Technical Report

DietaryBurdenCalculator 3.0.1

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1. Introduction

Fish dietary burden calculations are an important prerequisite to decide on further experimental testing (metabolism and/or feeding studies) as part of the consumer risk assessment. In the Commission Working Document *Fish dietary burden calculator* (European Commission, 2021) the principles of dietary burden calculation for fish are described. The dietary burden calculation follows a conservative approach in assuming that all fish feedstuffs that could have been treated with the pesticide have in fact been treated at the maximum admissible rate. The anticipated dietary burden of a pesticide is calculated based on a 'maximum reasonably balanced diet (MRBD)' approach for intensive feeding practices or according to the 'reasonably worst case diet/feed (RWCF)' approach for semi-intensive diets (Schlechtriem et al. 2016). The target composition of formulated feed for rainbow trout (Atlantic salmon) in grow-out culture should consist of around 42% (36%) crude protein and 15% (33%) crude fat (% of DM). In comparison, the target composition of common carp diets contains less protein and fat with around 35% of DM and 10% of DM, respectively. If several feed components are available many combinations of them would result in optimum protein and lipid concentrations for a given fish species.

In order to calculate the maximum dietary burden calculation of residues in fish feed the simplex algorithm is considered. Georg Dantzig presented this solution method for linear programs in 1947 (Shenoy 2007, p.44). It is the most important method for linear programming (Zimmermann et al. 2001, p.48). Due to the development of computers, the simplex method offers the possibility to solve large-scale linear programming problems quickly (Shenoy 2007, p.44).

In this technical report, we present how to formulate the maximum dietary burden calculation as linear program such that the simplex method can be applied. As a result, we obtain the feed composition leading to the maximum dietary burden value.

Furthermore, we present the functionality of the software *DietaryBurdenCalculator.* For this, we calculate the dietary burden for an active substance with respect to three different important aquaculture species, rainbow trout (*Oncorhynchus mykiss*), common carp (*Cyprinus carpio*) and Atlantic salmon (*Salmo salar*).

2. Mathematical background

In this section, we present the mathematical background of the maximum dietary burden calculation. For this, we explain the underlying assumptions and translate them into a linear equation system (modeling).

2.1 Assumptions

We calculate the maximum residue in fish feed. The following information shall be considered:

1. We consider three different fish species with specific requirements (different target compositions) that have to be satisfied.
2. The feed consists of several ingredients such as for example corn meal, peanut meal or olive cake.
3. These feed components have different characteristics according to their protein and lipid content (percentage) and their residue value (mg/kg).
4. The sum of the percentages of feed components is 100 %.
5. Each feed component has a percentage between 0 % and 100 %. The idea of a maximum reasonable balanced diet (MRBD) is considered, there exists a constant percentage smaller than 100 %. This value may differ according to the species.

We formulate above-mentioned conditions as a linear program that is solvable by the Simplex Method.

2.2 Modeling

The objective function is $\max S(x) = S_1 \cdot x_1 + \cdots + S_n \cdot x_n$. The maximum residue of feed has to be calculated which contains of the sum of the product of the residue and the percentage of each single component. The constraints determining the set of all possible solutions (feasible set) are:

Protein content:	$P_1 \cdot x_1 + \cdots + P_n \cdot x_n = P_{Fish}$
Lipid content:	$L_1 \cdot x_1 + \cdots + L_n \cdot x_n = L_{Fish}$
Inclusion limit :	$x_i \leq (R_{Fish})_i, \;\; i = 1, \cdots, n$
Logical constraint:	$x_1 + \cdots + x_n = 1$
Positive percentages:	$0 \leq x_i, \quad i = 1, \cdots, n$

The first couple of conditions guarantees that the protein and lipid content of feed correspond to the fish-specific requirements. The inclusion limit depends of the fish-specific maximum reasonable balanced diet (MRDB). The last couple of constraints depend of the properties of percentages. Negative percentages and percentages greater than 100 % are not allowed.

Table 1: List and description of parameters of the dietary burden problem

Parameter	Range	Description
L_{Fish}	$[0,1]$	Target content of lipid in feed with respect to the fish species (dry matter)
L_i	$[0,1]$	Lipid content of feed component $i = 1, \cdots, n$ (dry matter)
P_{Fish}	$[0,1]$	Target content of protein in feed with respect to the fish species(dry matter)
P_i	$[0,1]$	Protein content with respect to dry matter of feed component $i = 1, \cdots, n$ (dry matter)
$(R_{Fish})_i$	$[0,1]$	Maximum reasonable content of feed component $i = 1, \cdots, n$ (dry matter)
S_i	$\mathbb{R}_+$	Residue value in mg/kg of feed component $i = 1, \cdots, n$ (dry matter)
S	$\mathbb{R}_+$	Total residue value in mg/kg of feed (dry matter)
x_i	$[0, (R_{Fish})_i\,]$	content of feed component in diet $i = 1, \cdots, n$ (dry matter)

The Simplex Algorithm either solves above discussed linear program in finite number of steps or proves the insolubility of the problem.

In more detail, we write the equations in a simplex tableau, a special matrix system. We put the objective function in the last row that shows the current objective function value. The objective function coefficient demonstrates if the current value is the optimal value or has to be adapted.

For a standardized simplex tableau, finding a start solution is straightforward. Way of proceeding:

1. Finding an initial solution or proving the insolubility of the problem.
2. Improving the solution as long as there is no possibly better solution.

In the first step, we design a synthetic objective function. Solving the problem as long as the synthetic objective function value is zero yields the start solution. Before starting the first phase the right site of the linear equation system has to be positive, otherwise the equation hast to be multiplied with -1. In our problem, it is always the case because we are dealing with percentages. In addition to that, slack variables arising from the restrictions have to be added: We replace the inequation $x_i \leq (R_{Fish})_i, \;\; i = 1, \cdots, n$ by $x_i + x_{n+i} = (R_{Fish})_i, \;\; i = 1, \cdots, n$. Considering above mentioned rules one obtain the following simplex tableau

Basis	x_1	$\cdots$	x_n	x_{n+1}	$\cdots$	x_{2n}	b
?	P_1	$\cdots$	P_n	0	$\cdots$	0	P_{Fish}
?	L_1	$\cdots$	L_n	0	$\cdots$	0	L_{Fish}
?	1	$\cdots$	1	0	$\cdots$	0	1
x_{n+1}	1	0	0	1	0	0	$(R_{Fish})_1$
$\vdots$	0	$\ddots$	0	0	$\ddots$	0	$\vdots$
x_{2n}	0	0	1	0	0	1	$(R_{Fish})_n$
S	S_1	$\cdots$	S_n	0	0	0	0

.

The simplex tableau has to be expanded by synthetic variables such that the start solution of the help problem can be found directly. This can be seen in the following tableau:

Basis	x_1	$\cdots$	x_n	x_{n+1}	$\cdots$	x_{2n}	x_{2n+1}	x_{2n+2}	x_{2n+3}	b
x_{2n+1}	P_1	$\cdots$	P_n	0	$\cdots$	0	1	0	0	P_{Fish}
x_{2n+2}	L_1	$\cdots$	L_n	0	$\cdots$	0	0	1	0	L_{Fish}
x_{2n+3}	1	$\cdots$	1	0	$\cdots$	0	0	0	1	1
x_{n+1}	1	0	0	1	0	0	0	0	0	$(R_{Fish})_1$
$\vdots$	0	$\ddots$	0	0	$\ddots$	0	0	0	0	$\vdots$
x_{2n}	0	0	1	0	0	1	0	0	0	$(R_{Fish})_n$
$*$	$P_1 + L_1 + 1$	$\cdots$	$P_n + L_n + 1$	0	0	0	0	0	0	$P_{Fish} + L_{Fish} + 1$
S	S_1	$\cdots$	S_n	0	0	0	0	0	0	0

The start basis is $(x_{2n+1}, x_{2n+2}, x_{2n+3}, x_{n+1}, \cdots, x_{2n})^T$ and the simplex method may be applied to the problem. If the optimization value of the help problem is zero, then there exists a start solution to the original problem. Otherwise, the original problem is not solvable, because the restriction area is empty. In the second step, the original problem is solved. Therefore, the secondary objective function row and the column of the synthetic variables have to be deleted. The simplex method has to be applied to the resultant tableau.

2.3 Example

We consider a simple example to demonstrate the functionality of the simplex method.

$$\begin{aligned} \max\ & 3x_1 + 2x_2 \\ & 2x_1 + x_2 = 8 \\ & x_1 + x_2 = 6 \\ & x_1 \leq 5, x_2 \leq 5 \end{aligned}$$

At first, we have to transform the inequations to equations by adding slack variables x_3 and x_4. Doing so, we obtain the following constraints.

$$\begin{aligned} 2x_1 + x_2 &= 8 \\ x_1 + x_2 &= 6 \\ x_1 + x_3 &= 5 \\ x_2 + x_4 &= 5 \end{aligned}$$

We insert these equations into the simplex tableau.

Basis	x_1	x_2	x_3	x_4	b
?	2	1	0	0	8
?	1	1	0	0	6
x_3	1	0	1	0	5
x_4	0	1	0	1	5
OF	3	2	0	0	0

In a next step, we add two synthetic variables x_5, x_6 and the synthetic objective function to get a start basis.

Basis	x_1	x_2	x_3	x_4	x_5	x_6	b
x_5	2	1	0	0	1	0	8
x_6	1	1	0	0	0	1	6
x_3	1	0	1	0	0	0	5
x_4	0	1	0	1	0	0	5
OF	3	2	0	0	0	0	0
SF	3	2	0	0	0	0	14

Now, we have to choose the pivot column. The column is the defined by the smallest positive entry in the synthetic objective function row.

Basis	x_1	x_2	x_3	x_4	x_5	x_6	b
x_5	2	1	0	0	1	0	8
x_6	1	1	0	0	0	1	6
x_3	1	0	1	0	0	0	5
x_4	0	1	0	1	0	0	5
OF	3	2	0	0	0	0	0
SF	3	2	0	0	0	0	14

Now we have to decide which row to choose to obtain the pivot element. For this, we focus on the quotients b_i/a_{ij^*}. The element j^* is the pivot column, i is a possible pivot row and b_i is the corresponding right side entry. In this case, the pivot element is a_{42} (interpreting the coefficients of the equations as matrix $A = a_{ij},\ \ i = 2,\cdots,4,\ \ j = 1,\cdots,6$).

Basis	x_1	x_2	x_3	x_4	x_5	x_6	b	*Quotient*
x_5	2	1	0	0	1	0	8	$8/1 = 8$
x_6	1	1	0	0	0	1	6	$6/1 = 6$
x_3	1	0	1	0	0	0	5	–
x_4	0	1	0	1	0	0	5	$5/1 = 5$
OF	3	2	0	0	0	0	0	
SF	3	2	0	0	0	0	14	

After finding the pivot element, we have to standardize the pivot row by dividing the row by the pivot element. Then we generate zeros in the other entries in the pivot column. The original objective function row (OF) is not to be focused by finding the pivot element but has to be adapted as similar to the other rows.

Basis	x_1	x_2	x_3	x_4	x_5	x_6	b
x_5	2	0	0	−1	1	0	3
x_6	1	0	0	−1	0	1	1
x_3	1	0	1	0	0	0	5
x_2	0	1	0	1	0	0	5
OF	3	0	0	−2	0	0	−10
SF	3	0	0	−2	0	0	4

We repeat this procedure. The first entry in the synthetic objective function row is greater than zero. Hence, the first column is the next pivot column. By regarding the quotients, we receive the new pivot element a_{21}.

Basis	x_1	x_2	x_3	x_4	x_5	x_6	b	*Quotient*
x_5	2	0	0	−1	1	0	3	$3/2 = 1.5$
x_6	1	0	0	−1	0	1	1	$1/1 = 1$
x_3	1	0	1	0	0	0	5	$5/1 = 5$
x_2	0	1	0	1	0	0	5	–
OF	3	0	0	−2	0	0	−10	
SF	3	0	0	−2	0	0	4	

Again, we generate zeros in the pivot column except for the pivot element row. This entry has to be equal to one. By doing so, we obtain a new positive value in the synthetic objective function row, which identifies the new pivot column. The smallest quotient is in the first row, and thus $a_{14}$is the new pivot element.

Basis	x_1	x_2	x_3	x_4	x_5	x_6	b	*Quotient*
x_5	0	0	0	1	1	−2	1	$1/1 = 1$
x_1	1	0	0	−1	0	1	1	–
x_3	0	0	1	1	0	−1	4	$4/1 = 4$
x_2	0	1	0	1	0	0	5	$5/1 = 5$
OF	0	0	0	1	0	−3	−13	
SF	0	0	0	1	0	−3	1	

Again, we generate zeros at the remaining pivot column entries.

Basis	x_1	x_2	x_3	x_4	x_5	x_6	b
x_4	0	0	0	1	1	−2	1
x_1	1	0	0	0	1	−1	2
x_3	0	0	1	0	−1	1	3
x_2	0	1	0	0	−1	2	4
OF	0	0	0	0	−1	−1	−14
SF	0	0	0	0	−1	−1	0

We observe that there is no positive entry greater zero in the synthetic objective function row. Furthermore, the synthetic function value is equal to zero. That indicates that the original problem is solvable and the found basis is a permissible start solution. In addition to that, we can delete the synthetic variables and the synthetic objective function, such that we obtain a reduced simplex tableau.

Basis	x_1	x_2	x_3	x_4	b
x_4	0	0	0	1	1
x_1	1	0	0	0	2
x_3	0	0	1	0	3
x_2	0	1	0	0	4
OF	0	0	0	0	−14

There is no positive entry in the row of the original objective function such that the problem is already solved. The maximum value is 14 with $x_1 = 2$ and $x_2 = 4$. A problem like this with only two variables can also be solved graphically. As we consider in general more than two feed components, we cannot solve the dietary burden problem graphically.

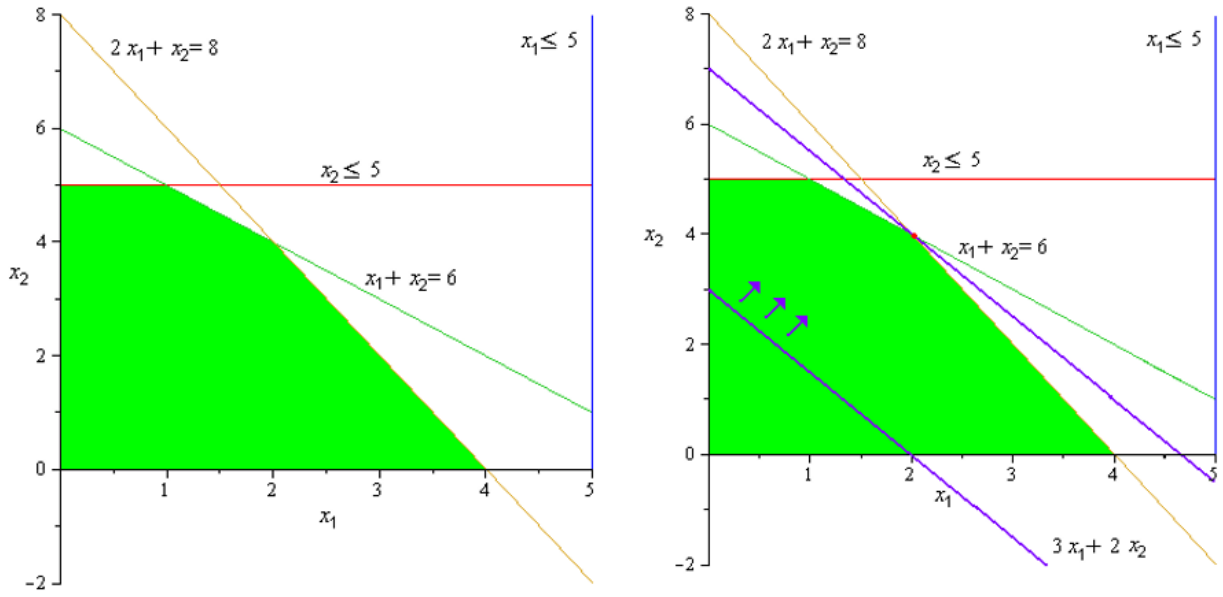

Figure 1: Graphical solution of the example

3. Working with the program *DietaryBurdenCalculator*

If you run the *DietaryBurdenCalculator,* at first, a start page appears (Figure 2). The user may continue or exit the program.

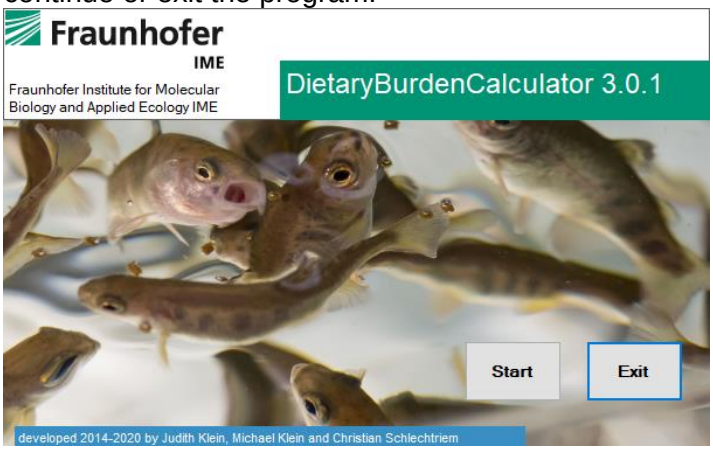

Figure 2: Start page of the DietaryBurdenCalculator

The surface of the program is divided into three different steps.

1. Creating an active substance entry and assigning residues to feed components.
2. Selecting the relevant feed components for optimization.
3. Choosing the fish species.

3.1 Substance data

There are different options to modify the substance database (Figure 3; on the left) including the opportunity to assign component specific residue values of a substance. Furthermore, you may edit your substance, add a new substance or copy an existing substance.
Click on
“Edit” – to edit an existing substance,
“Add” – to add an additional substance,
“Copy” – to copy an existent substance or
“Delete” – to delete an existent substance.

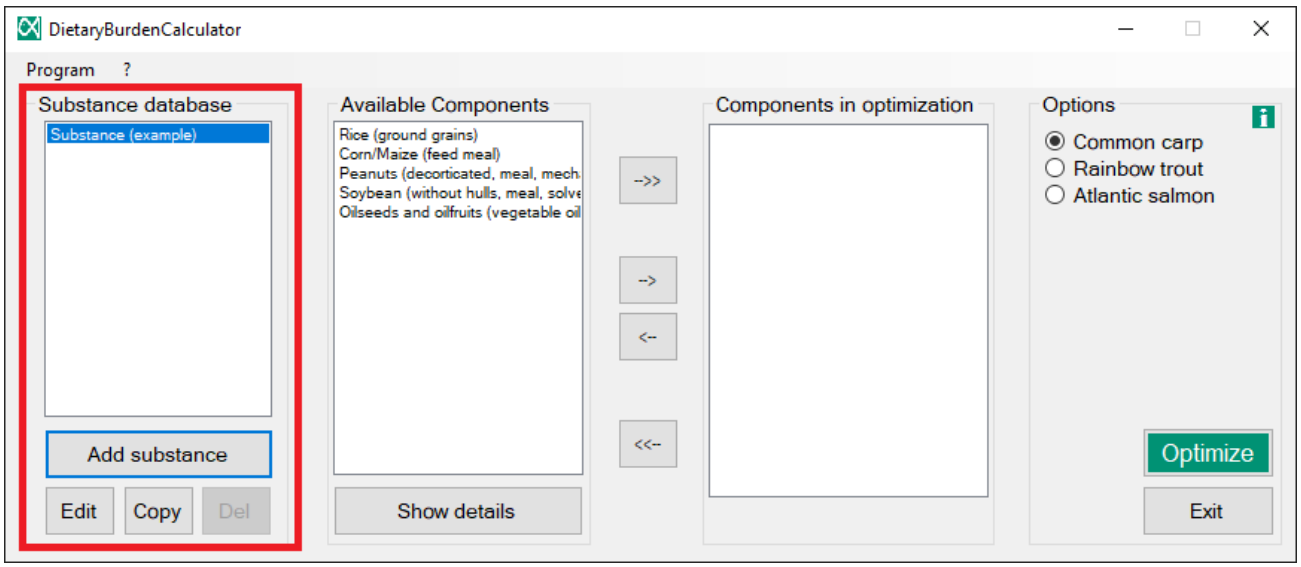

Figure 3: Substance database

Click on “Edit” (or “Add”) to open the substance database. Here you can enter the specific residue values of the different components. The residue values should be included on a fresh matter basis. The program re-calculates the residue value automatically on the components’ dry matter content.

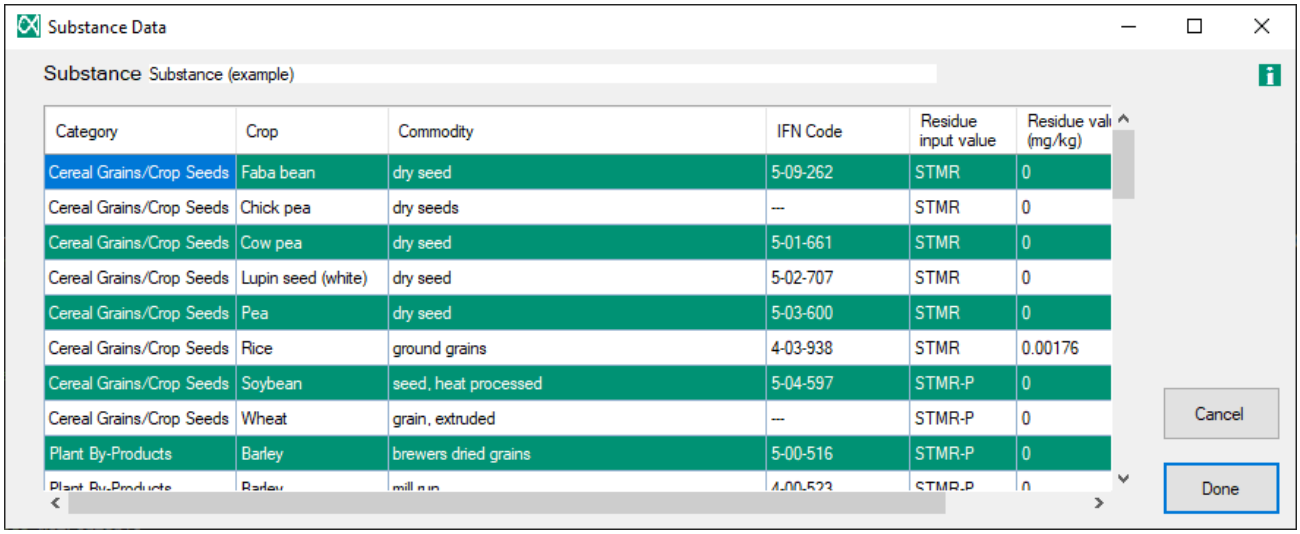

Figure 4: Adding residue values to the single feed components

For instance, we set the residue value of Corn/Maize (feed meal) to 0.263 mg/kg (fresh matter). According to the feedstuffs table (Table 7) this feed component has a dry matter content of 87.8 %. The calculator calculates the residue by

$$S_{DW} = \frac{S_{FW}}{DM} \cdot 100.$$

In this particular case, we obtain $\left(\frac{0.263}{87.8}\right) \cdot 100 = 0.299544419 \approx 0.3$. In the report, the *DietaryBurdenCalculator* refers to both values -the residue value (fresh weight) inserted by the user as well as the re-calculated residue value (dry weight).

3.2 Feed components

All components with a residue value greater than zero are listed as available components (Figure 5; middle).

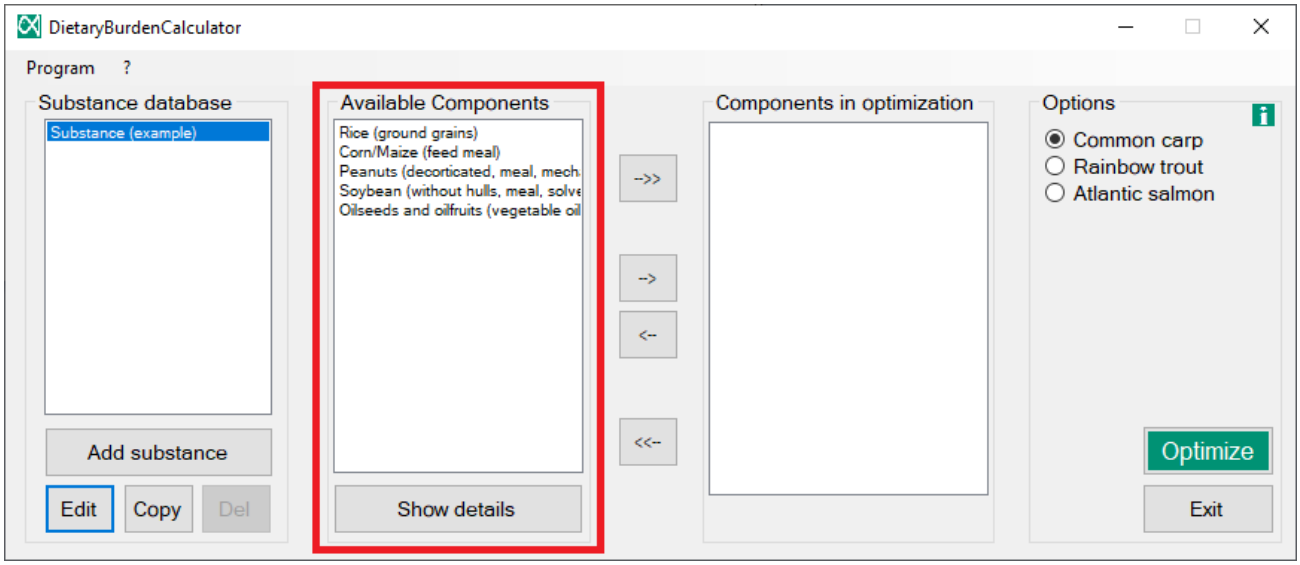

Figure 5: Available feed components

Click "Show details", if you wish to get more information about the available components. The list contains the categories of the available feed components, the crop (commodity), the protein and lipid content based on dry matter, the dry matter content, the recommended maximum inclusion rates for the three fish species, as well as the residue input value (e.g. STMR) and the residue value.

With the arrow buttons between the middle and the right list box, the user can select which components (all, or a smaller set) shall be considered for dietary burden calculation (Figure 6).

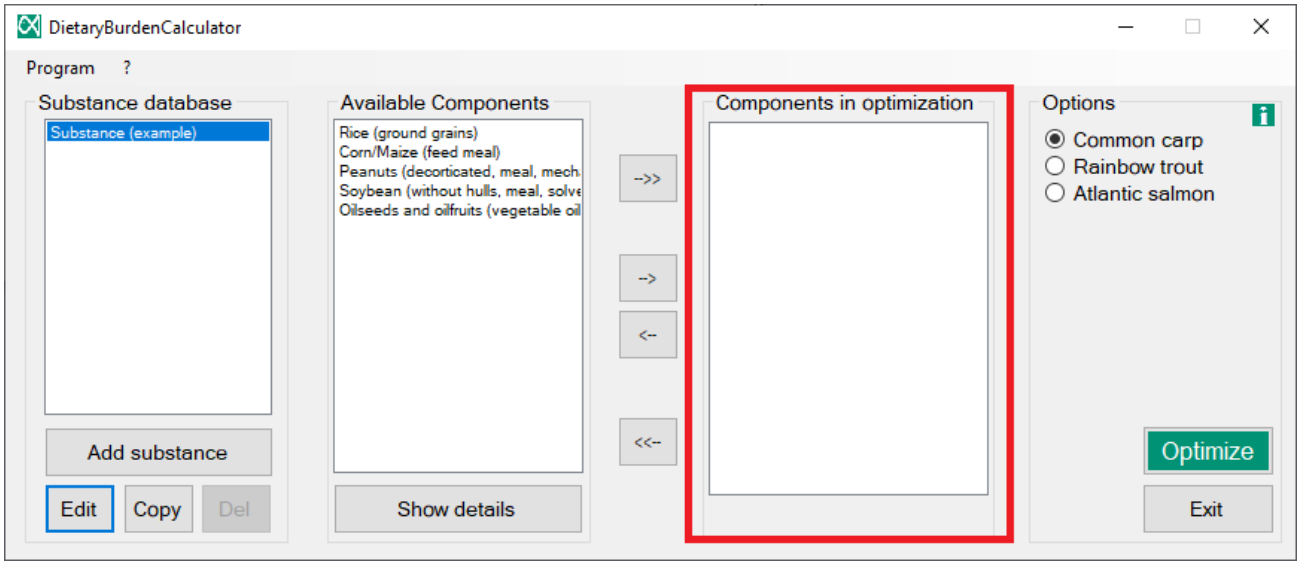

Figure 6: Feed components considered for dietary burden calculation

In addition to the chosen feed components, fishmeal (75.00% protein, 5.00% lipid), starch (0.1 % protein, 0.1% lipid) and oil (100% lipid) are considered to balance the diet if required. These components have a residue value equal to zero and represent protein concentrate (PC, fishmeal), a carbohydrate concentrate (CC, starch) and fat (F, oil). The content of these components are not restricted by maximum inclusion rates.

3.3 Options

In a third step, the user can change the fish species and choose between rainbow trout, common carp or Atlantic salmon (Figure 7). The different species have different dietary requirements.

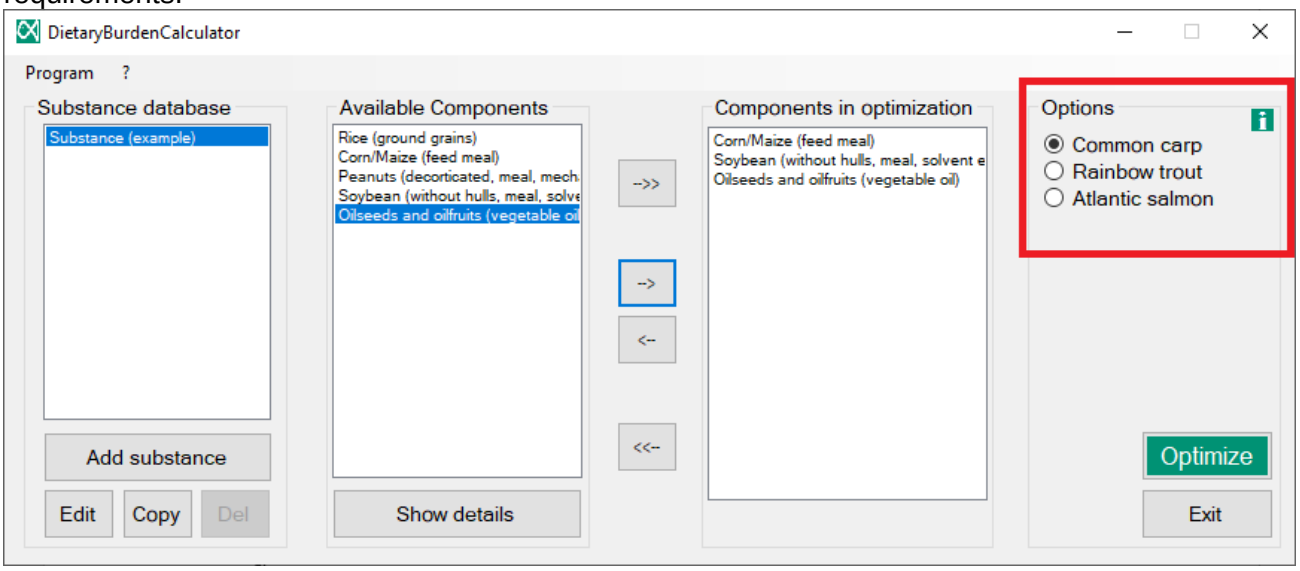

Figure 7: Options- choosing a fish species

3.4 Optimization

Clicking on the button “Optimize” starts the calculation procedure (Figure 8). A short summary of the result is presented on the input mask. If the font is black the dietary burden is <0.1 mg/kg. Red text indicates that the threshold value of 0.1 mg/kg had been exceeded.

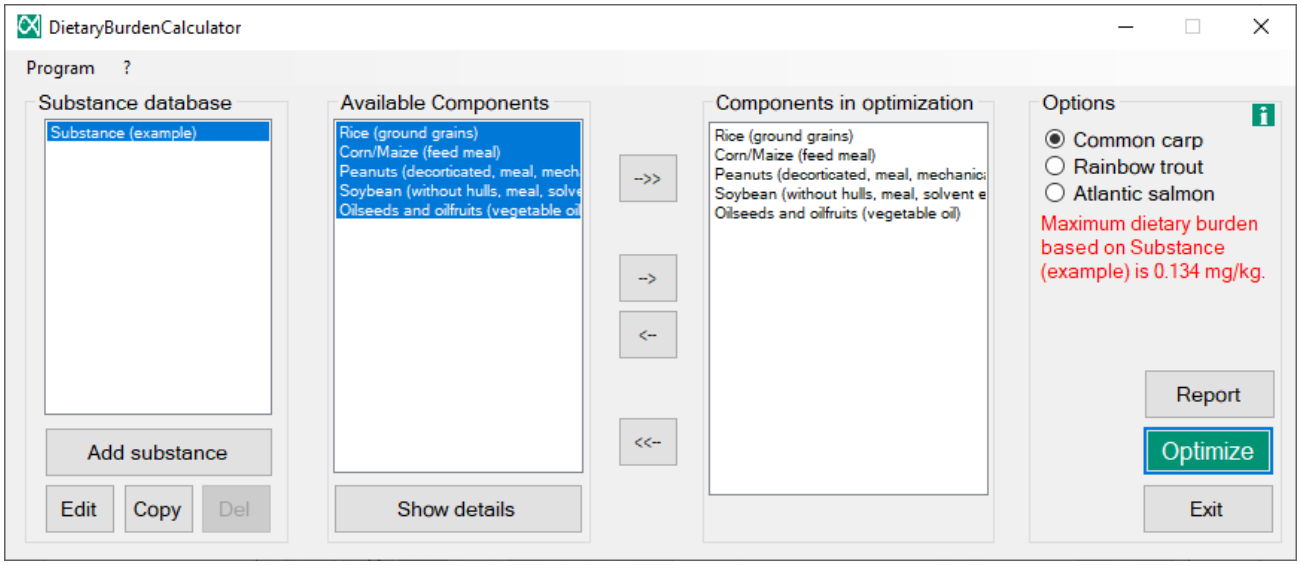

Figure 8: Dietary burden calculation

By clicking on the button “Report” a detailed calculation report is generated containing all input and output information related to the dietary burden calculation. The report specifies the fish species with the corresponding target protein and lipid requirement, the MRDB values, substance residue values of the available components, the calculated dietary burden, and the dietary formulation leading to the maximum dietary burden of the investigated substance as well as the contribution of each individual feed component to the dietary burden. Furthermore, you can present the data as chart or table, print the results or copy it into clipboard (Figure 9).

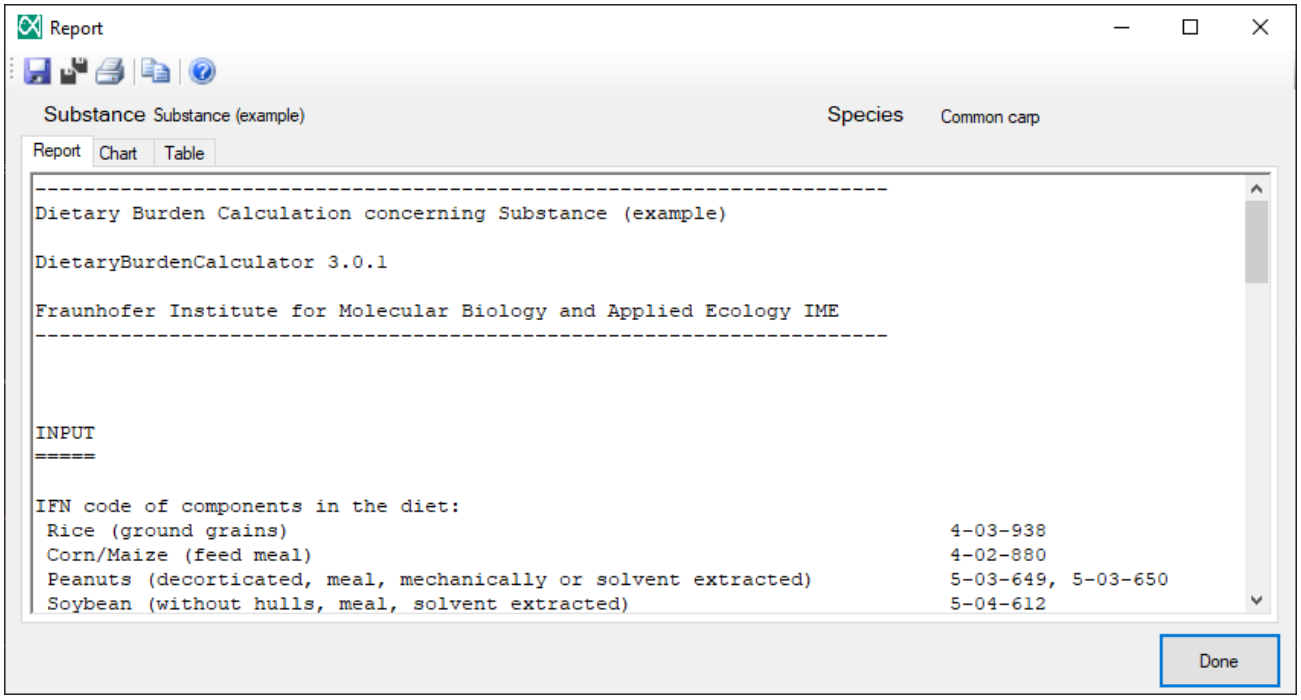

Figure 9: Calculation report

4. Fish dietary burden calculation (example)

An example including five feed components is provided by *DietaryBurdenCalculator* (Table 2): peanut (meal decorticated), soybean (meal decorticated), corn field (grain meal), rice (broken grains) and vegetable oil (oil).

Table 2: Chosen feed components with residue values

Feed component	Residue value (STMR)
Corn/Maize (feed meal)	0.2634
Peanuts (decorticated, meal, mechanically or solvent extracted)	0.08118
Soybean (without hulls, meal, solvent extracted)	0.04475
Oilseeds and oilfruits (vegetable oil)	0.01
Rice (ground grains)	0.00176

In addition to these feed components, the feed components fishmeal (PC), starch (CC) and oil (F) are added to balance the diet formulation if required.
The maximum dietary burden values for all species, common carp, rainbow trout and Atlantic salmon are calculated. Due to the different dietary requirements of the species, different results are obtained.
For common carp, we get a feed composition leading to 0.132 mg/kg burden (Table 3). The feed composition for rainbow trout and A. salmon lead to a much lower and not significant burden with 0.078 mg/kg and 0.011 mg/kg, respectively(Table 3).

Table 3: Worst case feed composition for carp, trout, and salmon

	Feed composition in %		
Feed component	Common carp	Rainbow trout	Atlantic salmon
Rice (ground grains)	0.02	6.64	0
Corn/Maize (feed meal)	35	20	0
Peanuts (decorticated, meal, mechanically or solvent extracted)	15	10	5
Soybean (without hulls, meal, solvent extracted)	30	15	10
Oilseeds and oilfruits (vegetable oil)	7.3	11.96	18.3
Fish meal (PC)	12.68	36.4	38.24

Starch (CC)	0	0	15.82
Oil (F)	0	0	12.64

Table 4: Dietary load of the active substance caused by the different feed components

	Dietary load in %		
Feed component	Common carp	Rainbow trout	Atlantic salmon
Rice (ground grains)	0	0.17	0
Corn/Maize (feed meal)	78.22	77.09	0
Peanuts (decorticated, meal, mechanically or solvent extracted)	10.06	11.56	39.72
Soybean (without hulls, meal, solvent extracted)	11.17	9.64	44.13
Oilseeds and oilfruits (vegetable oil)	0.54	1.54	16.15
Fish meal (PC)	0	0	0
Starch (CC)	0	0	0
Oil (F)	0	0	0

5. References

(1) European Commission (2021). COMMISSION WORKING DOCUMENT “Fish dietary burden calculator”; SANTE/10250/2021; 23 February 2021.

(2) Klein J, Klein M and Schlechtriem C, Dietary Burden Calculation for Aquaculture Diets: A Linear Programming Approach, in 127, VDLUFA-Kongress, Böden–Lebensgrundlage für Pflanze und Tier, VDLUFA-Schriftenreihe Band 71. VDLUFA-Verlag, Darmstadt, pp. 667–672 (2015).

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(4) Shenoy, G.V.: Linear Programming: Methods and Applications. New Age International, 2007. – ISBN 9788122410341

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6. Appendix 1: Reports generated by the software *DietaryBurdenCalculator*

6.1 Substance (example) - Common Carp

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Dietary Burden Calculation concerning Substance (example)

DietaryBurdenCalculator 3.0.1

Fraunhofer Institute for Molecular Biology and Applied Ecology IME
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INPUT
=====

IFN code of components in the diet:
 Rice (ground grains) 4-03-938
 Corn/Maize (feed meal)       4-02-880
 Peanuts (decorticated, meal, mechanically or solvent extracted)   5-03-649, 5-03-650
 Soybean (without hulls, meal, solvent extracted)   5-04-612
 Oilseeds and oilfruits (vegetable oil)     various


Target content for Common carp
 Crude fat     10.00%
 Crude protein 35.00%

Maximum principal content of components in the diet:
 Rice (ground grains) 50.00%
 Corn/Maize (feed meal)       35.00%
 Peanuts (decorticated, meal, mechanically or solvent extracted)   15.00%
 Soybean (without hulls, meal, solvent extracted)   30.00%
```

Oilseeds and oilfruits (vegetable oil) 10.00%
Fish meal(PC) 100.00%
Starch(CC) 100.00%
Oil(F) 100.00%

Percent dry matter of components:
Rice (ground grains) 88.0%
Corn/Maize (feed meal) 87.8%
Peanuts (decorticated, meal, mechanically or solvent extracted) 90.2%
Soybean (without hulls, meal, solvent extracted) 89.5%
Oilseeds and oilfruits (vegetable oil) -

Substance (example) residues in the components:
Rice (ground grains) 0.002 mg/kg (STMR-P)
Corn/Maize (feed meal) 0.263 mg/kg (STMR-P)
Peanuts (decorticated, meal, mechanically or solvent extracted) 0.081 mg/kg (STMR-P)
Soybean (without hulls, meal, solvent extracted) 0.045 mg/kg (STMR-P)
Oilseeds and oilfruits (vegetable oil) 0.010 mg/kg (STMR-P)

Substance (example) residues in the components (dry matter):
Rice (ground grains) 0.002 mg/kg (STMR-P)
Corn/Maize (feed meal) 0.300 mg/kg (STMR-P)
Peanuts (decorticated, meal, mechanically or solvent extracted) 0.090 mg/kg (STMR-P)
Soybean (without hulls, meal, solvent extracted) 0.050 mg/kg (STMR-P)
Oilseeds and oilfruits (vegetable oil) 0.010 mg/kg (STMR-P)

RESULTS
=======

Maximum dietary burden based on Substance (example) is 0.134 mg/kg (dry matter).

The respective composition of the feed is:
Rice (ground grains) 0.02%

Corn/Maize (feed meal) 35.00%

Peanuts (decorticated, meal, mechanically or solvent extracted) 15.00%

Soybean (without hulls, meal, solvent extracted) 30.00%

Oilseeds and oilfruits (vegetable oil) 7.30%

Fish meal(PC) 12.68%

Starch(CC) 0.00%

Oil(F) 0.00%

The dietary load of Substance (example) caused by the individual components is:

Rice (ground grains) 0.00%

Corn/Maize (feed meal) 78.22%

Peanuts (decorticated, meal, mechanically or solvent extracted) 10.06%

Soybean (without hulls, meal, solvent extracted) 11.17%

Oilseeds and oilfruits (vegetable oil) 0.54%

Fish meal(PC) 0.00%

Starch(CC) 0.00%

Oil(F) 0.00%

6.2 Substance (example) –Rainbow trout

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Dietary Burden Calculation concerning Substance (example)

DietaryBurdenCalculator 3.0.1

Fraunhofer Institute for Molecular Biology and Applied Ecology IME
----------------------------------------------------------------------


INPUT
=====

IFN code of components in the diet:
 Rice (ground grains) 4-03-938
 Corn/Maize (feed meal)       4-02-880
 Peanuts (decorticated, meal, mechanically or solvent extracted)   5-03-649, 5-03-650
 Soybean (without hulls, meal, solvent extracted)   5-04-612
 Oilseeds and oilfruits (vegetable oil)      various


Target content for Rainbow trout
 Crude fat     15.00%
 Crude protein 42.00%

Maximum principal content of components in the diet:
 Rice (ground grains) 10.00%
 Corn/Maize (feed meal)       20.00%
 Peanuts (decorticated, meal, mechanically or solvent extracted)   10.00%
 Soybean (without hulls, meal, solvent extracted)   15.00%
 Oilseeds and oilfruits (vegetable oil)      15.00%
 Fish meal(PC) 100.00%
 Starch(CC)    100.00%
 Oil(F) 100.00%

Percent dry matter of components:
 Rice (ground grains) 88.0%
 Corn/Maize (feed meal)       87.8%
 Peanuts (decorticated, meal, mechanically or solvent extracted)   90.2%
 Soybean (without hulls, meal, solvent extracted)   89.5%
 Oilseeds and oilfruits (vegetable oil)      -

Substance (example) residues in the components:
 Rice (ground grains) 0.002 mg/kg (STMR-P)
 Corn/Maize (feed meal)       0.263 mg/kg (STMR-P)
 Peanuts (decorticated, meal, mechanically or solvent extracted)   0.081 mg/kg (STMR-P)
 Soybean (without hulls, meal, solvent extracted)   0.045 mg/kg (STMR-P)
 Oilseeds and oilfruits (vegetable oil)      0.010 mg/kg (STMR-P)


Substance (example) residues in the components (dry matter):
 Rice (ground grains) 0.002 mg/kg (STMR-P)
 Corn/Maize (feed meal)       0.300 mg/kg (STMR-P)
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Peanuts (decorticated, meal, mechanically or solvent extracted) 0.090 mg/kg (STMR-P)
Soybean (without hulls, meal, solvent extracted) 0.050 mg/kg (STMR-P)
Oilseeds and oilfruits (vegetable oil) 0.010 mg/kg (STMR-P)

RESULTS
=======

Maximum dietary burden based on Substance (example) is 0.078 mg/kg (dry matter).

The respective composition of the feed is:
Rice (ground grains) 6.64%
Corn/Maize (feed meal) 20.00%
Peanuts (decorticated, meal, mechanically or solvent extracted) 10.00%
Soybean (without hulls, meal, solvent extracted) 15.00%
Oilseeds and oilfruits (vegetable oil) 11.96%
Fish meal(PC) 36.40%
Starch(CC) 0.00%
Oil(F) 0.00%

The dietary load of Substance (example) caused by the individual components is:
Rice (ground grains) 0.17%
Corn/Maize (feed meal) 77.09%
Peanuts (decorticated, meal, mechanically or solvent extracted) 11.56%
Soybean (without hulls, meal, solvent extracted) 9.64%
Oilseeds and oilfruits (vegetable oil) 1.54%
Fish meal(PC) 0.00%
Starch(CC) 0.00%
Oil(F) 0.00%

6.3 Substance (example) – Atlantic salmon

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Dietary Burden Calculation concerning Substance (example)

DietaryBurdenCalculator 3.0.1

Fraunhofer Institute for Molecular Biology and Applied Ecology IME
------------------------------------------------------------------------



INPUT
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IFN code of components in the diet:
 Rice (ground grains) 4-03-938
 Corn/Maize (feed meal)       4-02-880
 Peanuts (decorticated, meal, mechanically or solvent extracted)   5-03-649, 5-03-650
 Soybean (without hulls, meal, solvent extracted)   5-04-612
 Oilseeds and oilfruits (vegetable oil)      various


Target content for Atlantic salmon
 Crude fat     33.00%
 Crude protein 36.00%

Maximum principal content of components in the diet:
 Rice (ground grains) 0.00%
 Corn/Maize (feed meal)       0.00%
 Peanuts (decorticated, meal, mechanically or solvent extracted)   5.00%
 Soybean (without hulls, meal, solvent extracted)   10.00%
 Oilseeds and oilfruits (vegetable oil)      18.30%
 Fish meal(PC) 100.00%
 Starch(CC)    100.00%
 Oil(F) 100.00%

Percent dry matter of components:
 Rice (ground grains) 88.0%
 Corn/Maize (feed meal)       87.8%
 Peanuts (decorticated, meal, mechanically or solvent extracted)   90.2%
 Soybean (without hulls, meal, solvent extracted)   89.5%
 Oilseeds and oilfruits (vegetable oil)      -

Substance (example) residues in the components:
 Rice (ground grains) 0.002 mg/kg (STMR-P)
 Corn/Maize (feed meal)       0.263 mg/kg (STMR-P)
 Peanuts (decorticated, meal, mechanically or solvent extracted)   0.081 mg/kg (STMR-P)
 Soybean (without hulls, meal, solvent extracted)   0.045 mg/kg (STMR-P)
 Oilseeds and oilfruits (vegetable oil)      0.010 mg/kg (STMR-P)


Substance (example) residues in the components (dry matter):
 Rice (ground grains) 0.002 mg/kg (STMR-P)
 Corn/Maize (feed meal)       0.300 mg/kg (STMR-P)
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Peanuts (decorticated, meal, mechanically or solvent extracted) 0.090 mg/kg (STMR-P)
Soybean (without hulls, meal, solvent extracted) 0.050 mg/kg (STMR-P)
Oilseeds and oilfruits (vegetable oil) 0.010 mg/kg (STMR-P)

RESULTS
=======

Maximum dietary burden based on Substance (example) is 0.011 mg/kg (dry matter).

The respective composition of the feed is:
Rice (ground grains) 0.00%
Corn/Maize (feed meal) 0.00%
Peanuts (decorticated, meal, mechanically or solvent extracted) 5.00%
Soybean (without hulls, meal, solvent extracted) 10.00%
Oilseeds and oilfruits (vegetable oil) 18.30%
Fish meal(PC) 38.24%
Starch(CC) 15.82%
Oil(F) 12.64%

The dietary load of Substance (example) caused by the individual components is:
Rice (ground grains) 0.00%
Corn/Maize (feed meal) 0.00%
Peanuts (decorticated, meal, mechanically or solvent extracted) 39.72%
Soybean (without hulls, meal, solvent extracted) 44.13%
Oilseeds and oilfruits (vegetable oil) 16.15%
Fish meal(PC) 0.00%
Starch(CC) 0.00%
Oil(F) 0.00%

7. Appendix 2: Plant derived feed commodities for dietary burden calculation

Table 5: Lipid content (%), protein content (%), dry matter (DM) content (%) as well as fish specific maximum reasonable balanced diet (MRBD) content (%) of feed components (European Commission, 2021)

Crop	Commodity	Lipid (%)	Protein (%)	DM(%)	MRBD carp (%)	MRBD trout (%)	MRBD salmon (%)
Faba bean	dry seed	8.4	28.3	88	15	15	1.9
Chick pea	dry seeds	4.4	20.6	90.8	15	15	0
Cow pea	dry seed	4.9	25.1	88	15	15	0
Lupin seed (white)	dry seed	6.1	34.5	88	15	15	0
Pea	dry seed	1.7	23.7	90	15	15	3
Rice	ground grains	0.6	8.1	88	50	10	0
Soybean	seed, heat processed	5.4	38	89.2	9	3	2
Wheat	grain, extruded	1.9	13.5	87.7	15	10	9.9
Barley	brewers dried grains	7	25.9	92.3	15	10	10
Barley	mill run	14.1	10.5	90	15	10	0
Canola/Rape seed	meal, pre-press solvent extracted	3.8	38	93	10	8	5

Coconut/Copra	meal, mechanically or solvent extracted	2.2	21.9	90.2	15	10	3
Corn/Maize	feed meal	4.8	10.2	87.8	35	20	0
Corn/Maize	bran	5.7	15	87.5	20	5	0
Corn/Maize	gluten feed	3.5	24.7	90.1	20	10	0
Corn/Maize	gluten meal	3.6	59.9	91.3	20	15	4
Corn/Maize	starch, cooked	---	0.2	88	35	15	0
Corn/Maize	distiller's dried grains with solubles	10	27.8	90.8	35	10	5
Corn/Maize	distiller’s dried grains	10.2	28.5	92.3	10	3	0
Corn/Maize	distiller's dried solubles	11.3	29.5	90.6	10	3	0
Cotton seed	meal, mechanically or solvent extracted	1.2	44.2	90.8	15	5	5
Linseed	meal, mechanically or solvent extracted	2	35	90	7	5	0
Lupin seed (white)	meal, solvent extracted	6.1	34.5	89.5	15	9	9
Mustard seed	meal, solvent extracted	1.8	42.4	89.9	10	5	0
Palm kernel	meal	1.4	16.3	90	10	8	5
Peanuts	decorticated, meal, mechanically or solvent extracted	1	46.5	90.2	15	10	5
Potato	protein	2.8	81.8	89.4	3	2	0

Rice	bran	7.4	9	90	50	10	0
Rice	bran, solvent extracted	1.7	15.1	89.5	50	10	0
Rice	polishings	14.5	13.6	100	50	10	0
Rice	hulls	1	3.1	100	5	0	0
Rye	distiller's dried grains	6.9	21.2	90	10	3	0
Sesame seed	meal	4.8	45	92.4	20	10	0
Safflower seed	meal, mechanically or solvent extracted	6.9	45.2	91	7	5	0
Soybean	meal, mechanically or solvent extracted	1	45.9	90.6	30	15	10
Soybean	without hulls, meal, solvent extracted	0.8	49.8	89.5	30	15	10
Soybean	protein concentrate	0.1	84.3	92	20	20	21.3
Sunflower seed	without hulls, meal, mechanically or solvent extracted	3.2	43.5	92.6	20	10	6
Sunflower seed	meal, mechanically or solvent extracted	1.5	30.8	90.3	20	10	6
Wheat	bran	4.7	15.6	88.7	5	2	0
Wheat	flour	1.7	14.3	88	15	10	9.9
Wheat	germ meal	8.8	28.5	88.7	5	2	0
Wheat	gluten meal	1.5	80.1	91.4	5	2	6

Wheat	middlings	4.4	16.9	89.4	20	10	9.9
Wheat	distiller's dried grains	6.6	31.8	89.5	10	3	0
Oilseeds and oilfruits	vegetable oil	100	0	0	10	15	18.3

Table 6: Description, reference, IFN number, MRL number and class of feed components (European Commission, 2021)

Crop	Commodity	Description	Reference	IFN	MRL	Class
Cereal Grains/Crop Seeds	Faba bean	Dried beans are the residue of the normal packaging and processing of dried beans for human consumption. This residue shall consist of the broken, small, shriveled and cull beans. They shall be identified by variety such as navy, northern, pinto, kidney, etc. Where further processing, such as grinding, roasting, etc., has occurred, ground, roasted or other acceptable description may be part of the name, i.e. ground roasted dried beans	FAO 2009	5-09-262	300010	CC
Cereal Grains/Crop Seeds	Chick pea	Dried beans are the residue of the normal packaging and processing of dried beans for human consumption. This residue shall consist of the broken, small, shriveled and cull beans. They shall be identified by variety such as navy, northern, pinto, kidney, etc. Where further processing, such as grinding, roasting, etc., has occurred, ground, roasted or other acceptable description may be part of the name, i.e. ground roasted dried beans	FAO 2009	---	300030	CC
Cereal Grains/Crop Seeds	Cow pea	Dried beans are the residue of the normal packaging and processing of dried beans for human consumption. This residue shall consist of the broken, small, shriveled and cull beans. They	FAO 2009	5-01-661	300030	CC

		shall be identified by variety such as navy, northern, pinto, kidney, etc. Where further processing, such as grinding, roasting, etc., has occurred, ground, roasted or other acceptable description may be part of the name, i.e. ground roasted dried beans				
Cereal Grains/Crop Seeds	Lupin seed (white)	Dried beans are the residue of the normal packaging and processing of dried beans for human consumption. This residue shall consist of the broken, small, shriveled and cull beans. They shall be identified by variety such as navy, northern, pinto, kidney, etc. Where further processing, such as grinding, roasting, etc., has occurred, ground, roasted or other acceptable description may be part of the name, i.e. ground roasted dried beans	FAO 2009	5-02-707	300040	PC
Cereal Grains/Crop Seeds	Pea	Dried beans are the residue of the normal packaging and processing of dried beans for human consumption. This residue shall consist of the broken, small, shriveled and cull beans. They shall be identified by variety such as navy, northern, pinto, kidney, etc. Where further processing, such as grinding, roasting, etc., has occurred, ground, roasted or other acceptable description may be part of the name, i.e. ground roasted dried beans	FAO 2009	5-03-600	300030	CC
Cereal Grains/Crop Seeds	Rice	Ground rough rice or ground paddy is the entire product obtained in grinding the whole rice grain including the hulls.	FAO 2009	4-03-938	500060	CC
Cereal Grains/Crop Seeds	Soybean	Product resulting from heating whole soybeans without removing any of the component parts. It may be ground, pelleted, flaked or powdered.	FAO 2009	5-04-597	401070	PC
Cereal Grains/Crop Seeds	Wheat	Grain products in any of the normal forms such as whole, ground, cracked, screen cracked, flaked, kibbled, toasted or heat processed: barley, wheat, corn, rice-ground brown, ground paddy, ground rough, grain sorghum, broken or chipped rice, mixed feed oats, rice (brewers), oats, rye and triticale	FAO 2009	---	500090	CC

Plant By-Products	Barley	Dried extracted residue of barley malt alone or in mixture with other cereal grain or grain products resulting from the manufacture of wort or beer and may contain pulverised dried spent hops in an amount not to exceed 3%, evenly distributed.	FAO 2009	5-00-516	500010	CC
Plant By-Products	Barley	Entire residue from the milling of barley flour from clean barley and is composed of barley hulls and barley middlings.	AAFCO 2018	4-00-523	500010	CC
Plant By-Products	Canola/Rapeseed	Canola meal prepress solvent extracted, low erucic acid, low glucosinolate.	FAO 2009	5-05-145	401060	PC
Plant By-Products	Coconut/Copra	Coconut kernels with coats meal mechanical extracted is the ground residue, which remains after removal of most of the oil from dried meat of coconuts by a mechanical extraction process. May also be called "Copra Meal."	FAO 2009	5-01-572, 5-01-573	120050	CC
Plant By-Products	Corn/Maize	Fine siftings obtained from screened cracked corn, with or without its aspiration products added.	AAFCO 2018	4-02-880	500030	CC
Plant By-Products	Corn/Maize	Outer coating of the corn kernel with little or no starchy parts of the germ.	AAFCO 2018	4-02-841	500030	CC
Plant By-Products	Corn/Maize	Part of the commercial shelled corn that remains after the extraction of the larger portion of the starch, gluten and germ by the processes employed in wet milling manufacture of corn starch or syrup.	FAO 2009	5-02-903	500030	CC
Plant By-Products	Corn/Maize	Dried residue from corn after the removal of the larger part of the starch and germ, and the separation of the bran by the process employed in wet milling manufacture of corn starch or syrup, or by enzymatic treatment of the endosperm.	FAO 2009	5-02-900	500030	PC
Plant By-Products	Corn/Maize	Maize starch heat hydrolysed.	AAFCO 2018	4-08-023	500030	CC
Plant By-Products	Corn/Maize	Obtained after distillation of ethyl alcohol from grain or grain mixture, which has under gone yeast fermentation. Moisture content should be defined.	FAO 2009	5-02-843	500030	CC

Plant By-Products	Corn/Maize	Obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of a grain or a grain mixture by separating the resultant coarse grain fraction of the whole stillage and drying it by methods employed in the grain distilling industry.	FAO 2009	5-02-842	500030	CC
Plant By-Products	Corn/Maize	Obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of a grain or a grain mixture by condensing the thin stillage fraction and drying it by methods employed in the grain distilling industry	FAO 2009	5-02-844	500030	CC
Plant By-Products	Cotton seed	Obtained by finely grinding the cake, which remains after removal of most of the oil from the cottonseed either by a mechanical or solvent extraction process.; Obtained by finely grinding the flakes, which remain after removal of most of the oil from cottonseed by a solvent extraction process. It must contain not less than 36 % crude protein.	FAO 2009	5-01-625, 5-01-632	401090	PC
Plant By-Products	Linseed	Obtained by grinding the cake or chips, which remain after removal of most of the oil from flaxseed by a mechanical extraction process. It must contain not more than 10% fibre.; Obtained by grinding the flakes, which remain after removal of most of the oil from flaxseed by a solvent extraction process.	FAO 2009	5-30-287, 5-30-288	401010	PC
Plant By-Products	Lupin seed (white)	The ground residue, which remains after removal of most of the oil from the whole lupin seed by a mechanical or solvent extraction process.	OECD 2013	5-27-717	300040	PC
Plant By-Products	Mustard seed	Obtained by grinding the cake, that remains after removal of some of the oil by mechanical extraction, and removing most of the remaining oil by solvent extraction.	FAO 2009	5-12-149	401080	PC
Plant By-Products	Palm kernel	The ground residue, which remains after removal of most of the oil from the whole palm kernel by a mechanical or solvent extraction process.	OECD 2013	5-03-486	402020	CC

Plant By-Products	Peanuts	Peanut seeds without coats meal mechanical extracted: is a ground product of shelled peanuts, composed principally of the kernels, with such portion of the hull, or fibre, and oil as may be left in the ordinary course of manufacture.	FAO 2009	5-03-649, 5-03-650	401020	PC
Plant By-Products	Potato	Derived from de-starched potato juice from which the proteinaceous fraction has been precipitated by thermal coagulation followed by dehydration.	FAO 2009	---	211000	PC
Plant By-Products	Rice	Rice bran is the pericarp or bran layer and germ of the rice, with only such quantity of hull fragments, chipped, broken, or brewers' rice, and calcium carbonate as is unavoidable in the regular milling of edible rice. It must contain not more than 13% crude fibre. When the calcium carbonate exceeds 3%, the percentage must be declared in the brand name i.e. "Rice Bran with Calcium Carbonate not exceeding %".	FAO, 2009	4-03-928	500060	CC
Plant By-Products	Rice	Rice bran with germ meal solvent extracted) is obtained by removing part of the oil from rice bran by the use of solvents and must contain not less than 14% crude protein and not more than 14% crude fibre.	FAO, 2009	4-03-930	500060	CC
Plant By-Products	Rice	By-product of rice obtained in the milling operation of brushing the grain to polish the kernel.	FAO 2009	4-03-943	500060	CC
Plant By-Products	Rice	Consist primarily of the outer covering of the rice grain (with bran).	FAO 2009	1-08-075	500060	CC
Plant By-Products	Rye	Obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of a grain or a grain mixture by condensing the thin stillage fraction and drying it by methods employed in the grain distilling industry	FAO 2009	5-04-023	500070	CC
Plant By-Products	Sesame seed	Obtained after oil extraction. Unlike for other oil meals, this meal is usually obtained by mechanical extraction only and its residual oil content is high.	OECD 2013	5-04-220	401040	PC

Plant By-Products	Safflower seed	Safflower seeds meal mechanical extracted) is the ground residue obtained after extracting the oil from whole safflower seed by a mechanical extraction process.	FAO 2009	5-04-109, 5-04-110	401110	PC
Plant By-Products	Soybean	Obtained by grinding the cake or chips, which remain after removal of most of the oil from soybeans by a mechanical extraction process.	FAO 2009	5-04-600, 5-04-604	401070	PC
Plant By-Products	Soybean	Obtained by grinding the flakes remaining after removal of most of the oil from dehulled soybeans by a solvent extraction process.	FAO 2009	5-04-612	401070	PC
Plant By-Products	Soybean	Prepared from high-quality sound, clean, dehulled soybean seeds by removing most of the oil and water soluble non-protein constituents and must contain not less than 65% protein on a moisture-free basis.	FAO 2009	5-32-183	401070	PC
Plant By-Products	Sunflower seed	Obtained by grinding the residue remaining after the extraction process.; Obtained by grinding the residue remaining after extraction of most of the oil from dehulled sunflower seed by a solvent extraction process.	FAO 2009	5-30-033,5-30-034	401050	PC
Plant By-Products	Sunflower seed	Obtained by grinding the residue remaining after extraction of the oil from whole sunflower seed by a mechanical extraction process.	FAO 2009	5-27-477, 5-30-032	401050	PC
Plant By-Products	Wheat	Coarse outer covering of the wheat kernel as separated from cleaned and scoured wheat in the usual process of commercial milling.	FAO 2009	4-05-190	500090	CC
Plant By-Products	Wheat	Consists principally of wheat flour together with fine particles of wheat bran, wheat germ and the offal from the "tail of the mill". This product is obtained in the usual process of commercial milling and must contain no more than 1.5% crude fibre.	FAO 2009	4-05-199	500090	CC
Plant By-Products	Wheat	Consists chiefly of wheat germ together with some bran and middlings or shorts. It must contain not less than 25% crude protein and 7% crude fat.	FAO 2009	5-05-218	500090	CC

Plant By-Products	Wheat	By-product in the manufacture of starch from wheat. Water insoluble protein complex.	OECD 2013; Hertrampf and Piedad-Pascual 2000	5-05-221	500090	PC
Plant By-Products	Wheat	Consists of fine particles of wheat bran, wheat shorts, wheat germ, wheat flour and some of the offal from the "tail of the mill". This product is obtained in the usual process of commercial milling and must contain no more than 9.5% crude fibre.	FAO 2009	4-05-205	500090	CC
Plant By-Products	Wheat	Obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of a grain or a grain mixture by condensing the thin stillage fraction and drying it by methods employed in the grain distilling industry.	FAO 2009	5-05-193	500090	PC
Fat	Oilseeds and oilfruits			various	various	F

8. List of abbreviations

CC	Carbohydrate concentrate
CP	Crude lipids in percentage of dry matter
CL	Crude protein in percentage of dry matter
DM	Dry matter
F	Fat
MRBD	Maximum reasonable balanced diet
PC	Protein concentrate
STMR	Supervised trials median residue
STMR-P	Supervised trials median residue in processed commodity
IFN	Code International Feed Nomenclature code