POTENTIAL FOR REDUCING COSTS OF SALMON PRODUCTION BY DIETARY INCLUSION OF NOVEL RAPESEED/CANOLA PROTEIN PRODUCTS

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ABSTRACT

This review will emphasize the potential for using specially processed rapeseed/canola protein products as partial and total replacements of fish meal in diets of salmon and trout. Extensive use of one or more of these products in salmon diets could result in annual savings exceeding US $6 million at the current salmon production level in North America.

INTRODUCTION

Global farmed salmon production has increased dramatically. In 1985, 50,000 tonnes (MT) of farmed salmon were produced. Now, over 400,000 MT are harvested, with Norway alone accounting for half of the production.

Market values of farmed salmon can approach their production cost. The main variables influencing this include the efficiency of the culture operation, time of year, the quality and size of the market product, and the total of the wild salmon and farmed salmon harvest relative to consumer demand. Salmon farming profitability can be improved by emphasizing the importance of fish in the human diet (Higgs et al., 1995a) and by further reducing salmon production costs. Feed accounts for about half of the cost of farming salmon and close to two thirds of the feed cost originates from the protein sources (Prendergast et al., 1994). The latter is because of extensive reliance on expensive high quality low-temperature dried (LT) fish meals (>90% of dietary protein).

World fish meal production may remain near the present level of about 6 million MT (Higgs et al., 1995b) because world capture fisheries have plateaued between 90 and 100 million MT (New, 1991). Alternatively, fish meal production may decline because of direct use of fish in the human diet to support population growth (United Nations, 1992), and increased use of hydrolyzed fish as an organic fertilizer in agriculture (Pigott, 1994).

Future fish meal prices, in any case, are predicted to rise because of increased demands for this valuable commodity for finfish and crustacean culture, pet foods and specialty livestock feeds (Rumsey, 1993). Suitable inexpensive alternatives such as rapeseed/canola protein products that are of consistently high quality are therefore needed for cost efficient salmon production.

RAPESEED/CANOLA PROTEIN PRODUCTS

Overall assessment of the potential for using rapeseed/canola protein products in salmonid diets includes considerations of supply, cost and nutritive value. World production of oilseeds continues to increase. In 1993, 57.1 million MT of protein resulted from global production of oilcakes and meals (FAO, 1994). Of this total soybeans, rapeseed/canola, and fish meal accounted for 62.1%, 8.72%, and 6.89%, respectively. Thus, more protein is potentially available from rapeseed/canola for inclusion in animal diets than from fish meal. The cost of canola meal expressed in US $/kg protein is presently 46.1% of South American Anchovy meal (0.365 versus 0.791) and below that of soybean meal (0.419; J. Johnson and G. Deacon, personal communication). Rapeseed/canola meals are therefore potentially excellent alternatives to fish meal considering supply and cost alone.

When considering nutritive value, distinction must be made between commercial sources of rapeseed and canola meals themselves and between these products and others derived from them through processing. Canola is the registered name given to genetically selected varieties of rapeseed of the *Brassica napus* and *B. campestris* species that are low in both glucosinolates or antithyroid factors, and erucic acid. Upgraded rapeseed/canola meals and concentrates are prepared by first removing hulls or fiber from seeds or meal. Various solvents are then employed to decrease the levels of antinutritional factors, e.g. glucosinolates, sinapine, phytate (acid washing), and carbohydrate and concurrently increase protein content (McCurdy and March, 1992; Higgs et al., 1995b).

Upgraded canola meals are similar in proximate composition (except for fiber and nitrogen-free extract) to commercial sources of soybean meal. Concentrates, unlike rapeseed/canola meals, are more similar to fish meal in proximate composition and gross energy content (Table 1). The potential quality of protein in both the concentrates and the meals is similar to that of fish meal and higher than that of soybean meal for salmon (see EAAI indices, Table 1).

TABLE 1. Proximate compositions, gross energy contents and essential amino acid indices (EAAI) for selected sources of fish meal and oilseed protein products. EAAI was calculated according to Oser (1959) using the essential amino acid profile in the whole body of chinook salmon presmolts as the reference standard.

	HM[3]	AM[4]	R/CM[5]	RPC/[6] CPC	UG-[7] CM	SBM[8]
Proximate[1] constituents (% air-dry basis)						
Protein	72.0	65.4	38.0	63.0	49.8	48.5
Crude lipid	8.4	7.6	3.8	8.0	0.5	0.9
Crude fiber	0.6	1.0	11.1	4.7	8.4	3.4
Nitrogen-free extract	0.6	3.7	33.3	14.8	20.5	34.4
Ash	10.4	14.3	6.8	5.9	7.8	5.8
Moisture	8.0	8.0	7.0	3.6	13.0	7.0
Gross[1] energy (MJ/kg)	20.5	19.3	18.1	21.4	16.9	18.3
EAAI[2,9]	0.97	0.97	0.95	0.95	-	0.92

[1]From Higgs et al. (1994); [2]Reference essential amino acid pattern calculated by expressing each of the essential amino acids as a percentage of the total weight of the essential amino acids (Higgs et al., 1995a); [3]HM = herring meal; [4]AM = anchovy meal; [5]R/CM = rapeseed/canola meal; [6]RPC/CPC = rapeseed/canola protein concentrate; [7]UG-CM = upgraded canola meal (McCurdy and March, 1992); [8]SBM = soybean meal; [9]Essential amino acid compositions were obtained from NRC (1993) (HM, AM, R/CM, SBM) or were determined by AAA laboratory, Mercer Island, WA (RPC/CPC).

Rapeseed/canola meals not only have poorer proximate compositions and energy contents relative to the concentrates, but also they have generally higher levels of antinutritional factors that prevent full realization of their high inherent protein quality. Indeed, studies of the potential (digestibility assessments) and actual (growth trials) nutritive values of rapeseed/canola protein products clearly show that the concentrates and upgraded products have the greatest potential as total replacements for fish meal in diets for salmon and trout (Tables 2 and 3).

TABLE 2. Mean percent apparent crude protein (C.P.) and gross energy (G.E.) digestibility coefficients and digestible energy (D.E.) values of rapeseed/canola protein products and herring meal for trout and salmon[1].

		Apparent Digestibility (%)		
Species	Protein Product	C.P.	G.E.	D.E. (MJ/kg)
Rainbow trout[2] (*Oncorhynchus mykiss*)	Rapeseed meal	63.8-77.0	21.4-45.0	6.0-8.1
	Canola meal	83.2-87.1	72.4-75.4	
	Rapeseed protein concentrate	89.0-96.0[3]		
	Herring meal	92.0	91.0	18.8
Chinook salmon[4] (*Oncorhynchus tshawytscha*)	Canola meal	84.5	64.5	13.0
	Canola meal, gluco-free cultivar	87.9	71.0	13.9
	Rapeseed protein concentrate	95.6	80.5	18.2
	Herring meal	90.5	92.6	20.4
Atlantic salmon[4] (*Salmo salar*)	Canola meal	74.1-86.6	70.2-72.7	
	Canola meal, gluco-free cultivar	86.4	71.0	
	Canola protein concentrate	97.7	79.4	
	Herring meal	91.5-94.0	94.6	

[1]Adapted from Higgs et al., (1994; 1995b); Anderson et al., (1993, unpublished data); Prendergast et al. (1994, unpublished data); [2]Rainbow trout were held in fresh water; [3]Rapeseed protein concentrate comprised 95% of dietary protein and extruded wheat 5%; [4]Chinook and Atlantic salmon were held in sea water.

TABLE 3. Recommended (based on growth and feed conversion responses) dietary levels of rapeseed/canola protein products for salmonid species[1].

		Recommended dietary level	
Species	Rapeseed/canola product	(% dry wt.)	(% of dietary protein)
Rainbow trout (FW)[2] (*Oncorhynchus mykiss*)	Canola meal	10	10
	Canola meal & Finnstim™	23	20
	Rapeseed protein conc., undephy. & Finnstim™	25	39
	Rapeseed protein conc., dephy. & Finnstim™	37	59[3]
Coho salmon (FW) (*O. kisutch*)	Canola meal	22	18
Chinook salmon (FW) (*O. tshawytscha*)	Canola meal	20	16
	Rapeseed protein conc.	>19.9	>24.4
(SW)[2]	Canola meal, high temp. extrusion & Finnstim™	~23.2	~23.5
	Upgraded canola meal, fiber reduced, ethanol & acid-washed	-	≥25

[1]Adapted from Higgs et al., (1994), Prendergast et al., (1994, unpublished data), Satoh et al., 1993 (unpublished data); [2]FW=fresh water; SW=sea water; [3]Preliminary findings suggest that 95% of the protein in trout diets can originate from dephytinized rapeseed protein concentrate supplemented with Finnstim™ without significantly depressing growth rate (Prendergast et al., 1994, unpublished data).

For instance, the availability (digestibility) of protein in concentrates for salmonids is about 96%, whereas the range for percent protein availability in rapeseed/canola meals is wide and below that noted for fish meals. Acceptable dietary levels for canola meals in salmonids are also far below those observed for concentrates (Table 3). This is especially true if the concentrates are pretreated with the enzyme phytase before dietary inclusion and the diets are concurrently supplemented with Finnstim™ (palatability enhancer) to maintain excellent fish feed intake (Table 3; Table 4).

TABLE 4. Feed intake (mean daily dry feed intake per fish x 100 ÷ geometric mean wet weight of fish) of juvenile rainbow trout during each 21-day interval of an 84-day study in relation to selected diet treatments (Teskeredžic et al., 1995)[1].

Protein source and level	Feed intake (%/d)			
	Day 0-21	21-42	42-63	63-84
Herring meal, 59% of dietary protein	4.38	4.18	4.13	3.67
Undephytinized rapeseed protein concentrate (RPC), 59% of dietary protein	4.20	4.69	4.60	4.54
Dephytinized RPC, 59% of dietary protein	4.44	4.45	4.28	4.37

[1]Trout (initial weight, 4.2-4.4g) were held in 10.0-10.3°C well water on a natural photoperiod and fed isonitrogenous (430 g protein/kg) and isoenergetic (21.6 MJ gross energy/kg) diets to satiation three times daily. All diets contained 1.5% Finnstim™ (diet palatabiltiy enhancer).

Phytic acid is the hexaphosphate of myoinositol. High dietary levels of this compound may depress growth, feed efficiency, bioavailability of protein and zinc as well as thyroid function in salmonids (Higgs et al., 1995b). The removal of phytic acid, the only antinutritional factor present in high concentration (5.3-7.5%) in rapeseed/canola protein concentrates (Higgs et al., 1995b) has proven to be essential to attain the goal of complete replacement of fish and animal proteins in salmonid diets with a plant protein product (Prendergast et al., 1994 and Prendergast et al., 1994, unpublished data, Table 3). Other nutritional strategies such as mimicing the essential amino acid and cation-anion levels found in fish meal-based diets when using dephytinized rapeseed/canola protein concentrate are likely unnecessary (Prendergast et al., 1994). The pretreatment of concentrates with the enzyme phytase to remove phytic acid (Prendergast et al., 1994), is probably impractical and uneconomical. One promising alternative that appears partially helpful involves high temperature extrusion processing of canola protein products (Table 5).

TABLE 5. Weight gains (WG), specific growth rates (SGR), dry feed intakes (DFI) as a percentage of body weight, and feed efficiencies (FE) of post-juvenile chinook salmon in relation to diet treatment (Satoh et al., 1993, unpublished data)[1].

Protein source and level	Performance parameter			
	WG (g/fish)	SGR (%/d)	DFI (%/d)	FE[2]
Herring meal (HM) control	53.6	1.07	1.65[a]	0.90
Commercial canola meal (CM), 30% replacement of HM protein	35.1	0.79	1.32[b]	0.80
CM extruded with 90°C steam (L), 30% replacement of HM protein	46.0	0.97	1.71[a]	0.77
CM extruded with 150°C steam (H), 30% replacement of HM protein	50.7	1.01	1.64[a]	0.86

[1]Water temperature during the study declined from 12.0 to 9.5°C. Fish were fed the test diets to satiation twice daily for the first 6 weeks and once daily for the second 6 weeks. All diets were formulated to be isonitrogenous and isocaloric. Percentages of phytic acid in CM, CM-L and CM-H were 4.2, 3.8 and 3.0, respectively. Values with a common superscript were not significantly different (P=0.05); [2]Weight gain (g) ÷ dry feed intake (g/fish).

Other alternatives include orally administering phytase (Rumsey, 1993), blending hydrolyzed marine protein sources with canola protein products and wheat bran (natural phytase source) (Stone et al., 1984), incorporating ground transgenic seeds rich in phytase into diets (Pen et al., 1993), and genetically selecting canola for low phytate content.

COMMERCIAL PRODUCTION AND ECONOMICAL USE OF CANOLA CONCENTRATES

While many of the exciting research findings related to rapeseed/canola protein concentrates (RPC/CPC) were obtained using trout, it is probable that they are directly applicable to salmon. Trout are more sensitive than salmon to antinutritional factors within canola meal that adversely affect performance. The greatest challenge will therefore likely be to commercially produce CPC in an economical manner. Preliminary cost estimates prepared by Dr. Sandra McCurdy of the POS Pilot Plant Corp., Saskatoon, Saskatchewan, suggest that it should be possible to produce and market concentrates for about 80% of the cost of high quality fish meals/kg protein. Research efforts are presently underway to confirm this possibility and to develop novel, and hopefully more cost efficient, protocols for concentrate production. Some of these involve the application of microbial enzyme products such as cellulases and carbohydrases together with solvent extraction of meal.

The marketing of concentrates for $\leq 80\%$ of the cost of fish meal/kg protein will have considerable cost benefits for salmon farming, especially in North America. Here, there are abundant supplies of canola meal and insufficient domestic supplies of high quality LT fish meals. Our goal is to reduce salmon feed costs by at least US $70 per MT through extensive replacement of high quality fish meal with CPC. Successful achievement of this objective would result in annual savings of more that US $6 million at the current salmon production level in North America (~60,000 MT).

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