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White Worms – A Low Cost Live Feed for the Ornamental Industry

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What are white worms?

White worms (*Enchytraeus albidus*) are small (2-4 cm TL adult size) oligochaete worms that are easily grown in terrestrial systems (see NRAC Fact Sheet No. 223-2017), but can survive in both fresh and full-strength seawater, wriggle and attract predators, and do not impair water quality when added to aquaculture systems, making them ideal live feeds for cultured aquatic species. White worms show great promise as a live feed for a diverse set of cultured organisms during some period of their development, including freshwater and marine fishes, as well as some crustaceans, amphibians, reptiles, and birds. We believe white worms could be especially beneficial to the growing ornamental industry since there is a limited variety of small live feeds currently available and many of the "new" or emerging ornamental species readily consume white worms.

Key Findings

- White worms show potential as a live feed in intensive aquaculture systems, especially with ornamental fishes.
- White worms meet the needs of species that demand high protein, high lipid, low ash food items.
- White worms provide comparable amounts of EPA to other live feeds, but substantially less DHA.
- Enhancement of DHA in live white worm composition is possible and enriching worm feed with salmon oil is a cost-effective method to increase DHA levels.

Aquaculture industry feedback

To gauge the interest of the aquaculture industry and the utility of white worms as a live feed, we distributed almost 250,000 white worms *gratis* to 18 different in the US in exchange for feedback on their experiences using the worms.

The majority (83%) of testers worked in academic, research, or government facilities. The commercial entities that tested white worms grew ornamental species only. White worms were offered to 31 marine and freshwater fish species, plus three bird species in a public aquarium exhibit (Table 1). The majority (58%) of fishes were ornamentals.

Table 1. *Organisms fed white worms and their responsiveness after initial and repeated exposure to white worms, and generalized consumption of worms relative to the organisms' standard feeds.*

Target Species					Feeding Response Compared to Standard Feed		
	Scientific Name	Common Name	Life Stage	Size	After First Time	After Multiple Times	Total Amount Eaten
Ornamental Fishes	*Pethia conchonius*	Rosy Barb	juvenile/adult	2-3 cm	=	=	=
	Zebrasoma scopas	Scopus ang	adult	15-20 cm	↑	↑	↑
	Epalzeorhynchos frenatum	Rainbow Shark	fry	1 mm	=	=	=
	Amphiprion percula	Picasso Clownfish	adult	10-15 cm	=	=	↑
	Cirrhitidae	Hawkfish	adult	15-20 cm	=	=	↑
	Amphiprion ocellaris	Ocellaris Clownfish	juvenile/adult	1-8 cm	↑	↑	↑
	Amphiprion frenatus	Tomato Clownfish	juvenile/adult	1-8 cm	↑	↑	↑
	Premnas biaculeatus	Maroon Clownfish	juvenile/adult	1-10 cm	↑	↑	↑
	Pseudochromis fridmani	Orchid Dottyback	adult	6-8 cm	=	=	=
	Holacanthus tricolor	Rock Beauty Angelfish	adult	10-12 cm	=	=	=
	Halichoeres chrysus	Yellow Coris Wrasse	adult	6-8 cm	↑	↑	↑
	Poecilia latipinna	Sailfin Molly	adult	6-8 cm	↑	↑	↑
	Ecsenius bicolor	Bicolor Blenny	adult	6-8 cm	↑	↑	↑
	Betta spp.	Betta	adult	6-8 cm	↑	↑	↑
	Gambusia affinis	Mosquitofish	adult	6-8 cm	↑	↑	↑
	Cyprinodontiformes	Killifish	adult	6-8 cm	↑	↑	↑
	Hippocampus erectus	Lined Seahorse	adult	8-10 cm	↓	↓	↓
	Genicanthus bellus	Bellus Angelfish	adult	12 cm	=	=	↓
Other Fishes	*Acipenser fulvescens*	Lake Sturgeon	juvenile	8-13 cm	↑	↑	=
	Anoplopoma fimbria	Sablefish	early juvenile	0.5 g	↓	=	=
	Lutjanus campechanus	Northern Red Snapper	juvenile	8-13 cm	↓	=	=
	Sciaenops ocellatus	Red Drum	early juvenile	2 g	=	↑	↑
	Microgadus tomcod	Atlantic Tomcod	juvenile	8 cm	↓	↓	↓
	Sander vitreus	Walleye	fingerling	4-8 cm	↓	↓	↓
	Cyprinus carpio	Koi	adult	38-46 cm	↓	↓	↓
	Percina caprodes	Logperch	adult	10 cm	↑	=	=
	Paralichthys lethostigma	Southern Flounder	juvenile	1.5-20 cm	↓	=	=
	Oreochromis niloticus	Nile Tilapia	juvenile	3-8 cm	=	=	↑
	Menidia menidia	Atlantic Silverside	juvenile	5 cm	=	=	=
	Scaphirhynchus albus	Pallid Sturgeon	juvenile	8-13 cm	↑	↑	↓
	Pseudopleuronectes americanus	Winter Flounder	juvenile	6 cm	=	=	=
Birds	*Calidris alba*	Sanderling	adult	49-55 g	=	=	=
	Calidris minutilla	Least Sandpiper	adult	20-25 g	=	=	=
	Calidris pusilla	Semipalmated Sandpiper	adult	20-30 g	=	=	=

All target species ate the worms, however, for some species (e.g., Sablefish, Northern Red Snapper, Southern Flounder), repeated offerings of white worms were necessary to elicit a normal feeding response (Table 1). There were a few species (e.g.: Lined Seahorse, Atlantic Tomcod, Walleye, Koi) that did not eat as much as they typically did, even after repeated feedings of white worms. The majority of target species consumed white worms with the same intensity as they exhibit when offered their standard feeds (41%) or had a stronger feeding response to the white worms (35%). This latter group included sturgeons and ornamental fishes, specifically tang, clownfishes, wrasse, molly, blenny, betta, mosquitofish, and killifish (Table 1).

Most participants (56%) found using live white worms to be logistically on par with their current feed sources, or even easier to store and distribute (31%) than their standard feeds. All participants reported that there was no change in the water quality of the culture tanks from using live white worms.

Based on stakeholder input and the promising results of feeding white worms to ornamental fish, the best potential for using white worms is as a diet (live or possibly otherwise) for ornamental fishes. Ornamental culture is a growing sector in the aquaculture industry, valued at close to $30 million annually in Florida. While protocols have been established to rear many of the 'typical' aquaria fishes like damsels, dottybacks, gobies, and blennies, there is a strong market demand for production of other fishes like tangs, wrasses, and butterflyfish; for many of these latter species, feeding regimens have yet to be worked out. Judging from our experiences with live white worms, white worms may help with expanding the opportunities to culture these trickier species. Given that possibility, we asked the ornamental industry what they wanted nutritionally in a feed; the unanimous response was a live feed high in essential fatty acids, such as EPA and DHA.

Nutritional profile of white worms

White worms will eat almost anything, and this dietary flexibility is a main advantage to culturing them. However, what they consume can affect their proximate composition, fatty acid profile, and nutritional value. We examined white worm potential as "local recyclers" by testing five feeds (coffee grounds, spent brewing grains, stale breads, produce, and sugar kelp grown at UNH). In general, white worm cultures fed coffee grounds, stale bread, and spent brewing grains had higher production yields than cultures fed mixed produce or sugar kelp. Dependent on feeds, white worms were high in protein (49-69%) and lipids (10-27%), and low in ash (5-8%). Compared to fatty acid profiles reported for standard live feeds like enriched rotifers and *Artemia*, and copepods, white worms provided less n-3 long-chain polyunsaturated fatty acid content (DHA 0-0.5%, EPA 2-18%, total LC-PUFAs 4-25%).

Enriching white worms

White worms can be offered feed enrichments to augment their fatty acid content, and in particular, elevate their DHA levels. However, the degree of enrichment depends on the type of supplement used, as well as how much is used and the timing of supplementation. We evaluated the effects of five different easily available supplements added to spent brewing grains to see if white worm essential fatty acid content could be improved. The supplements included instant algae, salmon oil, flax oil, flaxseed meal, and wheat bran. We found that DHA levels are highest when the worms are harvested 10-12 hours after feeding the enrichment. Different supplements (Table 2) and different dosages (Table 3) yield different changes to the worms' fatty acid profile.

Table 2. *Characteristics of products tested as enrichments to white worm feed (spent brewing grains) and the resulting effects to white worm EPA and DHA.*

Enrichment Treatment	Dose Amount	Worm Sample EPA* (% dry matter)	Worm Sample DHA* (% dry matter)	Shelf Life (months)	Bulk Amount	Total Doses	Total Factor Cost	Unit Cost	Average Product Cost per Unit of Increased EPA	Average Product Cost per Unit of Increased DHA
Instant algae	75 mL	0.28b	0.22a	4	0.95 L	12.7	$56.15	$4.42	$7.02	$2.55
Salmon oil	75 mL (33.5 g)	0.48a	0.23a	4-10	907 g	27.1	$21.00	$0.77	$0.75	$0.91
Flax oil	75 mL	0.20b	0.01b	12	3.8 L	50.7	$38.00	$0.75	n/a	$0.03
Flaxseed meal	113 g (1 cup)	0.23b	0.00b	6	453 g	4.0	$3.39	$0.85	n/a	$38.00
Wheat bran	55.5 g (1 cup)	0.25b	0.00b	12	227 g	4.1	$1.69	$0.41	$1.13	n/a
Grains	0 mL	0.20b	0.00b	n/a	n/a		$0	$0		

*Differing letters within a column denote significant differences ($p<0.05$) between enrichments.

Because the costs of the supplements varied, it was useful to calculate the average product cost to see how much each supplement cost per unit increase of nutrient concentration in white worms. Wheat bran was the least expensive way to increase EPA levels, but the increase was marginal and supplementing with wheat bran did not increase DHA in our sample. Salmon oil was the most cost-effective means of increasing DHA, and the second-most effective way to increase EPA. The combined results make salmon oil the most ideal supplement out of the ones tested. Our results also show that a high dose of salmon oil fed to white worms shortly before harvest is the most efficient means of increasing EPA and DHA levels and the nutritional value of white worms.

Table 3. *Nutritional and economic impact of using varying amounts of salmon oil as an enrichment to spent brewing grains for white worm feed.*

Salmon Oil Dosage	Dose Amount	Worm Sample EPA* (% dry matter)	Worm Sample DHA* (% dry matter)	Shelf Life (months)	Bulk Amount	Total Doses	Total Factor Cost	Unit Cost	Average Product Cost per Unit of Increased EPA	Average Product Cost per Unit of In-creased DHA
Low	75 mL (33.5 g)	0.40b	0.17b	4-10	907 g	27.1	$21.00	$0.77	$1.05	$1.24
Medium	150 mL (67 g)	0.58ab	0.37ab	4-10	907 g	13.5	$21.00	$1.56	$0.55	$0.57
High	225 mL (100.5 g)	0.83a	0.61a	4-10	907 g	9.0	$21.00	$2.33	$0.33	$0.34
None	0 mL (0 g)	0.20c	0.00c	n/a	n/a		$0	$0		

*Differing letters within a column denote significant differences ($p<0.05$) between dosages.

Challenges

The biggest bottleneck to commercial white worm production is an efficient harvesting system that reduces labor and time while increasing worm output. In addition, most stakeholders involved with this project expressed interest in growing white worm in-house. However, the optimal temperature for worm growth and reproduction is 15-21 °C, so climate control will be necessary to maintain healthy white worm cultures for those aquaculturists located in tropical regions. Moreover, costs are high to ship live worms in water. Non-live white worm products (e.g., freeze-dried or frozen worms) or lighter methods for shipping live worms merit study.

Resources

There are only a few relevant references about white worms, information which we've taken the liberty to include in this Fact Sheet. We recommend:

DiMaggio, M. A., E. J. Cassiano, K. P. Barden, S. W. Ramee, C. L. Ohs, & C. A. Watson. 2017. First record of captive larval culture and metamorphosis of the Pacific blue tang, *Paracanthurus hepatus*. Journal of the World Aquaculture Society 48(3): 393-401.

Fairchild, E. A., A. M. Bergman, & J. T. Trushenski. 2017. Production and nutritional composition of white worms *Enchytraeus albidus* fed different low-cost feeds. Aquaculture 481: 16-24.

Fairchild, E. A. & M. L. Walsh. 2017. How to grow white worms. NRAC Fact Sheet No. 223-2017.

Ivleva, I. V. 1973. *Enchytraeus albidus*, in: Mass Cultivation of Invertebrates: Biology and Methods. Published for the National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Washington, D. C. by the Israel Program for Scientific Translations. Translated from Russian. pp. 8-38.

Memiş, D., M. S. Celikkale, & E. Ercan. 2004. The effect of different diets on the white worm (*Enchytraeus albidus* Henle, 1837) reproduction. Turkish Journal of Fisheries and Aquatic Sciences 4: 5–7.

Walsh, M. L. 2012. Potential of white worms, *Enchytraeus albidus*, as a component for aquaculture and stock enhancement feeds. World Aquaculture Magazine 43(3): 44-46.

In addition, many aquarium hobbyists post DIY white worm information online.

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