R&D Project Report

Project No. 12112	Project Title: Water addition at farm site	
Pr. Period: Sept2012 - Apr2014	File Name: P Report 12112-v1	Page 1 of 8
Working Group: Nutrition	Pr. Leader(s): MHI	Report Date: 12.5.2014
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Distribution List:		
Keywords: Moist feed, growth, digestibility, feed intake, Atlantic salmon, rainbow trout		

Executive Summary:

Moist feed was produced as a dry pellet with lower bulk weight (more expanded) and a higher water absorption capacity than a dry feed with similar recipe.

Two feed intake and digestibility trials in small scale were conducted with Atlantic salmon, one field growth trial with rainbow trout in large scale and one gut evacuation rate study in Atlantic salmon.

The production of feed with the right physical quality was a big challenge, both in small scale at TechCenter and in full scale at the Karmøy factory.

Trials have shown positive trends on feed intake. However, the results produced have not been consistent, and we have still not been able to show, with a statistical significance, that the growth with moist feed is higher than that of the dry feed.

The results are summed up in the table below (ns= not significant).

Effect of moist feed on	Feed intake	Growth	FCR	Digestibility	Gut evacuation
1 A. Atlantic salmon HHS	+ (ns)	+ (ns)	0	÷ (sign)	
1 B. Atlantic salmon HHS	+ (sign)	0	÷ (sign)	+ (sign)	
2. Gut evacuation HHS					Faster (ns)
3. Field study rainbow trout Fjordlaks	+ (ns)	+ (ns)			

Aim of Project:

To document a feed intake stimulation of a moisturized feed in salmonids.

Sub-goals:

- Find the effect of a moisturized feed on fish performance: feed intake, digestibility, growth, FCR
- Maintain feed intake at low temperatures
- Understand the mechanism behind a potential increased feed intake by monitoring gut evacuation rate
- Demonstrate that the water coating technology works in full scale and that the feed produce good results in a seawater rainbow trout farm

Background:
Increased fish performance with moist feed has been reported in several studies (FreFish, SeaFarm Products internal reports in Atlantic cod, 11043 CREATE, 11062 Moisture large scale Gifas). However, in most of these studies the feed formulation of the dry control feed has been different from that of the moist feed, thus, the moisturizing effect has not been isolated. The idea with the moist feed concept is to prepare the pellets to the digestion process by doing the first step which has to take place in the stomach: the soaking, before feeding the fish. The hypothesis is that the moist feed will be ready to enter the pylorus faster, thus, fish will be ready to have the next meal earlier, and the feed intake in total will be higher. In addition, the extra water in the pellet means the fish can reduce the drinking rate which would help osmoregulation for fish in full seawater.

Regulatory/ Intellectual Property Issues:
Our partner in this project, Seafarm Products, has a patent on the technology for adding water to the pellet by use of a deep water loop connected to the feeding devise. The pellets are subjected to high pressure at deep water. Pellets are compressed, air gets out of the pellets, and the decreasing pressure when pellet rises to the sea surface is utilized to fill the pores with water.

Materials and methods:
3 parts of the project were planned:

1. Small scale trial with Atlantic salmon to measure feed intake and digestibility
2. A short gut evacuation rate study with Atlantic salmon
3. A field study with rainbow trout in full scale to test the concept and technology

Part 1A: Feed intake and digestibility in 5kgs Atlantic salmon at HHS

A biological trial was conducted with Atlantic salmon, start weight 4.1 kg, at HHS the winter 2012/2013 with Power2000 feeds: dry or moist. Feed was produced at TechCenter. Daily feed intake (feeding in excess) was measured during 2 months, and digestibility was measured in the end (4.2°C). Yttrium (0.05%) was coated together with the water each day for 4 days prior to faeces stripping. The dry feed cages were fed a Ytterbium containing Power2000 (from another project) these 4 days.

, thus the feed intake trial had to be repeated (Part 1B).

Part 1B: Feed intake and digestibility in 2kgs Atlantic salmon at HHS

A biological trial was conducted with Atlantic salmon, start weight 1.4 kg, at HHS the winter 2013/2014 with Energy X feeds: dry and moist. Feed was produced at TechCenter . Daily feed intake (feeding in excess) was measured during 2 months (average temperature 5.6°C), and digestibility was measured in the end (5.0°C).

Part 2. Gut evacuation rate (GER) study

The gut evacuation rate study was performed 19.03.2013 at seawater temperatures of 4.3°C at HHS with Atlantic salmon of ca. 5 kg (same fish groups as above). Fish were fed diets without marker for 1 week followed by a 1 day starvation. The next day fish were fed feed with marker in one meal (time point 0), and this feeding regime (with marker) continued the following days.

- Dry feed:

    - without marker: Power2000 (the control from the moist feed trial)
    - with marker: Thea's diet containing Ytterbium
- Moist feed:
    - without marker: Power2000+ (basis for the moist diet) coated with water
    - with marker: Power2000 (as above) coated with water and 500 ppm Yttrium

Four fish from each group were sampled at 3, 6, 12, 27, 51 h after feeding. Fish that had not eaten were excluded from the sampling. Faeces content from stomach (ST), pylorus region (PY), mid intestine (MI) and distal intestine (DI) from 2 fish within each treatment group (duplicates) was collected in beakers. Total number of pooled samples: 2x4x5x2 = 80.

The evacuation pattern of the meal fed at time point 0 was followed by monitoring the marker concentration per dry matter in each compartment.

Part 3. Field study with rainbow trout in full scale to test the concept and technology

A field trial was conducted at Fjordlaks (Stranda) with two large scale cages (48x48 m, each containing 200 000 fish), one with a commercial dry feed, the other with moist feed (similar recipe). Start weight 1.7 kg, end weight 4.0 kg (June – December) (Average temperature June-November = 13.4°C). Fish weight increase was monitored by means of frame measurements every second week. Fish groups were not identical, and fish fed moist feed were slightly bigger at start. Feed was produced at The BioMar factory in Karmøy. The first 2 months the feed did not match the specifications for high robustness, low bulk weight and high capacity for water absorption (except for the very first production including wheat flour). Whole wheat was used as binder in both feed types.

The Karmøy factory was through many test productions with stepwise improvements. Primo August the technical quality was satisfactory, the feed absorbed >20% water and could be properly fed through the coating system at the farm.

Results:

Part 1A: Feed intake and digestibility in 5kgs Atlantic salmon at HHS

The moist feed resulted in average in 23% higher feed intake (all values standardized to a moisture content as in the dry feed) (Figure 1). The difference was not significant (t-test, α=0.05).The variation within treatment was high, the control of the biomass was low, with end fish numbers in the cages not matching with start numbers and morts+sampled. Thus, results were not conclusive. Average growth was low with a SGR of 0.14 (not far from expected/ growth tables).

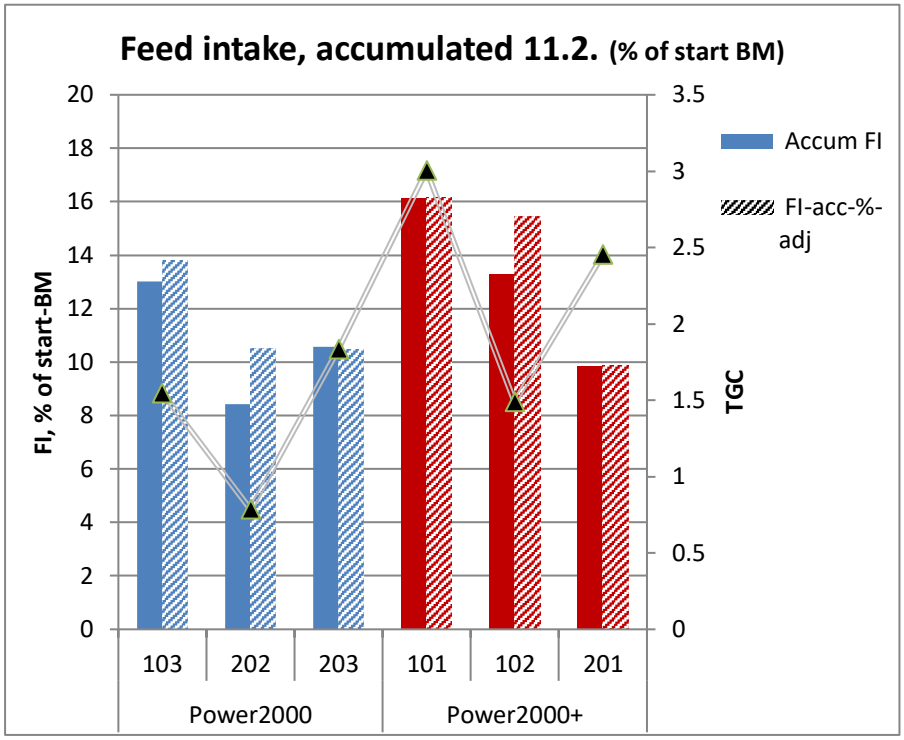


Figure 1. Accumulated feed intake (from start biomass or adjusted from end biomass) and growth (TGC or VF3) in Atlantic salmon fed either dry feed (Power) or moist feed (Power+)..

The digestibility of nutrients in the dry feed was in general higher than that of moist feed (t-test, $\alpha = 0.05$), significantly not for fat, though (Figure 2). The results were biased of two main reasons: 1: dry feed and moist feed were not exactly the same recipes since marker was not added in the test feeds from the start (dry feed (with marker) was taken from an earlier test with Power feed with other batches of raw materials). 2: The moist feed fed the 4 days prior to the stripping of faeces did not hold equal amounts of marker (feed coated with water and Yttrium each day).

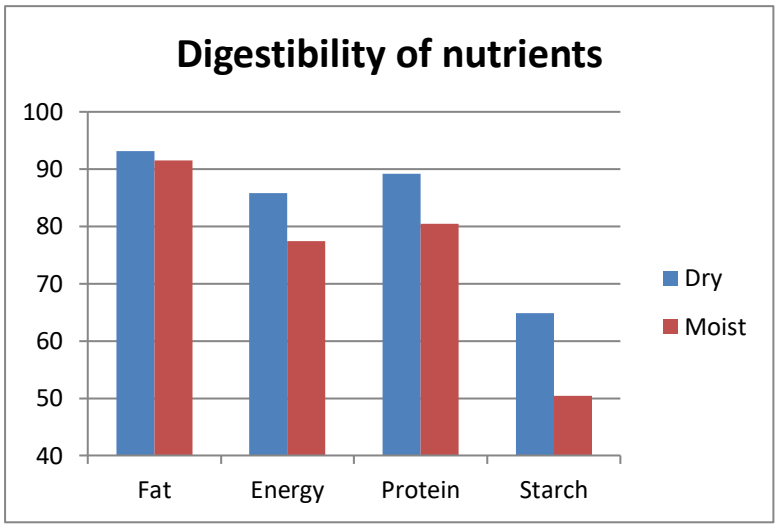


Figure 2. Digestibility (%) of nutrients in dry and moist feed fed 5 kgs Atlantic salmon at 4.2°C

Part 1B: Feed intake and digestibility in 2kgs Atlantic salmon at HHS

The feed intake was 8% higher, growth was equal, and FCR was 7% poorer with the moist feed compared to the dry feed. The differences in feed intake and FCR were significant (t-test, α= 0.05) (Figure 3). The feed intake and growth in general was very high with TGCs above 5 and SGRs of 0.70 (the double of expected from growth table values).

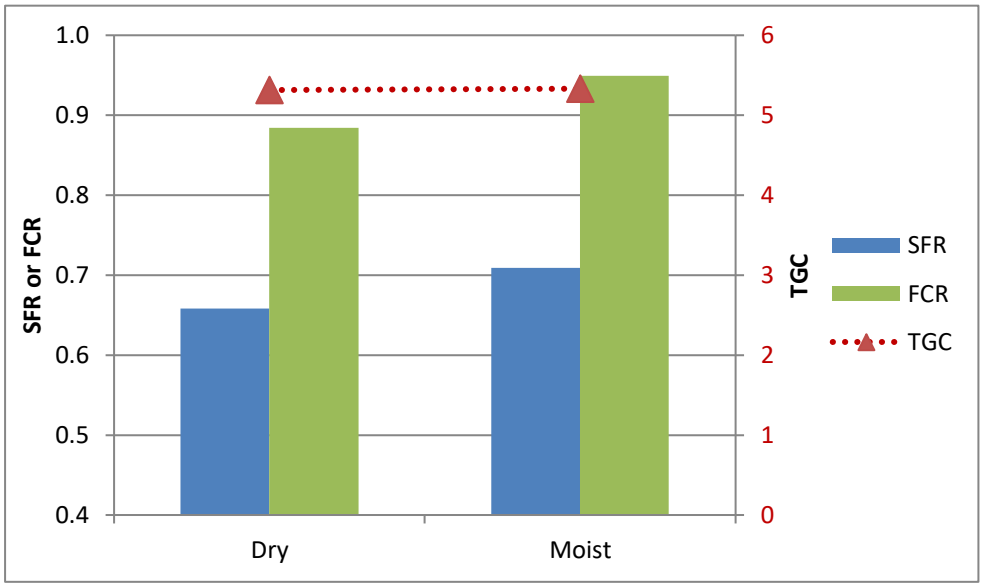


Figure 3. Feed intake (specific feeding rate=SFR), feed conversion ratio (kg eaten/kg growth = FCR) and growth (TGC = VF3) in Atlantic salmon fed either dry feed or moist feed.

The digestibility of all nutrients were significantly higher in moist feed than that of dry feed for all nutrients measured: fat, energy and protein (t-test, α = 0.05) (Figure 4).

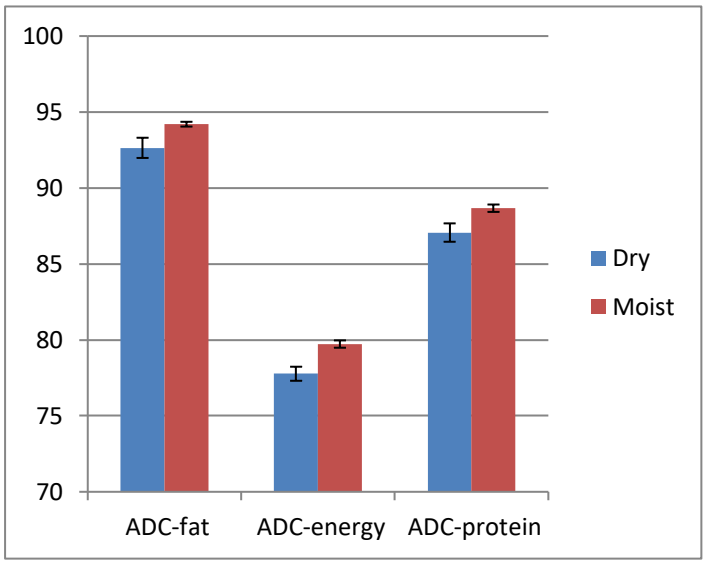


Figure 4. Digestibility (%) of nutrients in dry and moist feed fed 2.1 kgs Atlantic salmon at 5°C

Part 2. Gut evacuation rate (GER) study

The gut evacuation rate seemed to be higher for the moist feed than the dry feed. Significant differences could not be found due to high individual variation between fish. However, the pattern in pylorus (PY), mid intestine (MI) and distal intestine (DI) all confirm this trend (figure 5).

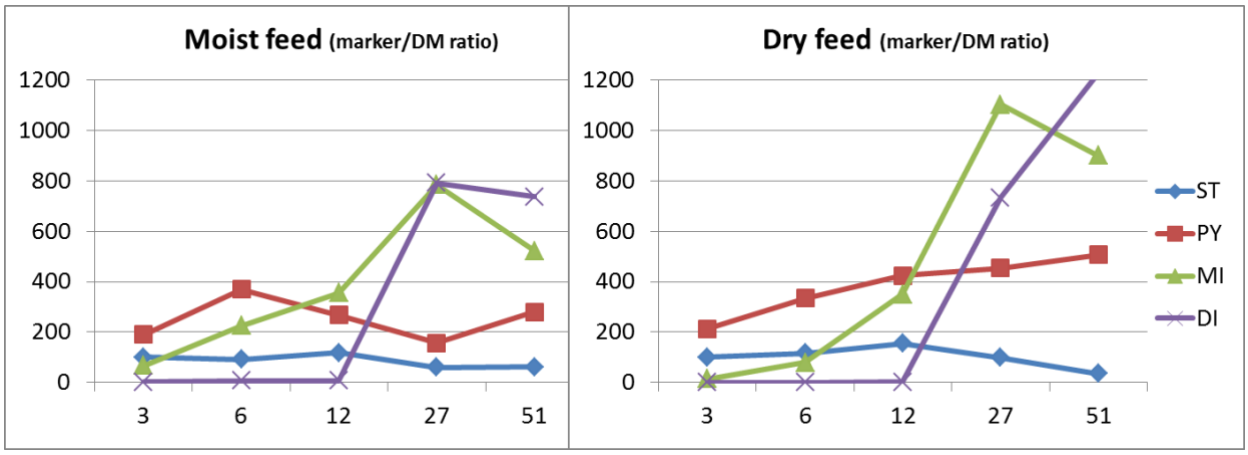


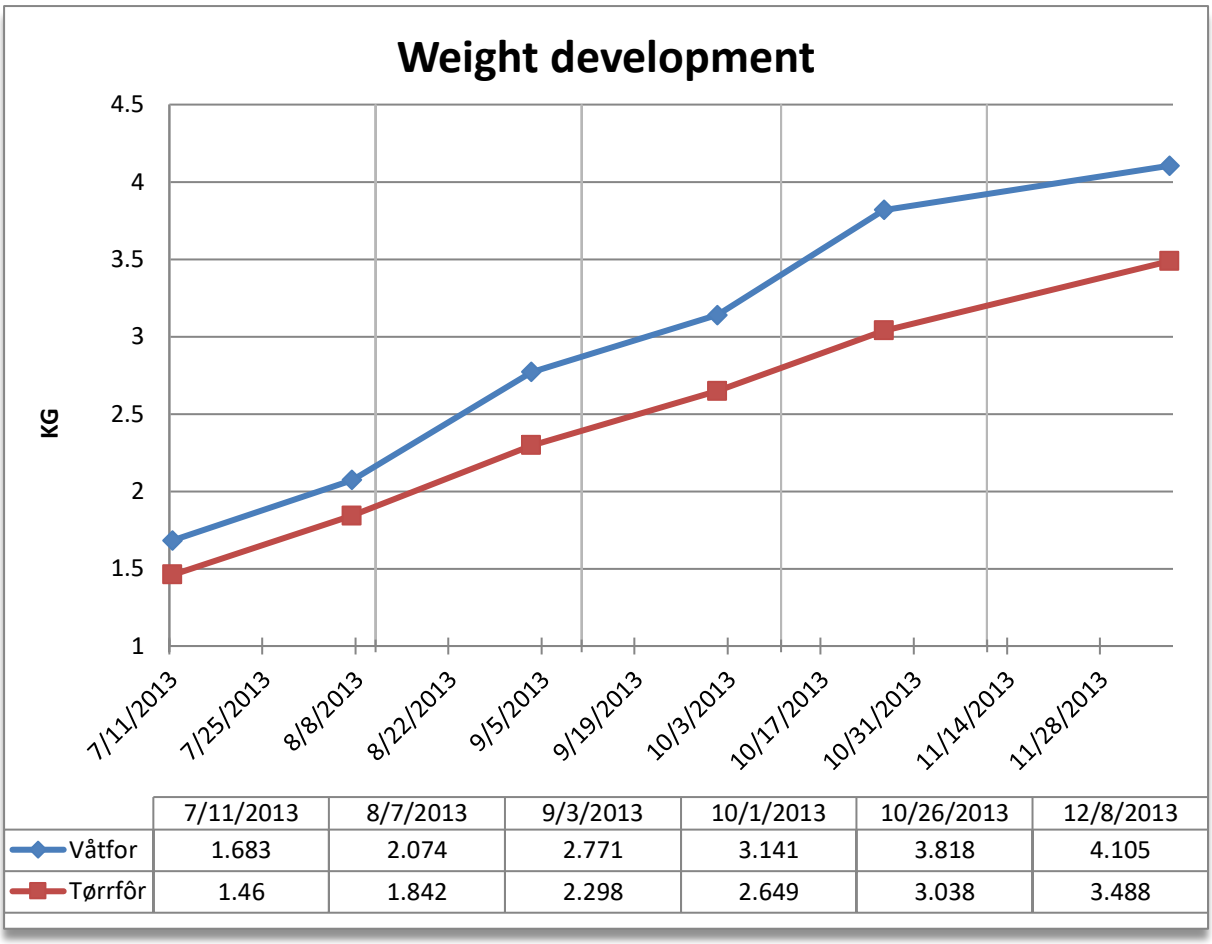
Figure 5. Gut evacuation rate of moist and dry feed in 5kgs Atlantic salmon

Part 3. Field study with rainbow trout in full scale to test the concept and technology

The unsuitable physical quality led to accumulation of feed particles in the water loop in connection to the coating system, a recirculation of “old porridge” which probably affected the quality of the feed into the cages, and probably resulted in higher feed waste.

The water loops of the coating system at the farm were blocked at temperatures way below 0°C during December. This also resulted in a stop in the feeding of moist feed to the test group.

An increase in the feed intake was seen during the weeks of feeding with moist feed with satisfactory quality (from August throughout November), and the total growth of the fish fed moist feed was in total 0.4 kg higher than that of the dry feed fed fish (figure 6). No statistics could be run.



	7/11/2013	8/7/2013	9/3/2013	10/1/2013	10/26/2013	12/8/2013
Våtfor	1.683	2.074	2.771	3.141	3.818	4.105
Tørrfôr	1.46	1.842	2.298	2.649	3.038	3.488

Figure 6. Growth of rainbow trout fed moist feed (Våtfor) or dry feed (Tørrfor) in large scale at Fjordlaks

Discussion:

The results from HHS in the 1B study were very consistent when it comes to increased feed intake, equal growth and increased digestibility. However, increased feed intake and higher digestibility together means we expect a higher growth, which was not the case here. Therefore, we think that the feed waste, thus the feed intake estimation, was not correct. Probably, with similar growth between the dry and moist feed together with a higher digestibility, the FCR was lower with the moist feed. This is, anyhow, surprising results, as far as we expected a higher feed intake and higher growth, but similar digestibility and FCR.

With the results described above, we have not been able to prove (with significant differences) a higher feed intake and growth with the moist feed. Two digestibility studies have given contradictory results. However, the second digestibility study (1B), with higher digestibilities of nutrients in moist feed were the most reliable since the marker was properly distributed in the feed at feed production in this case. We have also found been indications of positive feed intake effects of the moist feed in the field study with rainbow trout and in Atlantic salmon in the first trial at HHS (1A). The gut evacuation rate study indicated that moist feed may have a more rapid passage through the gut, which, in turn, may open for a higher feed intake.

Questions to be answered in future studies:

- What is the optimal physical quality of the pellet and how to achieve this with current raw materials at the factory?
- Is the increased feed intake connected to a certain period of the year for the different species?
    - Temperature, season, feeding rate,
- Can fat belching in trout be avoided with moist feed?