ESU-services
fair consulting in sustainability

# ライフサイクルアセスメント
# 生命週期評估
# 전 과정 평가
# வாழ்க்கை வட்டப் பகுப்பாய்வு
# ارزیابی چرخه عمر
# การประเมินวัฏจักรชีวิต
# Evaluarea Ciclului de Viață
# Posuzování Životního Cyklu
# Penilaian Daur Hidup
# Lífsferilsgreining
# Levenscyclusanalyse
# Livscyklusvurdering

**Life cycle assessment of novel plant products compared to animal products**

Dr. Niels Jungbluth, Samuel Solin
ESU-services GmbH, Schaffhausen

# Life cycle assessment of novel plant products compared to animal products

Dr. Niels Jungbluth, Samuel Solin
ESU-services GmbH, Schaffhausen

# Research Questions

- How can one compare novel plant products with their animal-based counterparts?
- What is the environmental impact of different novel plant products?
- What difficulties and uncertainties exist in models of novel plant products?
- Are novel plant products a good alternative to animal-based products in terms of nutritional value?
- How many portions are needed to satisfy the nutritional intake?

# Why study novel plant products?

- Nutrition in general and within nutrition meat and animal-based products have been identified as a major driver of environmental impacts.
- Huge increase of processed plant products in the last years.
- So far little is known about their environmental impacts and function

# Methodology and Data

- Studied **alternatives**: Milk alternative, red meat alternatives, poultry alternatives, egg alternatives, fish alternatives and cream alternatives
- **LCI** includes: breeding, feeding, housing, agriculture, energy consumption (storing etc.), transport, food losses (until supermarket)
- **LCIA** method: Ecological Scarcity 2021, European Footprint 3.0 and Global Warming Potential
- Background **data**: ESU world food database www.esu-services.ch/data/fooddata/

# Functional Unit

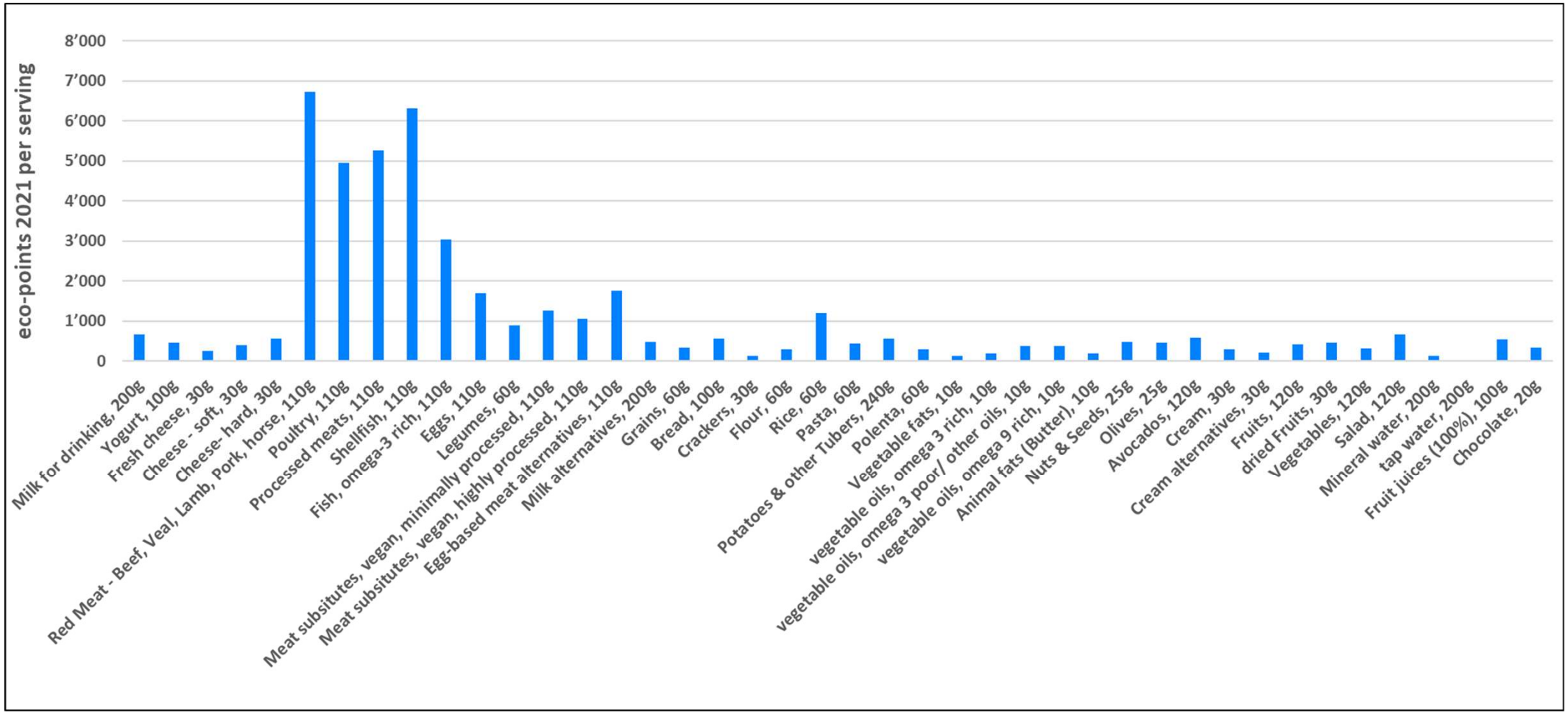
- How do you compare food items? Mass? Calories? Are novel plant products comparable to their animal-based counterparts?
- Unit: “Product per nutritional value (predominantly in animal-based products e.g. proteins, iron and more)“
- Does not include home transport, storage and preparation at home

# Nutritional recommendations

Recommended daily nutritional intake per day according to Swiss society for nutrition:

- 64 g protein
- 4 µg vitamin B12
- 1.5 g omega-3 fatty acids
- 1 g of calcium
- 15 mg iron
- 150 µg iodine
- 14 mg
- 1.4 mg riboflavin (vitamin B2)
- 15 µg vitamin
- 70 µg selenium

# Environmental impacts per serving




- Animal based products have the highest impacts per serving

# Plant products compared to their animal-based counterparts (ecological scarcity method 2021)

| Reduction potential of environmental impact | 64 g protein | 4 µg vitamin B12 | 1.5 g omega-3 fatty acids | 1 g of calcium | 15 mg iron | 150 µg iodine | 14 mg zinc[4] | 1.4 mg riboflavin (vitamin B2) | 15 µg vitamin D | 70 µg selenium |
|---|---|---|---|---|---|---|---|---|---|---|
| Drink instead of cow milk | 46% | -5% | 70% | -2% | na | -37% | 44% | | -92% | -96% |
| Instead of red meat … | | | | | | | | | | |
| Legumes | -81% | na | -46% | -98% | -96% | 930% | -19% | 51% | na | na |
| Meat subsitutes, vegan, minimally processed | -87% | 17120% | -77% | -98% | -87% | -88% | -43% | 105% | na | -97% |
| Meat subsitutes, vegan, highly processed | -82% | 11% | -94% | -97% | -89% | na | na | na | na | na |
| Egg-based meat alternatives | -61% | 99% | -63% | -95% | -46% | na | -88% | na | na | na |
| Instead of poultry … | | | | | | | | | | |
| Legumes | -70% | na | -25% | -98% | -97% | 6% | -89% | -74% | na | na |
| Meat subsitutes, vegan, minimally processed | -79% | 2245% | -68% | -97% | -95% | -55% | -76% | 43% | na | -87% |
| Meat subsitutes, vegan, highly processed | -72% | -85% | -91% | -97% | -96% | na | na | na | na | na |
| Egg-based meat alternatives | -40% | -73% | -48% | -94% | -79% | na | -95% | na | na | na |
| Instead of eggs … | | | | | | | | | | |
| Legumes | -59% | na | 168% | -63% | -76% | 1640% | -69% | 33% | na | na |
| Meat subsitutes, vegan, minimally processed | -72% | 16307% | 15% | -58% | -60% | 636% | -31% | 634% | na | -66% |
| Meat subsitutes, vegan, highly processed | -62% | 5% | -68% | -43% | -65% | na | na | na | na | na |
| Egg-based meat alternatives | -17% | 90% | 86% | -10% | 69% | na | -86% | na | na | na |
| vegetable oil instead of fish | | | | | | | | | | |
| omega 3 rich | na | na | -94% | 2489% | na | na | 729% | na | na | na |
| omega 3 poor/ other oils | 13140% | na | -89% | 4293% | 4147% | na | na | na | na | na |
| omega 9 rich | na | na | -100% | na | 2217% | 142734% | na | na | na | na |
| Vegan cream instead cream | -35% | na | -67% | 407% | -98% | na | na | na | na | na |

- High reduction potential on many nutrients

# Plant products compared to their animal-based counterparts (European footprint 3.0)

| Reduction potential of environmental impact (EF 3.0) | 64 g protein | 4 µg vitamin B12 | 1.5 g omega-3 fatty acids | 1 g of calcium | 15 mg iron | 150 µg iodine | 14 mg zinc[4] | 1.4 mg riboflavin (vitamin B2) | 15 µg vitamin D | 70 µg selenium |
|---|---|---|---|---|---|---|---|---|---|---|
| Drink instead of cow milk | 29% | -17% | 50% | -14% | na | -45% | 27% | | -93% | -96% |
| Instead of red meat ... | | | | | | | | | | |
| Legumes | -94% | na | -83% | -99% | -98% | -91% | -92% | -89% | na | na |
| Meat subsitutes, vegan, minimally processed | -89% | 14410% | -81% | -98% | -89% | -90% | -52% | 72% | na | -97% |
| Meat subsitutes, vegan, highly processed | -83% | 3% | -94% | -97% | -90% | na | na | na | na | na |
| Egg-based meat alternatives | -62% | 93% | -64% | -96% | -48% | na | -88% | na | na | na |
| Instead of poultry ... | | | | | | | | | | |
| Legumes | -91% | na | -78% | -99% | -99% | -68% | -97% | -92% | na | na |
| Meat subsitutes, vegan, minimally processed | -83% | 1813% | -74% | -98% | -96% | -63% | -80% | 17% | na | -90% |
| Meat subsitutes, vegan, highly processed | -75% | -86% | -92% | -97% | -96% | na | na | na | na | na |
| Egg-based meat alternatives | -43% | -74% | -51% | -95% | -81% | na | -95% | na | na | na |
| Instead of eggs ... | | | | | | | | | | |
| Legumes | -87% | na | -17% | -88% | -93% | 441% | -90% | -59% | na | na |
| Meat subsitutes, vegan, minimally processed | -76% | 13836% | -2% | -64% | -66% | 525% | -42% | 523% | na | -71% |
| Meat subsitutes, vegan, highly processed | -64% | -1% | -70% | -47% | -67% | na | na | na | na | na |
| Egg-based meat alternatives | -18% | 86% | 82% | -12% | 66% | na | -86% | na | na | na |
| vegetable oil instead of fish | | | | | | | | | | |
| omega 3 rich | na | na | -94% | 2197% | na | na | 636% | na | na | na |
| omega 3 poor/other oils | 2684% | na | -87% | 365% | 631% | na | na | na | na | na |
| omega 9 rich | na | na | -96% | na | 916% | 68473% | na | na | na | na |
| Vegan cream instead cream | -55% | na | -77% | 252% | -99% | na | na | na | na | na |

- Similar results

# Plant products compared to their animal-based counterparts (Global warming potential)

| Reduction potential of environmental impact (GWP) | 64 g protein | 4 µg vitamin B12 | 1.5 g omega-3 fatty acids | 1 g of calcium | 15 mg iron | 150 µg iodine | 14 mg zinc[4] | 1.4 mg riboflavin (vitamin B2) | 15 µg vitamin D | 70 µg selenium |
|---|---|---|---|---|---|---|---|---|---|---|
| Drink instead of cow milk | 40% | -9% | 62% | -6% | na | -40% | 38% | 1296% | -92% | -96% |
| Instead of red meat … | | | | | | | | | | |
| Legumes | -95% | na | -86% | -100% | -98% | -93% | -93% | -91% | na | na |
| Meat subsitutes, vegan, minimally processed | -88% | 15314% | -79% | -98% | -88% | -89% | -49% | 83% | na | -97% |
| Meat subsitutes, vegan, highly processed | -79% | 31% | -92% | -97% | -87% | na | na | na | na | na |
| Egg-based meat alternatives | -62% | 94% | -64% | -95% | -47% | na | -88% | na | na | na |
| Instead of poultry … | | | | | | | | | | |
| Legumes | -89% | na | -73% | -99% | -99% | -62% | -96% | -91% | na | na |
| Meat subsitutes, vegan, minimally processed | -74% | 2838% | -60% | -97% | -94% | -44% | -70% | 79% | na | -84% |
| Meat subsitutes, vegan, highly processed | -54% | -75% | -85% | -94% | -93% | na | na | na | na | na |
| Egg-based meat alternatives | -18% | -63% | -30% | -92% | -72% | na | -93% | na | na | na |
| Instead of eggs … | | | | | | | | | | |
| Legumes | -84% | na | 6% | -85% | -91% | 591% | -88% | -47% | na | na |
| Meat subsitutes, vegan, minimally processed | -60% | 22849% | 61% | -41% | -43% | 929% | -4% | 927% | na | -52% |
| Meat subsitutes, vegan, highly processed | -29% | 94% | -41% | 5% | -36% | na | na | na | na | na |
| Egg-based meat alternatives | 27% | 188% | 182% | 37% | 158% | na | -78% | na | na | na |
| vegetable oil instead of fish | | | | | | | | | | |
| omega 3 rich | na | na | -95% | 1826% | na | na | 517% | na | na | na |
| omega 3 poor/ other oils | 2935% | na | -86% | 407% | 697% | na | na | na | na | na |
| omega 9 rich | na | na | -96% | na | 775% | 58933% | na | na | na | na |
| Vegan cream instead cream | -59% | na | -79% | 217% | -99% | na | na | na | na | na |

# How many portions are needed?

| Number of servings | 64 g protein | 4 µg vitamin B12 | 1.5 g omega-3 fatty acids | 1 g of calcium | 15 mg iron | 150 µg iodine | 14 mg zinc[4] | 1.4 mg riboflavin (vitamin B2) | 15 µg vitamin D | 70 µg selenium |
|---|---|---|---|---|---|---|---|---|---|---|
| Milk for drinking, 200g | 10 | 9 | 1 | 4 | na | 8 | 18 | 3 | 150 | 30 |
| Red Meat - Beef, Veal, Lamb, Pork, horse, 110g | 3 | 1 | 0 | 96 | 6 | 56 | 3 | 4 | 8 | 8 |
| Poultry, 110g | 2 | 8 | 1 | 120 | 24 | 22 | 12 | 8 | 14 | 3 |
| Fish, omega-3 poor, 110g | 3 | 1 | 2 | 35 | 16 | 2 | 19 | 16 | 6 | 3 |
| Shellfish, 110g | 4 | 1 | 3 | 26 | 8 | 1 | 7 | 14 | na | na |
| Fish, omega-3 rich, 110g | 3 | 1 | 0 | 77 | 21 | 3 | 30 | 10 | 2 | na |
| Eggs, 110g | 5 | 3 | 0 | 19 | 8 | 3 | 11 | 4 | 8 | 3 |
| Legumes, 60g | 4 | na | 2 | 15 | 4 | 133 | 7 | 12 | na | na |
| Meat subsitutes, vegan, minimally processed, 110g | 2 | 727 | 1 | 12 | 5 | 40 | 11 | 46 | na | 2 |
| Meat subsitutes, vegan, highly processed, 110g | 3 | 6 | 0 | 20 | 5 | na | na | na | na | na |
| Egg-based meat alternatives, 110g | 4 | 6 | 1 | 19 | 14 | na | 2 | na | na | na |
| Milk alternatives, 200g | 20 | 11 | 2 | 6 | 38 | 7 | 35 | 70 | 18 | 2 |
| vegetable oils, omega 3 rich, 10g | na | na | 0 | 33333 | na | na | 4200 | na | na | na |
| vegetable oils, omega 3 poor/ other oils, 10g | 1600 | na | 1 | 6897 | 3000 | na | na | na | na | na |
| vegetable oils, omega 9 rich, 10g | na | na | 0 | na | 3000 | 30000 | na | na | na | na |
| Cream, 30g | 94 | 48 | 1 | 43 | 1000 | 39 | 187 | 30 | 121 | na |
| Cream alternatives, 30g | 85 | na | 0 | 303 | 25 | na | na | na | na | na |

- Number of necessary portions a problem for some nutrients

# Difficulties and uncertainties in the model

- Within the groups of food items there might be considerable differences concerning environmental impacts per portion and the nutrients per portion.
- Some plant-based alternatives contain enrichments for certain nutrients. So far it is difficult to analyze the environmental impact of such pure nutrients.
- Slight differences in the preparation of food in the kitchen are possible (e.g. shorter cooking time due to prebaking of the alternative)

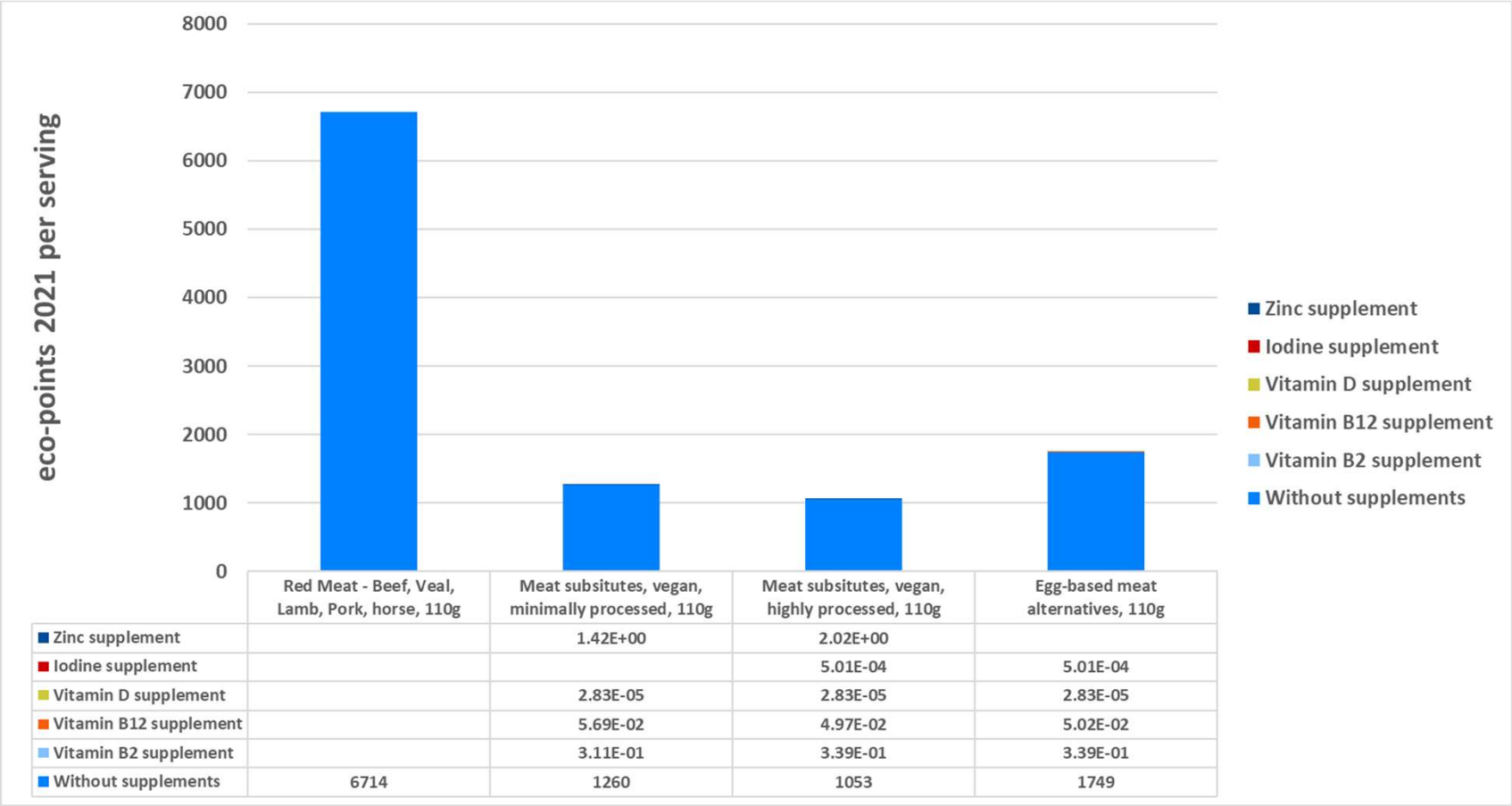
# A first estimation to added nutrients

- A first estimation was performed to assess the environmental impact of such added nutrients based on an input-output analysis with the bulk price
- The following eight nutrients were modelled: Vitamin A, B2, B12, D and E, as well as Calcium, Iodine and Zinc

| | Daily recommended dose according to Swiss society for nutrition | Environmental impact of added nutrients if taken separately | | |
|---|---|---|---|---|
| LCA Method | | Ecological scarcity method 2021 | EF 3.0 | GWP |
| Unit | | eco-points | µPt | kg CO2-eq |
| Vitamin A | 1 mg | 1.25E-01 | 6.95E-03 | 4.44E-05 |
| Vitamin B2 | 1.4 mg | 1.43E+00 | 7.92E-02 | 5.06E-04 |
| Vitamin B12 | 4 µg | 4.47E-02 | 2.48E-03 | 1.58E-05 |
| Vitamin D | 15 µg | 2.51E-04 | 1.40E-05 | 8.91E-08 |
| Vitamin E | 13 mg | 3.86E+00 | 2.14E-01 | 1.37E-03 |
| Calcium | 1 g | 2.94E+02 | 1.63E+01 | 1.04E-01 |
| Iodine | 150 µg | 3.06E-02 | 1.70E-03 | 1.09E-05 |
| Zinc | 14 mg | 7.31E+00 | 4.06E-01 | 2.59E-03 |

➢ Influence in an LCA of meat substitutes would be very small

# Added nutrients to animal substitutes




| | Red Meat - Beef, Veal, Lamb, Pork, horse, 110g | Meat subsitutes, vegan, minimally processed, 110g | Meat subsitutes, vegan, highly processed, 110g | Egg-based meat alternatives, 110g |
|---|---|---|---|---|
| Zinc supplement | | 1.42E+00 | 2.02E+00 | |
| Iodine supplement | | | 5.01E-04 | 5.01E-04 |
| Vitamin D supplement | | 2.83E-05 | 2.83E-05 | 2.83E-05 |
| Vitamin B12 supplement | | 5.69E-02 | 4.97E-02 | 5.02E-02 |
| Vitamin B2 supplement | | 3.11E-01 | 3.39E-01 | 3.39E-01 |
| Without supplements | 6714 | 1260 | 1053 | 1749 |

- Preliminary assessment shows no major environmental relevance

# Interpretation

- Protein and iron can be replaced very efficiently with several plant-based products and reductions of up to 90% for the environmental impacts
- It is difficult to replace vitamin B12 and seems only possible with plant-based alternatives with added vitamin B12.
- For calcium there are also good alternatives
- An obstacle can be the necessary servings per day to meet the necessary nutritional intake
- Nutrient supplements might overcome this obstacle if necessary

# Conclusion

- Meat alternatives are an effective substitution to the consumption of meat
- Environmental impacts are an important cause of health impacts and premature deaths. Reducing the environmental impact of food consumption is necessary.
- Further improvements can be expected by substituting even more animal-based products with plant-based products.

➢ Download the study on www.esu-services.ch/publications/foodcase/

➢ Niels Jungbluth, Martin Ulrich, Karen Muir, Christoph Meili, Maresa Bussa, Samuel Solin (2022) Analysis of food and environmental impacts as a scientific basis for Swiss dietary recommendations. ESU-services GmbH, Schaffhausen, Switzerland.

# Political implications

- The present policies of retailers to promote vegan or vegetarian products mainly/exclusively for the group of consumers with high environmental awareness and willingness to pay is questionable.
- Products should be made available for fair prices
- Direct and indirect subsidies on animal-based products should be reduced

# Copyright notice



**In case of any questions, please contact:**

**Dr. Niels Jungbluth, CEO - Chief Executive Officer**
**ESU-services Ltd. - fair consulting in sustainability**
**Rheinstrasse 20**
**CH-8200 Schaffhausen**
**www.esu-services.ch**
**tel +41 44 940 61 32**
**jungbluth@esu-services.ch**