



FISHMEAL-FREE DIETS & RAINBOW TROUT GROWTH RESPONSE

A PARTIALLY ANNOTATED BIBLIOGRAPHY

Ewen McLean



This document would not have been possible without the generosity and sustained enthusiastic support of the

Anthropocene Institute

<https://anthropoceneinstitute.com/>

855 El Camino Real

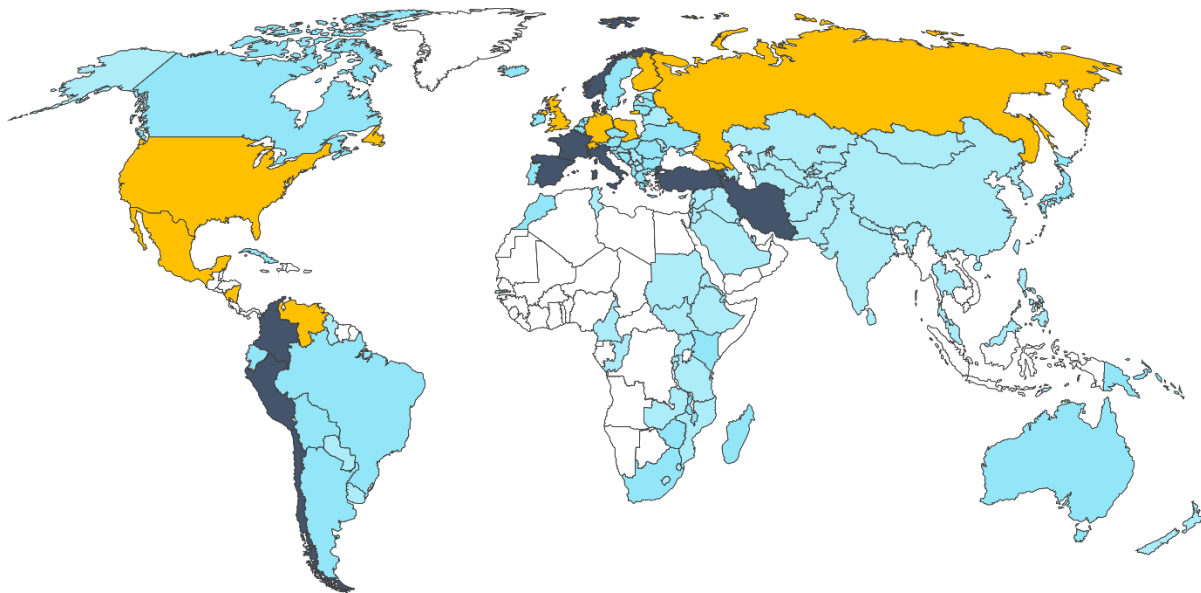
Ste 13A N399

Palo Alto, CA 94301

Preamble

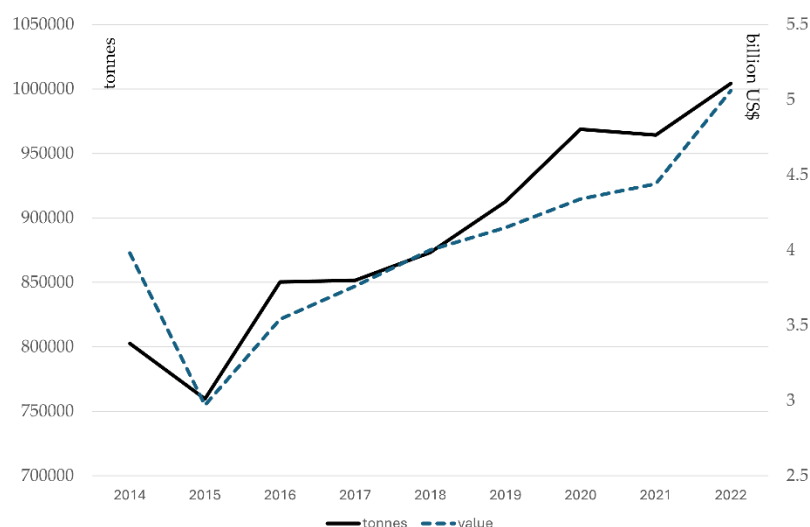
Due to its popularity as a sport fish and favorable eating qualities, rainbow trout has become one of the most widely distributed and farmed fishes in the world and, barring Antarctica, the species is cultivated on every continent (Fig. 1). Methods of production employ all systems of farming: tank, pond, raceway, cage, net-pen and RAS. Producers rear fish in monoculture and use triploid or all-female fish that grow larger since energy is diverted away from reproduction towards growth. These animals are also more uniform in size, have better flesh quality and avoid injuries due to interactions with males. Global production of rainbow trout as of 2022 exceeded one million tonnes (FAO, 2024a; Fig 2) with a market value of around \$5 billion. A projected market growth of approximately 5% is anticipated with a forecasted value of \$5-7 billion by 2031/3 (Fact.MR, 2024; Verified Market Research, 2024). As a founding species in contemporary aquaculture (Bardach *et al.*, 1972), farmers of rainbow trout have had to face many technical and sustainability challenges that loom over the entire industry. Feed represents not only the largest cost of production for trout but also the most significant contributor to nutrient discharges and environmental impact and it is the latter that consumers have started to scrutinize and consider as part of their willingness to pay for fresh fish, including trout (Menozzi *et al.*, 2020).

Figure 1. Ten main producer counties (dark blue), accounting for over half (682,000 tonnes) of the world's cultured rainbow trout, other prominent producers (yellow) and countries (light blue) where rainbow trout are farmed or used as stocked game fish. White represents countries where the species is absent.



Several methods have been employed to reduce the overall ecological effects of diet (Amirkolaie, 2011) and these include ingredient substitutions. Historically, trout feeds have incorporated fishmeal (FM) as the main source of protein with variations in formulae reflecting geography, life stage and sizes (FAO, 2024b). Over the last 2-3 decades, however, there have been significant reductions in FM use in commercial feeds (Aas *et al.*, 2022). This shift in FM use has been encouraged by increasing costs of the commodity due to increasing unpredictability in supply and due to concerns over the ecological and social impacts of using this ingredient by consumers. Nevertheless, reliance on FM as a trout feed ingredient endures and research has examined the potential for complete removal of marine resources, including FM, from trout feed formulations (Fig. 3). However, accessing existing knowledge, which is widely dispersed in literature, is challenging and this has sometimes led to research duplication.

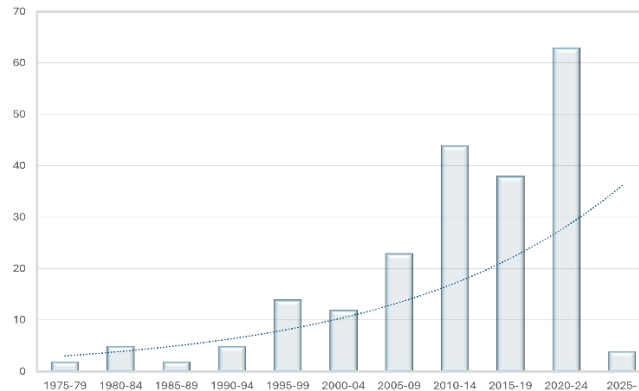
Figure 2. Production and value of cultivated rainbow trout between 2014-2022 (FAO, 2024a). The trend in both parameters is upward and remained resilient even during the global pandemic period 2020-2023. As with all fish farming operations during this time Covid-19 did, nonetheless, have an impact, with decreased production during 2020-2021. The decline in production during the 2014-2015 period is likely associated with the H1N1 pandemic and the financial credit crisis at that time.



As we move towards an increasing variety of novel ingredients that are focused on scaling production, future investigations, that aim to shake the dependence of trout cultivation from FM will, no doubt, intensify. For this reason, the present document was produced as a time-saving resource to collate publications that have examined only the growth response of trout to alternative feed proteins. The content herein highlights the fact that rearing trout on marine resource-free feeds is neither new nor fresh. Studies have been discharged with all manner of alternative proteins with trout since the last century and include those with single-celled organisms, terrestrial and aquatic plants, and a range of animals and their processing byproducts. Only articles that have examined the *complete* replacement of fishmeal from diets are included. This does not underestimate the substantial contributions of studies that have used only partial substitutions but merely acts to distillate the large volume of existing material.

Of the over 200 citations in the following listing, it is fair to say that the majority report poorer responses of trout to complete removal of FM by alternative plant proteins. Few have observed a parity in growth and fewer still, better performance. It does, however, appear that the more varied the FM replacers are, which has become more common with the appearance of PP isolates and concentrates, the closer we come to achieving parity in performance. This may result due to a dilution of antinutritional factors, with a comparable increase in growth being attained. Equally, it may be changes in the means of nutrient delivery, with a greater variety of proteins providing a more representative supply of nutrients. This appears to be enhanced further when alternative animal proteins are used since it is common for parity in growth to be achieved *versus* all FM-based diets and examples of this are included in the bibliography. Indeed, Marine resource-free feeds are already being used by commercial trout producers as exemplified by McFarland Springs in Susanville, CA, and those retailed by the international supermarket chain Auchan/Alcampo/Ashan. Moreover, Aquafeed manufacturers, such as Skretting AS, have developed FM-free diets suitable for rainbow trout and other salmonids. As the production cost of alternative feed ingredients, such as single cell and insect proteins, weaken clearly these will become more competitive ingredients. Without doubt the evidence that rainbow trout can be raised without ingredients from the marine warehouse is overwhelming and incontrovertible – just look inside this document.

Figure 3. Time course of published material incorporated into the present bibliography. As societal awareness of the damage of overfishing has increased, so have the number of papers published risen and they maintain an upward trend.



Inevitably we will have missed some published materials in our searches. There are many contributions that examine different aspects of FM-free reared fish without presenting growth data or as supplemental manuscripts to growth studies – these are not included here. The present text has been developed as a living document and we encourage those whose publications have been missed or are as yet to be, to inform us to include these at a later date.

Search methods employed

Over the last few decades there has been a dramatic increase in the amount of information on the worldwide web. This has generally led to the demise of traditional (manual) literature-hunting methods in favor of searching electronic databases and indices. When combined with increasingly sophisticated AI review tools, this permits rapid summarization and integration of knowledge contained within published material. This technological spring will no doubt ease construction of scientific manuscripts while also resulting in the appearance of an ever-increasing load of review-like articles. Although representing an exciting development it nonetheless does not diminish the responsibility of authors to ensure that their communications take thorough account of all prior pertinent literature. Although, wherever possible, the following references are linked to their internet location using their digital object identifier (Doi), when available, or by noting their web address for those without. It is well to remember that electronic information tends to be ephemeral, and this is especially the case for grey literature sources. Internet addresses change, become obsolete or may simply be deleted for a wide variety of reasons. The current bibliography was constructed using various search engines, including Google and Semantic Scholar and other electronic catalogues, the citation listings for each included paper, back issues of relevant journals and publisher's websites, key authors' web pages when available, proceedings volumes and meeting abstracts.

Literature cited

- Aas, T.S., Åsgård, T., Ytrestøyl, T. (2022). Utilization of feed resources in the production of rainbow trout (*Oncorhynchus mykiss*) in Norway in 2020. *Aquaculture Reports*, **26**, 101317.
- Amirkolaie, A.K. (2011). Reduction in the environmental impact of waste discharged by fish farms through feed and feeding. *Reviews in Aquaculture*, **3**, 19-26.
- Bardach, J.E., McLarney, W.O., Ryther, J.H. (1972). *Aquaculture: The farming and husbandry of freshwater and marine organisms*. John Wiley and Sons Inc., NY, USA. 896 pp.
- FAO (2024a). World aquaculture production 1950-2022. [www.fao.org /fishery/en/statistics/software/fishstatj](http://www.fao.org/fishery/en/statistics/software/fishstatj). [Accessed November 18th, 2024].
- FAO (2024b). Rainbow trout – *Oncorhynchus mykiss*. [https://www.fao.org/fishery/affris/species-profiles/ rainbow-trout/rainbow-trout-home/en/](https://www.fao.org/fishery/affris/species-profiles/rainbow-trout/rainbow-trout-home/en/) [Accessed November 18th, 2024].
- Fact.MR (2024). *Rainbow trout market*. <https://www.factmr.com/report/2084/rainbow-trout-market> [Accessed November 18th, 2024].
- McLean, E., Page, B., Barrows, R.T., Gatlin, D. III. (2025). Responses of rainbow trout to fishmeal replacement by single cell and plant proteins. In preparation.
- Menozzi, D., Nguyen, T.T., Sogari, G., Taskov, D., Lucas, S., Castro-Rial, J.L.S., Mora, C. (2020). Consumers' preferences and willingness to pay for fish products with health and environmental labels: Evidence from five European countries. *Nutrients*, **12**, 2650.
- Verified Market Research (2024). *Global rainbow trout market size by type (fresh, frozen, smoked, canned rainbow), by form (whole, fillets, steaks, portions), by distribution channel (supermarkets/hypermarkets, specialty stores, online retail, foodservice, convenience stores), by end-user (household, restaurants, hotels, catering services, food processing), and by geographic scope and forecast*. Report ID: 273597. Washington DC, USA. pp. 202.

List of abbreviations

3n = triploid; AA = amino acid; ADC = apparent digestibility coefficient; ALP = alkaline phosphatase; AP = animal protein; APC = alfalfa protein concentrate; APD = apparent protein digestibility; Asp = aspartic acid; BePC = bean protein concentrate; BM = barley meal; BMA = blood/hemoglobin meal; BOD = biological oxygen demand; BP/C = barley protein/concentrate; BSCP = bacterial single cell protein; BSF = black soldier fly; CAP = *Clostridium autoethanogenum* protein; Cas-Gel = casein-gelatin; CG/M/F = corn gluten/meal/feed; CM = crustacean meal; CP(C) = corn protein (concentrate); CPI = canola protein isolate; CSC = cottonseed concentrate; CSM = cottonseed meal; CSPP = cottonseed protein powder; Cu = copper; -d = days; DDG = dph = days post-hatch; Distiller's dried grains; DPP = dehydrated poultry protein; EAA = essential amino acids; EPM = extruded pea meal; ERE = energy retention efficiency; EWW = extruded whole wheat; FAA = free amino acids; FB(PC) = faba bean (protein concentrate); FC = feed consumption; FCR = feed conversion rate; Fe = iron; FE = feed efficiency; FeM(P) = feather meal (protein); FF = first feeding; FFS = full-fat soybean; FI = feed intake; FM = fishmeal; FO = fish oil; fSBM = fermented soybean meal; FSP = fermented soy protein; GDDY = grain distiller dried yeast; GIT = gastrointestinal tract; Glu = glutamic acid; Gly = glycine; GM, guar meal; GPX = glutathione peroxidase; H/LDCP = high/low dicalcium phosphate; (H)FM = (hydrolyzed) feather meal; HG = high glycoalkaloid; His = histidine; HSI = hepatosomatic index; IGF = insulin-like growth factor; Ile = isoleucine; IM = insect meal; IPFR = intraperitoneal fat ratio; K⁺ = potassium; K = condition factor; KM = krill meal; LER = lipid efficiency ratio; Leu = Leucine; LG = low glycoalkaloid; LM = leather meal; LS = linseed; LSM = lupin seed meal; Lys = lysine; MBM = meat and bone meal; Met = methionine; mg = magnesium; MGM = maize gluten meal; MHA = methionine hydroxy analogue; MM = meat meal; Mn = manganese; MNM = mixed nut meal; MR = muscle ratio; N = nitrogen; Na = sodium; NT = nucleotide; O₂ = oxygen; P = phosphorus; PER = protein efficiency ratio; P(B)M = poultry (byproduct) meal; PeM = dehulled pea meal; PePC/I = pea protein concentrate/isolate; Phe = phenylalanine; PI = protein intake; PM = pistachio by-product meal; PP = plant protein; PSM = pea seed meal; PNM = peanut meal; PO = poultry oil; PP = plant protein; PPC = potato protein concentrate; PPV = protein fixed/protein intake; PR = protein retention; PRO = Profine®; RC = rice protein concentrate; RDDG = rice derived distillers grain; RLM = red lentil meal; RS = rapeseed; RSM = rapeseed meal; d/RPC/I = dephytinized/rapeseed protein concentrate/isolate; (d)/(e)/(se)SBM = defatted, enzyme-treated, fermented, or solvent extracted soybean meal; SBME = soybean meal extract; SCP = single cell protein; Se = selenium; SF = soy flour; SI = soy isolate; SM/C = sunflower meal/concentrate; SGR = specific growth rate; SM = squid meal; SPC = soy protein concentrate; Suppl. = supplementation; TAN = total ammonia nitrogen; Tau = taurine; TGC = thermal growth coefficient; Thr = threonine; Trp = Tryptophan; TSS = total suspended solids; Tyr = tyrosine; vs = *versus*; VSI = viscerosomatic index; WF = wheat flour; WG/M = wheat gluten/meal; WM = wheat middlings; WLM = white lupin seed meal; WPM = whey protein meal; wt = weight, WW = whole wheat; Y/E = yeast/extract; Zn = zinc.

Annotated bibliography

Abanikannda, M.F., Shiflett, M.B., Morais, A.R.C., Hong, J., Sealey, W.M., Bledsoe, J.W. (2024). Evaluating inclusion of commercial pistachio by-product as a functional ingredient in rainbow trout fishmeal and plant meal-based diets. *Antioxidants*, **13**, 1280.

Doi: 10.3390/antiox13111280.

Employed both PP (SBM, SPC, CPC, WGM) and AP (FM, PBM, BM) ingredients supplemented with pistachio shell powder at 0-2%. Each diet was fed for 84-d to 19 g fish and at trial end, no differences were observed in wt for the PP diet irrespective of pistachio shell powder supplementation. In contrast pistachio shell powder inclusion did impact growth and SGR of fish fed the AP feed at 0.5 and 1% ($P < 0.05$).

Acar, Ü., Giannetto, A., Giannetto, D., Kesbiç, O.S., Yılmaz, S., Romano, A., Tezel, R., Türker, A., Güllü, K., Fazio, F. (2021). Evaluation of an innovative and sustainable pre-commercial compound as replacement of fish meal in diets for rainbow trout during pre-fattening phase: Effects on growth performances, haematological parameters and fillet quality traits. *Animals*, **11**, 3547.

Doi: 10.3390/ani11123547.

Investigated enzymatically treated black soldier fly and mealworm-based ingredient as a replacement for FM. Fish fed the insect ingredient grew poorer and had higher FCE than those of FM ($P < 0.05$). However, feed costs kg^{-1} were lower. Whole-body protein and lipid were lower and higher respectively ($P < 0.05$).

Adelizi, P.D., Rosati, R.R., Warner, K., Wu, Y.V., Muench, T.R., White, M.R., Brown, P.B. (1998). Evaluation of fish-meal free diets for rainbow trout, *Oncorhynchus mykiss*. *Aquaculture Nutrition*, **4**, 255-262.

Doi: 10.1046/j.1365-2095.1998.00077.x.

Assessed various PPs and concentrates (SBM, SPC, CGM, PNM, BMA) vs commercial trout feed and reported decrease wt gain, FI and PER and increase FCR over a 56-d trial. Results were not surprising since the commercial feed was 20% higher in crude protein and 50% higher in crude fat.

Alami-Durante, H., Médale, F., Cluzeaud, M., Kaushik, S.J. (2010). Skeletal muscle growth dynamics and expression of related genes in white and red muscles of rainbow trout fed diets with graded levels of a mixture of plant protein sources as substitutes for fishmeal. *Aquaculture*, **303**, 50-58.

Doi: 10.1016/j.aquaculture.2010.03.012.

Tested mixed diet (CGM, WGM, EPM, RSM) vs FM-based feed for 84-d resulting in decrease median diameter of white muscle fibers, wt gain, FE and PE and increase white muscle cathepsin D expression. ADC of diets for energy were significantly lower in full PP feeds.

Balasubramanian, M.N., Panserat, S., Dupont-Nivet, M., Quillet, E., Montfort, J., Le Cam, A., Medale, F., Kaushik, S., Geurden, I. (2016). Molecular pathways associated with the nutritional programming of plant-based diet acceptance in rainbow trout following an early feeding exposure. *BMC Genomics*, **17**, 449.

Doi: 10.1186/s12864-016-2804-1.

See also Geurden et al. (2013). Examined gene expression profiles in brain and liver of juveniles exposed to PP and FM-based diets during first 21-d feeding and then for 210-d on FM feed. Both groups of fish were then challenged with a PP based diet. Fish initially reared on a PP diet returned better ($P < 0.05$) FI and SGRs than FM fed trout. Over 1700 and 900 genes were affected in the brain and liver respectively following challenge. The nutritional programming affected genes involved in intermediary metabolism, protein folding, immune regulation and cytoskeletal proteins engaged in the stress response. In the brain, pathways implicated in sensory perception, synaptic transmission, cognitive processes and neuroendocrine peptides were impacted. The study indicates a strong role of early feeding strategies as a potential way to improve feeding practices and sustainability.

Baranek, E., Heraud, C., Larroquet, L., Sandres, F., Lanuque, A., Terrier, F., Skiba-Cassy, S., Jérôme, R. (2022). Taste receptors regulation of feeding behavior in rainbow trout (*Oncorhynchus mykiss*) fed from first feeding with plant based diet, XX. *International Symposium on Fish Nutrition And Feeding - Towards Precision Fish Nutrition And Feeding*, June 2022, Sorrento, Italy.

See below:

Baranek, E., Heraud, C., Larroquet, L., Surget, A., Lanuque, A., Terrier, F., Skiba-Cassy, S., Jérôme, R. (2024). Long-term regulation of fat sensing in rainbow trout (*Oncorhynchus mykiss*) fed a vegetable diet from the first feeding: focus on free fatty acid receptors and their signaling. *British Journal of Nutrition*, **131**, 1-16.

Doi: 10.1017/S0007114523001599.

Examined long-term effects (240-d) of feeding PP diets (CG, WG, PeM, LSM, RSM, WW) on regulation of fat perception by examining free fatty acid receptor (ffar) gene expression in the tongue. PP diet returned decrease wt gain, FE and FI ($P < 0.05$) and increased ffar1, 2a1a, 2b1.1/2 and ffar2b2b2 expression levels 20 min post-prandially. It was suggested that this response may act to decrease FI and be influential in regulating feeding motivation.

Barnes, M.E., Brown, M.L., Rosetrater, K.A., Sewell, J.R. (2012). An initial investigation replacing fish meal with a commercial fermented soybean meal product in the diets of juvenile rainbow trout. *Open Journal of Animal Science*, **2**, 234-243.

Doi: 10.4236/ojas.2012.24033.

Evaluated fSBM over 70-d and reported decrease wt gain, HSI, fillet protein and increased FCR ($P < 0.05$). Diets also contained WW and CGM @ 15%. There was no impact on fish health status.

Barnes, M.E., Brown, M.L., Rosetrater, K.A., Sewell, J.R. (2013). Preliminary evaluation of rainbow trout diets containing PepSoyGen, a fermented soybean meal product, and additional amino acids. *Open Fish Science Journal*, **6**, 19-27.

<https://benthamopen.com/contents/pdf/TOFISHSJ/TOFISHSJ-6-19.pdf>.

Reports on effects of additional EAAs (Lys, His, Met, Ile) on 100% FM replacement with fSBM, either as a mix or simply as Met addition. decrease wt gain, HSI and increased FCR ($P < 0.001$) were observed vs control diets. Diets had no impact on fillet composition or animal health.

Barnes, M.E., Brown, M.L., Bruce, T., Sindelar, S., Neiger, R. (2014). Rainbow trout rearing performance, intestinal morphology, and immune response after long-term feeding of high levels of fermented soybean meal. *North American Journal of Aquaculture*, **76**, 333-345.

Doi: 10.1080/15222055.2014.920748.

An important study since it highlights effects of trial length on observations. Experimental diets used were isonitrogenous and isocaloric and fed for 205-d with sampling at 94-d and again 110-d later. Initial sampling showed no effect of diet on wt or length growth and hence K and SGR. Nor were there differences in HSI, VSI or health parameters, but histological studies revealed differences in intestinal connective tissue and folds. In contrast to early samples, at 205-d fish fed the fSBM diet expressed decrease length and wt gain ($P < 0.05$) and changes in the health status of the liver but differences in intestinal structure passed.

Barnes, M.E., Brown, M.L., Neiger, R. (2015). Comparative performance of two rainbow trout strains fed fermented soybean meal. *Aquaculture International*, **23**, 1227-1238.

Doi: 10.1007/s10499-015-9879-6.

Evaluates two strains of trout (Shasta and McConaughy) to diets described in preceding papers but comparison of differences between strains are problematic due to different start wts used. Nevertheless, both strains experienced decreased wt gain and increased FCR ($P < 0.05$). The Shasta strain, however, showed morphological changes to the gut, expressing increased connective tissue and numbers of folds in the intestinal lamina propria.

Barrows, F.T., Frost, J.B. (2014). Evaluation of the nutritional quality of co-products from the nut industry, algae and an invertebrate meal for rainbow trout, *Oncorhynchus mykiss*. *Aquaculture*, **434**, 315-324.

Doi: 10.1016/j.aquaculture.2014.08.037.

Employed dietary mix of almond or pistachio meals with PBM, SPC, CPC and investigated growth vs FM-based feed over 84-d. No difference in wt gain, FCR or FI

Barrows, F.T., Gaylord, T.G., Stone, D.A.J., Smith, C.E. (2007). Effect of protein source and nutrient density on growth efficiency, histology, and plasma amino acid concentration of rainbow trout (*Oncorhynchus mykiss* Walbaum). *Aquaculture Research*, **38**, 1747-1758.

Doi: 10.1111/j.1365-2109.2007.01854.x.

Examines the effect of different plant meals and concentrates over 86-d period. Fish fed plant meals which included WG, CGM and SBM at high levels (47.6% protein as fed), performed equally to a commercial trout feed in terms of wt gain, SGR, FCR but performed poorly in terms of FI and energy retention efficiency (ERE; $P < 0.05$). The carcass also expressed higher lipid and moisture than commercial feeds. Comparison of plant concentrates (RC, SPC, BP) at high levels (48.9% protein as fed) with plant meals revealed no differences between groups for wt gain, SGR, FCR but ERE was higher ($P < 0.05$) in concentrate fed trout. Plasma Arg, and Trp were higher, His, Lys, Thr and Val 1 but Leu, Met, Phe, and Tyr lower in plant concentrate fed fish vs plant meal reared animals.

Barrows, F.T., Gaylord, T.G., Sealey, W.M., Porter, L., Smith, C.E. (2008). The effect of vitamin premix in extruded plant-based and fish meal based diets on growth efficiency and health of rainbow trout, *Oncorhynchus mykiss*. *Aquaculture*, **283**, 148-155.

Doi: 10.1016/j.aquaculture.2008.07.014.

Different dietary vitamin premixes were compared for PP and FM-based diets. Vitamin premixes were formulated to 1) NRC proposals, 2) vitamins increased to account for extrusion losses, 3) all vitamins increased assuming equal retention of 40% after. Trout were fed for 105-d. All PP-based diets and the FM-NRC fed fish grew equally, and had similar FCRs, but those fed FM plus 2)/3) returned higher wt gain ($P < 0.05$), better FCR and reduced FI vs PP-based diets.

Barrows, F.T., Gaylord, T.G., Sealey, W.M., Smith, C.E., Porter, L. (2010). Supplementation of plant-based diets for rainbow trout (*Oncorhynchus mykiss*) with macro-minerals and inositol. *Aquaculture Nutrition*, **16**, 654-661.

Doi: 10.1111/j.1365-2095.2009.00717.x.

Examined the differences in growth of trout fed a PP-based diet with or without supplemental Na, K⁺ and Mg vs a FM control. PP-based diets returned inferior growth, FCR, and FI ($P < 0.05$) when assessed against FM control animals. Lack of PP feed macromineral supplementation resulted in hepatic pathology whereas supplementations improved PP performance in wt gain.

Bartucz, T., Csókás, E., Nagy, B., Gyurcsák, M.P., Bokor, Z., Bernáth, G., Molnár, J., Urbányi, B., Csorbai, B. (2023). Black soldier fly (*Hermetia illucens*) meal as direct replacement of complex fish feed for rainbow trout (*Oncorhynchus mykiss*) and African catfish (*Clarias gariepinus*). *Life*, **13**, 1978.

Doi: 10.3390/life13101978.

Examined the response of rainbow trout fry to 100% replacement of FM with BSF meal. No differences in final wt, SGR, dry wt, length or survival.

Belghit, I., Philip, AJP., Maas, R.M., Lock, E.-J., Eding, E.H., Espe, M., Schrama, J.W. (2023). Impact of dietary glutamate and glycine on growth and nutrient utilization in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, **568**, 739311.

Doi: 10.1016/j.aquaculture.2023.739311.

A mix of BMA, FeM, PeP, BSF meals with and without Gly or Glu, were tested over 41-d using 87 g fish. The addition of Glu and/or Gly had no effect on growth but improved nutrient digestibility, possibly acting as an oxidative fuel.

Betiku, O.C. (2017). The influences of diet and water systems on rainbow trout gut microbiome in relation to nutrient utilization. Ph.D. dissertation in Animal and Range Sciences, Montana State University, Bozeman, Montana, USA. 210 pp.

See the following publications derived from Ph.D. research.

Betiku, O.C., Barrows, F.T., Ross, C., Sealey, W.M. (2016). The effect of total replacement of fish oil with DHA-Gold® and plant oils on growth and fillet quality of rainbow trout (*Oncorhynchus mykiss*) fed a plant-based diet. *Aquaculture Nutrition*, **22**, 158-169.

Doi: 10.1111/anu.12234.

Looked at the value of including DHA-Gold® (90 mg g⁻¹) in PP diets vs FO or flax and corn oil over 84-d. DHA supplemented diets returned heavier fish ($P < 0.05$) than either of the other treatments, increased FI and FCR, but no differences in fillet composition or shear force measurements.

Betiku, O.C., Yeoman, C.J., Gaylord, T.G., Americus, B., Olivio, S., Duff, G.C., Sealey, W.M. (2018). Water system is a controlling variable modulating bacterial diversity of gastrointestinal tract and performance in rainbow trout. *PLoS ONE*, **13**, e0195967.

Doi: 10.1371/journal.pone.0195967.

Examined response of rainbow trout to EAA balance animal (FM, PBM, BMA, SBC, SBM) and PP (SBM, SPC, CP) diets containing ethanol yeast. PP-based fed fish had inferior growth and body fat ($P < 0.001$) but body indices remained unaffected by diet.

Betiku, O.C., Yeoman, C.J., Gaylord, T.G., Ishaq, S.L., Duff, G.C., Sealey, W.M. (2023). Evidence of a divided nutritive function in rainbow trout (*Oncorhynchus mykiss*) midgut and hindgut microbiomes by whole shotgun metagenomic approach. *Aquaculture Reports*, **30**, 101601.

Doi: 10.1016/j.aqrep.2023.101601.

Used diets comprising SPI, CGM, SBM, WW and compared vs feeds containing PBM, BMA and FM. Both diets supplemented to meet muscle AA profile of trout. Fish grown for 112-d with larger sized animals for the animal protein diet at trial termination but no differences between groups for FI or FCR. Differences were found in the GIT microbiota between feeds, with the animal protein diet providing metabolites for microbial fermentation.

Biasato, I., Rimoldi, S., Caimi, C., Oddon, S.B., Chemello, G., Prearo, M., Saroglia, M., Hardy, R., Gasco, L., Terova, G. (2022). Efficacy of utilization of all-plant-based and commercial low-fishmeal feeds in two divergently selected strains of rainbow trout (*Oncorhynchus mykiss*): Focus on growth performance, whole-body proximate composition, and intestinal microbiome. *Frontiers in Physiology*, **13**, 892550.

Doi: 10.3389/fphys.2022.892550.

Compared two strains of trout developed to accept PP-based (US) and low FM feeds (Italy). Experimental diet comprised SPC, SBM, CGM and WGM and results were assessed against a commercial low FM trout formulation. Final body wts and SGR were higher for the US vs Italian strain when fed the PP or control diet ($P < 0.001$). Gut microbial analyses identified a *Cetobacterium* genus in the US strain which has been associated with a probiotic effect.

Bilgüven, M. (2022). Possibilities of using poultry by-product meal instead of fish meal as an alternative protein source in rainbow trout (*Oncorhynchus mykiss*, W.) feeds: Growth performance and unit production cost. *Journal of Agriculture Faculty Gaziosmanpasa University*, **39**, 65-70.

Doi: 10.55507/gopzfd.1098576.

This trial reports on the effects of switching out FM and FO with PBM and following trout performance for 70-d, with animals being fed ad libitum. PBM decrease growth, FI, PER and increase FCR ($P < 0.05$) but importantly also decrease cost kg^{-1} production by ~22%.

Blaufuss, P.C., Bledsoe, J.W., Gaylord, T.G., Sealey, W.M., Overturf, K.E., Powell, M.S. (2020). Selection on a plant-based diet reveals changes in oral tolerance, microbiota and growth in rainbow trout (*Oncorhynchus mykiss*) when fed a high soy diet. *Aquaculture*, **525**, 735287. Doi: 10.1016/j.aquaculture.2020.735287.

A SBM, CPC, and PBM was compared against a FM-based diet over an 84-d trial, starting with 78 g trout of 2 strains – one selected to perform on PP diets and the other not. Diet had no effect on growth parameters examined but the non-selected strain returned poorer wt gain, SGR and survival. FI and FCR were likewise poorer in the non-selected strain ($P \leq 0.03$) and both expressed increased thickness of the lamina propria with the non-selected strain expressing mild distal inflammation ($P < 0.01$).

Blom, J.H., Lee, K.J., Rinchard, J., Dabrowski, K., Ottobre, J. (2001). Reproductive efficiency and maternal-offspring transfer of gossypol in rainbow trout (*Oncorhynchus mykiss*) fed diets containing cottonseed meal. *Journal of Animal Science*, **79**, 1533-1539. Doi: 10.2527/2001.7961533x.

(see also Dabrowski et al., 2000). A CSM-based diet, containing 5% KM, CGM and Y, was examined for its potential to disrupt growth and reproductive performance. No effect was seen on brood growth but egg wt and embryo viability declined ($P < 0.05$).

Bockus, A.B., Powell, M.S., Sealey, W.M., Zito, P., Kurerov, Y., Sbisà, T., Carrillo-Longoria, J.A., Gaylord, T.G. (2025). Dietary trimethylamine oxide alters digestibility, intestinal histopathology, and gene expression in soy fed rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, **596**, 741810. Doi: 10.1016/j.aquaculture.2024.741810.

An 84-d trial using 84 g trout to examine impact of adding 0-1% trimethylamine oxide (TMAO) to PP/AP (SBM, CPC, PBM) v. FM diet. No effect of TMAO on growth, but did influence FI and FCR both of which were lower in the FM fed fish. K, HSI and VSI were higher ($P < 0.05$) in FM groups.

Bodin, N., Delfosse, G., Thu, T.T.N., Le Boulongé, E., Abboudi, T., Larondelle, Y., Rollin, X. (2012). Effects of fish size and diet adaptation on growth performances and nitrogen utilization of rainbow trout (*Oncorhynchus mykiss* W.) juveniles given diets based on free and/or protein-bound amino acids. *Aquaculture*, **356-357**, 105-115. Doi: 10.1016/j.aquaculture.2024.741810.

Used an isonitrogenous and isocaloric free AA-based diet and compared observations vs cod muscle meal after 25-d feeding of 0.7 and 2.86 g fish. Free AA were coated with agar to prevent leaching. Wt gain was reduced by 71 and 48% for the smaller and larger juveniles respectively fed the free AA diets vs cod muscle diets. This was partly explained by decrease FI and FE.

Borey, M., Parisen, C., Quillet, E., Terrier, F., Maunas, P., Burel, C., Lauga, B. (2018). Acute hypoxia reveals diverse adaptation strategies to fully substituted plant-based diet in isogenic lines of the carnivorous rainbow trout. *Aquaculture*, **490**, 288-296. Doi: 10.1016/j.aquaculture.2024.741810.

A mixed PP diet was compared to a FM-based feed for its ability to reduce hypoxic shock in 3 isogenic lines of trout. Although all lines expressed identical FI, FM fed animals returned better growth ($P < 0.01$). Two of the trout lines were indifferent to hypoxia.

Brinker, A., Reiter, R. (2011). Fish meal replacement by plant protein substitution and guar gum addition in trout feed, Part I: Effects on feed utilization and fish quality. *Aquaculture*, **310**, 350-360. Doi: 10.1016/j.aquaculture.2010.09.041.

Compared performance of trout fed diets comprising SPC, CG, WW or FM-based after 53-d feeding. Fish fed PP diets were lighter ($P < 0.0001$) with lower SGRs and poorer FCRs. SGRs and FCRs were not affected by dietary inclusions of 0.3% guar gum as a binder. Fillet % was lower in PP fed fish but there were no differences recorded in sensory evaluation between treatments.

Burr, G.S., Wolters, W.R., Barrows, F.T., Hardy, R.W. (2012). Replacing fishmeal with blends of alternative proteins on growth performance of rainbow trout (*Oncorhynchus mykiss*), and early or late stage juvenile Atlantic salmon (*Salmo salar*). *Aquaculture*, **334-337**, 110-116.

Doi: 10.1016/j.aquaculture.2011.12.044.

Compared the effects of SPC, CGM and BPC in feeds containing SBM, BM and PBM to a FM control diet in 19.5 g trout fed over 84-d. Wt differences were of the order FM>SPC>CGM=CGM ($P < 0.05$). FI was similar for FM and CGM/SPC with all three diets being higher than BPC ($P < 0.05$). FCRs were of the order FM < SPC=BPC < CGM.

Callet, T., Médale, F., Larroquet, L., Surget, A., Aguirre, P., Kerneis, T., Labbé, L., Quillet, E., Geurden, I., Skiba-Cassy, S., Dupont-Nive, M. (2017). Successful selection of rainbow trout (*Oncorhynchus mykiss*) on their ability to grow with a diet completely devoid of fishmeal and fish oil, and correlated changes in nutritional traits. *PLoS One*, **12**, e0186705.

Doi: 10.1371/journal.pone.0186705.

Mixed PP feeds comprising CG, WG, FB, SBM, LSM, with and without EPM were fed to a selected (3 generations) and non-selected line of trout (see: Le Boucher et al., 2011; 2012). Selected fish grew better over the 197-d trial on the PP feeds ($P < 0.01$) but at the same rate when fed FM-based feeds. FI was higher for both feeds but expressed lower feed efficiency in both cases for the selected line.

Callet, T., Dupont-Nivet, M., Cluzeaud, M., Jaffrezic, F., Laloë, D., Kerneis, T., Labbé, L., Quillet, E., Geurden, I., Mazurais, D., Skiba-Cassy, S., Médale, F. (2018). Detection of new pathways involved in the acceptance and the utilisation of a plant-based diet in isogenic lines of rainbow trout fry. *PLoS One*, **13**, e0201462.

Doi: 10.1371/journal.pone.0201462.

Using a PP diet (CG, WG, FB, SBM, LSM, EPM) growth of 3 isogenic lines of trout (selected for PPs and not) were compared against a full FM-based feed over a 35-d test period. Trout fed the PP diet grew less well ($P < 0.01$) when compared to the FM fed animals and there were differences in growth between tested lines. Wide variations in gene probe expression were seen among genotypes some of which might provide markers for selection programs.

Callet, T., Dupont-Nivet, M., Danion, M., Burel, C., Cluzeaud, M., Surget, M., Aguirre, P., Kerneis, T., Labbé, L., Panserat, S., Quillet, E., Geurden, I., Skiba-Cassy, S., Médale, F. (2021). Why do some rainbow trout genotypes grow better with a complete plant-based diet? Transcriptomic and physiological analyses on three isogenic lines. *Frontiers in Physiology*, **12**, 732321.

Doi: 10.3389/fphys.2021.732321

Using similar diets to those above, 3 genotypes were tested to evaluate growth, survival, FI and FE. No differences between genotypes for growth, FI or FE when fed FM-based feeds. Differences were, however, observed between genotypes when evaluating growth on the PP diet ($P < 0.001$) and this was due to changes in FE rather than FI. Rates for survival differed with genotype and diet. Diet, but not genotype, also influenced immune function (lysozyme, complement; $P < 0.01$). Transcriptomic results illustrated major shifts in metabolism between genotypes.

Cardona, E., Segret, E., Cachelou, Y., Vanderesse, T., Larroquet, L., Hermann, A., Surget, A., Corraze, G., Cachelou, F., Bobe, J., Skiba-Cassy, S. (2022). Effect of micro-algae *Schizochytrium* sp. supplementation in plant diet on reproduction of female rainbow trout (*Oncorhynchus mykiss*): maternal programming impact of progeny. *Journal of Animal Science & Biotechnology*, **13**, 33.

Doi 10.1186/s40104-022-00680-9.

A diet containing CG, SBM, PePC, SPC, BePC, APC, and *Schizochytrium* sp. biomass was judged against a FM feed as a broodstock diet and in an 84-d feed challenge of progeny. Brood females fed the PP diet were lighter ($P < 0.001$) than those fed the FM feed and expressed significant differences in egg diameter and fatty acid profiles and fry survival. However, there were no differences in wt gain or survival for challenged progeny at 84-d.

Cardona, E., Baranek, E., Vigor, C., Gros, V., Reversat, G., Surget, A., Larroquet, L., Maunas, P., Turrone, N., Oger, C., Galano, J.-M., Durand, T., Roy, J. (2025). A two-year plant-based diet alters the fatty acid profile and enzymatic and non-enzymatic lipid metabolites, in eggs and fry of female rainbow trout. *Aquaculture*, **595**, 741602.

Doi: 10.1016/j.aquaculture.2024.741602.

(See: Baranek et al., 2024) Comparing a commercial-type against an experimental PP-based feed from first feeding until first spawning of monosex trout. Brood females fed the PP diet were lighter than those fed the FM feed and expressed significant differences in egg diameter and spawn wt, fecundity and fry wt ($P \leq 0.05$).

Chemello, G., Renna, M., Caimi, C., Guerreiro, I., Oliva-Teles, A., Enes, P., Biasato, I., Schiavone, A., Gai, F., Gasco, L. (2020). Partially defatted *Tenebrio molitor* larva meal in diets for grow-out rainbow trout, *Oncorhynchus mykiss* (Walbaum): Effects on growth performance, diet digestibility and metabolic responses. *Animals*, **10**, 229.

Doi: 10.3390/ani10020229.

Evaluated the response of 78 g trout to a diet comprising 20% *Tenebrio molitor* larvae meal, 18% SPC, 7% WG, 8% CG and 7% SBM over 154-d and compared response to a diet that switched *Tenebrio* with 20% FM. There were no differences between diets for wt gain, FCR, PER, FI or mortality. HSI was higher in the insect fed fish and ADC for crude protein lower ($P < 0.05$). See also Bruno et al. (2023) *BMC Microbiology*, **23**, 248 <https://doi.org/10.1186/s12866-023-02990-y> for additional information on microbiome.

Cheng, Z.J., Hardy, R.W., Blair, M. (2003). Effects of supplementing methionine hydroxyl analogue in soybean meal and distiller's dried grain-based diets on the performance and nutrient retention of rainbow trout (*Oncorhynchus mykiss* (Walbaum)). *Aquaculture Research*, **34**, 1303-1330.

Doi: 10.1046/j.1365-2109.2003.00940.x.

Supplemented a PP-based diet (SBM, WG, WW) with Met hydroxy analogue and compared fish against a FM diet after 56-d feeding. Wt gain was poorer and FCR higher ($P < 0.0001$) for trout fed the PP diet. Supplementation of the PP diet with the Met analogue was without effect on evaluated parameters.

Craft, C.D. (2014). Growth, proximate composition, and metabolism of rainbow trout *Oncorhynchus mykiss* consuming alternative proteins. MS dissertation, Colorado State University, Department of Fish, Wildlife, and Conservation Biology. Fort Collins, CO, USA. 77 pp.

See below

Craft, C.D., Ross, C., Sealey, W.M., Gaylord, T.G., Barrows, F.T., Fornshell, G., Myrick, C.A. (2016). Growth, proximate composition, and sensory characteristics of rainbow trout *Oncorhynchus mykiss* consuming alternative proteins. *Aquaculture*, **459**, 223-231.

Doi: 10.1016/j.aquaculture.2016.03.039.

Eight experimental diets contained mixtures of alternative PPs (SBM, CPC, SPC, DDG, *Spirulina*) and animal by-products (PBM, FeM, BM) with or without supplemental Lys, Met and Thr, were compared against FM feeds with or without supplemental AAs. Diets were isolipidic with protein:lipid ratios of 40:20 and 45:20% and fed for 88-d. Only wt differences discerned at trial end were between FM + AAs and a PP (SBM, CPC, SPC) less AAs. Feed consumed did differ between groups, generally being higher

for fish receiving minus AA supplement diets. FCRs and whole-body protein levels were generally similar across diets with differences being observed for lipid. The PP + AA diet returned fillets that were firmer and higher in grassy flavor.

Cruz-Castro, C.A., Hernández, L.H.H., Araiza, A.F., Pérez, T.R., López, O.A. (2011). Effects of diets with soybean meal on the growth, digestibility, phosphorus and nitrogen excretion of juvenile rainbow trout *Oncorhynchus mykiss*. *Hidrobiológica*, **2**, 118-125.

www.scielo.org.mx/scielo.php?pid=S0188-88972011000200002&script=sci_arttext&tlng=en

Recorded decreased growth, FI and SGR ($P < 0.05$), for 4 g trout fed on a SBM feed for 50-d.

Barreto-Curiel, F., Parés-Sierra, G., Correa-Reyes, G., Durazo-Beltrán, E., Viana, M.T. (2016). Total and partial fishmeal substitution by poultry by-product meal (petfood grade) and enrichment with acid fish silage in aquafeeds for juveniles of rainbow trout *Oncorhynchus mykiss*. *Latin American Journal of Aquaculture*, **44**, 327-335.

Doi: 10.3856/vol44-issue2-fulltext-13.

Replacement of FM with PBM in ~4 g fish resulted in increased growth and SGR and reduced PER ($P < 0.05$) but no differences in FCR.

Dabrowski, K., Hassard, S., Quinn, J., Pitcher, T.J. (1980). Effect of *Geotrichum candidum* protein substitution in pelleted fish feed on the growth of rainbow trout (*Salmo gairdneri* Rich.) and on utilization of the diet. *Aquaculture*, **21**, 213-232.

Doi: 10.1016/0044-8486(80)90132-5.

Evaluated the effects of incorporating the fungus *Geotrichum candidum* into feeds as a FM replacer over 32-d. Dietary FM exchange resulted in growth retardation.

Dabrowski, K., Poczyczynski, P., Köck, G., Berger, B. (1989). Effect of partially or totally replacing fish meal protein by soybean meal protein on growth, food utilization and proteolytic enzyme activities in rainbow trout (*Salmo gairdneri*). New in vivo test for exocrine pancreatic secretion. *Aquaculture*, **77**, 29-49.

Doi: 10.1016/0044-8486(89)90019-7.

Comparison of FM vs SBM-based diets, both containing MBM, WM and Y, over 163-d. SBM reduced growth and survival substantially.

Dabrowski, K., Rinchar, J., Lee, K.-J., Blom, J.H., Ciereszko, A., Ottobre, J. (2000). Effects of diets containing gossypol on reproductive capacity of rainbow trout (*Oncorhynchus mykiss*). *Biology of Reproduction*, **52**, 227-234.

Doi: 10.1095/biolreprod62.2.227.

Using a CSM feed incorporating 5% KM, CGM WM and Y, fed over 131-d, growth remained unaffected. Circulating testosterone and estradiol levels and GSI of both males and females also remained similar.

Dabrowski, K., Lee, K.-J., Rinchar, J., Ciereszko, A., Blom, J.H., Ottobre, J. (2001). Gossypol isomers bind specifically to blood plasma proteins and spermatozoa of rainbow trout fed diets containing cottonseed meal. *Biochemica et Biophysica Acta*, **1525**, 37-42.

Doi: 10.1016/S0304-4165(00)00168-9.

Total FM replacement by solvent extracted cottonseed meal protein resulted in an apparent decrease in growth with no differences in FI. Gossypol content of CSM reduced sperm concentrations.

Davidson, J., Good, C., Barrows, F.T., Welsh, C., Kenney, P.B., Summerfelt, S.T. (2013). Comparing the effects of feeding a grain- or a fish meal-based diet on water quality, waste production, and rainbow trout *Oncorhynchus mykiss* performance within low exchange water recirculating aquaculture systems. *Aquacultural Engineering*, **52**, 45-57.

Doi: 10.1016/j.aquaeng.2012.08.001.

Compared effects of replacing FM and animal proteins with SPC and CPC over 98-d with an eye toward evaluating dietary effect on water quality in a RAS. At trial end, there were no differences in wt gain, K, survival or FCR. Skin-on and skin-off butterfly fillet yield was higher for PP fed fish ($P = 0.02$) as was whole body protein levels. PP feed had a negative impact on water quality with higher TAN, TSS and BOD and increased presence of fines of 2-30 μm .

Deborde, C., Hounoum, B.M., Moing, A., Maucourt, M., Jacob, D., Corraze, G., Médale, F., Fauconneau, B. (2021). Putative imbalanced amino acid metabolism in rainbow trout long term fed a plant-based diet as revealed by 1H-NMR metabolomics. *Journal of Nutritional Science*, **10**, e13.

Doi:10.1017/jns.2021.3.

Replacement of FM with a PP mix in first feeding diets and maintaining animals for 450-d, resulted in reduced growth and VSI ($P < 0.01$) with a reduction in HSI ($P < 0.05$). 48-h post-prandial plasma AA levels were increased in PP fish indicating poorer utilization or delayed delivery.

Defaix, R., Lokesh, J., Ghislain, M., Le Behec, M., Marchand, M., Veron, V., Surget, A., Biasutti, S., Terrier, F., Pigot, T., Panserat, S., Ricaud, K. (2024). High carbohydrate to protein ration promotes changes in intestinal microbiota and host metabolism in rainbow trout (*Oncorhynchus mykiss*) fed a plant-based diet. *Aquaculture*, **578**, 740049.

Doi: 10.1016/j.aquaculture.2023.740049

No differences in wt gain, SGRs or FI but decrease in PER ($P < 0.04$). HSI, and plasma glycogen were reduced in low-starch feeds whereas core microbiota diversity was higher.

Defaix, R., Lokesh, J., Frohn, L., Le Behec, M., Pigot, T., Veron, V., Surget, A., Biasutti, S., Terrier, F., Skiba-Cassy, S., Roy, J., Panserat, S., Ricaud, K. (2024). Exploring the effects of dietary inulin in rainbow trout fed a high-starch, 100% plant-based diet. *Journal of Animal Science & Biotechnology*, **15**, 6.

Doi: 10.1186/s40104-023-00951-z.

Using mixed PP feeds examined the effect of high and low levels of starch on growth of 31 g trout over 84-d. No effects on growth but high starch group expressed higher PER ($P < 0.001$) suggesting protei-sparing.

de Francesco, M., Parisi, G., Médale, F., Lupi, P., Kaushik, S.J., Poli, B.M. (2004). Effect of long-term feeding with a plant protein mixture based diet on growth and body/fillet quality traits of large rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, **236**, 413-429.

Doi: 10.1016/j.aquaculture.2004.01.006.

Replaced dietary FM/WW with a PP mix (CGM, WG, EPM, RSM) and fed trout of ~160 g for 168-d. At trial completion, PP fed animals expressed poorer growth, SGR, FE PER and dressed wt, and higher K, mesenteric fat, VSI and ω -6 FAs ($P < 0.05$).

Dietz, C., Wessels, S., Sünder, A., Sharifi, R., Gährken, J., Liebert, F. (2023). Does genetic background of rainbow trout impact growth and feed utilisation following fishmeal substitution by partly defatted insect meal (*Hermetia illucens*) or microalgae powder (*Arthrospira platensis*)? *Aquaculture Research*, **2023**, 4774048.

Doi: 10.1155/2023/4774048.

Using FM-free diets, growth response of 4 strains of trout was followed over 56-d. No differences between strains were recorded between FM reared and algae fed fish for growth, SGR, or FCR. Strains differed, however, in terms of protein deposition and PER. Differences were also detected between strains for growth when insect feed was examined but results are difficult to compare directly due to differing start sizes of experimental fish.

Drew, M.D., Ogunkoya, A.E., Janz, D.M., Thiessen, D.L. (2007). Dietary influence of replacing fish meal and oil with canola protein concentrate and vegetable oils on growth performance, fatty acid composition and organochlorine residues in rainbow trout. *Aquaculture*, **267**, 260-268.

Doi: 10.1016/j.aquaculture.2007.01.002.

A RPC-PBM-based feed was tested against a FM-PBM diet for 140-d resulting in decrease FI and growth and increase FE ($P < 0.05$).

Dupont-Nivet, M., Medale, F., Leonard, J., Le Guillou, S., Tiquet, F., Quillet, E., Geurden, I. (2009). Evidence of genotype-diet interactions in the response of rainbow trout (*Oncorhynchus mykiss*) clones to a diet with or without fishmeal at early growth. *Aquaculture*, **295**, 15-21.

Doi: 10.1016/j.aquaculture.2009.06.031.

Replaced FM with a mix of PPs to examine genotype \times diet interactions for early-stage growth of heterozygous clones of trout fed ad libitum. Study was divided into 2 periods of 26- and 24-d respectively and both diet and genotype had significant impacts on performance, with PP fed fish returning poorer wt gain and FI ($P < 0.0001$) during the first period and inferior wt, FE, FI and mortality ($P < 0.0001$) during the second period. The study illustrated the potential for selection of trout growth and PP-based diets.

Ekmay, R.D., Plagnes-Juan, E., Aguirre, P., Surget, A., Terrier, F., Frohn, L., Skiba-Cassy, S. (2024). Partially replacing plant protein sources with torula yeast in rainbow trout (*Oncorhynchus mykiss*) feed increases growth and factors related to immune status. *Journal of the World Aquaculture Society*, **55**, 169-186.

Doi: 10.1111/jwas.13047.

Replaced FM using mix of PPs with or without torula Y @ 10 or 20% diet. By 49-d, FM diet outperformed PP diet = diets with torula Y. By trial end differences in wt were realized FM=PP+10/20% yeast > PP fed trout ($P < 0.05$) and FI, SGRs and lysozyme activity differed between FM and PP diets, but there were no alterations between dietary groups for FCR, HSI, VSI or body composition.

Escaffre, A.-M., Kaushik, S.J., Mbrini, M. (2007). Morphometric evaluation of changes in the digestive tract of rainbow trout (*Oncorhynchus mykiss*) due to fish meal replacement with soy protein concentrate. *Aquaculture*, **273**, 127-138.

Doi: 10.1016/j.aquaculture.2007.09.028.

SPC + 0.42% Met was employed to replace dietary FM in isonitrogenous and isocaloric feeds which were fed for 90-d. Replacement of FM resulted in decreased wt gain, body length and HSI ($P \leq 0.01$). Diet had no influence on macromorphology of the gut but in the SPC fed fish enterocytes were shorter in the distal intestine ($P < 0.004$) and exhibited a more apical positioning of the nucleus and increased abundance of vacuoles. Hepatocyte volume of FM fed trout was greater ($P < 0.00001$) than SPC fed fish. The study illustrates lack of effect of SPC on intestinal inflammation but is indicative of changes in enterocyte metabolism.

Eya, J.C., Yossa, R., Perera, D., Okubajo, O., Gannam, A. (2017). Combined effects of diets and temperature on mitochondrial function, growth and nutrient efficiency in rainbow trout (*Oncorhynchus mykiss*). *Comparative Biochemistry & Physiology, Part B*, **212**, 1–11.

Doi: 10.1016/j.cbpb.2017.06.010.

Compared mixed PP feeds (SPC, SBM, WG, CG, WF, Y) against animal protein-based diets with different levels of fat (10 and 20%) following 180-d feeding and at 3 temps. (10, 14 and 18 °C). A diet \times temperature interaction impacted wt, K, FE, PER, LER ($P < 0.05$), with SGRs being impacted by temp. elevation ($P < 0.05$). Rearing fish @ 14 °C on a 40/10 PP diet represented the most economic.

Farsani, A.K., Hashemzadeh, I., Pirali, E. (2022). Effects of dietary fish meal replacement with yeast (*Saccharomyces cerevisiae*) on growth and feeding indices rainbow trout (*Oncorhynchus mykiss*) [in Arabic]. *Journal of Aquaculture Development*, **15**, 57-69.

https://aquadev.liau.ac.ir/files/site1/user_files_043860/irajhashemzadeh-A-10-523-1-6d770c5.pdf.

Fernández-Maestú, C., Calo, J., Martinat, M., Soengas, J.L., Roy, J., Blanco, A.M. (2025). Effects of a plant-based diet from first feeding on the intestinal expression of nutrient sensors in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, <https://doi.org/10.1016/j.aquaculture.2024.742093>.

Evaluated the effects of a PP-based diet on growth and gene expression over 100-d commencing with fry of 0.1 g. PP-fed fish performed as expected with reduced growth and SGRs and poorer FCRs.

Flores, G.H., Hernández, L.H.H., Araiza, M.A.F., López, O.A. (2012). Effects of total replacement of fishmeal with *Spirulina* powder and soybean meal on juvenile rainbow trout (*Oncorhynchus mykiss* Walbaum). *The Israeli Journal of Aquaculture - Bamidgeh*, **64**, no pagination, 8 pages.
http://hdl.handle.net/10524/31828.

Three experimental diets containing 75/25, 50/50, and 25/75 mixes of Spirulina powder and SBM to replace FM were judged against a FM and commercial diet over 50-d. No differences were discerned between diets for growth, FCR, PCE, FI, PO₄³⁻ excretion or survival.

Fontagné-Dicharry, S., Véron, V., Larroquet L., Godin, S., Wischhusen, P., Aguirre, P., Terrier, F., Richard, N., Bueno, M., Bouyssière, B., Antony Jesu Prabhu, P., Tacon, P., Kaushik, S.J. (2020). Effect of selenium sources in plant-based diets on antioxidant status and oxidative stress-related parameters in rainbow trout juveniles under chronic stress exposure. *Aquaculture*, **529**, 735684. Doi: 10.1016/j.aquaculture.2020.735684.

Although not containing a FM-based diet for comparison, three feeds were prepared to contain Se selenite (0.7 mg kg⁻¹), Se-enriched yeast (150 mg kg⁻¹) or no Se supplementation (formulations each exceeded 100%, however!) to examine the impact of this mineral on trout performance following an 84-d trial. A further two groups were reared under normal and stressful (decrease water flow and O₂) operating conditions. Se had no impact on any growth parameter examined (wt., survival, FI, FCR) and stressful operating conditions did not affect FCR although did have significant effects on all other parameters (wt., survival, FI, P < 0.05).

Frohn, L., Peixoto, D., Guyomar, G., Teixeira, C., Terrier, F., Aguirre, P., Haddad, S.M., Bobe, J., Costas, B., Richard, N., Pinel, K., Skiba-Cassy, S. (2024). Yeast extract improves growth in rainbow trout (*Oncorhynchus mykiss*) fed a fishmeal-free diet and modulates the hepatic and distal intestine transcriptomic profile. *Aquaculture*, **579**, 740226. Doi: 10.1016/j.aquaculture.2023.740226

A mixed animal (PBM, FeM, BM), and PP (CGM, SBM, WW, FB) diet with or without YE was compared against a commercial-like FM-based feed for 84-d. Final body wt and whole-body protein differed with the order FM>mixed diet +YE>mixed diet alone (P < 0.01) while K, FE, HSI lysozyme and alternative complement pathways did not. FI was highest (P < 0.006) in mixed diet alone<mixed +YE=FM. Fish receiving YE exhibited higher plasma immunoglobulin levels and intestinal folding in the proximal gut but there was no influence on goblet cell numbers. Addition of YE to FM-free diets thus has an apparent benefit.

Gaye-Siessegger, J., McCullagh, J.S.O., Focken, U. (2011). The effect of dietary amino acid abundance and isotopic composition on the growth rate, metabolism and tissue $\delta^{13}\text{C}$ of rainbow trout. *British Journal of Nutrition*, **105**, 1764-1771. Doi: 10.1017/S0007114510005696.

Using diets comprising synthetic AAs, trout growth was compared to a FM control over 70-d. Fish maintained on the control diet outperformed all others (P < 0.05) and it was apparent that dietary AA composition influenced protein gain with trout fed the fullest range of AAs being elite (P < 0.03) among the experimental groups. Compound-specific $\delta^{13}\text{C}$ for NEAAs indicated stability from diet to fish tissue.

Gaylord, T.G., Barrows, F.T. (2009). Multiple amino acid supplementations to reduce dietary protein in plant-based rainbow trout, *Oncorhynchus mykiss*, feeds. *Aquaculture*, **287**, 180-184. Doi: 10.1016/j.aquaculture.2008.10.037.

Over 84-d the effect of supplementing PP diets of initially 35 or 45% CP with EAAs (Met, Lys, Thr, and Gly in a 35% CP feed) increasing CP to 41.5 and 49% respectively. AA supplements increase growth at both CP levels. The diet containing 35% CP + EAAs attained similar wt to that expressed by both the intact and EAA supplemented 45% CP diets while the 35% feed with EAAs and Gly outperformed the

fish fed a 45% intact protein feed ($P < 0.05$). Some differences were noted in terms of plasma concentrations of the test EAAs. The inference from this study was that it may be possible to save dietary protein with judicious EAA supplementations.

Gaylord, T.G., Teague, A.M., Barrows, F.T. (2006). Taurine supplementation of all-plant protein diets for rainbow trout (*Oncorhynchus mykiss*). *Journal of the World Aquaculture Society*, **37**, 509-517. Doi: 10.1111/j.1749-7345.2006.00064.x.

Examined the value of dietary Tau (0, 0.5, 1 and 1.5%) addition to PP and FM-based feeds. The trial was of 63-d duration and at completion differences in wt gain between treatments were only seen in the PP feeds with significant ($P < 0.05$) wt advances in fish receiving supplemental Tau. FCR, PER and ERE were also favorably impacted with Tau addition.

Gaylord, T.G., Barrows, F.T., Teague, A.M., Johansen, K.A., Overturf, K.E., Shepherd, B. (2007). Supplementation of taurine and methionine to all-plant protein diets for rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, **269**, 514-524.

Doi: 10.1016/j.aquaculture.2007.04.011.

Following up from the findings described in Gaylord et al. (2006), in which imbalances in dietary Met:Cys ratios were thought to potentially mask the effects of Tau, an all PP diet was supplemented with 0, 0.5 or 1.0 % Tau together with 0, 0.5 and 1.0% Met. An 84-d trial was run at the termination of which PP diets supplemented with Tau had improved growth whereas when supplemented with Met, growth was decreased ($P < 0.01$). Neither supplementation impacted FCR, PER, ERE or HSI but FI was lower in Met and higher in Tau-supplemented feeds prompting the suggestion that all PP diets would benefit from its addition.

Gaylord, T.G., Sealey, W.M., Barrows, F.T., Myrick, C.A., Fornshell, G. (2017). Evaluation of ingredient combinations from different origins (fishmeal, terrestrial animal and plants) and two different formulated nutrient targets on rainbow trout growth and production efficiency. *Aquaculture Nutrition*, **23**, 1319-1328.

Doi: 10.1111/anu.12507.

An important, wide-ranging study that looked at the growth response of trout to ten different feed formulations over a period of 84-d. Lower wt gain ($P < 0.05$) in all PP-based feeds but Lys/Thr supplements increased wt gain v. non-suppl. PP diets ($P < 0.05$) and resulted in growth equivalence for two test PP diets + AAs with FM and AP diets. Fillet yields were also increased in supplemented PP diets but K remained unchanged across the groups.

Geurden, I., Borchert, P., Balasubramanian, M.N., Schrama, J.W., Dupont-Nivet, M., Quillet, E., Kaushik, S.J., Panserat, S., Médale, F. (2013). The positive impact of the early-feeding of a plant-based diet on its future acceptance and utilisation in rainbow trout. *PLoS One*, **8**, e83162.

Doi: 10.1371/journal.pone.008316.

An important study that demonstrated the advantages of early short-term feeding of trout fry with a PP-based in relation to later use in the growth cycle.

Gomes, E.F., Kaushik, S.J. (1993). Effect of replacement of dietary inorganic zinc by zinc/methionine on vegetable and animal protein utilization by rainbow trout. pp. 897-902, in: Kaushik, S.J. and Luquet, P. (editors), *Fish nutrition in practice: 4th international symposium on fish nutrition and feeding*. Biarritz, France, June 24-27, 1991. INRA Editions, Versailles, France.

Feeding isoenergetic and proteinaceous diets formulated with FM or PPs supplemented with either Met or Zn-Met for 147-d. The form of Met presented had no effect on growth, SGR, FGR, PER for either group but FM fed fish outperformed PP trout in every category ($P < 0.05$). There were no differences between feed types for plasma Zn levels. However, protein and energy digestibility were higher ($P < 0.05$) in PP and FM fed trout respectively.

Gomes, E.F., Rema, P., Gouveia, A., Kaushik, S.J. (1995a). Replacement of fish meal by plant proteins in diets for rainbow trout (*Oncorhynchus mykiss*): Effect of the quality of the fishmeal based control diets on digestibility and nutrient balances. *Water Science & Technology*, **31**, 205-211.

Doi: 10.1016/0273-1223(95)00440-X.

Compares performance of trout fed FM and PP diets. Wt gain and PER lowest in PP fed fish ($P > 0.01$), while ADC for protein and P were higher ($P < 0.05$).

Gomes, E.F., Rema, P., Kaushik, S.J. (1995b). Replacement of fish meal by plant proteins in the diet of rainbow trout (*Oncorhynchus mykiss*): digestibility and growth performance. *Aquaculture*, **130**, 177-186.

Doi: 10.1016/0044-8486(94)00211-6.

Fed either animal-, or PP-based feeds to 55g trout over 56-d. Wt gain, SGR, FI were all higher ($P < 0.01$) in fish fed animal protein feeds.

Gómez-Requeni, P., Caldach-Giner, J., de Celis S.V.R., Médale, F. (2005). Regulation of the somatotrophic axis by dietary factors in rainbow trout (*Oncorhynchus mykiss*). *British Journal of Nutrition*, **94**, 353-361.

Doi: 10.1079/BJN20051521.

Body wt gain, FI, SGR, FE, PER, and N, lipid and energy retention were all lower ($P < 0.05$) in fish fed a PP diet, while adipose tissue GHR and plasma GH were higher. There were no differences between PP and FM diets for IGF-1 and IGF-2 receptor presence in liver, white muscle or adipose tissue but IGFBP were higher ($P < 0.05$) in PP fed trout plasma.

Haghighyan, S., Mehrgan, M.S. (2015). The effect of replacing fish meal in the diet with enzyme-treated soybean meal (HP310) on growth and body composition of rainbow trout fry. *Molecules*, **20**, 201219751.

Doi: 10.3390/molecules201219751.

Examined impact of dietary FM replacement with enzyme-treated SBM over 60-d. The SBM diet returned poorer growth, FI, SGR and FCR ($P < 0.05$).

Hamad, T.N., Imani, A., Noori, F., Agh, N. (2024). The effect of various dietary MUFA content and n-6/n-3 ratios on rainbow trout (*Oncorhynchus mykiss*) fed on a whole plant protein based diet: growth performance, digestive enzymes activity, intestinal morphometry and fatty acids profile of muscle and liver. *Veterinary Research Communications*, **48**, 3035-3047.

Doi: 10.1007/s11259-024-10463-4.

A BM, CG, WG, Y and SBM diet supplemented with various plant oils was evaluated for their impact on growth and composition over 56-d. There were no between-group differences for FCR, PER, PPV or intestinal morphology although subtle differences were observed for wt gain, SGR and FCR between different dietary oil groups. FA ω -3/ ω -6 PUFA ratio was higher ($P < 0.05$) in the control diet which contained FO.

Hang, Y., Fu, Y., Jin, C., Hua, X. (2022). Effects of supplemental amino acids and bile acid in a completely replaced fish meal by enzymatically hydrolysed soybean meal diet on growth performance, liver health and fillet quality of rainbow trout (*Oncorhynchus mykiss*). *Aquaculture Research*, **53**, 3297-3308.

Doi: 10.1111/are.15837.

Supplemented an enzyme treated SBM-based feed with bile acid and or Met+Lys and examined growth response for 56-d. Growth, K and SGRs were poorest in the enzyme SBM-AA/BA group=SBM-BA<SBM+AA=SBM>FM group ($P < 0.05$). Intestinal protease activity was tremendously reduced in all SBM diets when compared with fish eating the FM diet. The fillet ω -3/ ω -6 PUFA ratio was also higher in FM fed trout.

Hauptman, B.S. (2012). Evaluation of the nutritional value of ethanol yeast in practical-type diets as an alternative protein source for rainbow trout, *Oncorhynchus mykiss*. MS thesis, Animal Range Science, Montana State University, Bozeman, Montana, USA. 54 pp.
<https://scholarworks.montana.edu/server/api/core/bitstreams/6551659d-776a-46a4-90e0-3f09d646b30e/content>.

See below.

Hauptman, B.S., Barrows, F.T., Block, S.S., Gaylord, T.G., Paterson, J.A., Rawles, S.D., Sealy, W.M. (2014). Evaluation of grain distillers dried yeast as a fish meal substitute in practical-type diets of juvenile rainbow trout, *Oncorhynchus mykiss*. *Aquaculture*, **432**, 7-14.

Doi: 10.1016/j.aquaculture.2014.03.026.

Replaced FM with GDDY in feed for 22 g trout and tested dietary modifications over 63-d. FCR and VSI increase and wt gain decrease ($P < 0.001$) in the GDDY fed fish, but FI increase ($P < 0.05$).

Heraud, C., Hirschinger, T., Baranek, E., Larroquet, L., Surget, A., Sandres, F., Lanuque, A., Terrier, F., Roy, J. (2022). Detection and modulation of olfactory sensing receptors in carnivorous rainbow trout (*Oncorhynchus mykiss*) fed from first feeding with plant-based diet. *International Journal of Molecular Science*, **23**, 2123.

Doi: 10.3390/ijms23042123.

Compared a FM and all PP-based feed over 238-d. From 20-d onwards until trial end, the FM fed trout were heavier and FI greater ($P < 0.05$) than the PP diet.

Hernández, O.E.A., Hernández, L.H.H., Miyasaka, A.S., Lugo, M.G. (2017). Effects of diets with whole plant-origin proteins added with different ratios of taurine:methionine on the growth, macrophage activity and antioxidant capacity of rainbow trout (*Oncorhynchus mykiss*) fingerlings. *Veterinary & Animal Science* **3**, 4-9.

Doi: 10.1016/j.vas.2017.04.002.

Essentially a repeat of the trials of Gaylord et al. (2007) where a PP-based (SPI, Spirulina powder) diet was supplemented with 1% Tau and Met at various levels and ratios (0/100, 25/25, 50/50, 75/25, 100/0 and 0/0). Wt gain, macrophage burst and antioxidant activity were elevated as dietary Tau increased with the 75/25 ratio providing optimum inclusion level.

Hong, J., Bledsoe, J.W., Overturf, K.E., Hardy, R.W., Small, B.C. (2024). Balancing dietary plant-based lipids and cholesterol to increase fillet omega-3 deposition in rainbow trout (*Oncorhynchus mykiss*) fed a diet without animal ingredients. *Aquaculture*, **578**, 740029.

Doi: 10.1016/j.aquaculture.2023.740029.

Principally containing CPC, SBM, SPC, WGM as protein, this diet was compared against a FM, PBM, BM-based feed over 84-d. Final wt was highest ($P < 0.05$) in FM based feeds but a PP diet in which soy oil was replaced by linseed oil achieved parity in wt gain, SGR and FI to the FM diet. No differences between treatments for FCR or survival were apparent.

Huang, H., Li, X., Cao, K., Leng, X. (2023). Effects of replacing fishmeal with the mixture of cottonseed protein concentrate and *Clostridium autoethanogenum* protein on the growth, nutrient utilization, serum biochemical indices, intestinal and hepatopancreas histology of rainbow trout (*Oncorhynchus mykiss*). *Animals*, **13**, 817.

Doi: 10.3390/ani13050817.

Complete FM substitution with SCP and CPSC. 56-d trial with 35 g rainbow trout. At trial end, FM-less fed fish were smaller, had poorer SGR and FCR and higher whole-body lipid levels ($P < 0.05$). PER, intestinal protease and amylase, and fold height, width and muscle thickness were also all lower ($P < 0.05$).

Idenyi, J.N., Eya, J.C., Abanikannda, M.F., Huber, D.H., Gannam, A.L., Sealey, W.M. (2023). Dynamics of mitochondrial adaptation and energy metabolism in rainbow trout (*Oncorhynchus mykiss*) in response to sustainable diet and temperature. *Journal of Animal Science*, **101**, 1-15.

Doi: 10.1093/jas/skad348.

No effect of temp on growth but lack of FM increased FI and FE ($P < 0.03$) and decreased LER and PPV ($P \leq 0.02$) in fish fed a diet comprising SPC, SBM, WLM, WG, Y, Spirulina + camelia oil over 150-d at 18 °C.

Idenyi, J.N., Abdallah, H., Adeyemi, A.D., Huber, D.H., Gannam, A.L., Sealey, W.M., Igwe D.O., Eya, J.C. (2025). Optimizing growth and mitochondrial function in rainbow trout, *Oncorhynchus mykiss* through ecofriendly dietary and changes in water temperature regimen strategies. *Aquaculture*, **595**, 741591.

Doi: 10.1016/j.aquaculture.2024.741591.

Used a PP diet combining a mix of 8 different ingredients and evaluated fish performance vs a FM, BM, FeM-based feed, at three temperatures (14, 18, 20 °C) for 150-d. Trout fed the FM-based diets outperformed others for FI, SHGR, FE and wt gain ($P < 0.05$).

Jalili, R., Tukmechi, A., Agh, N., Noori, F., Ghasemi, A. (2013). Replacement of dietary fish meal with plant sources in rainbow trout (*Oncorhynchus mykiss*); effect on growth performance, immune responses, blood indices and disease resistance. *Iranian Journal of Fisheries Science*, **12**, 577-591.

http://jifro.ir/browse.php?a_code=A-10-600-22&sid=1&slc_lang=en&ftxt=1&pure_pdf=1.

Replaced FM with WG, CG and SBM and fed 15 g fish for 64-d, resulting in decreased growth, SGR, and K and increased FCR ($P < 0.05$). There were no differences in serum lysozyme or complement activity or any other hematological parameter studied.

Kajbaf, K., Overturf, K., Kumar, V. (2024). Integrated alternative approaches to select feed-efficient rainbow trout families to enhance the plant protein utilization. *Scientific Reports*, **14**, 3869.

Doi: 10.1038/s41598-024-54218-2.

Evaluated FE of ~1600 individuals from 12 families to a PP feed (SBM, WGM, WF) using feeding-fasting and refeeding. Results suggest the possibility for improving FE in mixed lines.

Kaushik, S.J., Luquet, P. (1980). Influence of bacterial protein incorporation and of sulphur amino acid supplementation to such diets on growth of rainbow trout, *Salmo gairdneri* Richardson. *Aquaculture*, **19**, 163-175.

Doi: 10.1016/0044-8486(80)90017-4.

Substitution of FM with SCP had no impact on growth or FCE but decreased FI and FCE while increasing PER and PPV ($P < 0.05$). Body composition and ADC values were identical.

Kaushik, S.J., Cravedi, J.P., Lalles, J.P., Sumpter, J., Fauconneau, B., Laroche, M. (1995). Partial or total replacement of fish meal by soybean protein on growth, protein utilization, potential estrogenic effects, cholesterolemia and flesh quality in rainbow trout, *Oncorhynchus mykiss*. *Aquaculture*, **133**, 257-274.

Doi: 10.1016/0044-8486(94)00403-B.

Used SPC and SF to replace FM for a 84-d trial at the end of which the only difference determined was for VSI ($P < 0.05$) and circulating vitellogenin which was higher in SPC fed fish. Sensory evaluation revealed that FM feed increased flesh pinkness and texture but decreased juiciness.

Keramat Amirkolaie, A., Shahsavari, M., Hedayatyfard, M. (2014). Full replacement of fishmeal by poultry by-product meal in rainbow trout, *Oncorhynchus mykiss* (Walbaum, 1972) diet. *Iranian Journal of Fisheries Sciences*, **13**, 1069-1081.

http://jifro.ir/files/site1/user_files_eb12be/keramat-A-10-561-6-0b92019.pdf.

Reared 50 g trout for 60-d to compare FM- and PBM, SBM, WG feeds. Growth, SGRs, FCR and PER all better ($P < 0.05$) for the FM feed. Body fat and moisture was reduced and increased in animal protein fed fish respectively ($p < 0.05$).

Kesbiç, O.S., Acar, U., Kesbiç, F.I., Yılmaz, S. (2024). Growth performance, health status, gut microbiome, and expression of immune and growth-related genes of rainbow trout (*Oncorhynchus mykiss*) fed diets with pea protein replacement of fish meal. *Comparative Biochemistry & Physiology, Part B*, **273**, 110968.

Doi: 10.1016/j.cbpb.2024.110968

Assessed growth of ~37 g trout fed FM and PP diets over 60-d. fish receiving the PP-based diet (PeP, SBM, WM) were lighter, SGR, FCR and PER poorer and fillets less fatty ($P < 0.001$).

Kim, J.D., Kaushik, S.J., Breque, J. (1998). Nitrogen and phosphorus utilization in rainbow trout (*Oncorhynchus mykiss*) diets with or without fish meal. *Aquatic Living Resources*, **11**, 261-264.

Doi: 10.1016/S0990-7440(98)80009-0.

Compared an isonitrogenous and isoenergetic SPC, CGM, PeM, SBM feed against a herring meal containing food. Trials were undertaken with two fish size groups (24 g, 156 g) over 28-d. The diet based on SPC returned fish of lower wt, poorer FI and PER ($p < 0.05$) in the smaller fish with similar results for the larger group although PER was similar.

Koops, H., Tiews, K., Gropp, J., Schwalb-Bühling, A. (1981). Further results on the replacement of fishmeal by other protein feedstuffs in pellet feed for rainbow trout (*Salmo gairdneri*).

https://www.ices.dk/sites/pub/CM%20Documents/1981/F/1981_F3.pdf

International Council for the Exploration of the Sea, Mariculture Committee, C.M.1981/F:3. 24 pp.

Tested swine bristle meal, dried domestic sewage sludge, FB and whey proteins as replacements for FM.

Lansard, M., Panserat, S., Seiliez, I., Polakof, S., Plagnes-Juan, E., et al. (2009). Hepatic protein kinase B (Akt)-target of rapamycin (TOR)-signalling pathways and intermediary metabolism in rainbow trout (*Oncorhynchus mykiss*) are not significantly affected by feeding plant-based diets. *British Journal of Nutrition*, **102**, 1564-1573.

Doi: 10.1017/S000711450999095X.

CGM, SBM, WG replaced dietary FM in tested diet. Trial was run for 84-d. PP fed fish had lower wt, FI, FE and SGR ($P < 0.05$).

Lazzarotto, V. (2016). Consequences of long-term feeding trout with plant-based diets on the regulation of energy and lipid metabolism: special focus on trans-generational effects and early stages. Ph.D. dissertation, Sciences agronomiques, biotechnologies agro-alimentaires, Université de Pau et des Pays de l'Adour, France. 248 pp.

Research origin of following papers.

Lazzarotto, V., Corraze, G., Leprevost, A., Quillet, E., Dupont-Nivet, M., Médale, F. (2015). Three-year breeding cycle of rainbow trout (*Oncorhynchus mykiss*) fed a plant-based diet, totally free of marine resources: consequences for reproduction, fatty acid composition and progeny survival. *PLoS One*, **10**, e0117609.

Doi: 10.1371/journal.pone.0117609.

Long-term feeding (2-3 years) of PP diet (CG, SBM, WG, Durum wheat, WLM, PeM). No difference in wt between year-3 spawners. Major differences in neutral and polar lipid content of adults, ova and swim-up fry reflecting diet taken.

Lazzarotto, V., Corraze, G., Larroquet, L., Mazurais, D. (2016). Does broodstock nutritional history affect the response of progeny to different first-feeding diets? A whole-body transcriptomic study of rainbow trout alevins. *British Journal of Nutrition*, **115**, 2079-2092.

Doi: 10.1017/S0007114516001252.

Broodstock from previous study; examined growth of alevins for 21-d. Those from PP fed broods were smaller ($P < 0.001$) and sustained this through feeding vbs. FM brood alevins, irrespective of diet fed (FM/PP).

Lazzarotto, V., Médale, F., Larroquet, L., Corraze, G. (2018). Long-term dietary replacement of fishmeal and fish oil in diets for rainbow trout (*Oncorhynchus mykiss*): Effects on growth, whole body fatty acids and intestinal and hepatic gene expression. *PLoS One*, **13**, e0190730.

Doi: 10.1371/journal.pone.0190730.

Continuation of the previous study, over a 210-d and following 180-d period. Lower survival ($P < 0.05$) was observed for PP fed fish during the first period but was similar thereafter. Growth was alike during the first period but by the end of the trial, PP fed fish were smaller ($p < 0.05$). Plasma cholesterol was lower in PP fish for both periods and differences were recorded for whole-body lipid content with ω -3 PUFA DHA + EPA being elevated in control animals ($P < 0.001$).

Le Boucher, R., Quillet, E., Vandeputte, M., Lecalvez, J.M., Goardon, L., Chatain, B., et al. (2011). Plant-based diet in rainbow trout (*Oncorhynchus mykiss* Walbaum): Are there genotype-diet interactions for main production traits when fish are fed marine vs plant-based diets from the first meal? *Aquaculture*, **321**, 41-48.

Doi: 10.1016/j.aquaculture.2011.08.010.

PP-based feeds were compared to marine-based diets with better growth in the latter ($P < 0.0001$). Carcass and fillet yields were better in marine protein fed trout.

Le Boucher, R., Dupont-Nivet, M., Vandeputte, M., Kerneis, T., Goardon, L., Labbe, L., Chatain, B., Bothaire, M.J., Larroquet, L., Médale, F., Quillet, E. (2012). Selection for adaptation to dietary shifts: towards sustainable breeding of carnivorous fish. *PLOS One*, **7**, e44898.

Doi: 10.1371/journal.pone.0044898.

Evaluated genetic gains in selecting fish for PP diets. Using feeds comprising CGM, SBM, WG, LSM, EWW and comparing FM fed animals, decrease growth and survival over 250-d, but demonstration of selective gains after 1 generation.

Lee, K.J., Dabrowski, K., Blom, J.H. (2001). Replacement of fish meal by a mixture of animal by-products in juvenile rainbow trout diets. *North American Journal of Aquaculture*, **63**, 109-117.

Doi: 10.1577/1548-8454(2001)063<0109:ROFMBA>2.0.CO;2.

Isonitrogenous FM and mixed animal protein (MBM, PBM, BM, LM, FeM, squid liver powder) diets were compared over 112-d using ~1 g trout. At trial end FM fed trout was heavier ($P < 0.05$) but P absorption higher from the animal protein feed.

Lee, K.J., Dabrowski, K., Blom, J.H., Bai, S.C., Stromberg, P.C. (2002). A mixture of cottonseed meal, soybean meal and animal byproduct mixture as a fish meal substitute: growth and tissue gossypol enantiomer in juvenile rainbow trout (*Oncorhynchus mykiss*). *Journal of Animal Physiology & Animal Nutrition*, **86**, 201-213.

Doi: 10.1046/j.1439-0396.2002.00375.x.

FM was replaced by a mixture of animal protein (MBM, BM, FeM, PBM, 50%), CSM (25%) and SBM (25%) and fed to juvenile trout ~1 g for 112-d. Growth, FCE, PER, SGR was similar between diets.

Lee, K.J., Rahimnejad, S., Powell, M.S., Barrows, F.T., Smiley, S., Bechtel, P., Hardy, R.W. (2015). Salmon testes meal as a functional feed additive in fish meal and plant protein-based diets for rainbow trout (*Oncorhynchus mykiss* Walbaum) and Nile tilapia (*Oreochromis niloticus* L.) fry. *Aquaculture Research*, **46**, 1590-1596.

Doi: 10.1111/are.12313.

Used isonitrogenous and isoenergetic PP and PP+ salmon testes meal as FM alternatives and examined the response of trout over 63-d. The PP+testes diet was equaled in growth, PER, FI by the PP feed but outperformed the FM feed ($P < 0.05$).

Liu, B. (2016). The Effect of dietary nucleotide supplementation on growth and feed efficiency of rainbow trout (*Oncorhynchus mykiss*) fed fish meal-free and animal protein-free diets. MS thesis, University of Guelph, Guelph, Canada. 74 pp.
<https://atrium.lib.uoguelph.ca/server/api/core/bitstreams/8a37d409-40d4-4717-b6a8-609c6e729bb/content>.

Liu, Y., Chang, H., Lv, W., Ma, S., Qui, G., Lu, S., Han, S., Wang, C., Han, D., Zhang, Y., Liu, H. (2022a). Physiological response of rainbow trout (*Oncorhynchus mykiss*) to graded levels of novel *Chlorella sorokiniana* meal as a single fishmeal alternative or combined with black soldier fly larval meal. *Aquaculture*, **561**, 738715.

Doi: 10.1016/j.aquaculture.2022.738715.

Microalgae meal (Chlorella) alone, or with IM (black soldier fly) were examined as replacements for FM over a 56-d period using 67 g rainbow trout. Wt gain for all diets was the same except for the highest algal meal fed fish, which was heavier and had higher SGR ($P < 0.05$). Intestinal fold height was greater and muscle layer thickness greater in the proximal intestine for then high algal fed fish when compared to FM controls. There were differences also for plasma AAs levels and IgT, IL-1 β , IL8 and TNF α and TGF β in the gut for algal fed fish.

Liu, Y., Ma, S., Lv, W., Shi, H., Qui, G., Lu, S., Wang, D., Wang, C., Han, S., Liu, H. (2022b). Effects of replacing fishmeal with cottonseed protein concentrate on growth performance, blood metabolites, and the intestinal health of juvenile rainbow trout (*Oncorhynchus mykiss*). *Frontiers in Immunology*, **13**, 1079677.

Doi: 10.3389/fimmu.2022.1079677.

Compared isonitrogenous and lipidic FM/IM and CSC/IM diets over 56-d. Replacement of FM resulted in growth retardation and decrease K, VSI and FI ($P < 0.05$). There were no differences in FCR, plasma cholesterol or whole-body composition at trial end. Levels of trypsin were lower and lipase higher in the CSM/IM fed fish ($P < 0.05$). Intestinal fold height and width was lower and muscle thickness higher in fish receiving CSM/IM feeds ($P < 0.05$).

Lu, F., Haga, Y., Satoh, S. (2015). Effects of replacing fish meal with rendered animal and plant protein sources on growth response, biological indices, and amino acid availability for rainbow trout *Oncorhynchus mykiss*. *Fisheries Science*, **81**, 95-105.

Doi: 10.1007/s12562-014-0818-7.

Replaced FM using PBM, FeM and BM and evaluated growth of 16.7 g trout over 84-d. There was equivalence in wt gain, SGR, FI, HSI, MR, hematocrit, hemoglobin and survival but FCR and PER were higher and lower ($P < 0.05$) respectively for the animal protein fed fish which had lower moisture and protein and higher lipid whole-body content.

Luo, L., Xue, M., Wu, X., Cai, X., Cao, H., Liang, Y. (2006). Partial or total replacement of fishmeal by solvent-extracted cottonseed meal in diets for juvenile rainbow trout (*Oncorhynchus mykiss*). *Aquaculture Nutrition* **12**, 418-424.

Doi: 10.1111/j.1365-2095.2006.00443.x.

Total replacement of FM with solvent-extracted CSM caused decrease wt gain, SGR, FCE, FI, PER, ADC for crude protein and energy ($P < 0.05$) but had no impact on whole-body composition after a 56-d trial.

Longoria, J.A.C., Ávila, D.S., Hernández, L.H.H., López, O.A., Araiza, M.A.F. (2018). Reemplazo de harina de pescado con gluten de maíz en dietas de juveniles de trucha arcoíris (*Oncorhynchus mykiss*): efectos en crecimiento y otros parámetros fisiológicos [in Spanish]. *Hidrobiológica*, **28**, 257-263.

<https://hidrobiologica.izt.uam.mx/index.php/revHidro/article/view/1272/907>.

Describes the replacement of FM with CG and trial results following a 90-d trial. Wt gain, SGR, and muscle protein deposition were lower in CG fed fish ($P < 0.05$). CG increase O₂ consumption and N ammonium excretion.

Mambrini, M., Roem, A.J., Cravedi, J.P., Lallès, J.P., Kushik, S.J. (1999). Effects of replacing fish meal with soy protein concentrate and of DL-methionine supplementation in high-energy, extruded diets on the growth and nutrient utilization of rainbow trout, *Oncorhynchus mykiss*. *Journal of Animal Science*, **77**, 2990-2999.

Doi: 10.2527/1999.77112990x.

Reports on the effect of replacing FM with SPC with or without supplemented DL-Met (0.22 and 0.44%). FM fed trout (106 g) were heavier after the 90-d trial than animals fed the 100% replacement feeds, irrespective of the addition of Met. Nevertheless, SPC supplementation with 0.44% Met resulted in better growth than without ($P < 0.05$). Whole-body moisture and lipid were higher and lower respectively in SPC vs. FM feeds ($P < 0.05$). An in-depth sensory evaluation of baked fish illuminated a variety of differences between feeds.

Marjanović, S., Belošović, S.D., Stanković, M., Banjac, V.V., Rakita, S.M., Vranković, J.S. Marković, Z. (2024). Complete replacement of fishmeal with unconventional animal protein sources: A comparative study of the effects of use of mealworm, earthworm and zooplankton on growth parameters, fatty acid composition and sensory profile rainbow trout. *Aquaculture Reports*, **39**, 1025132.

Doi: 10.1016/j.aqrep.2024.102512.

Reports of the use of mealworm (Tenebrio molitor), earthworm (Eisenia fetida) and zooplankton (Brachionus angularis and Daphnia magna) as FM replacers. Body wt gain was highest in the mealworm diets which did not differ to those on FM which were similar to those fed earthworm-based diets. The zooplankton feeds performed the poorest of all ($P < 0.05$).

Matsunari, H., Iwashita, Y., Suzuki, N., Saito, T., Akimoto, A., Okamatsu, K., Sugita, T., Yamamoto, T. (2010). Influence of fermented soybean meal-based diet on the biliary bile status and intestinal and liver morphology of rainbow trout *Oncorhynchus mykiss*. *Aquaculture Science*, **58**, 243-252.

Doi: 10.11233/aquaculturesci.58.243.

Compared the effects of replacing FM with fSBM and SBM with or without EAA additions on ~12 g trout over 84-d. Trout in receipt of the FM-containing feeds outperformed all other groups in FI, wt gain and FE ($P \leq 0.004$). Addition of EAA to fSBM feeds had no effect when compared against fSBM alone. Surprisingly, SBM alone returned equivalent growth and feed efficiency to FSBM + EAAs. There were no differences in histology for the mid gut between treatments. However, in the distal intestine the mucosal folds of fish fed SBM diets had disintegrating microvilli with some parts of the surface epithelium having been disrupted.

Matty, A.J., Smith, P. (1978). Evaluation of a yeast, a bacterium and an alga as a protein source for rainbow trout 1. Effect of protein level on growth, gross conversion efficiency and protein conversion efficiency. *Aquaculture*, **14**, 235-246.

Doi: 10.1016/0044-8486(78)90097-2.

An early evaluation of SCPs (Pseudomonas sp., Spirulina sp., and Candida sp.) as alternatives to FM. Trials lasted 28-d and examined growth, FI and survival vs. a commercial diet. Bacterial protein diets were outperformed by FM feed in wt gain and FCE ($P < 0.01$). Algal diets were likewise outperformed by the commercial FM diet. In the yeast diet growth rate and FI exceed that of the commercial diet although was not significant.

Médale, F., Boujard, T., Vallée, F., Blanc, D., Mambrini, M., Roem, A., Kaushik, S.J. (1998). Voluntary feed intake, nitrogen and phosphorus losses in rainbow trout (*Oncorhynchus mykiss*) fed increasing dietary levels of soy protein concentrate. *Aquatic Living Resources*, **11**, 239-246.

Doi: 10.1016/S0990-7440(98)89006-2.

Sought to determine whether the addition of DL-Met to SPC diets increased growth performance of 102 g rainbow trout over 33-d. While the trial was not for a long duration, FI and SGRs were poorer in SPC

diets ($P > 0.05$) although wt gain was similar to fish fed FM-based feeds. Ammonia- and total N excretion was higher in SPC fed fish ($P < 0.05$). Fecal losses of P were higher in FM fed animals ($P < 0.05$).

Michl, S.C., Proksch, C., Hutchings, J.A., Schulz, C. (2017a). Alternative protein sources for first-feeding fry: the potential of nutritional programming in rainbow trout (*Oncorhynchus mykiss*). pp. 63-88, in: Michl, S.C. PhD. Dissertation, *Evaluation of plastic responses to nutritional programming by various feed sources in brown and rainbow trout fry*. Christian-Albrechts-Universität, Kiel, Germany. 152 pp.

Decreased growth ($P < 0.05$) of first feeding trout (21 dph) using diet of PePC, RPC, SPC, WG, CGM vs. marine APs over 93-d.

Michl, S.C., Ratten, J.-M., Beyer, M., Hasler, M., LaRoche, J., Schulz, C. (2017b). The malleable gut microbiome of juvenile rainbow trout (*Oncorhynchus mykiss*): Diet-dependent shifts of bacterial community structures. *PLoS One*, **12**, e0177735.

Doi: 10.1371/journal.pone.0177735.

Examined response of trout to PP-based diet (CG, SPC, PeP, RPC, WG) vs. mixed marine protein feed. PP-based diet returned poorest growth ($P < 0.05$). Differences in intestinal microbiota occurred ($P < 0.01$).

Miebach, A.C., Bauer, J., Adamek, M., Dietz, C., Gährken, J., Rosenau, S., Wessels, S., Tetens, J., Sünder, A., Jung-Schroers, V., Steinhagen, D. (2023). Influence of genetic adaption of rainbow trout (*Oncorhynchus mykiss*) fed with alternative protein sources based on *Arthrospira platensis* and *Hermetia illucens* on intestinal health and animal welfare. *Aquaculture Reports*, **32**, 101697.

Doi: 10.1016/j.aqrep.2023.101697.

See Dietz et al, (2023) for dietary ingredients. SGR, K, gutted and fillet yields did not differ but changes to fillet color and quality occurred. Fish fed the alternative protein diet had fillets that expressed higher hardness which was associated with decreased lipid levels ($P < 0.05$). Nine of nineteen odor descriptors were higher in fish fed the alternative protein feed ($P < 0.05$).

Moghaddam, M.R.M., Janmohammadi, H., Taghizadeh, A., Sheikhzadeh, N. (2014). Investigation of growth performance, carcass indices, fillet chemical composition and non-specific immune parameters of rainbow trout (*Oncorhynchus mykiss*) fed diets containing poultry by-product meal supplemented with canola meal and cottonseed meal. *International Journal of Fisheries & Aquatic Studies*, **2**, 220-226.

<https://www.fisheriesjournal.com/vol2issue2/Pdf/35.1.pdf>.

Compared PBM-based feed with a FM-based diet over 90-d. No difference in wt gain but decrease FCR, HSI, and plasma antiprotease activity.

Morales, A.E., Crdenette, G., De la Higuera, M., Sanz, S. (1994). Effects of dietary protein source on growth, feed conversion and energy utilization in rainbow trout, *Oncorhynchus mykiss*. *Aquaculture*, **124**, 117-126.

Doi: 10.1016/0044-8486(94)90367-0.

Employed casein and evaluated growth against FM feed. Similarity in wt gain and SGR but FI lower and FCR higher in casein diets ($P < 0.05$).

Movahedrad, F., Hajimoradloo, A., Zamani, A., Kolangi, H. (2018a). Effect of dietary fish meal replacement by AquPro (processed soybean meal) on growth performance and digestive enzymes activity in rainbow trout (*Oncorhynchus mykiss*) fry. [in Arabic]. *Iranian Scientific Fisheries Journal*, **27**, 47-59.

Doi: 10.22092/ISFJ.2018.116694

SBM replaced FM to produce isoproteinaceous and isocaloric feeds that were fed to 2.4 g trout for 42-d. Growth and FCR was reduced in SBM fed fish.

Movahedrad, F., Hajimoradloo, A., Zamani, A., Kolangi, H. (2018b). Effect of dietary fish meal replacement by AquPro on growth performance, body composition and total protease activity in rainbow trout (*Oncorhynchus mykiss*) fry. [in Arabic]. *Journal of Fisheries Science & Technology*, **7**, 215-222.

See above.

Moyano, F.-J., Cardenete, G., de la Higuera, M. (1992). Nutritive value of diets containing a high percentage of vegetable proteins for trout, *Oncorhynchus mykiss*. *Aquatic Living Resources*, **5**, 23-29.

Doi: 10.1051/alr:1992004.

Appraised the effect of replacing FM using SBM, LSM, CGM, PPC with 0.7% L-Met in 30 g trout over 56-d. Wt gain, SGR, FI, FE, PER and PPV were all superior ($P < 0.05$) in FM fed fish. However, cost of production was lower when using PP diets. A taste panel showed no differences between samples.

Murashita, K., Akimoto, A., Iwashita, Y., Amano, S., Suzuki, N., Matsunari, H., Furuita, H., Sugita, T., Yamamoto, T. (2013). Effects of biotechnologically processed soybean meals in a nonfishmeal diet on growth performance, bile acid status, and morphological condition of the distal intestine and liver of rainbow trout *Oncorhynchus mykiss*. *Fisheries Science*, **79**, 447-457.

Doi: 10.1007/s12562-013-0617-6.

A fine comparison of different fSBMs against SBM and jack mackerel meal-based feeds. The trial employed 18.4 g juveniles and lasted 70-d. Trout raised on the FM feed performed better, returning greater wt, SGR, and FER with lower FI ($P < 0.05$).

Murashita, K., Rønnestad, I., Furuita, H., Matsunari, H., Oku, H., Yamamoto, T. (2018). Effects of dietary soybean meal on the bile physiology in rainbow trout, *Oncorhynchus mykiss*. *Aquaculture*, **490**, 303-310.

Doi: 10.1016/j.aquaculture.2018.02.047.

Compared SBM/SPI-based diets with or without Tau vs jack mackerel meal-based feeds using ~20 g fish over 70-d. FM fed trout were heavier and had superior FER >SBM+Tau> SBM ($P < 0.01$).

Murray, A.P., Marchant R. (1986). Nitrogen utilization in rainbow trout (*Salmo gairdneri* Richardson) fed mixed microbial biomass. *Aquaculture*, **54**, 263-275.

Doi: 10.1016/0044-8486(86)90271-1.

Assessed the utility of SCP biomass comprising Hansenula anomala, Candida kruzei and Geotrichum candidum grown on malt whiskey spent wash as a protein source for trout and compared results against a casein diet over 30-d. There were no differences in wt gain, FGI, FER, or PPV. Dietary supplementation with L-Met resulted in better growth of fish fed the SCP biomass ($P < 0.05$)

Mushtaq, S.T., Mushtaq, S.A., Rawat, K.D., Chalkoo, S. (2019). Evaluation of growth response and body composition of rainbow trout, *Oncorhynchus mykiss* fingerlings fed diets containing low cost locally available feed ingredients. *Journal of Pharmacognosy & Phytochemistry*, **8**, 1873-1877.

<https://www.phytojournal.com/archives/2019/vol8issue4/PartAF/8-4-309-439.pdf>.

Evaluated various alternative protein sources (earthworm, Gammarus powder, silkworm pupae or waste) to substitute FM. At the end of the 120-d trial fed animals outperformed all those fed on alternative diets ($P < 0.05$).

Mustafa, M., Sirakov, I., Stoyanova, S. (2023). Effects of replacement of fishmeal with other alternative protein sources in the feed on hydrochemical parameters and flesh quality of rainbow trout (*Oncorhynchus mykiss*). *Agricultural Science & Technology*, **15**, 32-41.

Doi: 10.15547/ast.2023.01.004.

Replaced FM with an algal product and assessed growth of 7.6 g trout over 60-d.

Overturf, K., Gaylord, T.G. (2009). Determination of relative protein degradation activity at different life stages in rainbow trout (*Oncorhynchus mykiss*). *Comparative Biochemistry & Physiology*, **152B**, 150-160.

Doi: 10.1016/j.cbpb.2008.10.012.

Examined growth of 4.3 g trout over 167-d fed either a FM- or BM-based diet. Over the first 76-d of the trial fish fed the FM feed outgrew those maintained on the BM feed but, thereafter, growth parity was observed until trial end.

Overturf, K., Vallejo, R.L., Palti, Y., Barrows, F.T., Parsons, J.E. (2012). Microarray analysis of differential utilization of plant-based diets by rainbow trout. *Aquaculture International*, **20**, 213-232.

Doi: 10.1007/s10499-011-9490-4.

Used a PP+KM feed over a full production trial in concrete raceways and compared performance to animals reared on a FM feed. At the end of the trial, PP/KM fed fish were ~589 g whereas FM fed fish were ~645 g ($P < 0.05$). PP fed fish expressed upregulation of various immune-related genes and changes in genes engaged in cell oxidative stress.

Overturf, K., Barrows, F.T., Hardy, R.W. (2013). Effect and interaction of rainbow trout strain (*Oncorhynchus mykiss*) and diet type on growth and nutrient retention. *Aquaculture Research* **44**, 604-611.

Doi: 10.1111/j.1365-2109.2011.03065.x.

Compared 3 strains of rainbow trout and subjected each to a PP or FM diet over 84-d and judged their performance. A significant impact of strain (0.01) and interaction between strain and diet ($P < 0.03$) was observed for growth and PRE, but no effect of diet alone with each strain performing equally on PP and FM feeds.

Özdemir, K.Y., Yildiz, M. (2019). Effects of dietary fish meal replacement by red lentil meal on growth and amino acid composition of rainbow trout (*Oncorhynchus mykiss*). *Alinteri Journal of Agricultural Science*, **34**, 194-203.

Doi: 10.28955/alinterizbd.666012.

Looked at RLM as an alternative protein source, combining it with WG and CG. Comparison was made against an isonitrogenous and iso-lipidic FM-based diet over 60-d using 10 g fish. Wt gain, SGR, and K were all lower in the RLM fed fish ($P < 0.05$) but no differences were recorded between dietary groups for PER or FCR. HSI and VSI were both higher in the fish fed RLM ($P < 0.05$).

Palma, M., Bledsoe, J.W., Tavares, L.C., Romano, N., Small, B.C., Viegas, I., Overturf, K. (2021). Digesta and plasma metabolomics of rainbow trout strains with varied tolerance of plant-based diets highlights potential for non-lethal assessment of enteritis development. *Metabolites*, **11**, 590.

Doi: 10.3390/metabo11090590.

Gauged the effects of replacing FM/PBM/BM using SBM, SPC, CPC and WGM on growth of a trout strain selected for good growth on PP diets vs. two commercial lines over 270-d. Each strain fed the PP diet underperformed those on the AP feed ($P < 0.01$). At trial end, the selected fish fed the PP feed had intestinal fold lengths and heights that were deemed healthier than commercial strains ($P < 0.001$).

Palti, Y., Silverstein, J.T., Wieman, H., Phillips, J.G., Barrows, F.T., Parsons, J.E. (2006). Evaluation of family growth response to fishmeal and gluten-based diets in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, **255**, 548-556.

Doi: 10.1016/j.aquaculture.2005.11.029.

Compared response of three strains to FM or PP-based diets after 90-d and 270-d feeding. One strain was selected for PP feeds. At 90-d selected fish were heavier than the other strains when fed PP feeds but at 270-d one of the non-selected strains performed equally wt wise on the PP feed. All fish fed the PP diet had shorter and wider intestinal folds vs. those fed FM-based diets.

Panserat, S., Hortopand, G.A., Plagnes-Juan, E., Kolditz, C., Lansard, M., Skiba-Cassy, S., Esquerré, D., Geurden, I., Médale, F., Kaushik, S.K., Corazze, G. (2009). Differential gene expression after total replacement of dietary fish meal and fish oil by plant products in rainbow trout (*Oncorhynchus mykiss*) liver. *Aquaculture*, **294**, 123-131.

Doi: 10.1016/j.aquaculture.2009.05.013.

Two isoproteic, isolipidic and isoenergetic diets based on FM and PPs were fed to 121 g trout for 68-d. At final sampling, PP fed animals expressed reduced wt, FE, PE and FI ($P \leq 0.003$). Diets also caused differential expression in hepatic genes related to protein metabolism and others.

Panserat, S., Kolditz, K., Richard, N., Plagnes-Juan, E., Piumi, F., Esquerré, D., Médale, F., Corazze, G., Kaushik, S.K. (2008). Hepatic gene expression profiles in juvenile rainbow trout (*Oncorhynchus mykiss*) fed fishmeal or fish oil-free diets. *British Journal of Nutrition* **100**, 953-967.

Doi: 10.1017/S0007114508981411.

Used two isonitrogenous, isolipidic and isoenergetic diets, one a mixed PP (WL, CGM, WG, WW, PeM, SBM) and the other based on FM, to examine hepatic gene expression after 364-d of feeding. At trial end there were differences between groups for growth, FE and PER, favoring the FM fed fish ($P \leq 0.005$). Considerable differences were found in hepatic gene expression between the two dietary groups.

Parés-Sierra, G., Durazo, E., Ponce, M.A., Badillo, D., Correa-Reyes, G., Viana, M.T. (2014). Partial to total replacement of fishmeal by poultry by-product meal in diets for juvenile rainbow trout (*Oncorhynchus mykiss*) and their effect on fatty acids from muscle tissue and the time required to retrieve the effect. *Aquaculture Research* **45**, 1459-1469.

Doi: 10.1111/are.12092.

Total replacement of FM by PBM in isonitrogenous and isolipidic diets which were tested in 1.4 g rainbow trout for 80-d. At trial end, there were no differences in wt gain, FI, FCR or survival.

Parisi, G., de Francesco, M., Médale, F., Scappini, F., Mecatti, M., Kaushik, S.J., Poli, B.M. (2004). Effect of total replacement of dietary fish meal by plant protein sources on early post mortem changes in the biochemical and physical parameters of rainbow trout. *Veterinary Research Communications*, **28**, 237-240.

<https://link.springer.com/content/pdf/10.1023/B:VERC.0000044434.75094.b5.pdf#page=237>.

Reports the effect of replacing FM in isonitrogenous and isolipidic diets using a PP mix. Fish of 19 g were fed for 157-d and at trial end those fed the FM-based diet were heavier. At detach animals fed the PP diet slipped more rapidly into rigor ($P < 0.05$) and fillet length declined between 2-4 h ($P \leq 0.05$) but rebounded to equivalence by 24 h.

Pereira, J.O.B., Reis-Henriques, M.A., Sanchez, J.L., Costa, J.M. (1998). Effect of protein source on the reproductive performance of female rainbow trout, *Oncorhynchus mykiss* (Walbaum). *Aquaculture Research* **29**, 751-760.

Doi: 10.1046/j.1365-2109.1998.29100751.x.

Examined two FM-free and a FM-based feed (all isonitrogenous and isocaloric) fed for 364-d to 622 g mixed sex brood animals. No differences between feed groups were discerned for wt gain or FI but FCR were poorer in the PP fed fish ($P < 0.05$). Fecundity, spawning rate, egg numbers produced their wt female¹ were lower for fish maintained on PP ($P < 0.05$).

Perera, W.M.K. (1995). Growth performance, nitrogen balance and protein turnover of rainbow trout (*Oncorhynchus mykiss* (Walbaum)) under different dietary regimens. Ph.D. dissertation, University of Aberdeen, Scotland. 179 pp.

Perera, W.M.K., Carter, C.G., Houlihan, D.F. (1995). Feed consumption, growth and growth efficiency of rainbow trout (*Oncorhynchus mykiss* (Walbaum)) fed on diets containing a bacterial single-cell protein. *British Journal of Nutrition*, **73**, 591-603.

Doi: 10.1079/BJN19950061.

Replacing FM with SCP in isonitrogenous and isoenergetic diets, 9 g fish were subjected to a 132-d feeding trial at the end of which fish eating the SCP feed were smaller ($P < 0.05$).

Pérez-Pascual, D., Pérez-Cobas, A.E., Rigau, D., Rochat, T., Bernadet, J.F., Skiba-Cassy, S., Marchand, Y., Duchaud, E., Ghigo, J.-M. (2021). Sustainable plant-based diets promote rainbow trout gut microbiota richness and do not alter resistance to bacterial infection. *Animal Microbiome*, **3**, 47.

Doi: 10.1186/s42523-021-00107-2.

Fish were reared from first feeding on diets containing PP, PP/IM or PP/Y and compared against a FM control fed group over 84-d. At the end of the study, fish fed the IM and Y-containing feeds expressed equal wt gain to that of the FM control diet. Fish fed the PP-based diet were inferior in wt gain and FCR. The different protein sources had no impact on the ability of fish to withstand a Flavobacterium psychrophilum infection but affect the abundance of most prevalent bacterial phyla in the gut.

Pierce, L.R. (2008). Family growth response to fishmeal and plant-based diets shows genotype x diet interaction in rainbow trout (*Oncorhynchus mykiss*). M.S. Thesis, Virginia Polytechnic and State University, Department of Fisheries & Wildlife Sciences, Blacksburg, VA, USA. 48 pp.

See the citation below.

Pierce, L.R., Palti, Y., Silverstein, J.T., Barrows, F.T., Hallerman, E.M., Parsons, J.E. (2008). Family growth response to fishmeal and plant-based diets shows genotype x diet interaction in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, **278**, 37-42.

Doi: 10.1016/j.aquaculture.2008.03.017.

Compared Kamloops strain trout for their ability to grow on FM and PP based diets. Trout fed PP feeds grew less well ($P < 0.05$) than those on FM feeds. The study nonetheless provided evidence for genotype x diet interactions which may be useful for breeding programs.

Prabhu, A.J., Schrama, J.W., Mariojous, C., Godin, S., Fontangné-Dicharry, S., Geurden, I., Surget, A., Bouyssiere, B., Kaushik, S.J. (2014). Post-prandial changes in plasma mineral levels in rainbow trout fed a complete plant ingredient based diet and the effect of supplemental dicalcium phosphate. *Aquaculture*, **430**, 34-43.

Doi: 10.1016/j.aquaculture.2014.03.038.

Using FM aquafeed and PP diets similar in ingredients to those of Panse et al. (2008), subjected 78 g trout to 56-d feeding. PP feeds were either fortified or not with dicalcium phosphate. The FM fed fish outperformed PP fed trout in all areas evaluated ($P < 0.05$: wt gain, FI, FCR, PER, VSI, HSI). Addition of dicalcium phosphate reduced FI ($P < 0.05$).

Prabhu, A.J., Kaushik, S.J., Mariojous, C., Surget, A., Fontangné-Dicharry, S., Schrama, J.W., Geurden, I. (2015). Comparison of endogenous loss and maintenance need for minerals in rainbow trout (*Oncorhynchus mykiss*) fed fishmeal or plant ingredient-based diets. *Fish Physiology & Biochemistry*, **41**, 243-253.

Doi: 10.1007/s10695-014-0020-y.

Attempt at evaluating the mineral maintenance needs of trout fed PP-based feed vs. those on a FM diet. Diets were fed for 84-d to 36.5 g trout at different ration levels. A separate digestibility trial was also undertaken to measure apparent digestibility of P, Mg, K, Cu and Zn. Wt gain, FE was greater in FM feeds but FI lower. Higher ADCs were measured for P, Mg and Cu, with no differences for Zn ($P \leq 0.005$).

Prabhu, A.J., Geurden, I., Fontangné-Dicharry, S., Veron, V., Larroquet, L., Mariojous, C., Schrama, J.W., Kaushik, S.J. (2016). Responses in micro-mineral metabolism in rainbow trout to change in dietary ingredient composition and inclusion of a micro-mineral premix. *PLoS One*, **11**, e0149378.

Doi: 10.1371/journal.pone.0149378.

Essentially employing the same PP diet to the study above, plus RSM, with or without a micromineral mix (Fe, Cu, Mn, Se, Zn), fish growth was compared against a FM-based diet. FI, body wt, and FE were superior ($P > 0.001$) for FM fish. HSI was lower in PP feeds. Plasma Fe was higher in PP fed fish ($P > 0.006$).

Prabhu, A.J., Schrama, J.W., Fontagné-Dicharry, S., Mariojouis, C., Surget, A., Bueno, M., Geurden, I., Kaushik, S.J. (2018). Evaluating dietary supply of microminerals as a premix in a complete plant ingredient-based diet to juvenile rainbow trout (*Oncorhynchus mykiss*). *Aquaculture Nutrition*, **24**, 539-547.

Doi: 10.1111/anu.12586.

Ostensibly using the identical diets to those above, a growth trial was run for 84-d with ~20 g fish. PP diets varied Cu, Fe, Mn, Se and Zn content. Mineral addition had no effect on wt gain, with FM fed trout being heavier and expressing greater FI and FE ($P \leq 0.03$)

Rahnema, S., Borton, R., Shaw, E. (2005). Determination of the effects of fish vs plant vs meat protein-based diets on the growth and health of rainbow trout. *Journal of Applied Animal Research*, **27**, 77-80.

Doi: 10.1080/09712119.2005.9706544.

Compared FM vs. PP vs. FeM+MM Fish consuming the PP based diet had lower FI and ADG ($P \leq 0.02$) than either the FM or FeM/MM diets. Taste analysis determined that PP fed fillets were less tender and juicy ($P < 0.02$).

Rahnema, S., Borton, R. (2007). Determination of the effects of fish vs plant and feather meal-based diets on the growth and health of rainbow trout. *Journal of Applied Animal Research*, **32**, 113-117.

Doi: 10.1080/09712119.2007.9706860.

Replaced FM using CGM, FeMP, SBM and FeM and fed ~300 g trout for 90-d. At trial end Fish fed the Fm feed were heavier and had higher FI ($P \leq 0.02$).

Rajesh, M., Kamalam, B.S., Sharma, P., Verma, V.C., Pandey, A., Dubey, M.K., Ciji, A., Akhtar, M.S., Pandey, N., Sarma, D., Kaushik, S.J., (2022). Evaluation of a novel methanotroph bacteria meal grown on natural gas as fish meal substitute in rainbow trout, *Oncorhynchus mykiss*. *Aquaculture Research* **53**, 2159-2174.

Doi: 10.1111/are.15735.

Spray dried methanotrophic bacterial meal was used to replace dietary FM. Following a 63-d trial the SCP-based diet returned poorer growth, SGR, TGC, FI, and lower K ($P < 0.001$) and lipid ADC ($P < 0.05$). Gut trypsin and leucine aminopeptidase were higher ($P \leq 0.001$) in the control fish while ALP was lower ($P < 0.0001$). Fish fed the SCP diet exhibited increased size of supranuclear vacuoles and heightening of the posterior gut's epithelium ($P < 0.05$).

Read, E.S., Barrows, F.T., Gaylord, T.G., Paterson, J., Petersen, M.K., Sealey, W.M. (2014). Investigation of the effects of dietary protein source on copper and zinc bioavailability in fishmeal and plant-based diets for rainbow trout. *Aquaculture*, **432**, 97-105.

Doi: 10.1016/j.aquaculture.2014.04.029.

Determined that dietary Cu source had no effect on growth of animal (FM, BM) or PP fed trout. PP trout expressed superior growth ($P \leq 0.05$) FCR, ERE PRE and fillet ratios but HSI was higher in those fed the animal protein-based diet. Protein and Cu source also influenced whole-body mineral concentrations for Cu Mg and S (+ in PP), and Zn and Fe (+ in animal protein diets). The takeaway message of this trial was that care has to be taken when using PP diets in terms of mineral supplementations.

Rema, P., Saravanan, S., Armenjon, B., Motte, C., Dias, J. (2019). Graded incorporation of defatted yellow mealworm (*Tenebrio molitor*) in rainbow trout (*Oncorhynchus mykiss*) diet improves growth performance and nutrient retention. *Animals*, **9**, 187.

Doi: 10.3390/ani9040187.

Examined the potential for replacement of FM using a combination of KM, IM, SM and PP mix using 5 g trout over 90-d. At trial end the fish fed the IM-based were heavier, expressed better SGR, PER and FCR ($P < 0.05$) with lower FI.

Richard, N., Costas, B., Machado, M., Fernandez-Boo, S., Girons, A., Dias, J., Corraze, G., Terrier, F., Marchand, Y., Skibba-Cassy, S. (2021). Inclusion of a protein-rich yeast fraction in rainbow trout plant-based diet: Consequences on growth performances, flesh fatty acid profile and health-related parameters. *Aquaculture* **544**, 737132.

Doi: 10.1016/j.aquaculture.2021.737132.

Compared PP diets supplemented with Y and reported increased growth irrespective of 5, 10 or 15% addition to the feed which was associated with a decreased FI and FCR at highest level of incorporation ($P < 0.01$). N retention and body ash levels were increased in the 15% Y diet vs. controls ($P < 0.01$). Plasma lysozyme and peroxidase activity both decreased ($P \leq 0.009$) in 15% Y fed fish which illustrated increased internal intestinal perimeters ($P > 0.03$) together with muc5a and cldn3a both of which are important in the maintenance of intestinal barrier integrity.

Rinchard, J., Lee, K.-J., Dabrowski, K., Ciereszko, A., Blom, J.H., Ottobre, J.S. (2003). Influence of gossypol from dietary cottonseed meal on haematology, reproductive steroids and tissue gossypol enantiomer concentrations in male rainbow trout (*Oncorhynchus mykiss*). *Aquaculture Nutrition*, **9**, 275-282.

Doi: 10.1046/j.1365-2095.2003.00253.x.

Replacing FM with CSM in male trout over 270-d had no effect on growth, HSI, plasma sex steroid levels or sperm indices. However, haemoglobin and hematocrit levels declined ($P < 0.05$). A metabolomics approach was used to characterize the soluble fractions of the IM, Y and PP diets in attempts to isolate those compounds that may have influenced growth performances.

Roques, S., Deborde, C., Richard, N., Sergent, L., Kurz, F., Skiba-Cassy, S., Fauconneau, B., Moing, A. (2018). Characterizing alternative feeds for rainbow trout (*O. mykiss*) by ^1H NMR metabolomics. *Metabolomics*, **14**, 155.

Doi: 10.1007/s11306-018-1454-5.

Evaluated the effect of replacing FM with PP, IM, Y and algal-based products on 50 g trout over 84-d. Wt gain of FM fed fish was on par with that of all other groups but IM and Y diets outperformed the PP feed ($P < 0.05$). The FM diet returned better FCRs ($P < 0.05$)

Roques, S., Deborde, C., Skiba, S., Cala, O., Marchand, Y., Moing, A., Fauconneau, B. (2022). Critical assessment of metabolism and related growth and quality traits in trout fed spirulina-supplemented plant-based diets. *Aquaculture*, **553**, 738033.

Doi: 10.1016/j.aquaculture.2022.738033.

In a wide-ranging study the impact of supplementing PP-based feeds with Spirulina at 5 and 10% were assessed vs. a FM and full PP diet. No differences between groups were recorded for wt gain, SGR or whole-body composition. FI higher in the alternative protein feeds vs FM which also exhibited superior FCR, NRE, K, HSI and VSI ($P \leq 0.05$). PP fed fish had lower MUFA and higher PUFA than the FM group. Metabolomics was employed to assess the impact of dietary ingredients on metabolism related to growth and quality.

Roques, S., Deborde, C., Skiba-Cassy, S., Médale, F., Dupont-Nivet, M., Lefevre, F., Bugeon, J., Labbé, L., Marchand, Y., Moing, A., Fauconneau, B. (2023). New alternative ingredients and genetic selection are the next game changers in rainbow trout nutrition: a metabolomics appraisal. *Scientific Reports*, **13**, 19634.

Doi: 10.1038 /s41598-023-46809-2.

Compared FM and PP diets that also included DHA-rich algae or Spirulina and YE + insect hydrolysate using 49 g trout fed for 84-d. PP based-fish performed less well than fish receiving PP + Spirulina, YE and insect hydrolysate. FI was less in the PP fed fish and FCR higher ($P < 0.05$).

Rosenau, S., Ciulu, M., Reimer, C., Mott, A.C., Tetens, J., Mörlein, D. (2022). Feeding green: Spirulina (*Arthrospira platensis*) induced changes in production performance and quality of salmonid species. *Aquaculture Research* 53, 4276-4287.

Doi: 10.1111/are.15925.

Removed FM and replaced it with Spirulina in a more-or-less identical diet to examine effect on performance of 100 g rainbow trout over 70-d. Wt growth declined ($P < 0.05$) over the trial period for the algal fed fish as did body length and SGR and the fillets had a more intense yellow-orange coloration that were more tender ($P > 0.05$) than that of FM controls.

Ruiz, A., Sanahuja, I., Thorring, N.W., Lynegaard, J., Ntokou, E., Forones, D., Gisbert, E. (2023). Single cell protein from methanotrophic bacteria as an alternative healthy and functional protein source in aquafeeds, a holistic approach in rainbow trout (*Oncorhynchus mykiss*) juveniles. *Aquaculture*, 576, 739861.

Doi: 10.1016/j.aquaculture.2023.739861.

Substituted FM with SCP (methanotrophic bacteria) in isoproteic and isolipidic diets and fed 11 g fish for 83-d. 100% replacement of FM had no effect on growth, SGR, K, HSI, or FI, FCR, gut microbiota and structure or whole-body composition.

Rumsey, G.L., Siwiki, A.K., Anderson, D.P., Bowser, P.R. (1994). Effect of soybean protein on serological response, non-specific defense mechanisms, growth, and protein utilization in rainbow trout. *Veterinary Immunology & Immunopathology*, 41, 323-339.

Doi: 10.1016/0165-2427(94)90105-8.

182-d feeding trial with 2.6 g fish fed either a FM, SPC or SBM-based diet. Wt gain, apparent protein utilization was superior for FM fed trout >SPC> SBM ($P < 0.05$). Soya fed fish expressed increased neutrophil, monocyte and macrophage activity possibly indicating an inflammatory response.

Santigosa, A., Sanchez, J., Médale, F., Kaushik, S.J., Pérez-Sanchez, J., Gallardo, M.A. (2008). Modifications of digestive enzymes in trout (*Oncorhynchus mykiss*) and sea bream (*Sparus aurata*) in response to dietary fish meal replacement by plant protein sources. *Aquaculture*, 282, 68-74.

Doi: 10.1016/j.aquaculture.2008.06.007.

Rainbow trout of 19 g were fed for 84-d with FM or PP-based (CGM, WG, PeM, RSM) diet. FM fed animals were heavier ($P < 0.05$) by trial end. Relative intestinal length increased in fish maintained on the PP feeds.

Sarker, P.K., Kapuchinski, A.R., Vandenberg, G.W., Proulx, E., Sitek, A.J. (2020). Towards sustainable and ocean-friendly aquafeeds: Evaluating a fish-free feed for rainbow trout (*Oncorhynchus mykiss*) using three marine microalgae species. *Elementa Science of the Anthropocene*, 8, 5

Doi: 10.1525/elementa.404.

Replaced the FM component of animal and PP-based (PBM, BM, CVGM, SPC) diets with *Nannochloropsis* sp., *Isochrysis* sp. and *Schizochytrium* sp. and fed the resultant so-nitrogenous, iso-energetic and iso-lipidic feeds to 41 g trout for 84-d. At trial termination, FM fed fish were heavier and had superior SGHR and FCR and higher FI ($P \leq 0.02$). Fillet DHA was alike.

Sarker, P.K., and 12 others (2025). Towards sustainable aquafeeds: Microalgal (*Nannochloropsis* sp. QH25) co-product biomass can fully replace fishmeal in the feeds for rainbow trout (*Oncorhynchus mykiss*). *Scientific Reports*, in review.

Doi: 10.21203/rs.3.rs-5390416/v1.

Using a BM/FM/CGM/SPC/WG-based feed, exchanged FM with algal biomass and ran a 64-d feeding trial at the end of which, there were no differences in any growth parameter examined (wt gain, FCR, SGR, PER, FI, survival). Muscle EAA and presented FA content were, likewise, identical. There were no differences in the cost of formulated diets or economic conversion ratio.

Sayramoğlu, H., Öztürk, R.Ç., Ustaoglu, D., Terzi, Y., Yandi, I., Kayis, S., Capkin, E., Altinok, I. (2023). Effects of black soldier fly meal feeding on rainbow trout gut microbiota, immune-related gene expression, and *Lactococcus petauri* resistance. *Journal of Insects as Food & Feed*, **10**, 141-157. Doi: 10.1163/23524588-20230057.

Replaced dietary FM with BSF meal for a 90-d feeding trial. At study end, treated fish expressed higher diversity of gut microbiota and an increased survival to Lactococcus petaurid challenge.

Schumann, M., Holm, J., Brinker, A. (2022). Effects of feeding an all-plant diet on rainbow trout performance and solid waste characteristics. *Aquaculture Nutrition*, 1694245. Doi: 10.1155/2022/1694245.

Compared differences in waste output and growth between FM and PeM/WG diets, with or without 0.3% guar gum, using 71 g trout over a -d timeframe. All groups of fish had similar wt gain, SGR and FCR. Addition of guar gum had a negative impact on FM protein ADC which, in any event, was still higher than PP fed fish. Fecal stability of FM diets was better ($P < 0.05$).

Sealey, W.M., Hardy, R.W., Barrows, F.T., Pan, Q., Stone, D.A.J. (2011). Evaluation of 100% fish meal substitution with chicken concentrate, protein poultry by-product blend, and chicken and egg concentrate on growth and disease resistance of juvenile rainbow trout, *Oncorhynchus mykiss*. *Journal of the World Aquaculture Society*, **42**, 46-55. Doi: 10.1111/j.1749-7345.2010.00442.x.

Employed various poultry products (chicken concentrate, poultry by-product blend, or chicken and egg concentrate) as replacement for FM and examined growth over 56-d. Both concentrates outperformed ($P < 0.05$) the FM diet = growth of the PB blend.

Segura-Campos, J.M., Trujano-Rodríguez, A.A., Hernández-Hernández, L.H., Macedo-Garzón, B., Cardenas-Reygadas, R. (2021). Inclusion of fructooligosaccharides and mannanoligosaccharides in plant protein-based diets for rainbow trout *Oncorhynchus mykiss* fingerlings and its effects on the growth and blood serum biochemistry. *Hidrobiolgia*, **31**, 163-169. Doi: 10.24275/uam/izt/dcbh/hidro/2021v31n2/Segura.

Formulated diets consisting of RC, SPC, CPC and WG with one containing fructooligosaccharides and another, mannanoligosaccharides at 3% and fed these and a commercial control diet to 1.75 g fish for 60-d. Fish did not differ in wt gain, SGR or FCE although survival was reduced in the MOS group and those from the commercial feed group expressed higher serum triglyceride levels.

Slawski, H. (2011). Rapeseed protein products as fish meal replacement in fish nutrition. Ph.D. dissertation, Christian-Albrechts-Universität zu Kiel, FR Germany. 118 pp. https://www.tierzucht.uni-kiel.de/de/forschung/dissertationen-1/Dissertation_Slawski.pdf. Covers the two following contributions and describes unpublished study on albumin and globulin fractions of RPC on trout growth, but these feeds both contained FM components.

Slawski, H., Adem, H., Tressel, R.-P., Wysujack, K., Koops, U., Kotzamanis, Y., Wuertz, S., Schulz, C. (2012). Total fish meal replacement with rapeseed protein concentrate in diets fed to rainbow trout (*Oncorhynchus mykiss* Walbaum). *Aquaculture International*, **20**, 443-453. Doi: 10.1007/s10499-011-9476-2.

Followed growth of trout fed either a RPC-based PP diet with CM against a FM feed over 84-d. There were no differences in growth or FI, SGR or FCR, but gross protein efficiency was higher in the CPI fed fish ($P < 0.05$). There were no differences in hematological or histological parameters evaluated.

Slawski, H., Nagel, F., Wysujack K., Balke, D.T., Franz, P., Schulz, C. (2013). Total fish meal replacement with canola protein isolate in diets fed to rainbow trout (*Oncorhynchus mykiss* W.). *Aquaculture Nutrition*, **19**, 535-542.

Doi: 10.1111/anu.12005.

Examined the prospect of using CPI as a FM alternative for trout over a 70-d feed trial. 100% replacement of FM had no impact on wt gain, FI, FCR, PER or PPV.

Smith, P. (1976). Evaluation of single-cell protein in trout diets. Ph.D. dissertation, University of Aston in Birmingham, UK, 408 pp.

Snyder, G.S., Gaylord, T.G., Barrows, F.T., Overturf, K., Cain, K.D., Hill, R.A., Hardy, R.W. (2012). Effects of carnosine supplementation to an all-plant protein diet for rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, **338-341**, 72-81.

Doi: 10.1016/j.aquaculture.2011.12.042.

The effect of supplementing an SPI diet with Met, Lys, Thr and Gly, with or without carnosine, was examined against a FM control group fed over 63-d. Wt gain, FCR, PRE, ERE, muscle ratio were poorer in the SPI group compared to the FM fed fish ($P < 0.05$) but similar to all other groups. Differences in total plasma EAA concentrations, favoring the FM fed fish were also noted.

Song, Y., Sun, G., Wei, F., Wu, Z., Tian, H., Meng, Y., Ma, R. (2024). Replacing fishmeal and fish oil with complex protein and canola oil: Effect on organoleptic and nutritional quality of triploid rainbow trout (*Oncorhynchus mykiss*). *Foods*, **13**, 1591.

Doi: 10.3390/foods13111591.

A mixed diet comprising SBM, SPC, CGM, WG, and blood cell powder was used to replace FM. Feeds were fed to 208 g 3n trout for 84-d at which point there were no differences in wt, SGR, K gutted or fillet yields. The FM-free diet fillet had greater hardness and protein levels, but lower lipid ($P < 0.05$). There were differences ($P < 0.05$) in 9 of 19 odor descriptors in mixed diet fillets.

Spinelli, J., Houle, C.R., Wekell, J.C. (1983). The effect of phytates on the growth of rainbow trout (*Salmo gairdneri*) fed purified diets containing varying quantities of calcium and magnesium. *Aquaculture*, **30**, 71-83.

https://d1wqtxts1xzle7.cloudfront.net/52516207/0044-8486_2883_2990153-920170406-3079-1eqhgcu-libre.pdf?1491500894=&response-content-disposition=inline%3B+filename%3DThe_effect_of_phytates_on_the_growth_of.pdf&Expires=1734648223&Signature=PdhukOsYLj1REbxSkI2ckc6L3wAmHEKSEseXcsXxB4noKNf9yuyS04dG4be~kib7Od-QyVq6iwqLspu7g19AbNR1KUnfXM6fiotVgMPytdA13nBoTRCiY0XMq8NSWlgzWzuzisyD6MPDAgoB0UhMnkBCbVQ0fn2UUO3FIZDjdLHW-VDJgBKfHyPRoUqdXDV4ElgeuKsmdLDVaRKUAvmFmiivLeem5n-DCc3DskvlC~K39DuHTYrEb0h-apUbuVaRpLD5C5uVmQiQNgyZyoOanSYAd3ncsuQmOj6c4JGXoPQqmhZApSxIZ2KB1nralUjcdR1aG~dUwzxN9yq-7kQ__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA.

Examined differences in performance of trout fed a 0.5% phytic acid-casein-gelatin diet with and without a Ca-Mg additive for 150-d. Phytic acid reduced wt gain and FCR attributed to formation of casein-phytate complexes.

Staessen, T.W.O., Verdegem, M.C.J., Kolesti, P., Schrama, J.W. (2020). The effect of dietary protein source (fishmeal vs. plant protein) and non-starch polysaccharide level on fat digestibility and faecal bile acid loss in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture Research* **51**, 1170-1181.

Doi: 10.1111/are.14467.

Body wt gain in fish fed a PP (PeP, SPC, WG) vs FM feed was poorer ($P < 0.001$).

Steffens, W. (1987). Further results of complete replacement of fish meal by means of poultry by-products meal in feed for trout fry and fingerling (*Salmo gairdneri*). *Archiv Für Tierernaehrung*, **37**, 1135–1139.

Doi: 10.1080/17450398709428280.

Steffens, W., Richter, H., Golbs, S., Bentz, H., Martin, S., Schleicher, J. (1992). Use of alkane yeast and methanol-grown bacterial biomass as protein sources in the diet of rainbow trout. *Aquaculture*, **100**, 235.

Doi: 10.1016/0044-8486(92)90381-T.

Used a mixture of Y and SCP or SCP alone at 30% supplemented with Met and Lys and compared growth over 70-d. No differences in growth performance, body composition, hematological or histological changes were noted.

Stickney R.R., Hardy, R.W., Koch, K., Harrold, R., Seawright, D., Massee, K.C. (1996) The effects of substituting selected oilseed protein concentrates for fish meal in rainbow trout *Oncorhynchus mykiss* diets. *Journal of the World Aquaculture Society*, **27**, 57–63.

Doi: 10.1111/j.1749-7345.1996.tb00594.x.

Used a SPC to replace FM in isonitrogenous feeds. Over the 70-d trial SPC fed fish had reduced wt gain, and increased FCRs and APD ($P \leq 0.05$).

Tacon, A.J.G., Stafford, E.A., Edwards, E.A. (1983). A preliminary investigation of the nutritive value of three terrestrial lumbricid worms for rainbow trout. *Aquaculture*, **35**, 187–199.

Doi: 10.1016/0044-8486(83)90090-X.

Examined the utility of three species of earthworm – Eisenia foetida, Lumbricus terrestris, and Allolobophora longa, for inclusion in aquafeeds and reported that fish fed diets containing L. terrestris or A. longa grew equally well as trout maintained on the commercial diets. On the other hand, when fed frozen or freeze-dried E. foetida, fish were smaller ($P < 0.05$) and had lower FI.

Tefal, E., Peñaranda, D.S., Martínez-Llorens, S., Tomás-Vidal, A., Jauralde, I., Lagos, L., Moyano, F.J., Jover-Cerdá, M. (2024). Feeding of rainbow trout (*Oncorhynchus mykiss*) with organic ingredients replacing fish meal. *Aquaculture*, **592**, 741257.

Doi: 10.1016/j.aquaculture.2024.741257.

Evaluated a mixture of insect, seabass and pig by-product meals over 150-d using 67 g trout. Animals fed the FM control feed outperformed all others in wt gain, SGR and FCR. Differences in performance characteristics were registered between other groups, including changes in liver and intestinal architecture. On the other hand, gut microbiota remained stable across feed groups.

Terova, G., Gini, E., Gasco, L., Moroni, F., Antonini, M., Rimoldi, S. (2021). Effects of full replacement of dietary fishmeal with insect meal from *Tenebrio molitor* on rainbow trout gut and skin microbiota. *Journal of Animal Science & Biotechnology*, **12**, 30.

Doi: 10.1186/s40104-021-00551-9.

A 154-d feeding trial examined the response of 80 g trout to dietary FM replacement by mealworm larvae meal (see: Chemello et al., 2020 for growth response). The two diets, which were isoenergetic, isonitrogenous and isolipidic, had no major effects on gut microbiota.

Teskeredžić, Z., Higgs, D.A., Dosanjh, B.S., McBride, J.R., Hardy, R.W., Beames, R.M., Jones, J.D., Simell, M., Vaara, T., Bridges, R.M. (1995). Assessment of undephytinized and dephytinized rapeseed protein concentrate as sources of dietary protein for juvenile rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, **131**, 261–277.

Doi: 10.1016/0044-8486(92)90382-U.

Replaced herring meal using dephytinized and undephytinized RPC and fed ~4 g trout for 84-d. FI was similar for the three diets but during the last 21-d of the trial animals fed the RPC increased their feeding

vs. the FM group. At trial end however, the FM diets outperformed the RPC diets in terms of wt gain, FE and protein and energy utilization.

Timalsina, P., Yadav, C.N.R., Lamsal, G.P., Acharya, C.P., Pandit, N.P. (2017). Effect of stocking density and source of animal protein on growth and survival of rainbow trout fingerlings in flow-through system at Nuwakot, Nepal. *Aquaculture Reports*, **8**, 58-64.

Doi: 10.1016/j.aqrep.2017.10.002.

Compared PP diets containing shrimp meal with or without BMA (5%) over 249-d using 2 densities 540 vs. 675). No differences were detected between dietary treatments for SGR, FCR, PER or K. High stocking density reduced survival ($P < 0.05$).

Toledo-Solís, F.J., Larrán, A.M., Ortiz-Delgado, J.B., Sarasquete, C., Dias, J., Morais, S., Fernández, I. (2023). Specific blood plasma circulating miRs are associated with the physiological impact of total fish meal replacement with soybean meal in diets for rainbow trout (*Oncorhynchus mykiss*). *Biology*, **12**, 937.

Doi: 10.3390/biology12070937.

A FM-free diet (SPC, WG, CG, SBM, RSM, WM) was fed to young (23 g) rainbow trout for 63-d and gauged against a FM-based diet. The only difference recorded between groups was that for VSI and whole-body fat which were elevated in the PP fed fish.

Tusche, K. (2012). Optimized use of potato protein concentrates in organic aquaculture diets for rainbow trout (*Oncorhynchus mykiss*). Ph.D. dissertation, Christian-Albrechts-Universität zu Kiel, Germany, 105 pp.

[https://macau.uni-kiel.de/servlets/MCRFileNodeServlet/dissertation_derivate_00004303/Diss Tusche_2012.pdf](https://macau.uni-kiel.de/servlets/MCRFileNodeServlet/dissertation_derivate_00004303/Diss_Tusche_2012.pdf)

Tusche, K., Nagel, F., Arning, S., Wuertz, S., Susenbeth, A., Schulz, C. (2013). Effect of different dietary levels of potato protein concentrate supplemented with feed attractants on growth performance of rainbow trout (*Oncorhynchus mykiss*). *Animal Feed Science & Technology*, **183**, 202-209.

Doi: 10.1016/j.anifeedsci.2013.05.005.

In isonitrogenous and isoenergetic BM/PP feeds, FM was replaced with PPC and responses of trout evaluated over 56-d. Fish had similar FI, HSI and K at trial end but the PPC group weighed less, had a poorer SGR, FCR, PER and PPV and lower whole-body ash ($P < 0.05$).

Uslu, A.A., Özel, O.T., Örnekeçi, G.N., Çelik, B., Çankiriligil, E.C., Coşkun, I., Şenel, G.U. (2023). Insect larval meal as a possible alternative to fish meal in rainbow trout (*Oncorhynchus mykiss*) diets: Black soldier fly (*Hermetia illucens*), mealworm (*Tenebrio molitor*). *Journal of Limnology & Freshwater Fisheries Research*, **9**, 43-52.

Doi: 10.17216/limnofish.1081945.

Evaluated replacement of FM with black soldier fly or mealworm larval meals. Both feeds returned inferior performance in terms of FI, wt gain and SGR ($P < 0.05$). FCR was poorest for trout fed the mealworm diet which also expressed higher intestinal fold height and width ($P < 0.01$).

Vale Pereira, G., Conceição, L.E.C., Soares, F., Petereit, J., Buck, B.H., Johansen, J., Dias, J., Faccenda, F. (2023). Alternative feed formulations impact growth performance, flesh quality and consumer acceptance of rainbow trout (*Oncorhynchus mykiss*). *Journal of Marine Science & Engineering*, **11**, 1135.

Doi: 10.3390/jmse11061135.

Employed a variety of processed animal proteins and by-products and compared growth performance against a FM control feed. After 91-d, all diets with test ingredients equaled or exceeded the growth registered for the control group.

Vandeputte, M., Corraze, G., Doerflinger, J., Enez, F., Clota, F., Terrier, F., Horat, M., Larroquet, L., Petit, V., Haffray, P., Skiba-Cassy, S., Dupont-Nivet, M. (2022). Realised genetic gains on growth, survival, feed conversion ratio and quality traits after ten generations of multi-trait selection in rainbow trout *Oncorhynchus mykiss*, fed a standard diet or a “future” fish-free and soy-free diet. *Aquaculture Reports*, **27**, 101363.

Doi: 10.1016/j.aqrep.2022.101363.

In this valuable contribution, selected and control strains of trout were fed a commercial feed until 250-dph at which point selected fish were heavier ($P < 0.001$). From 264 dph onwards, fish were fed either a standard diet or a mixed PP feed (WW, PPC, SPC, CG, WG, Y, algal biomass, APC) and by trial end, 374 dph, selected fish retained their wt advantage irrespective of diet. Control fish required an additional 42-d to attain wt equality. Differences were noted in processing traits between strains and feeds.

Vélez-Calabria, G., Peñaranda, D.S., Jover-Cerdá, M., Llorens, S.M., Tomás-Vidal, A. (2021). Successful inclusion of high vegetable protein sources in feed for rainbow trout without decrement in intestinal health. *Animals*, **11**, 3577.

Doi: 10.3390/ani11123577.

A PP diet (WM, WGM, SBM,) was compared against a FM formula for 70-d. Fish in the PP group were smaller had lower survival, SGR and PER ($P < 0.05$) and higher FI and FCR. The proximal intestine of PP fed fish had greater fold thickness, thicker lamina propria and lower number of goblet cells ($P < 0.05$). There was no difference in gut architecture for the distal gut.

Velichkova, K., Sirakov, I., Stoyanova, S., Simitchiev, A., Yovchev, D., Stamatova-Yovcheva, K. (2024). Effect of replacing fishmeal with algal meal on growth parameters and meat composition in rainbow trout (*Oncorhynchus mykiss* W.). *Fishes*, **9**, 249.

Doi: 10.3390/fishes9070249.

Assessed the impact of an SBM-algal-based diet on growth and composition of fish of starting wt ~24 g over 60-d. Wt gain, survival, SGR and FCR were similar ($P > 0.05$) as too was the morphology of the intestine and body composition. The liver, however, appeared to have larger fat droplets in the algal diet fish.

Venold, F.F., Penn, M.H., Krogdahl, A., Overturf, K. (2012). Severity of soybean meal induced distal intestinal inflammation, enterocyte proliferation rate, and fatty acid binding protein (Fabp2) level differ between strains of rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, **364-365**, 281-292.

Doi: 10.1016/j.aquaculture.2012.08.035.

Evaluated a BM, WG, CG and SBM feed fed to a selected and non-selected strain of rainbow trout for 60-d, starting at 5 g against a FM-BM diet. Growth of non-selected fish on the PP diet was poorer whereas FCR did not differ. Distal intestinal morphology changed most significantly for intra epithelial leucocyte frequency which was highest in non-selected fish fed PP. The same fish also had more goblet cells whereas selected animals expressed a higher degree of supranuclear vacuoles when fed the PP diet ($P < 0.002$).

Véron, V., Panserat, S., Le Boucher, R., Labbé, L., Quillet, E., Dupont-Nivet, M., Médale, F. (2016). Long-term feeding a plant-based diet devoid of marine ingredients strongly affects certain key metabolic enzymes in the rainbow trout liver. *Fish Physiology & Biochemistry*, **42**, 771-785.

Doi: 10.1007/s10695-015-0174-21.

PP diet (SBM, WG, WLM, PeM) compared against FM feed. Trout fed the PP diet expressed increased wt gain, SGR, FI, FE. Plasma cholesterol and triglyceride levels were depressed in PP-fed fish ($P < 0.05$). Hepatic glutamate dehydrogenase gene expression was induced by the plant-based diet signifying AA imbalance linked to decreased protein retention.

Vilhelmsson, O.T., Martin, S.A.M., Medale, F., Kaushik, S.J., Houlihan, D.F. (2004). Dietary plant protein substitution affects hepatic metabolism in rainbow trout. *British Journal of Nutrition*, **92**, 71-80.

Doi: 10.1079/BJN20041176.

Reported decrease wt gain, SGR, PER and FE ($P < 0.05$) in fish fed PP diets after 84-d trial and changes in hepatic gene expression.

Wacyk, J., Powell, M., Rodnick, K., Overturf, K., Hill, R.A., Hardy, R.W. (2012). Dietary protein source significantly alters growth performance, plasma variables and hepatic gene expression in rainbow trout (*Oncorhynchus mykiss*) fed amino acid balanced diets. *Aquaculture*, **356-357**, 223-234.

Doi: 10.1016/j.aquaculture.2012.05.013.

Assessed isonitrogenous, isolipidic and isocaloric PP and FM-based diets in which supplies of EAAs were provided to balance dietary availability. FM-based diets outperformed PP feeds in terms of wt gain, FCR, and PRE ($P < 0.001$) and had higher whole-body lipid levels. SPI-based diets reduced hepatic expression of got2, alt1, gls02, redd-1, and asns when compared against FM diets.

Watanabe, T., Verakunpiriya, V., Watanabe, K., Viswanath, K., Satoh, S. (1997). Feeding of rainbow trout with non-fish meal diets. *Fisheries Science*, **63**, 258-266.

Doi: 10.2331/fishsci.63.258.

Evaluated 9 different dietary formulations containing alternative animal and PPs against a FM-based feed. All except two diets with excessive EAA supplementation performed equally to that of the FM group.

Welker, T.L., Overturf, K. (2023). Effect of dietary soy protein source on effluent water quality and growth performance of rainbow trout reared in a serial reuse water system. *Animals*, **13**, 3090.

Doi: 10.3390/ani13193090.

Compared mixes of SBM, SPC, fSBM with PBM vs. FM over 84-d. Wt gain and FCR was poorest for the SBM group with all others performing equally.

Welker, T., Barrows, F.T., Overturf, K., Gaylord, G., Sealey, W. (2016). Optimizing zinc supplementation levels of rainbow trout (*Oncorhynchus mykiss*) fed practical type fishmeal- and plant-based diets. *Aquaculture Nutrition*, **22**, 91-108.

Doi: 10.1111/anu.12232.

Evaluated the impact of dietary addition of Zn (0-120 mg kg⁻¹) on PP and FM-based feeds. Wt gain was lower in PP fed fish, irrespective of Zn supplementation although there was a dose-related increase in wt gain and FI up to 30 mg kg⁻¹ and decrease in FCR. Zn addition had no impact on growth of control FM fed trout.

Welker, T.L., Overturf, K., Abernathy, J., Barrows, F.T., Gaylord, T.G. (2018). Optimization of dietary manganese for rainbow trout, *Oncorhynchus mykiss*, fed a plant-based diet. *Journal of the World Aquaculture Society*, **49**, 71-82.

Doi: 10.1111/jwas.12447.

Examined the effect of supplementing PP diet with Mn over a 84-d trial. Fish given 2-8 mg Mn kg⁻¹ of diet expressed better growth while FCRs decreased with increasing dietary up to 8 mg kg⁻¹ dietary Mn. PERs and FI did not differ between groups

Wischusen, P., Heraud, C., Broughton, R., Surget, A., Lanuque, A., Terrier, F., Fontagné-Dicharry, S., Betancor, M.B. (2024). Vitamin B6 and selenium supplementation induce contrasting effects in the transsulfuration pathway of juvenile rainbow trout (*Oncorhynchus mykiss*) with interactive effects in stressed fish. *Aquaculture*, **593**, 741354.

Doi: 10.1016/j.aquaculture.2024.741354.

PP diets were supplemented with Se and Vit. B6 and fed to ~28 g trout for 84-d and growth performance evaluated. No differences were observed between groups for and growth parameter except increased FI for diets with Se+ and HSI for those in receipt of the B6+ feeds. Se addition increased expression of hepatic gpx which was associated with increased GPX activity.

Wong, S., Waldrop, T., Summerfelt, S., Davidson, J., Barrows, F., Kenney, P.B., Welch, T., Wiens, G.D., Snekvik, K., Rawls, J.F., Good, C. (2013). Aquacultured rainbow trout (*Oncorhynchus mykiss*) possess a large core intestinal microbiota that is resistant to variation in diet and rearing density. *Applied Environmental Microbiology*, **79**, 4974-4984.

Doi: 10.1128/AEM.00924-13.

Used a FM and PP-based (SPC, CGM, WGM) feed for ~310-d trout were held at high and low densities. There were no differences between density treatments, but FM fed trout were heavier than the PP trout ($P < 0.05$) while PP fed fish had greater FE and higher overall survival and dress yield. Only minor differences were apparent between groups with respect to gut microbiota.

Xie, S., Jokumsen, A. (1997). Replacement of fish meal by potato protein concentrate in diets for rainbow trout, *Oncorhynchus mykiss* (Walbaum): growth, feed utilization and body composition. *Aquaculture Nutrition*, **3**, 65-69.

Doi: 10.1046/j.1365-2095.1997.00074.x.

Evaluated PPC as an alternative to FM but at 100% substitution wt gain, SGR, mortality, FE, K, PER and PPV were startlingly inferior.

Yamamoto, T., Shima, T., Furuita, H., Suzuki, N. (2002). Influence of feeding diets with and without fish meal by hand and by self-feeders on feed intake, growth and nutrient utilization of juvenile rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, **214**, 289-305.

Doi: 10.1016/S0044-8486(02)00035-2.

Examined the effect of including EAAs to a diet based on SBM, CGM and MBM to mimic the composition of a FM diet. Responses were examined against an unsupplemented alternate protein feed. The trial lasted 60-d and at termination FM and EAA supplemented diet groups were similar for FI, wt gain, PER and composition when compared against the unsupplemented group ($P \leq 0.03$).

Yamamoto, T., Kuramoto, H., Furuita, H., Suzuki, N., Kohbara, J. (2003). The effectiveness of defatted soybean meal and corn gluten meal based non-fish meal diets for fingerling rainbow trout, *Oncorhynchus mykiss* [in Japanese]. *Suisanzoshoku*, **51**, 211-217.

Doi: 10.11233/aquaculturesci1953.51.211.

Tested 5 diets with 2 being PP-based (SBM, CGM, WF +/- Tau) and 3 that were based on MBM at 10, 20 and 30% against a FM control over 70-d. No differences recorded between any dietary group.

Yamamoto, T., Goto, T., Tanaka, N., Furuita, H., Sugita, T., Suzuki, N. (2007). Supplemental effects of essential amino acids and bile salts to a high-fat diet containing soybean meal, corn gluten meal and squid meal for rainbow trout *Oncorhynchus mykiss*. *Aquaculture Science*, **55**, 115-123.

Doi: 10.11233/aquaculturesci1953.55.115.

Employed SM and KM in PP-feeds (SBM, CGM) and compared against a FM diet. The SM/KM feed were supplemented with bile salts, or Asp/Glu, or remained unsupplemented. No differences in growth or SGR but FI and FE was poorer ($P < 0.03$) for all test diets. Whole body protein was higher and crude fat lower ($P < 0.001$) in FM fed trout.

Yamamoto, T., Iwashita, Y., Matsunari, H., Sugita, T., Furuita, H., Akimoto, A., Okamatsu, K., Suzuki, N. (2010). Influence of fermentation conditions for soybean meal in a non-fish meal diet on the growth performance and physiological condition of rainbow trout *Oncorhynchus mykiss*. *Aquaculture*, **309**, 173-180.

Doi: 10.1016/j.aquaculture.2010.09.021.

Compared two different fSBMs (fermented for 7 or 10-h) against FM and SBM feeds containing CGM for 70-d. FM and 10-h fSBM expressed better growth and SGRs ($P < 0.05$) than the other diets, FI was greater in FM-based fed fish. Whole-body composition did not differ between groups nor did plasma Glu, Ca, P, protein and triacylglycerol levels. Diet did not influence the histological features of the kidney, but the size of hepatic nuclei was larger in fSBM 10-h fed fish=FM=fSBM 7-h>SBM ($P < 0.01$). The distal

intestine did not differ between FM and fSBM fish, but structural alterations were evident in animals receiving SBM and fSBM 7-h. The study illustrates the benefit of longer fermentation of SBM on trout growth and health.

Yamamoto, T., Matsunari, H., Sugita, T., Furuita, H., Masumoto, T., Iwashita, Y., Amano, S., Suzuki, N. (2012). Optimization of the supplemental essential amino acids to a fish meal-free diet based on fermented soybean meal for rainbow trout *Oncorhynchus mykiss*. *Fisheries Science*, **78**, 359–366.

Doi: 10.1007/s12562-011-0456-2.

Examined the effect of supplementing a diet based on fSBM and CGM with EAAs and compared this with SBM, fSBM and FM fed trout after 70-d. Differences in wt gain SGR, FE, N retention was of the order FM>fSBM+EAAs>SBM=fSBM ($P < 0.05$). FI was highest for fSBM + EAAs. Plasma Glu, Ca, P, protein and triacylglycerol levels were identical for all diets. Only SBM caused structural changes in the distal intestine.

Yandi, I., Öztürk, R.Ç., Terzi, Y., Kayis, S., Altinok, I. (2023). Effects of chicken waste meal and vegetable substrate fed black soldier fly prepupae meal on rainbow trout (*Oncorhynchus mykiss*), *Journal of Insects as Food & Feed*, **9**, 427-439.

Doi: 10.3920/JIFF2022.0077.

Using BSF prepupae meal to replace FM, reduced growth, SGR, FCR. Differences were seen in goblet cell numbers in both proximal and distal intestine ($P < 0.05$).

Yanik, T., Dabrowski, K., Bai, S.C. (2003). Replacing fish meal in rainbow trout (*Oncorhynchus mykiss*) diets. *Bamidgeh*, **55**, 179-186.

Doi:

A diet incorporating MBM, BM, PBM, FM, CGM, Y, SBM was compared against a control FM (20%), CGM, Y, SBM group over 70-d @ 10 °C. No differences were recorded for wt gain, FCR or survival.

Yoshitomi, B., Aoki, M., Oshima, S.-I. (2007). Effect of total replacement of dietary fish meal by low fluoride krill (*Euphausia superba*) meal on growth performance of rainbow trout (*Oncorhynchus mykiss*) in fresh water. *Aquaculture*, **266**, 219-225.

Doi: 10.1016/j.aquaculture.2006.12.043.

Replaced FM with low fluoride KM and fed 4 g trout for 95-d at which point there was no difference in wt gain, FI, HSI or survival. A potential indicator of this trial is that KM does not act as a palatant.

Zamani, A., Khajavi, M., Nazarpak, M.H., Gisbert, E. (2020). Evaluation of a bacterial single-cell protein in compound diets for rainbow trout (*Oncorhynchus mykiss*) fry as an alternative protein source. *Animals*, **10**, 1676.

Doi: 10.3390/ani10091676.

Contrasted the effects of isonitrogenous (45.6% CP), isolipidic (21.5% CL) and isoenergetic, predominantly bacterial mixed diet (SCP, CPC, SBM, MBM, CGM, WF), against a FM-based feed. The SCP fed fish returned inferior growth, SGR, FCR, FI, K, PER and LER ($P < 0.05$).

Zamani, A., Khalaji, S. (2024). The evaluation of bacterial single cell protein on performance, digestive enzymes activity, gut histology and gut microbiota of rainbow trout (*Oncorhynchus mykiss*) fry [in Arabic]. *Tarbiat Modares University Journal of Fisheries Science & Technology*, **13**, 398-411.

<http://jfst.modares.ac.ir/article-6-72431-en.html>.

Replaced FM with SCP and examined growth of trout fry (2.5 g) over 42-d. SCP diet returned highest FCRs ($P < 0.05$). Differences were apparent in intestinal fold height between diets.

Zhang, Y., Øverland, M., Shearer, K.D., Sørensen, M., Mydland, L.T., Storebakken, T. (2012). Optimizing plant protein combinations in fish meal-free diets for rainbow trout (*Oncorhynchus mykiss*) by a mixture model. *Aquaculture*, **360-361**, 25-36.

Doi: 10.1016/j.aquaculture.2012.07.003.

Related the performance impact of various PP concentrate- (PePC, PPC, SPC, RPC) based diets and their mixes, each incorporating KM as a tentative palatant and EAA supplementations, against a FM feed, fed to rainbow trout for 72-d. FI was either the same or higher (CPC, SPC; $P < 0.02$) than that for FM with wt gain being similar across all diets. FCRs differed with diet in the order: FM=(PPC+RPC= PePC+PPC SPC+RPC)= all other concentrate mixes=CPC and SPC. Plasma P was elevated ($P < 0.001$) in FM fed trout

Zhang, C., Hu, L., Hao, J., Cai, W., Qin, M., Gao, Q., Nie, M., Qi, D., Ma, R. (2023). Effects of plant-derived protein and rapeseed oil on growth performance and gut microbiomes in rainbow trout. *BMC Microbiology*, **23**, 255.

Doi: 10.1186/s12866-023-02998-4.

In a comprehensive study of changes in gut microbiota, the effect of substituting 100% FM with a SBM, SPC, CGM, WG, CSPP, WM mix was examined. Diet had no impact on growth but affected the abundance and diversity of intestinal bacterial and fungal species.

Zhu, T., Corraze, G., Plagnes-Juan, E., Quillet, E., Dupont-Nivet, M., Skiba-Cassy, S. (2018). Regulation of genes related to cholesterol metabolism in rainbow trout (*Oncorhynchus mykiss*) fed a plant-based diet. *American Journal of Physiology: Regulatory, Integrative & Comparative Physiology*, 314, R58–R70.

Doi: 10.1152/ajpregu.00179.2017.

Compared response of PP selected and non-selected trout fed isonitrogenous, isolipidic, and isoenergetic PP (CG, WG, SBM, SPC, WLM, PeM) or FM-based diets over 184-d. FI and FE and body composition did not differ. HSI was lower and VSI higher ($P < 0.01$) in PP fed trout.

Zhu, T., Corraze, G., Plagnes-Juan, E., Montfort, J., Bobe, J., Quillet, E., Dupont-Nivet, M., Skiba-Cassy, S. (2019). MicroRNAs related to cholesterol metabolism affected by vegetable diet in rainbow trout (*Oncorhynchus mykiss*) from control and selected lines. *Aquaculture*, **498**, 132-14.

Doi: 10.1016/j.aquaculture.2018.08.058.

See Zhu et al. (2018) for diets. Compared response of PP selected and non-selected trout fed PP or FM-based diets over 180-d. At trial end selected fish were heavier irrespective of diet fed ($P < 0.001$). Selection for ability to grow on PP diets, therefore, was dual: growth and diet related.

