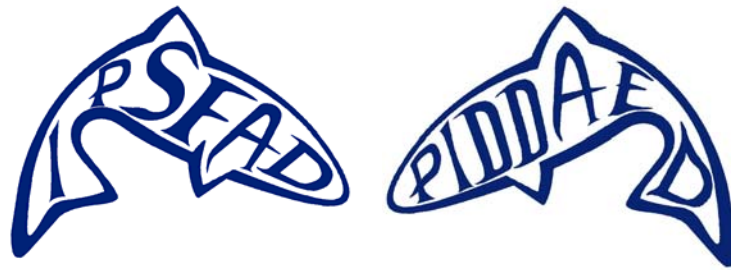


INTERPROVINCIAL PARTNERSHIP FOR
SUSTAINABLE
FRESHWATER AQUACULTURE DEVELOPMENT

DRAFT FINAL REPORT

TOWARDS RATIONAL REGULATIONS FOR
PHOSPHORUS CONTENT OF
CANADIAN SALMONID DIETS



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BACKGROUND

The Feeds Act regulates all legal aspects related to the control and regulation of the sale of animal feeds; the President of the Canadian Food Inspection Agency designates, under section 13 of the Canadian Food Inspection Agency Act, the inspectors and analysts necessary for the administration and enforcement of this Act.

The Feeds Act sets out the minimal/maximal dietary levels of nutrients in animal feeds, as well as accepted deviations from these levels. The establishment of legal nutrient levels in feeds is based on literature values for specific nutrient requirements, and often minimal levels are established to have a large margin of error, in order to avoid potential deficiency symptoms. In the past, the establishment of nutrient requirements has been based on studies measuring growth performance optimization as criteria for establishing minimal dietary requirements, with no regard for environmental impacts.

The current recommended level for P in salmonid feed is 1.0-2.5% (+/- 20%). Recent work has suggested that much lower levels may be fed, particularly in older fish. Given the environmental issues related to excessive effluent P, it would seem appropriate that the regulations related to feed nutrient levels keep pace with current scientific knowledge.

RATIONALE

The technology and scientific approaches used to establish nutrient requirements tend to evolve over time. This is particularly true for nutrients that have an environmental impact in the event over-supplementation. A clear example of this is the case of phosphorus in salmonid diets. Much work has been accomplished over the past 10 years related to the understanding of P requirements in salmonids. We currently have a much better understanding of a range of issues related not only P requirements, its dynamic nature with fish size/age, P bioavailability from different feed ingredients, and proper approaches for requirement expression.

SCIENTIFIC LITERATURE REVIEW

CHARACTERIZATION OF PHOSPHORUS IN AQUACULTURE EFFLUENTS

Effluent from aquaculture facilities has been previously characterized in a number of studies, both from land-based (Bergheim et al., 1984; Stechey & Trudell, 1990; Foy & Rosel, 1991; Rennert, 1994; Axler et al., 1997; Ouellet, 1998) and cage-site operations (Cornel & Whoriskey, 1993). In general, aquaculture effluents are characterized as having low concentrations of measured nutrients (suspended solids, ammonia nitrogen, nitrite, nitrate, total and dissolved P), which is mainly due to the high water flow rates in many land-based culture operations. Ouellet (1998) found that the total P in the effluent from four production sites during the summer months was 0.24 mg·l⁻¹, which is in agreement with previous studies (Stechey & Trudell, 1990; Rennert, 1994), but higher than the average value of 0.125 mg·l⁻¹ total P provided by Cripps (1994) following a summary of earlier studies. Interestingly, Ouellet (1998) also reported that the total P concentration in the effluent during winter months was approximately 50% of that found during the summer season, providing a potential important source of variation between studies when effluent nutrient concentrations are compared. The concentration of effluent P found in these studies is often an order of magnitude lower than that found in other industrial or domestic wastewater (Cripps, 1994). Even at these low P concentrations, the high water flow rates utilized in land-based salmonid operations results in significant P loading in receiving water bodies.

PHOSPHORUS IN FISH NUTRITION

Phosphorus is an essential macro-mineral for all fish species. As in higher vertebrates, P plays a key role in a variety of biological processes, including development, growth and reproduction. Given its physiological importance, P is found throughout the body, and ranks second only to calcium in abundance in the tissues of bony fish (Dosdat, 1992). Phosphorus is found mainly in fish bone, accounting for 86-89% of the total body P, and found mainly as calcium phosphate and hydroxyapatite (Lall, 1991). Bone acts as the principle P reservoir, although P is ubiquitous, being found in cells and extracellular fluids as organic phosphoric acid esters, phosphoproteins, phospholipids, and inorganic phosphate ions (Shearer, 1984). Fish scales represent another important site of P deposition, where as with bony tissue, P is complexed with calcium (Lall, 1989).

PRACTICAL ASPECTS OF PHOSPHORUS NUTRITION

Over the past two decades, increasing concerns over excessive P loading have resulted in a large number of studies aimed at better understanding issues related to phosphorus output from aquaculture production. Given that undigested, un-utilized and wasted feeds are the sole sources of waste-derived P, a large body of work related to nutritional issues has resulted in increased understanding of the role of P in physiological processes. In particular, much effort has been directed toward defining the P requirements for a range of cultured fish species. As well, the development of nutrient-dense diets and replacement of fishmeal with ingredients containing lower levels of P has permitted the formulation of diets that approach the P requirements to a greater degree. These developments, together with technological advances in feeding systems and those that remove undigested feed and feces from effluent water, have greatly reduced the release of P in effluent from aquaculture facilities.

Nutritional requirement of phosphorus

Specific nutrient requirements are determined using empirical methods involving feeding purified or semi-purified diets that are nutritionally complete apart from the nutrient under study. The supplementation of the basal diet with highly available nutrient concentrates permits the

formulation of diets with increasing levels of a particular nutrient. Predetermined criteria are followed during a subsequent feeding trial and the response to increasing levels analyzed to determine the required dietary level. To date, only one study has attempted using a factorial approach (Åsgård & Shearer, 1997); calculation of P requirement using a factorial model incorporating measurements of P availability, feed efficiency and normal whole-body P concentration resulted in a significantly higher P requirement than previously reported (Åsgård & Shearer, 1997). Further work in this area will result in more appropriate models to estimate P requirements.

The nutritional requirements for P have been reported for many economically-important aquatic species; Table 1.3 provides a brief summary of the methodologies and results of these studies. Whereas initial studies on P requirements were aimed at determining inclusion levels to avoid the development of P deficiency, more recent studies have been undertaken to minimize the level of dietary P inclusion and limit P excretion from culture facilities.

Phosphorus deficiency symptoms

Classically, feeding hypophosphatemic diets has been associated with depressed growth rate, feed intake, feed efficiency and reduced bone mineralization (Lall, 1989). Long-term P deficiency has also been reported to alter circulating inorganic P concentrations and alkaline phosphatase activity and certain liver gluconeogenic enzymes. Increased carcass lipid and decreased bone integrity have also been reported (Andrews et al., 1973; Ogino & Takeda, 1978; Lall, 1991). However, given phosphorus' ubiquitous metabolic role, it would be expected that P deficiency would result in widespread short-term physiological perturbations, the persistence of which would precipitate the above-mentioned conditions. More recently, a number of studies have characterized the development of P deficiency symptoms (Baeverfjord et al., 1998) and have identified a variety of relatively short-term indicators for P deficiency. (Skonberg et al., 1997; Sugiura et al., 2000c). Skin and whole body P, Ca and Mg were increased significantly in rainbow trout fed semi-purified diets with increasing levels of supplemental mineral P. Significant differences in tissue mineral levels were observed within 4 weeks, although differences were more evident following 8 weeks feeding the experimental diets. As well, plasma inorganic P was correlated with higher dietary P (Bureau & Cho, 1999), although Ca and Mg were unaffected (Skonberg et al., 1997). Sugiura et al. (2000) reported that concentrations of glucose-6-phosphate, ATP, creatine phosphate, glucose, total lipids and total cholesterol in blood or skeletal muscle were relatively unchanged following 24 days of dietary phosphorus restriction. Inorganic phosphorus and ATP levels in the blood, however, correlated significantly and positively with supplemental P. Furthermore, urinary phosphorus concentration was found to be a rapid and sensitive indicator for dietary intake of phosphorus and phosphorus status of the fish, and had an advantage over conventional response variables in estimating dietary phosphorus requirement (Sugiura et al., 2000b).

Table 1. Summary of experiments evaluating the nutritional requirements of P (g·kg⁻¹ DM) in a number of cultivated fish species.

Req (%)	Species	Source ²	Mass (g)	G:F ³	Response ⁴	Analysis ⁵	Ref.
3.7-5.6	RT	NaP	50	1.1	1,2,3,4,5,7,8	REG	A
3.4-5.4	RT	NaP	35	1.0	1,3,6,7	ANOVA	B
7-8	RT	K ₂ P+NaP	1.2	1.1	1,6,7	BL	C
4.1	RT	NaP	390	1.0	8	REG	D
4.0	CF	NaP	6	1.1	1,3,4,6	ANOVA	E
8	CF	CaP	6	0.99	1,3,6	ANOVA	F
8	CF	NaP	1.8	-	1,6	ANOVA	G
6-7	C	K ₂ P+NaP	5	0.8	1,3,6	BL	H
6	C	NaP	34	0.9	1,2,3,5	ANOVA	I
6	AS	CaP	6.5	0.5	1,3,6	ANOVA	J
6	AS	K ₂ P+NaP	57	0.9	1,3,4,6,8	ANOVA	K
5.6	AS	CaP ₂	15	0.9	1,3,4,7,8	REG	L
10	AS	CaP ₂	1.4	1.45	7	REG	M
5	TIL	NaP	0.8	0.52	1,2,6	ANOVA	N
5	SB	KP	10-20	0.6	1,3,6,8	REG	O
5.8	SB	KP	48	0.7	1,3,6,7	BL	P

¹Species: RT: rainbow trout (*Oncorhynchus mykiss*); CF: catfish (*Ictalurus punctatus*); C: carp (*Cyprinus carpio*); AS: atlantic salmon (*Salmo salar*); TIL: tilapia (*Oreochromis niloticus*); SB: striped bass (*Morone chrysops* × *M. saxatilis*).

²Source of P: NaP: sodium phosphate monobasic; KP: potassium phosphate monobasic; K₂P: potassium phosphate dibasic; CaP₂: calcium phosphate monobasic; CaP: calcium phosphate dibasic.

³Wet mass gain/feed intake (as is basis).

⁴Response variable 1: gain; 2: feed intake; 3: feed efficiency; 4: plasma inorganic phosphorus; 5: P retention; 6: scale and bone ash 7: bone or carcass P; 8 other variables.

⁵Analysis: REG: regression; ANOVA: analysis of variance; BL: broken line

⁶Reference: a: (Rodehutsord, 1996); b: (Ketola & Richmond, 1994); c: (Ogino & Takeda, 1978); d: (Sugiura et al., 2000b); e: (Wilson et al., 1988); f: (Andrews et al., 1973); g: (Lovell, 1978); h: (Ogino & Takeda, 1976); i: (Kim et al., 1996); j: (Ketola, 1975); k: (Lall & Bishop, 1977); l: (Vielma & Lall, 1998a); m: (Åsgård & Shearer, 1997); n: (Robinson et al., 1987); o: (Brown et al., 1993); p: (Dougall et al., 1996).

Studies investigating the effects of increasing dietary P levels on a variety of variables (e.g., growth, tissue P levels, metabolic indicators) have reported differential requirement levels for particular variables. The fact that different indicators were used to establish dietary P requirements may partially explain differences in reported requirement levels between studies. For example, working with rainbow trout, Rodehutschord et al. (1996) reported that the P requirement to attain 95% of the plateau for body weight gain was 3.7 g available P per kg feed DM, whereas that for whole body P deposition was 5.6 g · kg⁻¹ DM. Similar data in atlantic salmon (Baeverfjord et al., 1998) suggest that homeostatic mechanisms respond to short-term P shortages by sacrificing skeletal mineralization in order to ensure the continuity of more critical metabolic roles. Persistence of negative P balance beyond the limits of adaptation leads to a reduction in P reserves, and results in the appearance of pathological symptoms, including reduced growth. Several studies have shown that reduced bone mineralization in fish fed P deficient diets can be reversed by feeding P-replete diets (Hardy et al., 1993), although the capacity to completely reverse certain conditions (deformations, bone lesions) has been questioned (Baeverfjord et al., 1998).

Differences in basal diet composition may also contribute to variations in recommended P levels between studies. Phosphorus requirements are often expressed as a percentage of the diet, assuming 100% availability of the particular P form used in the study. However, given that feed intake is related to the energy density of the feed (Cho et al., 1982), basal diets having different composition may affect feed intake, and thus the absolute intake of dietary P. Therefore, it is preferable to express requirement as a function of the digestible energy of the diet (Rodehutschord, 1996). Using similar arguments, Sugiura et al. (2000) suggested that P requirement be standardized with feed efficiency or weight gain in order to eliminate confounding factors associated with different protocols, growth rates, feed composition, fish size and rearing conditions.

Bioavailability and sources of dietary phosphorus

The bioavailability of a nutrient is defined as the fraction of intake that is absorbed by the intestine and made available for metabolic use or tissue storage (Kotb & Luckney, 1972). Most of the required minerals are partially supplied by dietary ingredients, although the bioavailability of many minerals varies greatly. Depending on the mineral availability and the particular specie requirement, some macro- and micro-minerals are provided as supplements, the bioavailability of which may also vary. Thus it is important to have specific information on the absolute or relative bioavailability of minerals in feedstuffs and supplements in order to accurately meet dietary requirements. Phosphorus bioavailability in monogastric diets has received particular attention in recent years, and has been evaluated using a variety of techniques, including balance methods that provide information related to absolute absorption or retention, relative bioavailability versus a reference source, and in vitro tests of P solubility.

Methods to determine phosphorus bioavailability

Simple balance equations provide values for apparent P absorption (intake-fecal) and retention (intake-fecal-urinary); when compared to the intake values, apparent absorption and retention coefficients are derived (Littell et al., 1995). The use of isotopes permits the determination of true absorption by permitting the quantification of endogenous fecal contribution, although in general, endogenous losses are much lower for monogastrics versus ruminant animals (Kotb & Luckney, 1972). These methods permit the determination of apparent or true P absorption for an entire diet, but not for individual feed ingredients. Individual ingredient P availability may be evaluated if the particular ingredient contributes virtually all of the phosphorus in the experimental diet, or if the P is labelled with ³²P by growing plants using ³²P-labelled fertilizer. However the fish's aquatic environment, coupled with the large proportion

of animal protein used in certain practical fish diets, makes these approaches inconvenient for fish nutritionists.

Availability of P from individual ingredients has been widely studied in fish species by the replacement of a predetermined proportion of a reference diet by a specific ingredient (Cho et al., 1985). This approach has permitted the evaluation of apparent P availability of a wide variety of ingredients (Cho, 1993; Riche & Brown, 1996; Sugiura et al., 1998b), although apparent absorption coefficients provide only estimates of true bioavailability. Furthermore, differences in P levels in the basal reference and individual ingredients can lead to inaccurate estimates of apparent availability, although mathematical corrections for these effects can be employed (Forster, 1999).

In terrestrial monogastrics, P bioavailability of mineral sources have been widely estimated using relative biological assays using highly-available mineral reference sources employing the slope-ratio procedure (Littell et al., 1995). In this method, graded levels of either a test or reference mineral are added to a basal diet and responses (usually bone strength or whole body mineralization) regressed on the dietary mineral level. The ratio of the resulting slopes provides an estimate of the relative bioavailability. The success of this method, however, is contingent on a number of assumptions, which limits this method to concentrated mineral sources rather than macro-ingredients.

The simulation of gastric pH conditions using a variety of acids to provide in vitro solubility estimates has been correlated with in vivo P bioavailability. Hydrochloric acid, citric acid and neutral ammonium citrate have been used for in vitro assays, with citric acid solubility providing the most reliable criterion for the bioavailability of water-insoluble feed phosphates (Gueguen, 1999). These methods have been shown to provide reliable relative estimates for sources having large differences in P availability, although the ability to discriminate small differences in P availability seems to be limited (Soares, 1995).

Factors affecting phosphorus bioavailability

In terrestrial monogastrics, the availability of P is influenced by the dietary Ca: P ratio, with a wide ratio resulting in significantly reduced P bioavailability. In salmonids, several studies have revealed similar results, although the physiological validity of these studies has been questioned (Vielma & Lall, 1998b). The general consensus indicates that under practical conditions, the ratio of dietary Ca:P does not significantly alter P bioavailability, perhaps as a result of different Ca homeostatic mechanisms in fish as compared with terrestrial vertebrates (Flik et al., 1995).

The bioavailability of dietary P ultimately depends on its form and origin; that from mineral and animal sources shares common constraints, whereas P from plant-protein ingredients has distinct characteristics affecting P bioavailability. Phosphorus from mineral and animal origin are generally inorganic, and their bioavailability for terrestrial monogastrics is largely related to their solubility (Soares, 1995). Similar trends are observed in salmonids; sodium and potassium phosphate salts are essentially completely available (NRC, 1993), with decreasing bioavailability for less soluble salts of calcium phosphate (availability of monocalcium phosphate > dicalcium phosphate > tricalcium phosphate (Lall, 1991)). More complex forms of Ca-P, such as hydroxyapatite found in bone are sparingly available (Ogino et al., 1979). As the proportion of bone meal in the diet increases, there is a concomitant decrease in apparent P digestibility (Sugiura, 1998) and P retention (Vielma et al., 1999b). Important species differences exist related to calcium phosphate availability, as agastric species, such as carp, are observed to have a low capacity to retain P from mineral (Ogino et al., 1979) and bone (Sugiura et al., 1998a) sources of calcium phosphate, likely due to the lack of gastric acid secretion. The effect of gastric acidity on increasing mineral bioavailability has been previously linked to regulation of the chelation and complex formation of the element and by altering mineral transport mechanisms (Cross et al., 1990; Wood & Serfaty-Lacrosniere, 1992).

A number of recent studies have reported that apparent P digestibility and retention from diets containing complex forms of inorganic calcium phosphate increased as a result of dietary supplementation with citric (Sugiura et al., 1998a; Vielma et al., 1999b) or formic (Vielma & Lall, 1997) acid, the effect of which was duplicated by reducing the particle size of fish bone-meal from 350 µm to <60 µm (Vielma et al., 1999b). Sugiura et al. (1998) also reported that addition of sodium bicarbonate, thus increasing gastric pH, reduced the apparent digestibility of P in a fish meal-based diet. Therefore, by decreasing the gastric pH and increasing the surface area of the P source, certain P fractions can be more effectively solubilized and bioavailability increased.

In plant-protein sources, between 40-90% of the phosphorus is found bound to phytate (Ravindran et al., 1994), an organic complex that renders P unavailable to monogastric animals due to the lack of endogenous phytase activity required to hydrolyse phytate-bound P (Pointillart et al., 1984). Phytate-P is sparingly available to fish (Ogino et al., 1979); phytate also decreases the availability of a number of other essential minerals (Spinelli et al., 1983; Higgs et al., 1988; Gatlin & Phillips, 1989). Exogenous microbial phytase added to the feed containing phytate-P has been successfully used to improve P bioavailability in a variety of terrestrial monogastrics, and more recently incorporated in diets of a number of aquatic animals with varying degrees of success (Coelho, 1999).

STRATEGIES FOR REDUCED PHOSPHORUS LOADING

Excess P loading from aquaculture production arises uniquely from the feed, either as uningested feed or unassimilated and excreted fractions. This fact provides a clear opportunity in that it limits, and thereby simplifies the possible approaches to address the problem. To date, strategies to reduce P loading from aquaculture have centred on technologies that improve production efficiency or reduce feed waste, those that remove the solid and dissolved fractions of waste P from effluent water, and finally nutritional strategies that reduce P at its source using a number of approaches to improve P bioavailability and retention.

TECHNOLOGICAL DEVELOPMENT

Improved feeding systems

A variety of approaches based on bioengineering and biotechnological strategies have been developed as means to reduce waste load from aquaculture. The use of automatic feeders designed to control distribution by detecting uneaten feed using hydroacoustic probes coupled to a microprocessor control assembly (Summerfelt et al., 1995) is designed to distribute feed to the point of near satiation, while minimizing feed wastage. Related developments attempt to match feed distribution to species-specific diel and seasonal variations in feeding behaviour to maximize growth and reduce uneaten feed (Thorpe & Cho, 1995).

1.10.1.2. Improved solid and dissolved waste removal

Effluent water from land-based aquaculture facilities suffers from two major constraints: low concentration of potential pollutants and high flow rates (Foy & Rosel, 1991; Axler et al., 1997). Treatment of effluent water to concentrate and remove particulate and dissolved P forms has been widely studied, and a number of technologies developed for domestic water treatment facilities have been adapted. A variety of mechanical technologies to remove suspended solids can be divided into those providing mechanical separation (stationary, rotary and vibrating screens, media filtration), sedimentation strategies (sedimentation tanks/ponds, swirl separators, lamella separators) alone or in combination with flocculation (Cripps, 1994). Removal of dissolved forms of phosphorus is particularly problematic given their low concentrations in the effluent. Approaches to remove dissolved P using biological (Proulx et al., 1994; Tang et al., 1997; Dumas et al., 1998; Hussenot et al., 1998) or chemical (Drizo et al., 1997) processes have

been reported. Many of these technologies are subject to high initial capital investment, difficulty in controlling critical operational parameters (Chevalier et al., 2000), and are not applicable for cage culture operations (Cripps, 1994).

Improved fish performance

Endocrine manipulation to improve growth rate and feed efficiency will also reduce waste resulting from animal production. A number of approaches have been studied for fish, including the application of exogenous recombinant somatotropins (recombinant growth hormone (rGH)), which increase appetite, growth rate and feed efficiency in a wide range of aquatic species (McLean & Donaldson, 1993). However, the application of rGH however is limited by the fact that they are normally injected, which is impractical in a production setting. Technologies permitting oral administration of bioactive proteins to fish have been reported (McLean et al., 1999), although these products have not yet been commercialized. Other technologies to improve growth efficiency include the administration of growth hormone releasing factors, antibodies against somatostatin, and the application of placental lactogens (Mayer & McLean, 1995). The orally-applied repartitioning agents generally referred to as β -adrenergic agonists have also been studied in fish species, although work in salmonids using these compounds has yielded inconsistent results (Vandenberg & Moccia, 1998). Technology permitting the production of transgenic fish has developed rapidly over the past decade. Atlantic salmon expressing high levels of growth hormone have shown remarkable growth properties, although these fish have shown only marginally increased feed efficiency. Environmental and food safety regulatory issues are impeding the commercial introduction of this technology (Fletcher & Davis, 1991).

NUTRITIONAL STRATEGIES

A fundamental and key aspect to any waste management plan is its reduction at the source. Lall (1991) proposed several aspects related to nutritional approaches to reduce P output from aquaculture including: decreased feed wastage, improved feed efficiency, inclusion of feed ingredients with high P bioavailability, reduction of P in feeds without affecting fish growth and production efficiency.

High nutrient-dense diets

The formulation of high nutrient dense (HND) diets involves the selection of highly-digestible ingredients and elimination of those having low digestibility, energy and protein levels such as grain by-products rich in complex carbohydrates (Cho et al., 1994). This together with the selection of ingredients having low P contents along with properly balanced protein and energy rations results in highly-digestible diets promoting high growth rates, feed efficiency and reduced waste production, in terms of solids, and solid and soluble nitrogen and phosphorus. Cho and Bureau (1997) reported that using a HND diet results in 30% less P waste (solid and dissolved fractions) than when a practical diet was fed to rainbow trout. As well, feed efficiency is significantly improved by feeding these diets, which would offset increased feed costs as a result of higher inclusion of high-quality ingredients.

Low-phosphorus diets

Diets for salmonid fish species have traditionally been formulated to contain high levels of fish meal and other sources of animal by-products. These ingredients, while being highly digestible in terms of protein and energy (NRC, 1993; Bureau et al., 1999), may also contain elevated levels of P, often complexed with calcium (hydroxyapatite), which is poorly available. Sugiura (1998) reported that graded levels of fish bone meal fed to rainbow trout at dietary levels as low as 2%, resulted in a linear decrease in the apparent availability of a host of minerals including P. However, a number of animal by-products have been shown to have relatively high P apparent digestibility coefficients (ADCs), including blood meal, feather meal and low ash fish

meal and poultry by-product meal (Sugiura et al., 2000a). The replacement of fish meal by blood meal was reported to support high growth rates in rainbow trout and significantly improve P retention (Johnson & Summerfelt, 2000). The ability of feather meal to replace up to 15% of the dietary fish meal (Bureau et al., 2000), coupled with its low level of P versus other animal protein sources, indicates that it is a good candidate for inclusion in low-P diets. Removal of the bone-derived fraction of fish meal by mechanical deboning equipment (Babbitt et al., 1994) or of meat and bone meal by air-classification (Bureau et al., 1999) effectively lowers the P and ash levels in these sources, resulting in significantly improved bioavailability.

SUMMARY

Regulations on feed label P levels must account for variations in fish size/physiological state being cultured, ingredient type and P bioavailability and finally other dietary characteristics, including digestible energy level. This said, recent literature (Sugiura et al. (2000)), and unpublished work from our laboratory (Koko, G MSc thesis) supports the fact that particularly for larger rainbow trout (i.e >150 g body mass), dietary P requirements are significantly lower than previously published standards (NRC 1993). This work supports the proposal to lower minimal P levels for feed to salmonids from current levels.

PHOSPHORUS REGULATIONS IN FOREIGN JURISDICTIONS

DENMARK:

Denmark has faces a situation similar to Canada related to increased concern about P feed levels over 20 years ago and, since 1989, the government enforces very strict regulations about feed conversion rate, energy level and digestibility, phosphorus content, nitrogen content and ash content. The table below summarises some of the regulation imposed:

**Table I. Danish Legislation on Fresh Water Fish Farming
Grower feed
All calculations on 100% dry matter in feed.**

Feed	1. jan 90	1. jan 92	1995
Feed Conversion Rate max.	1.10	1.00	1.00
Gross Energy min. Kcal	5700	6000	5800
Metabolisability min.	74.0%	78.0%	80.0%
Metabolisable Energy min. Kcal	4218	4680	4640
Nitrogen max %	9.0%	8.0%	9.0%
Protein Content max %	56.3%	50.0%	56.3%
Phosphorous Content max. %	1.1%	1.0%	1.0%
Dust max. %	1.0%	1.0%	1.0%

The establishment of feed quotas has led to a major preoccupation with feed conversion ratios as this factor determines the overall productivity of a given farm. The aquaculture industry (feed producers and fish producers) had to develop new technologies and elaborate new strategies that satisfy both producers and governmental regulatory officials. These developments include those related to feed, farm management practices, new technologies permitting sustainable development, approaches taken to monitor the impact of production on surrounding ecosystems, and approaches to permit production in given areas.

OTHER REGIONS:

In Italy, aquaculture is mainly driven by mollusc farming, which covers about 72% of the total production and is carried out in marine and brackish waters; the remainder is mainly due to flow-through trout farming in freshwater environments (21%) for a production estimated in 49 000 t yr⁻¹ (FAO, 2000) There are actually 562 trout farms operating in Italy; most of these are located in northern mountain regions (Piemonte, Lombardia, Veneto, and Friuli) and utilize creek, river, or lake water; the predominant farmed species is the rainbow trout, *Oncorhynchus mykiss*. Many of these fish farms are small, with limited and local production (10–20 t yr⁻¹); trout densities and feed conversion ratio are in the range of 15–35 kgm⁻³ and 1.1–2 respectively. Managers sometimes collaborate with local authorities and natural parks in repopulation programmes aimed at improving the genetics of natural stocks, reintroducing

autochthonous species (*i.e. Salmo trutta marmoratus*) or increasing fish densities in the natural environment. The bibliography related to nutrient and organic matter release in these fish farms is poor, even if freshwater fish farming represents a relevant activity for Italian aquaculture (150 million yr⁻¹) and can greatly impact final receptors that are generally oligotrophic systems.

Bartoli M., D. Nizzoli, Longhi D., Laini A., Viaroli P. 2007. Impact of a trout farm on the water quality of an Apennine creek from daily budgets of nutrients *Chemistry and Ecology* Vol. 23, No. 1, February, 1–11

Of the different countries where regulations exist, Denmark stands out as having one of the most comprehensive and stringent environmental aquaculture regulations (Table 2). It is perhaps interesting to note that aquaculture production within the country has remained relatively static since the introduction of the Danish aquaculture law in 1989. Very few regulations exist on limit on production, diets contents, maximum FCR. More frequent are the regulations about limit on N and P load.

Table 2

Environmental legislation in the European Union with regard to aquaculture development and the environmental control measures of existing aquaculture operations^a

Country	EIA ^b need	Limit on production	Limit on N and P load	Diet contents	Maximum FCR ^c	Water treatment
Belgium	N	N	N	N	N	N
Denmark ^d	N	Y	Y	Y	Y	Y
Germany	N	N	Y	N	N	N
Greece	Y	N	N	N	N	N
Spain	N	N	N	N	N	N
France	Y	Y	N	N	N	N
Ireland	Y	Y	Y	N	N	Y/N
Italy	Y/N	N	Y	N	N	N
Netherlands	N	N	Y	N	N	Y/N
Portugal	N	N	N	N	N	N
UK—England and Wales	N	N	Y	N	N	Y/N
UK—Scotland	N	Y	Y	N	N	Y/N

N = no; Y = yes.

^a European Commission (1995).

^b EIA = environmental impact assessment.

^c FCR = food conversion ratio.

^d Danish regulations include restrictions on feed use, minimum gross energy levels of 6.0 Mcal/kg, maximum nitrogen and phosphorus levels of 8% and 1%, dust content not to exceed 1%, maximum FCR of 1:1 (1:1.2 in seawater, increase between influent and effluent concentrations (freshwater fish farms) must not exceed biological oxygen demand (BOD) of 1 mg/l, suspended solids (SS) 3 mg/l, total phosphorus 0.05 mg/l, total ammonia 0.4 mg/l, and total nitrogen 0.6 mg/l.

Tacon A.G.J.; Forster I.P.; 2003. Aquafeeds and the environment: policy implications.

Aquaculture, Volume 226, Number 1, 31 October 2003, pp. 181-189

DISCUSSIONS WITH REGULATORY AGENCIES

1) CANADIAN FOOD INSPECTION AGENCY (CFIA)

Discussions were held with the following representatives from the CFIA:

- a) Raymond Perron, Evaluation Coordinator,
- b) Michelle Borysenko, Evaluation Specialist

Discussions with CFIA highlighted our proposal to reduce salmonid feed P label levels as well as the scientific evidence to support lowered feed label levels for P.

MEETING HIGHLIGHTS

1. CFIA mentioned that there are current provisions to register feeds having P levels outside the legal levels.
2. CFIA mentioned an on-going effort to review and update Table 4 of Feeds Act, including P levels for salmonids.
3. CFIA suggested that we speak with Animal Nutrition Association of Canada to work to change label requirements.

2) ANIMAL NUTRITION ASSOCIATION OF CANADA (ANAC)

Discussions were held with the following representatives from the ANAC:

- a) Kathleen Sullivan, General Manager
- b) Julie Latrémouille, Regulatory Affairs

ANAC staff was sent documentation related to current project to amend Table 4, regarding salmonid feeds. We summarized our activities to date, and our desire to work with ANAC to accomplish Table 4 amendments.

MEETING HIGHLIGHTS

1. ANAC has convinced CFIA to review Table 4 for all animal species
2. This is an on-going consultation and will continue for next 18 months (according to 1 ANAC member).
3. Partnership has requested that we be consulted regarding P levels for salmonid feeds- this was accepted by ANAC.
4. We are attempting to amend upcoming meeting agenda during Eastern Nutrition Meeting (May 2007) to present the proposed fish feed labels, regarding P. (see Appendix 1)

Appendix 1: Feed workshop- P regulations issues will be added to agenda



Product Registration Workshop
Agenda
May 15, 2007
Hotel Palace Royal, Quebec City, Quebec

- 10:00 a.m. Welcome and scope of workshop
Kathleen Sullivan, General Manager, ANAC
Linda Morrison, National Manager, Feed Section, CFIA
- 10:10 a.m. Review of ANAC survey – Julie Latrémouille, Regulatory Affairs, ANAC
- 10:30 a.m. General Submission Flow – Annie Savoie, Biotechnology Specialist, CFIA
- 11:15 a.m. Building your label (part 1) – Raymond Perron, Evaluation Coordinator, CFIA
- 12:00 Lunch with keynote speaker: Veterinary Drug Directorate on Veterinary Natural Health Product
- 1:30 p.m. Building your label (part 2) – Raymond Perron, CFIA
- 2:30 p.m. Data Quality (part 1) – CFIA
Catherine Italiano, Toxicology/Biotechnology Coordinator
Michelle Borysenko, Evaluation Specialist
Annie Savoie, Biotechnology Specialist
- 3:15 p.m. Break
- 3:30 p.m. Data Quality (part 2) – Ms. Italiano; Ms. Borysenko; Ms. Savoie
- 4:30 p.m. Question & Answer Forum
- 4:50 p.m. Closing Remarks
Kathleen Sullivan and Linda Morrison
- 5:00 p.m. Adjournment

Note: workshop material will be provided on site.