Plant-Based Diet In Trout (*O. mykiss*): Are There Genotype-Diet Interactions For Main Production Traits When Fish Are Fed Marine *Vs* Plant-Based Diets From The First Meal ?

R. Le Boucher[1] [†] [¤], E. Quillet[*], M. Vandeputte[*†], J.M. Lecalvez[±], L Goardon[±], B. Chatain[†], F. Médale[•], M. Dupont-Nivet[*]

Introduction

Facing the finite size of fisheries resources, the important increase of aquaculture production during the last decades has led to the evolution of feed composition with an increasing substitution of fish meal and fish oil with terrestrial plant products. During the same period, selective breeding has been developed in fish and major improvements were achieved on growth, resulting in 4 to 20 % gain per fish generation (Olesen, Gjedrem, Bentsen *et al.* (2003); Chevassus, Quillet, Krieg *et al.* (2004)), and also on health and flesh quality traits.

Recent and fast co-evolution of these two major parameters of fish production raises issues about the consequences of feed composition changes on fish breeding, and on the possibility of selecting for growth with plant-based feed. To date, several authors already found significant genetic variability of growth traits with plant-based diets, indicating that genetic progress may be obtained even when feed contains high levels of plant products. But only Pierce, Palti, Silverstein *et al.* (2008) gave precise estimates of heritability, and for growth parameters only. However, the major problem would result in the existence of genotype-diet interactions because feeding fish, formerly selected with marine diets, on plant-based diets would lead to family re-ranking. Presently, results on the subject are quite uneven, e.g., in rainbow trout, Palti, Silverstein, Wieman *et al.* (2006) found no genotype-diet interaction conversely to Pierce, Palti, Silverstein *et al.* (2008) and Dupont-Nivet, Médale, Léonard *et al.* (2009).

Our work aimed at inferring accurate heritabilities and genotype-diet interaction estimates for rainbow trout (*Onchorhynchus mykiss*) in the case of a total substitution of marine ingredients by plant products from the first meal to 343 dpf (days post-fertilization), i.e. commercial pan-size for fish fed marine diet.

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[1] INRA, UMR1313 GABI, F-78350 Jouy-en-Josas, France

[†] Ifremer, F-34250 Palavas-les-Flots, France

[¤] AgroParisTech, UMR1313 GABI, F-75231 Paris 05, France

[•] INRA, UMR1067, NuAGe Nutrition, Aquaculture et Génomique, F-64310 St Pée-sur-Nivelle, France

[±] INRA, UE 937 PEIMA, F-29450 Sizun, France

Material and methods

Biological material. The experimental groups were produced at INRA facilities (PEIMA, Sizun, France), using the INRA SY strain of rainbow trout. 25 sires were mated with 10 dams in a full factorial mating design. All families were mixed after fertilization and reared in 5 tanks (0.25m$^{3)}$ on natural spring water (11.4°C). Experimental diets were produced in the INRA facilities (Donzacq, France). M1 and V1 were distributed to fish from the first feeding to 100 g and M2 and V2 to 100g fish onwards. From the first feeding, two batches were fed a marine ingredients based-diet (M1/M2) containing fish meal and fish oil while three others were fed a plant-based diet (V1/V2) devoid of marine ingredients and containing a blend of plant products (Table 1). During a transfer in 5.4 m^3 tanks (148 dpf, 13.4-18.3°C), 2,010 M and 4128 V fish were split up into 6 tanks (3M and 3V). At 213 dpf, fish of both diets were randomly split up into 12 tanks (6 per diet), individually tagged with passive integrated transponder and fin clipped for DNA analyses and parentage assignment (M: 42.79 ± 0.45 g, V: 23.71 ± 0.47 g).

1,000 fish per diet were slaughtered at 343 dpf to individually record sex, body weight, fork length, and weights of carcass, viscera, fillet and head. The corresponding yields were calculated (*Carc Y, Visc Y, Fil Y, Head Y in %* of body weight).

Table 1: Ingredients and proximal composition of the experimental diets

Diets	**M1**	**M2**	**V1**	**V2**
Ingredients (g/kg)				
Fishmeal	692	623	0	0
Maize gluten	0	0	250	170
Soybean meal	0	0	208	200
Wheat gluten	0	0	239	250
Extruded wheat	187	240	0	49.8
White lupin	0	0	70	57.2
Extruded dehulled pea	0	0	0	30
Fish oil	81	97	0	0
Rapeseed oil	0	0	62	62
Linseed oil	0	0	37	37
Palm oil	0	0	24	24
Soya lecithin	0	0	20	20
L-Lysine	0	0	15	15
L-Arginine	0	0	0	10
CaHPO4.2H20 (18%P)	0	0	35	35
Binder	20	20	20	20
Min. Premix	10	10	10	10
Vit. Premix	10	10	10	10
Composition (% DM)				
Crude Protein	54.6	47.1	50.5	44.8
Lipids	15.6	22.8	16.2	23.3
Energy kJ/g DM	22.5	23.5	23.2	23.6

Statistical analysis. The significance of diet, sex, tank, sire and dam effects as well as sire-diet and dam-diet interactions were tested with a linear model (SAS-GLM, SAS Institute Inc., Cary, NC). In a second step, an animal model was used to estimate the genetic parameters for each trait with REML methodology using ASREML (Gilmour *et al* (2002)). Genotype-environment interactions (GxE) were estimated through genetic correlations between each trait recorded for diet M and the same trait recorded for diet V, considered as two different traits in the analysis. GxE interaction is the difference between 1 and the genetic correlation. The closer to 1 is the genetic correlation, the smaller is the interaction.

Results and discussion

From the eyed stage to tagging, mortality rates were close in both diets (M=11.3%; V=13.3%) but diverged after tagging (M=9.3%; V=13.8%). When distributed from the first meal, the plant-diet had a highly significant effect on growth and processing traits (Table 2). Compared to a mean M fish, a mean V fish has a lower body weight (68.9 % of M), smaller length (80.8% of M), and has a bigger head ratio (+14.8%), and higher viscera proportion (+15.2%). As a result of such differences, V fish had smaller carcass and fillet yields (88.6 and 94% of M yields respectively).

Table 2: Means[a] and standard errors per diet, and P-values of indicated effects

	M	PB	Diet	Tank (diet)	Sex	Dam-Diet	Sire-Diet
BW	438.6±6.6	216.2±6.11	<0.0001	<0.0001	0.8139	0.0256	<0.0001
SL	301.9±1.4	243.9±1.51	<0.0001	<0.0001	0.0468	0.1194	0.0007
Carc Y	89.5±0.04	88.2±0.04	<0.0001	0.4545	0.0138	0.0102	0.0019
Visc Y	8.4±0.03	9.6±0.04	<0.0001	0.3230	0.0437	0.0014	0.0043
Head Y	12.5±0.09	14.4±0.09	<0.0001	<0.0001	<0.0001	<0.0001	0.0354
Fillet Y	32.4±0.07	30.5±0.07	<0.0001	<0.0001	<0.0001	0.0205	0.0650

[a] BW (body weight) in g, SL (fork length) in mm and processing traits yields corresponding respectively to carcass, viscera, head and fillet weights divided by the body weight (%).

Genetic parameters estimates are shown in Table 3. Body weight heritability was higher than those of previous works (Gjerde and Schaeffer (1989); Kause, A., Ritola, O., Paananen, T. *et al.* (2002) on 2-4 kg trout), so as fillet yield (Kause, A., Ritola, O., Paananen, T. *et al.* (2002)). No significant difference was observed among diets for heritabilities of the different traits. In linear models, sire-diet interaction was significant for all traits. However, genetic correlations were high for all parameters meaning a limited genotype-diet interaction, thus a low (even though significant) re-ranking of the families between diets.

Table 3: Genetic correlations between diets, and heritabilities with standard errors for growth and processing traits[a]

	Genetic correlation	h^2 (V) (± SE)	h^2 (M) (± SE)
BW	**0.91** ± 0.05	**0.65** ± 0.12	**0.61** ± 0.12
SL	**0.90** ± 0.05	**0.59** ± 0.12	**0.56** ± 0.11
Carc Y	**0.90** ± 0.06	**0.73** ± 0.15	**0.70** ± 0.15
Visc Y	**0.90** ± 0.05	**0.70** ± 0.12	**0.65** ± 0.13
Head Y	**0.89** ± 0.06	**0.65** ± 0.12	**0.57** ± 0.11
Fillet Y	**0.91** ± 0.05	**0.63** ± 0.12	**0.59** ± 0.12

[a] BW (body weight), SL (fork length) and processing traits yields corresponding respectively to carcass, viscera, head and fillet weights divided by the body weight in %.

Conclusion

This study pointed out for the first time that trout could be fed all plant-based diets from the first meal without negative effect on survival during the first months of life. Nevertheless, growth under plant diet was dramatically reduced (M fish were twice as heavy than V fish) as usually recorded in similar studies. Plant-based diet was also shown to increase viscero-somatic index and decrease carcass and fillet yields.

The experimental design allowed reaching a good accuracy in the assessment of genetic parameters. Heritability estimates were high for all traits, and in the same range under both diets indicating that selection for growth and processing traits will be equally efficient whatever the diet. The very low family re-ranking between extremely contrasted diets is a key information in the current context of fish product replacement in aquaculture feeds. It would indicate that previous genetic gain (obtained with full marine diet) may be preserved with a dramatic substitution on plant products, and even when early feeds are substituted. Yet, it is important to follow this parameter along the whole life cycle until fish fed the plant based diet reach the commercial size (pan-size and even large size trout). This comparison at the same age was the first part of the trial, our experiment will now continue to estimate interactions by comparing fish at the same weight.

References

Chevassus, B., Quillet E., Krieg F. *et al*. (2004) *Genet. Sel. Evol.* 36, 643-661.

Dupont-Nivet, M., Médale F., Leonard J. *et al.* (2009) *Aquaculture* 295, 15-21.

Gilmour, A.R., Gogel, B.J., Cullis, B.R. *et al*. (2002) User Guide Release 1.0.

Gjerde, B. and Schaeffer, L.R. (1989) *Aquaculture* 80, 25-44.

Kause, A., Ritola, O., Paananen, T. *et al.* (2002) *Aquaculture* 211, 65-79.

Olesen I, Gjedrem T, Bentsen HB *et al.* (2003) *J Appl Aquacult* 13, 179-204.

Palti, Y., Silverstein, J.T., Wieman, H. *et al*. (2006) *Aquaculture* 255, 548-556.

Pierce, L., Palti, Y., Silverstein, J.T. *et al*. (2008) *Aquaculture* 278, 37-42.