Anaerobic digestion of solid waste in RAS: Effect of reactor type on the biochemical acidogenic potential (BAP) and assessment of the biochemical methane potential (BMP) by a batch assay

Anaerobic digestion is a way to utilize the potential energy contained in solid waste produced in recirculating aquaculture systems (RASs), either by providing acidogenic products for driving heterotrophic denitrification on site or by directly producing combustive methane. In this study the biochemical acidogenic potential of solid waste from juvenile rainbow trout was evaluated by measuring the yield of volatile fatty acids (VFA) during anaerobic digestion by batch or fed-batch reactor operation at hydrolysis time (HT) / hydraulic retention time (HRT) of 1, 5, or 10 days (and for batch additional 14 and 20 days) in continuously stirred tank reactors. Generally, the VFA yield increased with time and no effect of the reactor type used was found within the time frame of the experiment. At 10 days HT or 10 days HRT the VFA yield reached 222.3 ± 30.5 and 203.4 ± 11.2 mg VFA g-1 TVS0 (total volatile solids at day 0) in batch and fed-batch reactor, respectively. For the fedbatch reactor, increasing HRT from 5 to 10 days gained no significant additional VFA yield. Prolonging the batch reactor experiment to 20 days increased VFA production further (273.9 ± 1.6 mg VFA g-1 TVS0, n=2). After 10 days HT / HRT, 16.8 - 23.5 % of total Kjeldahl N was found as TAN and 44.3 - 53.0 % of total P was found as ortho-phosphate. A significant difference between reactor types was detected for the phosphorous dissolution at 5 days HT / HRT as a relatively steep increase (of a factor 2-3) in ortho-P content occurred in fed-batch reactors but similar steep increase was only notable after 10 days HT for batch reactors. No differences between reactor types at the other HT / HRT were recorded for P as well as (for all HT / HRT for) N. Based on this study a HRT of approximately 5 days would be recommended for the design of an acidogenic continuously stirred reactor tank in a RAS single-sludge denitrification set-up. The biochemical methane potential of the sludge was estimated to 318 ± 29 g CH4 g-1 TVS0 by a batch assay and represented a higher utility of the solid waste when comparing the methane yield with the VFA yield (in COD units). This points towards a technological challenge of ultimately increase the acidogenic output to match the methane yield as both products are formed from the same reference point.

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Organisations: National Institute of Aquatic Resources, Section for Aquaculture
Authors: Suhr, K. I. (Intern), Letelier-Gordo, C. O. (Intern), Lund, I. (Intern)
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Publication information
Journal: Aquacultural Engineering
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 0.24g 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 0.51-0.56g 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 0.26-0.34g 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 0.08g/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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Organisations: National Institute of Aquatic Resources, Section for Aquaculture, BioMar A/S
Authors: Letelier-Gordo, C. O. (Intern), Dalsgaard, A. J. T. (Intern), Suhr, K. I. (Intern), Pedersen, P. B. (Intern), Ekmann, K. S. (Ekstern)
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Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.69 SNIP 1.406 CiteScore 1.54
Single-sludge denitrification in recirculating aquaculture systems: effects of pre-fermentation and pH

Single-sludge denitrification (DN) reactors in aquaculture use the carbonous solid fish waste produced in the system to reduce the discharged nitrate load. The solid waste is available for denitrifiers when present in soluble, readily biodegradable form, and the transformation is accomplished by bacterial hydrolysis and fermentation. The objective of this study was to quantify the effect of pre-fermentation of solid fish waste on single-sludge DN reactor efficiency. Pre-fermentation times tested were 0 d (no pre-fermentation), 1 d, 5 d, and 10 d, and the efficiency was quantified as the potential DN rate obtained in laboratory assays. Results showed that the highest DN rate was achieved with 1 d pre-fermentation. The volumetric DN rates measured in decreasing order were 23.4 +/- 0.00 mg NO₃-N L⁻¹ h⁻¹ (1 d), 20.5 +/- 0.35 mg NO₃-N L⁻¹ h⁻¹ (5 d), 17.0 +/- 0.47 mg NO₃-N L⁻¹ h⁻¹ (10 d), and 14.2 +/- 0.24 mg NO₃-N L⁻¹ h⁻¹ (0 d). It was suspected that the poor utilization of soluble COD (sCOD) in the 5 d and 10 d pre-fermentation treatments was due to the low starting pH (pH <7). Subsequently, the experiments were repeated in 0.1 M HEPES buffer (pH = 7.1) and showed a clear correlation between specific DN rate and sCOD content. Overall, the highest increase in potential specific DN rate was achieved by applying pre-fermentation; e.g., from 0 d to 1 d, the increase was 123% and 106% at unadjusted pH and pH 7.1, respectively. An additional 20% increase was achieved at pH 7.1 by prolonging the pre-fermentation time to 5 d.

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Effects of dietary protein: energy ratios on hydrolysis and fermentation of faecal solids from rainbow trout (Oncorhynchus mykiss) for denitrification

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Authors: Letelier-Gordo, C. O. (Intern), Dalsgaard, A. J. T. (Intern), Suhr, K. I. (Intern), Pedersen, P. B. (Intern)
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Main Research Area: Technical/natural sciences
Publication: Research - peer-review › Journal article – Annual report year: 2016

End-of-pipe single-sludge denitrification in pilot-scale recirculating aquaculture systems
A step toward environmental sustainability of recirculating aquaculture systems (RAS) is implementation of single-sludge denitrification, a process eliminating nitrate from the aqueous environment while reducing the organic matter discharge simultaneously. Two 1700 L pilot-scale RAS systems each with a 85 L denitrification (DN) reactor treating discharged water and hydrolyzed solid waste were setup to test the kinetics of nitrate and COD removal. Nitrate removal and COD
reduction efficiency was measured at two different DN-reactor sludge ages (high X: 33–42 days and low X: 17–23 days). Nitrate and total N(NO3−+ NO2−+ NH4+) removal of the treated effluent water ranged from 73–99% and 60–95% during the periods, respectively, corresponding to an overall maximum RAS nitrate removal of approximately 75%. The specific nitrate removal rate increased from 17 to 23 mg NO3−-N (g TVS d)−1 and the maximal potential DN rate (measured at laboratory ideal conditions) increased correspondingly from 64–68 mg NO3−-N (g TVS d)−1 to 247–294 mg NO3−-N (g TVS d)−1 at high and low X, respectively. Quantification of denitrifiers in the DN-reactors by qPCR showed only minor differences upon the altered sludge removal practice. The hydrolysis unit improved the biodegradability of the solid waste by increasing volatile fatty acid COD content 74–76%. COD reductions in the DN-reactors were 64–70%. In conclusion, this study showed that single-sludge denitrification was a feasible way to reduce nitrate discharge from RAS, and higher DN rates were induced at lower sludge age/increased sludge removal regime. Improved control and optimization of reactor DN activity may be achieved by further modifying reactor design and management scheme as indicated by the variation in and between the two DN-reactors.

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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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Scopus rating (2011): SJR 0.69 SNIP 1.406 CiteScore 1.54
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Scopus rating (2010): SJR 0.55 SNIP 0.945
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
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
Single-sludge denitrification in recirculating aquaculture systems: Effects of pre-fermentation and pH

Single-sludge denitrification (DN) reactors in aquaculture utilize the solid fish waste produced in the system to reduce the nitrate load discharged. The solid waste is available for denitrifiers when present in soluble readily biodegradable form. A transformation accomplished by bacterial hydrolysis (and fermentation). The objective of this study was to quantify the effect of pre-fermentation of the solid fish waste on single-sludge DN-reactor efficiency. Pre-fermentation times tested were: 0 (no pre-fermentation), 1 d, 5 d, and 10 d. The efficiency was quantified as the potential DN-rates in laboratory assessments. Results showed that the highest DN-rate obtained was achieved by 1 d pre-fermentation. The volumetric DN-rate measured in decreasing order was; 23.4 ± 0.00 (1 d); 20.5 ± 0.35 (5 d); 17.0 ± 0.47 (10 d); 14.2 ± 0.24 (0 d) mg NO3-N (L∗h)-1 It was suspected that the poor utilization of sCOD in 5 and 10 d pre-fermentation treatments were due to low start pH (below 7). Subsequently, the experiments were repeated in 0.1 M HEPES buffer pH=7.1, and showed a clear correlation between specific DN-rate and soluble COD content. Overall, the highest increase in potential specific DN-rate was achieved by applying pre-fermentation, e.g. from 0 d to 1 d the increase was 85 % and 106 % at unadjusted pH and pH 7.1, respectively. Additional 20 % increase was achieved at pH 7.1 by prolonging the pre-fermentation time to 5 d. At unadjusted pH conditions, the higher sCOD obtained by longer pre-fermentation was futile due to inhibitory effect of low pH

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Authors: Suhr, K. I. (Intern), Letelier Gordo, C. O. (Intern), Prat Busquets, P. (Intern)
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Host publication information
End-of-pipe denitrification using RAS effluent waste streams: Effect of C/N-ratio and hydraulic retention time

Environmentally sustainable aquaculture development requires increased nitrogen removal from recirculating aquaculture systems (RAS). In this study, removed solids from a large commercial outdoor recirculated trout farm (1000 MT year$^{-1}$) were explored as an endogenous carbon source for denitrification. This was done by (1) a controlled laboratory experiment on anaerobic hydrolysis of the organic matter (from sludge cones, drumfilter, and biofilter back-wash) and (2) an on-site denitrification factorial experiment varying the soluble COD (CODS)/NO$_3$-N ratio from 4 to 12 at hydraulic retention times (HRT) from 50 to 170 min in simple 5.5 m$^3$ denitrification reactors installed at the trout farm. The lab-experiments showed that the major part of the readily biodegradable organic matter was hydrolyzed within 14 days, and the hydrolysis rate was fastest the first 24 h. Organic matter from the sludge cones generated 0.21 ± 0.01 g volatile fatty acids (VFA) g$^{-1}$ total volatile solids (TVS), and the VFAs constituted 75% of CODS. Analogously, 1 g TVS from the drum filter generated 0.15 ± 0.01 g VFA, constituting 68% of the CODS. Comparison of the laboratory hydrolysis experiments and results from the on-farm study revealed as a rough estimate that potentially 17–24% of the generated VFA was lost due to the current sludge management. Inlet water to the denitrification reactors ranged in NO$_3$-N concentration from 8.3 to 11.7 g m$^{-3}$ and CODS from 52.9 to 113.4 g m$^{-3}$ (10.0 ± 1.2 ◦C). The highest NO$_3$-N removal rate obtained was at the intermediate treatments; 91.5–124.8 g N m$^{-3}$ reactor d$^{-1}$. The effect of the C/N ratio depended on the HRT. At low HRT, the variation in C/N ratio had no significant effect on NO$_3$-N removal rate, contrary to the effect at the high HRT. The stoichiometric ratio of CODS/NO$_3$-N was 6.0 ± 2.4, ranging from 4.4 (at the high HRT) to 9.3 (at the low HRT). A simple model of the denitrification reactor developed in AQUASIM showed congruence between modeled and measured data with minor exceptions. Furthermore, this study pointed to the versatility of the NO$_3$-N removal pathways expressed by the bacterial population in response to changes in the environmental conditions; from autotrophic anammox activity presumably present at low C/N to dissimilatory nitrate reduction to ammonia (DNRA) at high C/N, besides the predominate “normal” heterotrophic dissimilatory nitrate reduction (denitrification)

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Aquaculture, Department of Environmental Engineering, Urban Water Engineering
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 (Oncorhynchus 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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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
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Scopus rating (2013): SJR 1.136 SNIP 1.3 CiteScore 2.18
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
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Reducing nitrate emission from RAS by End-of-pipe single-sludge denitrification

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Authors: Suhr, K. I. (Intern)
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Controlling effluents from RAS – waste management strategies important for commercial RAS sustainability

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Authors: Pedersen, P. B. (Intern), Suhr, K. I. (Intern), Pedersen, L. (Intern)
Publication date: 2011

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Dambrugsteknologi – reduktion af kvælstofudledning fra Modeldambrug: Test af denitrifikationsfiltre

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Dambrugsteknologi – reduktion af kvælstofudledning fra Modeldambrug: Undersøgelse af biofilterelementer, biofilterkinetik og forhold af betydning for nitrifikationen

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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.

**General Information**

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**Test af denitrifikationsfiltre på Modeldambrug: Fra: Dambrugsteknologi. Samlerapport**

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**Towards environmentally sustainable aquaculture: Exploiting fermentation products from anaerobic sludge digestion for fueling nitrate removal in RAS**

Aquaculture is the world’s fastest growing food production sector (FAO, 2007). The continuous growth in many countries, however, relies heavily on the ability to reduce the emission of nutrients and chemicals from the fish farms. A way to manage and treat the nutrient aquaculture wastes is by production in recirculating aquaculture systems (RAS). In Denmark, more than 50 % of total fresh-water rainbow trout production is made in semi-intensive RAS, called ModelTroutFarms (MTF). MTF efficiently removes organic matter (93%), phosphorous (76%), and nitrogen (50%) (Svendsen et al., 2008). This makes nitrogen the limiting process parameter for further environmentally viable increase in production. Nitrogen removal is a two step transformation process, with (1) ammonia-N oxidation to nitrate-N in the RAS’ biofilter, and subsequently (2) nitrate-N reduction to N2 in the constructed wetlands. The latter being the final cleaning component of the MTF set-up. No specific denitrification filter has so far been implemented in Danish MTFs. An in-situ
study was conducted at a commercial MTF (1000 ton/year) for evaluating the potential of using the fermentation products from anaerobic digestion in the sludge storage basins, to fuel denitrification in specific denitrification filters. In experimental filters (5.5 m3) nitrate-containing outlet water was mixed with drainage water from the sludge storage basins according to a factorial design varying C/N ratio from 4 to 12 (CODs /NO3-N) and hydraulic retention time (HRT) from 50 to 180 min. The highest removal rate recorded, 125 g NO3-N/m3reactor/d, was found in treatments at the design center point, and multivariate response surface analysis modeled a maximum N-removal at C/N ratio of 8.8 and HRT of 114 min. The effect of C/N ratio depended on the HRT: At low HRT, variation in C/N ratio had no effect on N-removal. On the contrary, at high HRT, the highest N-removal was measured at high C/N ratio but significant ammonia-N was simultaneously produced, most probably by dissimilatory nitrate reduction to ammonia (DNRA). Running the filters at high HRT and low C/N ratio rendered a relatively lower nitrate-N removal rate but significantly higher ammonia-N reduction, which could indicate anaerobic ammonia oxidation (anammox) activity. A controlled laboratory anaerobic MTF sludge digestion experiment showed that app. 40% additional nitrate-N reduction could theoretically be achieved if implementing the use of fermented sludge as carbon source for denitrification. Besides the N-reduction, the directly linked sludge (organic matter) reduction is a beneficial side effect of such an operational set-up.

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Undersøgelse af biofilterelementer, biofilterkinetik og forhold af betydning for nitrifikationen: Fra: Dambrugsteknologi. Samlerapport

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Pedersen, L. (Intern), Suhr, K. I. (Intern), Pedersen, P. B. (Intern)
Number of pages: 10
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Publisher: Dansk Akvakultur
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Main Research Area: Technical/natural sciences
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Kvælstoffjernelse på modeldambrug ved hjælp af denitrifikationsfiltre

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Suhr, K. I. (Intern), Pedersen, P. B. (Intern)
Pages: 5-6
Publication date: 2010
Nitrification in moving bed and fixed bed biofilters treating effluent water from a large commercial outdoor rainbow trout RAS

The nitrification performance of two fixed bed (FB) biofilters and two moving bed (MB) biofilters was evaluated. They received the same cold (8 degrees C) influent water from a commercial outdoor RAS facility producing rainbow trout (average density 32 kg m(-3)). The filters were constructed as four identical 5.5 m(3) tanks with different filter media inside and tested simultaneously in duplicate. FB filters were filled with 4.2 m(3) polyethylene netshaped cylinders (Bioblok (R), 200 m(2):n(-3)), and MB filters with 2 m(3) polypropylene carriers (Biomedia, 850 m(2) m(-3)). Nitrification rates were measured 3(1/2) months after start-up, and inlet water was supplemented with ammonium chloride in order to determine maximum nitrification rates (0-order kinetics). The filters were conditioned at in inlet TAN concentration of 2.89 +/- 0.1 mg l(-1) and water in-flow ranging from 1 l s(-1) to 4 l s(-1). Expressed as volumetric total ammonia-N (TAN) removal rate, the MB filters had significantly higher removal rate (23 +/- 17 g N-1 m(-3) d(-1)) compared to the FB filters (92 +/- 2 g N-1 m(-3) d(-1)). Expressed as surface specific TAN removal rate MB filters had significantly lower removal (0.27 +/- 0.02 g m(-2) d(-1)) than FB filters (0.46 +/- 0.01 g m(-2) d(-1)). When conditioned to a higher inlet TAN concentration (6.27 +/- 0.39 mg l(-1)) for 2 weeks, the FB filters increased the removal rate (146 +/- 3 g m(-3) d(-1) or 0.73 +/- 0.01 g m(-2) d(-1)) while the MB filters had unaltered performance. The results indicate, that the more heterogeneous and stratified biofilm to be expected in FB, can react more flexibly when challenged with changes such as differences in TAN loading. The effect of dissolved oxygen level on FB filter nitrification rates was additionally tested at TAN 5.35 +/- 0.06 mg l(-1). Below approximately 60% saturation (7.1 mg O-2 l(-1)) measured at the filter outlet, nitrification rates started decreasing rapidly. An exponential expression (y = -10.05 + 10.48(1 - e(-0.0798x)), R-2=0.96) was found to model the whole data range from 40% to 80% DO saturation well. (C) 2009 E sevier B.V. All rights reserved.
A comparison of fatty acid composition and quality aspects of eggs and larvae from cultured and wild broodstock of common sole (Solea solea L.)

Eggs from a F-1 cultured broodstock of sole were compared with eggs from wild-caught breeders throughout one spawning season, to evaluate if egg quality may be affected by culture-related conditions. Fourteen batches of eggs from cultured broodstock and 17 batches from wild-caught sole were compared with respect to fatty acid (FA) composition, egg size, fertilization rate and hatching rate. Based on a multivariate analysis of the FA profiles, it was possible to discriminate between culture and wild inheritance. Eggs from cultured broodstock had high levels of C20:1(n-9), C18:2(n-6) and C18:3(n-3), whereas eggs from wild fish had high levels of C16:1(n-7), C20:4(n-6) and C20:5(n-3). Differences in FA profiles were most likely related to dietary differences. Fertilization and hatching rates were generally low and lowest in eggs from cultured broodstock, but not related to FA composition. Larval growth of one batch from each group was compared. Larval growth was not correlated to broodstock origin, FA composition or egg or larval size. However, larval survival was significantly lower for larvae from cultured broodstock.

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Lund, I. (Intern), Steenfeldt, S. J. (Intern), Suhr, K. (Intern), Hansen, B. (Ekstern)
Pages: 544-555
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), Sortkjær, 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
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Publisher: Danmarks Fiskeriundersøgelser
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Original language: Danish
Series: DTU Aqua-rapport
Number: 193-08
Main Research Area: Technical/natural sciences
Electronic versions:
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Links:
http://www.aqua.dtu.dk/Publikationer/Forskningsrapporter/Forskningsrapporter_siden_2008
Source: orbit
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Publication: Research › Report – Annual report year: 2008

Omsætning af ammonium-kvælstof i biofiltre på modeldambrug

General information
State: Published
Organisations: Section for Aquaculture, National Institute of Aquatic Resources
Authors: Suhr, K. (Intern), Pedersen, P. B. (Intern), Svendsen, L. (Ekstern), Michelsen, K. (Ekstern), Plesner, L. (Ekstern)
Number of pages: 58
Publication date: 2008

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Place of publication: Hirtshals
Publisher: Danmarks Fiskeriundersøgelser
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Original language: Danish
Series: DTU Aqua-rapport
Number: 194-08
Main Research Area: Technical/natural sciences
Electronic versions:
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http://www.aqua.dtu.dk/Publikationer/Forskningsrapporter/Forskningsrapporter_siden_2008
Source: orbit
Source-ID: 227579
Publication: Research › Report – Annual report year: 2008

Inhibition of Fungal Growth on Wheat and Rye Bread by Modified Atmosphere Packaging and Active Packaging Using Volatile Mustard Essential Oil

General information
State: Published
Organisations: Department of Systems Biology, Center for Microbial Biotechnology
Authors: Suhr, K. I. (Intern), Nielsen, P. V. (Intern)
Pages: M37-44
Publication date: 2005
Effect of weak acid preservatives on growth of bakery product spoilage fungi at different water activities and pH values

Inhibition of spoilage organisms from bakery products by weak acid preservatives in concentrations of 0%, 0.003%, 0.03% and 0.3% (w/v) was investigated experimentally on a substrate media with water activity (a(w)) and pH ranging from sourdough-fermented acidic rye bread to alkaline intermediate moisture sponge cake types (a(w) 0.80-0.95, pH 4.7-7.4). Initially, rye bread conditions (a(w) 0.94-0.97 and pH 4.4-4.8) in combination with calcium propionate were investigated. Results showed that the highest concentration of propionate (0.3%) at all conditions apart from high a(w) (0.97) and high pH (4.8) totally inhibited fungal growth for a 2-week period, with the exception of Penicillium roqueforti, Penicillium commune and Eurotium rubrum. Characteristically for the major spoiler of rye bread, P. roqueforti, Penicillium commune and Eurotium rubrum were stimulated by propionate and the stimulation was significantly enhanced at high water activity levels. The effect of propionate on production of secondary metabolites (mycophenolic acid, rugulovasine, echinulin, flavoglaucin) was also studied, and variable or isolate dependent results were found. Subsequently, a screening experiment representing a wider range of bakery products was conducted using calcium propionate, potassium sorbate and sodium benzoate. The obtained data was modelled using survival analysis to determine 'spoilage-free time' for the fungi. At the low a(w) level (0.80) only Eurotium species grew within the test period of 30 days. Higher water activity levels as well as higher pH values decreased spoilage-free times of the fungi. The preservative calcium propionate was less effective than potassium sorbate and sodium benzoate.
Antifungal activity of essential oils evaluated by two different application techniques against rye bread spoilage fungi

Aims: To study how antifungal activity of natural essential oils depends on the assay method used.

Methods and Results:
Oils of bay, cinnamon leaf, clove, lemongrass, mustard, orange, sage, thyme and two rosemary oils were tested by two methods: (1) a rye bread-based agar medium was supplemented with 100 and 250 μl l⁻¹ essential oil and (2) real rye bread was exposed to 136 and 272 μl l⁻¹ volatile oil in air. Rye bread spoilage fungi were used for testing. Method 1 proved thyme oil to be the overall best growth inhibitor, followed by clove and cinnamon. On the contrary, orange, sage and rosemary oils had very limited effects. Mustard and lemongrass were the most effective oils by the volatile method, and orange, sage and one rosemary showed some effects. Oil compositions were analysed by gas chromatography-mass spectrometry. Conclusions: Antifungal effects of the essential oils depended on the application method. Larger phenolic compounds such as thymol and eugenol (thyme, cinnamon and clove) had best effect applied directly to medium, whereas smaller compounds such as allyl isothiocyanate and citral (mustard and lemongrass) were most efficient when added as volatiles. Significance and Impact of the Study: This study proves that the method used for screening essential oils as potential antimicrobials should correspond with the application sought.
Factors affecting growth and pigmentation of Penicillium caseifulvum

Color formation, metabolite production and growth of Penicillium caseifulvum were studied in order to elucidate factors contributing to yellow discoloration of Blue Cheese caused by the mold. A screening experiment was set up to study the effect of pH, concentration of salt (NaCl), P, K, N, S, Mg and the trace metals Fe, Cu, Zn, Mn on yellow color formation, metabolite production and mold growth. Multivariate statistical analysis showed that the most important factor affecting yellow color formation was pH. The most pronounced formation of yellow color, supported by highest amount of colored metabolites, appeared at low pH (pH 4). Mold growth was not correlated to the yellow color formation. Salt concentration was the most important factor affecting mold growth and length of lag phase. Production of secondary metabolites was strongly influenced by both pH and salt concentration. The screening results were used to divide the metabolites into the following three groups: 1) correlated to growth, 2) correlated to color formation, and 3) formed at high pH. Subsequently, a full factorial experiment with factors P, Mg and Cu, showed that low P concentrations (2000 mg/kg) induced yellow color formation. Among the factors contributing to yellow color formation, pH and salt concentration are easy to control for the cheesemaker, while the third factor, P-concentration, is not. Naturally occurring variations in the P-concentration in milk delivered to Blue Cheese plants, could be responsible for the yellow discoloration phenomenon observed in the dairy industry.

General information
State: Published
Organisations: Center for Microbial Biotechnology, Department of Systems Biology
Authors: Suhr, K. I. (Intern), Haasum, I. (Ekstern), Steenstrup, L. (Ekstern), Larsen, T. O. (Intern)
Pages: 2786-2794
Publication date: 2002
Main Research Area: Technical/natural sciences

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Volume: 85
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Scopus rating (2016): CiteScore 2.66 SJR 1.304 SNIP 1.464
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Web of Science (2014): Indexed yes
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Scopus rating (2010): SJR 1.351 SNIP 1.517
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Natural food preservation

General information
State: Published
Organisations: Food Biotechnology and Engineering Group, Department of Systems Biology, Center for Microbial Biotechnology
Authors: Meyer, A. B. S. (Intern), Suhr, K. I. (Intern), Nielsen, P. V. (Intern), Holm, F. (Ekstern)
Pages: 124-174
Publication date: 2002

Host publication information
Title of host publication: Minimal processing technologies in the food industry
Place of publication: Cambridge
Publisher: Woodhead Publishing
Editor: Ohlsson, T.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 155144
Publication: Research › Book chapter – Annual report year: 2002

Multivariate Dataanalysis of Enzyme Production for Hydrolysis Purposes

General information
State: Published
Organisations: National Institute of Aquatic Resources, Section for Aquaculture
Authors: Schmidt, A. S. (Intern), Suhr, K. I. (Intern)
Number of pages: 40
Publication date: 1999

Publication information
Publisher: Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
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
Management and environmental improvement of recirculating aquaculture systems (38815)
The aim of this project was to identify new applicable measures and management strategies to optimize trout production in recirculating aquaculture systems (RAS), in particular the model trout farms. Model trout farms have gained lots of positive attention since their recent launch, as the rearing concept allows increased production, increased water reuse, and decreased nutrient discharge with obvious advantages for the natural fish fauna. Currently, model fish farms have generally experienced a certain fish mortality related to pathogens and suboptimal water quality. Scopes for improvement have been identified in terms of more focus on chemical and (micro-)biological water quality.

The project included four interrelated work packages:
1) Biological filtration (stable, optimal nitrification, nitrite accumulation issues, biofilter kinetics and management)
2) Denitrification: self-contained, operational end-of-pipe solution to reduce N-total from model trout farms
3) Water disinfection and sanitation: evaluation of UV systems disinfection efficacy, resulting water quality and test of easy degradable disinfectants to replace formalin
4) Gas saturation: consequences and effects of N super saturation and total gas pressure on fish performance in RAS.

Each WP addressed specific issues of concern based on current scientific knowledge and practical experience in dialogue with the aquaculture industry. The investigations included bench and pilot scale experiments conducted under controlled conditions at the research facilities at the Section for Aquaculture, DTU Aqua, Hirtshals. The project also included monitoring campaigns and experiments on commercial model trout farms in collaboration with stakeholders.

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).

National Institute of Aquatic Resources
Section for Aquaculture
Danish Aquaculture Organisation
UltraAqua
Model fish farmers
Period: 01/01/2011 → 31/12/2012
Number of participants: 4
Research area: Aquaculture
Contact person:
Pedersen, Per Bovbjerg (Intern)
Project Manager, academic:
Pedersen, Lars-Flemming (Intern)
Suhr, Karin Isabel (Intern)
Skov, Peter Vilhelm (Intern)
Project
Marine model trout farms (38816)
Based on the success with the development and implementation of Danish model trout farms in freshwater, a somewhat similar concept was developed for sea water farming of large trout and potentially also salmon in land-based, recirculating systems. Design and technology for the recirculation unit as well as for end-of-pipe treatment were developed and tested in 3 consecutive seasons.

During the project, design and operation were optimized and documented. End-of-pipe treatment, especially related to nitrogen removal and sludge hydrolysis were also investigated.

Based on the concept and the results achieved in the major unit in commercial scale at DTU Aqua premises in Hirtshals, it can be concluded that there is potential for such open land-based sea water farming units and that they can be operated commercially sustainable. Major issues related to reducing/preventing (toxic) algal blooms and supersaturation in seawater needs to be addressed before commercial operations should be initiated, though.

The project was coordinated by North Sea Science Park, Denmark.

The project was 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
North Sea Science Park
BioMar A/S
AquaPri Innovation
Billund Aquaculture Service Aps
RK Plast A/S
Grundfos A/S
Period: 01/01/2011 → 31/12/2015
Number of participants: 4
Research area: Aquaculture
Project participant:
Letelier-Gordo, Carlos Octavio (Intern)
Pedersen, Lars-Flemming (Intern)
Project Manager, academic:
Pedersen, Per Bovbjerg (Intern)
Suhr, Karin Isabel (Intern)

DTU centre for recirculation technology (38159)
Despite the obvious scientific relationship and correlation between recirculation technology, specifically biofiltration, and municipal waste-water treatment only limited scientific knowledge has been interchanged between these two areas.

DTU Environment has for many years been an internationally renowned actor within biofiltration processes and kinetics in waste water treatment. Combining this stronghold with the DTU Aqua expertise in recirculating systems is the basis for this project. Through project cooperation, student interchange and common research set-ups knowledge is exchanged and new insights developed.

In recirculation systems feed is the major input to the system, and the linkage between feed, water quality and system operation is important, yet missing knowledge, which will also be addressed by the group through a combined experimental and modeling approach.

Department of Environmental Engineering
National Institute of Aquatic Resources
Section for Aquaculture
Period: 01/01/2010 → 31/12/2015
Number of participants: 3
Research area: Aquaculture
Project participant:
Suhr, Karin Isabel (Intern)
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 an 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)
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)

Naturlige konserveringsmidler- og metoder til hæmning af skimmelsvampevækst på brød

Department of Systems Biology
Period: 01/09/1999 → 04/03/2005
Number of participants: 5
Phd Student:
Suhr, Karin Isabel (Intern)
Main Supervisor:
Nielsen, Per Væggemose (Intern)
Examiner:
Søndergaard, Ib (Intern)
Bertelsen, Grete (Ekstern)
Schnürer, Johan (Ekstern)

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

The influence of the atmospheric composition on the shelf life of MA-packed bread

The purpose is to develop models for the effect of modified atmosphere packaging (MAP) and active packaging (AP) on shelf life of wheat and rye bread. The model will include the shelf life limiting factors: fungal spoilage, stalling and sensorial quality. These models will be used to optimise the atmospheric composition, packaging material and packaging conditions of MA-packed bread. The project is a part of Center for Food Packaging, which beside DTU involves KVL, Danish Technological Institute and several Danish enterprises

Department of Biotechnology
Danish Technological Institute

Royal Veterinary and Agricultural University
Period: 01/01/1997 → 30/06/2000
Number of participants: 3
Project participant:
Suhr, Karin Isabel (Intern)
Amin-rad, Azar (Intern)

Project Manager, organisational:
Nielsen, Per Væggemose (Intern)

Financing sources
Source: Unknown
Name of research programme: Ukendt
Activities:

*Single-sludge denitrification in recirculating aquaculture systems: Effects of pre-fermentation and pH*
    Karin Isabel Suhr (Invited speaker)
    National Institute of Aquatic Resources
    Section for Aquaculture

Related event

*Annual International Meeting of the American Society of Agricultural and Biological Engineers Joint with the Canadian Society of Biological Engineers*
    13/07/2014 → 16/08/2014
    Canada
    Activity: Talks and presentations › Conference presentations

*Nitrogen removal in RAS farms for Baltic Sea coastal farming*
    Period: 5 Feb 2014 → 6 Feb 2014
    Karin Isabel Suhr (Speaker)
    National Institute of Aquatic Resources
    Section for Aquaculture
    Documents:
    aquabest_18_2014_report

Related event

*Nitrogen removal in RAS farms for Baltic Sea coastal farming: Sustainable aquaculture in the Baltic Sea Region - boosting regional development while limiting environmental effects*
    05/02/2014 → 06/02/2014
    Mariehamn, Åland Islands, Denmark
    Activity: Talks and presentations › Conference presentations