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Profitable Arctic charr farming in the Nordic countries

Testing of different diets for Arctic charr under practical conditions

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Executive summary

Feeding costs represent between 50-70% of the production costs in Arctic charr aquaculture and therefore it is of high importance for the industry to reduce the feeding cost in order to maintain good economy.

Earlier laboratory experiments had shown that the protein requirements for sustaining maximum growth of Arctic charr were significantly lower (~35%) than what was common in commercial diets for the species (42–48%). In addition, earlier trials showed that a replacement of a substantial part of fishmeal protein by plant protein was possible, without affecting growth and feed utilization.

The present study evaluated these earlier findings under practical conditions in commercial aquaculture production, to verify the results of the laboratory trials. Reduced protein content was combined with high fishmeal substitution in diets and the diets tested as compared to the commercial diets used by partners in the three Nordic countries involved. The evaluation was carried out at four Arctic charr farms, two in Iceland and one in Norway, in addition a fourth trial, with triplicate groups carried out in Sweden. An additional trial was set up in Iceland to study the effects of different amount of protein and plant protein on the environment and fish welfare. The quality of the fish produced was evaluated in all trials, either through sensory evaluation tests or by ordinary consumer tests.

In summary, the trials shoved somewhat variable effects of the novel diets on fish growth as compared to the control diet, with a somewhat reduced growth of fish observed in the Icelandic tests, while improved growth was obtained in the test carried out in Norway and equal growth in the Swedish trial. In addition, the Icelandic tests showed a tendency towards poorer feed utilisation of the test diets as compared to the control diet, while the opposite results were obtained in Norway and an equal feed utilisation between the groups was observed in the Swedish trial. No significant differences in quality of the fish produced were observed related to the different diets tested.

Based on the feed cost per kg fish produced, the overall conclusion drawn from all the tests was that the feeding cost was lower in the groups getting the test diets as compared to the control diets. This is explained by the lower raw material cost in the test diets where the fish meal content was partially replaced by plant protein meals and the diets contained 34–35% crude protein as compared with 42 – 48% crude protein in the control diets. However, in the additional experiment carried out in the research facilities at Holar, it was concluded that the difference between the price of the fish and the cost of raw materials in feed was highest in the control group, suggesting that the control diet would return the highest profit for the producer. This conclusion was drawn based on the effect of the different diets on the time it took to grow the fish to a slaughtering weight of ~700 grams, which is normally the minimum marketable size of Arctic charr.

Overall, the results of the tests confirm the results of laboratory trials previously carried out in Iceland, suggesting that Arctic char tolerates considerably lower content of protein and higher degree of fishmeal substitution than is used in the commercial diets presently available. Furthermore, the change in feed formulation for Arctic char only moderately affected the quality of the fish produced.

The results from the study of the effects of diets on the environment and animal welfare suggest that plant proteins can replace a substantial part of the fishmeal in diets for the species. However, a total replacement of fish protein with plant protein was not successful. Test diets with the highest replacement of fish meal with raw materials of plant origin gave acceptable growth and feed utilisation, albeit not quite as good as diets formulated from fish meal. The feed cost per kg fish produced using this diet was 5% lower than for the control diet. No evidence of enteritis was found in fish fed these plant based diets and there were no indications of compromised fish welfare. Furthermore, the environmental effects of the plant-based diets were found similar to the control diet representing commercial diets used in the Iceland.

The conclusions from the stakeholder meeting, where representatives from all levels in the value chain of the production of Arctic charr were invited, was that the work presented would not spoil the image of Arctic charr. The participants emphasised the importance of evaluating the effects of different diets on environmental and economic sustainability of the production, taking into account possible effects on the length of the production period.

The results of the project confirm that the raw material cost in Arctic charr farming can be reduced by 10–15 %, depending on the relative cost of protein of different origin. Whereas feed costs are at least 50 percent of the production costs in Arctic charr farming, the results suggest that the production cost in the Nordic charr industry can be reduced by 5–7,5 % and thereby strengthening the economy of the industry. In Iceland, the feed cost has already been lowered as a direct consequence of results provided by the project and Polarfeed in Norway has offered similar concept to Arctic charr farmers in Norway and Sweden.

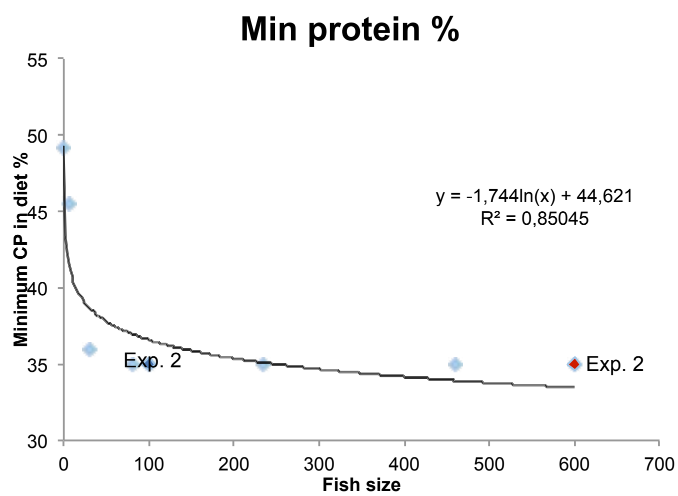
1. Introduction

Feed costs are the dominating costs in the production of Arctic charr. Common protein content in commercial diets is in the range of 42 – 48% and fishmeal content in the feed is in the range of 20 – 40% of the raw materials in the feed, representing 50 – 65% of total crude protein in the diet (Table 1).

As protein is the main component in the growth of animals, including fish, it is important to supply enough protein in the feed to support maximum growth. Plant protein raw materials frequently contain anti-nutritional components that can lead to reduced utilisation of the protein in the feed. However, animal trials are needed for to measure the effects of the anti-nutritional factors.

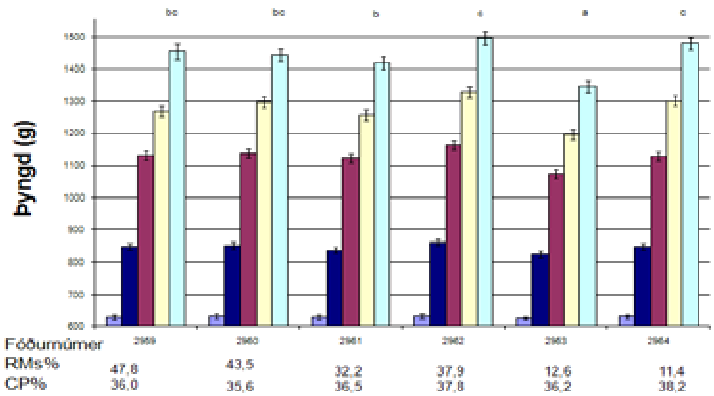
In fish, the main role of lipid is to supply energy for the metabolism but if the energy needed for maximum protein syntheses is met, there is no specific need for lipid or energy for growth. Results from laboratory trials have shown that minimum requirement for crude protein (CP) to support maximum growth in grow-out diets for Arctic charr is around 35% (Figure 1).

Figure 1. Pooled results of two series of experiments to determine minimum crude protein content in diets for maximum growth for Arctic charr of different size.



Another laboratory study showed that a diet, where only 23% of the protein came from fishmeal, resulted in growth comparable the growth on a diet with 90% of the protein being fishmeal protein (Figure 2).

Figure 2. Size development of Arctic charr fed diets with varying content of fishmeal (RMs%) in the diet. RMs%: % of fish meal in the feed formulation; CP%: % of crude protein in diets.



In light of these results, the aim of the present study was to combine these two findings and test them under practical conditions. The control diets in all tests consisted of the commercial diets used at the respective test farms (Table 1). For investigating only the effects of protein of different origin of the protein, the intention was to keep the lipid and energy content in the diets constant. However, due to a failure in feed production for the tests carried out in Norway and Sweden, the test diets contained higher lipid than the control diets. The lower protein content therefore results in higher inclusion of carbohydrates (NFE, nitrogen free extract) in the diets (Table 1).

Table 1. The nutritional composition (%) of test diets and commercial diets used in the project. Shown is the calculated (C) and analysed (A) content of the diets.

	ICELAND		NORWAY	SWEDEN
	Haukamýri	Rifós	Kirkenes charr	SLU
Control diet	(C)	(C)	(C)	(C)
Marine protein % of protein	50	54,4	65	65
Dry matter	92.5	92.5	91.8	NA
Protein	45	42.5	42.0	48.0
Lipid	23	25.0	25.0	25.0
Ash	7.1	7.4	7.3	8.0
Nitrogen free extractives	17.1	18.3	14.7	11.5
Relative raw material cost	100	100	100	100
Test diet	(C)	(C)	(A)	(A)
Marine protein % of protein	27	31,6	30	30
Dry matter	91.3	91.6	92.2	92.2
Protein	35	35.0	33.4	33.4
Lipid	23	25.0	30.7	30.7
Ash	6.3	6.4	5.3	5.3
Nitrogen free extractives	24.9	25.5	22.8	22.8
Relative raw material cost	**78**	**81**	**88**	**88**

2. Results from tests carried out in commercial fish production

2.1 Haukamýri fish farm in Iceland

2.1.1 Form of test

At Haukamýri fish farm, Husavík, Iceland, a single group of 56.000 fish was divided into two separate tanks to be fed with the two diets shown in Table 1. During the test the fish in each of the tanks was size graded resulting in three trials within the test. The test period was altogether 312 days, and the fish grew from about 120 grams to almost 700 grams. The water temperature during the overall test period varied between 7,8˚C and 8,2˚C with 8˚C as an average.

2.1.2 Diets and Feeding

The formulation, chemical composition and raw- material cost (RM cost) of the diets fed in the test can be seen in Table 2. Laxa Feedmill Ltd. Akureyri, Iceland produced both control- and test diets.

The diets were fed to the fish according to appetite and amount of feed offered to the fish was registered for each tank.

Table 2. Diets tested at Haukamýri fish farm in Iceland

	Control	Test
Formulation (%):		
Canola meal	10,00	28,72
Fish oil	13,01	16,54
Rape seed oil	4,30	0,00
High protein Soya	5,21	15,00
Corn gluten meal	20,00	14,07
Norsea mink fish meal (NSM)	31,16	13,09
Wheat	10,00	10,98
Vitamin and mineral Premix	1,00	1,00
Mono Calcium Phosphate	1,08	0,55
Colorants	0,60	0,60
Marine protein % of CP	50	27
Composition (%):		
Dry matter	92,5	91,3
Crude protein (CP)	45	35
Crude lipid	23	23
Nitrogen free extractives (NFE)	17,1	24,9
Ash	7,1	6,3
Cost:		
Raw material cost in IKR/kg feed	170	133
Relative raw material cost	100	78

2.1.3 Test results

The results of the growth test in the three different trials, measured by initial and final weights, specific growth rate (SGR) and feed conversion ratio (FCR) are shown in Table 3. The formulas used for calculation of SGR and FCR were as follows:

- SGR = 100*(LN (initial weight)-LN(final weight))/number of feeding days
- FCR = g of feed offered/ g fish growth (based on biomass growth)

Table 3. Fish weight, growth and feed utilisation at Haukamýri fish farm

	Trial 1		Trial 2		Trial 3	
Duration of tests in days	134		69		109	
Diet type	Control	Test	Control	Test	Control	Test
Initial weight (g)	116	130	307	313	380	358
Final weight (g)	334	334	429	436	721	650
Specific growth rate (SGR)	0,79	0,70	0,48	0,48	0,59	0,55
Relative SGR	100	89	100	99	100	93
Feed conversion ratio (FCR)	1,00	1,26	1,02	1,28	1,07	1,25
Relative FCR	100	126	100	126	100	117

2.1.4 Raw material costs

An economical evaluation of the effects of the different diets is presented in Table 4, showing the raw material cost per kg growth of the fish.

Table 4. Effects of diet on raw material cost of the production at Haukamýri fish farm

	Trial 1		Trial 2		Trial 3	
Diet type	Control	Test	Control	Test	Control	Test
Raw material (RM) cost (IKR/kg feed)	170	133	170	133	170	133
RM cost in IKR/kg growth	169	168	173	171	181	166
Relative RM cost/kg fish	100	99	100	98	100	91

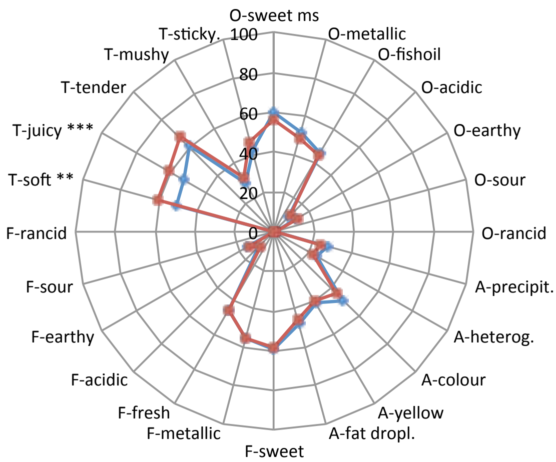
2.1.5 Summary of growth test results:

- The test diet had 22% lower raw material cost than the control diet
- The test diet had lower or equal specific growth rate compared to the control diet
- The feed conversion ratio (FCR) of the in the test diet groups was higher than in the control groups
- The raw material cost per unit growth was similar or lower for the test diet as compared with the control diet

2.1.6 Quality evaluation of the products

To evaluate the effect of the different diets on the quality of the product a sensory evaluation, by trained personnel, of filets from the fish was performed. The results of the sensory evaluation are shown in Figure 3. The attributes that mainly differed between the two dietary groups related to the taste of the fish, i.e. juiciness and softness.

Figure 3. Mean values of sensory attributes (scale 0–100) for groups control (blue line) and test (red line).



Consumer value of these parameters can differ and therefore a consumer preference test was undertaken and ordinary consumers asked to evaluate their perception of the softness and juiciness of the filets from the two test groups as well as their general liking of the fish (Table 5).

Table 5. Results from consumer preference test of Arctic charr fed different diets

	Test group 528			Control 273		
Parameter	General liking*	Softness**	Juicyness**	General liking*	Softness**	juicyness**
No. testers	28	28	28	29	29	29
Average	8,18	2,93	3	8,24	2,93	3
Max	9	4	5	9	4	5
Min	4	1	1	4	1	3

*) Scale: 1 – 9

**) Scale: 1 – 5

In summary there appears to be negligible differences in consumer´s perceived quality of the fish filet which can be related to the dietary treatment, even though significant differences in some of the attributes were observed in the sensory evaluation.

2.2 Rifós fish farm in Iceland

2.2.1 Form of test

At Rifós fish farm in Iceland, a single group of 56.000 fish from the same year class was divided into two separate cages to be fed with the two diets shown in Table 6. The cages are placed in a lagoon of brackish water. Average initial weight of fish was 140 and 160 g for the control and test group, respectively. The final weight was 830 grams for the control group and 860 g for the test group after a feeding period of 460 and 550 days for the control and test group, respectively. The fish was kept at ambient temperature of the lagoon, with average temperature of 7,4˚C during the test period (2,8˚C - 12,4˚C).

2.2.2 Diets and feeding

The formulation, chemical composition and raw material cost of the diets fed in the test are shown in Table 6. Laxa Feedmill Ltd. in Iceland produced both diets. The diets were fed to the fish according to appetite and the quantity of feed offered to the fish was registered for each cage.

Table 6. Diets tested at the fish farm Rifós

Diet type	**Control**	**Test**
Cage number	26	24
Raw materials (%):		
Canola meal	12,00	30,00
Fish oil	19,61	18,69
Fish meal	19,61	15,38
Corn gluten meal	20,00	12,78
High protein soya	5,21	10,43
Wheat	10,00	10,00
Wheat gluten meal	0,00	1,21
Vitamin and mineral Premix	1,00	1,00
Mono Calcium Phosphate	0,00	0,45
Colorants	0,05	0,05
Marin protein as % of Crude protein	54,43	31,63
Composition (%):		
Dry matter	92,50	91,60
Crude protein	42,50	35,00
Crude lipid	25,00	25,00
Nitrogen free extractives (rest)	18,34	25,50
Crude ash	7,40	6,40
Costs in IKR/kg feed:		
Raw material cost	189,12	152,47
Relative raw material cost	100	81

2.2.3 Test results

Table 7 shows the results of the growth test at Rifós, including initial and final weights, specific growth rate (SGR) and feed conversion ratio (FCR), calculated according to the following formulas::

- SGR = 100*(LN (initial weight)-LN (final weight))/ number of feeding days
- FCR = feed offered (g)/fish growth (g), (based on biomass growth)

The overall SGR in for the fish getting the test feed is about 20% lower compared to the control resulting in a longer growth period for the fish getting the test diet. The FCR is about 10% higher in the test group.

Table 7. Fish weights, growth and feed utilisation at Rifós fish farm

Diet type	Control	Test
Cage number	26	24
Feeding days	460	552
Initial weight (g)	140	160
Final weight (g)	830	880
Specific growth rate (SGR)	0,39	0,31
Relative SGR	100	80
Feed conversion ratio (FCR)	1,35	1,50
Relative FCR	100	111

2.2.4 Raw material cost

An economical evaluation of the effect of the different diets is presented in Table 8, showing the raw material cost per kg fish growth. Even though the feed conversion ratio in the test group is higher than in the control group, the raw material cost per kg growth is about 10% lower in the test group.

Table 8. Effects of diets on raw material cost of production at Rifós fish farm

Diet type	Control	Test
Cage number	26	24
Raw material (RM) cost (IKR/kg)	189,12	152,47
Relative RM cost	100	81
RM cost/kg growth (in IKR/kg)	255,31	228,71
Relative RM cost/kg growth	100	90

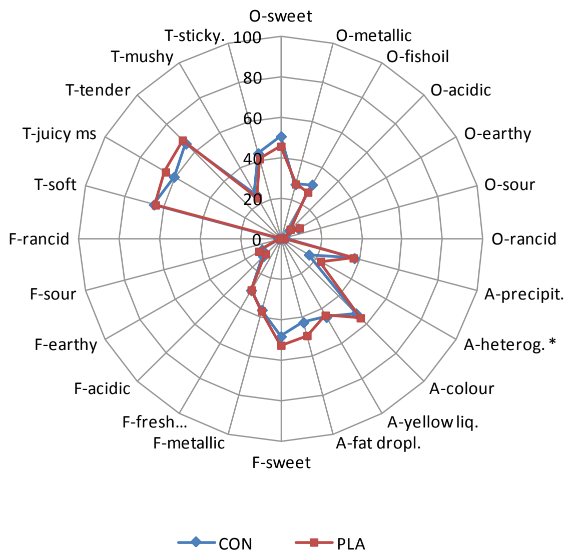
2.2.5 Summary of growth test:

- The test diet had 19% lower raw material cost than the control diet
- The test diet gave lower specific growth rate than the control
- The FCR was 10% higher in the test group as compared to the control.
- The raw material cost per unit growth of fish was 10% lower for the test diet

2.2.6 Quality evaluation of the products

For evaluation of the effects of the different diets on the quality of the final product, a sensory evaluation of filets from the fish was performed, carried out by trained personnel (Figure 4). Only minor differences in the evaluation of the sensory attributes were observed, even though that there is a tendency towards differences in some parameters, including sweet odour, juicy taste, fat droplets and heterogenic attitude of the fillet.

Figure 4. Mean values of sensory attributes (scale 0–100) on filets from the control (CON) and test (PLA) group.



In addition to the sensory evaluation, a consumer preference test was undertaken at the cantina at Matis Ltd. Here, the consumers were asked to evaluate their perception of the softness and juiciness of filets from the two test groups as well as their general liking of the fish (Figures 5 – 7).

Figure 5. Distribution in percentages of scores for general liking of filets from the test (PLA) and control (CON) group. Scale 1–9, 1="very bad", 9="very good".

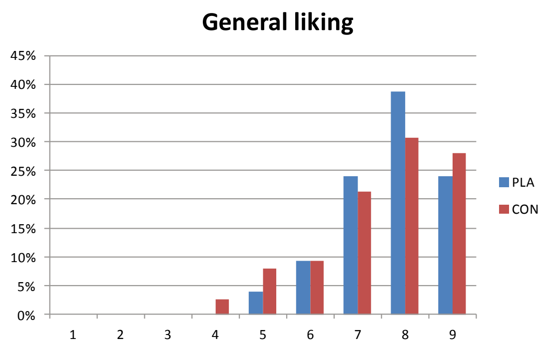


Figure 6. Distribution in percentages of scores for liking of softness of filets from the test (PLA) and control (CON) group. Scale 1–5, 1="much too firm",3="just right", 5="much too soft".

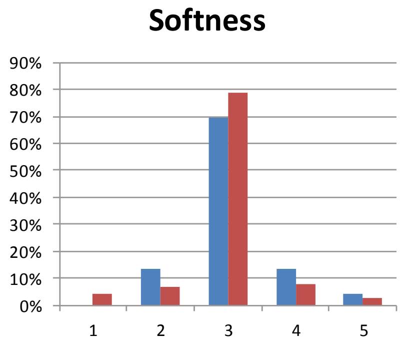
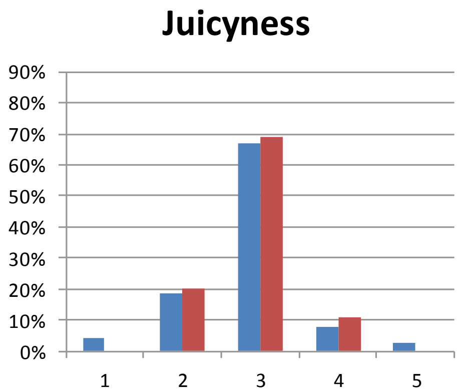


Figure 7. Distribution in percentages of scores for liking of juiciness of filets from the test (PLA) and control (CON) group. Scale 1–5, 1= „much too dry", 3="just right", 5= „much too juicy".



In summary both the test feed and the control feed produced Arctic charr of good quality according to the sensory evaluation as well as based on the consumer preference test.

2.3 Kirkenes charr in Norway

2.3.1 Form of test

At Kirkenes charr (Finnmarksrøya) fish farm, Kirkenes, Finnmark, Norway a single group of 78.626 fish from the same year class was divided into two separate tanks to be fed with the two diets shown in Table 9. Average initial weights were 260 and 270 grams respectively for the control and test groups. The test started the October 1. 2012 and was finalized January 12. 2013. The average temperature during the test period was 2 ˚C. The the final weight after a feeding period of 80 days was 360 grams for the control group and 395 grams for the test group.

2.3.2 Diets and feeding

The formulation, chemical composition and raw- material cost (RM cost) of the diets fed in the test can be seen in Table 9. Polarfeed AS, Øksfjord, Finnmark, Norway, produced the test diet but the control diet was a commercial feed from Skretting AS.

The diets were fed to the fish according to appetite and amount of feed offered to the fish was registered for each tank.

Table 9. Diets tested at the fish farm Kirkenes charr

Diet type	**Control (Skretting)**	**Test feed**
Tank number	K3	K4
Duration of experiment (days)	80	80
Raw materials (%):		
Fish meal	40,3	15,9
Fish oil/ rape seed oil	20,4	22,7
Soy protein concentrate SPC	15,0	20,0
Wheat	14,3	21,2
Sunflower meal	10,0	12,0
Wheat gluten meal	0,0	7,5
Mono crude protein	0,0	0,7
Vitamins, minerals and colorants	0,54	0,54
Fish meal protein of Crude protein (%)	65	30
Composition (%):	**Calculated**	**Analysed**
Dry matter	91,8	92,2
Crude protein	42	33,4
Crude lipid	25	30,7
Nitrogen free extractives (rest)	14,7	22,8
Ash	7,3	5,3
Costs:		
Raw material (RM) cost (NOK/kg)	6,66	5,85
Relative RM cost	**100**	**88**

2.3.3 Results of the test

The results of comparison of fish growth between commercial diet and new test diet is shown in Table 10. The results show that the test diet is actually performing better than the control diet, both with respect to fish growth and feed utilisation.

Table 10. Fish weights, growth and feed utilisation at Kirkenes charr fish farm

	Control feed (Skretting)	Test feed
Tank number	K3	K4
Duration of test in days	80	80
Initial no of fish	39197	39429
Initial average weight (g)	260	270
Initial biomass (kg)	10191	10646
No of fish day 80	39195	39419
Average weight at day 80 (g)	360	395
Biomass at day 80 (kg)	14110	15571
Biomass growth (kg)	3919	4925
Feeding (kg)	4500	4500
Specific growth rate (SGR)	0,41	0,48
Relative SGR	**100**	**117**
Feed conversion ratio (FCR)	1,15	0,91
Relative FCR	**100**	**80**

2.3.4 Raw material cost

The cost of new as compared with commercial diets is shown in Table 11.

Table 11. Effect of diet on raw material cost of production at Kirkenes charr fish farm

	Control feed (Skretting)	Test feed
Tank number	K3	K4
Raw material (RM) cost (NOK/kg)	6,66	5,85
Relative RM cost	**100**	**88**
RM cost per kg growth (NOK)	7,65	5,35
Relative RM cost of growth	**100**	**70**

Table 11 shows that the raw material cost is considerably lower using the test feed compared to the control in the test at Kirkenes charr.

2.3.5 Quality evaluation of the products

Filets of fish from the test at Kirkenes charr were evaluated at Nofima in Stavanger, Norway, for the effects of fish diets on sensory attributes in a triangle test with trained panellists. The results of the test showed that there was difference between the two types of filets. A list of comments from the panellists can be found in the table below (in Norwegian):

Comments Diet 3 (Control diet from Skretting)	Comments Diet 4 (test diet)
Friskere smak, saftigere	Tørr, smakløs
Friskere smak og lukt	Bløtere, litt mindre beisk
Saftigere (x3)	Mildere smak, saftigere
Snev av harsk lukt	Mindre frisk lukt og smak, rødere farge
Tørrere	Litt rødere
Noe syrligere smak, kraftigere lukt	Kraftigere rosa farge, god smak
Ferskere, saftigere	Mer rosa farge, tørrere
Litt friskere smak	Bleikere, muligens mindre smak
Mildere lukt, saftigere	Farge ulik, ellers lite merkbar forskjell
Friskere lukt, smak, farge. De to andre (anm.«diett 4») var nokså smakløse med snev av harsk lukt/smak	Lite smak – mindre enn de andre
Tydelig rødere, smak vanskelig å skille	Litt sterkere lukt, mildere smak
Mer rosa, litt tørrere	
Rødere farge, mer smak	

Filets from the fish were also subjected to consumer preference test of students at a collage in Kirkenes. Results from the parallel testing of fish from the two feeding groups are shown in Figures 8 – 10.

Figure 8. Distribution in percentages of scores for general liking of filets of fish from the test group (PLA) and control group (CON). Scale 1–9, 1="very bad", 9="very good".

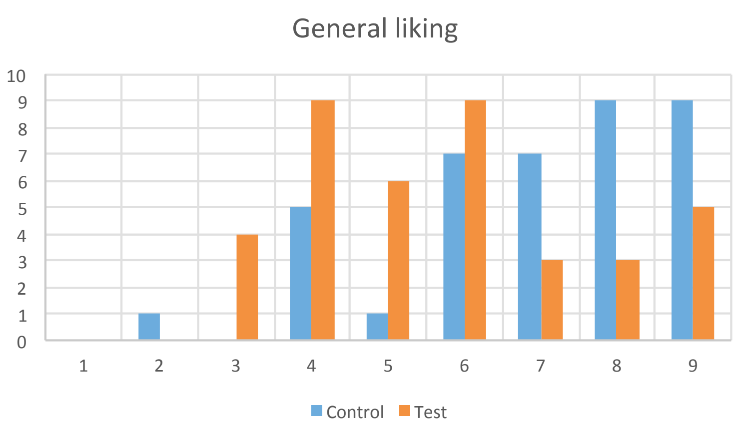


Figure 9. Distribution in percentages of scores for liking of softness of filets of fish from the test group (PLA) and control group (CON). Scale 1–5, 1="much too firm" ,3="just right", 5="much too soft".

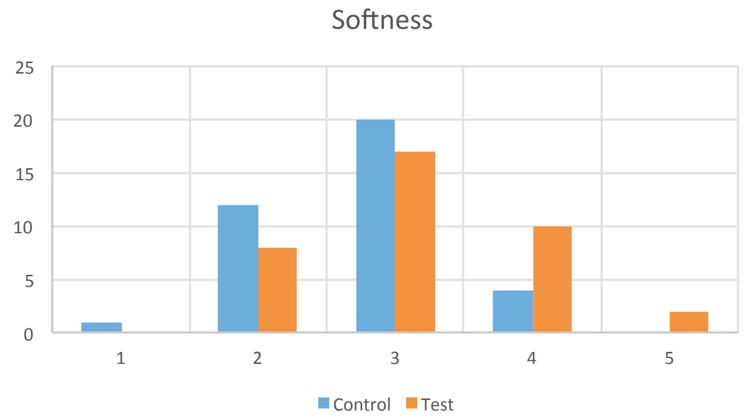
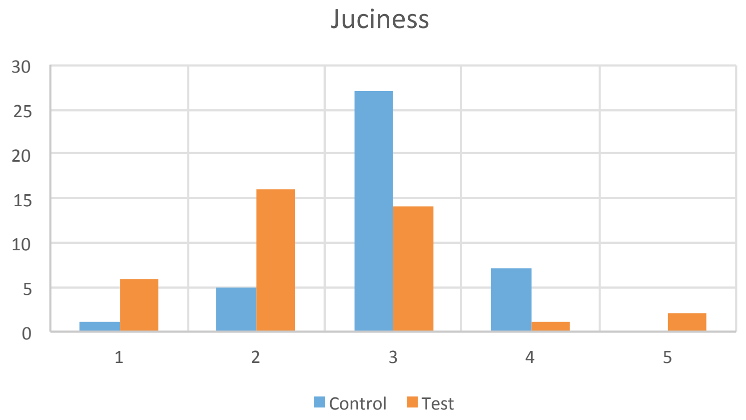


Figure 10. Distribution in percentages of scores for liking of juiciness of filets of fish from the test group (PLA) and control group (CON). Skale 1–5, 1= „much too dry", 3="just right", 5= „much too juicy".



There was a tendency towards better liking of the fish coming from the control group, but the results regarding softness and juiciness were more similar between the groups.

2.4 Umlax in Sweden.

By Hanna Carlberg and Eva Brännäs - Swedish University of Agricultural Sciences

2.4.1 Purpose (form) of test?

Detailed lab studies have resulted in new feed formulations with a total lower protein content for Arctic charr. A part of the remaining fish protein content in the feed has also been replaced by plant-based proteins. To be able to reduce the amount of fish based protein in the diet for farmed Arctic charr is a huge advantage, it reduces the prize of the feed as fish protein is one of the most expensive ingredients in commercial fish feed. Also, even more important, a reduced use of ingredients from the fisheries makes the farming of predatory fish species more sustainable due to replacement of fish meal with products from agriculture.

Previous lab studies comparing Arctic charr fed the new diet to control groups of fish fed commercial diets show no reductions in growth during the on-growing phase (100 g to slaughter size, 700-1000 g). However, to get acceptance by farmers and consumers the new formula must be evaluated in realistic farming conditions and the final product must be thoroughly tested, i.e. by sensory test panels.

2.4.2 On farm testing of recent research findings.

The objective is to test the diets at four fish farms located in the three participating countries (Iceland, Norway and Sweden). Here we report the activities in the Swedish trial only.

Task 1.1 – Growth and feed conversion of fish fed novel diets.

The new feed tested will be less expensive to produce due to reduced fish protein and oil content and an increased use of plant based raw materials. The control diets will be the commercial diets normally used by the Arctic charr farmers. The diets will be tested for the last 6 months of Arctic charrs main grow-out phase before the fish reach normal slaughter weight.

The following variables will be measured: Weight gain, growth rate, daily feeding rate and feed conversion ratio (based on the amount of feed offered in each tank/cage).

Feeding trial

The original plan was to test the new feed formula on a net-pen farm situated in the river Umeälven (Umlax AB) with a start in early summer 2012. It is only possible to keep Arctic charr in smaller net-pens close to the shore in summer and fall which was necessary to create the required replicate groups for the feeding trial. The river is dammed and the water level drops during winter and the fish can only be kept in large net pens further out from the shore. The new diet was not produced until October 2012 and by then it was too late to start the trial at the original site.

Instead the experiment was performed at the Aquaculture Center North (ACN) www.vbc.nu in Kälarne. This is in fact a more convenient place. It is an indoor facility aimed for commercial production of Arctic charr, mainly for stocking as well as for research. The owner of Umlax AB is also one of the owners of ACN why a shift of facilities did not require a change of partners.

The feed trial started in early December 2012 when six groups of 128 Arctic charr each (mean weight 355 g). Arctic charr from the 8th generation of the selected strain "Arctic superior" reared at ACN was used in the feed trial. Three groups were fed with the new diet and three groups with the control diet (Skretting). The groups were kept in densities that correspond to commercial conditions and were reared until the fish reached slaughter size (ca 600g) in June, six months later. The temperature ranged during the trial between 0.8 and 9.5 °C.

Feed Conversion Ratio trial

Because of limitations in the farming environment where feed waste could not be monitored in the feeding trial, a separate Feed Conversion Ratio (FCR) trial was conducted.

The trial lasted for four weeks during February and March 2014. Fish were kept in six tanks with 17 fish in each tank allowing for three replicates. Start weight was 531.3 g (S.D ± 15.1) and did not differ significantly between tanks or treatments. Temperature ranged from 2.5 to 2.8 °C (± 0.1). Feeding was conducted with belt feeders and daily ration adjusted ad lib. Waste pellets were flushed out of the tank continuously and counted daily. This allowed FCR to be determined as Feed intake (g)/ biomass gain (g).

The diets

The new feed was produced by Polarfeed in Norway based on similar ingredients as the commercial control feed (Skretting). This was to enable a level of digestible energy similar to the control feed as possible. However, in order to make the new diet durable in the water, an extra layer of coating had to be added resulting in a slightly higher fat content in the new feed compared to the control diet (Table 12 and 13).

Table 12. The ingredients in the experimental feed.

Diet type	**Control (Skretting)**	**Test feed Polarfeed**
Tank number	K3	K4
Duration of test (days)	80	80
Raw materials (%):		
Fish meal	40,3	15,9
Fish oil/ rape seed oil	20,4	22,7
Soy Protein Concentrate	15,0	20,0
Wheat	14,3	21,2
Sunflower meal	10,0	12,0
Wheat gluten meal	0,0	7,5
Mono Calcium Phosphate	0,0	0,7
Vitamins, minerals and colour	0,54	0,54
Fish meal protein of Crude protein (%)	65	30

Table 13. The nutrient content of the experimental feed.

	Polarfeed (%)	**Control (%)**
Crude protein	33.4	48
Crude lipid	30.7	25
Nitrogen free extractives	22,8	11.5
Ash	5.3	8

Results

There was no significant difference (t-test, P=0.65) in growth depending of diet (Figure 11 and Table 14).

Figure 11. Mean weight (±SD) of the final weight of the triplicate groups fed with the new feed (Polarfeed) and control feed (Skretting).

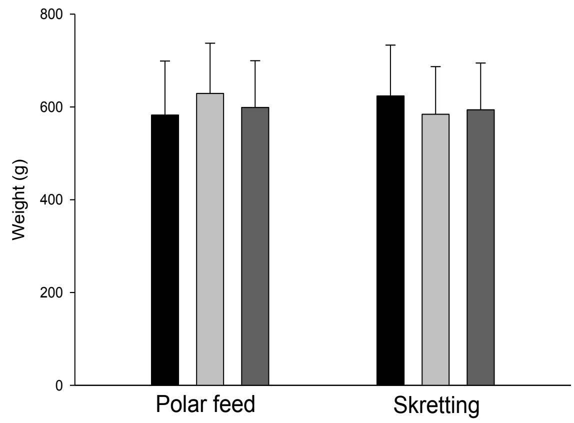


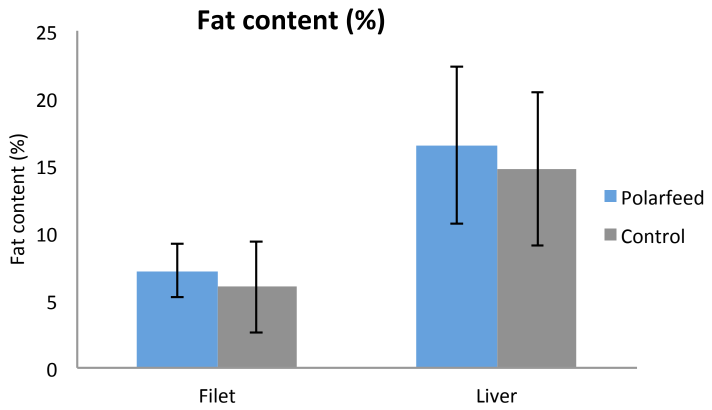
Table 14. Growth data (±SD) of the pooled data from triplicate groups of Arctic charr fed with the test feed (Polarfeed) and control feed (Skretting).

	Test diet (Polarfeed)	Control diet (Skretting)
Initial weight (g)	355	355
Final weight (g)	603.4 (23.6)	600.5 (20.6)
Specific growth rate (SGR)	0.28 (0.02)	0.29 (0.02)
Thermal growth coefficient TGC)	3.05 (0.24)	3.01 (0.21)
Condition factor	1.42 (0.02)	1.42 (0.03)

The six groups were fed with the same daily amount of feed ranging from 0.5-1% of the total weight of the groups. Feed rations varied depending on temperature and season, thus resulting in the same noticeable feed conversion ratio for both groups. Feed waste was not monitored. However, a specific trial determined the feed conversion ratio using a system with pellets collectors, enabling waste monitoring.

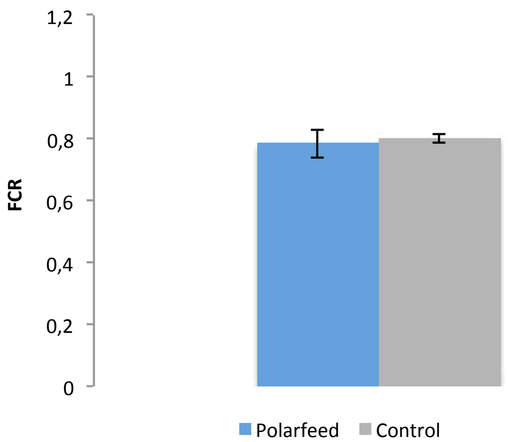
The fat content in the fillet and liver of 10 individuals from each group was analysed using a mid-infrared transmission (MIT) spectroscopy technique. The analysis show a higher fat content in the filets and liver (but not significant, t-test filet P-value = 0.329, liver t-test P-value = 0.404 (Figure 12). This result is as expected as the fat content in the experimental diet was higher.

Figure 12. Fat content in the liver and filet of Arctic charr fed with the test feed (Polarfeed) and control feed.



Feed conversion ratio was similar for the two treatments, Polarfeed fed fish had a FCR of 0.78 (S.D ± 0.05) and control feed fed fish 0.80 (S.D ± 0.01) (t-test, $p = 0.59$) (Figure 13).

Figure 13. Feed conversion ratio (FCR)of Arctic charr fed the test feed (Polarfeed) and the control feed (Skretting), respectively (n=3*2)



2.4.3 In market sensory evaluation.

Arctic charr from the feeding trials were slaughtered according to standardized methods; the fish were starved for 10 days, killed by a blow to the head, gills were cut and the fish were kept in water for bleeding. The fish were filleted, transported on ice to Umeå for evaluation in consumer test the following day. The test panel consisted of 31 colleges, all experienced fish consumers. The procedure used was based on the evaluation from task 3.1 and used the same templates as the in the Icelandic test. The fillets from the two blind samples were cooked to 52-54° C, in an oven without salt or pepper and served with melted butter on the side. The consumer panel filled out the forms individually; results are summarized in Figure 14-16.

The general impression by the consumer panel gave a slight favour for the Polarfeed fed fish but there was no statistical difference between the two pieces of fish (t-test, p=0.872, t-value -0.16).

Figure 14. General impression of the fillets from Arctic charr fed with the test feed (Polarfeed) and the control feed.

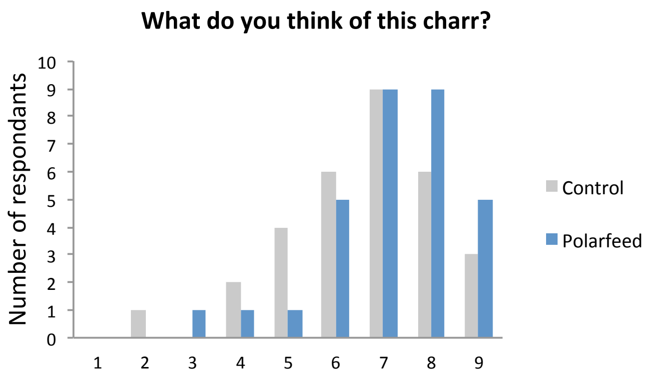


Figure 15. Evaluation of the softness of the fillets from Arctic charr fed with the test feed (Polarfeed) and the control feed.

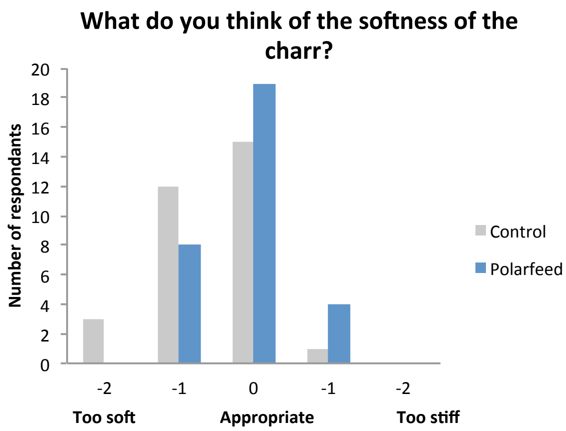
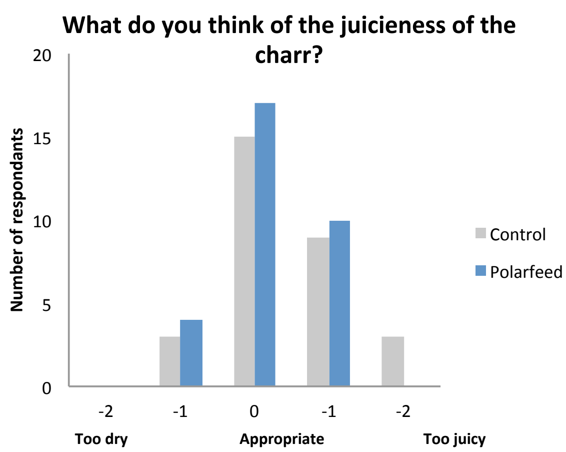


Figure 16. Evaluation of the juiciness of the fillets from Arctic charr fed with the test feed (Polarfeed) and the control feed.



2.4.4 Summary of results from the tests

The following general conclusions can be drawn from the tests with a new type of diets, with lower protein content and reduced use of fishmeal, as compared to a commercial diet normally used on the site:

- The fish grew equally well on the test diet and the commercial diet
- The fat content of filets was slightly higher in fish fed the test diet, resulting in a slightly fatter meat
- Consumers liked the fish fed the test diet equally well and even slightly better than the fish fed the control diet
- The feed conversion ratio was similar for the test diet fed fish and the control fish
- The test feed is economically profitable due to lower cost.

This a possible way forward for a more sustainable farming of Arctic charr due to lower feed cost and less use of marine ingredients. The results will be published in a peer-review magazine

2.5 Summary of results from practical tests carried out at all four sites.

A new type of diets, with lower protein content and reduced use of fishmeal, developed based on earlier laboratory trials tested at three different fish farms, two in Iceland (Haukamýri and Rifós) and one in Norway (Kirkenes charr). The intention was to test the diets at a fish farm in Sweden (Umlaks AB) but due to practical reasons, the trial carried out at the Aquaculture Centre North (ACN) in Kälarne, as an experiment with three replicates of the test diet a control diet.

The control diet used in all the tests was the commercial diet normally used at each site. In summary, the trials shoved somewhat variable effect on growth, i.e. somewhat lower growth in the Icelandic tests, better growth at Kirkenes and equal growth in Sweden, compared to the control diet. In similar way, there was The Icelandic tests showed a tendency to poorer feed utilisation of the test diet compared to the control while the opposite results were obtained in Norway and the feed utilisation was equal between the groups in the Swedish trial.

Based on the feed cost per kg fish produced the conclusion in all the tests was the same that it was lowest in the groups getting the test diet due to lower raw material cost in these diets.

Regarding the quality of the fish product there were not detected any important differences that could be related to the different diets fed to the fish.

Overall the conclusion of the performed tests confirm the results of the previous laboratory trials done in Iceland that Arctic char tolerates considerably lower content of protein and higher degree of fish meal substitution than is in the present commercial diets.

This change in feed formulation for Arctic char does only have moderate effect on the quality of the fish produced.

3. Effects of different diets on fish welfare and environment

Trial carried out at Holar University College in Iceland

By Helgi Thorarensen and Ólafur Ingi Sigurgeirsson

3.1 Introduction

Presently, most of the feed used for the three million tonne salmonid aquaculture industry is produced using high inclusions of fishmeal and fish oil. However, the limited supply of fishmeal, consumer concerns regarding sustainability of fisheries and the ethics of catching fish to feed fish have placed pressure on the aquaculture industry to seek other alternatives for raw materials. The development of feed for fish over the past few years has aimed at optimizing the use of raw materials and to look for alternative sources of raw material, primarily of plant origin, that can be used instead of fish meal and fish oil. This approach is more sustainable and, also more economical since the plant based raw materials are less expensive than fish meal or fish oil.

It is important for the growing Arctic charr aquaculture to develop feeds that are considered environmentally friendly. The species is marketed with references to pristine environment and in high-end markets that are willing to pay a premium for a product that is produced in accordance with strict environmental standards. Results from studies on Atlantic salmon and rainbow trout lead the way in developing new feed for Arctic charr. However, the life history of Arctic charr is different from the two other species and it is likely that the development of feed for the charr calls for special solutions.

Over the past few years, Matis and Holar University College have performed a number of studies where different raw materials for Arctic charr feed have been tested. The results show that fish meal and fish oil can be substituted for various plant products if they meet the nutritional requirements of the charr. Furthermore, studies have been performed where the protein and lipid requirements of Arctic charr have been determined. The aim of these studies has been to produce a more economical feed that meets strict environmental standards. In this project, feeds were formulated using plant materials and tested on industrial scale. These formulations were also tested in laboratory studies where the performance could be studied in more detail.

Although the use of plant-based raw materials may be a more environmentally friendly approach to growing charr, questions have been raised about the effect of these new feeds. The new feeds may affect the welfare of the fish since plant ingredients can contain anti-nutritional factors that disturb feed utilization and can cause enteritis in the fish. Therefore, fish welfare must be taken into account when feeds are developed. Moreover, the environmental effects of fish feed are not only due to fisheries. Part of the feed is not consumed or poorly utilized by the fish and this may affect the environment through the release of nitrogen and phosphorous, compounds that contribute to eutrophication. Moreover, poor feed utilisation and feed intake can impair the water quality in rearing systems and thus reduce growth rate, health and welfare of the fish. It is likely that feed formulated from plant-based raw materials may be less digestible and may in this respect have more environmental impact than feed made from fishmeal. This must also be taken into account when new feeds are developed. One of the objectives of this experiment was to investigate how these novel feeds affect the welfare of Arctic charr and the potential environmental impact of fish farms using the feed.

3.2 Materials and methods

3.2.1 Fish

The fish used for the experiment came for the Holar breeding programme for Arctic charr. The fish (initial body mass: 119.3 ± 0.4 mean ± se) were transported to Verið experimental station, where the experiments were conducted, and distributed among 16 tanks (0.8 m3), 60 fish in each tank. The fish were allowed to habituate to the tanks and the experimental diets for two weeks before the experiment commenced. The first measurement was performed after the two-week period and then every month until the experiment was completed. When measured, the fish were anaesthetized with 2-phenoxy ethanol (1:5000 2PE: water).

The fish were reared in partial recirculation systems at 10.1 ± 1.1 °C (mean ± standard deviation), salinity of 15.0 ± 1.8 ‰ and at oxygen levels of 99.5 ± 11.0%. The temperature, salinity and oxygen levels were recorded daily and adjusted as necessary.

3.2.2 Experimental diets

Four experimental diets were manufactured using a commercial extruder at Laxá Feed Mill in Akureyri, Iceland. The control diet was formulated to reflect the diet commonly used commercially in Arctic charr farming in Iceland. The other three test diets were formulated with lower protein content (34% compared to 42.5% in the commercial diet) and with different protein raw material composition (Table 15). One diet was formulated from plant proteins only without fishmeal (Plant protein – PP). The remaining two diets were formulated with the objective of reducing protein content (Low protein – LP) and low raw material cost (Low cost – LC) (Table 15). The protein sources in the latter two diets were fishmeal (Norsea mink, NSM, quality), soya- and rapeseed meal, corn gluten-meal and wheat gluten-meal used in different combinations (Table 15). The primary oil source was fish oil in all diets and estimated crude fat level was 25%. The feeds were produced in two different pellet sizes of 3mm and 4mm in diameter. The raw material in each diet was calculated according to raw material prices on the formulating day (20.03.2013).

3.2.3 Chemical analysis of feed

The moisture content was determined in a 5 g sample that was dried at 110°C overnight and then allowed to cool in a desiccator before the sample was reweighed (AOAC, 2000). Crude protein was calculated from total nitrogen content (0.5 g sample) determined in a Kjeldahl system following acid digestion and titration of sample distillate according to the ISO standard (ISO 5983, 2005). Crude lipid was determined gravimetrically following ethyl-ether extraction from a dried sample according to Ba 3-38 (AOCS, 1998) in a Soxhlet extractor. Ash content was determined as total inorganic matter by incineration of a 10 g sample at 550°C overnight followed by cooling in a desiccator before reweighing according to ISO standard (ISO 5984, 2002).

3.2.4 Feeding

The fish were fed continuously with automatic belt feeders. Feed traps were fitted to the outflow of all tanks to catch uneaten pellets. The number of uneaten pellets was counted and the weight of the uneaten feed estimated from the number of pellets and the mean weight of pellets. Net feed intake was calculated by subtracting the weight of uneaten feed from amount of feed presented. The feed conversion ratio (FCR) was calculated for each tank as

$$FCR = \frac{net\ feed\ intake}{increase\ in\ body\ mass}$$

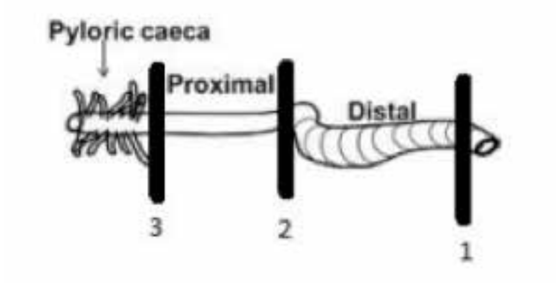
Table 15. Ingredient composition and calculated chemical composition of experimental diets used in the growth experiment for Arctic charr. Also shown are calculated raw material prices at formulation time.

	Control (C)	Plant protein (PP)	Low protein (LP)	Low cost (LC)
Ingredients (g/100g)				
Norsea mink fish meal, NSM	30.4	0	24,35	11,86
Rapeseed meal (Denmark)	15.0	11.5	33,1	29,9
Soya (47/5– Brazil)	5.2	45.0	0	12,54
Corn gluten meal (60CP)	20.0	0	7,79	15,84
Wheat gluten meal	1.5	10.6	0	0
Wheat	8	8.0	16,5	9,4
Fish oil	18.8	22.5	17,20	18,76
Vitamin- and mineral Premix	1.0	1.0	1.0	1.0
Carophyl red –10%	0.027	0.027	0.027	0.027
Carophyl pink–10%	0.027	0.027	0.027	0.027
Mono-calcium-phosphate	0	0	0.009	0.61
Fish meal protein of Crude protein (%)	50	0	50	24
Estimated composition (g/kg)				
Crude protein	425	340	340	340
Crude fat	250	250	250	250
Crude fiber	30.6	45.4	50	50
Crude ash	73.8	56.,7	69.9	61.6
Dry matter	920.3	910	914,4	913.7

3.2.5 Gut morphology

Gut samples for microscopic analysis were taken from five fish from each treatment. The samples were cross sections taken from three locations in each fish: (1) From the distal part of the hind gut; (2) from the junction of hind gut and mid gut; and (3) From the pyloric caeca (Figure 17). The samples were rinsed in saline water and then covered in freezing glue (tissue-Trek, OCT, Sakura, USA) and preserved in liquid nitrogen.

Figure 17. Locations where samples were obtained for microscopic analysis. Sections (10µm) of the samples were cut in a cryostat and mounted on slides. The slides were stained with haematoxylin/eosin and observed in a light microscope (Leica DMRA2) with mounted digital camera (Leica DC300F). Indicators of inflammation were estimated in the sections including the length of the mucosal folds and widening of the lamina propria. Inflammation is associated with shorter mucosal folds and larger central stoma. Furthermore the density of goblet cells was estimated.



3.2.6 Metabolism

Oxygen consumption of the fish and excretion of CO2 and nitrogen were measured just before the experiment was terminated and before the final measurement. These measurements were performed by turning off inflow of water into the tanks for 30 minutes and measuring the rate of decrease of oxygen concentration or the rate of increase in the concentration of the metabolites (CO2 and N). The Oxygen levels in the tanks were measured continuously with fibre-optic probes (OXY-4, Loligo Systems, Denmark). Water samples for CO2 and N were taken from all tanks before the inflow was turned off and again 30 minutes after the inflow was turned off.

The total alkalinity (TA) was measured with the single acid addition method at 25 °C. To a 100 mL water sample were added 25 mL of 0.1 M HCl and the resulting pH recorded and used to calculate the TA based on pH and temperature. The CO2 concentration was calculated based on the measured TA, original temperature and pH of the sample using CO2sys spreadsheet (http://cdiac.ornl.gov/ftp/co2sys/). The ammonia, nitrite and nitrate concentration were measured with optometric methods using standard kits (EPA METHOD 350.1(1993)).

3.2.7 Statistical analysis

The mean weight, length and condition factor of the fish were compared with mixed model ANOVAs where tanks were nested within diets. The condition factor of the fish was calculated as:

$$condition\ factor = 100 \times \frac{body\ mass}{length^3}$$

The growth is expressed as Thermal growth coefficient calculated a according to the formula (TGC is describing the growth corrected for the influence of temperature):

$$TGC = 1000 \times \frac{w_2^{\ 1/3} - w_2^{\ 1/3}}{\sum_{o}^{d} T}$$

where w1 and w2 are the initial and final body mass and d is the number of days between measurements and T is the daily mean temperature.

The FCR, oxygen consumption and excretion of metabolites were compared with a simple ANOVA. All statistical analyses were performed using R 3.1.0 (R core team 2014).

3.3 Results

3.3.1 Diet.

Results of chemical analysis of the composition (%) of the diets are shown in Table 16.

Table 16. Chemical analysis of the composition (%) of the diets.

	Control	Plant protein	Low protein	Low cost
Crude protein	40.9	38.0	33.5	33.8
Crude fat	22.2	19.9	19.5	20.8
Crude ash	6.4	5.0	6.5	6.3
Salt	2.0	0.07	1.6	0.8
Dry matter	92.5	90.8	90.5	89.8
NFE	21.0	27.2	29.8	28.1
Calculated gross energy content (Mj·kg^{-1})	22.1	21.5	20.7	21.0

The analysed protein content of the diets (Table 16) was different from the estimated protein content based on the formulation of the diets (Table 15). The protein content of the PP diet was higher than intended and higher than in the LP and LC diets. Otherwise, the analysed protein content was close to target values. The analysed lipid content (Table 16) was slightly lower than the target value of 25% (Table 15) in the formulation. The NFE was higher in the PP, LP and LC than in the C diet suggesting higher content of carbohydrates and fibres from the plant protein sources. The calculated energy content was similar in all diets.

3.3.2 Growth and condition factor

The mean weight of the fish fed the C diet increased by more than six fold during the experimental period (Figure 18) while the increase in size of the LP and LC groups was slightly less. However, the increase in size in the PP group was only about half of that of the other groups (Figure 18). The final size of the fish in the control (C) group was significantly higher, in both weight and length, than fish in the other groups (Figure 18 and 19). The mean weight and length of the low protein (LP) and low cost (LC) groups was not significantly different. However, the fish fed the plant protein (PP) diet were significantly smaller than fish in all other groups. Similarly, the TGC (thermal growth coefficient) over the entire experimental period (Figure 20) was lowest in the fish fed the PP diet (1.73) and significantly lower than in the other three groups. The TGC was highest in the fish fed the C diet (2.83) and significantly higher than in the LC group (2.58) but not in the LP group (2.68).

The condition factor significantly lower in the PP group than in the other three (Figure 21). In the control, low cost and low protein groups the condition factor increased significantly between all measuring dates, but was not significantly different among groups (Figure 21). The condition factor in the plant protein group increased from the first to the second measurement, but decreased significantly from day 80 to day 132.

Figure 18. Mean body-mass of Arctic charr fed different diets. Means identified with different letters are significantly different on each date. Vertical lines show ±standard error.

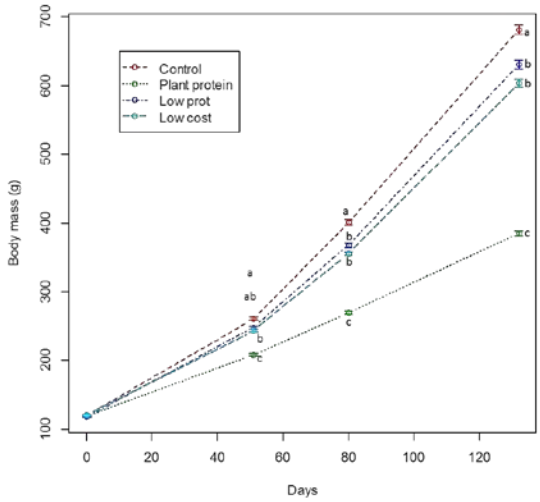


Figure 19. Mean length of Arctic charr fed different diets. Means identified with different letters are significantly different on each date. Vertical lines show ±standard error.

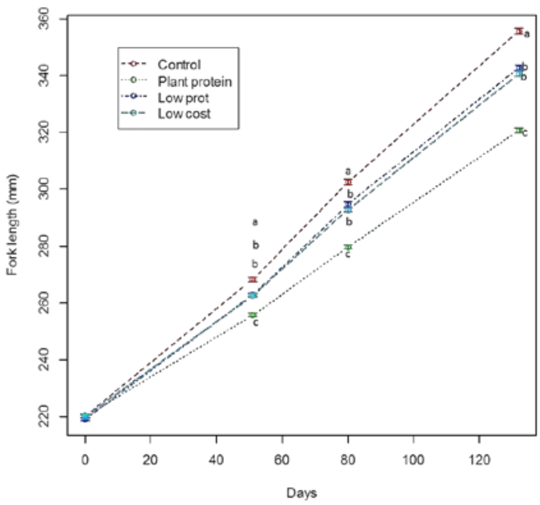


Figure 20. Thermal growth coefficient (±se) of Arctic charr fed different diets for 132 days. Means identified with different letters are significantly different.

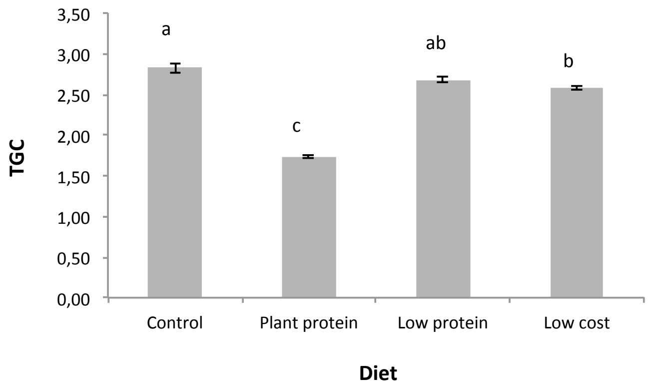
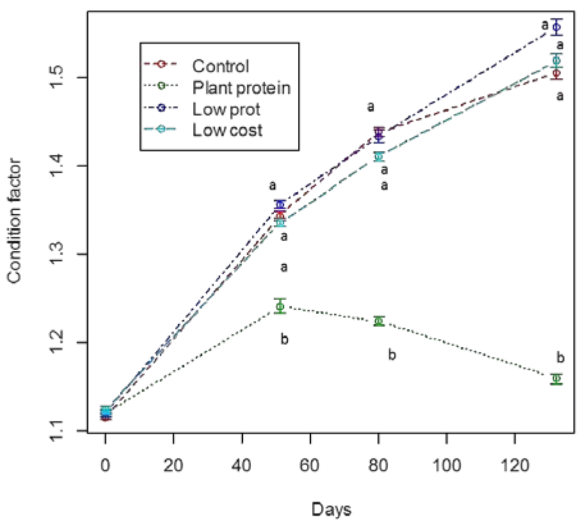


Figure 21. Mean condition factor (±se) of Arctic charr fed different diets. Means identified with different letters are significantly different on each date.



3.3.3 Feed intake and feed conversion ratio

The total feed intake was not significantly different in the control group (33.7 kg) and the low cost group (33.9 kg) (Figure 22). However, feed intake was significantly higher in the low protein group (35.8 kg). Total feed intake was significantly lower in the plant protein group (19.3 kg) than in all other groups. When feed intake was calculated as % of body mass·day-1, diet also affected feed intake (Figure 23). It was significantly lower in the plant protein group (1.03%) than in all other groups. The daily feed intake was significantly higher in the low protein (1.25%) and low cost (1.23%) groups than in the control group (1.09%).

The feed conversion ratio was significantly affected by diet. The FCR was significantly lower in the control group (0.99) than in all other groups while the in the plant protein group (1.25) it was significantly higher than in the other groups (Figure 24). The FCR in the low protein (1.17) and low cost (1.18) groups was not significantly different.

Figure 22. Total feed intake (kg feed consumed in each tank) of Arctic charr fed four different diets

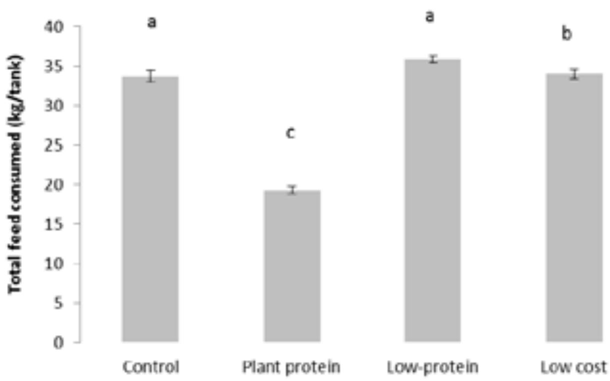


Figure 23. The daily feed intake (% of body mass·day-1) in Arctic charr (±standard error) fed three different diets. Means identified with different letters are significantly different.

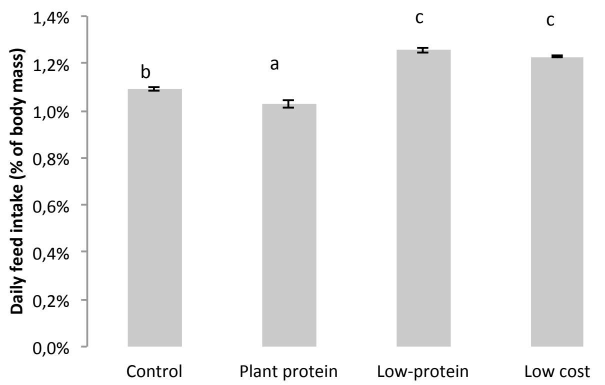
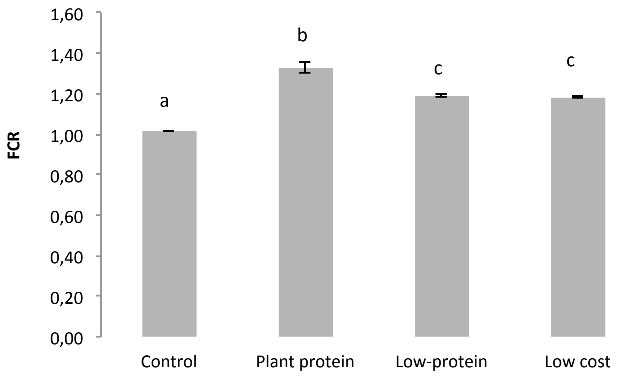


Figure 24. Feed conversion ratio of fish fed four different diets. Means identified with different letters are significantly different.



3.3.4 Metabolism

The oxygen consumption was significantly lower in the plant protein group than in the other three (Figure 25). However, the oxygen consumption was not significantly different in the control, low protein and low cost groups (Figure 25). The excretion of CO2 was highest in the plant protein group (Figure 26). Unfortunately, the measurements of nitrogen excretion were varible and did not appear reliable and the method used needs to be improved. Therefore, the mean ammonia quitients were not statistically different. However, the estimated ammonia quotient was highest in the plant protein and low cost groups.

Figure 25. Oxygen consumption of Arctic charr fed different diets.

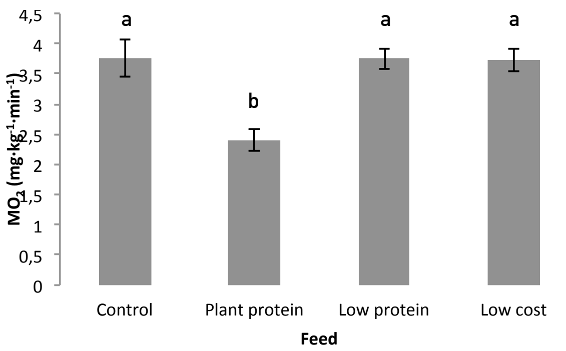
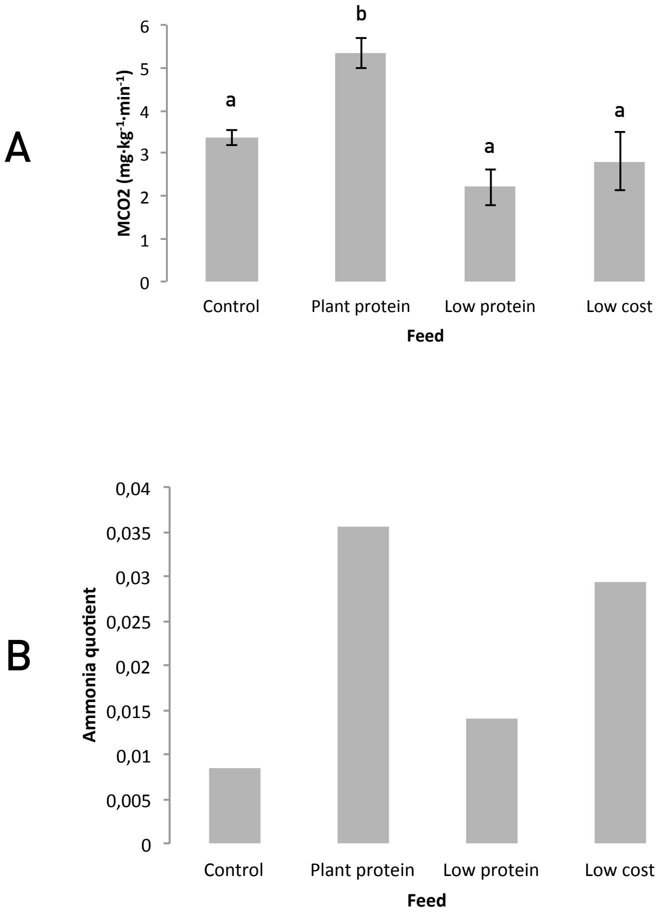


Figure 26. CO2 excretion (A) and ammonia quotient (B) (mmol NH3 excreted / mmol O2 consumed) in Arctic charr fed different diets. The data on ammonia were very variable and did not appear reliable. Therefore, no means were significantly different.



3.3.5 Intestinal morphology

There was a considerable difference among individuals in both the height of mucosal folds and stoma. There were also little differences among groups suggesting that enteritis was not more prevalent in the groups fed the different test diets than in the control group (Table 17).

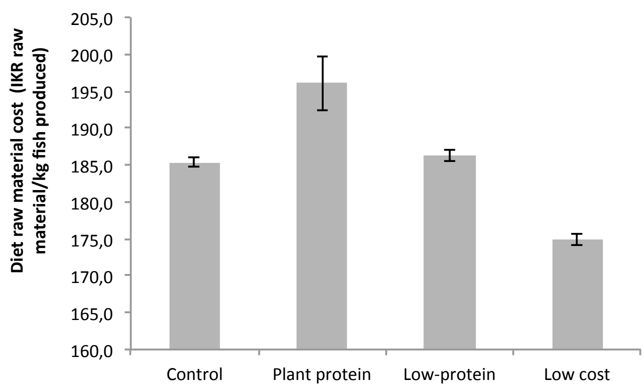
Table 17. Mean height of mucosal folds and width of stoma in the intestines of Arctic charr fed different types of feed. Values are shown ± standard deviation.

a) Height of mucosal folds (µm)		
	Hind gut	Mid gut
Control diet	682 ± 229	902 ± 193
Plant diet	637 ± 264	913 ± 352
Mean protein	792 ± 319	706 ± 234
Mean cost	553 ± 234	595 ± 235
b) Width of lamina propria (µm)		
	Hind gut	Mid gut
Control diet	7.9 ± 2.7	5.3 ± 0.8
Plant diet	5.1 ± 1.4	5.6 ± 1.7
Mean protein	5.1 ± 1.7	5.0 ± 1.8
Mean cost	5.4 ± 1.4	3.6 ± 1.6

3.3.6 Feed cost in the production.

The raw material cost of the diets ranged from 146 kr/kg for the plant protein diet to 183 for the control diet (see Table 18). However, the average raw material cost for production of one kilo fish biomass ranged from 175 kr/kg for the low cost diet to 195 kr/kg for the plant protein diet (Figure 27). The feed conversion ratio (FCR) was higest in the plant protein group but lowest in the control group (Figure 24).

Figure 27. The cost of raw materials (±se) for the different diets for each kg of fish produced.



3.4 Discussion

The results of this study suggest that plant based diets will not give as good growth performance as diets formulated from fish meal only. The control diet gave the best growth performance while the plant protein diet formulated primarily with soya as protein source and without fish meal, gave poor growth. Soya is known to contain anti-nutritional factors that may disturb feed utilisation and cause enteritis. Interestingly, there was no clear evidence found of enteritis in any of the groups (Table 17). Therefore, the plant based diets did not appear to compromise the welfare of the fish. The poor growth performance of the plant protein diet is likely caused by the low feed intake in that group (Figure 22 and 23). This may indicate low palatability of the soya meal for the Arctic charr.

Although the growth performance of fish fed a plant based diet without fish meal was compromised, the results of the project show that high inclusion of plant protein is acceptable if some fish meal is included as well. Both the low protein and low cost diets gave good growth, albeit not quite as good as the control diet. The low protein and low cost diets contained only 24% and 12% fish meal, respectively, compared with 30,4% in the control diet. In both diets there was a high inclusion of rapeseed meal, suggesting that this may be a good protein source for Arctic charr feed. This is an interesting result, since high inclusion of rapeseed meal has not proved successful in Atlantic salmon or rainbow trout diets (Collins et al., 2013). The plant protein feed was formulated with soya primarily as a protein source and no fish meal. The low cost diet contained some soya (13%) that gave comparatively good growth performance. This may suggest that low levels of soya inclusion may be acceptable in Arctic charr feed.

The choice of feed for production of Arctic charr will be based on a compromise between the raw material price for the feed and the growth rate and feed utilization of the fish. The price of the low cost feed was 20% lower than the price of the Control feed (Figure 27). However, since the feed conversion ratio (FCR) was higher in the plant protein, low protein and the low cost groups the difference in raw material price per kg produced is less, or only 5% lower in the low cost than in the control group. The price per kg produced with the plant protein diet was highest due to the high FCR and poor growth.

When choosing the most economical diet for a fish farm it is necessary to take other factors into account apart from the price of the feed, such as the production time. The growth rate of the control fish was highest and, therefore, the production time (to 700g) is shorter than for the other groups. The production time of the plant protein group was 64% longer than for the Control group, while the production time of the low cost group was 10% longer. The effect of production time on fish farm economics are complicated, affecting both possible production volume and the financial cost associated with building up the biomass. Here we estimated the effect of production time in terms of production volume and the associated difference in profit.

Table 18. Cost of diets produced for the experiment.

	Control	Plant protein	Low protein	Low cost
Raw material price for feed (IKR)[1]	183	148	156	146
Raw material cost/kg fish produced (IKR)	185	196	186	175
Relative raw material cost/kg fish produced	100%	106%	101%	95%
Expected production time (days) from 120 g to 700g[2]	138	227	145	152
Production volume relative to control[3]	100%	61%	95%	91%

1 Based on prices 2013.
2 The estimated production based on the overall Thermal growth coefficient in all groups. The production volume in the C group was set as 100%
3 Based on expected production time

Due to slower growth rate, the expected production volume with the plant protein diet is 39% lower than when fish are fed the Control diet (Table 18). However, the difference in production volume between the Control diet and low protein and low cost diet is less (5–9%). The benefits of lower (5%) feed cost for the low cost diet must be weighed against the reduced production volume (-9%). Based on the cost of feed used for these calculations it is likely that higher prodcution volume with the Control feed will return higher profits than for the low cost diet.

However, the supply of fish meal is limited and not likely to increase. Furthermore, consumers are concerned over the use of fish for producing aquaculture fish. Therefore, the fish farming industry will have to change strategy in diet formulation. The results from the present project show that there are possibilities of adjusting the fish feed formulations according to supply and prices of different raw materials, protein sources in particular. The low cost feed contained 12% fish meal. The fish-in-fish-out ratio (FIFO) in terms of protein is, therefore, somewhat less than 1, meaning that the fish fed this diet produce more fish protein than the fish caught to produce the fish meal. The FIFO for lipids is in these formulations higher than 1. However, previous research suggests that there is a possibility of reducing the marine lipid content without affecting the growth of the fish.

The different types of feed can affect water quality and effluent from fish farms. The low protein and low cost groups consumed more feed than the C group (Figure 23) while the growth rate of the former was slightly lower (Figure 19 and 20). This suggests that the nutritional efficiency of the low protein and low cost diets were less and more of the feed was lost with faeces. As a result the biological oxygen demand assoicated with the breakdown of faeces and lost food may be higher in the plant based diets than in the Control diet. This will increase the amount of organic nitrogen and phosphates lost to the environment. Furthermore, the ratio of metabolic CO2 produced (Figure 26) to O2 consumed (respiratory quotient; Figure 25) and the ammonia ratio (Figure 26) suggests that fish fed the plant protein and low cost diets use more protein as a source of energy than the control and low protein diets which contain more fish meal. Further research is required to determine the nutritional efficiency of the diets and to estimate which fraction is lost with faeces.

The novel diets, which included different levels of plant proteins, were tested under practical conditions (see Sections 2 and 3). The results of these tests suggest that plant proteins can in part substitute fish protein in the diet of Arctic charr. The plant-based diets are less expensive than the conventional diets using only fish meal. However, inclusion of plant proteins in the diet of Arctic charr may come at a cost to the farmer due to slower growth and lower production volume than when the conventional diets are used. However, these differences may only be marginal when plant proteins replace only part of the fishmeal.

The plant-based diets did not appear to affect the welfare of the fish; at least there were no indications of enteritis if fish fed plant proteins. However, the environmental impact of effluent from fish farms using the plant-based diets may be greater than for conventional diets in terms of BOD, nitrogen and phosphorous load. This must be weighed against the benefit of reduced inclusion of fishmeal in the plant based proteins. Whereas the new diets tested neither had any marked effect on fish welfare nor the environment, and whereas the fish meal protein in the new types of feed was replaced by plant protein raw materials which all are by-products from agricultural products, the substitution will increase the sustainability of the production and also lower the dependency on marine raw materials that are under an increasing pressure in terms of sustainability. Additionally, a reduction of the protein content in the diet itself reduces the emission of Nitrogen into the environment.

3.5 References

Collins, S.A., Øverland,M. Skrede A., Drew M.D, 2013: Effect of plant protein sources on growth rate in salmonids: Meta-analysis of dietary inclusion of soybean, pea and canola/rapeseed meals and protein concentrates, Aquaculture, 400–401,85–100

R Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/

4. Stakeholder meeting

4.1 Programme

One day Stakeholder workshop

Venue:	Matis ohf, Vinlandsleid 12, 113 Reykjavík, ICELAND
Date:	24. January 2014

Part 1: Primarily for the traditional value chain

8:30 – 9:00	Registration
9:00 – 9:10	Opening of the seminar – Arnljótur Bjarki Bergsson
9:10 – 9:55	Consumers perception of their food – Vilhjálmur Jens Árnason
9:55 – 10:25	Effect of new diets on growth, feed utilisation and economy – Ólafur Ingi Sigurgeirsson/Oddbjørn Jarijervi/Eva Eva Brännäs
10:25 – 10:40	Coffee
10:40 – 11:00	Effect of new diets on fish welfare and the environment – Helgi Thorarensen
11:00 – 11:20	Effect of new diets on fish quality – Aðalheiður Ólafsdóttir/Eva Brännäs
11:00 – 12:00	Panel discussion – Led by Jón Árnason
12:00 – 13:00	Lunch and networking

Part 2: An open seminar

12:00 – 13:00	Registration and Lunch
13:00 – 13: 30	Short presentation of project findings – Helgi Thorarensen/Jón Árnason/ Árni Ólafsson director of Menja
13:30 – 14:00	
14:00 – 14:20	Consumer view of Arctic charr – Retailer
14:20 – 14:40	Sustainability of Arctic charr farming – Birgir Örn Smárason
14:40 – 15: 00	Coffee
15:00 – 15:20	Organic farming of Arctic charr – Arnþór Gústavsson
15:20 – 16:20	Open panel discussion – Led by Vilhjálmur Jens Árnason
16:20 – 16:40	Conclusion and the way forward – Jón Árnason
17:00	Informal gathering at Matis
19:00	Dinner

Unfortunately presentation of the consumer view had to be omitted as no speaker could be found to cover that topic in spite of considerable efforts to identify the appropriate person.

4.2 Participants

In addition to participation of project partners, invitations ware sent to different stakeholders in the value chain of arctic charr farming. The invitations were sent by direct mailing. In Norway the organisation “Norsk røyeforum” supplied a list of stakeholders that were contacted. In Iceland invitations were sent to all members of “Landssamband fiskeldisstöðva” (Icelandic Fish farmers organisation). In Sweden SLU arranged the presentation of the meeting. The following attended the meeting:

List of participants

Name	Company	Country
Ingólfur Arnarson	Náttúra fiskeldi	ICELAND
Sófus Páll Helgason	Rifós	ICELAND
Gunnar Örn Kristjánsson	Fóðurverksmiðjan Laxá	ICELAND
Erik A Olufsson	Aquabest	SWEDEN
Eva Brannas	SLU	SWEDEN
Hanna Gilberg	SLU	SWEDEN
Birgir Þórisson	Klausturbleikja	ICELAND
Ásmundur Baldvinsson	Hólalax	ICELAND
Guðbergur Rúnarsson	Landsamband fiskeldisstöðva	ICELAND
Bergþóra Gísladóttir	Íslandsbleikja	ICELAND
Bernhard Laxdal	FishVet Group	NORWAY
Heiðdís Smáradóttir	Samheji	ICELAND
Árni Ólafsson	Menja	ICELAND
Helgi Thorarensen	Hólaskóli	ICELAND
Hjalti Bogason	Íslandsbleikja	ICELAND
Erlendur Jóhannsson	Fóðurblandan	ICELAND
Ólafur Ingi Sigurgeirsson	Hólaskóli	ICELAND
Arnþór Gústavsson	Hólaskóli	ICELAND
Rannveig Björnsdóttir	Matís	ICELAND
Jónína Jóhannsdóttir	Matís	ICELAND
Vilhjálmur Jens Árnason	Ráðgjafi	ICELAND
Birgir Örn Smárason	Matís	ICELAND
Arnljótur Bjarki Bergsson	Matís	ICELAND
Aðalheiður Ólafsdóttir	Matís	ICELAND

4.3 Minutes from the Open Stakeholder Workshop

Arnljótur Bjarki Bergsson opened the meeting and started the discussion at the meeting.

Vilhjálmur Jens Árnason: Consumer perception of their food

There is a growing group of men directing household grocery shopping and food preferences of families. The retail industry must change their strategy accordingly. Philosophers have not speculated much about consumer preferences but they have addressed perception and how we perceive our environment extensively. Important to address all senses when appealing to consumers Menu engineering. Restaurant sector has grown especially in Asia Pacific. Retail sector is also growing. Consumers are now more price conscientious than before. In the western world, about 10–20% of household income is spent on food. Consumption of those who live in urban areas are more varied than those who live in rural areas. The selection in supermarkets is high and the sector is structured to accommodate the preferences of consumers. Cereals 153kg/persons. Consumption of fish has grown by 53%. Meat consumption in Europe is around 53 kg/year twice the world average. Seafood consumption has decreased in the USA since 2006. Consumer behaviour. Basic needs e.g. bread yogurt cheese. 20% is bought on impulse. The length of time req. To make a buying decision <15 sec. Categorization, when marketing a product, can affect the choice of consumers. The image of the product: Where does it come from, is the environment clean. Perception of the Arctic. Categorization of arctic charr apart from trout or salmon. Generation change in use of computers apps etc when making consumer decisions.

Ólafur Ingi Sigurgeirsson: The effect of new diets on growth, feed utilization and economy.

The objectives of studies are to decrease feed cost, increase sustainability, test and evaluate new raw materials. Limited supply of fishmeal and fish oil. Effect of new raw materials in feed on the quality of fish. The development of Arctic charr diets has followed similar trends as in the Atlantic salmon industry. Nearly 2/3 of salmon feed is from plants. Fish in fish out ratio. Equality with 7% fish oil and 17% fish meal. Salmon production is now close to 1:1.1–1.8. The protein content of diets for Ac have been decreasing in accordance with results from experiments. Feed conversion is reduced as the protein content is reduced. Field-tests of feeds in large volume tanks or cages. Results suggest that the raw material costs are similar or up to 20% lower for the plant based feed. When protein content of diet is high, the plant based diets may perform as well or better than marine protein diets. The cost of feed was reduced up to 30% although is some cases there was no significant difference.

Protein requirements are size related although protein 34–35% appears to be enough for the grow-out phase. Feeds used in the project have low Fish in Fish out. Arctic charr can accept high inclusion of rapeseed meal.

Hanna Carlberg: report of trials at SLU
No difference in growth rates among Arctic charr fed conventional diets and those fed diets with high plant raw material inclusion. Consumers preferred fish that were fed the Polarfeed plant based diets. FCR will be compared

Helgi Thorarensen: Effect of new diets on fish welfare and Environment

The plant based diets appeared to have limited effects on the welfare of the fish. The oxygen consumption and carbon dioxide excretion of fish fed plant-based diets was about 20% higher than in control fish. Similarly, nitrogen excretion was about 50% higher in the fish fed plant-based diets and it is also likely that the excretion of phosphorus is also increased. Sections of charr gut did not reveal any evidence of enteritis in the fish fed plant based diets.

Aðalheiður Ólafsdóttir: Sensory evaluations and consumer surveys were conducted in Iceland, Norway and Sweden.

Charr fed plant feed were judged juicier, softer and tenderer that fish fed control feed. No difference was observed in consumer surveys (two in Iceland). No difference in sensory evaluations by panels. All thought the product was very good. Consumer survey in Sweden showed no difference. Consumer survey in Norway gave traditional feeds a higher score.

Open discussion:
Changes in consumer market and how that may affect consumer preference in the future eg with more men doing grocery shopping.

Do consumers detect differences in diets? Are we destroying the image of Arctic charr by feeding it plant-based diets? Does this affect our options for raw materials in diets? A number of options are available for raw materials in fish feed e.g. in insects that should be considered. Perhaps the Arctic part of the image of Arctic charr is not that important. Consumers choose primarily food based on prize. The consumers expect charr to be high in 18:3 fatty acids. The new diets contain as much 18:3 as older diets.

The Arctic is important in the image but price is also important. Cultural and religious emphasis may also affect the possible choice of raw materials. Meat meal may be a good raw material but may not be acceptable in many markets. Coming from a clean area may be more important than the Arctic as such.

Fish in fish out ratio of fish oil 5:1. In fish protein we are less than 1. The objective of having a ratio of less than one is certainly attainable. A number of options are available for oil from plants such as e.g. rapeseed oil.

Árni Ólafsson: Marketing of Arctic charr
Introduced Menja, the export company. Their marketing strategy and certification. Marketing of Arctic charr and how it is promoted. Price and how price is determined, where to market it. Size of fish marketed. Europe is interested in portion size while the US market wants as large fish as possible.

Birgir Örn Smárason: Sustainability of Arctic charr farming.

What are the indicators of sustainability in aquaculture? Economical / Social. Feed causes the main sustainability issue. Presented recent research on black soldier fly meal as feed for fish, reduced carbon foot print of fish feed.

Arnþór Gústavsson: Organic farming of Arctic charr.

Discussed the possibilities and constrains in organic farming.

General discussion and conclusion of the meeting.

General conclusion of the Stakeholder meeting was that the work presented would not spoil the image of Arctic charr. At the same time it was the emphases of the participants that is was important to evaluate the effect of different diets on sustainability and total economy in the production taking into account the possible effect on length of the production period.

5. Quality and Marketing

In 2014, Matis ohf. published information which can be regarded as comprehensive guidelines for production of Arctic charr and assessment of the effect of rearing practises on quality, welfare parameters and environmental impact (See: http://www.matis.is/english/iceland-arctic-charr). Even though this publication is designed for Iceland, it can be applied as a basis for similar information in other charr producing countries.

The results of the present project showed only minor effects of the new diets tested on the quality of the produced Arctic charr and therefore it was not found necessary to change the existing quality standards/databases for the production in the Nordic countries.

In order to evaluate the product quality of the Arctic charr, different types of quality evaluations were compared in the different diet tests carried out in the project. Two types of sensory evaluation were carried out. Sensory evaluation carried out by trained personnel where many different sensory parameters were evaluated, showed that two characteristics seemed to vary between the diets, i.e. softness and juiciness. These characters are in nature considered a matter of personal taste, with different consumers having different preferences. Sensory evaluation by untrained consumers confirmed the differences in softness and juiciness found in the evaluation by the trained panel. The third parameter of "general liking" gave a high score for both the fish getting the commercial diets and the test diets.

Possible revision of guidelines for Arctic charr farming were discussed at the stakeholder meeting. The conclusion of the discussion was that the tested, changes in the feed, did not require any changes in presentation of the fish towards the market. Discussions with partners in the project and Arctic charr farmers in general, in all participating countries, has supported this conclusion.

The project did not show any need for the development of a new quality database for the production of Arctic charr, related to the proposed alterations in the production chain.

6. Innovation process

The idea behind the project was to find out if feed formulation based on the need for nutrients, regardless of their origin, would interfere with the efficiency of Arctic charr farming and the image of the produced fish.

The project shows clearly that the Arctic charr has primarily need for certain nutrients but not any particular need for specific raw materials in the feed.

The project is innovative in different ways:

- Feeding carnivorous fish high content of plant protein raw materials in the feed.
- Compared to earlier practice in feed formulation for Arctic charr, the protein content in the new type of diet is significantly lower.
- The project therefore broadens the availability of raw materials available for future growth of the aquaculture indursty.
- The project showed that the quality assessment of the produced fish can be considerably simplified and may therefore be coordinated with marketing of the fish.
- The new feed formulations even increase the possibility of using local ingredients as important constituents in feed for Arctic charr.

Non of the participants in the project had any experience in innovative processes but were very satisfied with the way the project created value for them in their practical situations.

Table of abstract

Series title, number and report code of publication: Nordic Innovation Publication 2015:01			
Author(s): Arnason J, Carlberg H, Brännäs E, Thorarensen H, Sigurgeirsson Ol, Bjornsdottir R			
Organisation(s): MATIS Ltd. – Icelandic Food and Biotech R&D, ICELAND Swedish University of Agricultural Sciences, SWEDEN Holar University College, ICELAND			
Title (Full title of the report): **Profitable Arctic charr farming in the Nordic countries**			
Abstract: A new type of diets, with lower protein content and reduced use of fishmeal, developed based on earlier laboratory trials, were tested at Haukamýri and Rifós fish farms in Iceland and Kirkenes charr in Norway. In addition, a trial with three replicates was carried out at the Aquaculture Centre North (ACN) in Kälarne Sweden, with the new type of diet and control diet. The control diets used in all the tests were the commercial diets normally used at each site. The trials shoved somewhat variable effect on growth of fish fed the test diet, i.e. lower growth in the Icelandic trials, a better growth in the Norwegian trial and equal growth in the Swedish trial, compared to the control diet. Similarily the Icelandic trials showed a tendency to poorer feed utilisation in the test groups as compared to the control groups, better feed utilisation in the Norwegian tria and equal feed utilisation in the Swedish trial, compared to the control group. Feed cost per kg fish produced was lowest in the groups getting the test diets, due to lower raw material cost in these diets in all comparisons. No important differences in quality of the fish product, related to the different diets, were found in any of the studies. Overall the conclusion of the performed tests confirm the results of the previous laboratory trials previously carried out in Iceland, showing that Arctic char tolerates considerably lower content of protein and higher degree of fish meal substitution than found in the currently used commercial diets.			
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Publisher: Nordic Innovation Stensberggata 25, NO-0170 Oslo, Norway Phone: +47 – 47 61 44 00 info@nordicinnovation.org www.nordicinnovation.org		**Main contact person:** Name: Dr. Jon Arnason Organisation: MATIS Ltd. – Icelandic Food and Biotech R&D Address: Vinlandsleid 12, IS-113 Reykjavik, ICELAND Phone: +354 422 5000 / +354 858 5073 jon.arnason@matis.is	

Profitable Arctic charr farming in the Nordic countries

Testing of different diets for Arctic charr under practical conditions

Nordic Innovation Project No. P11081

The present project aimed at testing out new type of sustainable feed under practical Arctic charr conditions.

Results of the work showed that it is possible to reduce the feed cost of Arctic charr by reducing the protein content of feed to about 35% (compared to 42_48% in present commercial feed) and to reduce the content of fishmeal in the feed considerably without significant effects on efficiency, fish welfare, environment or quality of the fish produced.

Possible positive substitution of the content of fish oil in the feed where plant oils have not been a part of these trials.

The project confirms the findings from earlier laboratory studies, that there exists a potential to strengthen the economy of the Arctic charr industry in the Nordic countries, by changing present commercial diet used by the industry.

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