Utilization of feed resources in the production of Atlantic salmon and rainbow trout in Norway in 2020

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The utilization of feed resources in Norwegian production of salmon has previously been presented for 2010, 2012, 2013 (partly) and 2016 (Aas *et al.*, 2019, Ytrestøyl *et al.*, 2015). This is an update for 2020. In addition, the corresponding estimates for utilization of feed resources in Norwegian production of rainbow trout are presented for the first time.

The data are based on public data on production volumes, collected and analyzed samples of salmon and rainbow trout of slaughter size, and data on feed ingredients used provided by the feed companies BioMar AS, Cargill, MOWI ASA and Skretting AS.

The utilization of feed resources is estimated for the whole production of salmon and trout in Norway during one year. The calculations included all losses of feed ingredients, feed and fish. The data should not be compared directly to results obtained in controlled studies or in a small production of limited time.

Feed ingredients used in 2020

An overview of the ingredients used for production of feed for Atlantic salmon and rainbow trout is shown in Table 1, Table 2 and Figure 1. The composition of salmon feed in 2020 was similar to the feed used in 2016. Compared to 2016, the production volume of salmon has increased somewhat, and the amount of ingredients used increased correspondingly. Some novel ingredients, such as insect meal and micro algae, were used. These contributed in sum to 0.4 % of the ingredients used in salmon feed.

Atlantic salmon:

Feed ingredients used: 1,976 709 tons
Salmon produced: 1,467 655 tons

Rainbow trout:

Feed ingredients used: 116,990 tons
Trout produced: 89,667 tons

The resource utilization in production of rainbow trout was estimated for the first time, and there are no detailed data from previous years to compare with. The composition of trout feed resembled that of salmon feed.

Some farmers use salmon feed for production of trout, which results in an underestimation of the utilization of salmon feed and overestimates the utilization of trout feed. The production of trout is very small compared to the salmon production, and the error in estimates of the utilization of salmon feed caused by using some of the salmon feed for trout production is very small.

Table 1. Type of ingredients, given as tons and % of feed, used for production of feed for salmon and trout in 2020.

	Salmon feed		Trout feed	
Type of ingredient	**Ton**	**%**	**Ton**	**%**
Vegetable protein sources	800 266	40,5	46 401	39,7
Vegetable oils	397 793	20,1	23 251	19,9
Carbohydrate sources	247 039	12,5	14 195	12,1
Marine protein sources	239 710	12,1	15 712	13,4
Marine oils [1]	203 598	10,3	12 652	10,8
Other [2]	8 126	0,4	257	0,2
Micro ingredients	80 177	4,1	4 522	3,9
Sum	**1 976 709**	**100**	**116 990**	**100**

[1] Includes 4.531 tons of oil from trimmings from farmed fish used in salmon feed (0 in trout feed).

[2] Insect meal, single cell protein, fermented products, micro algae

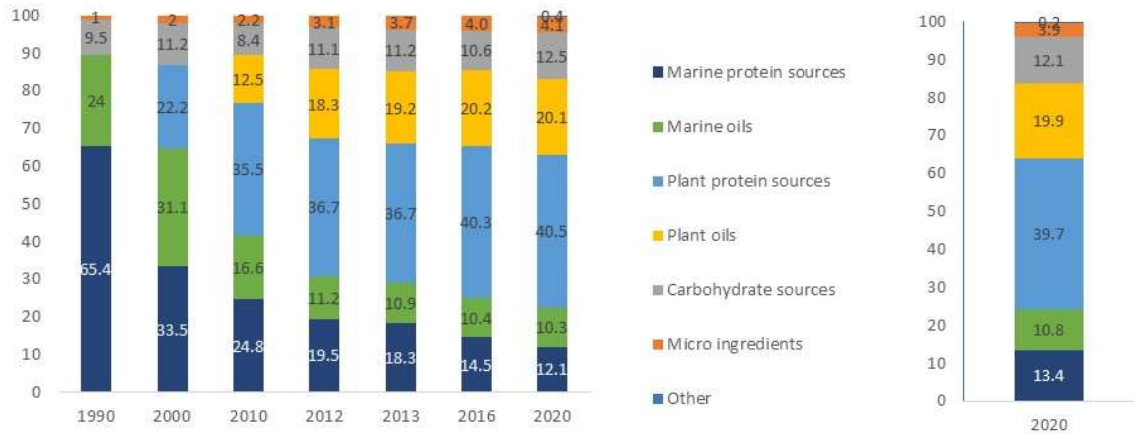

Figure 1. Ingredient sources (% of feed) in Norwegian salmon feed in 1990 – 2020 at left (Ytrestøyl et al., 2015, Aas et al., 2019). Ingredient sources (% of feed) in Norwegian trout feed in 2020 at right.

Table 2. Ingredients used, given as ton and %, for production of feed for Atlantic salmon and rainbow trout in 2020.

		Salmon feed		Trout feed	
	Ingredient	**Ton**	**%**	**Ton**	**%**
Vegetable	Soy protein concentrate	413 611	20.9	23 458	20.1
protein sources	Wheat gluden	193 904	9.8	11 413	9.8
	Guar protein	84 677	4.3	6 018	5.1
	Sunflower	67 798	3.4	3 837	3.3
	Pea protein	27 306	1.4	1 686	1.4
	Corn gluten	12 971	0.7		
Vegetable	Rapeseed oil	356 499	18.0	21 684	18.5
oils	Linseed oil	25 874	1.3	741	0.6
	Soy oil	7 392	0.4	180	0.2
	Camelina oil	7 022	0.4	538	0.5
	Coconut oil	1 006	0.1	108	0.1
Carbohydrate	Wheat	127 878	6.5	10 002	8.5
sources	Faba beans	70 568	3.6	3 111	2.7
	Pea flower	48 592	2.5	1 070	0.9
Marine protein sources	Marine protein, forage fish	174 172	8.8	11 078	9.5
	Marine protein, trimmings	65 539	3.3	4 634	4.0
Marine oils	Marine oil, forage fish	164 611	8.3	9 824	8.4
	Marine oil, trimmings	38 986	2.0	2 828	2.4
Other	Other [1]	8 126	0.4	257	0.2
Micro ingredients	Micro ingredients [2]	80 177	4.1	4 522	3.9
	Sum	**1 976 709**	**100**	**116 990**	**100**

[1] Includes insect meal, single cell protein, fermented products, micro algae

[2] Includes vitamin and mineral premixes, crystalline amino acids, astaxanthin etc.

Origin of the feed ingredients

The origin of marine ingredients is given as FAO main fishing areas and vegetable ingredients were given as country or geographic area (https://www.fao.org/fishery/en/area/search). Norwegian ingredients, which are fish meal and fish oil, is included in FAO fishing area 27. The FAO fishing area 27 was the dominating origin for marine ingredients, and Europe, Brazil (soy) and Russia were the dominating producers of plant ingredients (Figure 2).

Ingredients of Norwegian origin constituted 8 % of the ingredients for salmon feed, and 9% of the ingredients used for trout feed.

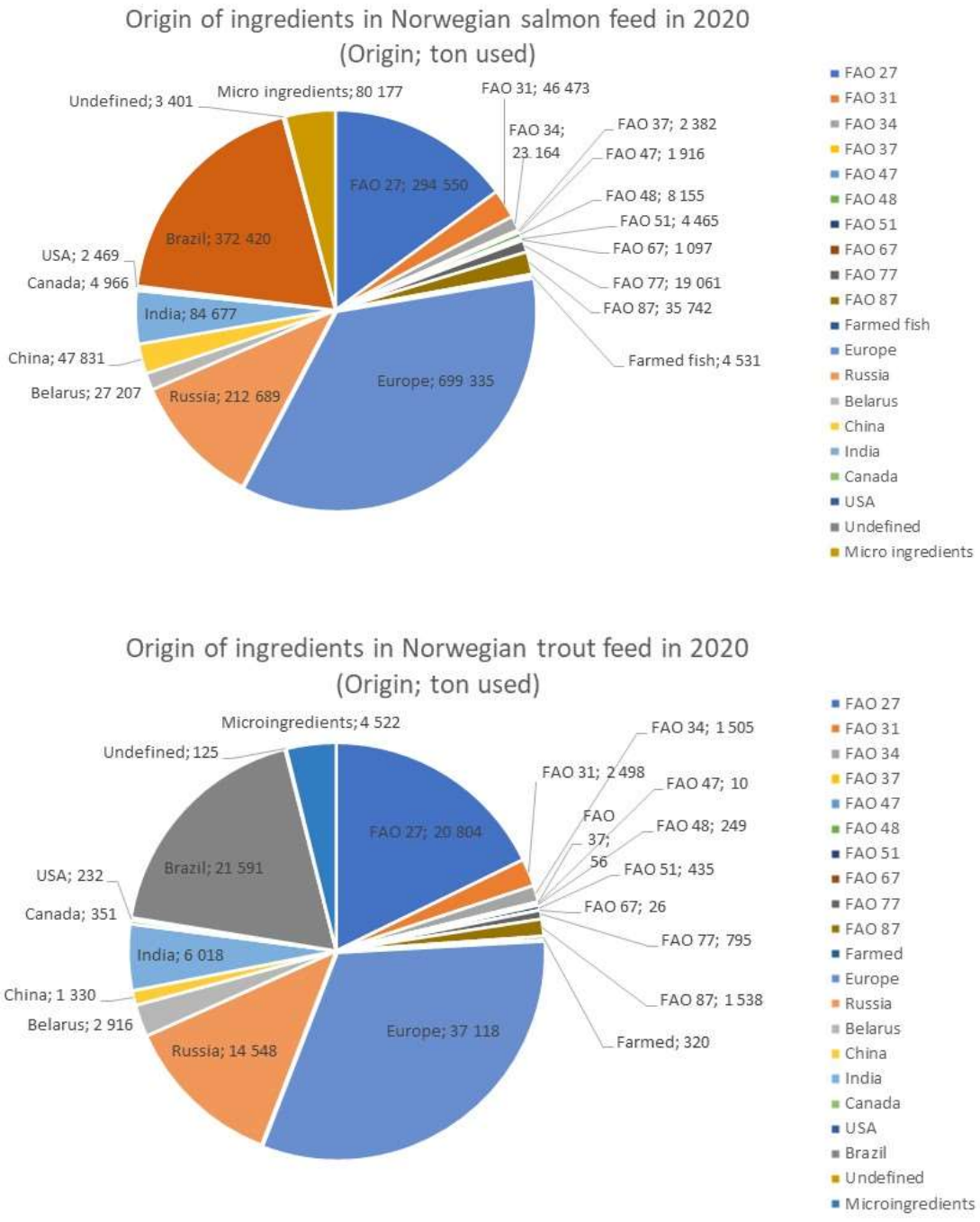

Figure 2. Origin of the ingredients used in Norwegian salmon feed (upper panel) and trout feed (lower panel) in 2020. Origin of marine ingredients are given as FOA main fishing areas. Norwegian ingredients, which are fish meal and fish oil, are included in ingredients from FAO fishing area 27. Fish oil produced from trimmings from farmed fish is given separately (Norwegian).

Certified ingredients

The majority of the marine ingredients used for both salmon feed and trout feed was certified by at least one certification system (Table 3, Table 4). All soy was non-GM certified.

Table 3. Amount (%) of ingredients used for salmon feed that are certified. One ingredient can be certified by more than one certification system, and the amount certified by the different systems can therefore not be summed.

	Marine trust	**MSC**	**Marine trust FIP**	**MSC FIP**	**Non GM certified**	**Non GM (not certified)** [1]
Marine protein, forage fish	68	80	13			
Marine oil, forage fish	63	45	32	5		
Marine protein, trimmings	86	86	7			
Marine oil, trimmings	69	61	3			
Vegetable protein sources					52	33
Vegetable oils						53
Carbohydrate sources						52
Other [2]						22
Micro ingredients						36

[1] Non-GM was not given by all feed producers if the ingredient was not certified. The real figures for non-GM ingredients without certification is higher than shown in the table.

[2] Includes insect meal, single cell protein, fermented products and micro algae.

Table 4. Amount (%) of ingredients used for trout feed that are certified. One ingredient can be certified by more than one certification system, and the amount certified by the different systems can therefore not be summed.

	Marine Trust	**MSC**	**Marine trust FIP**	**MSC FIP**	**Non GM certified**	**Non GM (not certified)** [1]
Marine protein, forage fish	66	85	0			
Marine oil, forage fish	61	45	18	9		
Marine protein, trimmings	88	88	0			
Marine oil, trimmings	73	64	0			
Vegetable protein sources					51	26
Vegetable oils						58
Carbohydrate sources						58
Other [2]						75
Micro ingredients						69

[1] Non-GM was not given by all feed producers if the ingredient was not certified. The real figures for non-GM ingredients without certification is higher than shown in the table.

[2] Includes insect meal, single cell protein, fermented products and micro algae.

Chemical composition of whole body and fillet of salmon and trout in 2020

Samples for chemical analysis of Atlantic salmon were collected at one location in the south of Norway, to location of the mid part of Norway, and one location in the north of Norway. The samples were collected at early summer and at late autumn. At each sampling, ten fish for whole body analysis and ten fish for fillet analysis were collected. The mean weight of the sampled salmon was 5.3 kg.

Samples for rainbow trout were collected in the same way as salmon samples, except these were sampled only at two locations. One location was in Hordaland, and one in Sogn and Fjordane. The mean weight of sampled trout was 4.4 kg for trout for whole body analysis and 4.1 kg for trout for fillet analysis.

Table 5. Chemical composition of whole body and fillet of Atlantic salmon and rainbow trout produced in Norway in 2020.

	Salmon whole body	**Salmon fillet**	**Trout whole body**	**Trout fillet**
Dry matter, %	41.7 ± 0.15	41.3 ± 0.32	45.2 ± 0.98	41.8 ± 0.53
Energy, MJ/kg	12.9 ± 0.1	12.7 ± 0.1	14.0 ± 0.4	13.0 ± 0.1
Ash, %	2.0 ± 0.1	1.9 ± 0.1	1.9 ± 0.2	1.8 ± 0.3
Lipid, %	22.9 ± 0.3	21.3 ± 0.5	26.3 ± 1.7	22.8 ± 0.8
Sum EPA+DHA	1.5 ± 0.1	1.5 ± 0.1	1.6 ± 0.2	1.5 ± 0.1
Sum n-3 fatty acids	2.6 ± 0.2	2.5 ± 0.2	2.9 ± 0.7	2.6 ± 0.5
Sum n-6 fatty acids	3.3 ± 0.1	3.1 ± 0.1	3.9 ± 0.2	3.5 ± 0.1
Sum saturated fatty acids	3.0 ± 0.1	2.9 ± 0.1	3.5 ± 0.5	3.1 ± 0.3
Ratio n-6/n-3	1.4 ± 0.1	1.3 ± 0.1	1.6 ± 0.3	1.5 ± 0.3
Protein, % [1]	16.8 ± 0.1	18.8 ± 0.3	16.1 ± 0.3	18.4 ± 0.5
Phosphorus, mg/kg	3 137 ± 58	2 406 ± 67	3 291 ± 242	2 211 ± 97

[1] N x 6.25

Economic feed conversion ratio, FCR_e

The FCR_e for salmon was 1.35, 1.25 or 1.28, depending on if it was calculated for feed ingredients 'as is', feed ingredients on dry matter basis, or on traded feed, respectively.

The corresponding estimates of FCR_e for trout was 1.30, 1.21 or 1.44, respectively.

$$FCR_e = \frac{\text{Feed used (ton)}}{\text{Fish produced (ton)}}$$

Retention of nutrients and energy

The retention is an estimate of the amount (%) of nutrients and energy from the feed that is retained in the fish. In fish nutrition, it is estimated from the amount of feed eaten. In this case, it includes all losses of feed and fish. Also, the fish can produce lipids from non-lipid precursors. The estimated lipid retention is thus the net amount of lipid obtained from the feed that is used. The estimates of retention used here can be referred to as 'apparent retention'.

The retention data of trout (Table 7) is somewhat overestimated due to some trout farmers using salmon feed for trout production. The volume of trout production is 6 % of the volume of salmon production, and some use of salmon feed for trout production has very little impact on estimates on feed utilization in salmon.

Formla for calculation of retention is shown in Aas *et al*. (2019; open access).

Table 6. Retention (%) of nutrients and energy in whole body, fille and trimmings, and the amount not retained (loss) in salmon produced in 2020.

	Retention in whole body	**Retention in fillet**	**Retention in trimmings [1]**	**Not retained - loss [2]**
Dry matter	33	21	12	67
Energy	39	25	14	61
Protein	34	25	9	66
Lipids [3]	57	35	23	43
EPA+DHA	49	32	17	51
Phosphorus	25	12	12	75

[1] Retention in whole body (%) – retention in fillet (%)

[2] 100 (%) – retention in whole body (%)

[3] Includes lipids synthesized from non-lipid precursors

Table 7. Retention (%) of nutrients and energy in whole body, fille and trimmings, and the amount not retained (loss) in trout produced in 2020.

	Retention in whole body	**Retention in fillet**	**Retention in trimmings [1]**	**Not retained - loss [2]**
Dry matter	37	21	16	63
Energy	43	25	18	57
Protein	33	23	10	67
Lipids [3]	63	34	29	37
EPA+DHA	62	35	27	38
Phosphorus	29	12	17	71

[1] Retention in whole body (%) – retention in fillet (%)

[2] 100 (%) – retention in whole body (%)

[3] Includes lipids synthesized from non-lipid precursors

Indicators for use of marine ingredients

The dependency on marine resources can be expressed with various indicators (Table 8). The fish-in-fish-out-ratio (FIFO) expresses the amount of fish used to produce farmed fish. The FIFO is different for fish meal and fish oil, and the amount of fish meal and fish oil used in the feed is different, and is therefore calculated separately for fish meal and fish oil.

The FIFO does not differentiate between forage fish and trimmings, and therefore the forage fish dependency ratio (FFDR) can be used. It is the same calculation as FIFO, but only including fish meal and fish oil from forage fish.

The ratio of nutrients in the marine ingredients and fish produced can also be estimated. The marine protein dependency ratio (MPDR) expresses the amount of protein from marine ingredients versus the amount of protein in the produced fish. The marine oil dependency ratio (MODR) is the corresponding estimate for marine oil.

In Table 8 the indicators for use of salmon and trout are given, and in addition, the indicators are estimated for the total of salmon and trout since some trout is produced with salmon feed. The formulae for the calculations are shown in Aas *et al*. (2019; open access).

It should be noted that indicators for use of marine ingredients is not a measure of sustainability.

Table 8. FIFO, FFDR, MPDR and MODR estimated for the production of salmon, trout and salmon+trout combined in 2020.

	Salmon	**Trout**	**Salmon + trout**
FIFO Marine protein sources	0.7	0.8	0.7
FIFO Marine oils	1.5	1.5	1.5
FFDR Marine protein sources	0.5	0.5	0.5
FFDR Marine oils	1.2	1.2	1.2
MPDR total	0.67	0.75	0.67
MPDR forage fish	0.49	0.53	0.49
MODR total	0.68	0.60	0.67
MODR forage fish	0.54	0.46	0.54

References

Aas, T.S., Ytrestøyl, T. & Åsgård, T. (2019) Utilization of feed resources in the production of Atlantic salmon (*Salmo salar*) in Norway: An update for 2016. Aquaculture Reports, 15**,** 100216.

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