Fishmeal with different levels of biogenic amines in Aquafeed: Comparison of feed protein quality, fish growth performance, and metabolism

The current study investigated the effects of fishmeal quality (low (LB) and high (HB) levels of endogenous biogenic amines) and feed extrusion temperatures (100 and 130 °C) on protein oxidation indicators and amino acids racemization (AAR) in extruded fish feed. Furthermore, the study investigated the accompanying effects on feeding the diets to juvenile rainbow trout (Oncorhynchus mykiss) on fish growth performance, in vivo amino acids (AAs) digestibility, and liver and plasma metabolites following an 8-week feeding trial. A principal component analysis (PCA) showed that better growth performance, secondary oxidation products, and racemized methionine correlated positively with a low content of biogenic amines, whereas the primary oxidation product, protein hydroperoxides, and in vivo AAs digestibility correlated positively with high content of biogenic amines. At an extrusion temperature of 100 °C, the growth performance of the fish decreased when the content of biogenic amines increased. In contrast, at an extrusion temperature of 130 °C, the growth performance was unaffected by the level of biogenic amines. The latter could be a consequence of the higher level of protein oxidation of LB fishmeal compared to HB fishmeal at this temperature. Higher levels of liver pyruvate and plasma lactate together with high level of betaine and AAs in both liver and plasma were associated with the LB fishmeal diets. The lower concentration of AAs especially in liver of fish fed with HB fishmeal demonstrated that these AAs might not be supplied sufficiently for the tricarboxylic acid cycle to generate energy and therefore a decreased growth was found in fish fed this diet. Furthermore, the results indicated that biogenic amines and feed attractants such as betaine are more decisive for evaluating the quality of fishmeal than protein quality parameters.
Nitrate removal from aquaculture effluents using woodchip bioreactors improved by adding sulfur granules and crushed seashells

This study examined the effects on nitrate removal when adding sulfur granules and crushed seashells to a woodchip bioreactor treating aquaculture effluents. Using a central composite design, the two components were added at three levels (0.000, 0.125 and 0.250 m³/m³ bioreactor volume) to 13 laboratory-scale woodchip bioreactors, and a response surface method was applied to find and model the optimal mixture ratios with respect to reactor performance. Adding 0.125 m³/m³ sulfur granules improved the total N removal rate from 3.27±0.38 to 8.12±0.49 g N/m³/d compared to pure woodchips. Furthermore, the inclusion of crushed seashells together with sulfur granules helped to maintain the pH above
7.4 and prevent a production (i.e., release) of nitrite. According to the modeled response surfaces, a sulfur granule:crushed seashell:woodchip mixture ratio containing about 0.2 m³ sulfur granules and 0.1 m³ crushed seashells per m³ reactor volume would give the best results with respect to high N removal and minimal nitrite release. In conclusion, the study showed that N removal in woodchip bioreactors may be improved by adding sulfur granules and seashells, contributing to the optimization of woodchip performance in treating aquaculture effluents.

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A comprehensive approach to assess feathermeal as an alternative protein source in Aquafeed
The effect of partially replacing fishmeal in aquafeed with feathermeal (FTH) at three levels (0%: FTH0, 8%: FTH8, 24%: FTH24) and two extrusion temperatures (100 and 130 °C) were evaluated in rainbow trout (Oncorhynchus mykiss) with respect to growth performance, metabolism response, and oxidative status of the feed proteins. Multivariate data analyses revealed that FTH24 correlated positively with high levels of: oxidation products, amino acids (AA) racemization, glucogenic AAs level in liver, feed intake (FI), specific growth rate (SGR), and feed conversion ratio (FCR); and low AAs digestibility. Both FI and SGR were significantly increased when 8 and 24% feathermeal was included in the feed extruded at 100 °C, while there was a negative effect on FCR in fish fed FTH24. In conclusion, higher oxidation levels in FTH24 may give rise to metabolic alterations while lower levels of FTH may be considered as fishmeal substitute in aquafeed for rainbow trout.
First experiences from full-scale denitrifying woodchip bioreactors operated end-of-pipe at commercial RAS

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Micro particles in Danish Model Trout Farms

General information
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Organisations: National Institute of Aquatic Resources, Section for Aquaculture
Authors: de Jesus Gregersen, J. (Intern), Pedersen, P. B. (Intern), Pedersen, L. (Intern), Møller, B. (Intern), Dalsgaard, A. J. T. (Intern)
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Optimizing RAS operations by new measures

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Scopus rating (2009): SJR 0.717 SNIP 1.424
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.734 SNIP 1.154
Scopus rating (2007): SJR 0.699 SNIP 1.088
Web of Science (2007): Indexed yes
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Particle surface area and bacterial activity in recirculating aquaculture systems

Suspended particles in recirculating aquaculture systems (RAS) provide surface area that can be colonized by bacteria. More particles accumulate as the intensity of recirculation increases thus potentially increasing the bacterial carrying capacity of the systems. Applying a recent, rapid, culture-independent fluorometric detection method (Bactiquant®) for measuring bacterial activity, the current study explored the relationship between total particle surface area (TSA, derived from the size distribution of particles >5 μm) and bacterial activity in freshwater RAS operated at increasing intensity of recirculation (feed loading from 0.043 to 3.13 kg feed m⁻³ make-up water). Four independent sets of water samples from different systems were analyzed and compared including samples from: (i) two individual constructed wetlands treating the effluent system water from two commercial, freshwater rainbow trout (Oncorhynchus mykiss) farms of different recirculation intensity; (ii) an 8.5 m³ pilot scale RAS; and (iii) twelve identical, 1.7 m³ pilot scale RAS assigned one of four micro-screen treatments (no micro-screen, 100, 60, or 20 μm mesh size micro-screens) in triplicate. There was a strong, positive, linear correlation (p < 0.05) between TSA and bacterial activity in all systems with low to moderate recirculation intensity (i.e. feed loading ≤1 kg feed m⁻³ make-up water). However, the relationship apparently ceased to exist in the systems with highest recirculation intensity (feed loading 3.13 kg feed m⁻³ make-up water; corresponding to 0.32 m³ make-up water kg⁻¹ feed). This was likely due to the accumulation of dissolved nutrients sustaining free-living bacterial populations, and/or accumulation of suspended colloids and fine particles less than 5 μm in diameter, which were not characterized in the study but may provide significant surface area. Hence, the study substantiates that particles in RAS provide surface area supporting bacterial activity, and that particles play a key role in controlling the bacterial carrying capacity at least in less intensive RAS. Applying fast, culture-independent techniques for determining bacterial activity might provide a means for future monitoring and assessment of microbial water quality in aquaculture farming systems.

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Transforming waste into new resources: optimizing sludge hydrolysis to improve nitrogen removal in aquaculture through denitrification

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Organisations: National Institute of Aquatic Resources, Section for Aquaculture
Authors: Letelier-Gordo, C. O. (Intern), Pedersen, P. B. (Intern), Dalsgaard, A. J. T. (Intern)
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Åbent hus på Lundby Dambrug
Increasing levels of dietary crystalline methionine affect plasma methionine profiles, ammonia excretion, and the expression of genes related to the hepatic intermediary metabolism in rainbow trout (Oncorhynchus mykiss)

Strictly carnivorous fish with high requirements for dietary protein, such as rainbow trout (Oncorhynchus mykiss) are interesting models for studying the role of amino acids as key regulators of intermediary metabolism. Methionine is an essential amino acid for rainbow trout, and works as a signalling factor in different metabolic pathways. The study investigated the effect of increasing dietary methionine intake on the intermediary metabolism in the liver of juvenile rainbow trout. For this purpose, five diets were formulated with increasing methionine levels from 0.60 to 1.29% dry matter. The diets were fed in excess for six weeks before three sampling campaigns carried out successively to elucidate (i) the hepatic expression of selected genes involved in lipid, glucose and amino acid metabolism; (ii) the postprandial ammonia excretion; and (iii) the postprandial plasma methionine concentrations. The transcript levels of enzymes involved in lipid metabolism (fatty acid synthase, glucose 6 phosphate dehydrogenase and carnitine palmitoyl transferase 1 a), gluconeogenesis (fructose-1,6-biphosphatase) and amino acid catabolism (alanine amino transferase and glutamate dehydrogenase) were significantly affected by the increase in dietary methionine. Changes in gene expression reflected to some extent the decrease in ammonia excretion (P=0.022) and in the hepatosomatic index (HSI; P
Modelling the effects of dietary methionine level and form on postprandial plasma essential amino acid profiles in rainbow trout (Oncorhynchus mykiss)

Aquafeed formulation is susceptible to affect amino acid (AA) availability for metabolic functions. Statistical models were applied to quantify the effect of dietary methionine level (from 6.01 to 16.17 g kg−1 dry matter) and form (free, coated or bound) on postprandial concentrations of plasma essential amino acid (EAA) in rainbow trout. Twelve diets were formulated with pea and soya protein concentrate or fish meal as the main protein ingredients and were supplemented or not with increasing amount of either crystalline or agar-coated methionine. Fish were acclimatized to one of the 12 diets for 6 weeks before postprandial plasma sampling (six sampling points up to 36 h, seven fish each time), further analysed for EAA content. Using generalized additive models, we show that (i) dietary methionine level and form explained 74% postprandial methionine plasma variations and that (ii) the methionine dietary form and plasma concentrations significantly affected the plasma concentrations of the other EAAs. Finally, linear model revealed a positive relationship (R2 > 0.9) between plasma concentrations of the three branched-chain AAs under the present experimental conditions. The results obtained add new information on the dietary effects on EAAs in the plasma availability and the interactions between them.

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Publication Information
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New approaches to improve the removal of dissolved organic matter and nitrogen in aquaculture
Reducing the environmental impact of aquaculture requires that waste treatment practices are further improved. Currently applied treatment technologies achieve good solids removal and nitrification. Yet discharge of nitrogen (N) and organic matter (OM) from fish farms is still often an important issue constraining aquaculture development, especially in sensitive areas. Possibilities for efficient end-of-pipe treatment exist for large intensive recirculating aquaculture systems (RAS), while smaller and especially the technically less advanced fish farms, struggle to...
Optimizing nitrate removal in woodchip beds treating aquaculture effluents

Nitrate is typically removed from aquaculture effluents using heterotrophic denitrification reactors. Heterotrophic denitrification reactors, however, require a constant input of readily available organic carbon (C) sources which limits their application in many aquaculture systems for practical and/or economic reasons. A potential alternative technology for removing nitrate currently applied for treating surface and drainage water is based on using wood by-products as a carbon source for denitrification. Using lab-scale horizontal-flow woodchip filters, the current study investigated the potential of optimizing woodchip reactors for treating aquaculture effluent. A central composite design (CCD) was applied to assess the effects of simultaneously changing the empty bed contact time (EBCTs of 5.0-15.0 h; corresponding to theoretical hydraulic retention times of 3.3-9.9 h) and bicarbonate (HCO₃⁻) inlet concentration (0.50-1.59 g HCO₃⁻/l) on the removal of NO₃-N at commercial farms. Laboratory studies were therefore carried out to test whether removal rates in woodchip bioreactor could be improved. Paper IV demonstrated that simultaneously changing the hydraulic retention time and adding bicarbonate to the inlet water of laboratory-scale woodchip bioreactors improved N removal. Moreover, the study indicated that sulfur-based autotrophic denitrification is potentially important to the overall N removal in woodchip bioreactors. A subsequent laboratory study demonstrated that higher N removal rates could be achieved in mixotrophic denitrification reactors containing mixtures of woodchips, sulfur granules and seashells (Paper V).

12 Altogether, the woodchip studies sustained that denitrifying woodchip bioreactors may represent an alternative and simple method for removing nitrate from dilute/low-organic-strength aquaculture effluents for which application of, for example, heterotrophic denitrification reactors needing input of organic carbon sources is generally not feasible.

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There is a need for simple, maintenance-free technologies for removing nitrogen (N) from aquaculture effluents. Denitrifying woodchip bioreactors have been used successfully to remove nitrate-N (NO₃-N) from ground and surface waters and may potentially be applied to dilute aquaculture effluents as well. Real-life applicability in commercial, outdoor fish farms including practical start-up issues such as e.g. time till stable performance and potential leaching are, however, unknown to the industry. This case study consequently investigated the temporal performance of a woodchip bioreactor (12.5 m³) during start-up. The bioreactor was operated end-of-pipe at a commercial, outdoor rainbow trout (Oncorhynchus mykiss) farm in Denmark operated at low recirculation intensity. Applying an empty bed contact time (EBCT) of 5 h, the specific objectives of the study were to resolve: i) how fast the bioreactor would start to remove NO₃-N; ii) how fast steady state was achieved; iii) which NO₃-N removal rates could be attained at the relatively low effluent temperature (∼8 °C) and iv) to which extent any concomitant leaching of phosphorous (P), ammonia or organic matter would occur. In- and outlet grab samples were obtained every 6 h until the bioreactor was in steady state (2 weeks) followed by weekly 24 h pooled samples for another 3 weeks (5 weeks in total). Additional grab samples were obtained from 9 sampling ports within the bioreactor on 3 consecutive days during steady state. Samples were analyzed for dissolved nutrients (total N, nitrate, nitrite, ammonium, total phosphorous, ortho-phosphorous, BOD5 and COD). In addition, oxygen, temperature and pH were logged every 30 min while sampling and alkalinity were measured once a week. Removal of NO₃-N started immediately and remained stable at 7.06 ± 0.81 g NO₃-N/m³/d (n = 6) throughout the sampling period. Increased effluent NO₂-N concentrations (peaking at 1.14 mg NO₂-N/l after 4–5 days) were transiently observed during the initial 11 days. After that, the woodchip bioreactor was largely in steady state with respect to N-balances corroborated by a close match between filtered total-N (TNdiss) and NO₃-N removal rates. Measurements within the bed showed that the majority of the influent dissolved oxygen (DO) was consumed within the first part of the bioreactor and that NO₃-N removal thereafter proceeded gradually with distance within the bed. Leaching of non-structural, dissolved organic compounds were observed just after startup, causing a short-term (1 week) increase in effluent concentrations of COD, BOD5, P and
ammonium. Additional measurements carried out until 147 days after start-up showed that the woodchip bioreactor continued to remove TN<sub>diss</sub> at an average removal rate of 7.81 ± 0.82 g N/m<sup>3</sup>/d, and that the initial leakage of P stopped altogether. In summary, the study demonstrated that woodchip bioreactors can effectively remove NO<sub>3</sub>-N from dilute aquacultural effluents at low temperatures and commercial conditions and that stable performance is achieved within a few weeks.

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Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.72 SNIP 1.437 CiteScore 1.61
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
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Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.615 SNIP 1.123
Scopus rating (2004): SJR 0.547 SNIP 1.204
Scopus rating (2003): SJR 0.893 SNIP 1.435
Supplementing enzymes to extruded, soybean based diet improves breakdown of non-starch polysaccharides in rainbow trout (Oncorhynchus mykiss)

Plant-based feed ingredients typically contain remnants of dietary fibres [DF; non-starch polysaccharides (NSP) and lignin] that have various antinutritive effects in carnivorous fish. Exoenzymes have been shown to improve the apparent digestibility coefficients (ADC) of plant-based diets presumably by assisting in the breakdown of NSP. This study examined the effects on NSP degradation when supplementing β-glucanase, xylanase, protease or a mix of the three enzymes to an extruded, juvenile rainbow trout (Oncorhynchus mykiss) diet containing 344 g kg⁻¹ de-hulled, solvent-extracted soybean meal (SBM). The NSP content in the non-supplemented control diet and in faecal samples from the dietary treatment groups was analysed to determine the recovery/apparent digestibility of cellulose and total non-cellulosic polysaccharide (T-NCP) sugar monomers. The enzymes had significant, positive effects at the pH range and temperature prevailing in the gastrointestinal tract: β-glucanase improved the ADC of mannose, galactose and uronic acids; xylanase and protease improved the ADC of xylose; and protease furthermore improved the ADC of mannose and uronic acids. There were no effects when supplementing all three enzymes together. In conclusion, exogenous enzymes may potentially be applied to fish feed containing SBM, assisting in the breakdown of NSP and alleviating some of the antinutritive effects...
An optimized and simplified method for analysing urea and ammonia in freshwater aquaculture systems

This study presents a simple urease method for analysis of ammonia and urea in freshwater aquaculture systems. Urea is hydrolysed into ammonia using urease followed by analysis of released ammonia using the salicylate-hypochlorite method. The hydrolysis of urea is performed at room temperature and without addition of a buffer. A number of tests were performed on water samples obtained from a commercial rainbow trout farm to determine the optimal urease concentration and time for complete hydrolysis. One mL of water sample was spiked with 1.3 mL urea at three different concentrations: 50 lg L\(^{-1}\), 100 lg L\(^{-1}\), and 200 lg L\(^{-1}\) urea-N. In addition, five concentrations of urease were tested, ranging from 0.1 U mL\(^{-1}\) to 4 U mL\(^{-1}\). Samples were hydrolysed for various time periods ranging from 5 to 120 min. A urease concentration of 0.4 U mL\(^{-1}\) and a hydrolysis period of 120 min gave the best results, with 99.6–101% recovery of urea-N in samples spiked with 100 or 200 lg L\(^{-1}\) urea-N.

The level of accurate quantification of ammonia using the method is 50 lg L\(^{-1}\) NH\(_4^+\)-N, and the detection level is 5–10 lg L\(^{-1}\) NH\(_4^+\)-N.

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ISI indexed (2012): ISI indexed yes
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Scopus rating (2011): SJR 0.725 SNIP 0.964 CiteScore 1.37
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.645 SNIP 0.936
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.637 SNIP 0.904
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Degradation of urea, ammonia and nitrite in moving bed biofilters operated at different feed loadings

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Dietary methionine level affects growth performance and hepatic gene expression of GH-IGF system and protein turnover regulators in rainbow trout (Oncorhynchus mykiss) fed plant protein-based diets

The effects of dietary level of methionine were investigated in juvenile rainbow trout (Oncorhynchus mykiss) fed five plant-based diets containing increasing content of crystalline methionine (Met), in a six week growth trial. Changes in the hepatic expression of genes related to i) the somatotropic axis: including the growth hormone receptor I (GHR-I), insulin-like growth hormones land II (IGF-I and IGF-II, respectively), and insulin-like growth hormone binding protein-1b (IGFBP-1b); and ii) protein turnover: including the target of rapamycin protein (TOR), proteasome 20 delta (Prot 20D), cathepsin L, calpains 1 and 2 (Capn 1 and Capn 2, respectively), and calpastatin long and short isoforms (CAST-L and CAST-S, respectively) were measured for each dietary treatment. The transcript levels of GHR-I and IGF-I increased linearly with the increase of dietary Met content (P <0.01), reflecting overall growth performances. The apparent capacity for hepatic protein degradation (derived from the gene expression of TOR, Prot 20D, Capn 1, Capn 2, CAST-L and CAST-S, respectively) were measured for each dietary treatment. The transcript levels of GHR-I and IGF-I increased linearly with the increase of dietary Met content (P <0.01), reflecting overall growth performances. The apparent capacity for hepatic protein degradation (derived from the gene expression of TOR, Prot 20D, Capn 1, Capn 2, CAST-L and CAST-S) decreased with increasing dietary Met level in a relatively linear manner. Our results suggest that Met availability affects, directly or indirectly, the expression of genes involved in the GH/IGF axis response and protein turnover, which are centrally involved in the regulation of growth. (C) 2014 Elsevier Inc. All rights reserved.

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Effect of plant proteins and crystalline amino acid supplementation on postprandial plasma amino acid profiles and metabolic response in rainbow trout (Oncorhynchus mykiss)

The use of aquafeeds formulated with plant protein sources supplemented with crystalline amino acids (CAAs) is believed to influence amino acid (AA) uptake patterns and AA metabolic fate. Oxygen consumption and ammonia excretion rates were measured in rainbow trout (468.5 ± 86.5 g) force fed 0.75 % of their body mass with a diet based on either (1) fish meal (FM), (2) pea protein concentrate (PPC), or (3) pea protein concentrate supplemented with histidine, lysine, methionine and threonine (PPC+) to mimic FM AA profile. The specific dynamic action and nitrogen quotient (NQ) were calculated for 48 h of the postprandial period. In parallel, plasma AA concentrations were measured in blood samples withdrawn from the caudal vein before and then 2, 4, 6, 8, 12, 20, 32 and 48 h after feed administration. The unbalanced diet PPC had a significantly higher NQ compared to FM (0.29 ± 0.09 and 0.18 ± 0.04, respectively), and plasma profiles of essential AAs reflected the dietary deficiencies. Supplementation with CAA in diet PPC+ resulted in an intermediary NQ (0.21 ± 0.04) and significantly affected plasma AA profiles, presenting greater and faster rises followed by sharp decreases compared to FM. The strongest effect was observed for methionine, presenting threefold higher concentrations at peak time for PPC+ compared to FM (297.0 ± 131.8 nmol ml(-1)), respectively. The differences in AA availability and metabolic profile in the pea diets compared to the FM diet were believed to be caused by an unbalanced dietary AA profile and CAA supplementation, rather than inclusion of plant protein concentrate.
End-of-pipe removal of nitrogen using woodchip beds

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Feed composition affects sludge as a resource for denitrification

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Nitrogen waste from rainbow trout (Oncorhynchus mykiss) with particular focus on urea

Particulate and dissolved nitrogen (N) waste components are removed in recirculating aquaculture systems (RAS) using different cleaning technologies, and to dimension and optimize their removal efficiency requires that the expected daily load of the different waste forms can be estimated. Using a laboratory, mass-balance approach, the current study examined the effects of commercially applied feeding levels on the loading of different N waste forms, including daily fluctuations in dissolved total nitrogen (TN), total ammonia nitrogen (TAN), urea-N, and non-characterized, dissolved N deriving from juvenile rainbow trout (Oncorhynchus mykiss). In addition, the study examined whether there was a removal of urea-N across a moving bed biofilter operated as end-of-pipe under commercial conditions. The laboratory, mass-balance study showed that there were no effects of feeding levels (1.3, 1.5 or 1.7% of the biomass per day) on the excretion of dissolved N components, which constituted the majority of total N waste (>81.6% on average). The excretion of urea-N and non-characterized, dissolved N components constituted 12–13% and 9–11%, respectively of dissolved TN. The excretion of urea-N was largely constant and independent of the daily feeding practice, whereas that of non-characterized N appeared to reflect the daily feeding activity, following the trends in TN and TAN. The time limited feeding regime applied in the laboratory study resulted in a pulse in the excretion of TAN that a biofilter may be unable to fully level out, potentially resulting in unnoticed, critical water quality conditions in intensive RAS during certain times of the day. Particulate N waste constituted a minor fraction of total N waste (<18.4% on average), and the actual loading depended on the digestibility of dietary protein/nitrogen. Results from the commercially operated, nitrifying biofilter showed that urea-N was removed at a rate of 0.014 g N m⁻² day⁻¹. Compared to the removal of TAN (0.208 g N m⁻² day⁻¹), the moving bed biofilter was 1.07 times more active in removing dissolved N than immediately expected when only considering TAN.

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Recirculation technology getting mature: Preface

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Reducing the dietary protein: Energy (P: E) ratio changes solubilization and fermentation of rainbow trout (Oncorhynchus mykiss) faeces

Nutrients discharged from aquaculture industries can detrimentally affect water recipients, and this problem must be addressed if the production is to be decoupled from the natural environment. Denitrification is a process by which nitrate is removed using soluble, readily biodegradable carbon compounds. Hydrolysis and concomitant fermentation of organic solids produces such soluble carbon compounds e.g. in the form of volatile fatty acids (VFAs). The current study examined the hydrolysis and the production of VFAs, the carbon:nitrogen ratio (C:N), and the release of nutrients (phosphorus and ammonium) from hydrolyzing and fermenting settable faecal solids (SFS) obtained from rainbow trout (Oncorhynchus mykiss). Triplicate tanks of fish were fed five isoenergetic experimental diets with different protein:energy (P:E) ratios: 15, 17, 19, 21, and 23. The SFS from four consecutive days were collected and pooled prior to incubation in 15, 1L anoxic/anaerobic batch reactors maintained at 20±2°C and continuous magnetic stirring. Daily samples from the batch reactors were obtained for 7 successive days and analyzed for total ammonia nitrogen (TAN), phosphorus expressed as orthophosphate (PO4³⁻-P), VFA, and soluble COD (sCOD). The results showed that the two lowest P:E ratio diets (i.e. 15 and 17) produced SFS with a significantly higher degree of solubilization measured as sCOD:total chemical oxygen demand (TCOD), compared to the higher P:E ratio diet 21 (0.30-0.29 versus 0.264 g sCOD/g TCOD). Inversely, SFS deriving from the lowest P:E ratio diet (i.e. 15) displayed the lowest degree of fermentation measured as VFAs/sCOD, compared to SFS deriving from the four higher P:E diets (0.36 versus 0.51-0.56 g VFA/g sCOD). In the same way, the lowest P:E diet showed a significantly lower solubilization of nitrogen measured as TAN:total Kjeldahl Nitrogen (TKN) compared to the three highest P:E diets (i.e. 19-23; 0.14 versus 0.26-0.34 g TAN/g TKN). The two lowest P:E diets (i.e. 15-17) showed on the contrary the highest solubilization of phosphorus expressed as PO4³⁻-P:total phosphorus (TP) (0.15 and 0.087/g, respectively) probably due to the lower pH obtained. All SFS produced enough soluble carbon, measured as VFAs, to stoichiometrically denitrify the nitrogen (N) contained in the faeces and potentially additionally 86-100% of all N produced from the fish culture process.

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Effects of dietary methionine on feed utilization, plasma amino acid profiles and gene expression in rainbow trout (Oncorhynchus mykiss)

Aquafeed formulation has evolved dramatically in response to shortages in marine raw materials, driven in part by the sustainable management of the wild stocks and an increased demand for nutrient-dense diets. Aquaculture of carnivorous species such as salmonids relies on extruded feeds with optimal protein and energy ratio to maximize the growth performances. To support the increasing demands, aquafeeds contain increasing contributions of protein products from alternative origin. Plant raw materials can be suitable substitutions for fish meal, benefiting from a high availability, low cost and similar nutritive properties. The major limitation in using plant derived protein, at least when using high quality protein concentrate, is the amino acid profiles of plant protein, which differs from that of fish meal. Their inclusion in
aquafeed results in a product deficient in essential amino acids (EAA) compared to dietary requirements. Supplementation with amino acids in crystalline form (CAA) is a common practice to balance the dietary amino acid profile to achieve high growth performances. However, complete substitution of fish meal using plant proteins and CAAs often results in poorer growth performances. The reason for this is often suggested to be related to difference in amino acid uptake kinetics during digestion, resulting in a temporal mismatch in amino acid availability, resulting in poorer at protein synthesis site. In addition to their role as building blocks in protein synthesis, amino acids also serve as substrates for synthesis of metabolic intermediates, and increasing evidence shows that amino acids also function as signaling factors in the regulation of intermediary metabolism and growth related pathways.

The present thesis comprises four supporting papers, based on two laboratories studies, investigating the effect of dietary amino acid level and form on i) growth performances, ii) plasma amino acid profiles and iii) on the expression of genes involved in hepatic metabolic and growth-related pathways in rainbow trout (Oncorhynchus mykiss).

The results from the first study are presented in Paper I and show that the protein source itself (fish meal or plant based) does not affect the plasma EAA profiles, but rather that plasma EAA levels reflect the dietary level. Supplementation with histidine, lysine and threonine in crystalline form to a plant based diet was, on the other hand, found to result in their plasma concentrations peaking earlier during the digestive process when comparing to other AAs supplied as protein-bound. In addition, to these early peaks in the plasma concentration, supplementation with crystalline methionine resulted in what can be best described as an apparent “accumulation” in the plasma, compared to fish fed similar dietary level but in protein bound form. The study further showed that the nitrogen excretion resulting from feeding an AA deficient diet was higher than for the fish meal control diet. Supplementation of the plant meal diet with crystalline amino acids tended to improved nitrogen utilization, almost equalling the results obtained for the fish meal control diet.

The relationship between dietary methionine level and form (free, coated and bound), and plasma amino acid profiles was further investigated in Paper II by applying statistical modeling to a large dataset (504 individuals and 20 variables). Using generalized additive models, it was shown that i) dietary methionine level and form explained 74 % of the variance in methionine plasma concentrations observed during digestion, and ii) that the dietary form of methionine and concomitant changes in methionine plasma concentrations significantly affected the plasma concentrations of several other essential AAs (arginine, histidine, isoleucine, leucine, lysine, phenylalanine, threonine and valine). Linear models revealed a positive relationship (R2>0.9) between plasma concentrations of the three branched chain amino acids (BCAAs; isoleucine, leucine and valine) during digestion of meals differing in dietary methionine levels.

Results from Paper III showed that dietary level and form (crystalline or protein-bound) of methionine affected the expression of hepatic genes related to i) the somatotropic axis and ii) protein turnover. For this purpose seven diets were fed to juvenile rainbow trout under control condition. The diets were formulated to differ only in methionine content (ranging from 0.6 to 1.29 % dry matter), supplied either in crystalline or protein-bound form. The transcript levels of the growth hormone receptor I (GHR-I) and insulin-like growth hormone I (IGF-I) increased linearly with dietary methionine content (P<0.01), which was reflected in the overall growth performances. In addition, the expressions of four components of the somatotropic axis investigated were significantly (P<0.05) affected by dietary methionine. The apparent capacity for hepatic protein degradation decreased with increasing dietary methionine level in a more or less linear manner. In comparison, the methionine source appeared to have limited effect on the expression pattern of protein degradation enzymes. The results suggest that methionine availability, influenced by dietary content or form, modulates the expression of genes involve in the GH/IGF response and protein turnover, further affecting growth performances.

Paper IV presents the results of the effects of dietary methionine level and form (free or bound) on hepatic intermediary metabolism using the same diets as in Paper III. The diets were fed to rainbow trout for 6 weeks, followed by sampling for i) hepatic gene expressions, ii) hepatosomatic index (HSI), iii) postprandial ammonia excretion, and iv) plasma methionine levels. The expression of several genes coding for enzymes involved in lipid metabolism (FAS, G6PD, CPT1a), gluconeogenesis (FBPase) and amino acid catabolism (ALT1, GHD and GLS01) responded in a linear manner (P<0.05) to gradual increase of dietary crystalline methionine; and were associated with a decrease in nitrogen excretion and relative liver mass. Additionally, the dietary form of methionine significantly affected postprandial plasma methionine concentrations as well as the expression of specific hepatic genes (G6PD, PEPCK, FBPase, G6Phase, ALT1, GHD and GLS02; P <0.05). Nitrogen excretion was found to be consistently higher for fish fed diets supplied with crystalline methionine than fish fed protein-bound methionine (P <0.05). This study is the first to demonstrate that expression of several genes related to intermediary metabolism respond in a dose-response manner to increasing levels of dietary methionine, and that the dietary source of methionine affect hepatic metabolism at the transcriptional level.

Dietary methionine, possibly in concert with other amino acids, appears to be a key regulatory factor in the expression of several genes involved in growth and intermediary metabolism. Furthermore, the gene expression seem to be significantly affected by crystalline methionine supplementation, as a possible explanation to the different utilization of CAA supplemented plant based diets, compared to conventional fish meal based diets.

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Removal of urea, ammonium and nitrite in moving bed biofilters operated at different loadings

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Effects of dietary energy density and digestible protein: energy ratio on de novo lipid synthesis from dietary protein in gilthead sea bream (Sparus aurata) quantified with stable isotopes
The effects of varying dietary digestible protein (DP) and digestible energy (DE) content on performance, nutrient retention efficiency and the de novo lipogenesis of DP origin were examined in triplicate groups of gilthead sea bream (Sparus aurata), fed nine extruded experimental diets. In order to trace the metabolic fate of dietary protein, 1·8% fishmeal was replaced with isotope-labelled whole protein (.98% 13C). The experiment was divided into a growth period lasting 89 d, growing fish from approximately 140 to 350 g, followed by a 3 d period feeding isotope-enriched diets. Isotope ratio MS
was applied to quantify the 13C enrichment of whole-body lipid from dietary DP. Between 18.6 and 22.4% of the carbon derived from protein was recovered in the lipid fraction of the fish, and between 21.6 and 30.3% of the total lipid deposited could be attributed to dietary protein. DP retention was significantly improved by reductions in dietary DP:DE ratio, while the opposite was true for apparent digestible lipid retention. Both overall DE retention and whole-body proximate composition of whole fish were largely unaffected by dietary treatments, while feed conversion ratios were significantly improved with increasing dietary energy density. The present study suggests that gilthead sea bream efficiently utilises dietary nutrients over a wide range of DP:DE ratios and energy densities. In addition, they appear to endeavour a certain body energy status rather than maximising growth, which in the present trial was apparent from inherently high de novo lipogenesis originating from DP.

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Effects of organic plant oils and role of oxidation on nutrient utilization in juvenile rainbow trout (Oncorhynchus mykiss)

Producing organic fish diets requires that the use of both fishmeal and fish oil (FO) be minimized and replaced by sustainable, organic sources. The purpose of the present study was to replace FO with organic oils and evaluate the effects on feed intake, feed conversion ratio (FCR), daily specific growth rate (SGR) and nutrient digestibility in diets in which fishmeal protein was partly substituted by organic plant protein concentrates. It is prohibited to add antioxidants to organic oils, and therefore the effects of force-oxidizing the oils (including FO) on feed intake and nutrient digestibility was furthermore examined. Four organic oils with either a relatively high or low content of polyunsaturated fatty acids were considered: linseed oil, rapeseed oil, sunflower oil and grapeseed oil. Substituting FO with organic oils did not affect feed intake (P > 0.05), FCR or SGR (P > 0.05) despite very different dietary fatty acid profiles. All organic plant oils had a positive effect on apparent lipid digestibility compared with the FO diet (P < 0.05), whereas there were no effects on the apparent digestibility of other macronutrients when compared with the FO diet (P > 0.05). Organic vegetable oils did not undergo auto-oxidation as opposed to the FO, and the FO diet consequently had a significantly negative effect on the apparent lipid digestibility. Feed intake was not affected by oxidation of any oils. In conclusion, the study demonstrated that it is possible to fully substitute FO with plant-based organic oils without negatively affecting nutrient digestibility and growth performance. Furthermore, plant-based organic oils are less likely to oxidize than FOs, prolonging the shelf life of such organic diets.
Farming different species in RAS in Nordic countries: Current status and future perspectives

Recirculating aquaculture systems (RAS) have gained increasing interest in recent years as a means to intensify fish production while at the same time minimize the environmental impact. Considerable hands-on experience has accumulated within the Nordic countries over the last 20-30 years in designing, building, and operating intensive land-based RAS for different species. This study compiles and assesses published literature along with un-published hands-on experiences with rearing different species in RAS in the Nordic countries, including Atlantic salmon (Salmo salar), rainbow trout (Oncorhynchus mykiss), European eel (Anguilla anguilla), pike perch (Stizostedion lucioperca), Arctic char (Salvelinus alpinus), sturgeon (order Acipenseriformes), Nile tilapia (Oreochromis niloticus), and European lobster (Homarus gammarus). High capital costs are one of the biggest challenges to sustainable RAS calling for large scale intensive productions to reduce investment -and operation costs. Consistent with this, production of Atlantic salmon smolts in indoor RAS and rainbow trout in outdoor Model-Trout-Farms (MTFs) have been the commercially most successful productions so far. Aside from end-of-pipe treatment including sludge handling and efficient nitrogen removal, much of the RAS technology applied is well known and is, as such, more or less ready to apply for culturing a variety of species. Successful production of “new” species in RAS therefore largely comes down to identifying the biological requirements of that specific species, and designing the RAS to fulfill and support the specific requirements. Well established brood-stocks and continuous supply of offspring is furthermore a prerequisite for successful RAS production of most species. Successful operations of less intensive RAS such as aquaponic systems appear to be feasible primarily when culturing more exotic species targeted for selected customers.

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Authors: Dalsgaard, A. J. T. (Intern), Lund, I. (Intern), Thorarinsdottir, R. (Ekstern), Drengstig, A. (Ekstern), Arvonen, K. (Ekstern), Pedersen, P. B. (Intern)
Glycogenesis and de novo lipid synthesis from dietary starch in juvenile gilthead sea bream (Sparus aurata) quantified with stable isotopes

The effects of replacing a digestible energy source from fat (fish oil) with carbohydrate (wheat starch) on performance, glycogenesis and de novo lipogenesis was examined in triplicate groups of juvenile gilthead sea bream (Sparus aurata), fed four extruded experimental diets. In order to trace the metabolic fate of dietary starch, 0.7% wheat starch was replaced with isotope-labelled starch (98% 13C). Fish were fed the experimental diets for three consecutive 10 d periods, and isotope ratio MS was applied to quantify 13C enrichment of liver and whole-body glycogen and lipid pools over the three feeding periods. Glycogenesis originating from dietary starch accounted for up to 68.8% and 38.8% of the liver and whole-body glycogen pools, respectively, while up to 16.7% of the liver lipid could be attributed to dietary starch. Between 5 and 8% of dietary starch carbon was recovered in whole-body lipid, and estimated deposition rates of de novo synthesised lipid originating from starch ranged from 18.7 to 123.7 mg/kg biomass per d. Dietary treatments did not significantly affect growth, feed performance or body composition of the fish, while the hepatosomatic index and glycogen content of whole fish and livers correlated directly with dietary starch inclusion level. The study suggests that gilthead sea bream efficiently synthesises glycogen from both dietary starch and endogenous sources. In contrast, lipogenesis from carbon derived from starch seems to play a minor role in overall lipid synthesis and deposition under the specified experimental conditions.
Influence of inclusion level and form of dietary methionine in plant protein based diets on growth performances, ammonium excretion and postprandial methionine plasma levels in rainbow trout (Oncorhynchus mykiss).

**General information**

State: Published

Organisations: National Institute of Aquatic Resources, Section for Aquaculture, BioMar A/S

Authors: Rolland, M. (Intern), Larsen, B. K. (Intern), Holm, J. (Ekstern), Dalsgaard, A. J. T. (Intern), Skov, P. V. (Intern)

Publication date: 2013

Event: Abstract from Aquaculture Europe 13, Trondheim, Norway.

Main Research Area: Technical/natural sciences

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Nitrogen waste load from juvenile rainbow trout (Oncorhynchus mykiss)

**General information**
Nutritional value of mussel meal in fish feed: a sustainable, high-quality protein source

General information
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Organisations: National Institute of Aquatic Resources, Section for Aquaculture
Authors: Larsen, B. K. (Intern), Dalsgaard, A. J. T. (Intern), Pedersen, L. (Intern), Pedersen, P. B. (Intern), Baardsen, G. (Ekstern), Hansen, A. (Ekstern), Jokumsen, A. (Intern)
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Preface: Recirculation technology: science meets practice

General information
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Organisations: National Institute of Aquatic Resources, Section for Aquaculture
Authors: Dalsgaard, A. J. T. (Intern), Pedersen, L. (Intern), Pedersen, P. B. (Intern)
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
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BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.72 SNIP 1.437 CiteScore 1.61
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BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.946 SNIP 1.377 CiteScore 1.72
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.69 SNIP 1.406 CiteScore 1.54
ISI indexed (2011): ISI indexed yes
**Removal of nitrogen, phosphorous and organic matter in a constructed wetland treating effluents from a Model Trout Farm**

**General information**
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Organisations: National Institute of Aquatic Resources, Section for Aquaculture
Authors: Dalsgaard, A. J. T. (Intern), von Ahnen, M. (Ekstern), Pedersen, P. B. (Intern)
Publication date: 2013
Event: Poster session presented at Aquaculture 2013, Gran Canaria, Spain.
Main Research Area: Technical/natural sciences

**Effects of exogenous enzymes on apparent nutrient digestibility in rainbow trout (Oncorhynchus mykiss) fed diets with high inclusion of plant-based protein**

**General information**
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Dalsgaard, A. J. T. (Intern), Verlhac, V. (Ekstern), Hjermitslev, N. (Ekstern), Ekmann, K. S. (Intern), Fischer, M. (Ekstern), Klausen, M. (Ekstern), Pedersen, P. B. (Intern)
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BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.11 SJR 0.903 SNIP 1.425
Web of Science (2016): Indexed yes
Effects of feed loading on nitrogen balances and fish performance in replicated recirculating aquaculture systems

This study investigated the effects of applying four fixed feed loadings to three replicated recirculating aquaculture systems (RAS) on water quality changes, nitrogenous balances and growth performance of rainbow trout (Oncorhyncus mykiss). Feed loadings ranged from 1.6 to 6.3 kg feed/m³ make-up water, with a constant make-up water renewal of 4.7% of total water volume per day in all twelve RAS. Fish densities ranged from 14 to 92 kg/m³ during the prolonged trial of 10 weeks. Selected water quality parameters were measured during two intensive sampling campaigns, evaluating biofilter nitrification performance and diurnal patterns of total ammonia nitrogen (TAN) and nitrite concentrations. No fish mortality occurred during the study. Feed conversion ratios varied between 0.91 ± 0.04 and 0.95 ± 0.02, and were unaffected by feeding load. Mean nitrate-nitrogen levels ranged from 54 ± 7 to 196 ± 10 mg/L at steady state, and the concentration of nitrogenous compounds and organic matter were all positively correlated to feed loading. The TAN loading to the RAS from the specific feed type was assessed in a separate mass-balance study and used as input in a descriptive mathematical model (AQUASIM® software) developed to simulate processes affecting N mass-balances in the RAS. Nitrification kinetic rate constants were applied to the biofilter, and fractions of nitrifiers in suspended solids in the water phase were estimated based on existing information from waste water treatment processes. Two model scenarios successfully simulated the measured TAN concentration in the experimental RAS. The first model scenario applied a first-order area-based nitrification rate (k1a) constant of 0.2 m/d, estimating a fraction of active nitrifiers (fN) in the water phase of 4% of the total suspended solids. The second model scenario used a k1a of 0.1, estimating a fN of 8% with similar predictability as in the first scenario. Overall, this study provided new information on fish performance and resulting water quality during
steady state RAS operation. Furthermore, the study demonstrated that kinetic modeling can be applied to simulate measured TAN concentrations in experimental RAS.

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Organisations: Section for Aquaculture, National Institute of Aquatic Resources, Urban Water Engineering, Department of Environmental Engineering
Authors: Pedersen, L. (Intern), Suhr, K. I. (Intern), Dalsgaard, A. J. T. (Intern), Pedersen, P. B. (Intern), Arvin, E. (Intern)
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Main Research Area: Technical/natural sciences

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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
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Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
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Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.136 SNIP 1.3 CiteScore 2.18
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Web of Science (2012): Indexed yes
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Scopus rating (2011): SJR 1.294 SNIP 1.542 CiteScore 2.39
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Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.151 SNIP 1.394
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.941 SNIP 1.263
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 0.909 SNIP 1.173
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.019 SNIP 1.318
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.008 SNIP 1.689
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.915 SNIP 1.236
Effects of plant proteins on postprandial, free plasma amino acid concentrations in rainbow trout (Oncorhynchus mykiss)

Postprandial patterns in plasma free amino acid concentrations were investigated in juvenile rainbow trout (Oncorhynchus mykiss) fed either a fish meal based diet (FM) or a diet (VEG) where 59% of fish meal protein (corresponding to 46% of total dietary protein) was replaced by a matrix of plant proteins from wheat, peas, field beans, sunflower and soybean. Blood samples were obtained from the caudal vein of 7 fish in each dietary treatment group prior to feeding, as well as: 2, 4, 6, 8, 12, 24, 48 and 72 h after feeding (sampling 7 new fish at each time point), and plasma amino acid concentrations were subsequently measured by HPLC. Nutrient digestibility and ammonia excretion of the two experimental diets were measured in a parallel experiment using a modified Guelph setup. Results showed that the appearance of most amino acids (essential and non-essential) in the plasma was delayed in fish fed the VEG diet compared to those fed the FM diet. Essential and non-essential amino acids furthermore appeared more or less synchronously in the plasma in fish fed the FM diet, while the appearance was less synchronised in fish fed the VEG diet. Differences in plasma concentrations between the two dietary treatment groups correlated largely with the amino acid content of the two diets except for methionine, lysine and arginine, where the differences were more extreme than what would be expected from differences in dietary concentrations. The apparent protein digestibility coefficient was higher in the VEG diet than in the FM diet (93 versus 92%; t-test, P<0.05), supporting that protease inhibitors from plant protein ingredients were not the cause of the delay. The apparent digestibility coefficient of carbohydrates (calculated as nitrogen-free extract (NFE)) was much lower in the VEG than in the FM diet (51 versus 76%; t-test, P<0.05). Combined with a higher NFE content in the VEG diet, this meant that there was 2.7 times more indigestible NFE in the VEG than in the FM diet (6.1 versus 2.2 g 100−1 g feed). Such difference may suggest that the uptake of amino acids (AA) was affected by dietary carbohydrates. Total ammonia-nitrogen (TAN) excretion was slightly, but non-significantly, higher in VEG fed fish than in FM fed fish (59 versus 55 mg TAN g−1 digested protein; t-test, P>0.05). In conclusion, the study showed that amino acid uptake patterns are affected when replacing fish meal with plant based protein ingredients.

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Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Larsen, B. K. (Intern), Dalsgaard, A. J. T. (Intern), Pedersen, P. B. (Intern)
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Scopus rating (2016): CiteScore 2.75 SJR 1.101 SNIP 1.524
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Influence of protein source on amino acid uptake patterns and protein utilization in rainbow trout Oncorhynchus mykiss

Matrixes of different protein sources (fish and plant products) combined with the use of crystalline amino acids allow for formulation of diets that meet fish requirements with little or no effect on protein digestibility and/or feed intake. Despite this, a total or partial replacement of fish meal induces reduced growth performances that remain partly unexplained. The
The aim of the current study was to investigate the effect of exchanging the protein source on protein utilization. Marine (fish meal) and vegetable (pea protein) sources were used with or without supplementation of crystalline amino acids to the fishmeal diet level (see Table 1). Amino acid uptake patterns were assessed by the appearance of amino acids in the blood stream following the ingestion of a meal, while dietary protein utilization was evaluated by examining the metabolic response to digestion and ammonium and urea excretion rates during digestion. Four treatments, 3 diets and 1 control (no feeding), were applied to rainbow trout with an average body mass of 500 grams. Fish were either force fed one of the 3 diets at a ration corresponding to 0.75% of the body mass, or no force feeding. Four fish at a time (one per treatment) were placed in individual chambers for 48h. Blood and water samples were collected at time 0 and then at 2, 4, 6, 8, 12, 20, 32 and 48 hours post feeding. The protocol was repeated until 8 replicates per treatment were obtained.

The results were obtained through 2 separate experiments.

In the first part, oxygen consumption was recorded continuously, while water was sampled as detailed above and analyzed for ammonium and urea content.

The second part of the experiment was designed to collect blood samples. After the feeding treatment fish were held in separate containers for the above described time sampling. Fish were killed by a blow in the head and blood was collected from the caudal vein with heparinized syringes. Plasma and red blood cells content were stored separately at -80 for amino acid content analysis.

The ammonium excretion profiles (Figure 1) will be correlated with the amino acid profile in the blood and oxygen consumption during digestion to investigate the effect on protein utilization for each treatment.
Feed and organic matter

Organic waste from fish production is conventionally measured as BOD5 (biological oxygen demand measured during 5 days) and COD (chemical oxygen demand (includes BOD5)). Organic waste is of particular concern for several reasons. The easily degradable part (BOD5) may have an immediate, negative impact on the receiving water body by reducing dissolved oxygen concentrations and increasing sedimentation. Within aquaculture systems, a high organic load may affect fish health and performance directly (e.g., gill disease) as well as indirectly (proliferation of pathogenic bacteria and parasites, reduction of dissolved oxygen concentrations, etc.). In recirculating aquaculture systems (RAS), a high organic load caused by limited water exchange may affect biofilter performance by favouring heterotrophic bacteria at the expense of autotrophic, nitrifying bacteria. Organic waste in RAS primarily originates from undigested feed, but also metabolic losses, mucus, dead tissue, feed waste and intake water may contribute. The nutrient composition of the feed affects the quantity and composition of the organic (undigested) waste, and including for example plant protein ingredients may affect the distribution between particulate and unsedimented (suspended and dissolved) organic waste. Quantifying aquaculture waste, including organic matter, nitrogen (N) and phosphorus (P), into different waste fractions (particulate and unsedimented) is essential for optimising the design of different treatment setups with specific cleaning objectives. A series of studies were carried out to measure the solid and unsedimented waste from juvenile rainbow trout (Oncorhynchus mykiss) fed three commonly applied commercial diets (Dalsgaard and Pedersen, 2011). Furthermore, it was hypothesized that particulate COD can be calculated from undigested nutrients. There were only minor differences between the diets. Generally, 48% of ingested N was recovered in the water and 7% in the solids. For phosphorus, 1% was recovered in the water and 43% in the solids. More COD was recovered as solids than as unsedimented waste, while
it was opposite for BOD5. A BOD5/COD ratio of 0.5 was derived, indicating that unsedimented organic waste is characterized by easily degradable organic matter. In comparison, a solid BOD5/COD ratio of 0.2 indicated that this waste fraction contains high amounts of hard-to-degrade organic matter. The study confirmed that solid COD can be quite accurately calculated from the composition of undigested nutrients

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**Influence of feed ingredients on water quality parameters in RAS**
Although feed by far is providing the major input to RAS, relatively little is published about the correlation between feed composition and the resulting water quality in such systems. In a set-up with 6 identical RAS, each consisting of a fish tank (0.5 m3), a swirl separator, a submerged biofilter (0.67 m3/100 m2) and a trickling filter (0.17 m3/33 m2), two different feed types were tested in a triplicate set-up. The two feed types used were identical recipes (44% protein, 30% fat) except for the inclusion of 0.2 % guar gum (Grindsted Guar, Danisco) in one of the types. The inclusion level of plant-based protein in the diets was relatively high (68% of protein). Growth performance (SGR, FCR) was not different between the feed types. Fish in each system - and thereby the system itself - were fed 500 g feed/day. After 8 weeks on the same commercial feed type, test feed was administered to the systems for 49 consecutive days. Each week, 24h-water samples (1 sample/hour) were collected from each system. The sludge collected in the swirl separator that day was also collected. Water and sludge were subsequently analysed for nitrogen, phosphorous and organic matter content. Inclusion of guar gum had impact on water quality in the systems as well as on matter removed by the swirl separators. In the RAS water, phosphorous (Ptot and Pdiss) concentrations were reduced by guar gum. Organic matter content (CODdiss) in the water was also reduced. Corresponding to this, more dry matter, more COD and more phosphorous were removed by the swirl separators. As might be expected from the high protein digestibility (determined in a separate study), no effects were generally observed on nitrogen compounds

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Renseeffektivitet på Model 1 dambrug: Rapportering af WP4 under dambrugsteknologi-projekten

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Replacement of fish meal with a matrix of organic plant proteins in organic trout (Oncorhynchus mykiss) feed, and the effects on nutrient utilization and fish performance

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Authors: Lund, I. (Intern), Dalsgaard, A. J. T. (Intern), Rasmussen, H. T. (Ekstern), Holm, J. (Ekstern), Jokumsen, A. (Intern)
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Solid and suspended/dissolved waste (N, P, O) from rainbow trout (Oncorhynchus mykiss)

Quantifying aquaculture waste into different waste fractions will make it possible to design different treatment setups for obtaining specific cleaning objectives. The aim of this study was therefore to measure “all” solid and suspended/dissolved (i.e. unsedimented) waste from juvenile rainbow trout (Oncorhynchus mykiss) fed three commonly applied commercial diets, “all” waste referring to: total nitrogen (N), total ammonia nitrogen (TAN=NH₃-N+NH₄-N), total phosphorus (P), and organic matter characterized by the chemical oxygen demand (COD) and the biological oxygen demand after 5 days (BOD₅). Furthermore, it was hypothesized that solid COD waste can be calculated from undigested nutrients. Two experiments were carried out using a modified Guelph System. Nitrogen and phosphorus waste was derived from mass-balances based on all measured values in the first experiment. Apparent digestibility coefficients (ADCs) were used to
calculate the solid amounts of undigested nutrients. These were subsequently used for calculating the solid COD output, verified by direct COD measurements. The output of solid and suspended/dissolved BOD5 and COD was measured in the second experiment. There were just minor differences between the dietary treatment groups in the waste produced. On average, 48% of the ingested N was recovered in the water (TAN constituting 64–79% of this) and 7% in the solids. In comparison, 1% of the ingested P was recovered in the water and 43% in the solids. A breakpoint value of 5.6 g standardized available P kg⁻¹ dry feed was found, below which the dissolved P excretion was minimal and above which it increased rapidly. More COD was recovered as solid waste than as suspended/dissolved waste, while it was opposite for BOD5. A BOD5/COD ratio of 0.5 indicated that the suspended/dissolved waste was characterized by easily degradable organic matter, while a solid BOD5/COD ratio of 0.2 indicated that this waste fraction contained high amounts of hard-to-degrade organic matter. Finally, the study showed that solid COD waste can be quite accurately calculated from the composition and content of undigested nutrients.
Effects of supplemental enzymes on apparent nutrient digestibility in rainbow trout (Oncorhynchus mykiss) fed plant-based diets

Exogenous enzymes are widely applied in feed for monogastric animals including pigs and poultry as a means to increase the nutritional value of viscous grains by reducing the anti-nutritional effects of primarily non-starch polysaccharides (NSPs). In comparison, there is very limited information on the effects of enzymes in fish feed apart from phytase. Phytase works by hydrolyzing phytic acid, and numerous studies have documented that phytase supplementation increases phosphorus availability in fish fed diets with high inclusion levels of plant proteins. Plant derived proteins are increasingly
used in fish feed due to growing demands for and high price variations in fish meal, but high inclusion levels in diets for carnivorous fish are hampered by a great variety of anti-nutritional factors (ANFs), which reduce nutrient utilisation. Exogenous dietary enzymes may potentially help to alleviate these effects, and the objective of the present study was to evaluate the effects of supplementing protease and pectinase to a diet containing approximately 30% soybean meal, rapeseed meal or sunflower meal on nutrient digestibility in juvenile rainbow trout (Oncorhynchus mykiss). Digestibility trials were carried out using a modified Guelph set-up. Rainbow trout were fed the un-supplemented diets and enzyme supplemented plant-based diets in triplicates for three weeks. While moderate effects of the enzymes on nutrient digestibility were obtained with sunflower and rapeseed meal based diets, both enzymes significantly increased (P <0.05) the apparent digestibility coefficients (ADCs) of protein, lipid and nitrogen-free extract (NFE) in soybean meal based diets. Hence, the study provided preliminary results on the potential of protease and pectinase to increase the nutritional value of proteinaceous feed ingredients for fish. However, it also reinforces the complexity of using exogenous dietary enzymes and that more research is required to better understand the mechanisms of actions.

Organic vegetable proteins and oil in feed for organic rainbow trout (Oncorhynchus mykiss)
The demand for organic trout is increasing, stressing the need for organic, vegetable feed ingredients as replacement for fish meal, as the principles of organic aquaculture encourage the development of feed that do not deplete global fish stocks. In addition, the organic code of practice does not allow addition of artificial amino acids to the feed, and optimization of the amino acid profile of organically based diets must therefore derive from the protein sources alone. The aim of this study was to evaluate the digestibility and growth performance of organic vegetable dietary ingredients as replacement for fish meal and fish oil in feed for organic rainbow trout (Oncorhynchus mykiss). Six iso-energetic and iso-nitrogenous diets were prepared, comprising a fish meal and fish oil based control diet and three diets in which the inclusion of fish meal was gradually reduced from 59 to 35 % and replaced by a matrix of organic horse bean, pea and rape in the proportion of 1:1:0.7. In the last two diets, the inclusion of fish oil was reduced by 50 and 100 %, respectively and replaced by flax seed oil high in omega-3 fatty acids. Digestibility was measured directly using a modified, flow-through Guelph System consisting of 18 tanks, and feeding each diet in triplicates. Growth performance was measured using a recirculation system consisting of 12 square formed fibre glass tanks. The fish were reared in duplicate for 9 weeks, from an initial individual weight of about 60 g to a final weight of about 200 g. The fish showed good growth performance with a specific growth rate (SGR) of 1.8 % d-1, and a feed conversion ratio (FCR) of 0.75, and there were no significant differences between the groups. Likewise, there were no significant differences in nutrient digestibility between the diets. The results indicate that a matrix of organic horse bean, pea and rape may partially replace fish meal, and flax seed oil may replace fish oil in feed for organic rainbow trout without compromising growth performance and feed utilization.
Effect of supplemented fungal phytase on performance and phosphorus availability by phosphorus-depleted juvenile rainbow trout (Oncorhynchus mykiss), and on the magnitude and composition of phosphorus waste output

The effect of a supplemental fungal phytase on performance and phosphorus availability by juvenile rainbow trout fed diets with a high inclusion of plant based protein and on the magnitude and composition of the waste phosphorus production was tested in a 2 × 3 factorial design at a temperature of 11 °C. Two factors comprised of two dietary fungal phytase levels (0 or 1400 U kg−1 feed−1), and three dietary total phosphorus levels (0.89, 0.97 or 1.12%). All fish were acclimated to the lowest total phosphorus diet for 16 days, which included 0.29% phytate-phosphorus and no supplemental fungal phytase, to ensure that they were depleted of phosphorus prior to the feeding trial. Growth and feed conversion ratios were not significantly affected by the increasing dietary phosphorus level or supplemental fungal phytase. Phosphorus availability increased significantly as a result of phytase supplementation, reaching an upper level of 74% at an available dietary phosphorus concentration of 0.71%. Adding fungal phytase to the diets improved the availability of phytate-phosphorus from an average of 6 to 64%. The fish retained 53–79% of the ingested phosphorus, while 24–44% was recovered in the faeces. The particulate phosphorus waste output was significantly higher in faeces from fish fed diets without fungal phytase compared to fish fed phytase supplemented diets. The dissolved/suspended phosphorus waste output represented 2–13% of the ingested phosphorus, and there was a significant increase in the dissolved/suspended phosphorus waste output from fish fed the phytase supplemented diet containing 0.71% available phosphorus, suggesting that the phosphorus requirement was reached at this phosphorus level. Consistent with this, there was a substantial increase in the dissolved/suspended phosphorus waste output from fish fed the phytase supplemented diet containing 0.81% available phosphorus, suggesting that the phosphorus requirement was exceeded in this group. This study demonstrated that phytase supplementation will be advantageous to the fish and the environment if supplemented to low-phosphorus diets containing a large share of plant-derived protein. Conversely, the results demonstrated that fungal phytase should not be supplemented to diets in which the available phosphorus level already

Danish model trout farms – Technology and environmental impact

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Jokumsen, A. (Intern), Plesner, L. J. (Ekstern), Pedersen, P. B. (Intern), Dalsgaard, A. J. T. (Intern), Lund, I. (Intern), Paulsen, H. (Intern), Rasmussen, R. S. (Intern)
Publication date: 2009
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 252713
Publication: Research › Conference abstract for conference – Annual report year: 2009
meets the requirement of the fish, as this will lead to a significant increase in the dissolved/suspended phosphorus waste output.

**General information**
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Dalsgaard, A. J. T. (Intern), Schøn Ekmann, K. (Ekstern), Pedersen, P. B. (Intern), Verlhac, V. (Ekstern)
Pages: 105-112
Publication date: 2009
Main Research Area: Technical/natural sciences

**Publication information**
Journal: Aquaculture
Volume: 286
Issue number: 1-2
ISSN (Print): 0044-8486
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.75 SJR 1.101 SNIP 1.524
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.103 SNIP 1.254 CiteScore 2.12
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.002 SNIP 1.34 CiteScore 2.16
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.136 SNIP 1.3 CiteScore 2.18
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.212 SNIP 1.487 CiteScore 2.32
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.294 SNIP 1.542 CiteScore 2.39
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.151 SNIP 1.394
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.941 SNIP 1.263
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 0.909 SNIP 1.173
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.019 SNIP 1.318
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.008 SNIP 1.689
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.915 SNIP 1.236
Nørå Dambrug - et modeldambrug under forsøgsordningen. Statusrapport for 2. måleår af moniteringsprojektet med væsentlige resultater fra første måleår

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Svendsen, L. M. (Ekstern), Sortkjær, O. (Ekstern), Ovesen, N. B. (Ekstern), Skriver, J. (Ekstern), Larsen, S. E. (Ekstern), Pedersen, P. B. (Intern), Rasmussen, R. S. (Intern), Dalsgaard, A. J. T. (Intern)
Number of pages: 91
Publication date: 2009

Publication information
Place of publication: Hirtshals
Publisher: DTU Aqua. Institut for Akvatiske Ressourcer
ISBN (Print): 978-87-7481-099-5
Original language: Danish
Series: DTU Aqua-rapport
Number: 207-09
ISSN: 1395-8216
Main Research Area: Technical/natural sciences
Electronic versions:
207_09_Noeraa_Dambrug_statusrapport_2maaleaar.pdf
Links:
http://www.aqua.aau.dk/Publikationer/Forskningsrapporter/Forskningsrapporter_siden_2008
Source: orbit
Source-ID: 256052
Publication: Research › Report – Annual report year: 2009

Proteinafgrøder til økologiske regnbueørreder (Oncorhynchus mykiss)

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources, Section for Fish Diseases, Section for Aquatic Protein Biochemistry
Authors: Jokumsen, A. (Intern), Lund, I. (Intern), Dalsgaard, A. J. T. (Intern), Dalsgaard, I. (Intern), Nielsen, H. H. (Intern), Rasmussen, H. T. (Ekstern), Larsen, V. J. (Ekstern), Jessen, P. B. (Ekstern), Holm, J. (Ekstern)
Publication date: 2009
Event: Poster session presented at Økologi-kongres, Odense, Danmark.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 252715
Publication: Research › Poster – Annual report year: 2009

Rens Dambrug - et modeldambrug under forsøgsordningen. Statusrapport for 2. måleår af moniteringsprojektet med væsentlige resultater fra første måleår

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Environmental benefits achieved by applying recirculation technology at Danish trout farms (Model Trout Farm)

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Pedersen, P. B. (Intern), Svendsen, L. (Ekstern), Sortkjaer, O. (Ekstern), Ovesen, N. (Ekstern), Skriver, J. (Ekstern), Larsen, S. (Ekstern), Rasmussen, R. S. (Intern), Dalsgaard, A. J. T. (Intern)
Number of pages: 139
Publication date: 2008

Host publication information
Title of host publication: Proceedings from the Aquacultural Engineering Society's Fourth Issues Forum
Series: Aquaculture Engineering Society Proceedings
Number: VI
Main Research Area: Technical/natural sciences
Conference: Aquacultural Engineering Society's Fourth Issues Forum, Roanoke, Virginia, 01/01/2008
Source: orbit
Source-ID: 241948
Publication: Research › Article in proceedings – Annual report year: 2008

Kongeåens Dambrug - et modeldambrug under forsøgsordningen. Statusrapport for 2. måleår af moniteringsprojektet med væsentlige resultater fra første måleår

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Svendsen, L. (Ekstern), Sortkjaer, O. (Ekstern), Ovesen, N. (Ekstern), Skriver, J. (Ekstern), Larsen, S. (Ekstern), Pedersen, P. B. (Intern), Rasmussen, R. S. (Intern), Dalsgaard, A. J. T. (Intern)
Number of pages: 74
Publication date: 2008

Publication information
Place of publication: Hirtshals
Publisher: Danmarks Fiskerundersogelser
ISBN (Print): 87-74-81065-0
Original language: Danish
Series: DTU Aqua-rapport
Number: 182-08
Main Research Area: Technical/natural sciences
Electronic versions:
182-08_elektronisk_samlet.pdf
Links:
http://www.aqua.dtu.dk/Publikationer/Forskningsrapporter/Forskningsrapporter_siden_2008
Source: orbit
Source-ID: 227602
Publication: Research › Report – Annual report year: 2008

Modeldambrug under forsøgsordningen. Faglig slutrapport for "Måle- og dokumentationsprojekt for modeldambrug"

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Svendsen, L. (Ekstern), Sortkjaer, O. (Ekstern), Ovesen, N. (Ekstern), Skriver, J. (Ekstern), Larsen, S. (Ekstern), Boutrup, S. (Ekstern), Pedersen, P. B. (Intern), Rasmussen, R. S. (Intern), Dalsgaard, A. J. T. (Intern), Suhr, K. (Intern)
Number of pages: 222
Publication date: 2008

Publication information
Økosystemmodel for Ringkøbing Fjord: Skarvbestandens påvirkning af fiskebestandene

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources, Section for Coastal Ecology, Section for Freshwater Fisheries Ecology, Section for Management Systems
Authors: Dalsgaard, A. J. T. (Intern), Christensen, V. (Ekstern), Nicolajsen, H. (Intern), Koed, A. (Intern), Støttrup, J. (Intern), Grooss, J. (Ekstern), Bregnballe, T. (Ekstern), Sørensen, H. (Ekstern), Christensen, J. (Ekstern), Nielsen, R. (Ekstern)
Number of pages: 71
Publication date: 2008

Publication information
Place of publication: Hirtshals
Publisher: Danmarks Fiskeriundersøgelser
ISBN (Print): 87-74-81055-1
Original language: Danish
Series: DTU Aqua-rapport
Number: 178-08
Main Research Area: Technical/natural sciences
Electronic versions: 178-08_elektronisk_samlet.pdf
Links:
http://www.aqua.dtu.dk/Publikationer/Forskningsrapporter/Forskningsrapporter_siden_2008
Source: orbit
Source-ID: 225222
Publication: Research › Report – Annual report year: 2008

Tingkærvad Dambrug - et modeldambrug under forsøgsordningen. Statusrapport for 2. måleår af moniteringsprojektet med væsentlige resultater fra første måleår

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Svendsen, L. (Ekstern), Sortkjær, O. (Ekstern), Ovesen, N. (Ekstern), Skriver, J. (Ekstern), Larsen, S. (Ekstern), Pedersen, P. B. (Intern), Rasmussen, R. S. (Intern), Dalsgaard, A. J. T. (Intern)
Number of pages: 77
Publication date: 2008

Publication information
Place of publication: Hirtshals
Publisher: Danmarks Fiskeriundersøgelser
ISBN (Print): 87-74-81073-5
Original language: Danish
Series: DTU Aqua-rapport
Number: 187-08
Tvilho Dambrug - et modeldambrug under forsøgsordningen. Statusrapport for 2. måleår af moniteringsprojektet med væsentlige resultater fra første måleår

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Svendsen, L. (Ekstern), Sortkjær, O. (Ekstern), Ovesen, N. (Ekstern), Skriver, J. (Ekstern), Larsen, S. (Ekstern), Pedersen, P. B. (Intern), Rasmussen, R. S. (Intern), Dalsgaard, A. J. T. (Intern)
Number of pages: 70
Publication date: 2008

Publication information
Place of publication: Hirtshals
Publisher: Danmarks Fiskeriundersøgelser
ISBN (Print): 87-74-81068-1
Original language: Danish
Series: DTU Aqua-rapport
Number: 184-08
Main Research Area: Technical/natural sciences
Electronic versions:
184-08_elektronisk Samlet.pdf
Links:
Source: orbit
Source-ID: 227610
Publication: Research › Report – Annual report year: 2008

Abildtrup dambrug - et modeldambrug under forsøgsordningen: statusrapport for 1. måleår af moniteringsprojektet

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Svendsen, L. (Ekstern), Sortkjær, O. (Ekstern), Ovesen, N. (Ekstern), Skriver, J. (Ekstern), Larsen, S. (Ekstern), Pedersen, P. B. (Intern), Rasmussen, R. S. (Intern), Dalsgaard, A. J. T. (Intern)
Number of pages: 59
Publication date: 2007

Publication information
Place of publication: Hirtshals
Publisher: Danmarks Fiskeriundersøgelser
Original language: Danish
Series: DFU-rapport
Number: 174-07
Main Research Area: Technical/natural sciences
Electronic versions:
174-07_elektronisk_index Ny.pdf
Links:
Source: orbit
Source-ID: 227596
Publication: Research › Report – Annual report year: 2007
Lejstrup dambrug (øst) - et modeldambrug under forsøgsordningen: Statusrapport for 1. måleår af moniteringsprojektet

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Svendsen, L. (Ekstern), Sortkjaer, O. (Ekstern), Ovesen, N. (Ekstern), Skriver, J. (Ekstern), Larsen, S. (Ekstern), Pedersen, P. B. (Intern), Rasmussen, R. S. (Intern), Dalsgaard, A. J. T. (Intern)
Number of pages: 55
Publication date: 2007

Publication information
Place of publication: Hirtshals
Publisher: Danmarks Fiskeriundersøgelser
ISBN (Print): 978-87-7481-036-0
Original language: Danish

Nørå Dambrug - et modeldambrug under forsøgsordningen: Statusrapport for 1. måleår af moniteringsprojektet

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Svendsen, L. (Ekstern), Sortkjaer, O. (Ekstern), Ovesen, N. (Ekstern), Skriver, J. (Ekstern), Larsen, S. (Ekstern), Pedersen, P. B. (Intern), Rasmussen, R. S. (Intern), Dalsgaard, A. J. T. (Intern)
Number of pages: 56
Publication date: 2007

Publication information
Place of publication: Hirtshals
Publisher: Danmarks Fiskeriundersøgelser
Original language: Danish

Rens dambrug - et modeldambrug under forsøgsordningen: statusrapport for 1. måleår af moniteringsprojektet

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Svendsen, L. (Ekstern), Sortkjaer, O. (Ekstern), Ovesen, N. (Ekstern), Skriver, J. (Ekstern), Larsen, S. (Ekstern), Pedersen, P. B. (Intern), Rasmussen, R. S. (Intern), Dalsgaard, A. J. T. (Intern)
Number of pages: 55
Publication date: 2007
Tingkærvad Dambrug - et modeldambrug under forsøgsordningen: Statusrapport for 1. måleår af monitoringsprojektet

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Svendsen, L. (Ekstern), Sortkjær, O. (Ekstern), Bering Ovesen, N. (Ekstern), Skriver, J. (Ekstern), Larsen, S. (Ekstern), Pedersen, P. B. (Intern), Rasmussen, R. S. (Intern), Dalsgaard, A. J. T. (Intern)
Number of pages: 53
Publication date: 2007

Ejstrupholm Dambrug - et modeldambrug under forsøgsordningen. Statusrapport for første måleår af moniteringsprojektet

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Svendsen, L. (Ekstern), Sortkjær, O. (Ekstern), Ovesen, N. (Ekstern), Skriver, J. (Ekstern), Larsen, S. (Ekstern), Pedersen, P. B. (Intern), Rasmussen, R. S. (Intern), Dalsgaard, A. J. T. (Intern)
Number of pages: 54
Publication date: 2006
Kongeåens Dambrug - et modeldambrug under forsøgsordningen. Statusrapport for første måleår af moniteringsprojektet

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Svendsen, L. (Ekstern), Sortkjær, O. (Ekstern), Ovesen, N. (Ekstern), Skriver, J. (Ekstern), Larsen, S. (Ekstern), Pedersen, P. B. (Intern), Rasmussen, R. S. (Intern), Dalsgaard, A. J. T. (Intern)
Number of pages: 51
Publication date: 2006

Electronic versions:
164-06, elektronisk.pdf

Links:
http://www.difres.dk/dk/publication/files/18122006$164-06,%20elektronisk_index.pdf

Source-ID: 227597
Publication: Research › Report – Annual report year: 2006

Tvilho Dambrug - et modeldambrug under forsøgsordningen. Statusrapport for første måleår af moniteringsprojektet

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Svendsen, L. (Ekstern), Sortkjær, O. (Ekstern), Ovesen, N. (Ekstern), Skriver, J. (Ekstern), Larsen, S. (Ekstern), Pedersen, P. B. (Intern), Rasmussen, R. S. (Intern), Dalsgaard, A. J. T. (Intern)
Number of pages: 48
Publication date: 2006

Electronic versions:
168-06, elektronisk.pdf

Links:
http://www.difres.dk/dk/publication/files/18122006$168-06,%20elektronisk_index.pdf

Source-ID: 227609
Publication: Research › Report – Annual report year: 2006

Fatty acid biomarkers: validation of food web and trophic markers using C-13-labelled fatty acids in juvenile sandeel (Ammodytes tobianus)

A key issue in marine science is parameterizing trophic interactions in marine food webs, thereby developing an understanding of the importance of top-down and bottom-up controls on populations of key trophic players. This study validates the utility of fatty acid food web and trophic markers using C-13-labelled fatty acids to verify the conservative incorporation of fatty acid tracers by juvenile sandeel (Ammodytes tobianus) and assess their uptake, clearance, and
metabolic turnover rates. Juvenile sandeel were fed for 16 days in the laboratory on a formulated diet enriched in (13)C16:0 followed by 14 days on a formulated diet enriched in (13)C18:3(n-3). An exponential model was employed to estimate the uptake and clearance rates of recovered labelled fatty acids as a function of growth and fatty acid metabolism. The model predicted a faster uptake of (13)C18:3(n-3) than (13)C16:0 (0.0353 and 0.0086 day(-1), respectively), consistent with a structural role of (n-3) polyunsaturated fatty acids in cell membranes, whereas saturated fatty acids presumably play a larger metabolic role. Clearance and metabolic rates of assimilated (13)C16:0 were estimated as 0.0572 and 0.0211 day(-1), respectively. Lack of temporal trends in nonlabelled fatty acids confirmed the conservative incorporation of labelled fatty acids by the fish.

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources, Section for Population Ecology and Genetics
Authors: Dalsgaard, A. J. T. (Intern), St. John, M. (Intern)
Pages: 1671-1680
Publication date: 2004
Main Research Area: Technical/natural sciences

Publication information
Journal: Canadian Journal of Fisheries and Aquatic Sciences
Volume: 61
Issue number: 9
ISSN (Print): 0706-652X
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.56 SJR 1.322 SNIP 1.163
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.256 SNIP 1.051 CiteScore 2.22
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.443 SNIP 1.379 CiteScore 2.6
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.421 SNIP 1.081 CiteScore 2.25
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.324 SNIP 1.196 CiteScore 2.29
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.423 SNIP 1.09 CiteScore 2.13
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.425 SNIP 1.118
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.451 SNIP 1.196
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.589 SNIP 1.379
Web of Science (2008): Indexed yes
Fatty acid trophic markers as measures of energy transfer through marine food webs exemplified by sandeel

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Dalsgaard, A. J. T. (Intern)
Number of pages: 131
Publication date: 2003

Fatty acid trophic markers in the pelagic marine environment

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources, Section for Population Ecology and Genetics
Pages: 225-340
Publication date: 2003
Main Research Area: Technical/natural sciences
An approach to the modelling of persistent pollutants in marine ecosystems

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources, Section for Management Systems
Authors: Dalsgaard, A. J. T. (Intern), Jarre, A. (Intern), Walters, C. (Ekstern), Pauly, D. (Ekstern)
Pages: 16
Publication date: 1998
Main Research Area: Technical/natural sciences

Publication information
Journal: ICES Council Meeting
Volume: V:10
ISSN (Print): 1015-4744
Ratings:
ISI indexed (2013): ISI indexed no
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Web of Science (2003): Indexed yes
Combining knowledge of the Strait of Georgia: Report from workshop discussions: From: Back to the future: Reconstructing the Strait of Georgia ecosystem

General information
State: Published
Organisations: Unknown
Publication date: 1998

Publication information
Publisher: University of British Colombia. Fisheries Centre
Original language: English
Series: Fisheries Centre Research Reports
Number: 6(5)
ISSN: 1198-6727
Main Research Area: Technical/natural sciences
Links:

Fishing down marine food webs

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Pauly, D. (Ekstern), Christensen, V. (Ekstern), Dalsgaard, A. J. T. (Intern), Froese, R. (Ekstern), Torres Jr., R. (Ekstern)
Pages: 860-863
Publication date: 1998
Main Research Area: Technical/natural sciences

Publication information
Journal: Science
Volume: 279
Issue number: 5352
ISSN (Print): 0036-8075
Ratings:
BFI (2018): BFI-level 3
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 12.012 SNIP 8.269 CiteScore 12.68
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 12.305 SNIP 7.87 CiteScore 12.43
Mass-balance food web ecosystem models as an alternative approach for combining multiple information sources in fisheries

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Number of pages: 815
Publication date: 1998

Host publication information
Title of host publication: Fishery Stock Assessment Models : Proceedings of the International Symposium on Fishery
Stock Assessment Models for the 21st Century
Mass-balance models of the Strait of Georgia: the present, one hundred, and five hundred years ago: From: Back to the future: Reconstructing the Strait of Georgia ecosystem

General information
State: Published
Organisations: University of British Columbia
Publication date: 1998

Publication information
Publisher: University of British Colombia. Fisheries Centre
Original language: English
Series: Fisheries Centre Research Reports
Number: 6(5)
ISSN: 1198-6727
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 315951
Publication: Research › Report – Annual report year: 1998

Preliminary mass-balance model of Prince William Sound, Alaska, for the pre-spill period, 1980-1989

General information
State: Published
Organisations: Unknown
Authors: Dalsgaard, A. J. T. (Intern), Pauly, D. (Ekstern)
Number of pages: 33
Publication date: 1997

Publication information
Publisher: University of British Colombia. Fisheries Centre
Original language: English
Series: Fisheries Centre Research Reports
Number: 5(2)
ISSN: 1198-6727
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 315953
Publication: Research › Report – Annual report year: 1997
Projects:

Micro particles in Aquaculture: cause and effects and ways to remove them
National Institute of Aquatic Resources
Period: 15/01/2017 → 31/03/2020
Number of participants: 4
Phd Student:
de Jesus Gregersen, Joao (Intern)
Supervisor:
Pedersen, Per Bovbjerg (Intern)
Pedersen, Lars-Flemming (Intern)
Main Supervisor:
Dalsgaard, Anne Johanne Tang (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD

Design and operation optimization of constructed wetlands at rainbow trout farms (39430)
This project aims at improving the design and operation of constructed wetlands with respect to the removal of waste nutrients and organic matter deriving from model trout farm systems type I and III.
The project contains five work packages:
1. Selection of representative fish farms to be part of a user group and where testing and measurements will be carried out
2. Mapping and characterization of selected wetlands
3. Measuring the effects of flow velocity, water column depth, and hydraulic retention time on the removal of nutrients and organic matter
4. Data analysis
5. Project management, administration and dissemination of results.
The projects is coordinated by

The project is funded by Ministry of Environment and Food of Denmark and the European Maritime and Fisheries Fund (EMFF)
National Institute of Aquatic Resources
Section for Aquaculture
Danish Aquaculture Association
Period: 06/10/2016 → 11/01/2019
Number of participants: 3
Research area: Aquaculture
Project participant:
Pedersen, Per Bovbjerg (Intern)
Dalsgaard, Anne Johanne Tang (Intern)
von Ahnen, Mathis (Intern)

Resource efficiency in practice: from sugar beet waste to fish feed ingredient (Starfish) (39368)
Sugar beet is a commonly cultivated crop in Denmark and the waste pulp is primarily sold as cow feed. The pulp, however, contains a potential prebiotic compound (pectin) that, if added to fish feed at low concentrations is hypothesized to:
1) improve the feed utilisation by the fish allowing more fish to be produced per amount of feed applied
2) stabilize the structure of the faecal waste so that it may be easier collected and removed reducing the discharge of nitrogen- and phosphorous
3) improve the overall immunological system/health status of the fish whereby the use of medicine and therapeutics may be reduced.
The objective of the project is to test these potential, beneficial effects of pectin in rainbow trout (Oncorhynchus mykiss) and tilapia (Oreochromis niloticus) by adding different molecular sizes and concentrations to the feed and measuring the effects on feed utilisation, faecal structure and fish health.
The project is coordinated by DTU Aqua. The project is funded by Ministry of Environment and Food of Denmark through the Green Development and Demonstration Program (GUDP).

National Institute of Aquatic Resources
Section for Aquaculture
CP Kelco ApS
BioMar A/S
Period: 01/08/2016 → 31/07/2019
Number of participants: 4
Research area: Aquaculture
Project participant:
Larsen, Bodil Katrine (Intern)
Skov, Peter Vilhelm (Intern)
Phd Student:
de Jesus Gregersen, Joao (Intern)
Project Coordinator:
Dalsgaard, Anne Johanne Tang (Intern)

Future Microbial Water Quality within Aquaculture Recirculation Systems
National Institute of Aquatic Resources
Period: 01/12/2014 → 21/03/2018
Number of participants: 6
Phd Student:
Rojas-Tirado, Paula Andrea (Intern)
Supervisor:
Pedersen, Per Bovbjerg (Intern)
Main Supervisor:
Pedersen, Lars-Flemming (Intern)
Examiner:
Dalsgaard, Anne Johanne Tang (Intern)
Attramadal, Kari (Ekstern)
Verdegem, Marc (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD

New physicochemical and technological approach for high quality and sustainable fish feed production (Exipro) (39189)
Aquaculture is the globally fastest growing food producing sector, and extruded fish feed is the largest expenditure in the production of carnivorous fish.

The quality of the different protein raw materials used in fish feed varies considerably, and even small differences in the nutritional quality can have large effects on fish performance, their degree of feed utilization and consequently the environment.

The production of high quality, nutrient-dense fish feed requires that the dietary matrix is extruded into pellets. However, the extrusion process can alter and deteriorate the nutritional quality of proteins. Currently, the extrusion process is based entirely on empirical learning, and little is known about the chemical reactions and physical processes that take place inside the extruder, i.e., the extruder is largely a 'Black Box'. In addition, little is known about concomitant effects on feed utilization.

The aim of Exipro is to optimize the extrusion process by clarifying the changes and damages on different protein ingredients that happen in the extruder, and to use the knowledge to improve the quality of fish feed. Hence, the objectives of the project are to:
- Determine the effects of extrusion on the physicochemical and chemical properties of proteins in fish feed
- Determine the effects of these changes on fish growth performance, metabolism, protein retention, and nitrogen excretion
- Develop a generic extrusion optimization tool for different protein ingredients.
The project is coordinated by University of Copenhagen.

The project is funded by Innovation Fund Denmark.

National Institute of Aquatic Resources
Section for Aquaculture
University of Copenhagen

Aarhus University

BioMar A/S
Period: 01/09/2014 → 31/12/2017
Number of participants: 3
Research area: Aquaculture
Project participant:
Larsen, Bodil Katrine (Intern)
Vega, Victoria Valdenegro (Intern)

Project Manager, academic:
Dalsgaard, Anne Johanne Tang (Intern)

Environmentally effective nitrogen removal in fish farming using sludge hydrolysis (wiN-wiN) (39119)
Reducing nitrogen discharge is important to fish farms and their environmental performance. Removal of nitrogen can be done by applying denitrification filters end-of-pipe (i.e. before discharge) through an anaerobic de-nitrification process using organic carbon as energy source.

Using external carbon is costly and introduces additional organic matter into the system. In contrast, sludge produced by the farmed fish might provide the organic matter given that a hydrolysis process can be controlled and optimised according to the needs of the denitrification process.

The project strives to establish, optimize and demonstrate an integrated system in commercial scale able to hydrolyse generated sludge and subsequently use it as energy source for nitrogen removal in end-of-pipe denitrification filters.

This project is coordinated by HME, Denmark.

The project is funded by the Danish Ministry of Food, Agriculture and Fisheries through the Green Development and Demonstration Program (GUDP) and the partners involved.

National Institute of Aquatic Resources
Section for Aquaculture
HME

Lundby Dambrug
Period: 01/08/2013 → 31/12/2016
Number of participants: 4
Research area: Aquaculture
Project participant:
von Ahnen, Mathis (Intern)
Dalsgaard, Anne Johanne Tang (Intern)
Phd Student:
Letelier-Gordo, Carlos Octavio (Intern)

Project Manager, academic:
Pedersen, Per Bovbjerg (Intern)

Optimized sludge hydrolysis and improved nitrogen removal through denitrification

National Institute of Aquatic Resources
Period: 15/04/2013 → 15/03/2017
Number of participants: 7
Phd Student:
Letelier-Gordo, Carlos Octavio (Intern)
Supervisor: 
Dalsgaard, Anne Johanne Tang (Intern)
Main Supervisor: 
Pedersen, Per Bovbjerg (Intern)
Examiner: 
Lund, Ivar (Intern)
Lund, Ivar (Intern)
von Rijn, Jaap (Ekstern)
von Rijn, Jaap (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: 1/3 DTU-stip, 2/3 FUR/andet
Project: PhD

New approaches and methods to improve the removal of dissolved nutrients in aquaculture
National Institute of Aquatic Resources
Period: 01/04/2013 → 30/06/2016
Number of participants: 6
Phd Student: 
von Ahnen, Mathis (Intern)
Supervisor: 
Pedersen, Per Bovbjerg (Intern)
Main Supervisor: 
Dalsgaard, Anne Johanne Tang (Intern)
Examiner: 
Jokumsen, Alfred (Intern)
Healy, Mark Gerard (Ekstern)
Schulz, Carsten (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: 1/3 DTU-stip, 2/3 FUR/andet
Project: PhD

Development of sustainable technologies and modeling tools in aquaculture aiming at increasing overall production (UDTÆNK) (39030)
The project aimed at developing methods and modeling tools that may assist the aquaculture industry in expanding its production while minimizing the environmental impact.

To obtain this, the project included six work packages concerning:
- Increased production of rainbow trout by providing methods for reducing the discharge of nitrogen and organic matter.
- Increased production in net cages by providing academic guidance to social workers on concurrent production of trout and mussels.
- Improved sustainability of the industry by providing guidance on optimal system design with respect to reducing nutrient discharge.

The project was funded by the Danish Ministry of Food, Agriculture and Fisheries and the European Fisheries Fund (EFF).
National Institute of Aquatic Resources
Section for Aquaculture
Dansk Akvakultur
Period: 09/07/2012 → 31/05/2015
Number of participants: 6
Research area: Aquaculture
Project participant: 
Pedersen, Per Bovbjerg (Intern)
Larsen, Bodil Katrine (Intern)
IT-solutions for environmental control of trout farms (39094)

In the project a IT-solution for direct reporting of environmental performance data from trout farms to the Municipality registration system was developed. Also, calculations of compliance with allowances etc. can be calculated and evaluated regularly by the farmer.

DTU Aqua further developed a discharge prediction model, able to calculate the resulting discharge from a ModelTroutFarm of any given layout and dimensions. This model ("Dambrugsmodellen" i.e. "the Trout Farm Model") is based on the existing Produktionsbidragsmodel ("Waste Production Model") and data and monitoring results from all treatment devices added and incorporated into a predicitive model. Both models are now widely used by the authorities as well as in the industry.

This project was coordinated by the Danish Aquaculture Association.

The project was funded by the Danish Ministry of Food, Agriculture and Fisheries and the European Fisheries Fund (EFF).

National Institute of Aquatic Resources
Section for Aquaculture
Danish Aquaculture Association
DHIDenmark
Aarhus University

Traditional trout farms (39095)

Nutrient removal is imperative for Danish fish farms and upcoming requirements for environmental performance though application of BAT (Best Available Technology) cannot be met by traditional fish farms since simple, low-cost technologies does not exist. Removal of dissolved nutrients in low concentrations and large water volumes is especially difficult.

In the project, potential low-cost technologies for removing nitrogen and organic matter were tested and documented. Removal and turn-over of organic matter and nitrogen in biofilters was studied, and the performance of constructed wetlands on traditional farms was also investigated during a full year. In these farms, wetlands efficiently remove particulate matter and associated nutrients (O and P) whereas dissolved matter is almost not removed due to the hydraulic load and short residence time. Depending on the concentrations in the incoming water, requirements for O and P net-removal could be met, whereas a need for simple, low-cost nitrogen removal was clearly demonstrated.

This project was coordinated by the Danish Aquaculture Association.

The project is funded by the Danish Ministry of Food, Agriculture and Fisheries and the European Fisheries Fund (EFF).

National Institute of Aquatic Resources
Section for Aquaculture
Danish Aquaculture Association
Commercial trout farms
Period: 05/07/2012 → 01/06/2016
Number of participants: 3
Research area: Aquaculture
Project participant:
von Ahnen, Mathis (Intern)
Pedersen, Per Bovbjerg (Intern)
Project Manager, academic:
Dalsgaard, Anne Johanne Tang (Intern)

PhD in Recirculating Aquaculture Systems
National Institute of Aquatic Resources
Period: 01/04/2012 → 02/09/2015
Number of participants: 5
Phd Student:
Fernandes, Paulo (Intern)
Main Supervisor:
Pedersen, Per Bovbjerg (Intern)
Examiner:
Dalsgaard, Anne Johanne Tang (Intern)
Brinker, Alexander (Ekstern)
Leiknes, TorOve (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Eksternt finansieret virksomhed
Project: PhD

Amino acid uptake patterns in fish fed plant based protein and the effects on protein utilization.
National Institute of Aquatic Resources
Period: 01/04/2011 → 27/08/2014
Number of participants: 7
Phd Student:
Rolland, Marine (Intern)
Supervisor:
Dalsgaard, Anne Johanne Tang (Intern)
Holm, Jørgen (Ekstern)
Main Supervisor:
Skov, Peter Vilhelm (Intern)
Examiner:
Lund, Ivar (Intern)
Espe, Marit (Ekstern)
Skiba-Cassey, Sandrine (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Ansat eksternt
Project: PhD

Best available technology applicable to traditional pond farms (38811)
As a consequence of environmental concerns – also following the Water Framework Directive legislations – traditional Danish pond farms need to install and operate (affordable) technology to reduce environmental impact from fish farming. In this project the best available technology applicable to traditional Danish flow-through pond farms was assessed and defined. Different technologies were installed/evaluated on selected farms and environmental effects were analysed, evaluated and discussed. Based on the study the best available technology and its applicability and effects on traditional farms was established, and the environmental authorities were supplied with details regarding what can realistically be done on this type of farms.
Nutrients (N & P) as well as organics, the pollutants most immediately relevant to the watercourse in such farms, were considered in the assessment. The project was coordinated by Danish Aquaculture Association, Denmark. The project was funded by the Danish Ministry of Food, Agriculture and Fisheries and the European Fisheries Fund (EFF).

National Institute of Aquatic Resources
Section for Aquaculture
Danish Aquaculture Organisation
Aarhus University
Period: 01/01/2011 → 01/01/2013
Number of participants: 2
Research area: Aquaculture
Project participant:
Dalsgaard, Anne Johanne Tang (Intern)
Project Manager, organisational:
Pedersen, Per Bovbjerg (Intern)

**HPLC and amino acids uptake patterns in fish fed plant-based protein (38803)**
One of the issues of the rapidly growing aquaculture sector is to find fish meal substitutes. The main focus has been on plant proteins as a substitute for fish meal in the diet formulation. However, significant incorporation of plant proteins in the fish diet often results in reduced growth and/or impaired feed efficiency. Recent trials performed at our lab have shown that the profile of amino acid uptake (timeline) varies between rainbow trout fed plant based diet and fish meal diet. This difference in amino acid availability might well influence the protein synthesis and could add to the explanation of reduced performance of fish fed plant based diets and also the observed increased ammonia excretion.

Following these initial observations made in 2011 the project will perform a series of experiments to further examine how and why amino acid uptake patterns differ. Correlations between amino acid profile in the diet and amino acid in the blood following feeding will be made for different plant protein sources and added crystalline amino acids.

The concomitant effects on liver enzyme activity and protein synthesis will be examined and relevant indicators for protein synthesis (i.e. growth) hopefully determined. Specific digestibility and nitrogen excretion studies as well as traditional growth studies will be performed to support the findings.

The project is coordinated by DTU Aqua.

National Institute of Aquatic Resources
Section for Aquaculture
BioMar A/S
Period: 01/01/2011 → 31/12/2015
Number of participants: 5
Research area: Aquaculture
Project participant:
Skov, Peter Vilhelm (Intern)
Dalsgaard, Anne Johanne Tang (Intern)
Pedersen, Per Bovbjerg (Intern)
Roland, Marine (Intern)
Larsen, Bodil Katrine (Intern)
Project Manager, academic:
Larsen, Bodil Katrine (Intern)

**Innovative practices and technologies for developing sustainable aquaculture in the Baltic Sea region (AQUABEST) (38924)**
In opposite to the global trend, aquaculture production in the Baltic Sea region had stagnated. It is widely accepted that aquaculture had great potential to feed the growing human population in the era of declining wild stocks ("Blue Revolution"), but new production has to be built on sustainable practices and technologies. The European Union has identified this challenge and has adopted aquaculture as a flagship project in the EU strategy for the Baltic Sea region.

Firstly, AQUABEST demonstrated that Baltic Sea region aquaculture was capable of becoming a nutrient neutral food production system. This was assessed to be achieved by replacing oceanic feed ingredients and plant products harvested
at other continents with regional feed ingredients. Potential regional ingredients included Baltic Sea fish catches and Baltic Sea grown mussels not used for human consumption, as well as plant proteins and single cell proteins produced and processed in the region.

Secondly, AQUABEST adapted lessons from maritime spatial planning projects, developed them into guidelines and by regional testing demonstrated that spatial planning tools can be adapted to create environmentally, economically and socially sustainable aquaculture. Spatial planning activities were completed by activities that could support farmers to move fish cages offshore and which could support mussel farmers to adapt technologies that tolerated harsh winter conditions in the northern Baltic Sea.

New farming technologies using recirculating water have been developed especially in Denmark. The third solution of AQUABEST was to transfer these technologies to other regions and further develop them to adapt to brackish water conditions of the Baltic Sea. Furthermore, although recirculation farms already released much less nutrients in the effluent than conventional farms, nitrogen release of these farms could be further diminished.

As the final outcome, AQUABEST carried out regional self-evaluation of current environmental regulation models in aquaculture. A novel ecosystem-based regulation needed new approach, environmental policy instruments and economic incentives. Concrete improvements were proposed after dialogue between major stakeholders.

The project was coordinated by Finish Game and Fisheries Research Institute, Finland.

The project was funded by EU, InterReg (regional collaboration).

National Institute of Aquatic Resources
Section for Aquaculture
Finnish Game and Fisheries Research Institute
The Government of Åland
Jämtland County Council
Lund University
Swedish Board of Agriculture
Polish Trout Breeders Association
Institute of Food Safety, Animal Health and Environment
Belarusian State Agricultural Academy
Danish Aquaculture Organisation
Association of Marine Aquaculture Ltd
Johann Heinrich von Thünen-Institute
University of Tartu
University of Helsinki
Period: 01/01/2011 → 31/12/2014
Number of participants: 5
Research area: Aquaculture
Project participant:
Pedersen, Per Bovbjerg (Intern)
Suhr, Karin Isabel (Intern)
Dalsgaard, Anne Johanne Tang (Intern)
Pedersen, Lars-Flemming (Intern)
Project Manager, academic:
Jokumsen, Alfred (Intern)

Relations
Activities:
Nitrogen removal in RAS farms for Baltic Sea coastal farming
Microparticles in Recirculating Aquaculture Systems
Nordic network and conference on aquaculture recirculation technology (NordicRAS) (38842)
DTU Aqua has taken the initiative to establish a Nordic Network on Recirculating Aquaculture Technology (RAS). The idea is motivated by the facts that: (i) the geographical location and species composition requires certain breeding conditions and solutions, and (ii) the Nordic region has an excellent academic and commercial background for initiating such collaboration.

The purpose of the network is to strengthen Nordic research and research collaboration in RAS and associated water treatment including e.g. application of existing techniques in new setups, resolving potential new research areas, and investigating innovative operation forms that ensure high water quality. We anticipate that the network will become a continuous activity which could result in the establishment of consortiums that perhaps could apply for national and transnational European research funding, exchange of students, development of projects and potential educational programmes, etc.

The network is coordinated by DTU Aqua, and was founded at a steering committee meeting in April 2011 with country representatives from Denmark, Norway, Sweden, Finland and Iceland.

As one of its first activities, the network organises a RAS workshop in Helsinki on October 5-6, 2011. The aim of the workshop is to bring researchers and industrial partners with an interest in RAS together, creating a unique opportunity for exchanging practical experiences and scientific knowledge on the newest developments in RAS. We anticipate that the workshop will become a recurrent event every other year in the country holding the presidency of the Nordic Council of Ministers.

National Institute of Aquatic Resources
Section for Aquaculture
Period: 01/01/2011 → …
Number of participants: 2
Research area: Aquaculture
Project participant:
Pedersen, Per Bovbjerg (Intern)
Project Manager, academic:
Dalsgaard, Anne Johanne Tang (Intern)
Project

Nordic Network and Conference on Aquaculture Recirculation Technology (NordicRAS) (38842 & 39099 & 39223)
DTU Aqua has taken the initiative to establish a Nordic Network on Recirculating Aquaculture Technology (RAS). The idea is motivated by the facts that: (i) the geographical location and species composition requires certain breeding conditions and solutions, and (ii) the Nordic region has an excellent academic and commercial background for initiating such collaboration.

The purpose of the network is to strengthen Nordic research and research collaboration in RAS and associated water treatment including e.g. application of existing techniques in new setups, resolving potential new research areas, and investigating innovative operation forms that ensure high water quality. We anticipate that the network will become a continuous activity which could result in the establishment of consortiums that perhaps could apply for national and transnational European research funding, exchange of students, development of projects and potential educational programmes, etc.

The network is coordinated by DTU Aqua, and was founded at a steering committee meeting in April 2011 with country representatives from Denmark, Norway, Sweden, Finland and Iceland.

The main activity of the network will be to organise a RAS workshop every second year in one of the Nordic countries. The first workshop will be held in Helsinki (Finland), October 2011, the second workshop in Aalborg (Denmark) October 2013, and the third workshop in Molde (Norway) September - October 2015. The aim of the workshops is to bring researchers and industrial partners with an interest in RAS together, creating a unique opportunity for exchanging practical experiences and scientific knowledge on the newest developments in RAS.

This project is coordinated by DTU Aqua.

In 2011, the project was funded by AG-Fisk (Nordic Council of Ministers) and “Formandskabspuljen” (Nordic Council of Ministers). In 2012, follow-up activities and planning of future activities was funded by AG-Fisk. In 2013 and 2015 it was funded by AG-Fisk.

National Institute of Aquatic Resources
Section for Aquaculture
Period: 01/01/2011 → 31/12/2017
Number of participants: 2
Helpdesk for aquaculture (HelpDesk) (38696)

In the project different environmental issues related to regulation of aquaculture have been addressed according to specific needs and questions from the Ministry of Food, Agriculture and Fisheries and the Ministry of Environment.

Specifically, a calculation model for predicting waste generated from fish farming has been developed. This Excel-based model is able to calculate the waste generated by the fish depending only on the fish performance (FCR) and the composition and digestibility of the feed used.

The model, valid for rainbow trout up to 800 g/pieces in freshwater, was verified through various experiments using commercial feed types, and is now a central element in the regulation of the Danish freshwater trout farming industry. It is used throughout the industry and administration and has generated a common background and baseline for all stakeholders.

A group consisting of the Ministry for Food, Agriculture and Fisheries, the Ministry of Environment, the Danish municipalities' organization Local Government Denmark was formed and acted as reference/steering group.

The project was coordinated by DTU Aqua.

The project was funded by the Danish Ministry of Food, Agriculture and Fisheries and the European Fisheries Fund (EFF).

Amino acid metabolism in gilthead seabream (Sparus aurata) - the fate of protein derived nitrogen

National Institute of Aquatic Resources

Section for Aquaculture
Period: 01/01/2010 → 30/11/2013
Number of participants: 3
Research area: Aquaculture
Project participant:
Dalsgaard, Anne Johanne Tang (Intern)
Project Manager, academic:
Pedersen, Per Bovbjerg (Intern)
Jokumsen, Alfred (Intern)
Project

Amino acid metabolism in gilthead seabream (Sparus aurata) - the fate of protein derived nitrogen

National Institute of Aquatic Resources
Period: 01/03/2009 → 06/02/2013
Number of participants: 8
Phd Student:
Ekmann, Kim Schøn (Intern)
Supervisor:
Campbell, Patrick James (Ekstern)
Dalsgaard, Anne Johanne Tang (Intern)
Holm, Jørgen (Ekstern)
Main Supervisor:
Skov, Peter Vilhelm (Intern)
Examiner:
Pedersen, Per Bovbjerg (Intern)
Damgaard Poulsen, Hanne (Ekstern)
Pereira de Oliva Teles, Aires Manuel (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Eksternt finansieret virksomhed
Project: PhD
Enzymes in fish feed: Optimization of protein digestibility in fish production (38396)

The demand for aquaculture products is increasing globally and is expected to keep increasing in proportion with the growth in the global human population. A limiting factor for the expansion of the aquaculture industry is the dependency of fish meal, which is the primary protein source in feed for carnivorous fish (trout, salmon, turbot, cod etc.). Increasing world market prices on quality fish meal is reflected in the price of fish feed, and has intensified the international competition for finding ways to optimise the use of alternative plant-based proteins in fish feed.

Enzymes are catalysts that increase the speed of the processes in which they are involved. A high degree of specificity makes enzymes an excellent tool for increasing specific reactions, e.g. the degradation of complex feed ingredients to digestible nutrients. The addition of enzymes to fish feed has the potential of improving the nutritional value of the feed, reducing production costs and loss of valuable nutrients to the environment. Enzymes are already widely used in feed for broilers and pigs, while only phytases have been approved for commercial fish production.

The objective of this project was to promote the use of industrial enzymes in fish feed as a means to improve the utilization by the fish of existing and/or alternative protein sources. The project consisted of four work packages: 1) Identification of relevant enzymes and feed ingredients; 2) Feed production; 3) Test of feed quality in a digestion model; 4) Data analyses, reporting and preparing publications. Low-grade soybean cake, sunflower cake and rapeseed cake were chosen as alternative plant-based protein sources in three diets. The effects of three exogenous enzymes in liquid form (Ronozyme®VP (β-glucanase, pectinase), Ronozyme®WX (xylanase) and an experimental protease) on nutrient digestibility was examined. The study showed that Ronozyme®VP and the experimental protease were able to significantly improve the nutrient digestibility primarily in the soybean cake diet at doses of 150-300 mg kg⁻¹. No clear effect of RONOZYME®WX on nutrient digestibility was observed with any of the ingredients tested. The overall conclusion of the project was that Ronozyme®VP and the experimental protease have potential to increase the nutritional and energetic value of proteinaceous plant-based feed ingredients in fish feed.

The project was coordinated by DTU Aqua.

National Institute of Aquatic Resources
Section for Aquaculture
BioMar A/S
Novozymes A/S
DSM Nutritional Products

Period: 01/01/2008 → 31/12/2010
Number of participants: 6
Research area: Aquaculture
Project participant:
Pedersen, Per Bovbjerg (Intern)
Poulsen, Erik (Intern)
Larsen, Ole Madvig (Intern)
Sproegel, Ulla (Intern)
Frandsen, Dorthe (Intern)
Project Manager, academic:
Dalsgaard, Anne Johanne Tang (Intern)

Monitoring and Documentation of the Performance of ModelTroutFarms (ModelTroutFarm)

De-coupling fish production and environmental impact is a sustainable way of increasing aquaculture. In order to achieve increased production and—simultaneously— reduced environmental impact a new farming concept was developed, tested and demonstrated.

Applying cost-efficient technologies from recirculation on large, traditional flow-through farms provided the basic concept for ModelTroutFarms. Through intensified production in concrete tanks, the former earthen ponds could be used as constructed wetlands for end-of-pipe treatment of the discharged water.

Due to recirculation, water consumption was reduced by a factor 25, so damming of natural water courses was no longer needed for supplying water to the farm. As a consequence, dammings could be removed leaving the water course to its natural flow.

A reduction of some 80 % in organic matter and phosphorous discharge was achieved, and 50 % of the nitrogen was removed.
Through the concept, technical and practical means of decoupling fish production and environmental impact was demonstrated in large scale commercial operations. Concomitantly, legislation was changed and now approximately 50% of the Danish fresh water production is in ModelTroutFarms.

This project was coordinated by DTU Aqua.

National Institute of Aquatic Resources
Section for Aquaculture
Aarhus University

Eight trout farms
Period: 01/01/2003 → 31/12/2008
Number of participants: 4
Research area: Aquaculture
Project participant:
Rasmussen, Richard Skøtt (Intern)
Dalsgaard, Anne Johanne Tang (Intern)
Suhr, Karin Isabel (Intern)
Project Coordinator:
Pedersen, Per Bovbjerg (Intern)

Monitoring and documentation of the performance of ModelTroutFarms (ModelTroutFarm) (38192)
Decoupling fish production and environmental impact is a sustainable way of increasing aquaculture. In order to achieve increased production and, simultaneously, reduced environmental impact a new farming concept was developed, tested and demonstrated.

Applying cost-efficient technologies from recirculation on large, traditional flow-through farms provided the basic concept for ModelTroutFarms. Through intensified production in concrete tanks, the former earthen ponds could be used as constructed wetlands for end-of-pipe treatment of the discharged water.

Due to recirculation, water consumption was reduced by a factor 25, so damming of natural water courses was no longer needed for supplying water to the farm. As a consequence, dammings could be removed leaving the water course to its natural flow.

A reduction of some 80% in organic matter and phosphorous discharge was achieved, and 50% of the nitrogen was removed.

Through the concept, technical and practical means of decoupling fish production and environmental impact was demonstrated in large scale commercial operations. Concomitantly, legislation was changed and now approximately 50% of the Danish fresh water production is in ModelTroutFarms.

This project was coordinated by DTU Aqua.

The project was funded by the Danish Ministry of Food, Agriculture and Fisheries and the European Fisheries Fund (EFF).

National Institute of Aquatic Resources
Section for Aquaculture
Aarhus University

Eight trout farms
Period: 01/01/2003 → 31/07/2011
Number of participants: 4
Research area: Aquaculture
Project participant:
Rasmussen, Richard Skøtt (Intern)
Dalsgaard, Anne Johanne Tang (Intern)
Suhr, Karin Isabel (Intern)
Project Coordinator:
Pedersen, Per Bovbjerg (Intern)