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A Review of Using Canola/Rapeseed Meal in Aquaculture Feeding

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ABSTRACT

Recently, an increasing cost of fishmeal due to decreased marine supplies and increased demand from various other sectors of the feed industry has resulted on the ongoing search for alternative protein sources for aquaculture feeds. To date, the majority of research on fishmeal replacement with alternative proteins in fish diets has focused on the use of protein derived from plant sources. Plant protein ingredients are of lower nutritional value than fish meal and contain secondary compounds which reduce their value in aquafeeds. Canola/rapeseed meal is evaluated with respect to its chemical composition and impact on the animals' performance. Canola/rapeseed meal has relatively higher protein content than the other oilseed meals, except soybean meal. The main limitative factors for using this meal are antinutritional ingredients such as glucosinolates (GLs), phenolic compounds (tannins and sinapine), phytate and fibre. Nutritional value of canola/rapeseed meal varies depend on oil extraction method and process. Many researches have been conducted to enhance nutritional value of the meal. It has been shown that the meal can improve the performance of the aquatic animals. Also, use of canola/rapeseed meal has no significant adverse or negative effect on the weight, size, carcass quality, odor, taste or the other physiological features of the animals. In recent years, cultivation of canola/rapeseed and use of its meal by different aquaculture farms has shown a progressive trend in Iran, as well as the other countries. So, this review presents recent findings on use of canola/rapeseed meal in the diets offered to fish and shrimp.

Key words: Canola meal, rapeseed meal, aquaculture, fish, shrimp

INTRODUCTION

Canola and its meal: Canola and rapeseed are names used to describe the plants *Brassica napus* and *Brassica campestris*. The name canola, a combination of two words -Canadian and oil, is given to particular varieties in which the seeds yield oil with less than 2% erucic acid and the meal contains less than 30 μmol g^{-1} glucosinolates. These varieties of rapeseed are genetic variations developed by Canadian plant breeders specifically for these nutritional qualities (Bell, 1993). World production and 20 top canola/rapeseed producer countries are listed in Table 1. Also, changes in world area harvested, production and supply of rapeseed and its meal from 2004 to 2010 are shown in Table 2 and 3.

In Iran, plant breeders, mainly in Golestan province, since 1998 have worked on improvement of quality of the plant. In recent 12 years, researchers in ORDC (Oilseed Research and Development Company, Tehran, Iran) used selective breeding to develop varieties of rapeseed low in both erucic acid and glucosinolates (Table 4). The researches are led to reduce glucosinolates content up to 77.3% and increase rapeseed area harvested and production up to 26 and 20 times, respectively.

Table 1: Top canola/rapeseed producers in the world by country (tones)-2008

Rank	Country	Production
1	Canada	12642900
2	China	12102010
3	India	5833000
4	Germany	5154700
5	France	4719053
6	Ukraine	2872800
7	Poland	2105840
8	UK	1973030
9	Australia	1615000
10	Czech Republic	1048943
11	Russia	752200
12	Romania	673033
13	USA	660334
14	Hungary	651500
15	Denmark	629200
16	Belarus	513959
17	Slovakia	424444
18	Iran	390000
19	Pakistan	390000
20	Lithuania	330200
	WORLD	57856158

Source: Faostat.fao.org (2010)

Table 2: Rapeseed area harvested and production in the world, 2004-2010

		Years					
Factors		2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Area harvested (million hectares)	Rapeseed	26.68	27.26	26.49	28.29	31.1	30.91
Production (million metric tons)	Rapeseed	46.04	48.5	45.09	48.52	58.24	59.37

USDA, 2010

Table 3: Rapeseed meal production and total supply in the world, 2004-2010

		Years					
Factors		2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Production (million metric tons)	Rapeseed meal	24.32	26.57	25.95	27.64	30.76	32.95
Total supply (million metric tons)	Rapeseed meal	27.18	29.61	29.59	31.43	34.52	36.99

USDA, 2010

Table 4: Average values of Iranian rapeseed, 1988-1992

Year	Erucic acid (% in fatty acid)	Glucosinolates (μmol g^{-1})	Fiber (%)	Ether extract (%)	Protein (%)
1988	4.200	48.80	12.2	41.70	24.42
1989	0.346	28.30	11.2	42.26	26.00
1990	0.460	8.61	11.5	24.52	25.40
1991	0.500	9.20	12.0	42.65	25.20
1992	0.400	10.11	11.8	43.30	26.00

ORDC (oil Research and Development Company); QC: Lab, 1993 (unpublished data)

The primary product of canola is its oil content, but canola meal is also a valuable protein resource for use in animal nutrition. Some researches have been directed into the assessment of the nutritional value of canola meal for a range of animals (Bergeron and Jacques, 1989; Ahmadauli *et al*., 2008; Newkirk, 2009; Enami and Safafar, 2010; Mussaddeq *et al*., 2001).

There are three factors affecting canola meal nutritional quality and value as below:

- The residual oil content of the meal
- The levels of glucosinolates and their breakdown products
- The level of heat imparted during oil extraction

Protein quality of canola meal, indeed any protein meal, is affected by the various processing steps involved in their production. Notably, excess heating during oil extraction processes can result in reduced digestibility of protein and some amino acids, particularly lysine.

The amino acid balance of canola protein is the best of the commercial vegetable protein sources currently available (Friedman, 1996). Furthermore, canola meal protein is approximately half the cost of fish meal per kg of protein. Canola meal contains small amounts of heat labile (glucosinolates) and heat stable (phytic acid, phenolic compounds, tannins and fibre) anti-nutritional factors (Table 5). Canola meal contains relatively high levels of fibre including approximately 14.5% cellulose, 5.0% hemicellulose and 8.3% lignin. This results in a crude fibre content of 10.6% for commercial canola meal (Mwachireya *et al*., 1999). Nevertheless, the fibre component of canola meal does dilute the amount of protein and energy in the meal. Canola meal may be converted into Canola Protein Concentrate (CPC) by aqueous extraction of protein (Mwachireya *et al*., 1999; Thiessen *et al*., 2004). CPC contains approximately the same crude protein level as fish meal and high levels of lysine and methionine relative to corn gluten and soybean meal. The process used to concentrate the protein results in a CPC is completely devoid of phytate and contains extremely low levels of glucosinolates. CPC might allow a higher level of fish meal replacement in aquafeeds without affecting fish growth performance.

Chemical composition: The minimum crude protein level for Canadian canola meal is 36.0% (12% moisture basis), although the actual protein content usually is 36-39% (Table 5). The

Table 5: Comparison of composition of Iranian and Canadian rapeseed meal

Ingredients (%)	Iranian rapeseed meal[a]	Canadian rapeseed meal
Moisture	12.0	12.0[b]
Ash	6.7	6.01[b]
CP	37.57	36.0[b]
EE	1.8	3.50[c]
CF	13.97	11.70[b]
Ca	0.74	0.62[d]
P	1.13	1.06[d]
Gls (μmol g^{-1})	5.74	7.20[d]
Sinapin	0.78	1.00

CP: Crude Protein; EE: Ether Extract; CF: Crude Fiber; Ca: Calcium; P: Phosphorous; Gls: Glucosinolates; [a]ORDC (Oil Research and Development Company)- Quality Control lab., 1993(unpublished data); [b]Newkirk (2009), [c]Bell (1993), Slominski and Campbell (1990), [d]Bell and Keith (1991), Bell *et al*. (1999)

Table 6: Amino acids composition of canola meal (36% CP basis)*

Amino acids	Average (%)	Amino acids	Average (%)
Pro	2.15	Phe	1.38
Ser	1.44	Ala	1.57
Thr	1.58	Arg	2.08
Try	0.48	Asp	2.61
Tyr	1.16	Cys	0.86
Val	1.97	Glu	6.53
His	1.12	Gly	1.77
Iso	1.56	Met	0.74
Leu	2.54	Met+Cys	1.60
Lys	2.00		

*Newkirk *et al*. (2003)

Table 7: Essential minerals of canola meal*

Mineral	Mean value	Mineral	Mean value (%)
S (%)	0.85	Se (mg kg^{-1})	1.1
Mg (%)	0.54	Ca (%)	0.63
Cu (mg kg^{-1})	5.80	P (%)	1.01
Fe (mg kg^{-1})	166.00	Available P (%)	0.3-0.5
Mn (mg kg^{-1})	52.00	Na (%)	0.1
Mo (mg kg^{-1})	1.40	Cl (%)	0.1
Zn (mg kg^{-1})	58.00	K (%)	1.22

*Bell (1984)

minimum allows for yearly variation in canola seed composition due to growing conditions. Canola meal has a good amino acid profile for animal feeding (Table 6). Like many vegetable protein sources canola meal is limiting in lysine but it is noted for having high levels of methionine and cystine. Amino acid content varies with protein content and can be calculated by multiplying the crude protein content of the meal by the proportion of amino acid as a percentage of protein. As shown in Table 5, the oil content of Canadian canola meal tends to be relatively high at 3.5% compared to 1-2% oil in canola meals produced in most other countries (e.g., Iran), mainly because in Canada canola gums are added back to canola meal at 1-2%. Addition of gums to canola meal increases the energy value of canola meal. The carbohydrate matrix of canola meal is quite complex. The levels of starch, free sugars and soluble non-starch polysaccharides in canola meal total about 15% which should result in a significant contribution to digestible energy. However, it appears that these carbohydrates are protected by cell walls and that their actual contribution to digestible energy is modest (Bell, 1993; Slominski and Campbell, 1990). The 11.7% crude fibre is higher than in soybean meal because, unlike soybean meal, the canola hull stays with the meal and the hull is a relatively high proportion of the canola seed. The data show that canola meal is a relatively good source of essential minerals (Table 7) compared to other vegetable-origin oilseed meals. Canola meal is an especially good source of selenium and phosphorus. Similar to other vegetable sources of phosphorus where it is present as phytate, the bio-availability is estimated to be 30-50% of the total phosphorus level. Information on the vitamin content of canola meal is very limited but it appears to be rich in choline, biotin, folic acid, niacin, riboflavin and thiamin. As is recommended with most natural sources of vitamins in animal feeds, users should not place too much reliance on these values and use supplemental vitamin premixes instead. It is recognized that energy levels will vary as nutrient composition varies-especially protein, oil and fibre (Newkirk, 2009).

Anti-nutritional factors: The low glucosinolate content of canola, compared to previous cultivars of rapeseed, constitutes the major improvement in meal quality achieved by plant breeders (Table 4). Canola glucosinolates are composed of two main types, aliphatic and indolyl. Aliphatic glucosinolates comprise approximately 85% of the glucosinolates present in canola meal while indolyl glucosinolates account for the other 15% (Newkirk *et al*., 2003). As shown in Table 5, the total glucosinolate content of Iranian and Canadian canola meals are approximately 5.74 and 7.2 μmol g^{-1}, respectively (Newkirk *et al*., 2003). By comparison, traditional rapeseed meal contains 120-150 μmol g^{-1} of total glucosinolates. There are many different types of glucosinolates with different breakdown products-thiocyanate, isothiocyanate, oxazolidinethione (goitrin) and nitriles. Each of these products will have a unique effect on the animal-most will inhibit thyroid hormone production but others will affect the liver. The reason that glucosinolates are expressed on a molecular (μmol g^{-1}) basis rather than on a weight (mg kg) basis is that glucosinolates have significantly different molecular weights depending on the size of their aliphatic side chain. Since the negative effect on the animal is at the molecular level, the most accurate estimate of this effect can be gauged by expressing glucosinolate concentration on a molecular basis (Tripathi *et al*., 2007). In addition to the toxic effect of glucosinolates, their bitter taste results in reduced feed intake for many animals (Bell, 1993; Mawson *et al*., 1994). The level of glucosinolates in Iranian canola has continued to decrease in recent years due to selection pressure by canola plant breeders (Table 4). Other average values of Iranian rapeseed are shown in table 4. There are a few minor components in canola meal which may have anti-nutrient effects (Bell, 1993). Tannins are present in canola meal at a range of 1.5-3.0%, with brown-seeded varieties having higher levels than yellow-seeded varieties. The tannins in canola meal do not appear to have the same negative effects on palatability and protein digestibility than they do in other plants. Sinapine traditionally has been thought to impart a bitter taste to canola and therefore potentially impact feed intake (Clandinin, 1961). Recent work by Qiao and Classen (2003) showed that while sinapine may have a bitter taste, at the levels found in canola meal it did not affect feed intake or growth rate. Canola meal also contains approximately 0.85% phosphorus bound to phytic acid which is not very digestible by monogasterics. Trading rules for canola meal in Canada and US are shown in Table 6.

Canola meal in aquatic animals: The evaluation of feed ingredients is crucial to nutritional research and feed development for aquaculture species. In evaluating ingredients for use in aquaculture feeds, there are several important knowledge components that should be understood to enable the judicious use of a particular ingredient in feed formulation (Enami, 2003a; Enami, 2003b; Enami, 2002). This includes information on (1)ingredient digestibilities, (2) ingredient palatability and (3) nutrient utilization and interference (Glencross *et al*., 2007; Gomes *et al*., 1993; Gomes *et al*., 1995). Progressive trend of aquaculture and fish farming in Iran, similar to the other countries, makes us to choose an alternative protein source (Table 8). Canola meal is commonly used in aquaculture diets for species such as salmon and trout, catfish, carp, tilapia, bass, perch, sea bream, turbot and shrimp. Canola meal and rapeseed meal are also commonly included in carp diets, which are normally vegetable protein based. Several studies performed on total or partial

Table 8: Trading rules for canola meal*

Characteristic (as fed)	Canada and US
Protein (%) (min)	36
Fat (oil) (%) typical (min)	2
Protein + fat (%) (min)	37
Moisture + fat (%) (max.)	15
Moisture (%) (max.)	12
Crude fibre (%) (max.)	12
Glucosinolates (μmol g^{-1}) (max.)	30
Sand and/or silica (%) (max.)**	1
Screen analysis (pellets)	90

*COPA, 2008; Canadian oilseed processors association. Trading rules. http://copaonline.net/ Winnipeg, Manitoba; **% retained on 2 mm screen

replacement of protein sources, specially fish meal and soybean meal, by canola/rapeseed meal in fish and shrimp diets that are briefly discussed later and listed in Table 9, according to factors assessed. In a survey conducted by Hardy and Sullivan (1983), using canola meal in rainbow trout (*Salmo gairdneri*) production diets led to following results: Weight gain was not affected by dietary canola meal level. Food conversion values and organoleptic properties were not influenced by dietary treatments. Feed costs were reduced by $18.70 (U.S.) per metric ton compared to control diet at the highest level of dietary canola meal (20%). Thyroid function was significantly affected by dietary canola meal. Dose-related changes in the histological appearance of the thyroid and alterations of plasma thyroxine and 3,5,3'-triiodothyronine levels indicated that compensatory adjustments in thyroid function allowed normal growth to proceed in the canola-fed fish (Higgs *et al*., 1995).

Canola meal in shrimp diet: Some experiments are conducted on using canola/rapeseed meal for shrimp diets. In a study undertaken by Lim *et al.* (1997) to determine acceptable dietary concentrations of high-fibre canola meal (CMHF) and low-fibre canola meal (CMLF)for juvenile shrimp (*Penaeus vannamei*), it was postulated that one or more fibre-reduced and solvent-extracted canola protein products may be cost-effective substitutes for fish meal protein. In another survey performed by Buchanan *et al.* (1997) on enhancement of nutritional value of canola meal by addition enzymes in diets for juvenile *Penaeus monodon*, results showed higher live weight gain and better FCR (feed conversion ratio) for the low canola +enzyme diets than the others. Addition of sucrose to the canola-based diet resulted in a significantly higher live weight gain ,but did not change the FCR values. Suarez *et al.* (2009) performed a trial on substitution of fish meal with plant proteins for white shrimp (*Litopenaeus vannamei*) growth results over a long term period and in clear water indicated the possibility for fish meal replacement with soybean plus canola meals. It is revealed that adding extruded canola meal to diet have no significant effect on performance of blue shrimp (*Litopenaeus stylirostris*) (Cruz-Suarez *et al*., 2001).

Canola meal in fish diets: Canola meal is well-established as a feed ingredient in salmon and trout diets where it has been routinely fed for over 20 years (Higgs *et al*., 1996). Canola meal is used at up to 20% inclusion levels in salmonid diets but it is desirable to further displace fish meal in the diet due to limited world supplies and the growing demand for these highly valued species (Newkirk, 2009). A research by McCurdy and March (1992) on Processing of canola meal for

Table 9: Some of the performed experiments on using canola/rapeseed meal in aquaculture

		Examined species	
Factor(s) Assessed	Researchers	Scientific name	Common name
Apparent digestibility			
	Wu *et al*. (2006)	*Sparus latus*	Yellowfin seabream
	Zhou *et al*. (2004)	*Pseudosciaena crocea*	Yellow croaker
	Burel *et al*. (2000c)	*Oncorhynchus mykiss*	Rainbow trout
		Psetta maxima	Turbot
	Allan *et al*. (2000)	*Bidyanus bidyanus*	Australian silver perch
	Luo *et al*. (2009)	*Synechogbius hasta*	
	Luo *et al*. (2008)	*Eriocheir sinensis*	Chinese mitten crab
	Tibbetts *et al*. (2006)	*Gadus murhua*	Atlantic cod
	Tibbetts *et al*. (2004)	*Melanogrammus aeglefinus*	Juvenile haddock
	Sklan *et al*. (2004)	*Oreochromis niloticus*	Tilapia
	Cheng and Hardy (2002)	*Oncorhynchus mykiss*	Rainbow trout
Digestibility			
	Glencross *et al*. (2003a,b)	*Pagrus auratus*	Red seabream
	Pavasovic *et al*. (2007)	*Cherax quadricarinatus*	Redclaw crayfish
	Drew *et al*. (2007)	-	Finfish
	Allan and Booth (2004)	*Bidyanus bidyanus*	Silver perch
	Mwachireya *et al*. 1999)	*Oncorhynchus mykiss*	Rainbow trout
Performance			
	Zhang *et al*. (2008)	*Pseudosciaena crocea*	Large yellow croaker
	Lim *et al*. 1998)	*Ictalurus punctatus*	Channel catfish
	Satoh *et al*. 1998)	*Oncorhynchus tshawytscha*	Chinook salmon
	Erdogan and Olmez (2009)	*Pterophyllum scalare*	Angel fish
	Yigit and Olmez (2009)	*Oreochromis niloticus*	Tilapia (fry)
	Suarez, *et al*.. (2009)	*Litopenaeus vannamei*	White shrimp
	Viegas *et al*. (2008)	*Piaractus masopotamicus*	Pacu juvenile
	Santigosa *et al*. (2008)	*Oncorhynchus mykiss*	Trout
		Sparus aurata	Seabream
	Przybyl *et al*. (2006)	*Acipenser ruthenus*	Starlet
	Lanari and D'Agaro (2005)	-	Sea bass
	Afzal-Khan *et al*. (2003)	*Labeo rohita*	Rohu fingerling
	Booth and Allan (2003)	*Bidyanus bidyanus*	Juv. Silver perch
	Brown *et al*. (2003)	*Oncorhynchus mykiss*	Rainbow trout
	Thiessen *et al*. (2003)	*Oncorhynchus mykiss*	Rainbow trout
	Galdioli *et al*. (2002)	*Prochilodus lineatus*	Curimbata fingerling
	Soares *et al*. (2001)	*Oreochromis niloticus*	Nile tilapia
	Cruz-suarez *et al*. (2001)	*Litopenaeus stylirostris*	Blue shrimp
	Webster *et al*. (2000)	*Morone chrysops* × *M.saxatilis*	Sunshine bass
	Burel *et al*. (2000b)	*Psetta maxima*	Turbot
		Oncorhynchus mykiss	Rainbow trout
	Soares *et al*. (2000)	*Leporinus macrocephalus*	Piavuçu fingerling
	Lim *et al*. (1997)	*Penaeus vannamei*	Juvenile shrimp
	Buchanan *et al*. (1997)	*Penaeus monodon*	Juvenile prawn
	Webster *et al*. (1997)	*Ictalurus punctatus*	Channel catfish
Thyroid status			
	Burel *et al*. (2001)	*Oncorhynchus mykiss*	Rainbow trout
	Burel *et al*. (2000a)	*Psetta maxima*	Turbot
	Pradet-Balade *et al*. (1999)	*Psetta maxima*	Turbot

Table 9: Continued

		Examined species	
Factor(s) Assessed	Researchers	Scientific name	Common name
Phosphorous availability			
	Sajjadi and Carter (2004)	*Salmo salar*	Atlantic salmon
	Riche and Brown (1999)	*Oncorhynchus mykiss*	Rainbow trout
	Riche and Brown (1996)	*Oncorhynchus mykiss*	Rainbow trout
Aminoacid availability			
	Gaylord *et al*. (2004)	*Morone chrysops* × *M.saxatilis*	Hybrid striped bass
	Sales and Britz (2003); Sales and Britz (2002)	*Haliotis midae*	South African abalone
Non-specific defencemachnisms and oxidative stress			
	Sitja-Bobadilla *et al*. (2005)	*Sparus aurata*	Gilthead seabream
Physiological and biochemical parameters			
	Shafaeipour *et al*. (2008)	*Oncorhynchus mykiss*	Rainbow trout

incorporation in trout and salmon diets revealed that Solvent-washing of fiber-reduced meal improved fish response to canola meal, probably due to reduced glucosinolate content, but possibly also due to reduced sinapine content and alterations in protein availability. In this research, due to processing of canola meal, Protein concentration was increased by 25-40% by washing and glucosinolate concentration was reduced by 40-90%. Many studies have been conducted to evaluate efficacy of canola meal and other canola protein products on performance, apparent digestibility, thyroid status, physiological and biochemical parameters and some other biological factors of aquatic animals. Nearly, in all experiments using canola meal had no or not significant adverse effect on animal performance or other factors, however, it can reduce the total cost of the diets. Results of a survey by Lim *et al*. (1998) showed that canola meal can comprise about 31% of the diet of channel catfish (*Ictalurus punctatus*) by replacing half of the amount of soybean meal used in control diet without adversely affecting growth or any other aspect of performance. In a study conducted by De Francesco *et al*. (2004) data showed that long-term feeding a diet in which fish meal was totally replaced by a mixture of plant protein sources significantly affects growth and quality criteria such as morphometric traits, fat deposits, fillet chemical composition and organoleptic characteristics of large commercial size rainbow trout. Forster *et al*. (1999) concluded that dietary phytase has potential to improve the nutritive quality of CPC for rainbow trout and the availability of phytate phosphorus. Sajjadi and Carter (2004) suggested that phytase supplementation to canola meal-based diets can increase phosphorous availability. Extrusion cooking of canola meal improves its nutritive value for Chinook salmon (*Oncorhynchus tshawytscha*) in seawater (Satoh *et al*., 1998). The low canola diet for angel fish (*Pterophyllum scalare*) can result in higher weight gain, but adding of cellulase enzymes in different ratios to diets have no effect in growth parameters and nutrient digestibility(Erdugan and Olmez, 2009). It has been indicated that protein from canola meal can replace up to 10% of protein from fish meal in diets for tilapia (*Oreochromis niloticus*) fry. In pacu (*Piaractus mesopotamicus*) juveniles diets, inclusion of up to 19% of canola meal did not impair the fish growth (Viegas *et al*., 2008). Shafaeipour *et al*. (2008) showed that canola meal has potential to replace substantial levels of fish meal in diets for carnivorous fish (rainbow trout) without compromising performance. There is no declines in fish performance between the highest inclusion levels of the expeller-and solvent-extracted canola meals (Glencross *et al.*, 2004b), but heating expeller meal at 120 or 150°C for 30 min result in progressive reductions of all nutrients and energy digestibilities (Glencross *et al.*, 2004a). For Nile tilapia, canola meal can be included at 35.40% of diets, substituting 48.17% of soybean meal protein in diets in the growing phase (Soares *et al.*, 2001). Affecting digestibility and metabolic utilization of dietary nutrients and energy, also can be seen due to concomitant presence of glucosinolates, depressing the thyroid function in rainbow trout (Burel *et al.*, 2000a). In a 12-week feeding trial, performed by Webster *et al.* (1997), results showed that use of canola meal in practical diets for channel catfish (*Ictalurus punctatus*) may allow producers and feed mills to formulate more economical diets by adding another plant protein source to ingredients used in commercial catfish diets. Study performed by Safari and Boldajii 1985 revealed that 40% inclusion of canola meal is feasible to replace compared with 40% soybean meal, because of improvement of growth performance in rainbow trout. Partial replacement of canola meal results in a higher energy availability to fish and also better performance of fish. High levels of fibre, either alone or together with phytate, have the greatest adverse effects on the digestibility of canola protein products for rainbow trout. Results by Thiessen *et al.* (2004) confirm that Canola-Protein Concentrates (CPC) can replace up to 75% of fish meal protein with no significant decrease in growth or feed efficiency. In an experiment in Nile tilapia, fish were fed diets containing 24.7% CPC, replacing fish meal, soybean meal and corn gluten meal (Borgeson *et al.*, 2006). The fish receiving the CPC diets grew significantly faster than those receiving the control diets (2.29 vs 1.79 g day^{-1}). These findings confirm fish meal replacement with higher levels of CPC in aquafeeds without affecting fish growth performance. Levels of dietary fibre less than 8% generally do not impact fish growth performance indicating that any feasible inclusion rate of canola meal (<50%) should not have a negative effect on fish growth performance (Hilton and Slinger 1986; Poston, 1986). Studies by some researchers have identified some of thyroidal compensation and the goitrogenic issues associated with fish fed canola meals (Higgs *et al.*, 1982; Burel *et al.*, 2001; Leatherland, 1994). These workers also examined the use of canola meal as a function of diet protein content, but reported no negative effects in protein-limiting diets, but concluded that it the total dietary inclusion level of the canola meal is below 30% of the diet with keeping the glucosinolate content of the diet below 2,650 μmol kg^{-1} (Higgs *et al.*, 1983). Davies *et al.* (1990) showed a practical inclusion limit of 15% rapeseed meal in tilapia feeds. It has been showed that rapeseed protein concentrate can comprise 39% of the dietary protein (fish meal only 11%) for rainbow trout without adversely affecting performance (Teskeredzic *et al.*, 1995).

CONCLUSIONS

Replacement of fish meal with different plant proteins in aquaculture diets has some problems as mentioned below:

- Aquaculture diets are nutrient dense and total replacement by plant proteins, such as canola meal, would increase diet mass that result in decreasing in feed intake by animals. It is recommended to add canola meal in diet partially, concomitant with fishmeal
- Virtually canola meal contains heat-labile and heat-stable secondary compounds, such as glucosinolates, tannins, phytate and dietary fibres. These compounds can be eliminated or reduced by new processing technologies to enhance nutritional properties of canola meal

The aquaculture feed industry must find alternatives to fish meal to meet the high rate of industry growth. However canola meal has a relatively low energy and protein content to be widely used as a feed ingredient in fish and shrimp diets, but the processing of canola meal to make new nutrient dense products including improved canola meal or Canola Protein Concentrate (CPC) could play an important role in replacing fish meal in aquaculture feeding.

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