and DCVC. Although, the diets were formulated to be isocaloric and isonitrogenous, proximate analysis revealed differences in the ether extract, protein and ash values (Table 2). The growth response is shown in Fig. 1. There were no significant differences ($P > 0.05$) among average final body

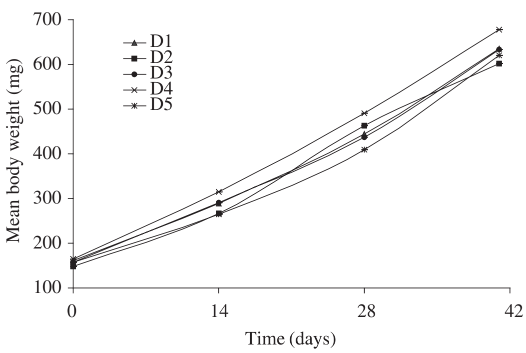

Figure 1 Growth response of shrimp *Litopenaeus vannamei* fed the experimental diets.

Table 3 Response of shrimp *Litopenaeus vannamei*, over a 41-day feeding trial*, to five experimental diets containing graded replacement levels of DCVC

	Experimental diets				
	D1	D2	D3	D4	D5
	% DCVC				
Parameter observed	0	10	20	30	40
Initial weight (mg)	162.0 ± 0.005	148.0 ± 0.016	158.0 ± 0.003	165.0 ± 0.010	158.0 ± 0.008
Final weight (mg)	635.2 ± 0.050	601.0 ± 0.054	634.0 ± 0.307	678.1 ± 0.050	620.5 ± 0.45
Weight gain (%)	292.37 ± 41.16	304.42 ± 9.97	299.39 ± 26.64	310.54 ± 28.08	292.81 ± 41.80
FCR	1.70 ± 0.07	2.22 ± 0.37	1.93 ± 0.071	1.89 ± 0.087	1.85 ± 0.181
Survival (%)	89 ± 3.84	78 ± 16.77	82 ± 10.18	82 ± 7.69	89 ± 3.84
Dry feed intake (mg)	806.41 ± 0.068	1000 ± 0.214	918.26 ± 0.06	970.7 ± 0.042	851.7 ± 0.005

*Means of three replicates ± SD.
DCVC, double co-extruded tuna viscera and corn; FCR, feed conversion ratio; SD, standard deviation.

weight for the different dietary treatments. Average final body weight was highest for diet 4 (30% replacement). Feed performances are shown in Table 3. The shrimp accepted the experimental diets and fed actively for the duration of the experiment. The feed intake was higher for shrimp fed with DCVC replacement diets while the control group showed the lowest intake. A high conversion ratio between 1.7 and 2.2 was obtained, for all treatments, indicating excellent digestibility as well as palatability of all diets. Moreover, there were no significant differences ($P > 0.05$) among WG for the different treatments. The shrimp almost tripled their weight in all groups during the test period of 41 days. Survival rates of shrimp ranged between 78% and 89% and did not differ significantly among the different dietary treatments.

Discussion

Our results show that in a shrimp diet co-extruded tuna viscera and corn flour have a nutritional value similar to fish meal and starch, providing the adequate levels of protein and energy. Robinson and colleagues (1985) found diets with either soybean meal or fish meal as the sole protein source less successful than diets containing mixes of different protein sources. Cruz-Suárez and colleagues (2001) stated that when alternate ingredients are used to make diets containing the same concentration of digestible energy and digestible protein meeting nutrimental requirements, similar performances can be expected while Sudaryono, Hoxey, Kailis and Evans (1995) reported that the optimal growth for shrimp was not only influenced by dietary protein level but was also affected by dietary protein source. Within the conditions of this experiment, co-extrusion processing of tuna viscera and corn flour produced an acceptable feed ingredient to replace up to 40% of the fish meal protein allowing growth rates similar to those exhibited by the fish meal and soybean meal-based control diet. Deshimaru and Kuroki (1974) reported that lipid levels in excess of 12% suppressed growth of penaeid shrimp. In the present study, the lipid levels of 11.3% and 12.08% in diets 4 and 5, respectively, had no adverse affects. Additionally, there were no indications of the feed being rejected or that high levels of either test ingredient resulted in a decrease in palatability. Successful results with dry extrusion-cooked protein mixes have been observed by Carver, Akiyama and Dominy (1989) and Davis and Arnold (2000). Dominy and Lim (1991) reported that a fresh wet squid viscera by-product mixed with soybean meal showed an increase in shrimp performance. Although the tested products generally cost less than high-quality fish meal, the cost effectiveness of substituting these products for fish meal will vary depending on the location and cost of the ingredients. Tuna by-product can vary considerably in quality. Further studies are recommended to evaluate other by-products from the canning industry and by-products from the other industries for the partial or complete replacement of fish meal in *L. vannamei* diets.

Conclusion

Tuna by-products used in this study, when properly processed, can be a good source of high-quality protein for partial replacement of fish meal in shrimp diets, without any adverse effect on the growth and survival of white shrimp. The extrusion process is an alternative disposal method for converting tuna industry waste into a high-quality ingredient.

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