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Improved health and growth of fish fed mannan oligosaccharides: Potential mode of action

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ABSTRACT

Nowadays, aquaculture industry still confronts several disease-related problems mainly caused by viruses, bacteria and parasites. In the last decade, the use of mannan oligosaccharides (MOS) in fish production has received increased attention due to its beneficial effects on fish performance and disease resistance. This review shows the MOS use in aquaculture with a specific emphasis on the effectiveness of the several MOS forms available in the market related to disease resistance, fish nutrition and the possible mechanisms involved. Among the main beneficial effects attributed to MOS dietary supplementation, enhanced fish performance, feed efficiency and pathogen protection by potentiation of the systemic and local immune system and the reinforcement of the epithelial barrier structure and functionality are some of the most commonly demonstrated benefits. These combined effects suggest that the reinforcement of the intestinal integrity and functionality, together with the stimulation of the innate immune system, are the primary mode of action of MOS in fish. However, the supplementation strategy related to the structure of the MOS added, the correct dose and duration, as well as fish species, size and culture conditions are determinant factors to achieve improvements in health status and growth performance.

1. The use of mannan oligosaccharides (MOS) in aquaculture: a general overview

Most MOS products tested in the aquaculture sector derive from the outer cell wall of yeast (*Saccharomyces cerevisiae*), where they are present in complex molecules linked to the protein fraction. The main described effects of MOS are related to pathogen colonization blocking and immune system stimulation. In addition, growth and food conversion improvement has been associated to its dietary supplementation. The use of MOS as a pathogen colonization blocker evolves from the concept that some sugars as mannose could be used as inhibitors of pathogen adhesion to intestinal cells. Bacterial adhesion, which is mediated by the interaction of bacteria with specific carbohydrate groups present on cell surface via specific lectins, is a necessary step in microbial colonization and pathogenesis [1]. Therefore, the objective of including MOS in aquaculture feeds is to reduce pathogenic bacteria intestinal attachment by using a component that resists the passage along the gut during digestion and mimics the specific carbohydrates groups of intestinal cells. This mechanism will favor bacterial adhesion to MOS and their removal with feces, reducing the incidence and severity of the potential disease. In the other hand, the effect of MOS as immune modulator is probably based in the activation of pattern recognition receptors (PRR) and proteins (PRP), triggering the innate immune system in response to a non-self-substance.

The number of studies concerning the effect of MOS in fish is limited, and in some cases, disparities in the results have been observed, which in part could be explained due to the structural differences of the MOS used [2], dose supplemented, time of supplementation, culture conditions, fish species or age. For example, growth and/or feed utilization were improved by feeding MOS supplemented diets in some fish species [3–15] (Tables 1 and 2), however other studies reported a lack of effect on fish performance or feed efficiency after MOS dietary administration [16–23] (Tables 1 and 2). Feeding MOS has been found to modulate some immune-related parameters in fish [3,5,7,9,10,12,13,15,22,24–28], whereas in other studies some of those parameters remained unaffected [9,19,29,30] (Tables 3 and 4).

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Table 1
Effects of MOS supplementation on fish performance.

Effect	Dietary supplementation		Form	Species	Experimental conditions			Significance level	Reference
	Time	Dose			Initial body weight (g)	Initial culture density (kg/m^3)	Diet crude protein (%)		
Growth performance	from 8 dph	0.2% of commercial enrichment treatment (DW)	Bio-Mos®[a]	Cobia larvae (*Rachycentron canadum*)		7.5 larvae/L		NS	[38]
	3 weeks	0.4 & 0.6%	Bio-Mos®[a]	Nile tilapia (*Oreochromis niloticus*)	0.013	0.16	40	$P < 0.05$	[6]
	4 weeks	0.2%	Bio-Mos®[a]	Channel catfish (*Ictalarus punctatus*)	10.6 ± 0.1	8.35	32	NS	[18]
	4 weeks	1%	Bio-Mos®[a]	Red drum (*Sciaenops olivaceus*)	10.9 ± 0.2	1.5	50	NS	[10]
	5 weeks	0.3%	Product not specified	Gulf of Mexico sturgeon (*Acipenser oxyrinchus*)	130	5.6	50	NS	[16]
	6 weeks	0.2%	Bio-Mos®[a]	Channel catfish (*Ictalarus punctatus*)	19.3 ± 0.3	2.5	32 FLD	NS	[19]
	6 weeks	0.2%	Bio-Mos®[a]	Channel catfish (*Ictalarus punctatus*)	45.8 ± 1.2	6	36 SKD	NS	[19]
	45 days	0.1%	ActiveMOS®[b]	Common carp (*Cyprinus carpio*)	1.3 ± 0.17	0.26	35	NS	[22]
	45 days	0.2, 0.4, 0.6, 0.8 & 1%	ActiveMOS®[b]	Nile tilapia (*Oreochromis niloticus*)	13.62 ± 0.72	0.9	40	NS	[29]
	46 days	0.2 & 0.4%	ActiveMOS®[b]	Giant sturgeon (*Huso huso*)	46.89 ± 2.57	0.35	31	NS	[21]
	8 weeks	1%	Immunoster®	Giant sturgeon (*Huso huso*)	95.68 ± 10.05	–	42	NS	[8]
	8 weeks	3%	Immunoster®	Giant sturgeon (*Huso huso*)	95.68 ± 10.05	–	42	$P < 0.05$	[8]
	8 weeks	0.5% + 10^7 *Bacillus clausii* 0.25% + 10^7 *B. clausii* + 0.25% FOS	Bio-Mos®[a]	Japanese flounder (*Paralichthys olivaceus*)	21	2.3	48.5–48.7	$P < 0.05$	[9]
	8 weeks	1%	Bio-Mos®[a]	Red drum (*Sciaenops olivaceus*)	7	2.2	40	NS	[28]
	60 days	0.2, 0.4 & 0.6%	Bio-Mos®[a]	European sea bass (*Dicentrarchus labrax*)	60.64 ± 0.85	7	48	NS	[13]
	60 days	0.4%	Bio-Mos®[a]	European sea bass (*Dicentrarchus labrax*)	116	10	48	NS	[27]
	60 days	0.4%	Bio-Mos®[a]	European sea bass (*Dicentrarchus labrax*)	44.95 ± 2.99	4	50	$P < 0.05$	[14]
	60 days	1%	MOS[c]	Rohu fingerlings (*Labeo rohita*)	4.15 ± 0.07	0.41	32–33	$P < 0.05$	[7]
	9 weeks	0.4%	Bio-Mos®[a]	Channel catfish (*Ictalarus punctatus*)	9.9 ± 0.4	3.25	Low/high extrusion temperatures	NS	[20]
	9 weeks	0.2 & 0.4%	Bio-Mos®[a]	Gilthead sea bream (*Sparus aurata*)	29	9.8	43 FM 46 SBM	NS	[40]
	67 days	0.2 & 0.4%	Bio-Mos®[a]	European sea bass (*Dicentrarchus labrax*)	33.75 ± 7.69	3	44–46	$P < 0.05$	[12]
	70 days	1 & 2%	PatoGard™[f]	Atlantic Salmon (*Salmo salar*)	679.0 ± 2.0	0.8	37.1 (FM + 32% SBM) 35.2 (Fm + 14%SBM + 14%SFM)	$P < 0.05$	[33]
	80 days	0.15, 0.3 & 0.45%	MOS[d]	Hybrid red tilapia (*Oreochromis mossambicus* × *Oreochromis niloticus*)	9.8 ± 0.3	1.5	20–25	NS	[17]
	12 weeks	0.4% (M) 0.4% + *Enterococcus faecalis* 1%, (EM) 0.4% + *E. faecalis* 1%, +Polyhydroxybutyrate 1% (EMP)	Bio-Mos®[a]	Rainbow trout (*Oncorhynchus mykiss*)	13.2 ± 0.2	6.6	40 (M, EM, EMP)	$P < 0.05$	[5]
	12 weeks	0.2 & 0.4%	Bio-Mos®[a]	Gilthead sea bream (*Sparus aurata*)	170	20	44	$P < 0.05$	[11]
	90 days	0.15%	Bio-Mos®[a]	Rainbow trout (*Oncorhynchus mykiss*)	37.5 ± 0.1			$P < 0.05$	[4]
	90 days	0.2%	Bio-Mos®[a]	Rainbow trout (*Oncorhynchus mykiss*)	30	2.4	Net cage	$P < 0.01$	[3]
	90 days	0.2%	Bio-Mos®[a]	Rainbow trout (*Oncorhynchus mykiss*)	30	2.4	Raceway	$P < 0.01$	[3]
	4 months	1%	Not specified	Atlantic Salmon (*Salmo salar*)	200.2 ± 0.6	8	47	NS	[66]
	14 weeks	0.4%	Bio-Mos®[a]	Atlantic Salmon (*Salmo salar*)	47	0.08	44	NS	[32]
	150 days	0.8%	ECHOMOS[e]	Sharpsnout seabream (*Diplodus puntazzo*)	100	6.7	44 SBM	NS	[23]

DW: dry weight; FM: fish meal; FLD: floating diet; NS: Not affected; SBM: soybean meal; SFM: sunflower meal; SKD: sinking diet.
[a] (Alltech, Inc., Nicholasville, KY, USA).
[b] (Biorigin, Lencxois Paulista, Sao Paulo, Brazil).
[c] (Guybro Chemicals, Mumbai, India).
[d] (Aqua-Myces, Vitamix Ltd, Colombia).
[e] (Mazzoleni Prodotti Zootecnici Cologno al Serio, BG, Italy)
[f] (Biotec Parmacon ASA, Tromsø, Norway).