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Review

Effect of plant protein sources on growth rate in salmonids: Meta-analysis of dietary inclusion of soybean, pea and canola/rapeseed meals and protein concentrates

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ABSTRACT

Six parallel meta-analyses were conducted to determine the effect of the dietary inclusion rate of pea meal (PM), pea protein concentrate (PPC), soybean meal (SBM), soy protein concentrate (SPC), canola/rapeseed meal (CM) and canola/rapeseed protein concentrate (CPC) on the specific growth rate (SGR) of salmonid fish. From 1794 growth studies involving the feeding of these six test ingredients to salmonid fish, 45 studies were selected for inclusion in the meta-analysis. The relationship between SGR and the dietary inclusion level of plant-based feed ingredients was calculated using Cohen's d (CD), which measures differences between control and experimental means. The results of these meta-analyses showed an increase in the dietary inclusion of SBM, SPC, CM and CPC (not PM or PPC) leads to a significant reduction in SGR. Weighted regressions of inclusion level for each test ingredient on effect size showed significant, negative linear relationships between SGR and dietary inclusions of SBM, SPC, CM and CPC. For PM and PPC, there was no significant relationship between SGR and inclusion rate. The results suggest that the effect of plant ingredients on growth performance of salmonids depends on the specific ingredients and their inclusion levels. The higher effect sizes observed when ingredients are fed at lower inclusion levels and lack of significant impact of feeding mixed diets suggest that feeding low levels of several ingredients might be beneficial.

Contents

Abbreviations: CD, Cohen's d; CM, Canola meal; CPC, Canola protein concentrate; PM, Pea meal; PPC, Pea protein concentrate; SBM, Soybean meal; SD, Standard deviation; SEM, Standard error of the mean; SGR, Specific growth rate; SPC, Soy protein concentrate.

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1. Introduction

Depletion of wild fish stocks has led to the necessity of including plant-based ingredients in fish feeds. A wide variety of plant-based ingredients and their use in fish feeds have been investigated, including pulses, such as soybeans, peas, faba beans and lupins, as well as other protein sources such as canola, rapeseed, flax and cottonseed meal. The general consensus of these studies is that replacing fish meal with plant products at high levels in salmonid diets will negatively impact growth (Barrows et al., 2007; de Francesco et al., 2004; de la Higuera et al., 1988; Drew et al., 2005; Glencross et al., 2004; Leatherland and Hilton, 1998; Lee et al., 2006). These studies, however, use different methodologies to assess the ingredients. The use of controls and test ingredient inclusion levels vary, as do the ways in which growth is depicted, including average daily gain, specific growth rate (SGR) and thermal growth coefficient (TGC). SGR is a popular reporting method for fish growth studies, although the use of TGC is increasing. There are discrepancies among some papers in the calculations of these parameters, as in some cases, when growth is reported as SGR, the correct logarithmic equation is not used, rather calculations used more commonly to present other measurements of growth, such as average daily gain and percent per day. What remains constant, regardless of the calculation utilized, is their purpose, which is to serve as an indicator of the effect of the test treatment on fish growth.

Several reviews have been conducted on this topic of feeding plant proteins to fish. In a meta-analysis, Sales (2009) investigated the effect of soybean meal (SBM) on different fish species and Enami (2011) reviewed the use of canola/rapeseed in fish feeds. These papers examine a single protein source, which makes comparisons between ingredients difficult. A review article by Francis et al. (2001) addresses this dilemma, although the focus is on the antinutritive properties of feed ingredients, rather than fish growth. Hua and Bureau (2012), used meta-analysis and simulated data to examine the effect of plant proteins on TGC.

We investigated six plant-based fish feed ingredients by systematic review and meta-analysis, using a standardized methodology to determine the relationships between the dietary inclusion of these feed ingredients on growth in salmonids. The six ingredients chosen for this study were: pea meal (PM), pea protein concentrate (PPC), SBM, soy protein concentrate (SPC), canola/rapeseed meal (CM) and canola/rapeseed protein concentrate (CPC). These ingredients vary in their nutrient (Table 1) and antinutrient composition (Burel et al., 2000; Drew et al., 2005; Hilton and Slinger, 1986; Lee et al., 2006; Oliva-Teles et al., 1994; Torstensen et al., 2008). They were selected on the basis of available data and because they are recognized as commonly acceptable protein sources. All are used in practice and are included in many commercial salmonid diets. Protein concentrates from each of the three plant sources were selected to determine if feeding these ingredients affects salmonid growth differently from conventional meals.

The purpose of this meta-analysis is to: 1) Examine the completeness of the research related to the replacement of fish meal with PM, PPC, SBM, SPC, CM and CPC in salmonid diets and identify any information gaps. 2) Form a comprehensive illustration and comparison of all available data in the literature.

2. Materials and methods

2.1. Search strategy and inclusion criteria

Mix Version 2.0 (Bax, 2010), a professional software for performing meta-analysis in Excel, was used to conduct the meta-analyses following the principles provided by the Cochrane Handbook for Systematic Reviews of Interventions (Higgins and Green, 2008) and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement (Moher et al., 2009). In January of 2012, study selection was conducted searching ISI WEB OF KNOWLEDGE (1899–2010) and SCIRUS (1800–2011) using the following search terms and Boolean operators: Topic (complete document) = (canola OR pea OR peas OR rapeseed OR soy OR soya OR soybean) AND Topic (complete document) = (char OR salmon OR trout) AND Topic = (growth OR SGR). These studies were separated based on ingredient type: PM, SBM, CM, PPC, SPC and CPC. Manual searches supplemented the database search strategy. To prevent selection bias, pre-specified inclusion criteria were: 1) random allocation of animals; 2) use of plant protein, not plant oil; 3) growth study; 4) use of salmonid fish species; 5) presence of a control group not fed the test ingredient; 6) written in English or French. Duplicate reports, reviews and conference proceedings were removed. Studies that included high glucosinolate, high euricic acid rapeseed meal were excluded. Only defatted SBM and CM were included in their respective meta-analyses. Studies investigating other main effects, such as the effect of adding phytase to the test diets were excluded, as were any studies where the test ingredient was included in the control diet. If the study contained diets with more than one test ingredient, results were analyzed separately for each individual test ingredient.

2.2. Data extraction

A standardized proforma was used to independently extract relevant data from each study. These data included information on: study design, sample size, species, test ingredient type and inclusion level. Additional requirements included the use of an appropriate control diet, specific growth rate (SGR) as the measure of growth or sufficient data to calculate SGR and a reported standard deviation (SD) or data sufficient to calculate SD.

2.3. Statistical analysis

SGR values reported are based on the following equation: $SGR = 100 * [(\ln W_1) - (\ln W_0)] / D$, where W_0 and W_1 represent initial and final weights (experimental unit means), respectively, and D represents the number of feeding days. Where trials reported growth as TGC, SGR was calculated by the authors using other growth information reported (Romarheim et al., 2006). In trials with factorial designs, only the growth data for the treatments fed were compared (Yamamoto et al., 2002). In cases where experimental diet formulation changed during the course of the experiment, data from the first experimental period (until the change in dietary formulation) was used in the analysis, as in following periods, start weights differed among treatments (Torstensen et al., 2008). If data were not separated, the entire experimental period was used to calculate SGR.